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European Space Agency
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Columbia Aftermath for ESA

Jörg Feustel-Büechl
ESA Director of Human Spaceflight

The *Columbia* accident has been a tremendous shock for the whole space community, and the loss of the seven astronauts in such tragic circumstances touches us all in the global space-faring community. Indeed, the shock is being felt at every level of space activity. For ESA, and particularly our engineers and scientists involved in STS-107, it was an intensely grave event as they had been closely cooperating with the *Columbia* astronauts. Europe, in having a significant 600 kg of payloads on this mission, was heavily involved with crew training in Houston and mission operations. Indeed, the whole crew visited ESTEC in May 2001 as part of their payload familiarisation training programme.

Of the seven ESA payload investigations, three lost the biological and medical data samples that were being returned for ground analysis, so there will be no results from that research. This is a particular regret as the crew performed these experiments impeccably during the mission.

The Columbia Accident Investigation Board (CAIB), created by the NASA Administrator immediately after the accident, has yet to reach a firm conclusion but there is still some time to go before the final report is delivered from the 60-day investigation. We hope the root cause of the tragedy is clarified in that final CAIB report.

The Internationa Space Station (ISS) is severely affected by the *Columbia* loss. Directly after the accident, ESA took the necessary steps to ensure that we are taking the right decisions with our ISS Partners. With almost daily meetings, we continue to investigate what steps and activities are needed in order to hold the Station in a safe condition. The Shuttle fleet, typically used to transport large elements for ISS assembly, is also a crucial logistics carrier for resupplying the Station. This route is obviously closed for a while, so it was necessary to assess alternative measures to get the Station into a safe mode and to maintain it there. Two major decisions have already been taken within that context. The first concerned using the Soyuz for crew exchange: the

The STS-107 crew during training at ESTEC in May 2001. From left: William McCool, Mike Anderson, Laurel Clark, Rick Husband, Ilan Ramon, Kalpana Chawla and David Brown.

Soyuz-TMA2 taxi mission on 26 April will carry two new long-stay crewmembers to the Station and the present crew of three will return in the Soyuz currently docked at the Station. This means that the flights for ESA astronauts Pedro Duque and André Kuipers have to be delayed by 6 months. In other words, Pedro will make his flight in October 2003 and André in April 2004. The Spanish and Dutch governments have been very constructive and flexible in supporting ESA in rearranging these flights, and both governments are to be congratulated for their cooperation and solidarity in this process.

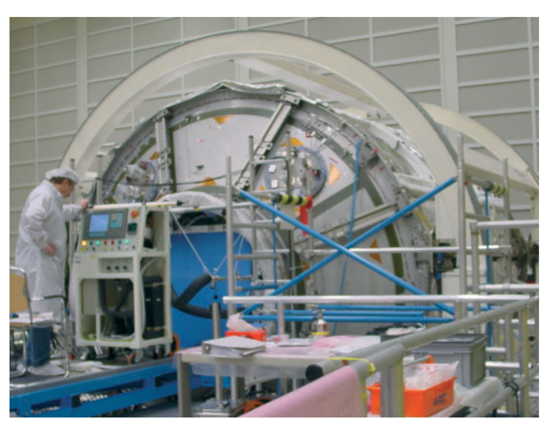
Reducing the permanent crew to two requires the supplies and resources to be properly controlled and managed. So the second decision is to increase the Progress flight rate – it is expected that these will rise from three to four in 2003, and from four to five in 2004. The financial arrangements for these resupply flights still have to be settled with our Russian counterparts.

As a direct consequence of the Orbiter fleet being grounded, the Station assembly sequence has been put on hold. A positive effect of this is to provide the resident crew with more time for research. We are currently very busy searching for opportunities within the existing infrastructure and 2-person crew. The Progress flights will be able to deliver research equipment to the Station once the supply needs have been satisfied on the manifest.

The planning for reassigning Christer Fugelsang's flight opportunity on STS-116, previously scheduled for July 2003, will be delayed until the Shuttle launches restart and a revised launch and assembly schedule is determined.

We are not yet sure of the delays that we must endure for the launch of Columbus, previously planned for October 2004. There will in all probability be some delays before Shuttle flights resume but whether they will translate directly into slippage of the Columbus launch schedule remains to be determined. We will know only when the post-*Columbia* Shuttle manifest is issued.

For the Automated Transfer Vehicle (ATV), the situation is reversed. There is now increased



pressure to deliver earlier so that it can be used for resupply operations. This is very much welcomed by the Partners in order to provide a more robust Station scenario overall. From our side, we are determined to meet the original September 2004 launch date and possibly even improve on it.

Programme Action Plan

Independently of the *Columbia* accident, we continue with the implementation of the Programme Action Plan that was agreed with our Partners at the 6 December 2002 Heads of Agency meeting in Tokyo. This 2003 Plan requires a number of actions in order to bring the Station back to its original capabilities. Two major issues need to be resolved: settling the detailed configuration of the Station and, secondly, the agreements within the Partnership to accomplish that. Some progress has already been made with the provision by NASA of both the Life Support System and Node-3 to the Station. A further major issue, the provision of sufficient Soyuz spacecraft between 2006 and 2010, still needs to be agreed. 2010 is the end date because it marks the entry of the NASA Orbital Space Plane into service as a crew return vehicle. I personally hope that we will have a workable baseline solution by mid-2003 for procurement of an additional two Soyuz vehicles per year, thereby allowing a resident crew of six from 2006 to 2010.

Columbus assembly is proceeding as planned, with good progress being made. ATV development is also going positively. The ATV Critical Design Review (CDR) recently began and is planned to finish with the CDR Board Meeting in June 2003.

ESA's utilisation preparation of the Station has, largely, been undisturbed by the *Columbia* events. We are continuing as planned with the development of our research facilities. It is our intent not to slow down as a consequence of *Columbia* but to follow our original path at least until we know the final consequences of the accident.

The Columbus Control Centre, to be located at Oberpfaffenhofen (D), is a key element of our overall programme, as is the ATV Control Centre at Toulouse (F). The development contracts for these centres are now close to conclusion. The Columbus Control Centre contract with DLR will be signed by ESA on 31 March and the ATV Control Centre contract with CNES also around that date.

Finally, we continue to follow the Astronaut Policy that also actively supports national short-duration flights with the Russians. We are looking forward to having a European astronaut aboard the Columbus 1E Shuttle launch. Our first astronaut for a full increment of several months will arrive shortly after Columbus is attached to the Station. We are about to nominate the prime and back-up candidates for that opportunity so that they can begin formal training. The Astronaut Policy also provides opportunities for those European astronauts currently not in active training to provide technical support to the various projects. This not only bridges the gaps between flights but also helps to build the astronauts' stock of expertise and is highly appreciated by the technical teams. ■

ESA astronaut assignments and collateral duties.

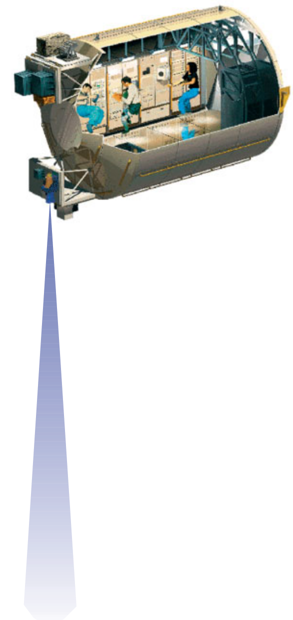
Jean-François Clervoy (F)	Les Mureaux: ATV operations support
Frank De Winne (B)	ESTEC: supporting the Module Project Division for Columbus
Pedro Duque (E)	ISS Advanced Training. Star City: crew training for Soyuz-TMA 3 flight scheduled for October 2003
Reinhold Ewald (D)	ESTEC: ISS and Soyuz operations support
Léopold Eyharts (F)	ISS Advanced Training. JSC: ISS Branch: Systems, Software; Shuttle Branch: Payload General Support Computer
Christer Fuglesang (S)	JSC: crew training for STS-116/12A.1 ISS Assembly Flight
Umberto Guidoni (I)	ESTEC: ESA payloads
André Kuipers (NL)	Star City: crew training for Soyuz-TMA 4 flight April 2004
Paolo Nespoli (I)	ISS Advanced Training. JSC: Shuttle Branch, Cape Crusader
Claude Nicollier (CH)	JSC: EVA Branch member, support work includes European hardware EVA interfaces and working as Astronaut Instructor for robotics and EVA
Philippe Perrin (F)	Toulouse Space Centre: ATV operations support
Thomas Reiter (D)	ISS Advanced Training. Soyuz-TMA Return Commander Training. EAC: support to the Columbus project
Hans Schlegel (D)	JSC: Capcom Branch
Gerhard Thiele (D)	EAC: Acting MSM-AA
Michel Tognini (F)	JSC: ISS Branch, responsible for Russian interfaces
Roberto Vittori (I)	JSC: Shuttle Branch, working on Vehicle System Upgrade

ATV: Automated Transfer Vehicle. JSC: NASA Johnson Space Center.

Left: the appearance of Columbus at Astrium in Bremen (D), as of 7 March.

Right: testing the ATV avionics.

An Eye for Columbus



The Commercial RapidEye-ISS Camera

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Introduction

The Columbus module is set to become a commercial provider of Earth-observation services according to the plans of RapidEye AG. Incorporated in December 1998, RapidEye is a satellite-based geo-information service company, concentrating on the agricultural and cartographic markets. They offer geographic information products, which are integrated into the clients' work processes and therefore offer significant cost advantages and/or new revenue potential.

A commercial Earth-observation service from Columbus is under study ...

The ability to guarantee delivery of information products is the key for any successful commercial Earth observation service. Reliability can only be achieved if the data source is able to provide full coverage of countries and continents within a few weeks and on a regular basis. This understanding led to the definition of the RapidEye system. RapidEye is a satellite-based remote-sensing system consisting of five satellites offering a multi-spectral (and optional stereo) imaging with a resolution of 6.5 m of any point on Earth at least every day. The camera swath is 80 km. Ground processing, data analysis and information generation will take place at RapidEye's premises or jointly with partners, based on proprietary algorithms and standard software. RapidEye plans to establish a reliable and sustained service for its customers from early 2006.

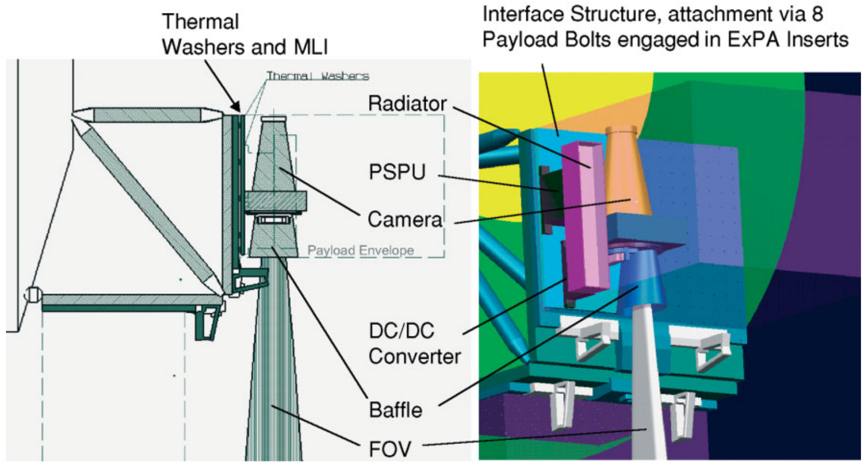
RapidEye and ESA are evaluating the addition of a sixth RapidEye camera to the External Payload Facility (EPF) of the Columbus module. It would be identical to those flying on the satellites and it would be operated on a commercial basis by covering its costs with income generated from customers.

The RapidEye constellation.

Why a RapidEye-ISS Camera?

A RapidEye camera on the ISS will penetrate new markets and improve services to existing markets. It will take high-resolution images of major parts of Europe, North America and Asia, enabling the company to offer regular and frequent updates of highly accurate maps. The detection of changes even in urban areas – new dwellings, streets, roads and bridges –

The RapidEye-ISS camera on the Columbus external facility.



RapidEye camera accommodation on the lower Columbus EPF position.

will be possible. The combination of large-area coverage, high resolution and high revisit rate, as well as low cost, will allow maps to be updated frequently.

New, affordable consumer services will appear. Using the Internet, people will be able to see up-to-date images of their next holiday destination to check for snow coverage, water pollution or hotel location. Moving house will be made easier by taking a quick and inexpensive look at the new city, the site of the new house, the infrastructure, etc.

Products and Service Benefit

The ISS is ideally suited for providing a permanent, maintainable, high-resolution Earth-pointing camera. The location on the Columbus EPF ensures an undisturbed view of the Earth's surface. This additional service significantly improves the offering from the satellite constellation by:

- improving the ground resolution from 6.5 m to 4-4.5 m;
- improving coverage up to around 51° latitude (e.g. Amsterdam, London, Kiev);
- increasing frequency of revisits to more than one per day;
- increasing capacity and redundancy of the overall constellation.

Target Market

The availability of such products translates into benefits for the final customers who use the information for:

- urban mapping;
- agricultural producers and traders for precision farming and crop-yield assessment;
- agricultural insurance companies and traders to assess high-value crop risk;
- reproduction of direct images in high-resolution;
- tourism planning for location information.

Market analysis by Frost & Sullivan shows that the overall Earth remote-sensing market is expanding in excess of 13% per year and will reach €5 billion in 2006. This market covers the totality of remote-sensing activities, including airborne remote-sensing and the complete value-adding market. The market for satellite remote sensing (excluding value-added activities) is projected by Frost & Sullivan to be almost €600 million.

Such a market needs high-resolution, low-cost images as well as high-quality information and services. The RapidEye constellation can provide these at competitive cost. More importantly, RapidEye will be the only constellation providing daily revisits and global coverage, thus offering regular and guaranteed information.

Project Status

The RapidEye project entered its hardware phase at the end of 2002. It is currently planned to launch the satellites by the end of 2005. The feasibility of installing the camera on the lower Columbus EPF position is now being investigated by a pre-Phase-A study. Following completion of this study, it is planned to begin Phase-A in 2003.

As part of the commercialisation process of the ISS, ESA, RapidEye AG, Kayser-Threde GmbH and other partners intend to realise this project together. ESA will partly finance it, Kayser-Threde will be responsible for the technical aspects and RapidEye AG will assume operational control of the camera, process the data and market the images and information services.

The decision to proceed to Phase-B and -C/D will be taken during 2003, at the end of the Phase-A study, based on the technical and programmatic feasibility of the project and the prospects of the return offered to the investors by RapidEye's business plan. ■

Odissea: Operations and Ground Segment

Lessons for the Future

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The Odissea mission in October 2002 provided valuable experience for the Columbus era in planning and performing experiments aboard the ISS ...

Introduction

Three Soyuz flights to the International Space Station have been sponsored and flown so far by European countries using ESA astronauts: Claudie Haigneré (France), Roberto Vittori (Italy) and the Odissea mission of Frank De Winne (Belgium). The sponsorship, financially supporting the launch and use of Soyuz as the ISS lifeboat, is helping to secure the operation of the Station during its early years. Delivering experiments aboard both the unmanned Progress and the manned Soyuz, combined with the available time of the visiting crew of up to three astronauts, provides a unique opportunity to conduct important experimentals. Odissea used this opportunity to the maximum. Frank De Winne's schedule of 23 experiments encompassed four in the ESA-developed Microgravity Science Glovebox (MSG) in the US Destiny module and the remainder performed in the Russian segment. He was assisted by Soyuz commander Sergei Zalutin and flight engineer Yuri Lonchakov. For example, the two Russians acted as test subjects in all of the human physiology experiments.

The Odissea mission has generated a remarkable technical, technological and scientific legacy. An important result for ESA is the experience gained in mission preparation, integration and operations that will be critical for future European activities aboard the ISS.

Frank De Winne working with the Microgravity Science Glovebox.

The Ground Segment and Operations

Although the Soyuz missions are controlled by Russia's Mission Control Centre in Moscow (MCC-M), Odissea required us to create a specific ground system that could coordinate experiments conducted in the modules of two International Partners (IPs) by a crew belonging to a third IP.

This ground segment consisted of different European and IP operations centres hosting the teams involved in Odissea's payload operations. It was designed as a decentralised network, with the main operations coordination team located at the Erasmus centre at ESTEC. This configuration was designed for smooth coordination of payload operations as the European crew moved back and forth across the Russian and US segments, linking with the different networks as they did so, using both IPs' Station and ground networks.

The mission and payload operations organisation scheme relied on close cooperation by the Odissea project team with the Russian MCC-M team and the MSG Telescience Support Center (TSC) team. ESA payload activities in the MSG were coordinated with the Payload Operations and Integration Center (POIC) at the NASA Marshall Space Flight Center (MSFC) in Huntsville, Alabama, through the MSG operations team at the MSFC TSC.

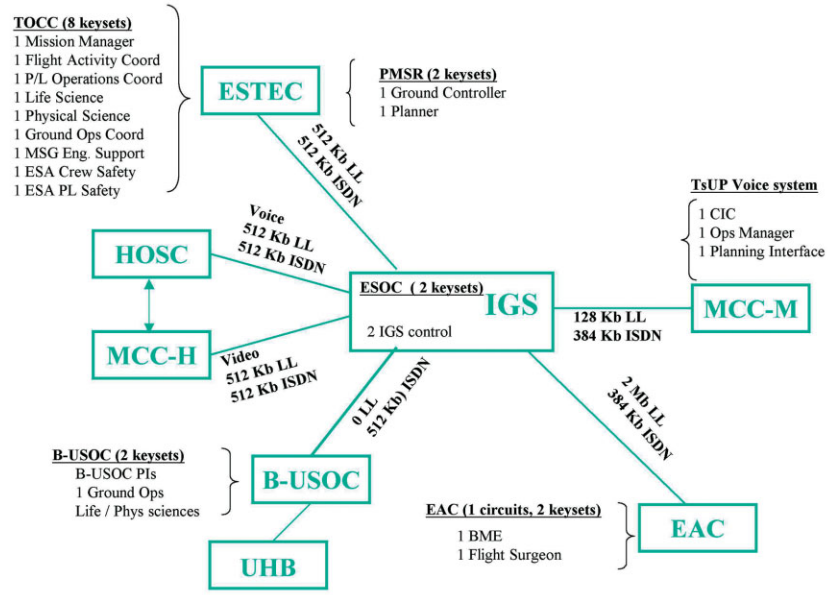
Based on the experiment programme requirements and IP interfaces, a detailed operations implementation plan was drawn up for the operations integration to follow. The activities included:

- definition of the operations organisation scheme and the role of teams at each centre;
- preparation of the ground segment, based on voice, data, video services and bandwidth requirements for each of the participating remote sites;
- procurement of hardware and software;
- preparation with NASA of ground databases defining telemetry and commands;
- preparation of ground procedures and displays, operations handbooks and a repository for flight products;
- preparation of operations-support tools, including planning viewers and operations change request systems;
- preparation of the ground planning timeline;
- training of the payload operations and ground operations personnel;
- simulations involving both ground and flight operations personnel from all centres, with one simulation during crew training at the NASA Johnson Space Center (JSC);
- certification of the ground segment.

This work was carried out in parallel with experiment development and integration, and the flight-planning activities.

Each remote site was in charge of producing its set of operations procedures and console handbooks, and in implementing its security system. Operations interface procedures specific to the Soyuz-5S taxi flight were developed in coordination with ESA, NASA and RSC-Energia.

Two months before the mission, a Joint Integrated Simulation involving JSC, MSFC and all European sites provided the framework for all European and NASA teams (crew, flight operations, ground operations, science operations) to rehearse their roles and



The ground communications system for Odissea. Acronyms are explained in the text.

procedures, exercise interfaces coordination between the remote centres, and test teams with simulated payload failures that created deviations from the nominal flight timelines and allowed operations teams to exercise the replanning cycles. A second simulation was performed a few days before launch. These simulations provided NASA-MSFC and ESA with multi-partner operations for the first time, a crucial requirement when Columbus is active and when ISS partners have facilities and experiments operating in each other's modules. The simulations were also milestones in the Odissea certification process.

The Ground Segment

The Odissea ground segment linked up the following teams and centres:

- ESA Odissea Operations Coordination Team at the Taxi Operations Coordination Centre (TOCC), in the Multimedia Library of the Erasmus Centre, ESTEC for payload management and coordination;
- Belgian Science Payload Operations Team at the Belgian User Support and Operations Centre (B-USOC) in Brussels for the experiment scientific and technical support;
- ESA Mission Operations Support Team at MCC-M for the operations management and crew interface coordinators (CICs);
- ESA Astronaut Support Team at ESA's European Astronaut Centre (EAC) for the crew surgeon and medical support;
- Communication Network Support Team at ESA's European Space Operations Centre (ESOC), for ground communications support;
- NASA MSG Operations Team at MSFC-TSC, with local ESA representation;
- NASA Payload Operations Team for the ISS at MSFC-POIC;

– NASA Operations Team for the ISS at JSC's Mission Control Center-Houston (MCC-H);
– Interconnected Ground System (IGS) Phase-1 Team at ESTEC, for planning management and ground segment control.

Scenes from TOCC during the Odissea mission.

The operations set-up reused a communications system conceived originally by ESOC to support Spacelab remote operations with NASA MSFC and the Goddard Space Flight Center (GSFC) via leased lines and ISDN, including the Atlas-2, Atlas-3, IML-2, LMS and Hitchhiker missions. IGS Phase-1, an autonomous Intranet with gateways to secure networks of other space agencies, formed the core of the communication system. Its successor will be the core of the Columbus ground segment communication system. The IGS interconnected all European centres to POIC, MCC-H and MCC-M via a combination of leased lines, ISDN and the central IGS node at ESOC.

The IGS system at each European node consisted of a rack accommodating ISDN/leased line interfaces, a modem for rack remote maintenance, a multiplexer/demultiplexer serving a Network router, a video Codec, and NASA voice system routing equipment. In addition, the equipment at ESTEC included three data servers to handle data communications between the MCC-H and MCC-M interfaces and remote users located either locally at ESTEC or distributed at EAC and B-USOC. Effectively, the data were acquired once and redistributed to limit the number of clients towards the international partners. These servers included the Data Services Subsystem (DaSS) server to handle file exchange and notably planning products with MCC-M and MCC-H, an ISP/WATTS server collecting ISS housekeeping data from MCC-H, and a TreK workstation server for redistribution of payload telemetry to 12 user workstations at ESTEC and B-USOC. Ground communications network planning and operation were performed from the Phase-1 Management Support Room (PMSR) at ESTEC, also in Erasmus.

Given the short time for deploying a European voice system, it was decided to use the MSFC Huntsville Voice Distribution System (HVODS) with a configuration of 39 voice loops managed by MSFC POIC, and deployed at all European sites, albeit with an overall limitation of eight pairs of keysets that could be supported by the IGS interface at MSFC. The loop configuration included standard MSFC payload operations loops, to which were added Belgian Taxi Flight-specific loops established for European coordination, and ISS loops pulled from JSC. At MCC-M, the set-up made use of a Russian voice system available at the ESA support room. Seamless voice communication among all sites was finally achieved by extending six loops from MCC-H to MCC-M and patching them together with other essential MCC-H loops into the HVODS system at MSFC. This resulted in:

– direct voice contact between the European team at Moscow, using Russian keysets, and all European centres, equipped with HVODS, via Huntsville and Houston;
– direct access, some restricted to listen mode, to Russian and US space-to-ground loops, space-to-ground translation loops, all ISS Flight Director, ISS Operations and US Payload Operations Center loops used by NASA.

The Operations Tools

The Odissea ground segment also relied partly on existing operational tools either from NASA or from the IGS Phase-1, and partly on specific developments such as experiment displays for telemetry, a man-machine interface for telecommanding the PROMISS experiment, and an Operations Change Management System by ESA/MSM that allows submission and approval of mission execution operations changes issued by participating European Centres. The Tables provide an overview of the operational tools that were deployed for payload operations and mission management support from the European centres.

Of the 23 experiments, only the four involving MSG used ISS telemetry and telecommand resources. For these, the MSG TSC defined and baselined on ESA's behalf Ground Data Services data sets through the Payload Data Library process for remote access to TreK and POIC services, thereby routing real-time MSG telemetry from the Payload Data Services System (PDSS) to the remote TreK server at ESTEC, and accepting commands directly from B-USOC.

Operations

The daily operations activities at TOCC included the coordination of payload operations, of potential modifications to flight procedures, the coordination and approval of planning update inputs to NASA and Russia, and the handling of off-nominal situations related to the experiment programme.

The TOCC team provided the decision-making functions for the mission, mission management, operations management, science coordination, mission safety, ground segment control and operations as well as flight planning, and the interfaces to all partners' control centres. ESA, responsible for integration of the overall Odissea science programme, built a balanced timeline by performing trade-offs among the MSG payloads, the remaining science payloads in the Russian module and other Odissea crew activities, such as public relations. ESA payload activities for MSG were coordinated with POIC through the MSG operations team at the MSFC TSC.

MCC-M was responsible for the overall integration of the Soyuz flight programme, development of the integrated plan for the crew's timeline, and the operations of the European payloads in the Russian segment. MCC-H was responsible for the overall integration of the ISS, developing the integrated plan for the ISS crew's timeline, and integrating the Soyuz crew's timeline in the On-board Short Term Plan (OSTP).

In close cooperation with the Russian flight controllers, the ESA crew support team was in direct contact with the visiting crew. This included medical support by a doctor from EAC in contact with the Russian medical staff, with private communication lines to the crew available if required.

After daily contacts with the crew on the research programme and operational activities, the crew interface coordinators (CICs) discussed the issues with the payload coordinators in the user centre and in ESTEC, with the Russian partners and with NASA representatives. Every day, a 'Form 24' with the daily planning was sent to the Station. Other inputs to the crew, like new or updated Russian flight procedures, were then sent as a radiogram and/or directly by voice during the following Russian communications pass. In parallel, MCC-H uploaded daily updates of the OSTP for display on the US Destiny module system laptop.

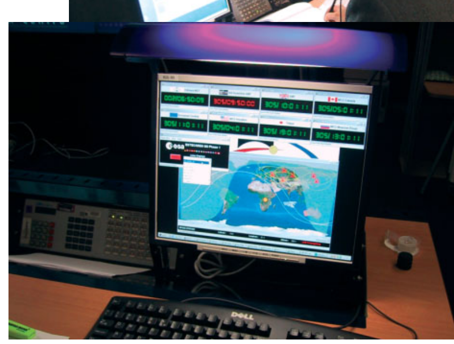
The communications sessions used a VHF channel when there was coverage by the Russian ground stations, which occurred only a few times per day.

The involvement of the crew in MSG operations in the Destiny module resulted in additional regular contacts via the S-band communications sessions of the US segment with Houston, which greatly increased the number of opportunities for crew feedback to European operations teams. In addition, space-to-ground contacts included private phone calls through the S-band links on the US side, email exchange and amateur radio sessions.

The important role played by TOCC in coordinating payload activities was demonstrated several times, including the difficult but ultimately successful activation of PROMISS, the NANOSLAB failure to activate, and the real-time adjustment of the time window for COSMIC ignition by the crew to ensure video coverage to the ground. The spectacular images from COSMIC were received in real-time at TOCC and B-USOC, where scientists could comment on the quality of the combustion process for direct feedback to the crew. This was made possible by working precisely to a detailed timeline modified by the availability of NASA's TDRSS satellite coverage. When NANOSLAB failed to activate, a long troubleshooting session began with Frank De Winne and all the ground teams, Unfortunately, it was not possible to assess or resolve the problem.

TOCC's role was to react to any changes throughout the mission by coordinating decisions and prioritising changes in the schedule to any of the European experiments. The goal was to minimise the impact on the crew while maximising the return on the experiments.





Telemetry and Telecommand Tools.

Function	*Tools*	*Provided by*	*Implemented at (available)*
Telemetry	TreK v.2, Telescience Resource Toolkit, user workstation software providing access to NASA payload housekeeping telemetry (MSG). A TreK server implemented at ESTEC served as relay for all TreK user workstations at TOCC and B-USOC.	NASA MSFC	TOCC B-USOC (TSC)
	MSG ground displays.	NASA MSFC	Idem
	COSMIC displays developed by B-USOC.	B-USOC	TOCC B-USOC
	PACRATS, provided a TreK plug-in display development and run-time environment used for MSG experiment displays, with most of them initially developed to support the integration process. PACRATS displays for all MSG experiments developed by NASA TSC with support from B-USOC and ESA.	NASA MSFC TSC	TOCC B-USOC (TSC)
	ISP/WATTS ISS Displays, providing ISS US segment and ISS RS data visualisation through DaSS (Data System Services).	ESA Phase-1	TOCC B-USOC EAC MCC-M
Telecommand	TreK v.2, Telescience Resource Toolkit, for direct commanding to POIC command server.	NASA MSFC	TOCC B-USOC
	PROMISS experiment command interface frontend for TreK.	B-USOC	Idem

Video and Voice Tools.

Function	*Tools*	*Provided by*	*Implemented at (available)*
Video	Multimedia Library video wall	ESA	TOCC
	Windows Multimedia player to display ISS video and NASA TV streamed by ESOC through the Internet	ESA	All
Voice	HVODS Keysets	ESA and NASA	TOCC EAC B-USOC
	Russian keysets as part of equipment furnishing the MCC-M ESA Room	RSA - Russia	MCC-M

Planning and Operations Management Tools.

Function	*Tools*	*Provided by*	*Implemented at (available)*
Planning	CEPP, STP and OSTP web-based viewer with an interface to the NASA Consolidated Planning System, the successor of which (Operations Preparation and Planning System) will be implemented at the Columbus Control Centre.	ESA Phase-1	TOCC B-USOC EAC MCC-M
	MSFC Web OSTPV/MPV, providing access to the MSFC Short-Term Plan, a copy of the JSC-originated STP.	NASA MSFC	TOCC B-USOC EAC (TSC)
Operations Management	ESA OCMS, the Operations Change Management System developed to support the submission/approval of operations changes by all European Teams.	ESA MSM Support	TOCC B-USOC EAC MCC-M
	Web EHS, providing access to MSFC Ops Change Request System, and providing a data flow interface for TreK users (start/stop, APID selection).	NASA MSFC	TOCC B-USOC EAC (TSC)
	Drop box for file exchange (planning, etc).	ESA Phase-1	TOCC EAC MCC-M
	ESA FTP server for repository of flight procedures, payload and experiment technical specifications and operations manuals, joint operations procedures and ISS flight rules.	ESA	All

Acronyms not explained in text. APID: Application Identifier. CEPP: Customised ESA Planning Publisher. EHS: Enhanced HOSC System. HOSC: Huntsville Operations Support Center. OSTPV: Onboard Short Term Plan Viewer. PACRATS: Payloads and Components Real-time Automated Test System. STP: Short Term Plan.

Commanding of the PROMISS experiment was successfully performed from B-USOC, without resorting to the backup command function in place at the ESTEC coordination centre.

Acquired Experience

The Odissea mission was a first step in coordinating ISS operations with multiple partners. Neither NASA nor Russia had ever performed payload operations across multiple control centres and continents. The Odissea requirements were established to link all the Partners and to operate seamlessly in nominal and off-nominal situations. For the first time, all the ISS Partners involved in payload operations depended on each other to achieve mission success.

This set-up, with some adaptations to reflect specific experimental programmes and involvement of national USOCs, is ready to support the next two ESA Soyuz missions and may, later on, integrate the Columbus Ground Segment, which will be coordinated by the Columbus Control Centre.

Odissea presented a remarkable opportunity for all the teams to acquire an understanding of ISS processes and experience in using operational tools as precursors to those being developed for Columbus payload operations. Participation in a Soyuz mission for a user site such as B-USOC, as well as ESTEC, provides a real scenario for understanding the issues in operating payloads in the ISS-US segment environment. All European payloads in Destiny will be operated in a similar fashion, with similar interfaces to POIC. It also provides a test for Columbus development and operations teams looking for early feedback on the use of ISS and Columbus tools.

Conclusion

Two further European-sponsored Soyuz taxi missions are now being prepared, although their exact details are uncertain following the loss of Shuttle *Columbia*. The first, sponsored by Spain, aims at Spanish-ESA astronaut Pedro Duque flying on the Soyuz of October 2003. The second, sponsored by The Netherlands, will have Dutch-ESA astronaut André Kuipers flying on the Soyuz of April-May 2004.

The highly successful results of Odissea prove that these missions are an excellent way for European astronauts and experiments to access the ISS. The experience gained in preparing the astronauts, integrating the facilities and experiments into missions, and preparing the ground segment and the operations is remarkable. This experience is already proving valuable for preparing the coming Soyuz flights. In particular, the experience acquired in the ground segment and operations is being used for the next two missions and in preparing payloads operations for the Columbus era. ■

Medical Support for Odissea

The ESA Crew Medical Support Office

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Introduction

The Odissea mission with Frank De Winne was the third Soyuz mission to the ISS with an ESA astronaut as a Soyuz crewmember. The ESA Crew Medical Support Office (MSM-AM) provided the medical support to Frank during all phases of his mission.

The experience gathered by the Office from supporting Shuttle missions and Soyuz flights to the Mir space station proved essential for Frank's medical support during his training in Star City. However, the in-flight support concept was very different from the way medical operations services were provided to ESA astronauts in the past. The main reason is that the ISS uses multilaterally coordinated medical support, so the Medical Office is using these Soyuz opportunities to prepare for its responsibilities in future ISS Expeditions.

This article focuses on the new aspects of ESA's medical support concept for missions to the ISS, as well as the development of the ground support infrastructure at the European Astronaut Centre (EAC) and related coordination among International Partners.

ESA continues to develop its expertise in providing medical support to its crewmembers ...

Overview

The ESA Crew Medical Support Office at EAC in Cologne is responsible for providing medical services to ESA astronauts during ISS, Soyuz and Shuttle operations. The primary goal is to maintain crewmembers' physical, mental and social well-being. A team consisting of an ESA Flight Surgeon (ESA FS) and an ESA Biomedical Engineer (ESA BME) was assigned in early 2002 to support Frank De Winne. The ESA FS primarily takes care of the clinical aspects. He spent a significant time with Frank pre- and post-flight, supported him during medical tests, medical evaluations, experiment training sessions, baseline data collections and travelled to Kazakhstan for the landing, and assisted him in the first 4 weeks after landing. The ESA BME focused on the pre-flight coordination with the different ESA teams and Partner Medical Operations teams, as well as the more technical and conceptual aspects of the mission preparation and ground support infrastructure.

Distributed Medical Operations Support

ISS Medical Operations (ISS MedOps) in principle do not distinguish between the Soyuz crew and the ISS Increment crew. As soon as the Soyuz spacecraft docks with the Station, the medical responsibility for the complete crew aboard the Station lies with the ISS Crew Surgeon (ISS CS), in the Mission Control Center Houston (MCC-H). The ISS CS is supported by different Partner Medical Operations teams, depending on crew composition, mission profile, onboard medical systems and the scientific programme.

Back in the late 1990s, all ISS Medical Partners decided to introduce progressively a distributed medical operations support scenario with different Partner Medical Teams supporting the ISS CS from their own agency medical support consoles. The various Soyuz missions to the Station provide the ESA Medical Office with ideal opportunities to build up the infrastructure, to refine the operational support concept and to gather operational experience. This ensures that the Medical Office is ready to provide long-duration mission medical support after the Columbus module arrives in orbit in late 2004 and the first ESA Increment crewmember starts working onboard ISS.

Working the medical consoles at EAC.

Build-up of Medical Consoles at EAC

The build-up of the medical consoles started in January 2002 with the installation of the Integrated Ground Segment (IGS) Phase-I node. This is a secure network of leased and on-demand lines of voice, video and data services that can be configured according to mission needs. Voice and data services are permanently supported by a 256 Kb leased line. Two bundled dial-up ISDN channels provide a back-up. Video is provided only on demand using ISDN dial-up connections (384 Kb). Alternatively, private Internet streaming video or ESA TV can be selected.

Security is a key requirement for the medical consoles, ensured by using separate machines on separate networks:

- three IGS machines linked to the IGS data network;
- two Internet computers outside the ESA firewall, one of which used VPN tunnelling to access different NASA sites;
- two Office Automation computers connected to EAC's office automation network.

Two 52-cm plasma screens display ISS video, the location-appropriate clocks and the ISS groundtrack monitor. As a temporary solution, two Huntsville Voice Distribution Systems were used, made available by NASA's Payload Operations Control Center at the Marshall Space Flight Center.

With the basic technical infrastructure in place, the operational build-up of the consoles began. A key component was the fact that the Medical Office is an integrated member of two different teams – the ISS MedOps Team and the ESA Mission Operations Team for Odissea.

As a member of the ISS MedOps Team, the Medical Office supported the ISS CS and ISS BME, who were familiar with the basics of the Odissea mission but relied on the ESA Medical Office team for all details regarding the experiment programme, ESA astronaut issues, etc.

As a member of the Odissea Mission Operations Team, the Medical Office coordinated with other ESA teams such as payload operations, crew operations and planning to provide medical services to the ESA astronaut.

The following operational tools were implemented specifically at EAC to support the Medical Office's role as a member of the ISS MedOps Team:

Voice loops ISS Surgeon, a non-private loop, used by all console positions in MCC-H to contact the ISS CS; ISS MedOps, a non-private loop, used by all console positions in MCC-H to contact the ISS BME; Surgeon R/T a semi-private loop, used by the different Partner medical teams to coordinate ISS MedOps issues. It allowed the Medical Office to discuss issues with the ISS CS and the Russian Medical Team simultaneously;

OSTPV the Onboard Short-Term Planning Viewer allowed teams outside of MCC-H to view the correct Short Term Plan (STP) being used aboard ISS as well as the different draft STPs being discussed on the ground;

MedOps Displays all ISS CS displays and the Environmental Control and Life Support System (ECLSS) displays were available in real-time on the medical consoles, using the WATTS Java-application. They allowed the Medical Office to monitor a wide range of ISS systems affecting crew health.

The main tools that supported the Medical Office's role as a member of the Odissea Mission Operations Team included:

Voice loops multiple ESA-internal voice loops allowed communication with key members of the Odissea team, both in the Taxi Operations Coordination Centre (TOCC) at ESTEC and the Mission Control Centre Moscow (MCC-M);

OCMS this is a web-based tool used by all ESA positions to insert and coordinate operational change requests;

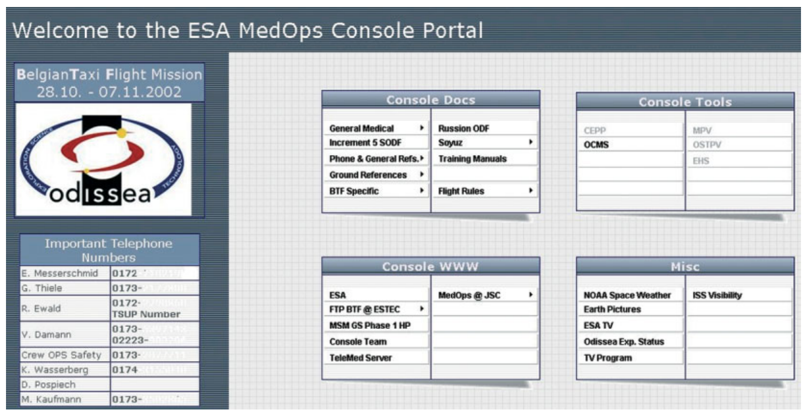
CEPP the Central ESA Planning Product gave access to ESA-specific timeline information.

The Medical Office further developed the ESA MedOps Portal, which provided a single interface to all software tools, console documentation and the main web pages used on-console.

In-flight Medical Operations Support

The medical support concept worked exceptionally well during the mission. The assigned ESA FS supported the launch in Baikonur. Afterwards, he supported the crew operations team at the TsUP control centre TsUP in Moscow (MCC-M) during the mission. An ESA FS and ESA BME manned the two medical consoles at EAC. Their shifts started an hour before the crew awoke and ended an hour after the crew went to sleep. These 18 h were split into two shifts, with an overlapping handover period of an hour.

A large amount of coordination among the different operational teams was needed to resolve several issues that contributed to the mission's success. For example, the mandatory daily exercise of the three ISS crewmembers generated unacceptable microgravity disturbances for ESA's COSMIC materials combustion experiment. It was discovered they were unacceptable only during the 2-min combustion process for each individual reactor. Between each process (six in total), a pause of at least 30 min was needed to reconfigure the equipment. A coordinated solution was developed which had Frank notifying the crewmember to stop exercising for a few minutes when he was ready to ignite the next reactor, allowing simultaneous completion of both activities.



The MedOps Portal is a single interface to all software tools, console documentation and the main web pages used on-console.

As a second example, late in the evening (01:00 UT) on Flight Day 8, the crew discovered that the Microgravity Science Glovebox (MSG) loading port was not completely sealed. The crew requested further information about potentially hazardous leaks from experiments inside MSG. Within 30 min, the Medical Office evaluated the issue and provided the ISS CS with the toxicological information to send up to the crew before they went to sleep, assuring them that the issue was not generating a health concern.

Conclusions

The two examples above illustrate how the Office operated as a valuable and integrated team member to provide timely and critical support.

The Medical Office will use the Spanish and Dutch Soyuz missions in October 2003 and April/May 2004, respectively, to refine its operational concept and technical infrastructure further, as well as to gather experience for future Increment flights. ■

The real-time Environmental Control and Life Support display.

The ICAPS / IMPF Laboratory

ESA's premier research facility for plasma and dust physics on the ISS

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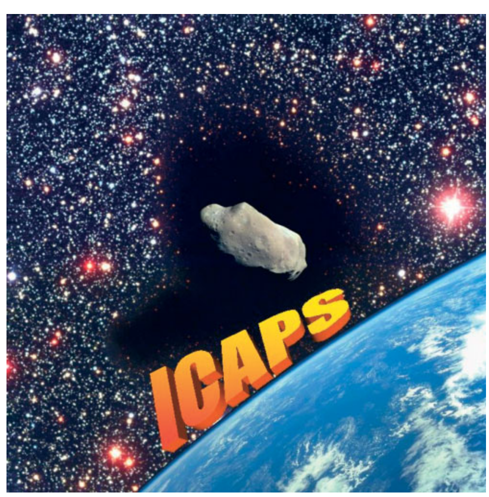
Introduction

The International Microgravity Plasma Facility (IMPF) and Interactions in Cosmic and Atmospheric Particle Systems (ICAPS) laboratory are destined to be ESA's premier research facility for plasma and dust physics aboard the ISS. IMPF will investigate complex plasmas (such as the recently-discovered 'plasma crystals'), while ICAPS will look at, for example, how planets form from dust clouds, and how particles in our atmosphere affect the weather.

A new-generation research facility for Columbus is already under development...

The European Programme for Life and Physical Sciences Research in Space (ELIPS) was approved by the Ministerial Conference in Edinburgh (UK) in November 2001. In September 2002, under the auspices of this framework, ESA's Human Spaceflight Research and Application Programme Board approved the initiation of the ICAPS/IMPF Laboratory Phase-B study. The contract award to industry for Phase-B is expected in early 2003.

Initially conceived as two separate facilities with very different development histories through Phase-A, IMPF and ICAPS were combined in May 2002 on the recommendation of their individual scientific advisory boards. This merger has provided the researchers and engineers with a feasible route to realising both projects without any loss of the original scientific objectives of these unique projects. They share hardware, ISS accommodation and operations, and data processing and downloading functions, thereby eliminating duplication of expensive development, manufacturing and qualification.

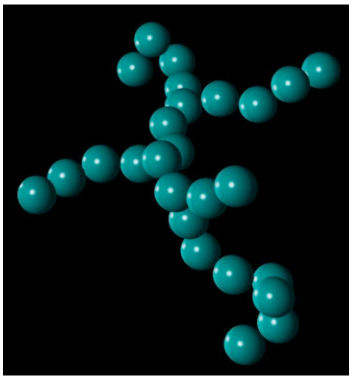


ICAPS History and Science Drivers

ICAPS will investigate interactions of cosmic and atmospheric particle systems under microgravity conditions. Why 'switch gravity off'? In a dust cloud in a terrestrial laboratory, gravity forces larger particles to sediment out, and drives turbulent diffusion, eventually collapsing the dust cloud completely. To simulate planet formation in terrestrial laboratories, and further our understanding of how our Solar System formed, or understand how particles interact in our own atmosphere, we need to tackle aggregation and evolution of dust clouds in a manageable environment, without gravity getting in the way. Aboard the ISS, microgravity can be maintained for at least 30 days, allowing us to simulate the processes involved in planetary growth from a small dust cloud.

In response to ESA's Announcement of Opportunity 'Physical Sciences and Microgravity Applications (AO 98/99)', ESA's Topical Team for ICAPS submitted the scientific proposal AO-99-018. The ESA-funded Phase-A feasibility study was completed in September 2002 by Kayser-Threde (D) and its subcontractor Nubila (I), with close cooperation

A 3-D reconstruction of a fractal aggregate formed by Brownian motion under microgravity during the Cosmic Dust Aggregation Experiment aboard Shuttle mission STS-95 in October 1998.



from the extensive international scientific user community.

A range of experiments will try to understand planet formation in a series of dust-aggregation experiments. In addition, ICAPS will address a number of other key scientific questions concerning small dust particles in our Solar System. For example, ICAPS will study simulated cometary dust. Until the Rosetta lander touches down on a comet, observations of how ejected dust and ice scatter and interact with sunlight are our only route to understanding the behaviour and make-up of cometary nuclei.

The surfaces of asteroids are covered by 'regolith' – layers of loose and fluffy fragmentary debris. The formation and evolution of regolith depends on the asteroid's gravity and on the mechanical properties of its particles. ICAPS will be used to form such fluffy dust layers and study their physical properties.

ICAPS will also study systems of interest to atmospheric and aerosol sciences. If there were no particles or water vapour in the atmosphere, our weather would be very different. At present, we cannot predict when and where a cloud will start raining. ICAPS will study the interactions of aerosols with droplets or ice crystals on atmospheric timescales, by making model clouds of pollutants and precipitants.

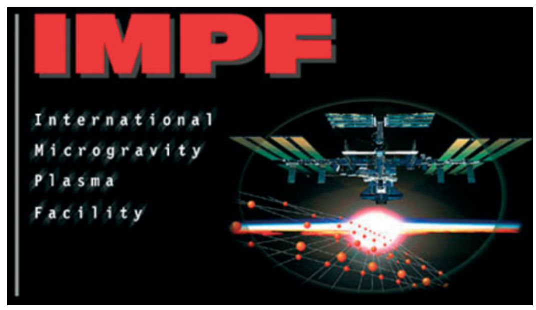
ICAPS is also an exciting prospect for long-term research and industrial applications. Potential industrial applications include the development of aerosol technologies, improved abatement strategies, and particle-based cleaning devices. Light-scattering techniques are already used in the paper industry to control bleaching and quality, but ICAPS will improve our knowledge of light-scattering both theoretically and experimentally.

Following the work of the ESA Topical Team 'Physico Chemistry of Ices in Space', it is envisaged that an 'ice experiment' insert, capable of reaching very low pressures and temperatures will be added to ICAPS, perhaps in 2012. This instrument will not only reach more realistic space-like conditions, but will allow us, for the first time, to simulate precisely the conditions under which stars, planets and comets form, and to study the physical and chemical properties of the dust in these regions.

For further information on ICAPS, please visit *www.icaps.org*

IMPF History and Science Drivers

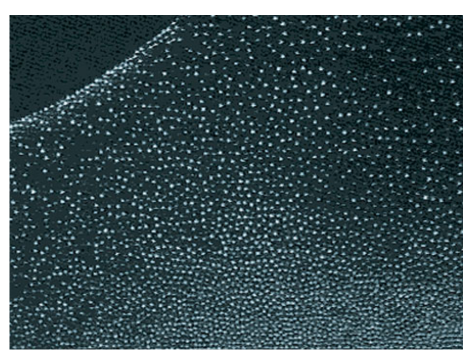
IMPF will investigate complex plasmas under microgravity conditions. Initially developed in response to the same Announcement of Opportunity as ICAPS, its Phase-A Feasibility Study and Special Development, in which selected critical hardware items were



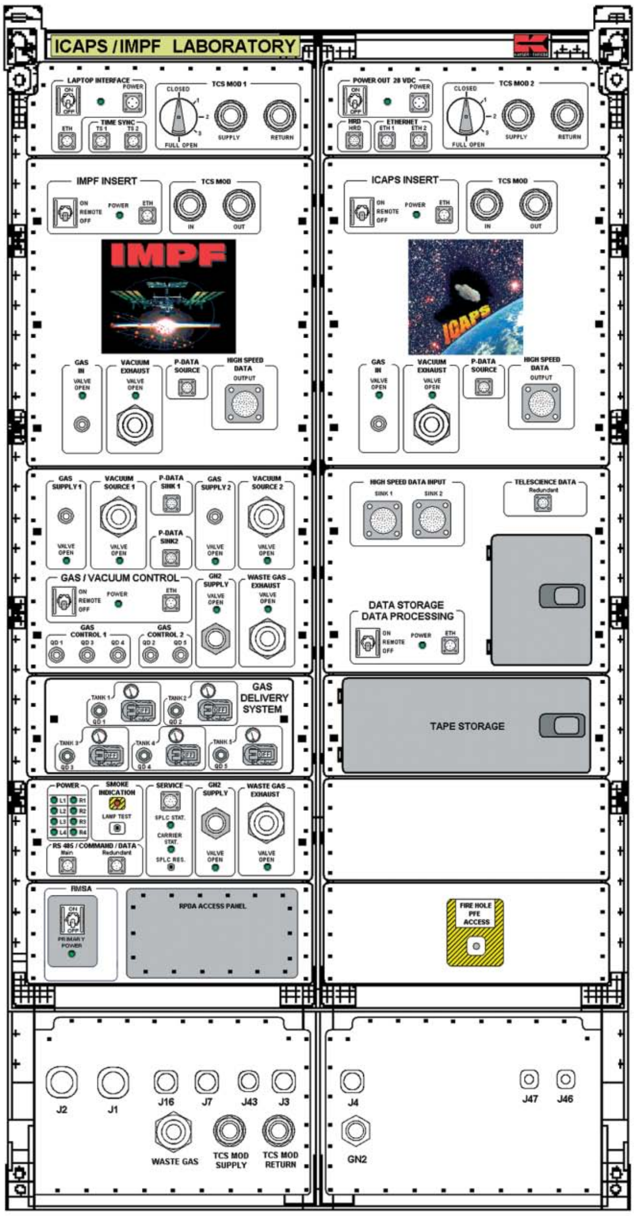
developed and tested on parabolic flight campaigns, was funded by DLR. This proposal formed the basis of a DLR-funded Phase-A feasibility study, concluded in December 2001 by Kayser-Threde with close cooperation from the Max-Planck-Institute for Extraterrestrial Physics (MPE) and the extensive international scientific user community.

A complex plasma contains ions, electrons, neutral gas and micron-sized particles at low-temperature. The micro-particles are highly charged, each collecting up to 100 000 surface electrons. They therefore interact strongly through the electrostatic (Coulomb) force. These interactions have yielded observations of entirely new phenomena, including a 'plasma crystal' of an ordered, self-organised structure of micro-particles. This was observed at MPE in 1994 for the first time. Space experiments, complementing laboratory experiments on Earth, are important for removing the influence of gravity, which exerts a significant stress on the complex plasma system.

A complex plasma is a unique system that can be used to study many important fundamental processes in physics such as



A plasma crystal in microgravity; width shown is 1.4 mm.



Front panel view of the ICAPS/IMPF Laboratory.

crystallisation and other phase transitions (e.g. glass transitions), at the kinetic and microscopic levels. Furthermore, interactions between plasmas and micro-particles are of great interest in astrophysics, where dust formation in stellar atmospheres, planet formation and even star formation can occur under 'dusty plasma' conditions. Technology applications include the avoidance of dust contamination during microchip production by plasma etching.

The 'PKE Nefedov' experiment aboard the ISS has already shown some surprising, new behaviour of complex plasmas under microgravity conditions, including the surface structures of complex plasmas and charged induced dilation transitions. IMPF will be a modular, long-term facility, which will allow the systematic study of fundamental aspects and applications of complex plasmas, responding to exciting new and unexpected results as they occur. Via telescience, IMPF will be at the disposal of many different international research groups, allowing us to exploit this facility fully and to make important progress in the rapidly growing research field of complex plasmas.

For further information on IMPF please visit *www.mpe.mpg.de/www_th/plasma-crystal/index_e.html*

The Laboratory Design Concept

To maximise the use of existing hardware, ICAPS/IMPF will be hosted in ESA's Columbus module using Japan's International Standard Payload Rack (ISPR) and built from a range of Standard Active Containers (SACs). Common support services, such as vacuum and gas control, and high-speed/high-volume realtime data acquisition, are integrated in 4-PU ('Panel Unit') and 8-PU SACs. Typically, all the experiment 'inserts' will be integrated in 12-PU SACs, which offer payload capacities of 110 litres, 56 kg and 560 W power consumption. This modular design permits fast and easy on-orbit reconfiguration for even larger experiments.

The laboratory design is a multi-user concept with high modularity on the level of the laboratory infrastructure and the individual experiments. This will allow the engineers and scientists to make maximum and optimal use of the facility over the lifetime of the ISS, and through perhaps more than one generation of users, beyond the existing experiment teams. Furthermore, it allows for multiple repeats of experiment runs, vital for verification of new and unexpected observations, and scientific credibility in the wider literature. Rapid reaction and response to the experiments will be possible, with the inclusion of on-orbit and telescience-reconfigured science protocols, as well as future on-orbit upgrades and/or refurbishment of the experiment modules.

Schedule

Depending on the Human Spaceflight Research and Application Programme Board approving the Phase-C/D budget in 2004, the ICAPS/IMPF Laboratory will become available to the international scientific community from 2008 aboard ESA's Columbus module. For more information on research opportunities, researchers should contact the ISS Utilisation and Microgravity Promotion Division (MSM-GAP) at ESTEC: Jorge Vago, tel +31 71 565-5211, Jorge.Vago@esa.int ■

Towards the Future

Developments in the Directorate

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Introduction

Development of the many European elements of the International Space Station is almost complete. European industry now has considerable expertise in manned space vehicle development. It is a leader in the design, development and production of space modules. When the Automated Transfer Vehicle (ATV) is completed in 2004, Europe's capability will extend to automatic cargo transportation in space, technologically and operationally rivalling that of Russia, and arguably exceeding that of NASA.

In order to sustain Europe's leading position in human spaceflight, we need to continue the evolution towards future space infrastructure and exploration. As the development phases of today's projects approach conclusion, the Directorate has initiated a major effort to prepare a new vision for human spaceflight. As part of its recent reorganisation, it has concentrated all the related preparatory activities in its new Development Department. With the intention of submitting a dedicated 'Preparatory Programme' to ESA's Member States in late 2004, preliminary activities are already underway under various existing programmes, with all the work being coordinated and integrated to form a coherent whole. The different activities are performed under the following programmes:

- the *Studies, Technology and Evolution Preparation* (STEP) programme, which aims to improve the existing services of the European segment of the ISS; reduce operational costs for the current ISS; and plan future capabilities in preparation for future developments. This is a slice of the ISS Exploitation Programme subscribed to, so far, by Belgium, The Netherlands, Spain and Switzerland.
- the *Interim Technology Effort for Reusable Transportation and Atmospheric Reentry Systems*, managed in cooperation with the Directorate of Launchers, and including technologies related to space transportation and atmospheric reentry for crew and cargo vehicles. This makes use of the legal frame of ESA's General Support & Technology Programme (GSTP) and is funded via dedicated subscriptions from Austria, Belgium, Italy, The Netherlands, Spain and Switzerland.
- the *General Study Programme*, covering the strategic subjects of human spaceflight: crew transportation, payload transportation, on-orbit servicing platforms and vehicles, long-duration habitats and ATV evolution.
- *ISS Development Programme*, small funds to enable coordination by Prime Contractors of the above activities.

ESA is already studying what needs to come after Columbus, ATV and its other current ISS activities ...

Main Activity Themes

The future of European human spaceflight will build on the achievements of the last 25 years and will lead Europe through independent initiatives and international cooperation towards a new set of projects. The current ISS infrastructure needs to be improved, to increase the scientific return from this world-class facility and to expand its applications. A next-generation in-orbit infrastructure, allowing substantial operations growth to include in-orbit servicing, spacecraft integration and mission support, long-duration autonomous habitats, and future activities such as space tourism and in-space power generation can be envisaged. The exploration of celestial bodies making use of the space infrastructure is also being prepared, under the Aurora programme.

Independent of the eventual overall long-term future programme(s), specific enabling technologies are mandatory. However, Europe has not yet mastered some domains and, in others, the state-of-the-art must be improved. The main themes have been identified for priority development in the coming months and years:

- *closed-loop systems for long-duration manned spaceflight*. Regenerative closed-loop food systems and life support / water systems will minimise supply logistics for near-Earth operations and eliminate them for exploration missions.
- *habitats*. Large-volume, ergonomically designed living and working quarters for long-duration occupation and travel.
- *robotic systems*, to reduce the non-intellectual and dangerous work of astronaut activities, both EVA and IVA.
- *transportation and reentry systems for astronauts and payloads*. Includes ATV evolution, which might also form the basis of mobile servicing systems and/or scientific freeflyers.

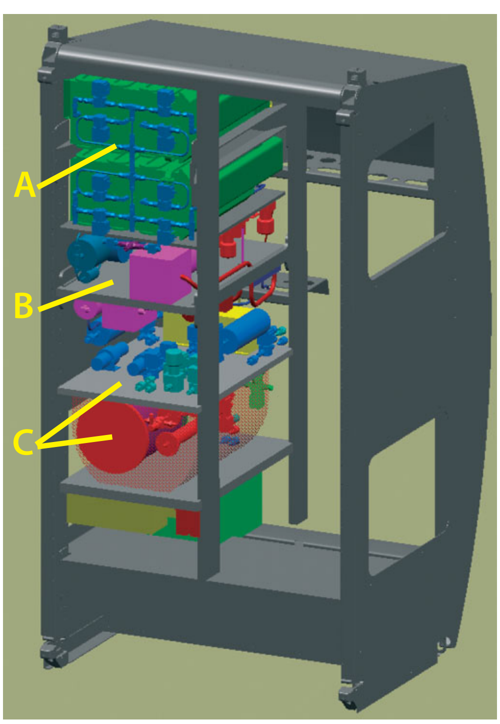
Activities Status

Within the main themes identified above, the following activities have been initiated:

Closed-loop systems

ARES, an Air Revitalisation System, will be designed for installation in any suitable location within the ISS pressurised modules. It will control carbon dioxide and oxygen levels, while achieving considerable economic savings by reducing the upload of water required by the baseline system envisaged by NASA. An elegant breadboard of this system will be assembled and tested to verify the technology.

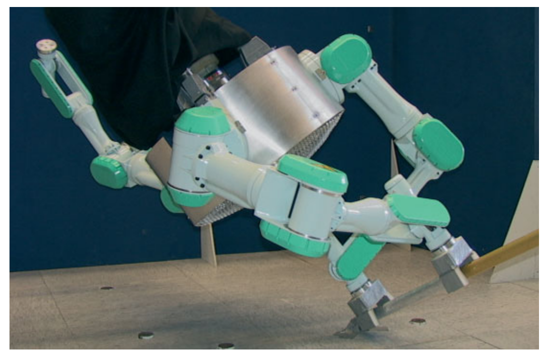
Studies will design a container for closed-loop food systems (making maximum use of the MELISSA 'micro-ecological life support alternative' project) that could be placed on the ISS to verify the technologies.



The ARES air revitalisation system will be more economical than current systems. A: carbon dioxide absorber. B: Sabatier reactor. C: electrolyser.

Habitats

Scenarios and solutions for space-based, low-orbit vehicles to perform in-orbit servicing functions are being studied in order to evaluate inflatable modules and associated subsystems that will be required for humans to survive long-duration space exposure. In parallel, the long-term habitability ergonomics of such a habitat are being studied. A crew restraint for long-duration work, based on a new concept, is planned to be flight-tested on the ISS by ESA astronaut Pedro Duque during a Spanish Soyuz taxi mission. The closed-loop systems described above will be necessary for such habitat elements.



A Eurobot mockup at ESTEC.

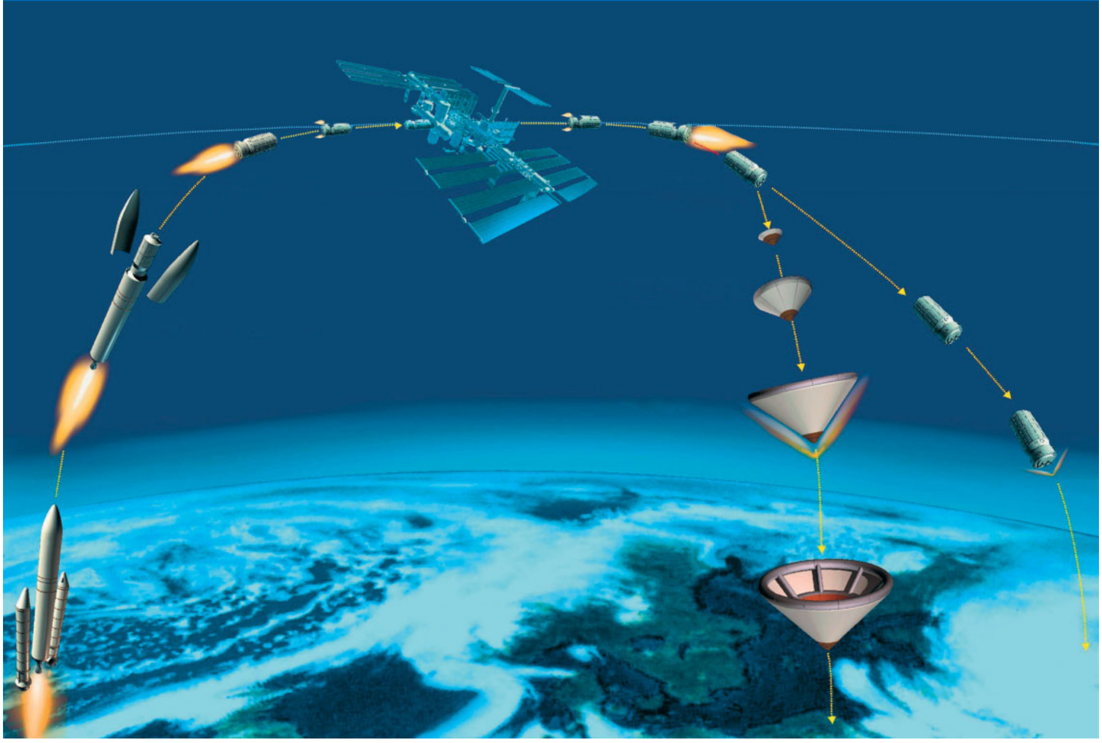
Robotics

Design studies of a quasi-autonomous robot called Eurobot, a space robot to support astronauts during long spaceflights and planetary exploration, will be conducted. Eurobot will be autonomous or controlled by an operator on Earth or inside the spacecraft, and will translate along the space station structure with arms gripping standard EVA interfaces. With dextrous end-effectors, Eurobot will perform or support EVA tasks, such as manipulating payloads or parts of the ISS infrastructure and perform inspections. It will seek its home base, where its batteries will be recharged. The robotics simulators developed for the European Robot Arm (ERA) will verify Eurobot's functions, and a 1 *g* demonstrator will be constructed in ESTEC's Erasmus building.

Large-scale robotic assembly study, scenarios for future robotic assembly at the ISS of large space structures like XEUS, or exposed ISS payload facilities tended by ERA, will be studied.

Space transportation and reentry

Inflatable Reentry and Descent Technology (IRDT) / Payload Download System, demonstration of



A potential future payload return system, using ATV.

inflatable reentry concepts as a precursor to an operational concept for payload retrieval from the ISS. The ISS has limited download flexibility, restricted to the Shuttle (high capability but high cost / fixed opportunity) and the Raduga capsule (very limited capability). An ATV- and/or Progress-based payload download system could save on download costs compared to Shuttle and increase capability compared to Raduga.

The *Interim Technology Phase for Space Transportation and Atmospheric Reentry* includes development and demonstration activities in hot structures and thermal protection systems, reusable metallic structures and control surfaces, mechanisms, avionics and man-machine interface technologies. The development of the International Berthing and Docking Mechanism (IBDM) engineering unit is a continuation of activities under the X-38/Crew Return Vehicle programme and represents a significant potential contribution by Europe to any future ISS visiting vehicle.

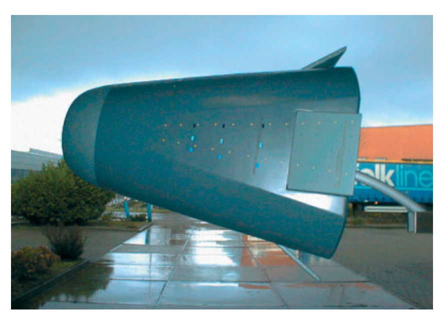
Within this domain, the development and flight of 'Expert' is being undertaken. Expert is a reentry vehicle for in-flight experimentation, designed to provide reentry conditions for the study of critical aerothermodynamic phenomena, such as laminar-to-turbulent transition, material catalytic properties, shock-wave / boundary layer interactions, real gas and rarefaction effects.

ATV-derived infrastructure elements / evolution study, involving configuration and operational studies towards European human access to space capability and/or combined logistics and experiment vehicle. These studies will be harmonised with the payload download system work, ATV being a prime candidate base for that deployment system.

Human Transportation

In addition to the items above, proposals are being developed to evaluate potential manned transportation systems. These are embryonic at the moment, but under consideration are:

- *Orbital Space Plane.* European participation in NASA's Orbital Space Plane to carry humans to and from orbit and to serve as the ISS crew return vehicle is being discussed with NASA.
- *European Crew Transporter to LEO studies.* Include feasability of launching manned Soyuz missions from Kourou. Additional studies on aspects for an evolved transporter, launched on either Soyuz from Kourou or on unmodified Ariane-5, are planned.
- *Earth reentry capsule/lifting reentry demonstrator vehicle* for a high-energy reentry mission as required by a sample return from Mars, focusing on thermal protection system and aerothermodynamics.



A mockup of the Expert reentry vehicle.

Conclusion

The work to establish a preparatory programme for the future of human spaceflight is underway, but much remains to be done. In the climate of small budgets and undetermined delays to the Space Station programme caused by the tragic loss of Shuttle *Columbia*, the challenge is to generate ideas that are practical, useful, attractive and beneficial to mankind.

The ISS Education Programme

The Future of Space and Technology Education

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Introduction

An ISS Education Programme has been developed by ESA, coordinated with and complementing the Agency's corporate Education and Outreach activities. The long-term objectives of the programme are to: maximise the use of the ISS as a tool for teaching science-related topics in European classrooms; increase the number of students of scientific/ technical disciplines at secondary and University level, with an emphasis on female students; improve the quality of scientific/ technological teaching and support the development of modern, high-tech teaching tools.

> *The creation of educational material focusing on the ISS is now well underway ...*

In 2001, the educational activities focused on the definition and promotion of the programme as well as the definition of an ISS Education Fund supported by entities external to ESA. In 2002 we developed 'content' and built on the input and contacts established in 2001 with external entities (UNESCO, European Union/Commission, publishers and the European teaching community).

The aim over the next 5 years is to consolidate the above with the production of educational material for 8-18 year olds (written, video, web-based), activities targeting university-level students (student experiments aboard the ISS) and events for students and teachers (seminars, conferences, teacher exchanges), some examples of which are outlined below. Where possible, some of these activities will be implemented in coordination with other institutions and organisations, such as national space agencies and other ISS International Partners, education ministries, non-governmental organisations and the EC.

Promotional activities, including contests and special events, will also be developed to support the awareness and distribution of the programme.

> If you are a teacher interested in receiving an ISS Education Kit and are prepared to provide feedback on its content, contact
> *Solveig.Pettersen@esa.int*
>
> For more information on the ISS Education Programme of activities, please visit
> *http://www.esa.int/spaceflight*

Education Activities to date

Educational Material for 8-18 year olds

In October 2002 the first pilot ISS Education Kit, aimed at pupils aged 12-15, was distributed to more than 700 teachers across Europe. The kit, developed in collaboration with teachers, describes the ISS with related interdisciplinary exercises that challenge the students' creativity, stimulate their curiosity and encourage them to discuss the topics presented. Different topics and teaching methods make it relevant to existing curricula and teaching practices in Europe.

The pilot kit will be followed up by an extensive evaluation after which the final ISS kit will be produced and translated into several languages this year.

A pilot ISS Education Kit for 8-12 year olds as well as 'Lessons in Life and Physical Sciences' for 15-18 year olds will also be developed during the course of 2003/2004. Furthermore, a programme of educational experiments targeting 12-15 year olds will be filmed aboard the Station during the April and October 2003 Soyuz missions involving European ESA astronauts. The footage will then be made available to schools across Europe.

Targeting University-Level Students
In August 2002, the SUCCESS contest was launched to invite university students to propose experiments for flight aboard the ISS. The final selection of proposals is planned for the first quarter of this year.

Within the 'Pyramid of Space' programme of the ESA Education and Outreach Office, university students are also given the opportunity to fly experiments on parabolic flights and unmanned Foton missions. Two of the student experiments (WINOGRAD and CHONDRO) launched on the recent but ill-fated Foton mission will now fly aboard the ISS during the next two Soyuz missions in April and October.

These flight opportunities are important as they represent the acceptance and recognition of student research by the scientific community.

Events and Opportunities for Teachers
In 2001, ESA invited secondary school teachers to *TeachSpace 2001*, the first ISS education conference, with the aim of better understanding their needs and where ESA could be of assistance in establishing networks and developing suitable material. One of the outcomes was the pilot ISS Education Kit.

In March 2003 a *TeachSpace in Primary Education* workshop will be held at ESTEC in order for ESA to identify which topics are taught at primary level across European curricula and what material ESA can provide to support teachers' efforts.

In addition, one or more teachers are collocated on a yearly basis within the MSM Directorate to develop the material for the ISS Education kits.

The ISS Education Fund
The fund's main objective is to provide financial support for the development, integration and testing of student experiments that will fly on the ISS. These experiments can call on up to 1% of ESA's accommodation and operational resources (up/down mass, crew time, power, data links) on the ISS.

Following its formal establishment in July 2002, the fund will be activated this year, beginning with the nomination of its Participants and Honorary Participants.

Conclusion
The Space Station and human spaceflight are of great interest to youth. ESA is obliged to foster this interest and channel it into a renewed interest in science and technology education so that they will be motivated to become a science-literate and space-educated generation. ■

Working at TeachSpace 2001.

Listening in to the Cosmonauts

Monitoring the ISS Radio Communications

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Listening to ISS crews talking with Russian mission control ...

Introduction

The Russians' use of relatively low radio frequencies on their manned spaceflights is convenient for radio amateurs and services trying to listen in on their space communications. Beginning with the Mir space station (1986-2001), the shortwave bands were no longer used by manned spacecraft and stations. The most important channels for Mir voice communications were 143.625 MHz Frequency Modulation-Narrow (VHF-1) and 130.165 MHz FM-N (VHF-2). Channels for telemetry and beacon transmissions were active in the 165, 166, 600 and 900 MHz bands. The manned Soyuz ferries were equipped with the voice channels 121.750 MHz FM-N and 130.165 MHz FM-N, and telemetry and beacon channels at 165, 166 and 900 MHz. The unmanned Progress freighters use the same frequencies but, of course, do not need the voice channels.

The author's display for tracking the ISS orbital location.

For those of us who had listened in to Mir operations for many years, it was no surprise when the Zvezda Service Module of the ISS began using almost the same frequencies – Zvezda was originally built as part of a Mir-2. In addition, Zarya was based on the same design as some of the Mir modules. So the switch from Mir to the ISS was very simple for long-term radio observers.

Monitoring Russian ISS Communications

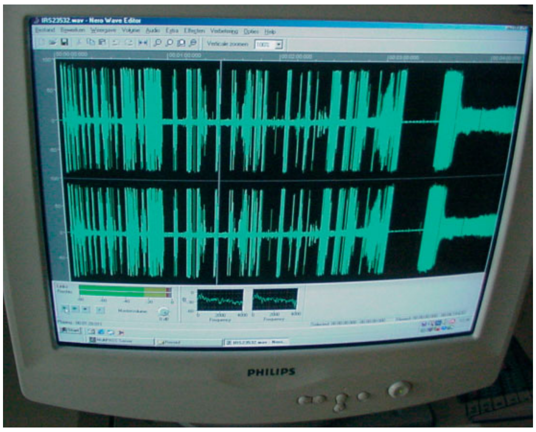
We can hear Zvezda's downlink voice channel using receivers tuned to the 144-145 MHz amateur bands. Most radio ham receivers can also reach 121.750 and 130.165 MHz. I use the Yaesu-9600, Icom-R7000 and FRG-7700 receivers with an FRV-7700 converter. The receivers are fed by active broadband antennas. But the cosmonauts can also be heard on much simpler equipment – many hand scanners can receive space channels. More information can be found on sites such as *www.amsat-dl.org/* and *www.amsat-uk.org/*. Cheap, second-hand receivers can often be found for sale on radio amateur websites.

Unfortunately, the amount of ISS voice communications via Russian channels is much less than aboard Mir. The cosmonauts now often use the systems in NASA's segment, which we cannot hear because they are routed via the TDRS geostationary satellite system.

Topics discussed between the cosmonauts and Mission Control Centre-Moscow (TsUP-M) concern mainly the life support systems that are the responsibility of the Russian flight engineers (this is Nikolai Budarin during the current Expedition-6).

A Daily Routine for Effective Monitoring

The ISS orbital inclination of 51.6° means there are six daily passes within the range of West European listeners. Voice communications can be expected during the first four of the sequence. We can readily compute the



The amount of ISS traffic during orbit 23532.

windows when ISS reception is possible, using 'two-line elements' that can be downloaded from, for example, *www.Celestrak.com*. Alternatively, predictions are freely available at *www.heavens-above.com*.

When the Station is flying from west to east, it passes over my position in The Hague (NL) and is within range of the most westerly tracking stations in Russia (Shcholkovo and St Petersburg). Communications with MCC-M then begin. Reception of the radio traffic is very simple using amateur equipment. Many radio amateurs are even able to communicate with the Station (see the article in *On Station 10*, September 2002, pp.14-15). They receive ISS Packet Radio and voice at 145.800 MHz and transmit via 145.990 MHz (P/R) or 145.200 MHz (Voice).

Listening to Soyuz

Soyuz ferry flights to the Station typically take 2 days and there is insufficient information to compute the exact passes, so manual monitoring is inevitable. Some 4.5 hours after the launch of a Soyuz we need to listen intently, as then we can expect to hear the crew talking on 121.750 MHz. This traffic is *always* interesting because the commander has a lot to report on the state of the Soyuz in a short time. We can expect the same during the upcoming Soyuz flights with ESA astronauts Pedro Duque (April) and André Kuipers (October). During his October 2002 flight, Frank De Winne could be heard talking with Kuipers in Dutch. At the same time, a second receiver is useful for monitoring the Soyuz telemetry channels: 922.755, 167.873 and 166.134 MHz. The receiving mode for these channels is Single Side Band (SSB). Of course, it is not possible to decode the telemetry itself, but it provides information such as the time of closest approach (when the Doppler shift is zero). If the Station raises its orbit, Zvezda (628.125, 630.125 MHz) and Zarya (633.850 MHz) telemetry signals can help to correct the old calculations before the official two-line elements become available.

Docking with the ISS

Of course, the Soyuz approach and docking with the ISS takes place within radio range of MCC-M. This means that western European observers can hear the final stages. Voice communications can be expected via 121.750 MHz (Soyuz), 143.625 MHz (ISS) and sometimes 130.165 MHz. Soft capture always occurs a few minutes after the loss of signal at my location in The Netherlands, so I have to wait until the following pass to be sure that capture and docking were successful. The best way to do this is via the three channels (143.625, 130.165, 121.750 MHz) where intensive voice traffic can be expected. The Soyuz guest crew waits to enter the Station, air-seal checks are performed, the hatches are opened and the crews meet. During this or the following pass, Russian space VIPs, representatives from the foreign cosmonaut's home country, family and friends send their congratulations to both crews. The

The author listening to the ISS.

130.165 MHz channel is often active with strong signals.

The guest cosmonauts usually have an intensive scientific programme to perform and employ all the possible communications sessions with scientists in MCC-M. Often it is necessary to use two channels: one for the guest cosmonaut and the other for the ISS commander to discuss technical and operational matters.

Guest cosmonauts also often establish contacts via the ISS ham equipment according to a published schedule (more information can be found at *www.ariss-eu.org*). It is always worthwhile to pick up this voice traffic from the ham channel at 145.800 MHz. ■

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