Building the Future

Acquiring Experience for Space Station and Columbus Operations

Aldo Petrivelli
Research Operations Department, Directorate of Human Spaceflight, Microgravity and Exploration, ESTEC, Noordwijk, The Netherlands

In the run-up to launching and operating Columbus, ESA has gained broad experience in operations on the International Space Station. This includes four Soyuz visits and the 6-month Astrolab mission, involving European astronauts, ground teams and infrastructure in a challenging collaboration with Russian and American partners.

Introduction

With the launch of its Columbus laboratory module at the end of 2007, ESA will become fully responsible for operating the European segment of the International Space Station (ISS). The Agency has developed the internal and industrial set-up to manage the module's integration with the ISS and its full-time operations, both independently and in collaboration with the Station's international partners.

Five European astronauts have already flown Soyuz missions of up to 11 days to the Station: Claudie Haigneré on the Andromède mission, Roberto Vittori (Marco Polo and Eneide), Frank De Winne (Odissea), Pedro Duque (Cervantes) and André

Kuipers (DELTA). ESA's centres and teams were major players in four of these missions, with Andromède directly supported by CNES and Eneide by ASI. The Russian cosmonauts were involved in ESA's experiments during these missions as part of the Soyuz contracts, and NASA's crewmembers also contributed. In all, more than a hundred European experiments were performed.

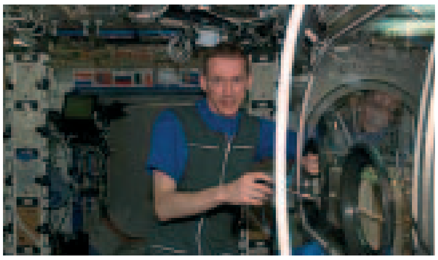
ESA astronaut Thomas Reiter completed his 6-month stay aboard the Station with the Astrolab mission in December 2006. This in particular has given ESA first-hand experience of long-term and multi-crew operations, helping greatly to create and test the management and organisation techniques for working in the challenging Station environment.

The Soyuz Missions

The Odissea mission began with the Soyuz launch from Baikonur Cosmodrome on the morning of 30 October 2002. Aboard the maiden Soyuz-TMA spacecraft were commander Sergei Zalyotin and flight engineers Frank De Winne and Yuri Lonchakov. Nine days of intense effort aboard the Station saw a range of scientific and educational activities successfully completed. On 10 November, the visiting crew returned in Soyuz-TM 34, making a rare night landing in Kazakhstan.

Being able to deliver experiments via the unmanned Progress ferries and the manned Soyuz, combined with the available time of the three visiting crewmembers, created a unique opportunity for a long schedule of experiments. Odissea made full use of this opportunity. A total of 23 experiments were performed, some with more than one human test subject and four in the ESA-developed Microgravity Science Glovebox. The glovebox was installed in May 2002 in the US Destiny laboratory; the other experiments were carried out in Russian facilities.

Odissea was the first ISS mission requiring a distinct ESA structure. It also confirmed the need for careful coordination of ESA's support for the experiments conducted in the Station's Russian and US segments. This was provided by the Operation Support Centre in ESTEC, linked to the Belgian User Support Operations Centre (USOC), Mission Control Centre Moscow (MCC-M) and to NASA's Huntsville Operational Support Center (HOSC) and Mission Control Center Houston (MCC-H).



Odissea: Frank De Winne with the ESA-built Microgravity Science Glovebox

The Cervantes mission began on 18 October 2003, with Pedro Duque flying on Soyuz-TMA 3 with cosmonaut Alexander Kaleri and astronaut Michael Foale. Duque became the sixth European astronaut to visit the Station, and during his 8-day stay he performed 21 experiments in life and physical sciences, Earth observation, education and technology.

Cervantes: Pedro Duque in October 2003

DELTA: André Kuipers in the Station's Zvezda module

Real-time operations were coordinated from the Erasmus Payload Operation Centre at ESTEC. Invaluable experience was gained by the Flight Control Teams in different support centres, such as the Spanish and Belgian USOCs, which assisted the ESA experiments.

A broad range of international cooperation was involved. The European Astronaut Centre (EAC), NASA Marshall Telescience Support Center, ESA's Moscow Mission Operation Support Team (MOST), Increment Management Control at NASA's Johnson Space Center, NASA Payload Operation Integration Center at the Marshall Space Flight Center and the communications network team at ESA's European Space Operations Centre (ESOC) all contributed to the mission success.

The DELTA mission began with the Soyuz-TMA 4 launch on 19 April 2004, carrying André Kuipers, Gennadi Padalka and Michael Fincke to the Station. This mission saw deep cooperation between ESA and the Dutch authorities – a difficult set of 28 experiments was prepared by a joint team from ESA and Dutch industry. This collaboration was a key element in the mission's success, and important experience for handing over operations to industry. This mission also allowed ESA to run some experiments before and after André's visit.

Eneide: Roberto Vittori in the Destiny laboratory module

ESA's real-time operations were coordinated from the new Erasmus Facility Responsible Centre, which was gaining its first experience for working with Columbus.

DELTA also saw the first experiments activated during the 2-day journey of Soyuz to the Station – several biology experiments were carried out in the two ESA Kubik incubators.

The Eneide mission confirmed the objectives of the previous missions: expand the experience of European astronauts, obtain scientific results, promote research in science and technology, stimulate educational interest in young people, expand operational experience with the Station, and promote political and commercial international links.

During his 10-day flight and 8 days aboard the Station in April 2004, Roberto Vittori successfully carried out 27 experiments developed mainly by Italian industry and research centres and ESA. Roberto also made numerous education and public relations contacts with Italian organisations.

For the first time in these missions, the real-time operations were coordinated from the Columbus Control Centre (Col-CC), in Oberpfaffenhofen (D). This was the interface between Roberto, the USOCs and the control centres in Moscow and Houston. All medical and crew aspects were managed from EAC in Cologne (D). Overall mission management was provided from ESTEC.

The Astrolab Mission

The long-duration Astrolab mission began on 4 July 2006 when Space Shuttle *Discovery* lifted off from Kennedy Space Center in Florida with Thomas Reiter and six NASA crewmembers. Thomas remained aboard the Station as the third crewmember, and returned in December 2006 on the next Shuttle, after 6 months of working as a flight engineer. He was accompanied on the descent by ESA astronaut Christer Fuglesang, who played a key role in *Discovery*'s Station assembly mission. Reiter's stay spanned Increments 13 and 14 (an 'Increment' denotes a resident crew's period aboard the Station). This was the first time since the *Columbia* tragedy there had been a 3-man ISS crew.

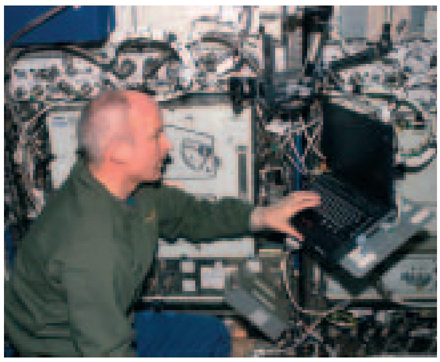
For ESA, Astrolab marked a new phase in human spaceflight. It was a unique mission that witnessed numerous firsts for the Agency. As part of the Station crew, Thomas performed ISS systems tasks, routine tasks, scientific, technology and educational experiments, and a spacewalk. This was his third venture outside, having already undertaken two spacewalks during his Mir mission of 1995–96.

The system tasks normally demand most of the crew time, involving maintenance to onboard systems, upgrading and adding facilities to meet new requirements and accommodating modules. For example, during his mission, Station assembly flight 12A took place in September 2006 and Soyuz-TMA 9 docked a few days later. Those were very intense working days for the astronauts and ground teams alike.

Routine tasks involve housekeeping, inspection of vital life-support systems, inventory checks, personal hygiene, physical exercise, eating and private medical conferences with the crew surgeon on Earth. These are all part of a normal day for ISS crewmembers.

Astrolab: Thomas Reiter working on the Pulmonary Function System in Destiny. ESA provided the PFS for the Human Research Facility

Astrolab: Thomas Reiter working on the Station's internal thermal control system



NASA astronaut Jeff Williams with the European Modular Cultivation System behind

ESA's complement of experiments during Astrolab totalled 40, and several others were performed as part of the overall set-up. In fact, the mission itself extended beyond Reiter's residence. Astrolab was part of the ESA Long Duration Mission (LDM). Owing to the repeated deferrals of the ULF-1.1 (Utilization & Logistics Flight-1.1) Shuttle launch, the LDM experiments had already started at the beginning of Increment 12, when the first hardware was uploaded and operated by Valery Tokarev and Bill McArthur. The same happened at the beginning of Increment 13, when Station Commander Pavel Vinogradov took over 13 experiments for ESA. Mikhail Tyurin, the Russian cosmonaut of Increment 14, continued with some ESA activities. ESA experiments were continued by Greg Olsen, a member of the visiting crew on Soyuz-TMA 7 and Anousheh Ansari, part of the Soyuz-TMA 9 visiting crew.

For the first time, preparation and mission operations were run by industry, paving the way for ESA's Automated Transfer Vehicle (ATV) and Columbus in 2007.

Astrolab was a commercial procurement from the Russian Federal Space Agency (Roskosmos) for a European astronaut to stay aboard the ISS for 6 months. With that, Thomas Reiter became part of the ISS crew as a 'Russian cosmonaut', able to work in both the Russian and American segments.

Coordinating the mission with the various international partners was critical. All the Astrolab hardware was delivered by Russian and US spacecraft, mostly for use in the Russian segment but some throughout the entire ISS. This involved ESA in close and continuous contact with Russian and NASA organisations.

The same flight that took Thomas to the Station also delivered three ESA facilities: the Minus Eighty-degrees Laboratory Freezer for the ISS (MELFI), the European Modular Cultivation System (EMCS) and the Percutaneous Electrical Muscle Stimulator (PEMS). Thomas helped to commission EMCS and MELFI into routine use.

LDM's key objectives were to extend European knowledge and experience in human space missions, and to conduct microgravity experiments. ESA selected 40 experiments that fitted into the available crew time, from educational demonstrations for school children to advanced plasma physics.

The full achievements of the Astrolab mission are still being assessed. Interim reviews with everyone involved and the preliminary results confirm a very positive outlook.

An Eye on Columbus

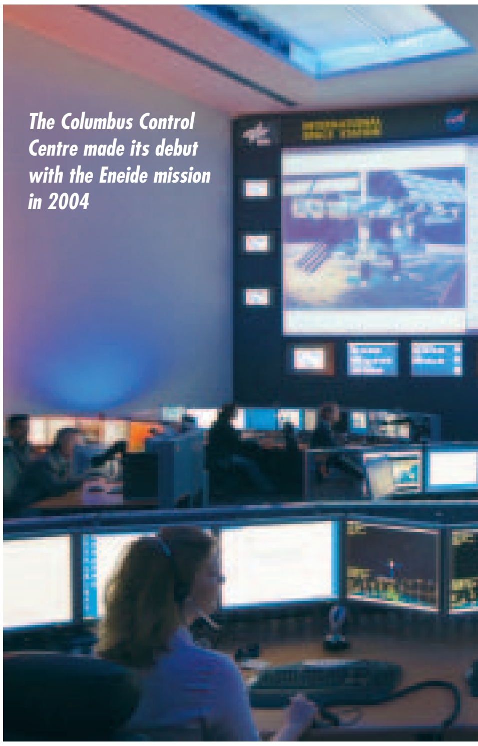
With an eye on Columbus operations, ESA has exercised most of the infrastructure and teams before the module's launch. This was particularly the case for Astrolab. ESA assigned the technical management to an industry consortium: the Industrial Operator Team (IOT). This is a joint industrial effort, led by Astrium-ST-Germany and Alcatel Alenia Spazio-Italy, with the participation of German space agency DLR, aimed at providing an end-to-end turnkey service to ESA. In addition, the USOCs help to prepare and operate the payloads and experiments.

In this set-up, ESA retains the overall management of the mission, while the IOT is responsible for the day-to-day technical management of European assets such as laboratories, ground network, space experiments and astronauts involved in the ISS Increments.

ESA manages the contracts for procuring IOT and USOC resources and services, and procures flight resources from NASA via specific barter agreements and from Roskosmos via commercial contracts.

The interfaces with NASA for specific missions and overall programme management involve the Mission Management Team, the Increment Integration Team, the Training Control Board, the Payload Control Board, and the Ground Segment Control Board.

The interfaces with the Russians are much more streamlined. They are largely managed by RSC Energia as the hardware integrator for Progress and Soyuz launches and as operator of the Russian portion of the ISS. The Gagarin Cosmonaut Training Centre takes care of the Soyuz crew training, while the Institute of BioMedical Problems is responsible for the medical aspects of manned flights.



The Columbus Control Centre made its debut with the Eneide mission in 2004

ESA's Mission Coordination and Control Board (MCCB) has the ultimate authority over ESA activities aboard the Station. It is chaired by the ESA Mission Manager and co-chaired by IOT and USOC representatives.

The MCCB mandates the Mission Management Team (MMT) to provide programme oversight and direction during real-time operations in order to assure crew safety, proper operations and to improve mission success. It is specific to each Increment and becomes active upon the positive conclusion of the ESA Operations Readiness Review. The MMT then coordinates all functional areas running the mission and is key to the success of the mission.

The Increment Integration Team (IIT) is the forum where the mission elements are assembled into an integrated package. It is chaired by the Increment (Integration) Manager, who is responsible to the ESA Mission Manager for timely mission reviews and deliveries.

Crew training for the ESA crew is coordinated by EAC in close cooperation with its Russian and NASA counterparts. For the Astrolab mission, most of Reiter's payload training took place at EAC. There was also some at NASA in Houston because of his schedule and the location of the training hardware.

Some experiments, especially biomedical, require baseline data to be collected on the astronaut before and after a flight for comparison with the flight results. Most of the Astrolab Baseline Data Collection (BDC) sessions took place at EAC, but for those in Russia and the US the BDC coordinator worked closely with his counterparts there.

For Astrolab, the ESA control centres were in regular operation for an entire Increment for the first time. ESA has set up its own ground network to interconnect the European centres as well as to the US and Russian centres.

The Columbus Control Centre in Germany is a key player in Europe's Station operations. It will be ESA's main control centre once Columbus is launched. It provides online services (communications, monitoring, archiving, commanding), distribution of databases and coordination of all the centres. Astrolab's Flight Control Team was hosted there. The communications for real-time operations between Col-CC and the international partners, the Engineering Support Centres, USOCs and EAC are provided by the IOT Ground Segment service.

ESA's Moscow Operations Support Team in MCC-M provides Col-CC with direct interfaces to the Russian team when needed.

European scientists are supported by several USOCs throughout Europe. The USOCs interface with, and can host, the science teams. They are connected to the ESA ground network and work closely with the Flight Control Team at Col-CC for real-time operations of their experiments, facilities or payloads.

Training and simulations for real-time mission operations are conducted in the ESA ground control centres (Col-CC, MOST and USOCs). Personnel train not only on ESA's various operations tools and processes, but also those of the ISS partners. Several simulations take place before each mission, divided into standalone simulations with only one centre, integrated simulations with multiple European centres, and Joint Multilateral Simulation Training involving all European centres and partner centres.

Conclusions

Preparing for Station missions is comparable to combining a number of different projects on a single road leading to the flight and its activities. These different projects each have their own organisations and teams that, most of the time, want to bring their own elements to the flight and have their own direct and exclusive control over the process. In practice, of course, this is not feasible. The necessity is to deliver to a team that integrates and operates all the elements efficiently and effectively; this is the industry mission integration and operations team that is taking shape within ESA. It is developing infrastructures, organisation, experience and a strong team spirit, thanks to the opportunities offered by previous missions.

After each mission and Increment, the integration and operations processes are evaluated, and recommendations are made on improvements. Odissea was the first ISS mission with an ESA organisation behind it. That organisation has developed and adapted as it has supported subsequent missions.

Apart from its undisputed value as a long-duration mission, Astrolab was also important as the première of the working mode for Europe involvement in future Increments. It was a testbed for improving processes, reinforcing working modes and building working relationships among industries, research centres and space agencies in preparation for the launch and exploitation of the main European Station assets: ATV and Columbus.

In almost all the activities, it was necessary to have fully integrated European, Russian and US teams. This was also the case for the European teams: the science, commercial and educational users, the communication teams, and the mission implementation teams from ESA, IOT and USOCs. All needed to work closely together. This challenging set-up demands great effort but ESA can proudly display important results for all to see.

The missions so far were unique opportunities for ESA to gain significant operational experience rapidly and to develop expertise for future European space activities. This does not mean by any stretch of the imagination that it is time to rest on our laurels. The missions have been highly successfully, but not totally so. They have given ESA confidence, experience and working relationships with their international partners, but it is now the time for consolidating, improving and ironing out the wrinkles ready for adding and exploiting the Columbus laboratory in orbit.