Operations and Infrastructure

The Agency's excellence in mission operations was again demonstrated in 2005 with the landing of the Huygens probe on Titan, and the successful launch and injection of Venus Express into its interplanetary orbit. The exceptional media coverage of these missions further increased the general public's awareness of European space activities. Other highlights were the insertion of SMART-1 into its operational lunar orbit and the impressive performance of the spacecraft's innovative electric-propulsion system, the start of operations of the MARSIS radar onboard Mars Express, and the smooth launch and early operations phase (LEOP) for MSG-2. The ground-segment and mission-operations preparations for the CryoSat launch were also flawless, and can be reused for the CryoSat-2 mission. The inauguration of ESA's second deep-space ground station at Cebreros in Spain added another key element to the operations infrastructure.

One of the Directorate's prime strategic objectives is the strengthening of its strategic position in the provision of mission-operations support both for ESA's own and for external customer's programmes. The ESA Member States' subscriptions to the ExoMars mission and the decisions on the way forward for the Galileo IOV Phase offer welcome opportunities, to which the Directorate is well prepared to respond. In parallel, efforts will continue on adequate positioning of the well-proven mission operations competencies for other future programmes like the Galileo Operational Phase and GMES.

Another main strategic objective of the Directorate is to further improve the value of the services delivered to its customers. The matrix approach with the Programme Directorates resulted in the concentration of competencies, creating synergies at Agency level. A strengthened, but also more cost-effective organisation at each ESA site will in future provide one face to internal customers. A merger of the Information Systems and Site Services Departments is therefore being prepared for roll-out by mid-2006. These measures go hand in hand with a new structure for the IT service portfolio. The extension of ISO certification to the entire Directorate's Quality Management System is another cornerstone for meeting customer expectations in all areas.

The ESA deep-space antenna at New Norcia in Western Australia

Artist's impression of the Huygens probe's landing on Titan

The goal of establishing closer cooperation with other European spaceflight operations centres resulted in a cross-service Framework Agreement with DLR, under which both agencies will share network facilities, communication networks and flight-management data. A highlight of the international cooperation was the observation of NASA's Deep Impact collision with comet Temple-1 by ESA's XMM-Newton and Rosetta spacecraft.

Ongoing Missions

Cassini-Huygens

On 14 January, the Huygens mission was completed with the successful descent and landing of the probe on Titan. The data sets returned by the onboard instruments were astonishing and provided the scientists with an amazing first glimpse into this remote world. As part of the joint NASA/ESA/ASI mission to Saturn and its moons, the Cassini spacecraft, after flawlessly supporting the Huygens mission, is continuing its tour of Saturn with its rings and satellites, producing ever more exciting new views of and data about the Saturnian system.

A Huygens image of Titan's surface

The Main Control Room at ESOC during the launch preparations for Venus Express

Venus Express

Venus Express was launched on 9 November from Baikonur in Kazakhstan. The space and ground segments performed so well that, after an almost perfect injection of the spacecraft onto its interplanetary trajectory, the launch and early orbit phase (LEOP) was completed in record time (just 53 hours). One of the highlights was the transmission of the first commands from ESA's new 35 m deep-space ground station in Cebreros, Spain. A final trajectory-correction manoeuvre put the spacecraft on a direct course to Venus. Full spacececraft platform commissioning was accomplished within just one week, allowing payload switch-on and testing to be completed by mid-December. These tests demonstrated that the instruments work together very well, with adequate spacecraft performance and within required margins.

Rosetta

About a year after its launch, Rosetta was back completing its first Earth swing-by on 4 March at a distance of 1900 km. During this period, the Moon was used as a target to validate the asteroid flyby mode and operations planned for 2008 and 2010. Rosetta is now on its way to Mars, which it is due to swing-by on 27 February 2007.

Mars Express

The Mars Express operations profile involves 30 to 40 ground-station passes per week, interleaved with up to 150 different observations during 25 Mars orbits. With a moderate Earth-Mars distance and favourable planetary-illumination conditions for the optical instruments, the second half of the year allowed maximum communications capability with all ground stations. Despite a very tight 70% power-management limitation, two major eclipse seasons were endured without impacting on the science return. ESOC also prepared and executed the successful deployment and commissioning of the MARSIS payload's single 10 m and two 20 m antenna booms.

SMART-1

With its entry into lunar orbit in March, SMART-1 became the first European spacecraft to orbit the Moon, delivering a continuous stream of scientific data. The spacecraft's novel electric-propulsion system demonstrated excellent performance, with xenon utilisation reaching 99.5% after optimisation of the lunar orbit. The spacecraft will impact on the Moon's surface in August 2006, thereby completing the first European lunar exploration mission.

XMM-Newton

By year's end XMM-Newton, launched on 10 December 1999, had completed 1111 orbits, involving the flawless execution of almost 5 million telecommands and close to 16 000 attitude manoeuvres to view selected X-ray science sources. The available fuel will allow operations well beyond the already extended end-of-mission in March

2010. Migration to a new mission control system was successfully completed at ESOC and the Science Operations Centre at ESAC.

Ulysses

6 October marked the 15th anniversary of the spacecraft's launch. After several mission extensions, Ulysses is now on its third orbit over the poles of the Sun, and continues to deliver first-class science data from this unique perspective. With each revolution, however, the output from the Radio-isotope Thermoelectric Generator (RTG) decreases and there is less power available to heat the spacecraft when it is far from the Sun. Recent operational activities by the ESA flight control team at JPL have therefore focused on avoiding propellant freezing, and the first indications of increasing temperatures were noted as Ulysses once again makes its way towards perihelion.

Cluster-II

After more than five years of formation flying, the Cluster fleet started its second mission-extension phase with an increase in the inter-spacecraft distance from 1000 to 10 000 km. This new formation strategy will allow future formation changes to be implemented faster and with significantly less fuel. The 'triangle multi-scale constellation' established during the summer – with three satellites forming a 10 000 km triangle and two satellites just 1000 km apart – allowed the neutral sheet of the Earth's magnetosphere to be analysed on two scales simultaneously. The constellation was changed to a 10 000 km tetrahedron in November to probe the magnetosphere's northern cusp.

Integral

While conducting extensive observations, platform and payload calibrations and upgrades to the instrument-related onboard software were performed during the year, which helped to improve the scientific return. The good performance of the onboard and ground systems was an important factor in the decision to extend the mission until 2010. To keep the ground systems up-to-date, several upgrades were implemented, including the swap to the new ESOC control system infrastructure.

ERS-2

With the new gyroless operating mode and X-band, low-bit-rate, real-time mission control, the primary ground stations and the satellite itself could be operated without major anomalies or degradations. To compensate for the failure of the onboard tape recorders, the real-time X-band ground-station network, operated from ESRIN, was increased to 12 stations, including seasonal and permanent Antarctic stations. ERS-2 still generates data from all of its instruments for more than 98.5% of the planned time, and the spacecraft's yaw pointing continues to be tuned to improve product quality. The ability to remove ERS-2 from orbit at the end of its lifetime has been reinforced with new onboard software that will allow de-orbiting even with significant degradation of the gyroscopes that are still operating.

Envisat

The mission's very high scientific data return continued, with 75% of the science data now directly downlinked through the Artemis data-relay satellite to the Payload Data Handling facilities at ESRIN. Support was provided to numerous disaster-monitoring operations, such as the Indian Ocean tsunami, Hurricane Katrina over New Orleans, and a major oil-storage-depot fire near London. Upgrades were made to the Envisat ground segment to support the mission beyond its initial five-year lifetime, preparing now for operations until 2010.

Proba-1

This mission celebrated four years in orbit, and continues to support the Earth Observation Programme and requests received via the International Charter on Space and Major Disasters.

Missions in Preparation

CryoSat

The ground-segment validation tests were successfully concluded, verifying all internal and external interfaces and product-generation tools. Facilities and tools to support launch and routine operations phases were validated, including the mission control system, simulator and ground stations. The simulation campaign was also

successfully completed, including two network countdowns with the ground stations and the dress rehearsal with the satellite. When, on 8 October, CryoSat failed to reach orbit due to a launch-vehicle malfunction, all ground-segment and operations-related activities were suspended and secured for re-use during the anticipated CryoSat-2 mission.

GOCE

Flight operations segment development was completed on schedule, and both the mission-specific and new-infrastructure components were delivered and underwent significant unit-level testing. An important milestone was the execution of the first system validation test, during which the flight operations segment successfully commanded a wide range of unit-level operations on the satellite engineering model. By year's end, preliminary compatibility testing with the rest of the ground segment had started, in preparation for overall ground-segment validation in 2006.

Aeolus

Preparation of the flight operations segment progressed according to plan. Important milestones included the successful closure of the spacecraft Critical Design Review and the assignment of the development contracts for the spacecraft simulator and mission control system. The last quarter of the year saw the start of preparations for system testing.

Herschel/Planck

The Herschel and Planck ground systems are beginning to take shape, with the first deliveries of the mission control system and simulator installed and operating. A first contact was made with the Planck spacecraft in the Cannes integration facilities, and telemetry was received and processed successfully. Flight dynamics utilities were delivered for incorporation into the science operations planning systems.

LISA Pathfinder

The main ground-segment activities were the consolidation of the mission-analysis and space-to-ground interface designs. The new launch date in the second half of 2009 will allow the Cebreros ground station to support the mission (instead of a 15 m ground station), thereby allowing some spacecraft design constraints to be relaxed. The Ground Segment Requirements Review was successfully concluded, allowing the go-ahead to be given for the detailed specification of the operational ground segment and the initial definition of the science ground segment.

Gaia

To help ensure that mission design and deliverable items meet the standards required for successful and cost-effective operations, ESOC participated in the preparation of the technical specifications for the spacecraft and its instruments. Preliminary requirements for the operational ground segment are under evaluation.

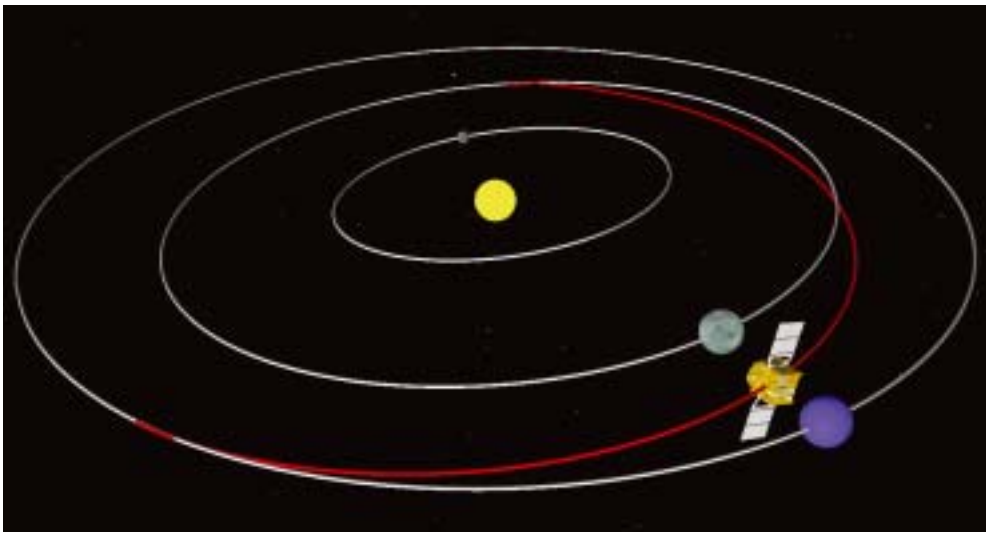
Bepi Colombo/SOLO

Support was provided in the preparation of the industrial Invitation to Tender (ITT), planned for release in early 2006.

Flight Dynamics and Mission Analysis

Flight dynamics and mission analysis shared the honours in terms of mission highlights in 2005. Rosetta's successful Earth gravity-assist manoeuvre on 4 March was performed using the ORATOS flight-dynamics system. Passing within just 1900 km of Earth, its fly-by could even be observed by amateur astronomers. Interplanetary activities were again the focus when Venus Express was sent on its way to our neighbouring planet, with ESOC's experts determining the injection orbit and performing the planned correction manoeuvre to put the spacecraft on the right trajectory for Venus Orbit Insertion on 11 April 2006. The year closed with the successful launch and early orbit phase (LEOP) operations for the MSG-2 mission for Eumetsat.

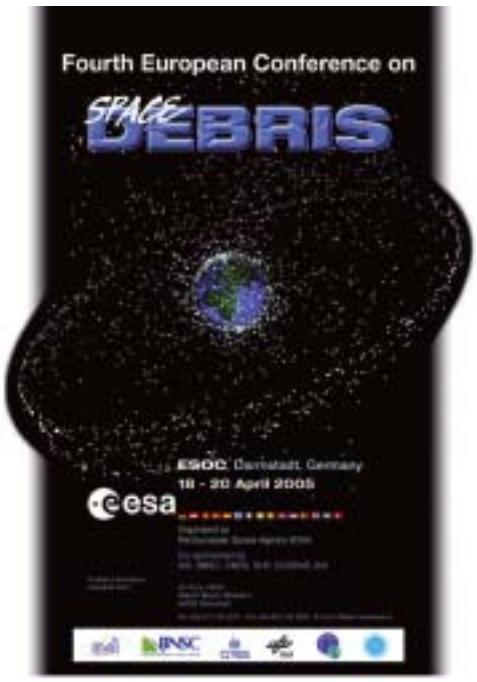
Mission analysis focused on mission baselining and refinement for Galileo and the various other ESA missions in preparation. One example was LISA Pathfinder, which must reach an orbit around the L1 Lagrangian point, some 1.5 million kilometres away from Earth in the direction of the Sun.



The flight path of Venus Express through the Solar System

Space Debris Office

ESOC's space-debris analysts routinely monitor close encounters between Envisat and ERS-2 and known, catalogued debris objects, and if necessary initiate avoidance manoeuvres. On 26 November, for example, a 1400 kg Cosmos-3M orbital stage passed within just 500 metres of Envisat.



In April, around 300 experts from all of the major space-faring nations met at ESOC for the Fourth European Conference on Space Debris, the World's largest event dedicated to this subject. 120 papers were presented, summarising the current state of research on space debris and meteoroids. Discussions focused on the future path for research and methods of debris reduction, protection and control, and also provided a forum in which to discuss policy issues, regulations and legal aspects.

Ground Systems Engineering

ESA continued to upgrade and expand its ESTRACK tracking network, including the development of specialised communications and ranging equipment. The inauguration of the ESA deep-space ground station at Cebreros, near Madrid, in September was a major milestone for the ESTRACK network. Like its sister station in New Norcia, Western Australia, it has a 35 m diameter antenna, but the Cebreros antenna is designed both for X-band up- and downlinking (8 GHz) and for the newly allocated Ka-band frequencies (32-34 GHz). With these new facilities, ESOC is well prepared to serve the needs of ESA's current and near-term scientific missions. A third deep-space antenna is being considered for the medium term to improve capacity for additional Mars missions and to achieve greater coverage and redundancy for future ESA exploration missions.

During 2005, a new and very ambitious ranging project known as 'Delta DOR' was initiated. It supports faster and more precise orbit determination for deep-space satellites for critical manoeuvres like swing-by orbit insertion. The concept is based on an interferometric measurement of the satellite's position (angle) by two compatible, but widely separated ground stations, such as New Norcia and Cebreros. With highly precise atomic clocks and a very stable reception system, the data at the two ground stations are synchronised using a common quasar before and after the transmission of a spacecraft signal. A lengthy correlation process follows, during which about 10 Gbytes of data have to be processed. The first test campaigns were carried out using Rosetta and Venus Express, with the goal of being ready for the latter's Venus Orbit Insertion in April 2006. The project is very ambitious due not only to the technical installations and algorithm development needed, but also the extremely tight timeline.

As in previous years, ESA provided extensive support to the European Technology Harmonisation effort for ground-segment software. EGOS, the ESA Ground Operation System, is attracting a lot of attention from flight operations centres and Industry. The first EGOS Workshop took place in November at Eumetsat in Darmstadt, Germany, and attracted 160 participants from Europe and the USA. EGOS provides a general architecture for all ground-segment data subsystems in order to improve interoperability and, being based on Unix/Linux, will ensure vendor independence. ESOC's operational software includes an open-licence policy and support for Member State industries on product lines such as SCOS-2000, SIMSAT, PSS and TMTCS. Today, more than 70 licences for SCOS-2000 have been granted in Europe. New users in 2005 who are integrating and validating their control centres based on this software include SES for Astra-1M, and Galileo for the In-Orbit Validation phase.

EGOS
ESA Ground Operation System

As the cost-effective provision of mission-control systems and simulators depends on good standards, ESA is taking a key role in actively contributing to ECSS and CCSDS standardisation. Some 23 data systems for ongoing missions are currently supported, and 10 systems are being developed for missions in preparation.

Navigation Support

The ESA Navigation Support Office is active in the governing body and technical areas of the International GNSS Services (IGS). It participates in an IGS Working Group interacting with Galileo and other Global Navigation Satellite System (GNSS) developments. ESA is one of seven global IGS Analysis Centres delivering high-quality products to the scientific community. Significant expert support is provided to Galileo in the design of satellite-navigation-related algorithms and systems, their verification and operation. In collaboration with European partners, a prototype facility to accurately define and maintain the terrestrial reference frame and the setting up of a GIOVE receiver network for experimentation with prototype receivers at several ESA sites were initiated. A new GNSS tracking site was established at Faaa in Tahiti, in collaboration with Météo-France.

The ESA Navigation Facility has been fully integrated and began operations in May with the validation of the GRAS GSN service. It will be used for ESA and third-party projects, including high-precision orbit determination for Earth-observation satellites – currently ERS-2 and Envisat – and various types of GNSS-related activities.

Third-Party Support

ESA continued to market spare operations-facility capacity and expertise to external customers. The level of activities was similar to previous years, with an average of one enquiry received per week, 15 proposals generated and 11 contracts awarded. Major third-party activities included the successful LEOP service for MSG-2, the LEOP preparation for MetOp-1, and the development of the GRAS ground-support network for Eumetsat. From Redu, in-orbit testing support was provided to Eutelsat, precise GPS orbit/clock data were provided to Fugro, and various

The ESA Navigation Facility at ESOC

hosting services were provided to New Skies and Vitrociset. Activities also included LEOP support to Syracuse-3A for CNES from Perth (W. Australia), to OICETS for JAXA from Kiruna (S), preparation of LEOP support to Kompsat-2 for KSAT and to DLR's TerraSAR-X, and various navigation projects for the Galileo Joint Undertaking.

Network of Centres Initiative

ESA/ESOC and the national European flight operations centres of CNES (F), DLR (D) and Telespazio (I) were involved in the Network of Centres proposal for the Galileo IOV Operations Segment in 2004. The proposal was further refined in 2005 and expanded to include additional partners, namely Aena, Hispasat and Inmarsat. Thus, the Network of Centres has been able to propose a coherent solution for the Galileo IOV system operations, serving as a good precedent for the applicability of Network of Centres solutions for future European space missions.

In parallel, coordination continued with CNES and DLR on joint Phase-A activities for projects from each agency and a roadmap for further harmonisation of flight operations infrastructure. Practical implementation of this cooperation is manifested in the cross-service Framework Agreement with DLR for Network Services, through which ESA and DLR will share network facilities, including ground tracking stations, communication networks and flight-management data and the LEOP support provided to CNES for Syracuse-3A and to DLR for TerraSAR-X.

ESA Site Management

It was another challenging year in terms of site management, with continuing severe limitations on budget, exacerbated by knock-on effects from 2004 and continuous pressure to provide the required level of facilities and services. Only a limited number of new infrastructure projects were initiated, strictly related to compliance with statutory health, safety and security regulations. The only exception was the enhancement and extension of the ESAC operations facilities needed to house the additional scientific staff arriving on site.

Major steps were taken to improve security, including the installation of an Agency-wide security-badge access system, as well as video surveillance systems and security command centres at a number of sites.

The new Operations Building at ESAC

Regarding health and safety, ESTEC and ESA Headquarters had to re-quantify the presence of on-site asbestos and to establish plans and funding for its removal. The on-going asbestos removal at ESTEC continued apace and immediate actions were initiated for the Asbestos Removal Plan 2.

An often overlooked workload is support to the programme and communications offices at the various sites for launch and similar events, for conference organisation and meetings of official bodies, as well as for visits by high-ranking officials like heads of government. In this respect also, 2005 was an exceptionally busy year.

The Department has been instrumental in the preparation of the five-year ESA Infrastructure Strategic Plan, which brings together the Directorate of Operations and Infrastructure and Directorate of Technical and Quality Management strategies regarding future infrastructure investments.

Over and above these 'traditional' activities, new tools were introduced to improve the financial management of the Department, which also achieved ISO 9001 certification by end of the year. Last but not least, in the drive for greater efficiency in terms of cost and customer service, further organisational changes will take place in 2006 to ensure that the Department can succeed in its mission to provide all of the facilities and services necessary for ESA staff to operate in a safe, healthy and secure environment.

ESA Corporate Information Technology

The specification for the largest outsourcing contract ever placed by ESA for corporate IT and related services was issued and tendering started. The contract will be managed from ESRIN as the main ESA corporate IT centre and implemented in 2006, after having grouped together the different IT services and having improved infra-structure standardisation.

A major refurbishment of the corporate computing centre at ESRIN, where all major ESA Management Information Systems reside, was completed in 2005. A detailed review of some of these information systems was also started, in view of the changes needed to support the Agency's ongoing administrative reform activities.

An upgrading of the informatics infrastructure at ESAC was initiated with the procurement of 1 Gigabit/s high-capacity connections to Europe's major research networks. Full upgrading to ESA corporate establishment standards will be achieved in 2006. Another highlight of the year was the successful rollout of the new 'flexitime system', for which Establishments were equipped with automated badge readers that also provide an identity check for all staff.

As part of the preparations for new projects that will involve classified information, information security was thoroughly reviewed. The most important aspects are implemented in the latest ESA Security Regulations, which were adopted by Member States in 2005. In cooperation with national security authorities, a project team, leveraging the Directorate's skills in information systems, physical and document management security, established the formal and technical framework and finalised the technical requirements for an ESA Security Office.

Synergies between the Directorate's corporate and mission-operation information and communication technologies and the corporate IT and site-management activities were analysed in depth, with a view to their merger into a single organisational unit by mid-2006. This new Department will bring the services closer to the users, whilst at the same time reducing the cost of day-to-day operations.