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on station

The Newsletter of the Directorate of Manned Spaceflight and Microgravity

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in this issue

European Space Agency
Agence spatiale européenne

Directorate of Manned Spaceflight and Microgravity
Direction des Vols Habité et la Microgravité

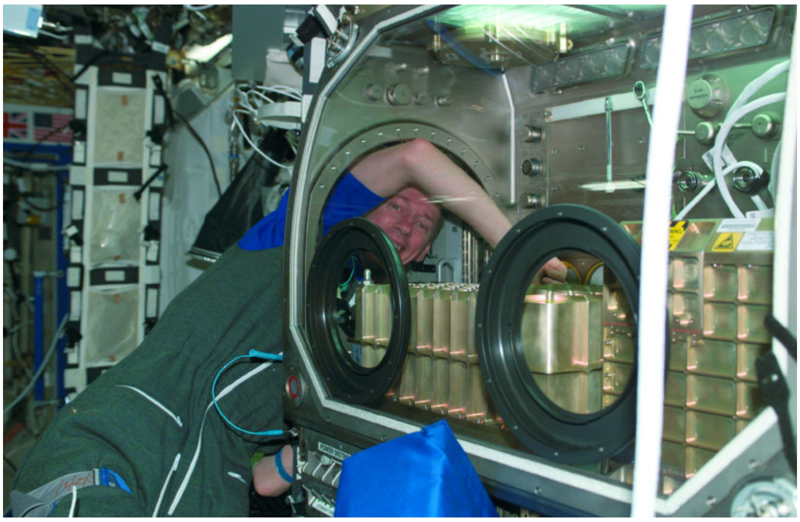
First Mission for Erasmus Taxi Operations Coordination Centre

Jörg Feustel-Büechl
ESA Director of Manned Spaceflight and Microgravity

The recent successful flight of ESA astronaut Frank De Winne aboard a Soyuz Taxi represents the fourth European mission to the International Space Station, following those of Umberto Guidoni, Claudie Hagnieré and Roberto Vittorio. This Belgian-sponsored flight was of double importance. Firstly, it took another European to the Station and had a large scientific programme of 23 experiments that kept De Winne and his colleagues very busy. Secondly, we established in the Erasmus building at ESTEC in The Netherlands a Taxi Operations Coordination Centre (TOCC) to coordinate the scientific programme between our American and Russian partners and the scientists at the Belgian User Support Operations Centre (USOC) in Brussels. Indeed, TOCC is a precursor for our USOC operations in the Columbus era.

The Station is in excellent technical shape and, with De Winne's mission, we had the 32nd flight to the ISS. There have been no major problems since the first Station element, Zarya, was launched in November 1998. Compared with previous international undertakings, there has never been anything of such magnitude and it really is making excellent progress. Considering that elements are developed and built continents apart, and that they never meet each other until that first contact in space, it is really a world-class achievement. We can congratulate everyone involved in the Station's development!

As far as the overall status of the Station is concerned, we took a very important step at the Space Station Control Board (SSCB) on 14/15 October in agreeing to launch the first Automated Transfer Vehicle (ATV) 'Jules Verne' on 27 September 2004, followed closely by our Columbus laboratory on 7 October 2004. Columbus will be launched with four or five scientific racks and one or two external platforms. This will enable Columbus to perform an attractive research programme despite there being only three Station crewmembers at that time, helped by a number of the research facilities being largely automatic. The launch



Frank De Winne working with the Microgravity Science Glovebox aboard the Station's Destiny module. (NASA)

agreements were endorsed by the Multilateral Control Board (MCB) on 15 October, so we are now entering the final phase of preparing for these two most important European contributions.

We have therefore nominated two ESA Mission Managers: Bernardo Patti for Columbus, and Robert Lainé for ATV, who have the major tasks of coordinating all the activities and schedules, and making sure that everything – from the space segment to the ground segment – is ready to support end-to-end operations when the two elements join the Station.

The MCB also addressed the studies into the various option paths towards an acceptable End-State of the Station. Progress has been less than expected so the Partners, under Chairman Fred Gregory (the responsible NASA Deputy Administrator) decided on an accelerated plan to define the option paths by early December. On 6 December there will be a Heads of Agency meeting and we hope to take a big step forward in defining the way forward to achieve an attractive Station End-State. Since the October MCB, we have seen good progress that gives me hope that by the December meeting we will at least know what is the right 'option pass' even though we might not have a final decision. ('Option pass' means that the End-State would be defined but that the configuration options in that End-State remain to be further detailed.) The final End-State goal will then entail further work before we can select a final configuration, which is expected for early 2003. I hope that this will provide the final clarification on the configuration sometime in February/March 2003 and in time for the next ESA Ministerial Conference. The way our Partners – and particularly NASA – are addressing the problem gives me a measure of optimism that we will restabilise the Station programme in the coming months.

After a lengthy process, we can see light at the end of the tunnel and we all hope that it will lead to a crew of 6 from 2006 and a full crew of 7 from 2010. Although that is a year later than originally planned, it is still acceptable. It also means that, with the Columbus launch in October 2004, we have good utilisation prospects: we expect to spend the rest of 2004 in commissioning Columbus before gradually building up utilisation in 2005. This is only marginally slower than the original plan because only ESA and NASA have research modules at the Station in the period up to 2007, when Japan's module arrives. Our utilisation priorities – and those of our Partners – are well-defined, so we know precisely what needs to be done in the years to come.

In respect of ESA astronaut opportunities,

Frank De Winne (left) with his Soyuz colleagues. (NASA) we are able to offer an average of three flights/year. With a Corps of around 15 astronauts, we can achieve each an average of one flight every 5 years. That is, I believe, extremely good. We have had three flights this year and are looking forward to another three in 2003 (Soyuz Taxi flights with two European astronauts, and Christer Fuglesang on a US Cooperation Shuttle flight in July). Of course, in 2004 we have the opportunity with Columbus to see the first European astronaut as part of an Increment crew, and other flight opportunities.

Unfortunately, we had the launch failure on 15 October of Foton-M1 on a Russian Soyuz launcher. The investigation committee is still looking at the cause and we expect their report soon. The total loss of the 44 ESA-sponsored experiments is a tremendous blow for the scientific community. We now have to see how we can continue our cooperation in this area. The total loss for us amounted to around €25 million, including the launch.

In September, we held our fourth Industry Day and took the opportunity to brief European industry on the status of all of our programmes. Our first research facility aboard the Station, the Microgravity Science Glovebox (MSG), is working well and was used by Frank De Winne for a number of European experiments. The DMS-R data management system supplied by ESA for Zvezda passed two years of operations in July. Its operational reliability reflects well on European industry and the Agency. MELFI has now been accepted by NASA for its first launch in 2003. Columbus, ATV, Cupola and Hexapod are all on schedule. A concern for us at the moment is the development of Node-2 because it has to be delivered by March 2003 to pave the way for the Columbus launch. The schedule is very tight and we know that industry is making every effort to maintain that milestone. There is a further concern with the ground-segment development that was, for financial reasons, delayed for quite some time. Now we have to intensify our effort so that not only the Columbus Control Centre and the ATV Control Centre are ready but also the USOCs. I would like to encourage all those participating in the ground segment, both within the Agencies and industry, to do their very best to ensure that these activities do not appear on the critical path in the 18 months remaining until they need to be fully operational.

As far as that part of the Period 1 of the Exploitation Programme that was blocked at the Ministerial Conference in Edinburgh in November 2001 is concerned, we hope to move forward with a reasonable End-State configuration early next year, which is a pre-condition for the unblocking. This is important so that the launches and operations of ATV and Columbus are not jeopardised.

In summary, the ISS is in excellent technical shape and, on the political side, we are seeing considerable movement that we hope will lead to a fruitful conclusion at the end of this year/early next year, and recover programme stability by defining a concrete End-State option path.

ISS launches planned for the next 14 months.

Flight #	Launch	Element/Task	Vehicle/Mission
34: 10P	02 Feb 03	Logistics (Progress-M)	Soyuz
35: ULF-1	11 Mar 03	Expedition-7 Crew/**MPLM**	Shuttle STS-114
36: 6S	26 Apr 03	Taxi Flight (**ESA Astronaut**)	Soyuz-TMA 2
37: 12A	23 May 03	P3/P4 Truss	Shuttle STS-115
38: 11P	26 May 03	Logistics (Progress-M1)	Soyuz
39: 12P	30 Jul 03	Logistics (Progress-M)	Soyuz
40: 12A.1	31 Jul 03	Expedition-8 Crew/P5 Truss/ (**Christer Fuglesang**; 3 EVAs)	Shuttle STS-116
41: 13A	02 Oct 03	S3/S4 Truss	Shuttle STS-117
42: 7S	18 Oct 03	Taxi Flight (**ESA Astronaut**)	Soyuz-TMA 3
43: 13A.1	13 Nov 03	S5 Truss	Shuttle STS-118
44: 13P	18 Nov 03	Logistics (Progress-M1)	Soyuz
45: 15A	15 Jan 04	Expedition-9 Crew/S6 Truss	Shuttle STS-119
46: 10A	19 Feb 04	Node-2	Shuttle STS-120

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

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

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

March 2003: Maxus-5 sounding rocket

March-April 2003: 34th Parabolic Flight Campaign

April 2003: Soyuz Taxi flight with ESA Astronaut Pedro Duque

April 2003: Node-2 delivery to Kennedy Space Center

April 2003: Hexapod delivery to Langley Research Center

April 2003: Columbus completed and placed in storage

April 2003: ERA completed and placed in storage

July 2003: Cupola delivery to Kennedy Space Center

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

October 2003: 35th Parabolic Flight Campaign

Columbus & Node-2

Bernardo Patti & Daniele Laurini
Manned Spaceflight Programme Department, D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Bernardo Patti@esa.int; Daniele Laurini@esa.int

Two of ESA's major contributions to the International Space Station are nearing completion ...

Introduction

Despite all the problems in ISS development and reductions in the number of Shuttle flights, the baseline launch date of October 2004 for ESA's Columbus laboratory module has remained stable for more than 2 years. A recent revision of the ISS Assembly Sequence confirmed that date. Before Columbus can go to the Station, Node-2 must be launched first, as it provides the attachment port for the European module.

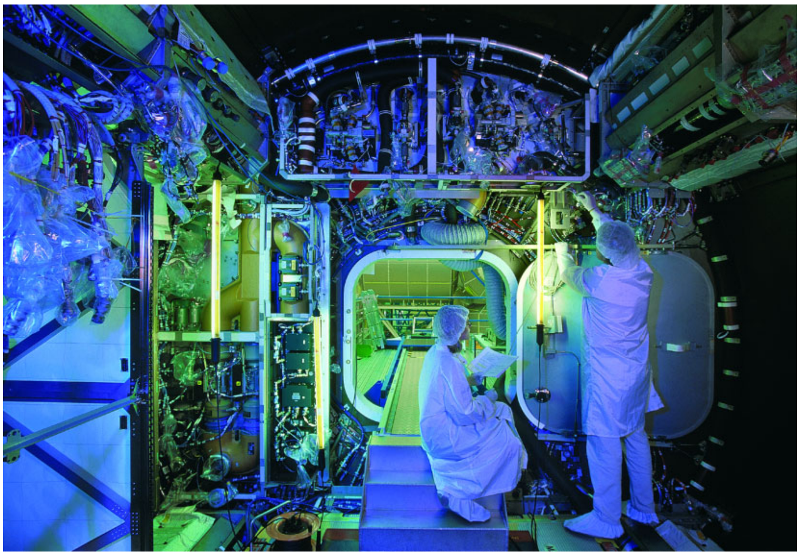
Columbus is now well into the final phase of its development. Its status will be reviewed next Spring to confirm its readiness for payload integration. Node-2 will be completed in early 2003 and delivered to the Kennedy Space Center in time for launch aboard the Shuttle in February/March 2004.

Columbus Testing

The Columbus Qualification and Acceptance Test Campaign is now at its peak at prime contractor Astrium GmbH in Bremen (D). The Flight Model (FM) was powered up for the first time early this year, involving all its subsystems and using an advanced version of the system software. Initial checkout and power polarity tests were successful before a very important milestone was achieved in August: qualification tests jointly performed with NASA and Station prime contractor Boeing on the electrical power and audio interfaces, and especially on all the Columbus-ISS software interfaces. The latter test demonstrated the robustness of Columbus, especially in off-normal conditions.

The functional qualification test campaign, using the Electrical Test Model (ETM), is also well underway. Achievements include manual commanding of the subsystems and qualification of the generic payload functional interfaces. Very important ESA/NASA bilateral verification tests on Columbus-ISS interfaces have been successful, including the electrical power interface and the High Rate Data Link interface. ETM's functional qualification campaign will be completed by year's end.

The next milestone of the Columbus Module Verification programme will be the completion of the FM integration and acceptance test phase. A combined Qualification and Flight Acceptance Review (QR/FAR1) in April 2003 will be conducted to determine whether Columbus is ready for initial payload facility integration and checkout. The module will then be stored until the first payload facility (Biolab) is verified on the Rack Level Test Facility (RLTF). All payload



Top/bottom: working on Columbus at Astrium.

facilities will be integrated into Columbus in October 2003.

Columbus enhancements were recently studied to improve the communications resources of the European ISS infrastructure and to solve some technology obsolescence in the video system. The work would be performed during the storage phase; the final decision will be taken in early 2003.

During the second half of 2003, all the system and payload operational items will be integrated into the overall Columbus ground segment. The electrical system functional testing began in September 2002 to pave the way for delivery to Florida by the end of March 2004 for the remainder of ground processing.

Node-2 End-to-End Testing

After a series of delays, the Node-2 integration and final test activities have gathered pace at Alenia Spazio in Torino (I). Several major items were prepared in parallel for installation in Node-2:

– the primary structure was outfitted with attachments for the internal and secondary structures; internal and external harnesses were mounted and all the external heater mats and thermistors installed;
– the four internal standoffs were integrated with all the harness, piping and valves;
– the major internal secondary structures (four alcove and midbay structures, resembling tall, thin cupboards) were outfitted to support most of Node-2's communications, command and control, life support and thermal control equipment;
– four large subsystem racks were readied to accommodate mainly command and control and power distribution equipment.

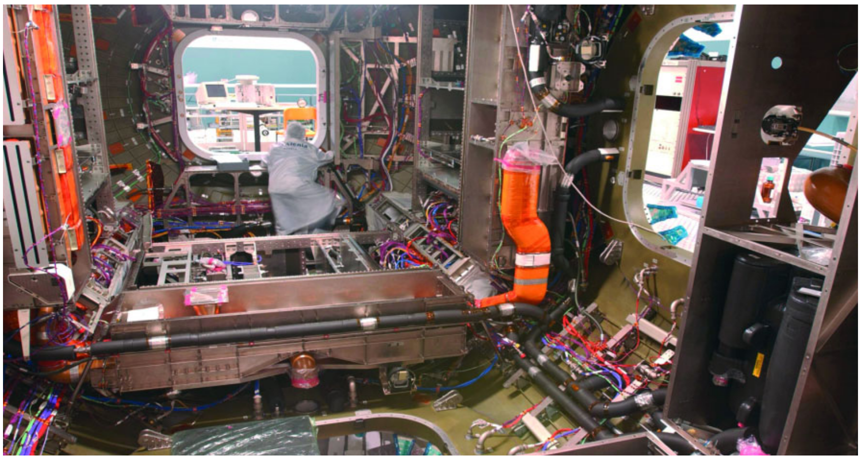
Bonding and leak tests of each fluid connection at each step ensured that no problems would appear later during the system-level tests. Many of the connections are not readily accessible once these large building blocks are integrated into the Node. Following these checks, the pipes carrying cold fluids were covered with insulation to avoid condensation from the humid air during operations. Finally, each outfitted secondary structure was partitioned into 'fire enclosures' by means of soft flame-retardant panels.

Integration into the Node primary structure was a choreographed operation involving a large overhead crane and dedicated Ground Support Equipment (GSE) to keep these heavy objects stable as they were inserted through one of the Node's axial hatches and lowered into position. The Node could be rotated to help position the secondary structure.

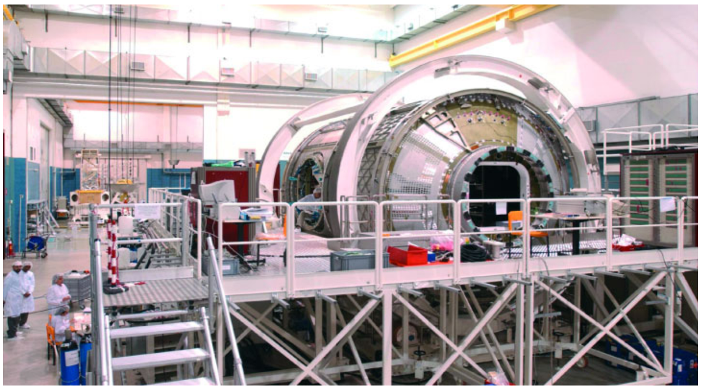
Following integration, the fluid connections, piping insulation and bonds were checked. In parallel – and using up to three shifts per day – the external secondary structure attachment points were added, together with the rest of the external harness. Internally, automated end-to-end testing of the integrated harness has verified that each connector pin is properly assigned and connected. A NASA/Boeing team has integrated the active and passive Common Berthing Mechanisms.

The overall system end-to-end functional testing began in October to pave the way for delivery to Florida by the end of March 2003 for the remainder of ground processing.

As well as accommodating Columbus, Node-2 is also the connecting element for the 'Kibo' Japanese Experiment Module, the Centrifuge Accommodation Module and the Shuttle. It also provides the access port for the Multi Purpose Logistics Module during visits to the Station.



Working on Node-2, September 2002. (Alenia)



Node-2 approaches completion in Torino. (Alenia)

ESA Plans for Future ISS External Payloads

Giacinto Gianfiglio
Head of Mission Implementation of External Payload Section, ISS Utilisation Division, D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: giacinto.gianfiglio@esa.int

Introduction

Unlike a conventional satellite, which orbits the Earth pointing in the same direction (unless commanded otherwise), the ISS orbits rather like an airplane, keeping its main axis parallel to the local horizon. This is a great advantage for both all-sky investigations and Earth observations because an instrument can automatically scan most of the sky during the 90-min ISS orbit. ESA will exploit this unique feature for world-class research and commercialisation.

A second generation of payloads is under study to exploit the Columbus External Payload Facility ...

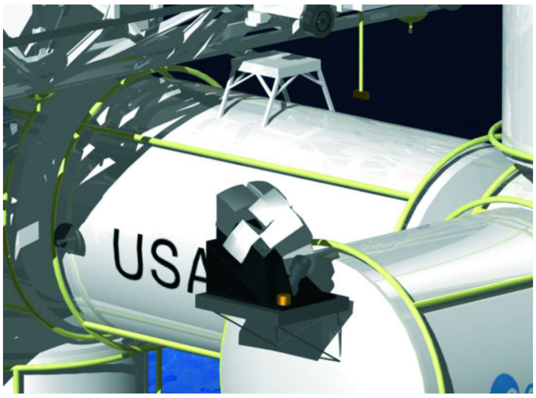
The first generation of ESA external payloads – ACES, SOLAR, EXPORT and EuTEF – was described in On Station #8 (March 2002, pp.8-9). They will occupy the Columbus External Payload Facility (EPF) during 2004-2008. EuTEF and SOLAR will be launched atop a 'lite' version of the Integrated Cargo Carrier in October 2004 on the 1E Flight, together with the Columbus module itself. The next launch opportunity, in 2006 (at the earliest), will be used by ACES and EXPORT. Future payloads, however, are already under study: Lobster, EUSO, ROSITA and RapidEye.

Second-Generation Payloads

Lobster and EUSO (originally proposed for the science directorate's Flexi-Missions) and ROSITA (an unsolicited proposal) were handed to D/MSM for feasibility studies, now being jointly performed by the two Directorates. By contrast, RapidEye is a pathfinder project in the context of ISS Commercialisation.

Lobster

Lobster is an all-sky monitoring package in the soft X-ray band (0.1-3.5 keV), based on lobster-eye X-ray optics. A novel arrangement of Micro



Channel Plates provides an extremely wide field of view. Lobster will generate a catalogue of about 250 000 X-ray sources every 2 months with a spatial resolution of a few arcmin.

The instrument is being developed by the University of Leicester (UK) with various co-investigators. It consists of six lobster-eye telescopes, collectively covering 22.5 x 162° and imaging almost the entire sky every ISS orbit. In this way, detailed long-duration light curves will be recorded for an unprecedented number of objects. In addition, Lobster will be sensitive enough to detect the soft X-ray emission associated with gamma-ray bursts.

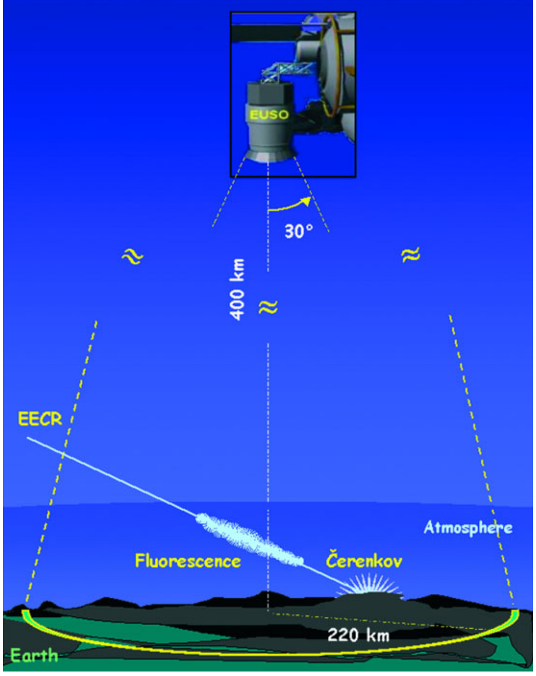
It will occupy EPF's zenith position for the best possible view of the sky.

An initial feasibility study showed that Lobster can be accommodated on an Express Pallet adapter. A 12-month Phase-A study, funded by D/SCI, began in July 2002.

Extreme Universe Space Observatory (EUSO)

EUSO is devoted to investigating the highest energy processes in the Universe, answering questions in fundamental physics, cosmology and astrophysics, by using Earth's atmosphere as a giant cosmic ray detector.

EUSO will observe the flash of fluorescent



light and the reflected Cerenkov radiation when an Extreme Energy Cosmic Ray (EECR, with energy >3×10^{19} eV) interacts with the atmosphere. 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.

EUSO will take advantage of the continuous Earth-pointing provided by the lowest balcony of the EPF. By nadir-looking with a 60° field of view, it will detect around 1000 events per year, allowing a sensitive search for objects producing EECRs.

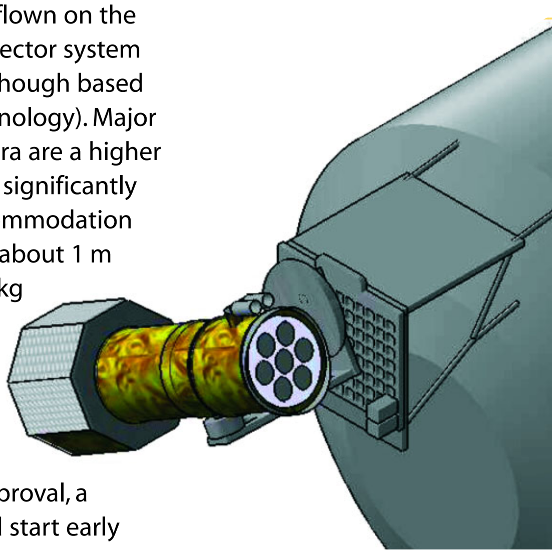
A large consortium of investigators led by IASF-CNR of Palermo (I) is developing this UV telescope, which uses a lightweight double Fresnel lens optics system, a highly segmented focal surface detector array and sophisticated onboard image processing. Owing to its large dimensions (2.5 m diameter and 4 m length), EUSO needs a dedicated carrier and will occupy the whole lower EPF balcony.

Following an initial feasibility study, the EUSO Phase-A study, cofunded by D/SCI and D/MSM, began in March 2002 and will be completed in June 2003. It has already been demonstrated that it is possible to accommodate such a class of payload on the EPF, provided the total mass on each balcony remains below 1500 kg.

ROentgen Survey and Imaging Telescope Array (ROSITA)

ROSITA will perform an all-sky survey and imaging in the medium-energy X-ray range up to 10 keV with an unprecedented spectral and angular resolution. The main scientific goals are to identify all obscured accreting black holes in nearby galaxies and distant active galactic nuclei, to detect the hot intergalactic medium of several ten-thousand galaxy clusters and to study in detail the physics of galactic X-ray sources, like supernova remnants and X-ray binaries.

The telescope will be supplied by MPE of Garching (D) and consist of a replica of the Wolter-1 mirror system already flown on the Abrixas satellite and a novel detector system currently under development (though based on XMM-Newton's pn-CCD technology). Major improvements of the new camera are a higher time and energy resolution and significantly reduced ghost images. The accommodation feasibility of this large payload (about 1 m diameter, 2.5 m length and 380 kg mass) on the upper starboard EPF position was shown by the pre-Phase-A study performed by ESTEC's Concurrent Design Facility in September 2002. Following D/SCI and D/MSM approval, a 12-month Phase-A study should start early next year.



Lobster (facing page), EUSO (top left) and ROSITA (above).

RapidEye

The ability to guarantee delivery of information products is the key for any successful commercial Earth observation service. Reliability is achieved only if full coverage of countries and continents can be provided within a few weeks on a regular basis. This understanding led to the definition of the RapidEye system: a constellation of four remote-sensing satellites, orbiting at about 600 km altitude, to provide multi-spectral (and optionally stereo) imaging at a resolution of 6.5 m for any point on Earth, on a daily basis. To enhance and complement the satellite constellation, the RapidEye AG company (D) has proposed to fly an identical camera on the Columbus EPF. This will provide improved resolution (4-4.5 m), better coverage of regions around 51° latitude, different observation times than the satellites, additional capacity and redundancy, and significantly promote the ISS.

The feasibility of installing the RapidEye-ISS on the lower starboard EPF position is now under study. Following completion of this pre-Phase-A study, it is planned to begin a 6-month Phase-A early in 2003.

Conclusion

Assuming a successful conclusion of the running studies and approval of the mission funding, Phase-B (and subsequently Phase-C/D) will begin with the goal of achieving readiness for flight in 2009, at the earliest. ■

Precious Seconds of Microgravity

ESA's Parabolic Flight Campaigns

Vladimir Pletser
Microgravity Projects Division (MSM-GMM), D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Vladimir.Pletser@esa.int

Introduction

Parabolic flights in aircraft can provide up to 20 s of reduced gravity, allowing short microgravity experiments, hardware and procedures testing, and astronaut training before a spaceflight. They complement other microgravity opportunities, ranging from drop towers (seconds) to the Space Station (months). Their real value lies in improving the quality and success rate of experiments before spaceflight, and in confirming or correcting (sometimes conflicting) results from space experiments.

The Parabolic Flight Campaigns are an important element of ESA's microgravity activities ...

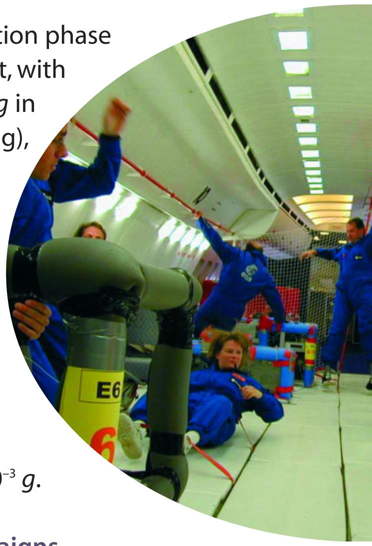
Since 1984, ESA's Microgravity Programme has organised 33 such research campaigns using six different aircraft. More than 400 experiments have been conducted during more than 3000 parabolas and a total time of 17 h of weightlessness. In parallel, ESA's Outreach and Education Department has organised five campaigns for student experiments.

Since 1997, the Airbus A300 'Zero G' – the world's largest aircraft for parabolic flights – has been used by ESA, CNES, DLR and industrial customers, managed by the French company Novespace, a subsidiary of CNES. The Airbus is operated by the Centre d'Essais en Vol (CEV, French Test Flight Centre) and maintained by the Sogerma company.

Microgravity during Parabolic Flights

Microgravity is created by free-falling, when the sum of all forces, other than gravity, acting on the carrier is nil or strongly reduced. For the Airbus A300, it is attained by flying the following manoeuvres:

– from steady horizontal flight, the aircraft climbs at 47° (pull-up) for about 20 s, generating 1.8-2 *g*;
– engine thrust is strongly reduced for 20-25 s, compensating for air drag (parabolic free fall);
– the aircraft dives at 42° (pull-out), accelerating at 1.8-2 *g* for about 20 s, to return to steady horizontal flight.



A microgravity transition phase of about 5 s appears first, with variations of about 10^{-1} *g* in the Z-axis (floor to ceiling), followed by about 20 s with levels of a few 10^{-2} *g*, while accelerations along the X-axis (aft to front) and Y-axis (right to left) are less than 10^{-2} *g*. For experiments left free-floating, levels can be improved to typically 10^{-3} *g*.

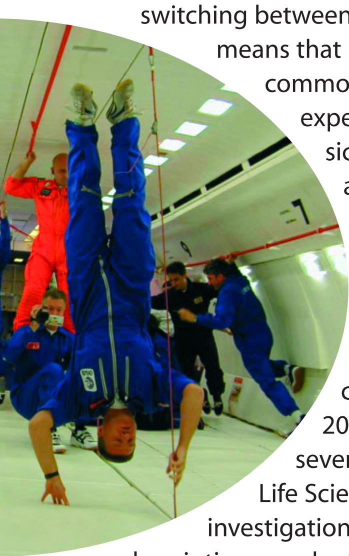
Parabolic Flights Campaigns

The main advantages of parabolic flights for microgravity investigations are: the short turnaround time (typically a few months between proposal and execution), the low cost (ESA provides the flight free of charge), the flexibility (laboratory-type hardware is most commonly used), experimenters performing their own investigations, and experiment modifications between parabolas and flights.

Precautions are taken to ensure that all operations are safe and that participants are prepared. Flying experimenters must pass a medical examination in a qualified Aeronautical Medical Centre. ESA and Novespace help in hardware design and safety aspects. Technical visits are made to the institutions to review the equipment. A safety review is held with ESA and CEV a month before the campaign to discuss the integration of all equipment and assess the overall safety of the campaign.

The campaign itself lasts 2 weeks. The first week is devoted to experiment installation in the aircraft. The second follows a well-established schedule for flight operations. On Monday morning, a tour of the aircraft verifies that all equipment complies with the safety standards. A mandatory flight briefing takes place that afternoon. Three flights are made during the following three mornings, each of 30 parabolas in sets of five. Friday is a backup day in case of bad weather or technical problems. The flights, from the Bordeaux-Merignac international airport, last about 2.5 h.

During the flights, specialised personnel supervise and support the experiments. A Flight Surgeon supervises the medical aspects of flight operations and helps participants in case of sickness. The repeated switching between low- and high-gravity means that motion sickness is quite common, sometimes hampering experiments. Anti-motion sickness medication is available on request before each flight.



The Recent Campaign

The most recent (33rd) ESA campaign was conducted in September 2002 with ten experiments: seven Physical Sciences, two Life Sciences and one Technology investigation (see table). Experiment descriptions can be found in: *http://www.spaceflight.esa.int/users/file.cfm?Filename=miss-parafl-33*. After a campaign, investigators submit abstracts with preliminary results to ESA's Microgravity Database at: *http://www.esrin.esa.it/htdocs/mgdb/mgdbhome.html*

Most of the experiments of recent campaigns resulted from peer reviews after ESA Announcements of Opportunities. Simpler 'look and see' experiments are still flown from time to time. Unsolicitated proposals are always welcome.

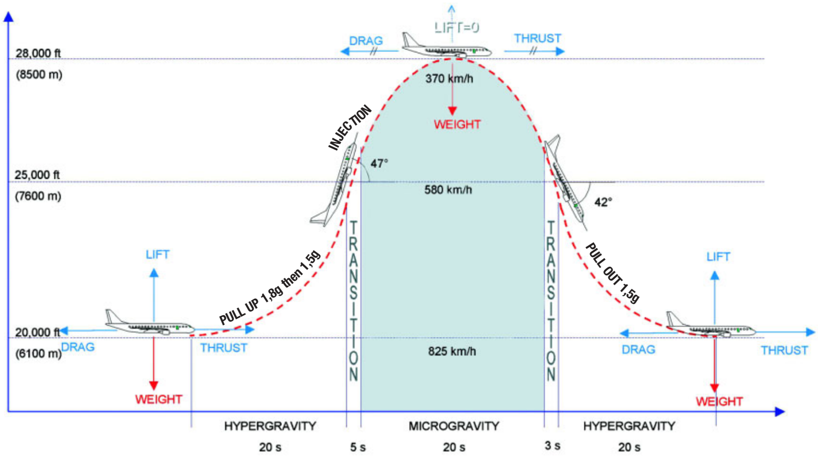
Conclusion

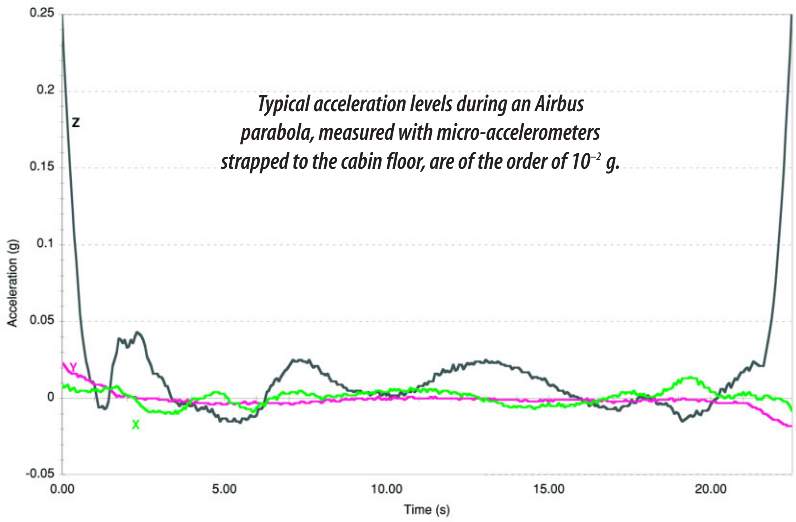
The quality and duration of microgravity obtained, the flexibility and variety of opportunities and the ease of flight preparation make aircraft parabolic flights a unique and versatile microgravity tool. They are particularly valuable for preparing gravity-related science and technology experiments for Space Station missions. ESA will therefore continue to organise two campaigns a year until at least 2006.

Experiments of the 33rd ESA Parabolic Flight Campaign

- Two phase loop with condensing-separating system for the evaporative convection and turbulence in pure fluids experiment
- Vibrational phenomena in inhomogeneous media
- Laminar diffusion flames representative of fires in microgravity environments
- Microgravity ignition tests of insulating materials
- Investigations on soot concentration and primary particle sizes under microgravity by advanced laser-induced incandescence techniques
- Tests of an 'Interactions in Cosmic and Atmospheric Particle Systems' ICAPS facility for ISS
- Validation of an experimental set-up for the ESA Droplet Combustion Insert
- In vivo monitoring of the mechanical environment of bone and comparison of its specific characteristics in microgravity and normal gravity
- Effect of gravity on the reorganization of the chromosome after centrifugation
- Deployment and stabilisation of tether/telemanipulator

Parabolic flight manoeuvres.





Typical acceleration levels during an Airbus parabola, measured with micro-accelerometers strapped to the cabin floor, are of the order of 10^{-2} g.

Training for STS-116

Preparing to Expand the ISS

Graham T. Biddis
On Station Contributing Writer

Introduction

ESA astronaut Christer Fuglesang is scheduled to fly on Shuttle mission STS-116 in July 2003 as a NASA Mission Specialist. On a recent visit to Europe from his training at NASA's Johnson Space Center in Houston, he spoke with *On Station*.

Christer Fuglesang will be the first Swede in space and the first ESA astronaut to perform EVAs during an ISS mission ...

What is your background?

I grew up in Stockholm and attended the Bromma Gymnasium, after which I went to the Royal Institute of Technology to study physics and mathematics. I went on to do a PhD in particle physics at Stockholm University and then got a Fellowship at CERN in Geneva. While I was there, ESA announced the astronaut opportunity. It took around 2 years between my application and selection, so after my Fellowship I returned home and worked at the Manne Siegbahn research institute. The final decision came in May 1992.

How did you get on with EuroMir training?

The toughest part was getting to grips with the Russian language. Apart from 'nyet', I didn't know a word of Russian. So, during the winter of 1993, we had a lot of language classes in Cologne in preparation for going to Russia, but, in hindsight, it was far from enough. When we got to Russia, we started classes on the Soyuz and Mir, and the first couple of months were really hard.

What were your specific responsibilities?

My main responsibility was for the ESA payloads but we also trained on some Mir systems, including life support and thermal control. On Soyuz, I handled life support from the right-hand seat. The Russians never really expected that a visiting cosmonaut would have to take control as that was always under the Russian commander's responsibility. But they did want visitors to be sufficiently familiar with the systems.

With the unification of the ESA Astronaut Corps, did you see significant changes?

It was certainly a wise step to unify the various European interests into one Corps. One of the current issues is that flights are not necessarily being organised by ESA but rather with individual European countries buying their own flights and then asking ESA to fly their astronauts. In this sense, I feel that we are only halfway to where we should be with a unified Corps. More flight opportunities are needed, rather than reducing the Corps size. Coming from a small country, I hope that each member of the Corps will get an equal opportunity to fly irrespective of nationality.

How were you selected for STS-116?

During the 1990s, NASA generally treated all astronauts stationed in Houston in the same way, independent of nationality. Unfortunately, this changed about the time when my NASA Astronaut Class started to fly. Partly, I think, because we had so many foreigners. Now it is mainly a question of agreements between NASA and the astronaut's home country or sponsoring agency, and of how successful the latter is in having their deal implemented. In my case, I was selected partly because my

Astronaut Class was coming to an end and partly because my EVA skills fit well into the four spacewalks planned for STS-116. This expertise came first from my Soyuz/Mir work and, more importantly, from my NASA EVA training.

What are your responsibilities on STS-116?
First of all, there are no European payloads on STS-116. In contrast, STS-107 carries a large number of ESA payloads but no ESA astronaut.

On the 11-day STS-116 mission, I will perform three of the four EVAs. During launch, I will be Mission Specialist #1, sitting on the flight deck's right-hand seat. Just after main engine shutdown, I will photograph the departing External Tank with a 400 mm telephoto lens. I will then coordinate the swap from launch- to on-orbit configuration, such as stowing the suits and seats. Fortunately, the new Station crew sitting 'downstairs' are old hands at this.

While docked, I am the Loadmaster for most of the logistics movements between *Atlantis* and the Station. There are a lot of items stowed in our Spacehab lockers for the up-crew, such as food, clothes, experiments and personal items, and they all have to be moved to the Station. At the same time, items for the down-crew will make the reverse trip.

For descent, I will coordinate the configuration for landing with the returning crew. This involves setting up the special seats that enable the ISS crew's horizontal transfer after so long in weightlessness. I will be sitting downstairs with them.

I hope to perform an experiment that I have been working on since Mir: SilEye/Alteino, delivered to the Station by Roberto Vittorio in April 2002. This detector studies the light flashes seen by many astronauts, as well as the Station's radiation environment. I hope that the Italian Space Agency makes it an official European experiment.

But my most important work is the three EVAs. In the first – and probably the most spectacular – we will add the P5 Truss element to the ISS. Shuttle's Canadarm will hand it over to the Station's Canadarm2, which will truck it down to the port truss end. It must be carefully passed through a gap between the existing solar arrays where there are literally only centimetres to spare in both directions. During that operation, my main task is to talk to the arm controller so that P5 doesn't hit any Station parts. There are no good camera views so I have to advise 'up a little' or 'down a little' to guide the 1800 kg unit. This whole activity is hampered by the solar arrays because they need to be at a specific orientation and cannot be stowed out of the way.

The other EVAs will reconfigure the Station's power and thermal cabling and plumbing so that, after checkout, the new arrays can be brought on line.

STS-116 will also bring up many spare parts for us to stow on the outside of the Station ready for later repair and replacement EVAs. A spectacular job will be retraction of an existing solar array on P6, now on top of Z1. From earlier experiences, there is considerable nervousness about retraction, but it must be done in preparation for the later transfer of P6 to its final position on P5.

I will not be involved in the fourth EVA and will be most likely continuing my Loadmaster tasks. I have also signed up for various Detailed Science Objective tests in support of human physiology research, including checks on the vestibular system to investigate speedier recovery of the body after changes during flights.

And thoughts on future opportunities?
Of course, I would like to fly as an Expedition crewmember, but realise that I must continue training after STS-116 until my turn comes!

Shuttle training at the Johnson Space Center. Above is the full STS-116 crew; Christer is third from left. (All photos NASA)

Training for ISS

First International Astronaut Class Trained at EAC

Hans Bolender, Loredana Bessone, Andreas Schoen & Herve Stevenin
Astronaut Training Division, European Astronaut Centre, Cologne, Germany
Email: Hans.Bolender@esa.int

Introduction

After years of preparation, ESA's ISS training programme is now operational. Between 26 August and 6 September 2002, the European Astronaut Centre (EAC) at Cologne delivered the first ESA advanced training course to an international ISS astronaut class: two from NASA, four NASDA (Japan) and four ESA (France, Germany, Italy and Spain). They began their advanced training in 2001 at NASA's Johnson Space Center in Houston and at NASDA's Japanese Training Centre in Tsukuba.

ESA's astronaut-training programme for the ISS is now operational ...

Advanced Training

Following the Astronaut Basic Training (provided independently by each International Partner to its own astronauts), the Advanced Training marks the start of multilateral training. It is designed for *international* astronaut classes and is provided jointly by all Partners at their training sites around the world. During multilateral training, each Partner is in charge of training *all* ISS astronauts on those elements it contributes to the Station programme. The 1-year Advanced Training provides a more in-depth understanding of systems and subsystems, payloads and payload support systems, transport vehicles and related operations. It focuses on generic ISS onboard tasks and interaction with the ground control centres and prepares crewmembers for an assignment to flight.

During their stay at Cologne, the class participated in 33 classroom and hands-on training lessons for ESA's main contributions, namely Columbus (including the four ESA payload racks) and the Automated Transfer Vehicle (ATV).

Columbus training focused on familiarising the astronauts with the technical layout of the module, the characteristics and capabilities, and the operational concepts and modes. They received knowledge-based training on the different systems and subsystems, their components, functions and redundancies. Special attention was paid to the data management system (DMS) as – seen from a crew operations perspective – the central element of the Columbus module. Training objectives relate to understanding the DMS architecture, its vital layer and nominal layer, and its redundancies and reconfiguration capabilities. Working with crew displays, navigation within the displays, monitoring and commanding is another key element.

The Orbital Replaceable Unit (ORU) concept used for Columbus maintenance was introduced, together with an explanation of the major ORUs and their functions and locations. This knowledge-oriented part concluded with a lesson on the Columbus operational modes, mode transitions and their operational drivers and consequences.

On ATV, the astronauts received an overview on the overall mission concept, systems and subsystems, before a closer insight into the three major groups of crew tasks: rendezvous

Hands-on training on the Data Management System in the Columbus trainer at EAC.

and docking, cargo operations and emergencies.

As ATV will dock automatically, crew intervention will be rather limited. However, the training is important for overall Station safety. The crew learns to monitor the rendezvous using video images of the approaching ATV and the data provided by on onboard displays to assess if it is on a safe trajectory and if intervention is required. The crew can pause ATV's approach, or command it into to a collision-free orbit.

ATV will resupply the Station with a wide range of dry cargo, water, gases and fuel. The astronauts familiarised themselves with the basic cargo operations and handling. Filling ATV with rubbish is not a simple task and requires training. Special attention has to be paid to keeping the centre of mass within a certain range to allow a safe undocking and departure from the Station.

Finally, an overview of ATV-specific and Station generic emergencies was provided. The first group deals with emergencies during rendezvous, docking, undocking and departure. The second covers a fire in the vehicle and rapid depressurization of the ATV.

After the first week, the astronauts visited the Columbus flight model at prime contractor Astrium in Bremen. The training concluded with an introduction to the four ESA experiment facilities (European Drawer Rack, Fluid Science Laboratory, European Physiology Modules and Biolab) for Columbus.

Training Readiness Reviews

In preparation of the first advanced training block, two Training Readiness Reviews were conducted at EAC in June and August. They were supported by training experts and astronauts from NASA, NASDA and the Canadian Space Agency, who analysed and evaluated ESA's advanced training concept, the development process, training content and instructional design of lessons and courses. Furthermore, the fidelity of the crew training facilities and the subject matter expertise and delivery skills of ESA training instructors were evaluated. The multilateral review board finally testified to ESA's readiness for advanced training by declaring the reviews successful.

Delivering the first ESA training course provided a good opportunity for the Astronaut Training Division to determine the status of the ESA training programme. Comments and recommendations made by the training experts and astronauts have been carefully evaluated and the results are being fed back into the training development process for the Increment-specific training (the final phase in the ISS training flow; see figure). The Increment-specific training prepares an assigned Station crew to perform all the tasks planned for a specific long-duration ISS flight.

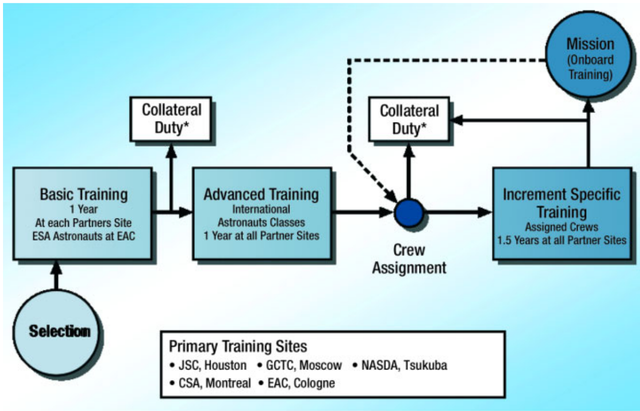
Training Preparation for 1E and its Increment

As a consequence of delaying Japan's Kibo research module to 2006, ESA is now the next Partner in line to launch its module. Changes to the assembly sequence suggest that the Columbus launch of October 2004 will no longer include a crew-exchange. According to current planning, the long-stay crew will have been aboard the Station since July 2004 by the time Columbus arrives.

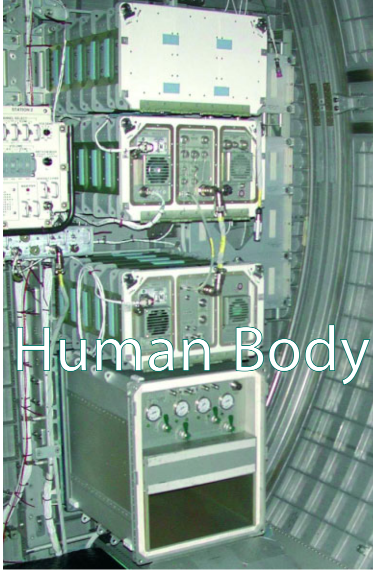
Under this scenario, training for the Shuttle and ISS crews will be a special challenge, not only because it is the first Increment-specific training provided by ESA, but also because it requires training for a Shuttle crew and prime and back-up Increment crews. Moreover, the training for the ISS crews needs to be advanced 3 months compared to the original schedule. According to the draft assembly sequence, the first ATV launch is scheduled for the same Increment, so the Station crews must also prepare for ATV operations.

Training schedule updates are being prepared, and coordination of Shuttle and Increment training with our NASA counterparts has begun. The first Increment-specific crew training at EAC is expected for the last quarter of 2003. Preparations have started and we are confident of mastering the challenge.

The first international astronaut ISS advanced training class at EAC. From left: Satoshi Furukawa (NASDA), Stephanie Wilson (NASA), Paolo Nespoli (ESA), Thomas Reiter (ESA), Pedro Duque (ESA), Koichi Wakata (NASDA), Leopold Eyharts (ESA), Takao Doi (NASDA), Nicole Stott (NASA) and Aikihido Hoshide (NASDA).



The ISS training flow.



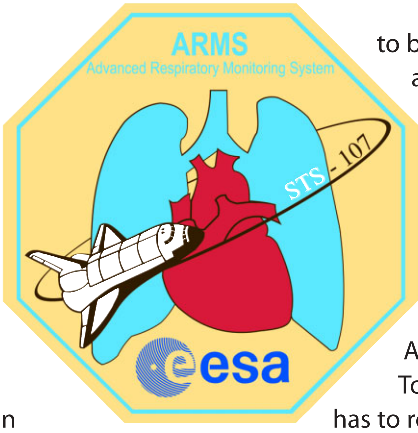
ARMS

Improving our Understanding of the Human Body

Ing Oei & Marine Le Gouic
Microgravity and Space Utilisation Department, MSM-GMP
D/MSM, ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Email: Ing.Oeii@esa.int & Marine.Le.Gouic@esa.int

ESA's ARMS human physiology research facility is ready for flight on Shuttle STS-107 ...

Introduction



ESA's Advanced Respiratory Monitoring System (ARMS) is scheduled to fly on the STS-107 Shuttle Spacehab research mission in January 2003. Eight European experiments will investigate the effects of microgravity on human physiology using ARMS, providing insights into certain clinical cases that are not yet well understood.

ARMS is a facility to research human pulmonary (lungs), cardiovascular (heart and blood vessels) and metabolic physiology. Its predecessors – Anthrorack & RMS II (Respiratory Monitoring System II) – flew respectively the German STS-55 Spacelab D2 mission in April 1993 and the Euromir 1995 mission. It was developed by a consortium led by Innovision of Denmark. A bicycle ergometer is used to stress the body and study its reactions.

There are three ARMS units: the Training and Flight Spare units are used for crew training and Baseline Data Collection (BDC), plus the Flight Unit. ARMS was tested in microgravity for the first time during ESA, DLR and CNES parabolic flight campaigns in 1999.

The STS-107 crew has trained since 2001 to operate ARMS and, more difficult, how to behave as test subjects. It is quite an undertaking since crewmembers are often asked to control their respiratory flow, respiratory pressure, respiratory frequency and pedalling speed. The software gives them visual feedback of these parameters through ARMS' laptop screen.

To collect baseline data, the crew has to repeat their orbital experiments regularly, together with some specific ground-only variations. BDC began around 9 months before launch to obtain the baseline data against which in-flight (adaptation to microgravity) and post-flight data (readaptation to 1 *g*) will be compared. Crew dedication is very important as four must each devote 21 h during flight, 80 h to training, 60 h to BDC and 44 h post-flight.

Top: ARMS installed in Spacehab.
Bottom: Crewmember Ilan Ramon with the RIP band around his chest while exercising on the bicycle.

Physiology of the Heart

The body is an ingenious system of numerous control loops and sensors that we still do not fully understand. The heart is a muscle that continuously pumps blood through the whole body, by contraction of the muscle fibres. It consists of two smaller upper chambers (atria) and two large chambers (ventricles). The right atrium receives deoxygenated blood from all organs and releases it into the right ventricle. That then pumps its contents into the lung circulation, where the carbon dioxide in the blood is exchanged for oxygen. From the lung circulation, the oxygen-saturated blood travels to the left atrium and then into the left ventricle. The left ventricle squeezes the blood to the head and the rest of the body. A natural pacemaker, the Sinus Atrial node, sends an electrical signal through the heart muscle fibres to trigger the timely contractions of the four chambers.

Blood from the ventricles flows through the arteries to the organs, then returns via the veins to the atria. At rest, an average of 5 litre/min is pumped, known as the cardiac output. During heavy exercise, this output can increase 5-6 times to fulfil the body's oxygen demand. During each contraction, the blood is pumped into the aorta and smaller arteries, causing their elastic walls to expand and shrink directly after the left ventricle has emptied its contents. It is this expansion and recoil of the arteries that we feel pulsating in our necks and wrists.

Another parameter that can easily be measured is the blood pressure, which rises and falls according to the pumping cycle of the heart. When the ventricles contract, they squeeze blood into the arteries, making the pressure rise rapidly. When the ventricles relax, they fill with blood from the atria so they are ready for the next contraction. During this relaxation period, the pressure drops.

Doctors measure blood pressure with an inflatable cuff around the upper arm, which compresses and closes the artery. By slowly deflating the cuff, the force with which the blood is squeezed through the arteries by the pumping heart can be measured. The pressure measured by this method gives only two values. The high (systolic) value corresponds to the pressure produced during the contraction of the left ventricle, while the low (diastolic) value reflects the relaxation of the ventricles. In reality, the blood pressure is a continuous signal. One of the ARMS instruments, Portapres, continuously measures the blood pressure at finger level using a clever combination of an applied external pressure through a finger cuff and light controls.

To measure the electric activity of the heart, an electrocardiogram (ECG) is used. For the ARMS experiments where only the heart rate and rhythm are important, a 3-electrode ECG is recorded using the Portapres.

Our Lungs

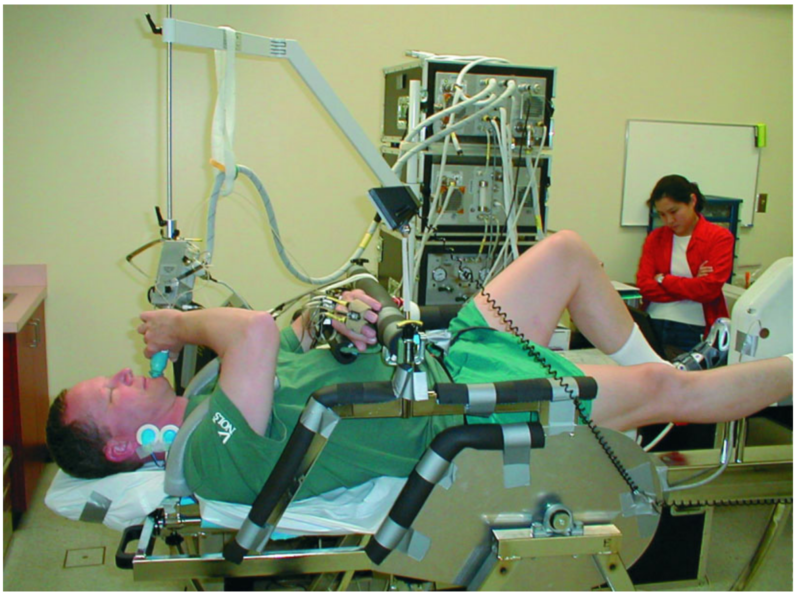
The lungs' most important function is to exchange oxygen and carbon dioxide in the blood. When air is inhaled, it travels through branching airways ending in little sacs, called alveoli. Blood circulates around these alveoli and through a simple diffusion process oxygen and carbon dioxide are exchanged.

Since the heart and lungs work closely, they are referred to as the cardiopulmonary system. This close relationship means that some heart functions can be obtained through measurements of the lung function. For instance, the blood flow through the heart can be calculated from the rate that respiratory gases disappear while breathing in a closed circuit.

Just as pulmonary functions tests are commonly used in clinics to test lung performance, these tests are also performed with ARMS. Spirometry determines lung volume during slow maximum in- and expiratory effort. It also measures the flow rate. Breathing frequency is measured using the Respiratory Inductance Plethysmograph (RIP), a band worn around the chest; breathing causes a change in inductance in the wires.

STS-107 experiments using ARMS

- Cardiopulmonary and muscular adaptations during and after microgravity (Prof. Dr. D. Linnarsson, Sweden)
- Effects of microgravity on total peripheral resistance in humans (Dr. P. Norsk, Denmark)
- Physiological parameters that predict orthostatic intolerance after space flight (ground experiment) (Dr. J. Karemaker, The Netherlands)
- Multiparametric assessment of the stress response in astronauts during space flight (Prof. Dr. M. Pagani, Italy)
- Adaptation of spontaneous baroreflex sensitivity to microgravity (Dr. M. Di Rienzo, Italy)
- Initial effects of microgravity on central cardiovascular variables in humans (Dr. R. Videbaek, Denmark)
- Influence of weightlessness on heart rate and blood pressure regulation: responses to exercise and valsalva manoeuvre (Dr. U. Hoffmann, Germany)
- Arterial baroreflex control of sinus node during exercise in microgravity conditions (Dr. F. Iellamo, Italy)



Crewmember Dave Brown on the tilt table, reaching for the Respiratory Valve Unit and mouthpiece. The ARMS facility is in the background.

ARMS Technical Summary

Two photo- & magneto-acoustic gas analysers with Nafion inlet:
Analyser 1 measures: O2, 0-100%; CO2, 0-12%; SF6, 0-2%; Freon 22, 0-3%.
Analyser 2 measures: O2, 0-100%; CO, 0-0.3%; CH4, 0-3%.
Signal/noise generally better than 250 at half-scale.
Gas signal response time 160 ms or better, except for CO (300 ms). Sampling frequency: 33 Hz for each gas.

Gas supply:
372 litres Rebreathing 1 mix (25% O2, 1-3% Freon 22, 1% SF6, 0.3% CO, 2.4% CH4, balance N2).
62 litres Rebreathing 2 mix (1-3% Freon 22, 1% SF6, 0.3% CO, balance O2).
372 litres Rebreathing 3 mix (60% O2, 1-3% Freon 22, 1% SF6, balance N2).
62 litres Calibration mix (13% O2, 3% CH4, 0.3% CO, 8% CO2, balance N2).

Respiratory Valve Unit:
Computer-controlled Respiratory Valve Unit, including automatic Rebreathing Bag emptying and filling.
Mouthpiece pressure, ±100 mbar, 0.2 mbar accuracy, up to 200 Hz sampling.

Flowmeters:
Ultrasonic Flowmeter: ±12 litre/s, 2% accuracy, 200 Hz sampling. (Flowmeter not used for STS-107.)
Turbine Flowmeter: ±15 litre/s, 2% accuracy, 20 Hz sampling.
Differential Flowmeter: ±15 litre/s, 2% accuracy, 200 Hz sampling.

Continuous Blood Pressure & ECG signal (acquired by Portapres model 3.1):
Finger BP Curve 10-300 mm Hg, 0-240 beats/min, 200 Hz sampling.
Systolic, Diastolic, Mean, Heart Rate, Inter-beat-Interval data.
ECG, 3 electrodes. 30-250 beats/min, 200 Hz sampling.
Hardware detection of R_{peak} with 1 ms accuracy.

Ambient conditions monitoring:
Temperature 5-40°C; Pressure 950-1050 mbar; Humidity 10-95% RH

Respiratory Induction Plethysmograph (RIP):
Measurement of ribcage movement for breathing frequency. On STS-107, RIP will measure only frequency (1 band); no volume determination will be made.

Experimenter-provided equipment for STS-107:
Isometric muscle exercise using Handgrip Dynamometer. Manual readout of instantaneous pressure, 0-1.6 bar. Manual readout of maximal pressure reached during experiment.
Oxygen saturation measured by Infrared Pulse Oxymeter (MicrO2, Siemens). Manual readout of %SaO2, 0-100%. Manual readout of heart rate, 30-250 beats/min.
Haemoglobin measured by Haemoglobin Photometer (HemoCue). Manual readout, range 0-256 g/litre.
Breathing pressure measured by Spirovis. Manual readout of maximum inspiratory & expiratory pressure.
Breathing pressure measured by thigh cuffs, from Neurolab, manually inflated.

The diffusion capacity refers to the ability of oxygen to diffuse from the alveoli into the blood. It is reduced with age and emphysema (a lung disease in which the alveoli are irreversibly damaged; commonly caused by cigarette smoking), and is increased during exercise. During the ARMS experiments, the pulmonary function will be determined using different gas mixtures carrying components not normally found in air. These components are non-toxic and are selected according to their mass and solubility in the blood, thus making it possible to assess various cardiovascular and pulmonary characteristics. Crewmembers will perform various breathing manoeuvres that differ in breathing frequency, depth and flow rate.

To measure oxygen saturation, an infrared pulse oxymeter is placed over the fingertip and connected to the electronic and display unit. It is used in clinics but it can also be used by pilots to measure their own oxygen saturation at high altitudes in unpressurised cabins. Hypoxia (low oxygen saturation) may lead to impaired judgement and vision in flight.

ARMS Science and its Benefits

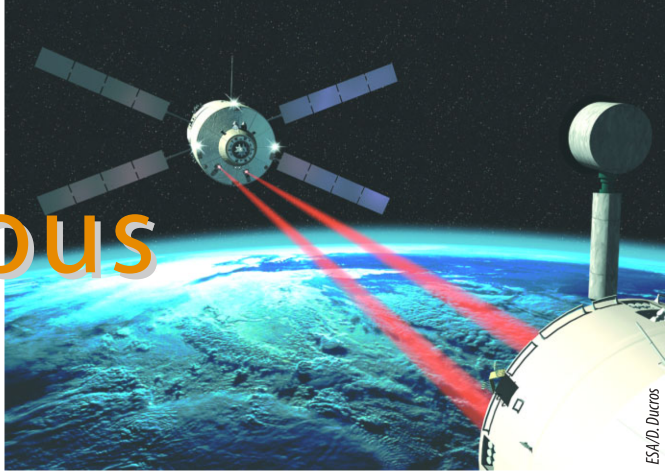
Orthostatic intolerance produces dizziness, light-headedness and even fainting when upright, while these symptoms are absent lying down. An inadequate pressure-control mechanism leaves the head with insufficient blood as the subject moves from horizontal to upright. Baroreceptors in the arterial walls help to regulate the cardiovascular system. For example, if they sense a decrease in blood pressure they can cause the blood vessels to constrict so that the blood pressure rises.

In clinics, orthostatic intolerance is a common problem in patients after long-term bedrest. Several ARMS experiments will study different factors (including blood pressure variability, control mechanisms in the nervous system, and exercise) that may influence orthostatic intolerance. Two ground experiments use a tilt table to investigate the blood pressure-control mechanism. The subject is secured on a tilt table, then tilted back and forth from a horizontal position to near-upright within 1 s. Previous spaceflights showed similarities between clinical and post-flight orthostatic intolerance, so these experiments are expected to benefit medical science.

Clinical studies have shown that the gas exchange in patients with severe lung insufficiency can be improved by treating them in the prone (face down) position. The mechanism behind this is unknown. An ARMS experiment will investigate the gas exchange in prone and supine (face-up) positions, and in microgravity.

The results from this and previous human physiology research missions will benefit human performance not only in extreme environments (space, Arctic expeditions, high altitude) but also medically. These experiments will lead to a better understanding of how our body tunes the fine mechanisms and may lead to new treatment methods.

ATV: Rendezvous with ISS



***Heinz Wartenberg*[1] *& Patrice Amadieu*[2]**
[1]System & Avionics Section, [2]AIV & ISS Integration; ATV Project, D/MSM, Les Mureaux, France
Email: Heinz.Wartenberg@esa.int; Patrice.Amadieu@esa.int

Introduction

One of ESA's most ambitious contributions to the International Space Station (ISS) will culminate in 2 years, when the Automated Transfer Vehicle (ATV) is launched by Ariane-5 and, after 5 days, performs an automatic rendezvous and docking with the ISS. From a total launch mass of up to 20.5 t, ATV will deliver up to 9 t of supplies, payloads, crew items and propellant. During its stay of 6 months, ATV will also provide reboost and attitude control for the Station. On departure, ATV will take up to 5.5 t of waste (including up to 840 kg of liquid wastes), for destructive reentry into the atmosphere.

The first mission (named 'Jules Verne') will be a premiere for Europe in more than one sense: it will be the first rendezvous and docking ever by a European spacecraft, it will be the first automated rendezvous with a space station using optical sensors, and the first ever where the target's attitude motion is compensated for by the chaser. Ensuring the safety of the ISS crew was an essential design driver.

When the Automated Transfer Vehicle docks with the ISS, it will be a first for Europe ...

The Rendezvous Scenario

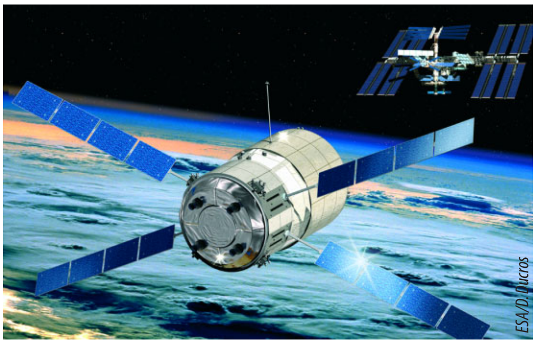
Ariane-5 will inject ATV into a 51.6° orbit at an altitude between 200 km and 300 km, 50-150 km below the ISS, depending on the Station altitude at the time. On separation from Ariane, the essential ATV subsystems are automatically activated and ATV stabilises its attitude, establishes radio communication with the its Control Centre (ATV CC) in Toulouse via the NASA TDRSS and ESA Artemis data relay network, and deploys its solar array.

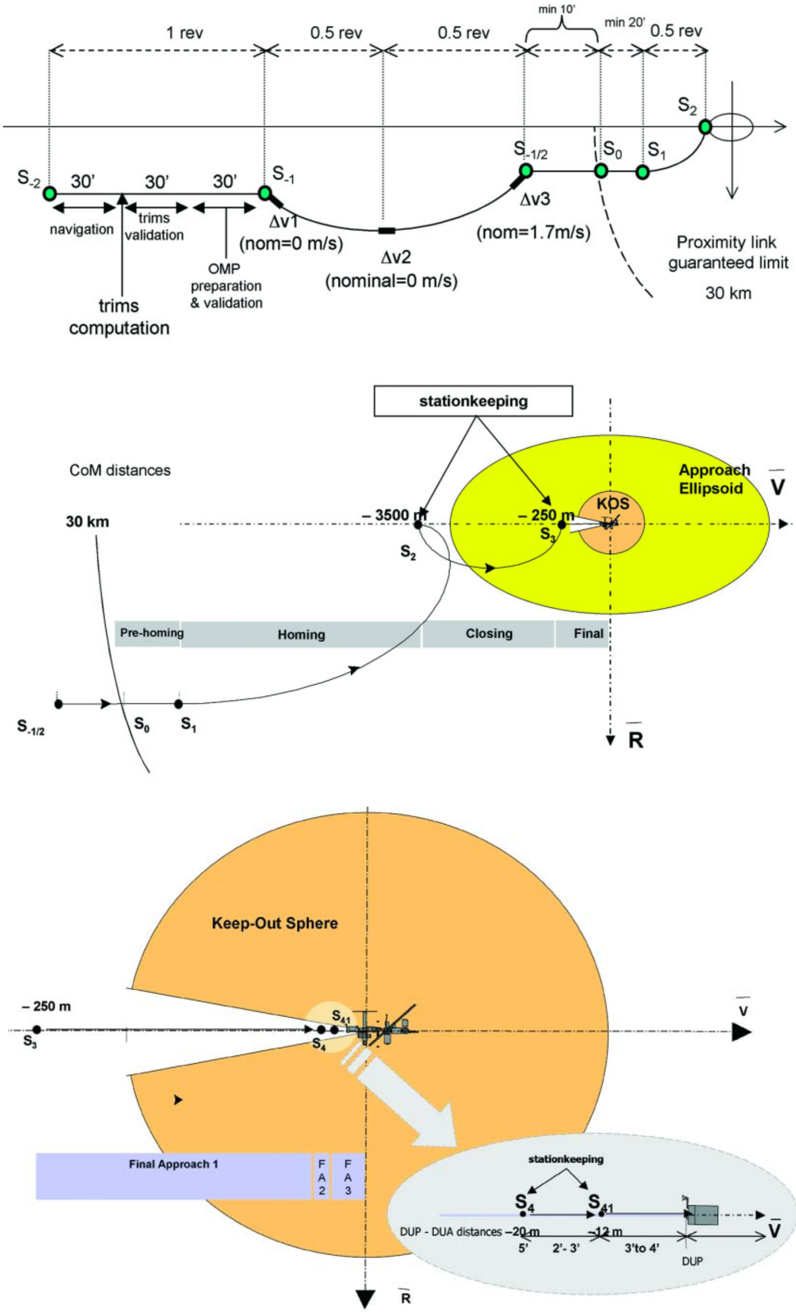
Altitude Raising and Phasing

A sequence of orbital manoeuvres brings ATV to an intermediate orbit 10-15 km below the Station, where the natural drift due to orbital dynamics corrects the relative phase angle. When ATV is 200 km behind the ISS, trim manoeuvres then position it in exactly the same orbital plane as the ISS, still at a slightly lower altitude, so that the relative drift brings them closer and closer. At 30 km out (point S0), direct ATV-ISS radio communications are established, allowing ATV to initiate relative navigation to the Station using GPS data from both ATV and ISS receivers, processed by ATV.

Homing

At point S1, about 20 km behind the Station, the ATV CC commands ATV to begin its homing manoeuvre, which consists of a two-boost transfer lasting 45 min. It brings ATV to point S2 on the same orbit and about 3.5 km behind the ISS, still outside the ISS 'Approach Ellipsoid' (an ellipsoid of 4000 x 2000 x 2000 m centred on the ISS centre-of-mass, with the long axis along the velocity vector, or V-bar). All ATV operations inside the Approach Ellipsoid are 'combined operations' and involve the mission control authorities in Houston, Moscow and Toulouse. S2 is the first stable hold point of ATV with





Top: the series of orbital manoeuvres. (OMP: Onboard Mission Plan.)
Centre: the homing approach from point S1.
Bottom: the final approach from point S3.
(Illustrations: EADS)

respect to the ISS; ATV stays there for up to 90 min, in preparation for final approach.

Closing

Once the Mission Control Centre in Houston gives the go-ahead for Approach Initiation, the ATV CC commands the vehicle to enter the Approach Ellipsoid. The Closing manoeuvre brings it to point S3, 250 m behind the ISS. It must not enter the ISS 'Keep Out Zone' – a safety sphere of radius 200 m, centred around the ISS centre-of-mass. This exclusion is guaranteed by using an 'eccentricity increase' manoeuvre to get from S2 to S3: two burns perpendicular to the orbital tangent bring ATV to S3 in half an orbit (45 min). If the braking burn fails at S3, then ATV naturally returns to S2 in another half-orbit.

Final Approach and Docking

Between S3 and docking, ATV approaches on a 'forced' translation along the ISS velocity vector to the docking port at the aft end of Zvezda. 'Forced' means that, in addition to the 220 N thrusters propelling ATV towards the ISS, perpendicular thrusters are firing towards Earth to stop the orbit rising.

To ensure proper capture and acceptable docking loads, ATV's docking probe has to meet Zvezda's docking cone within a radius of 10 cm and a lateral velocity of less than 2 cm/s. To meet these conditions, the relative navigation during final approach is based on ATV's optical sensors, with corresponding passive target patterns close to Zvezda's port. While measurements from the Videometer primary sensor are used in the active guidance, navigation & control (GNC) loops to control ATV's motion, the information provided by the Telegoniometer secondary sensor is provided to the Flight Control Monitoring (FCM) system to supervise the performance of the active loop.

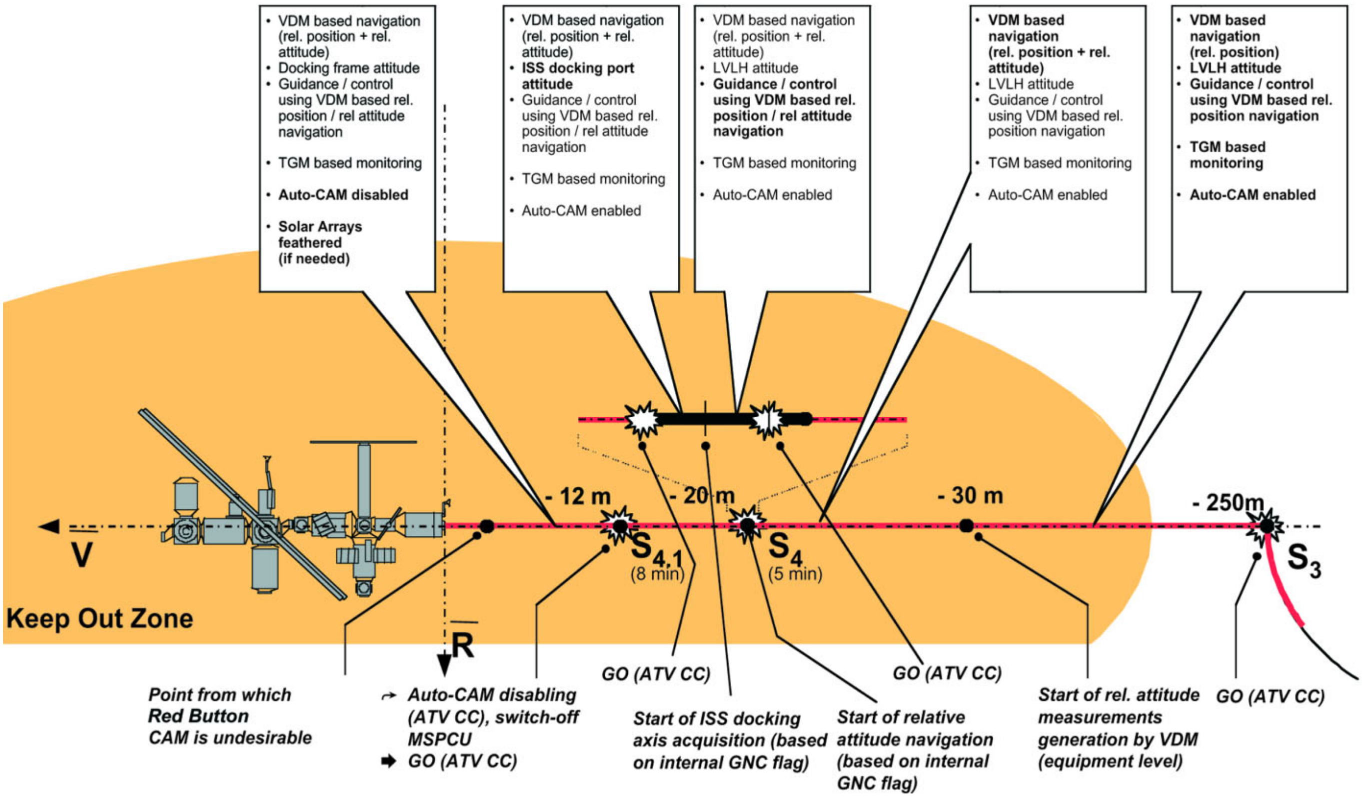
Principle of the Videometer

The Videometer delivers range and line-of-sight angles to the GNC system, and, from within 30 m, relative attitude angles, based on triangulation. A diverging laser beam emitted by diodes on the ATV front cone towards Zvezda is returned by a pattern of reflectors, imaged by a CCD. The pattern size provides the range, its position on the CCD yields the line-of-sight angles, and its apparent shape gives information about the relative attitude angles.

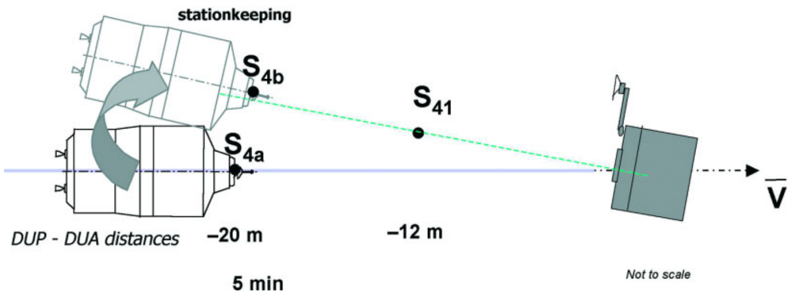
Principle of the Telegoniometer

The Telegoniometer delivers range and line-of-sight angles to the FCM, based on time-of-flight measurement. Collimated laser pulses from a diode scan the ISS vicinity and are returned by three reflectors on Zvezda. The light-pulse travel time provides the distance, and the positions of two beam steering mirrors give the two line-of-sight angles.

Once the rendezvous sensor relative navigation is properly acquired, the ATV CC commands ATV to leave S3 and enter the Keep-Out Zone. This final approach is performed in several steps, each initiated by ATV CC command for ATV to proceed automatically to the next hold point:



- S3 to S4, 20 m from docking. ATV stays on the V-bar and controls its motion relative to the ISS based on range and line-of-sight information from the Videometer.
- S4 to S41. Before reaching S4, the sensor mode changes to relative attitude measurement. From then on, ATV's docking port always aligns with Zvezda's, thereby tracking any movements of the ISS.
- S41 to docking. At S41, about 12 m out, ATV performs a last hold, for the crew and ground to confirm that all is ready for docking. It resumes the approach on command from the ATV CC; there are no more mode or configuration changes. The crew closely monitors this last part of the approach using information independent of ATV's onboard systems (Zvezda video camera visual image, and range and range-rate readings from the Russian Kurs rendezvous system on Zvezda).



Top: the approach from S3. (CAM: Collision Avoidance Manoeuvre. LVLH: local-vertical, local-horizontal. TGM: Telegoniometer. VDM: Videometer.) Above: from S4, ATV matches the ISS motion. (DUA: Docking Unit Active. DUP: Docking Unit Passive). (Illustrations: EADS)

How Safety is Ensured

In accordance with the principle of two-fault tolerance (2FT) against failures that could endanger crew safety, all ATV onboard functions involved in the rendezvous and docking operations are designed 2FT. A first failure will in general be recovered by the onboard FDIR (Fault Detection, Isolation and Recovery) function without interrupting the mission. After a second failure in the same functional chain, ATV performance may be degraded, but the FDIR will still ensure safety by executing a safe departure from the Station (ESCAPE manoeuvre).

During rendezvous, the independent Flight Control Monitoring system, which runs in parallel with the active GNC loop, permanently supervises vehicle performance and triggers corrective actions in case of discrepancy.

To ensure ultimate safety, and to cover any 'unforeseen' problems (such as a crash of the onboard flight software), the Proximity Flight Safety (PFS) system continuously monitors the approach trajectory. In the event that safety thresholds are violated, it triggers a Collision Avoidance Manoeuvre (CAM), which propels ATV into a safe trajectory far away from the Station.

An additional safety layer on top of the onboard resources is provided by the ATV CC, which during rendezvous is in continuous contact with ATV and can interrupt the mission at any time. During final approach, the Station crew will visually monitor ATV and can command it to stop or fly away by using the ESCAPE or RED BUTTON CAM command.

Research in Destiny

Graham T. Biddis
On Station Contributing Writer

During their occupation of the Space Station from June to November 2002, the Expedition-5 crew performed a wide range of investigations ...

Expedition-5's Peggy Whitson inserts an experiment cartridge in the autoclave for the Zeolite Crystal Growth experiment. (NASA)

Introduction

The ISS Expedition-5 crew began its research aboard the Station's Destiny laboratory on 7 June 2002 and ended in November. The previous 8A configuration was changed to UF-2 with the visit of STS-110 in April 2002, and from UF-2 to 9A at the beginning of October.

Rack Payloads

Express Rack #1 (ER-1) hosted:

Microgravity Acceleration Measurements System (MAMS) and **Space Acceleration Measurement System II** (SAMS-RTS) Remote Triaxial sensors 1 & 2 to characterise the Station's microgravity environment.

Biotechnology Cell Science Stowage Resupply (BCSS-R & BCSS-5) supports biological cell culture research. Sub-rack modules provide semi-automated bioreactors, gas supplies, computer control and passive and low-temperature stowage. This cell culture system is an interim platform for cell research until the Biotechnology Facility is delivered.

Microencapsulation Electrostatic Processing System (MEPS) is an automatic manufacturing experiment to create research microcapsules through curing, filtering, washing and harvesting microcapsules for analysis on the ground.

ER-2 hosted:

Active Rack Isolation System (ARIS) actively damps out vibrations. The ARIS ISS Characterization Experiment (ARIS-ICE) is testing its performance.

Zeolite Crystal Growth Furnace Units 1 & 2 contain a multi-zone furnace for processing multiple samples of zeolite crystals and other smart materials. ZCG-S1/2 carry the sample solutions in cylindrical, Teflon-lined, triple contained aluminium or titanium autoclaves.

In the transition from UF-2 to 9A, the ADVASC support system locker was transferred from ER-4 into ER-2.

ER-4 hosted:

Biotechnology Specimen Temperature Controller (BSTC), part of the BCSS, can house 32 tissue culture modules at a carefully controlled 36°C. The **Gas Service Module** (GSM) supports the BCSS.

Protein Crystal Growth – Single Locker Thermal Enclosure System (PCG-STES) is an incubator/refrigerator to house devices for growing biological crystals in microgravity.

Advanced Astroculture Growth Chamber (ADVASC) consists of two single middeck lockers. One contains the support systems and typically remains onboard for 1-2 years. The second is a growth chamber for larger plants.

Advanced Thermoelectric Refrigerator/Freezer (ARTIC1) preserves biological samples.

Commercial Generic Bioprocessing Apparatus (CGBA) is a commercial plant biotechnology locker for research into tissue production, pharmaceutical production, biosubstrate growth, etc.

Space Acceleration Measurement System II (SAMS-ICU) Interim Control Unit, previously in an ER-1 drawer.

In the transition from UF-2 to 9A, the ADVASC growth chamber locker was returned to ground; the ADVASC support locker was transferred from ER-4 to ER-2; the PCG-STES locker was exchanged for a brought-up new STES Locker into ER-4; the CGBA was delivered by 9A and inserted into ER-4.

ER-3 and ER-5 do not yet have any payloads.

The **Human Research Facility** (HRF-1) is used to study the physiological, behavioural and chemical changes in humans caused by spaceflight. The **Gas Analyzer System for Metabolic Analysis Physiology** (GASMAP) analyses metabolic function, cardiac output, lung diffusing capacity, lung volume, pulmonary function and nitrogen washout. The **Ultrasound Imaging System** (Ultrasound) provides enlarged 3D images of the heart and other organs, muscles and blood vessels. The **Pulmonary Function in Flight** (PuFF) unit is researching changes in lung anatomy and performance caused by spacewalks or microgravity. The focus is on measuring changes in the evenness of gas exchange in the lungs, and on detecting changes in respiratory muscle strength. Each PuFF session includes five lung function tests.

The **Microgravity Science Glovebox**, provided by ESA, will be transferred to Columbus once that module is attached to the Station. (In the meantime, ESA shares usage of other facilities until Columbus is operational.) As part of the initial MSG science activities, two investigations were conducted during Expedition-5: Pore Formation and Mobility During Controlled Directional Solidification in a Microgravity Environment Investigation (PFMI); Solidification Using a Baffle in Sealed Ampoules (SUBSA). SUBSA uses a moving baffle to see if convection is reduced in the melt, thereby improving semiconductor crystal formation

Peggy Whitson working with the Microgravity Science Glovebox. (NASA)

Deployed Payloads

Interactions for studying crew and crew-ground team relationships during long-term space missions. The crew fills out a laptop questionnaire of their interactions with each other and ground controllers.

Earth Knowledge Acquired by Middle School Students (EarthKAM) uses a digital camera to enable thousands of students to photograph and examine Earth from an astronaut's perspective. Via the Internet, they control the camera and post the photographs for public viewing.

HRF Extravehicular Activity Radiation Monitor (EVARM) is a radiation dosimeter badge reader, with 12 (four sets of three) small dosimeter badges, each uniquely identified. A set is placed in an EVA suit to measure radiation levels at different body locations.

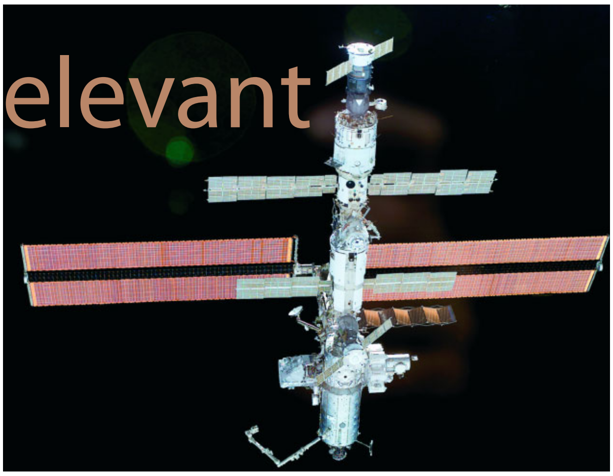
HRF Urine Collection Kit (UCK), a Nomex container housing the Urine Collection Devices (UCD), Ziploc containment bags, towelettes and gauze pads.

HRF Renal Stone for observing changes in renal function and increased risk of kidney stones induced by weightlessness. Beginning 3 days before launch and continuing for 14 days after their return, the crew are ingesting two potassium citrate pills (a proven Earth-based therapy) or placebos daily and collecting urine samples to learn whether the pills are effective.

Attached Payloads

The first attached payload experiment mounted outside the Station, Materials ISS Experiments (MISSE), consists of two suitcase-sized packages carrying experimental materials for solar power cells, radiation shielding, paint, optical materials and lightweight building materials. The experiment will remain exposed to the harsh environment of space for around a year before being retrieved and returned to Earth for study.

Recent & Relevant



MPLM Flight Experience

After five flights, the Multi-Purpose Logistics Module (MPLM) has proved itself to be a valuable part of the ISS programme, and its ESA-provided Environmental Control and Life-Support System (ECLSS) has performed flawlessly.

The ECLSS is liked by ISS crews, who appreciate the quiet of MPLM for sleeping in. What was a little crew secret during Leonardo's maiden flight has become an approved flight rule, after ventilation and air vitality analyses have confirmed astronaut safety. The arrival of an MPLM at the Station is eagerly awaited, not only for the supplies it brings but also for a few good nights' sleep.

MPLM's air cleanliness is also appreciated by the crew. Immediately after opening the hatch during Leonardo's first flight, the crew noticed many particles and metal shavings floating around, the results of late drilling work and some dirty cargo. The crew was asked to continue unloading wearing goggles but the air ventilation system quickly trapped all the particles on the return filters, making the eye protection unnecessary. Ground cleanliness and work procedures have since been improved.

No ground maintenance has been required on the ECLSS so far. The positive pressure relief valves have been calibrated to a different pressure crack point at NASA's request and the inter-module ventilation had its closing vanes adjusted to improve valve tightness. Not bad for several hundred pieces of hardware delivered by ESA starting in 1998!

Normal ground operations involve: cleaning of return filters, including cabin fan inlet filter; checking pressure control valve pressure crack/reseat point; leak testing of all valves; functional testing of cabin fan, temperature and pressure sensors; visually inspecting ducting.

Leak testing and valve functional checking – the bulk of ECLSS ground operations – are performed using the specially-developed Gas Leakage Test Stand. The MPLM ground servicing crew at NASA's Kennedy Space Center – MPLM's home – have praised the reliability and accuracy of this equipment.

The success of MPLM's ECLSS is a tribute to the efforts of Astrium-Dornier, Europe's leading company for space life-support systems. ■

Odissea Success

Soyuz-TMA 1 approaches the ISS for docking 1 November. (NASA)

ESA astronaut Frank De Winne returned safely to Earth on 10 November after a successful Soyuz mission to the ISS involving 9 days of scientific research. The Odissea mission crew of Sergei Zalyutin, Yuri Lonchakov and Frank flew aboard the first uprated Soyuz-TMA and returned in the old TM-34 Soyuz that was left by Roberto Vittori's crew last May as an emergency return vehicle.

Frank described his first voyage into space as '*the most intense, challenging and unbelievably fulfilling 11 days of my professional life*.' His substantial programme of 23 experiments (see *On Station* #10, September 2002, pp4-5) included four in the Microgravity Science Glovebox – an important research facility developed by Europe.

The next issue of On Station will include more detailed coverage of the Odissea mission. See pp1-3 of this issue for mission photographs and other information. ■

Foton-M1 Launch Failure

The Soyuz launcher carrying the Foton-M1 research satellite failed a few seconds after lift-off from the Plesetsk cosmodrome on 15 October at 18:20 UT. Foton carried 44 experiments sponsored by ESA, totalling 650 kg. (See *On Station* #10, September 2002, pp6-7 for experiment details.)

The report of the State Inquiry Board headed by Russian space officials is expected to report soon on the causes of the accident. A press conference given by the head of Rosaviakosmo, Yuri Koptev, on 18 October provided initial information. One of the strap-ons took 2 s to reach full thrust, pulsed for 1.5 s and 4 s after launch lost all power. It then fell away from the vehicle, as it is designed to do when thrust no longer holds it in place. It fell back on the pad, where the ruptured tanks led to a large fire that significantly damaged the pad. The launcher automatically shut down the other three strap-ons 20 s after launch, and it struck the ground about 1 km from the pad and exploded. Unfortunately, a soldier watching from the integration building was killed.

Preliminary analysis indicated that the hydrogen peroxide supply to the propellant turbopumps was blocked by a foreign body. ■

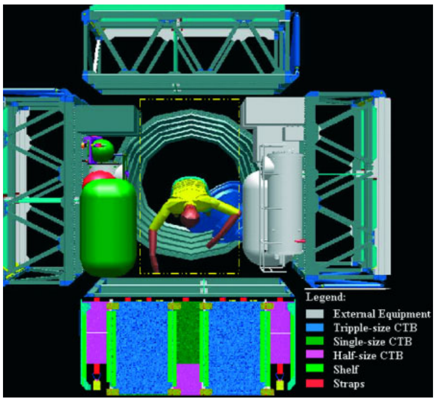
Recent & Relevant

ATV Cargo Meeting

The first ATV Cargo Integration Technical Interchange Meeting (TIM) took place at ESTEC in July, between ESA, NASA, CNES, Alenia Spazio and EADS-LV, to agree on the ATV cargo analytical and physical integration processes. ATV can carry up to 4000 kg of reboost propellant, 860 kg of refuelling propellant, 857 kg of water, and 102 kg of gas (nitrogen, oxygen and/or air). These capabilities and the cargo needs for 2004 were discussed during the TIM, and the projected cargo breakdown for the first ATV flight in late 2004 was determined.

NASA, ESA and industry agreed to all the cargo integration processes and milestones for that first flight. NASA will maintain the first ATV cargo manifest, obtain all the necessary information from cargo providers and update their MIDAS Database. The first release of the ATV manifest is planned for September 2003. Then, the database will be updated weekly as cargo manifests requests are approved. The ESA Database will then interface with MIDAS. ESA's CAST software will optimise the loading of cargo items in stowage containers and their positions inside the ATV racks.

The Crew Transfer Bag (CTB) is the primary stowage container, as it is for the ISS. Half, single and triple CTBs will be strapped to the inside of the ATV racks. Other non-standard and standard stowage and payload containers such as ISIS drawers can be the mounted to the adapter plates on the rack front.



ESA astronaut Jean-François Clervoy and NASA astronaut Marsha Ivins were instrumental in devising the method for locating the hardware inside the racks and maintaining an inventory of launch cargo, temporary stowed cargo and return cargo. The Partners agreed to a 9-digit location coding system for all launch cargo. Barcodes will allow the astronauts to scan the container or item on each ATV shelf, for automatic updating of the ISS Inventory Management System. The astronaut participants also recommended the location of handholds on the racks to help cargo transfer in orbit.

There will be three cargo-packing facilities: NASA will pack US cargo at the Kennedy and Johnson centre; Alenia Spazio will pack ESA and other International Partner Cargo at the Turin Cargo Integration Facility in Italy. The integrated cargo will be shipped to Kourou, where it will be loaded into ATV.

Marketing ISS Assets

ESA recently selected Ogilvy Brand Relations in Brussels (B) to help develop a branding and communications strategy for the ISS. ESA's objective is to raise commercial demand for use of the European assets aboard the Station. The ISS is one of the world's most sophisticated research laboratories and a unique platform for marketing, sponsorship and other less conventional space activities. And yet, outside the aerospace community, many companies are still unaware of this potential.

Antonio Rodotà, ESA's Director General, said '*In the ISS, ESA is offering a platform for new activities. We are convinced that, through the ISS, we can help European companies convey compelling messages to their markets and increase their competitive advantage around the world.*'

'*In the past, human spaceflight has wrongly retained an exotic and elitist image. With the ISS, this is changing. Human spaceflight will become an everyday experience*,' explained Jörg Feustel-Büechl, ESA's Director of Manned Spaceflight and Microgravity. '*The Station offers companies and organisations the opportunity, for the first time, to exploit manned spaceflight for commercial purposes. By opening a unit exclusively devoted to marketing the station's facilities, ESA is leading the ISS commercialisation effort. ESA and its commercial partners can offer tailored packages to interested companies, taking care of everything from space certification of payloads to launches, flying and running programmes on board the Station, and delivering results and payloads back to customers on Earth. ESA can arrange favourable financing deals and guarantees that its clients' intellectual property is fully protected at all stages of a programme. Ogilvy will help us explain these opportunities to a wide audience.*'

Ogilvy will help ESA to develop the Station's brand image and design a communications strategy to put the ISS in the public eye in Europe and to raise its potential among the European business community.

Although the communications programme will focus on the R&D community, it will also reach out to newer kinds of space entrepreneurs, active in marketing, entertainment and tourism. The R&D effort will concentrate on health, biotechnology, environment, food and new materials. The fact that most companies lack experience in the commercial exploitation of space, combined with the state of today's economy, will make this a complex and challenging programme.

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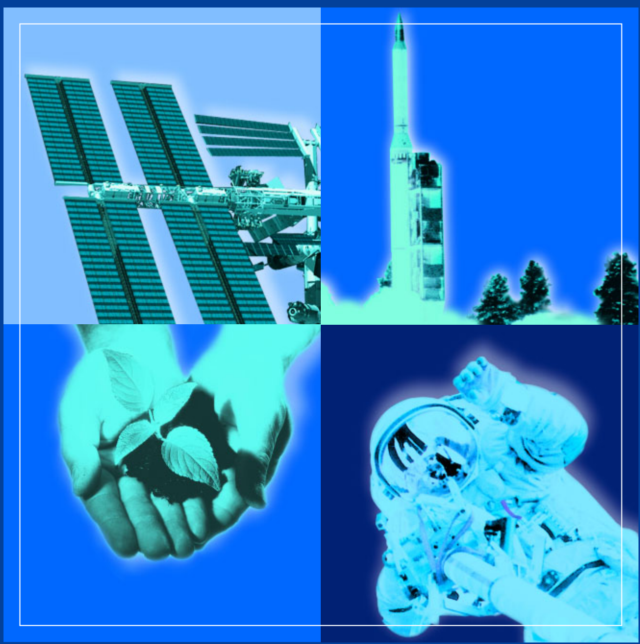
For a free subscription or change of address, please contact Frits de Zwaan at Frits.de.Zwaan@esa.int

ESA Publications Division/SER-CP
ESTEC, Postbus 299, 2200 AG Noordwijk, The Netherlands
Fax: +31 71 565-5433

Editor: Andrew Wilson (Andrew.Wilson@esa.int)
Contributing Writer: Graham T. Biddis
Design & Layout: Eva Ekstrand & Carel Haakman

Education Kit



International Space Station

Europe's first ISS Education Kit for students aged 12-15.

ESA has published an ISS Education Kit to meet the requirements for teaching Space and subjects related to the ISS to European students, aged 12-15.
The kit is available only in English and includes simple, modular and interdisciplinary material based on existing European curricula, making it suitable for teaching a wide range of subjects.
If you work in the education sector and are prepared to give feedback by **mid-January 2003** on the content of the kit then please contact Solveig Pettersen at
Tel: +31 (0) 71 565 5755,
Fax: +31 (0) 71 565 4499
or Email: *Solveig.Pettersen@esa.int*

The main objectives of the kit are to:

- Introduce the ISS as a motivating and ideal tool for teaching;
- Increase the awareness and interest in science and technology research in space among the youth;
- Stimulate curiosity and creativity through active participation;
- Highlight the important contributions being made by space technology and science to the well-being of society;
- Focus on future, possible areas of space research and technology, as well as the importance of international cooperation and cross-cultural interaction.

esa

For further information about the ISS Education Initiatives please visit: *www.esa.int/spaceflight*