Facilities

ESTEC

ESTEC was extremely busy, with the simultaneous system and verification testing of several ESA spacecraft. In addition to the newly arrived Herschel Payload Module structural model, testing of the Automated Transfer Vehicle (ATV), the Herschel structural model and the Planck telescope continued, resulting in a very high workload for the Centre. In view of the ATV's 2007 launch, astronaut training was also performed for late access to space-vehicle parts.

ESTEC Test Centre

Elements of the Vega small launcher were also tested. The payload mechanical dummy and the upper-composite mechanical model underwent vibration testing from June to August, and the latter, including the fairing, underwent acoustic tests in the Large European Acoustic Facility (LEAF) in October.

In parallel with the spacecraft and subsystem testing, the continuous replacement and updating of ageing test equipment continued with the replacement of the mass-property measurement facility, acquired from APCO Switzerland, which came into operation at the end of February. Successful refurbishments were also performed on the control/command and motion systems of the Large Space Simulator (LSS).

Transient vibration tests were conducted on an Airbus A380 luggage pallet using the Hydra (hydraulic shaker) in July. The novel aspect of this test was the simultaneous introduction in six degrees of freedom of transient test excitations that have been measured during flight, for verification of the loaded pallet. The use of this type of aeronautical testing for the verification of satellite hardware will now be considered.

Engineering Laboratories

Power Laboratory
Several ideas and concepts developed within the power-systems and power-conditioning laboratories at ESTEC generated patent applications both in Europe and in the USA. Following up a previous application in France, a US patent was filed for 'Segregated maximum power-point tracking based on step-up regulation', an idea that has been further developed and breadboarded and

which might be used in the power system for BepiColombo. Another new patent application was filed in France for the 'Single-point failure-free S4R concept with respect to battery overcharge', which can preclude single-point failures causing battery overcharging and can be applied, for instance, in the Galileo IOV power system currently under development. Another ESA patent, on 'Zero voltage switching – zero current switching push-pull with regulation', was issued by the French Patent Office in December.

Battery Test Centre

In view of future ESA planetary exploration missions requiring high battery specific energies, a test campaign on new low-temperature lithium-ion cells was initiated in the European Space Battery Test Centre with cells provided by two leading European space battery suppliers. Based on a preliminary mission profile for a Mars rover in the framework of the ExoMars project, a test profile covering descent, landing and operations on the Martian surface was elaborated in cooperation with the cell suppliers. The results will provide a sound basis for the selection of low-temperature lithium-ion cell technology for ExoMars and other future ESA planetary exploration missions.

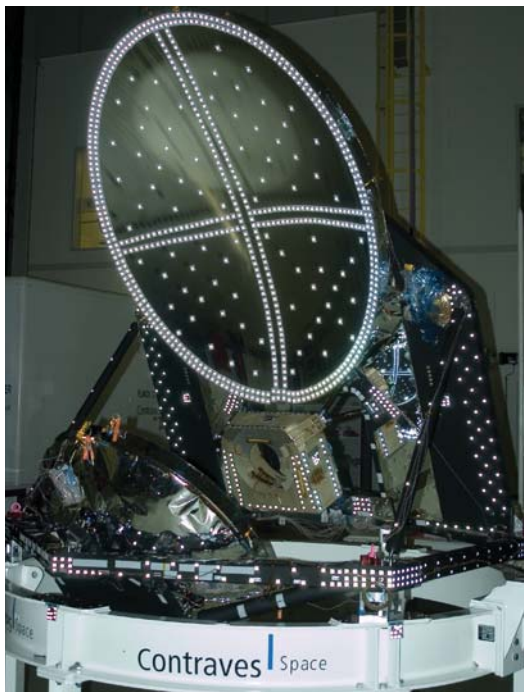
Concurrent Engineering

ESA continued its use of concurrent engineering for space applications and further enhanced the Concurrent Design Facility (CDF) at ESTEC (NL). The latter was used for studies at various levels, such as mission-system, instrument-concept and technology-reference studies, for a wide range of ESA programmes. Studies were also carried out to analyse the potential of disruptive technologies. The CDF concurrent-engineering methodology was applied to the reviews of industrial studies for several programmes. The work of the Herschel-Planck 'Tiger Team' deserves a special mention in this context, whereby a group of European and other experts, scientists and engineers worked together in the CDF to address a complex problem on the Herschel telescope.

Work continued on developing a robust open-source-design server to enable collaborative, concurrent and distributed engineering of space systems based on standard definitions.

The CDF also supported ESA's Education activities through the European Students Moon Orbiter project, involving a large student community, and with training in the context of the ESA Internal University.

The Herschel structural model on the Hydra test facility at ESTEC (NL)



The Planck telescope with videogrammetry targets mounted

The Herschel telescope

ESOC and the Stations

ESOC continued to respond to the immense public interest in space in Germany by maintaining a high level of visibility throughout the year.

The Establishment

The Centre hosted three major space-operations events, associated with the Venus Express orbit insertion, SMART-1's controlled impact on the Moon and the MetOp launch, attended by a total of around 700 invited guests. With some 13 000 visitors, tours of the Control Centre were again at an all-time record. The support given to a number of well-attended space exhibitions in Germany provided an additional window on ESA activities and successfully raised the public's space awareness.

In July, ESA's Director General Jean-Jacques Dordain and ESOC's Head of Establishment Gaele Winters hosted a visit by the new German Chancellor, Angela Merkel, and Roland Koch, Prime Minister of ESOC's host region Hessen. A live call was made to the Hessen-born ESA astronaut Thomas Reiter, as the first of a series of in-flight calls during his six-month stay on the International Space Station.

The Business Incubator Initiative, an ESA Technology Transfer Programme activity already operating successfully at ESTEC, was extended to ESOC in 2006. In close cooperation with and co-financed by the State of Hessen, it was joined by leading industries and research institutions in the region. With a special focus on supporting start-up companies developing innovative satellite-navigation applications, it attracted significant interest from throughout the region. The start-up companies will be hosted by the Technology and Innovation Centre of the Technical University of Darmstadt, located in the immediate vicinity of ESOC.

A number of high-calibre conferences and meetings were hosted at ESOC, involving some 1000 participants drawn from the international scientific, political and industrial communities. They included the second Galileo User Congress organised by the German Government.

German Chancellor Angela Merkel in the Main Control Room at ESOC with Hessen's Prime Minister Roland Koch (centre) and ESA's Director General Jean-Jacques Dordain

The Control Centres

Automated operations for ESA's Deep-Space Ground Stations were introduced at the ESOC Operations Control Centre, marking a further step towards reliable and cost-efficient ground operations. Two of the multi-mission operations facilities at the Centre, the Project Support Room and the Software Support Room, were refurbished and the installations modernised to support upcoming critical mission-operations phases.

The Columbus laboratory will be operated and controlled by the Columbus Control Centre located at DLR in Oberpfaffenhofen (D). The qualification and acceptance of this Control Centre were successfully completed and extensive end-to-end system-validation tests were conducted with the Columbus flight unit and various simulators.

The Automated Transfer Vehicle (ATV) will be operated and controlled by the ATV Control Centre, located at CNES in Toulouse (F). This Control Centre has achieved preliminary acceptance by ESA and an extensive series of system-validation tests were carried out to ensure that the ATV and the Control Centre can communicate properly. The ATV simulators, for crew training at EAC in Cologne and Star City near Moscow and for ground personnel training at the ATV Control Centre, were delivered and are operational.

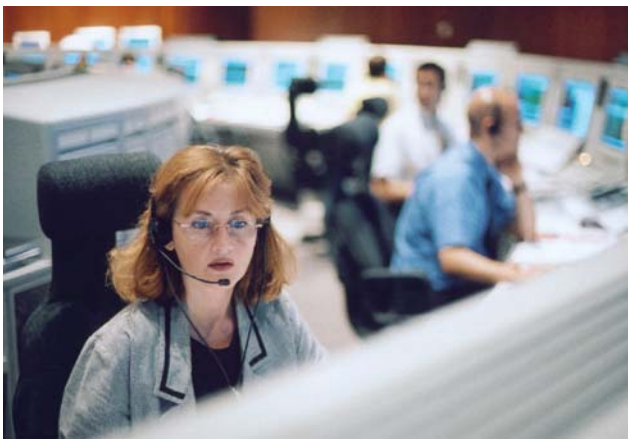
The ATV Control Centre in Toulouse

Mission Operations Infrastructure

The Secure Mission Operations Project will provide mission data systems at ESOC with a second data centre. In the future, missions will be able to distribute their computer systems infrastructure across two physically separated locations, thereby improving the overall resilience of the ground segment. Civil works for the new data centre were completed during 2006 and the essential communications and computer-system services will be installed early in 2007.

A new communications solution for high-volume Delta-DOR data transfers from the deep-space antennas

The Main Control Room at ESOC



was very successfully exploited for the Venus Express orbit insertion.

The Stations

The ESTRACK core network, comprising Cebreros, Villafranca and Maspalomas in Spain, Redu in Belgium, Salmijaervi/Kiruna in Sweden, Perth and New Norcia in Western Australia and Kourou in French Guiana, successfully completed more than 56 000 hours of spacecraft tracking for the various classes of missions:

- for the deep-space missions like Mars Express, Rosetta and Venus Express from the two 35 m deep-space antennas at New Norcia (Australia) and Cebreros (Spain);
- for the near-Earth scientific missions like XMM-Newton, Clusters 1-4, Integral and SMART-1 with classical Telemetry, Telecommand and Tracking (TT&C) antennas in the 15 m range from Kourou (Fr. Guiana), Maspalomas and Villafranca Terminal-2 (Spain), Perth (Australia) and Redu (Belgium);
- for the low-Earth-orbit Earth Observation missions like ERS-2 and Envisat from the Kiruna station (Sweden).

The 35 m ground station at Cebreros, ESA's second deep-space station, successfully supported the Venus Express mission and will be used for ESA's future missions such as LISA Pathfinder, Gaia and Bepi Colombo.

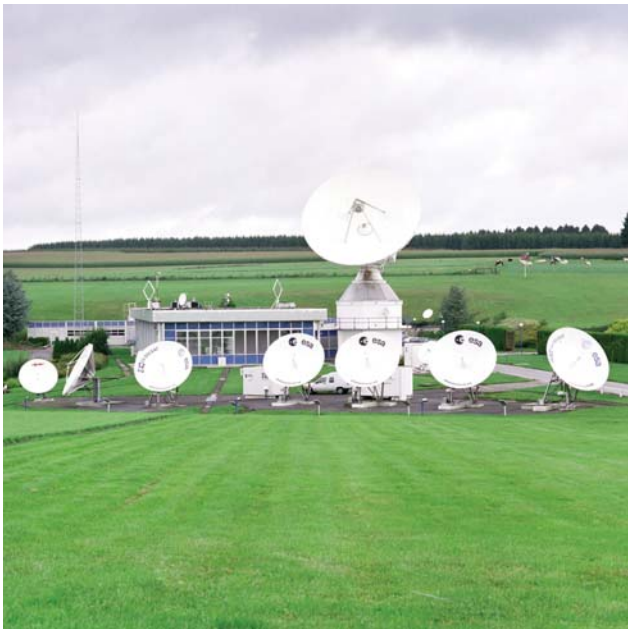
The Redu ground station successfully supported the Proba-1 technology-demonstration mission and is now preparing for Proba-2. An Announcement of Opportunity for the exploitation of the facilities was released and promising opportunities for securing and strengthening Redu's future role were identified.

International Cooperation

ESA benefits from long-term leasing arrangements with Member State countries hosting its ground stations. To support the ESA launcher programme, new ground stations are being built at Santa Maria in the Azores (P), and those in Perth (W. Australia) are being upgraded.

Ground-station support was prepared for the Chinese Chang'E 1 lunar mission during its transfer and orbit-insertion phases. Support to the Chinese Double Star and the Japanese ASTRO-F missions continued successfully.

ESA's deep-space ground station at Cebreros in Spain



ESA's ground station at Redu in Belgium

ESAC

The European Space Astronomy Centre (ESAC), located at Villanueva de la Cañada near Madrid, is a relatively new arrival to the ESA scene. The new facility occupies the grounds of the Villafranca Satellite Tracking Station (VILSPA) and it hosts the scientific operations for ESA's astronomy and planetary missions, as well as their scientific archives.

In the future ESAC, building on the experience of ESA's present suite of planetary missions, is expected to host activities related to the Exploration Programme. Another synergistic activity is that the data processing of the Earth Observation SMOS (Soil Moisture and Ocean Salinity) mission will be located there. Further expansion is expected by it taking an important role in the future Space Surveillance Network. VILSPA also continues as a ground station site, but with a reduced activity level. Since October 2006, ESAC has been managed under the ESA Science Directorate.

2006 was marked by major activities towards developing the site. Extensive refurbishment and a new construction project were undertaken as the site is prepared for a growing number of staff. The site is also being brought up to standard to be able offer the same level of services as ESA establishments (ESTEC, ESOC, HQ and ESRIN). In particular, the IT network has been enhanced and brought up to date using the latest technology to cope with today's high demand for fast and stable high-volume data exchange as the site becomes a central node for European space science data. The host country has played a major part in the development plan that commenced in 2005.

Science

ESAC is now the default location for science operations and archiving activities for all future missions undertaken in the Science Directorate. Over the year there has been a steady expansion of the operational archives for the astronomy missions Infrared Space Observatory (ISO), the XMM-Newton X-ray observatory and the Integral gamma-ray observatory. However, 2006 also marked the arrival of and the first developments for the planetary sciences at ESAC. The missions concerned are: Mars Express, SMART-1, Giotto, Huygens and Rosetta. One highlight here was the release of a map-based interface to the Mars Express data. At the same time, developments in preparation for missions not yet launched continued. In particular, the build-up of the Herschel team began in earnest.

As Herschel work built up, the year marked the official end of the post-operational phase of ISO. ISO was the world's first observatory-class spacecraft working in the infrared band and its archiving was a very important task. The final milestone, making available final data products of the long-term archive, was marked by a well-attended celebratory colloquium in December, during which the many technical and scientific achievements of the mission were reviewed.

Work with XMM-Newton continues apace, with nearly 2000 astronomers worldwide being involved in its Calls for Proposals. The XMM-Newton Science Workshop on 'Variable and Broad Iron Lines around Black Holes' took place at ESAC 26–28 June. The meeting concentrated on bringing together the many discoveries from the European XMM-Newton, US Chandra and Japanese Suzaku missions.

Following its successful move to ESAC in 2005, the Integral Science Operations Centre (SOC) consolidated its operations in Spain during the year. Major highlights included measurements of the high-energy cosmic background radiation using the Earth as an occulting source, and the introduction of 'Key Programmes' as a method of further expanding its use by the community.

The Japanese Akari mission was launched in February and embarked on its all-sky survey at infrared wavelengths. ESA's cooperation with the Japanese agency JAXA in Akari acts as a scientific bridge for the European community between ISO and Herschel missions. As well as the distribution of observing time to European observers, ESAC mission activities included

the production and use of a system to accurately determine where the telescope is pointing at all times.

As launch approaches in 2008, the development of the Herschel Science Centre at ESAC has picked up speed, with particularly significant expansions of data-processing system development and preparations for the initial Herschel Calls for Key Programme observing proposals. In parallel, the Planck Science Office was transferred from ESTEC to ESAC. Although the Herschel and Planck spacecraft are being developed in parallel, their science facilitation through ESAC is very different. In 2006, the Planck team focused on the coordination of science ground-segment development and testing, and on the development of software tools for the operational phase.

The start of industrial work in ESTEC on the Gaia mission, a mission to map up to a billion stars in our galaxy, marked also the kick-off for buildup of the Gaia SOC. Once again, ESAC's role is to be mission-specific and here the enormous scale of the data analysis required is the central issue. The first significant accomplishment was in demonstrating the feasibility of the astrometric global iterative solution for a Gaia-like dataset containing 1 million objects and 5 years of observations.

The year also saw the start of the planned transfer of solar-system science operations to ESAC with the arrival of the first staff and contractors; the main buildup is foreseen for 2007.

Operations

The main TT&C activities were performed using the VIL-2 terminal supporting the cooperative ESA-CNSA DSP mission. VILSPA continued to serve a back-up role for several ESA missions, including XMM-Newton, SMART-1, Cluster and Integral.

Communication and Education

The new ESAC is working to integrate with the surrounding community and to bring the European space endeavour to the attention of the wider community. ESAC welcomed about 3000 visitors in 2006 during numerous scientific and general public events, opening its doors to guests and the international press for ESA launches and other key events like the Venus Orbit Insertion in April. Several media days were also organised with the Spanish ESA astronaut Pedro Duque, in response to press requests. ESAC hosted a Science Week in May and another in November, which were attended by a total of about 1500 students and also the general public, helping to increase awareness of ESA and its scientific missions, and the activities of ESAC. A major event in June hosted several VIP visits and a special visit by 80 prize-winning students sponsored by the Spanish Ministry of Education and the Instituto Nacional de Técnica Aeroespacial.

In addition over 200 interviews were managed by ESAC Communications Office during the year, as well as a special Euronews TV feature. A new dedicated ESAC website was also launched.

Resource Management

During 2006 the ESAC Administration was reinforced with the creation of a local Human Resources Service and the harmonisation of local administrative procedures to bring them fully in line with the other ESA sites.

Aerial view of ESAC

ESRIN

ESA's centre for Earth observation in Frascati (I) hosted numerous scientific conferences, high-level scientific workshops, industrial meetings and reviews, as well as VIP visits and events for the general public during the year.

They included the European Advisory Working Group on the European Strategy for Earth Observation in February, the CEOS-SIT (Strategic Implementation Team) Meeting, the Executive Board Meeting of the International Charter on Space and Major Disasters. An Atmospheric Chemistry Science Conference and the MIPAS Workshop attracted many scientists. The EPS/MetOp RAO Workshop involved the meteorological community, while the Global Wetlands Symposium and the DUE Epidemio Workshop attracted the service industry active in these EO application areas. A special workshop was organised in April on the GMES space component to present progress in the programme. Another special workshop in November involved all of the international GOCE scientific community in preparing for the mission. A symposium was also organised at ESRIN on the Proba mission.

There were more than 25 000 visitors to ESRIN in 2006. The Open Day in March attracted the general public in large numbers, including more than 1000 students, as also did the Science Week and the European Researchers' Night organised jointly with all of the other research centres in the Frascati area.

Many media representatives were welcomed to the site for ESA launch-related events and for specially organised media days. One of the highlights was an in-flight call to the International Space Station during the stay of ESA astronaut Thomas Reiter in November.

Visit to ESRIN by representatives of the Japanese space agency JAXA in November

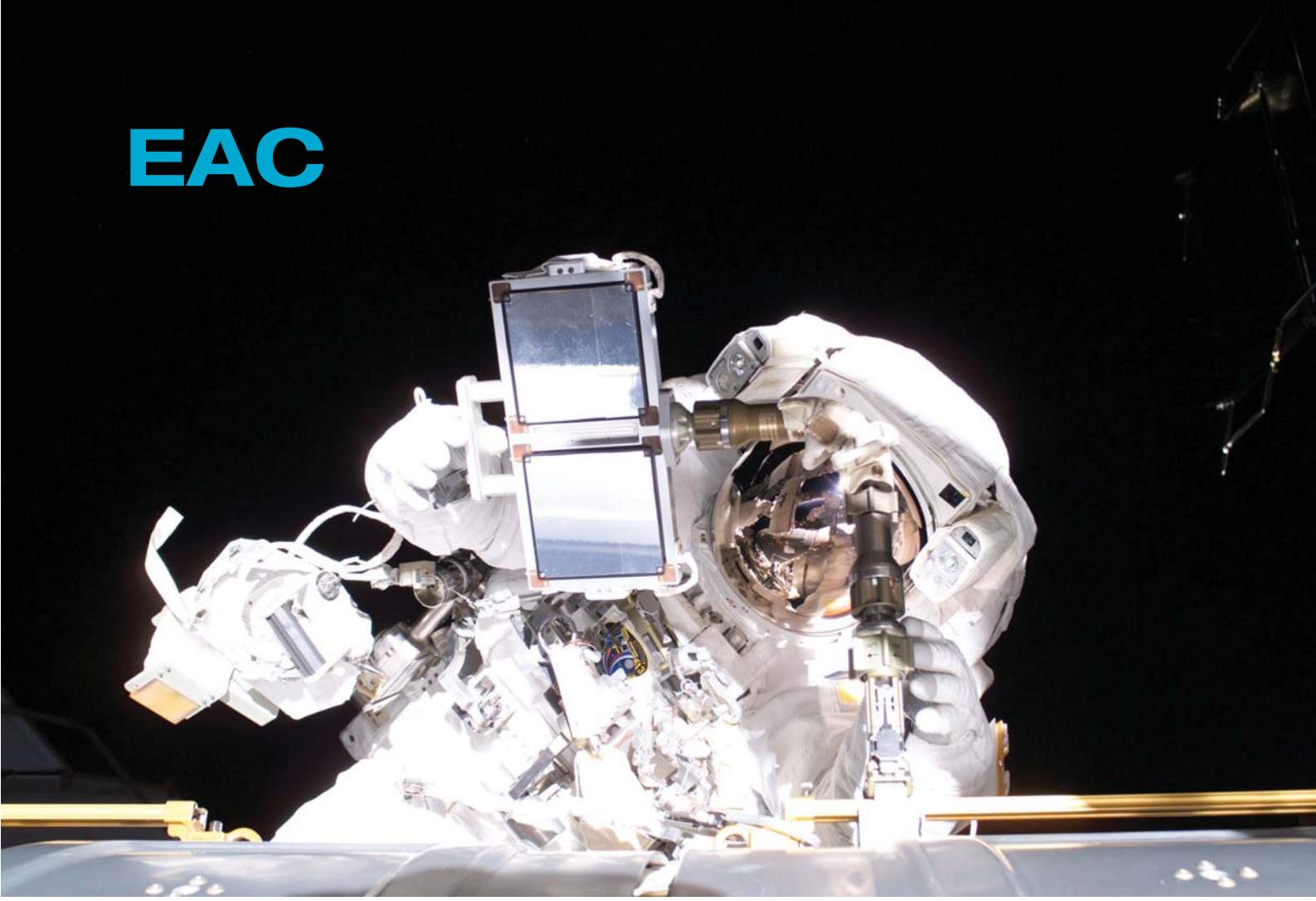
ESRIN also hosted numerous VIP visits, including that of the Austrian Secretary of State for Research, a delegation from the German Aerospace Centre (DLR), a delegation from Luxembourg, a group from the United Space Alliance, a delegation from Korea, and a delegation from the French Parliament, the European Commission and Eumetsat.

Last but not least, the establishment played host for various educational activities designed to attract and train the next generation of space engineers and scientists, including: a Delft University of Technology session, the Masters Courses of Roma Sapienza University, and the traditional Envisat Summer School. There were over 70 school and university student visits, giving hundreds of young people the chance learn about an ESA establishment from the inside.

Some 10 so-called 'pre-incubation activities' were also developed at ESRIN in 2006 within the framework of the agreement between ESA and the Business Innovation Centre (BIC) of the Lazio Region of Italy.

Visit by the Austrian Secretary of State for Transport, Innovation and Technology, Eduard Mainoni (front centre) in July

EAC



Thomas Reiter during his first EVA from the ISS on 3 August

The year was dominated by the two very successful 'Astrolab' and 'Celsius' missions carried out by ESA astronauts Thomas Reiter and Christer Fuglesang, respectively.

Having received training both at Johnson Space Center and at the Gagarin Cosmonaut Training Centre, Thomas Reiter and his backup Leopold Eyharts completed their training for the long-duration 'Astrolab' mission at EAC in May. Frank De Winne supported the mission as Mission Manager Advisor.

On 4 July, Space Shuttle 'Discovery' (STS-121) lifted off from Kennedy Space Center carrying Thomas Reiter on his journey to the International Space Station (ISS). On 6 July Reiter joined his fellow crew members, Russian Pavel Vinogradov and American Jeff Williams, and took up his duties onboard as flight engineer. During his 'Astrolab' mission, he carried out numerous operational and maintenance activities for both the US and Russian segments of the ISS. Reiter is the first non-American and non-Russian astronaut to serve as a 'permanent' ISS crew member. As the flight engineer, he was in charge of vital tasks associated with the Station's guidance, control and life-support systems, power control and communications, crew health and safety and extravehicular activities (EVAs).

Following a successful spacewalk by ISS commander Pavel Vinogradov and NASA science officer Jeff Williams, on 3 August Reiter became the first ESA astronaut to perform a spacewalk from the ISS. Here too he had considerable experience to draw upon, having performed two EVAs during his six-month EuroMir mission in 1995.

During their 6½-hour EVA, Reiter and Williams set up external hardware including the Floating Potential Measurement Unit, designed to monitor ISS electrical charging and improve rendezvous and docking and EVA safety, and two Materials International Space Station Experiments (MISSE-3 and 4). They also prepared Station truss components for future assembly work, by

EVA familiarisation training in the Neutral Buoyancy Facility at EAC

installing a motor controller on the thermal radiator rotary joint and deploying the new EVA infrared camera to monitor the condition of critical reinforced carbon-carbon materials.

In September, Vinogradov and Williams returned to Earth to be replaced by NASA commander Michael Lopez-Alegria and Russian flight engineer Mikhail Tyurin, with whom Reiter continued his 171-day mission.

Reiter operated ESA, NASA and Russian research facilities in support of international science experiments and conducted a programme of European experiments in the fields of human physiology and psychology, microbiology and plasma physics. He also performed technology demonstrations as well as industrial and educational experiments for universities and primary/secondary schools. This was the first long-duration mission for an ESA astronaut on the ISS and it provided highly valuable experience.

The ESA medical support team continuously monitored the ESA astronaut's health from the Medical Control Centre at EAC and coordinated all health-related issues with the Columbus Control Centre in Munich (D) and the partners' control centres in Moscow and Houston. The 'Astrolab' mission served as the final verification of the EAC medical team's readiness to support future long-duration missions.

On 9 December, Space Shuttle 'Discovery' (STS-116) lifted off at 02:47 CET from Cape Canaveral, the first night launch in four years. It carried ESA astronaut

Christer Fuglesang during his unscheduled EVA to free a jammed solar array

Christer Fuglesang, the first Swede to go into space, as a mission specialist to the ISS. During his stay on board, Fuglesang participated in two EVAs to attach new hardware to the Station and to reconfigure its electrical power system. He later participated in an extra, unscheduled, spacewalk to help free a solar array that had become jammed during retraction. He spent a total of 18 hours 14 minutes outside the Station. Reiter and Fuglesang returned to Earth together on Space Shuttle 'Discovery' on 22 December.

The first ESA Automated Transfer Vehicle (ATV) training was provided to the ISS Expedition-15 crew in September and December, when the Russian prime and backup crew members received 'ATV Part-1 Training' at EAC. Earlier in the year, the International Partners (IP) pool astronauts, with the exception of Thomas Reiter,

Expedition-15 crew members Oleg Kotov and Fjodor Yurchikin during ATV rendezvous and docking training at EAC

Leopold Eyharts and Christer Fuglesang, had undergone the same training. Final ATV refresher training has taken place at the Gagarin Cosmonaut Training Centre and the Expedition-15 crew have been formally certified for onboard ATV operations. Expedition-16 crew members from NASA, Roskosmos (RKA) and ESA began their Columbus laboratory and payload training at EAC in December.

Columbus flight control team training and simulations for the 1E and Expedition-16 teams conducted under EAC's responsibility are progressing according to schedule. In December, the first joint NASA/ESA simulations, involving the Columbus Control Centre and Houston Mission Control Centre flight control teams were successfully conducted.

ESA astronaut Paolo Nespoli has been assigned to the crew of Space Shuttle flight STS-120 to the ISS, due for launch in autumn 2007. This flight will carry Node-2, the interconnecting module built in Europe for NASA as part of the Columbus launch barter agreement. Hans Schlegel has been selected as a member of the crew for Columbus/Shuttle flight 1E at the end of 2007.