Technical and Quality Management

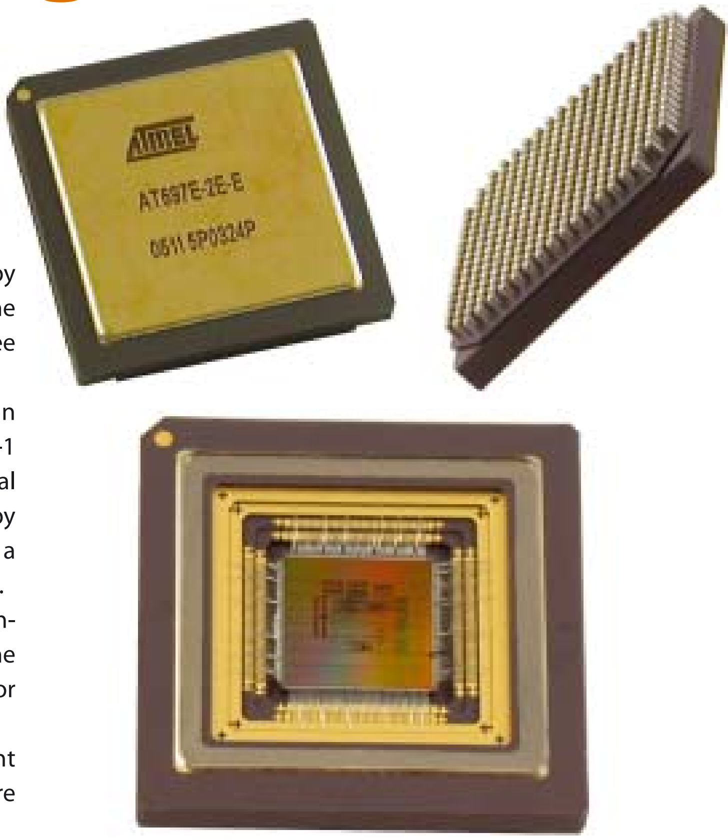
Electrical Engineering

Power Systems

The 7th European Space Power Conference, organised by ESA in Stresa (I), was an opportunity to measure the progress made in space power systems over the last three years. Major highlights were:

- The first reports on the operation of lithium-ion batteries in space, including the SMART-1 and Proba-1 missions and, even more significantly, the operational telecommunications satellites being manufactured by Astrium and Alcatel Alenia Space, giving Europe a definite lead over the USA in this technology domain.
- The presentation of the status of European high-efficiency multi-junction solar cells, which now rival the US competition in terms of end-of-life performance for the equivalent of 15 years in orbit.
- The development of new maximum-power-point tracking systems, which are being used more and more for all types of missions.

Two patents were filed, one relating to high-voltage power-supply efficiency improvement, and one to a simple modular maximum-power-point tracking concept, which were a good reflection of the Power and Energy Conversion Division's efforts to remain at the forefront of design solutions for space applications.



Prototype radiation-hardened microprocessor chips from Atmel, France

Data Systems

Prototypes of high-performance, radiation-hardened, LEON microprocessors, resulting from ESA contracts with Atmel (F) and Gaisler Research (S), were released for evaluation. These 100 MHz microprocessors, which make use of the latest 0.18-micron silicon technology, will be at the heart of future European spacecraft computers.

More than 50 'ESA IP Cores' were provided to various space companies and research centres across Europe. These cores are hardware description language (VHDL) design databases that can be reused as building blocks in larger integrated circuits (ASIC or FPGA), thereby saving on design time and cost.

Triggered by reliability problems associated with currently used Field Programmable Gate Arrays (FPGA), special emphasis was put on guiding projects in how to use FPGAs for onboard applications with better quality control. An innovative test system called FT-UNSHADES was also developed to validate the effectiveness of logic introduced to mitigate radiation-induced upsets, serving as a powerful alternative/complement to expensive and less deterministic radiation test campaigns.

Control Systems

Significant milestones were achieved in the development and validation of cutting-edge guidance, navigation and control (GNC) system technologies in support of future ESA missions. They included studies and prototyping for: formation-flying systems, autonomous hybrid navigation systems, safe precision entry, descent and landing systems, robust ascent vehicles, and solar-sail techniques.

Considerable effort was also devoted – together with national agencies and European Industry – to preparing detailed roadmaps for AOCS sensors and actuators, defining the most appropriate products for different classes of missions. In the gyroscope area, development of MEMS (Micro-Electromechanical System) rate sensors was initiated based on upgraded terrestrial technology, which will provide a significant improvement compared to today's units for acquisition and safe modes, and also for star trackers.

A high-accuracy, four-axis, fibre-optic gyroscope is being manufactured for the Planck and ADM-Aeolus spacecraft, while a more compact redundant single-axis version has been designed for Galileo.

Radio Navigation

Direct hands-on support was provided in the development and testing of the GIOVE and Galileo IOV payload Customer Furnished Items (CFIs) and for the GIOVE payload review and acceptance tests. On the system side, the RF Payload Division was heavily involved in the preparation and execution of the GIOVE system tests. On the ground-segment side, the Division's support covered the development of the Galileo mission segment and reference receivers. All of these efforts contributed to the timely launch of GIOVE-A in December.

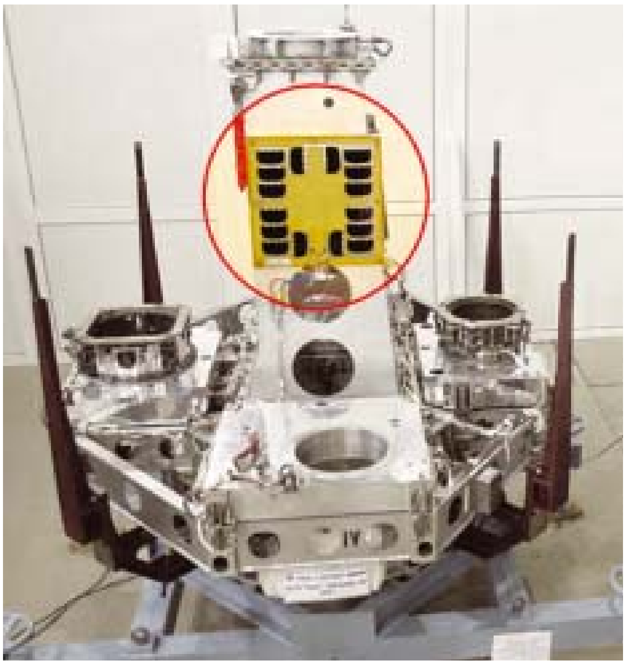
Support was also provided for the EGNOS Operational Readiness Review, and in the deployment and expansion of the EGNOS infrastructure.

Communications

Activities in this domain included support in the preparation of the AlphaSat proposal for submission to the Ministerial Council, and the analysis of several missions and payload scenarios demonstrating the latest technologies and possible new services, examples being:

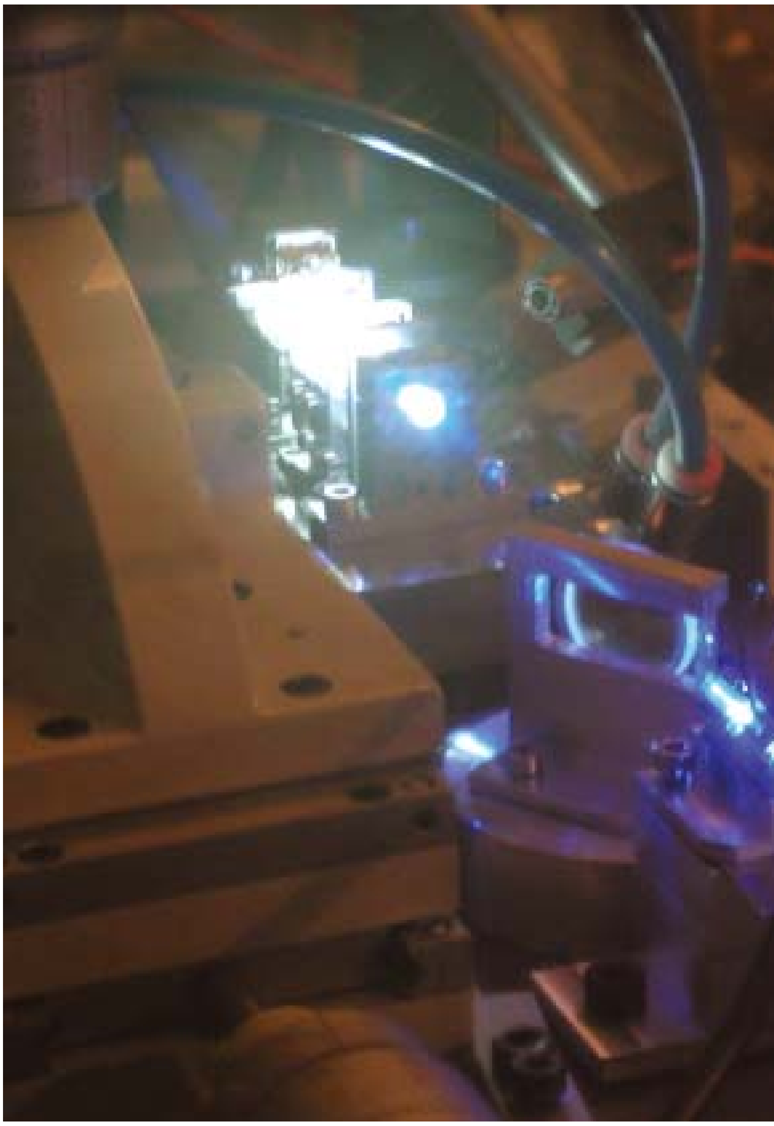
- Support to the introduction of Digital Video Broadcasting with Return Channel via Satellite (DVB-RCS)
- Support to SpaceForScience, setting up DVB-RCS collaborative platform development. SpaceForScience aims to facilitate scientific cooperation in Europe, and southern and eastern Europe in particular, by providing virtual, collaborative working and education applications for research institutions, via either fast academic networks or bi-directional telecommunications satellite links using the HellaSat space segment.

European low-mass, low-cost MEMS rate sensor unit


An Asolant antenna unit mounted on a launch adaptor

Electromagnetics and Antennas

In-flight testing of an ESA-funded R&D activity to combine spacecraft solar arrays and antennas began in October, when a test unit was launched into low Earth orbit. Combining these two spacecraft components into a single unit promises substantial mass and cost savings for future missions. The successful in-flight demonstration of the Advanced Solar Antenna (Asolant) means that this novel technology is now available for future space missions.

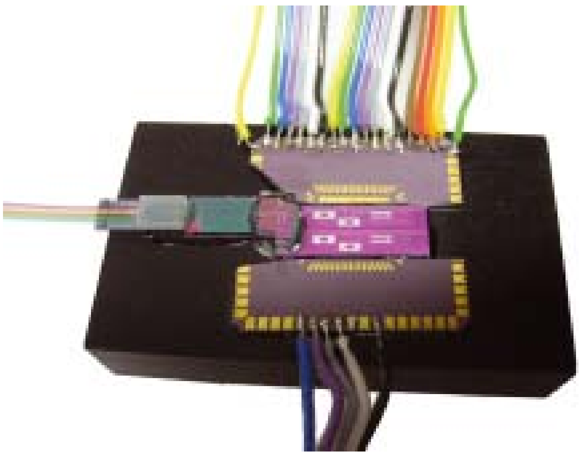


A new ADF-EMS antenna design system provides extensive design capabilities using several electromagnetic modelling tools. Conceived and implemented by a team of European SMEs, research centres and universities, it can be used to design ground-based antennas as well as those installed on spacecraft.

Mechanical Engineering

Mechatronics and Optics

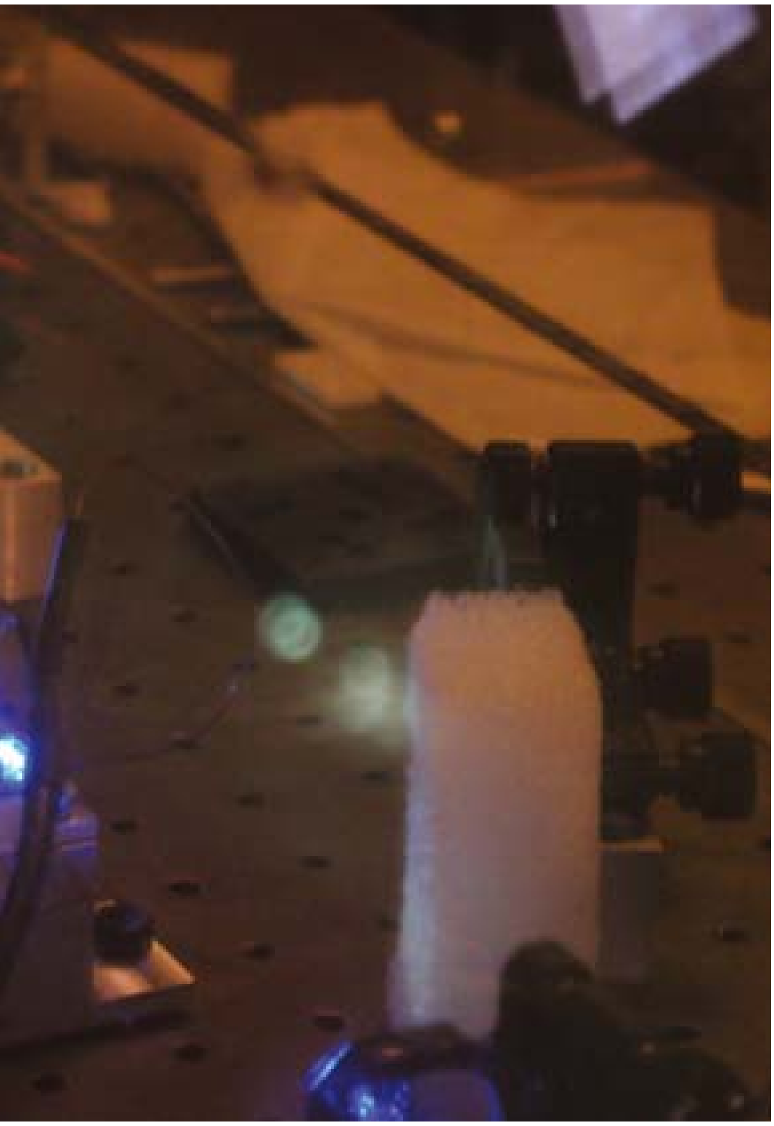
The Mechatronics and Optics Division undertook a wide range of technology-development, engineering-support and laboratory-infrastructure activities. In the area of optical engineering, development effort was concentrated on enabling and emerging technologies like lightweight telescopes and optical micro/nano technology, primarily in support of ESA's scientific and telecommunications missions. High-precision optical metrology sensors were breadboarded that will enable the formation flying of the Darwin constellation of satellites with micrometre precision over inter-satellite distances of up to 250 metres. A demonstrator of the Gaia primary telescope mirror made of SiC100 material was realised, to allow interferometric performance testing at cryogenic temperatures. Similarly, a telescope assembly was produced using this material for the NIRspec instrument, one of ESA's contributions to the NASA James Webb Space Telescope. For Herschel-Planck, support focused on the verification and metrology of the Planck reflectors and the procurement of the Herschel SiC telescope.



A multi-functional, silicon-on-insulator integrated-optics chip

Investigation of the many aspects of using optical techniques for handling electronic signals onboard satellites led to the design of a 'photonic payload' for next-generation space telecommunications systems. Generic integrated-optics silicon-on-insulator (SOI) waveguide technology was developed to demonstrator level, in pursuit of producing easily applicable building blocks such as bends, mirrors, vertical tapers, couplers and switches.

Extensive use was made of the Optical Ground Station (OGS) at Izaña on Tenerife. A laser communication campaign was performed between the islands of Tenerife and La Palma on behalf of DLR to evaluate free-space ultra-high-data-rate transmission through the atmosphere in preparation for a bidirectional space-to-ground optical link experiment between the German TerraSAR-X satellite and the OGS. Significant progress was also made in the development of laser technologies for applications in science, navigation and Earth observation. A compact laser system meeting the stringent frequency-stability and noise specifications for the LISA mission was also produced. In anticipation of future needs in the satellite navigation and telecommunications domains, a diode-laser-pumped, rubidium atomic-frequency standard was realised, achieving a frequency stability of 4×10^{-14} over a



Low-shock clamp-band opening device

Testing of an Nd:Mixed-garnet Q-switching laser

The dexterous Exoskeleton human/machine interface for Eurobot

few hours from a compact device. Significant effort was also directed towards the development of tunable laser sources for future-generation, Earth remote-sensing missions involving lidars (DIAL).

Expertise was provided to many ESA projects in the assessment and use of automation and robotics technologies. For planetary science, the development of a micro-rover and related geochemical investigation instrument suite was pursued up to engineering-model stage. The development continued of a communication and localisation subsystem for micro-probes to be released into the Venusian atmosphere. Activities in the field of planetary exploration focused on preparations for the ExoMars mission, addressing the development of terra-mechanics test equipment and the breadboarding of rover autonomous navigation. In the domain of orbital robotics, the Eurobot project was supported through the development of critical subsystem breadboards, such as the dexterous arms, the tool-exchange device, and the dexterous human/machine interface (Exoskeleton).

In the area of mechanisms, technical guidance and project support were provided to virtually all ESA projects, with mechanisms experts participating in many project reviews

Finite-element model used for MSG-2 dynamic shock analysis

and in-orbit-anomaly investigations. Much effort was devoted to preparing miniaturised mechanical devices for the Aurora Exploration Programme, such as moles, drills, seals, and capture and docking mechanisms. The development of electric-propulsion pointing mechanisms was stepped up to ensure their availability for the next generation of high-power electric-propulsion systems. The momentum-wheel development for the Galileo testbed GIOVE-A was achieved within a very tight schedule, allowing the timely delivery of flight units, a key factor in the mission's success. Special emphasis was also placed on electro-mechanical thrust-vector control systems for launchers, berthing and docking mechanisms for the International Space Station and Exploration Programme, and hold-down and low-shock release mechanisms for payload adaptors.

Important technology developments in the area of life and physical science instrumentation included the completion of the development of a confocal laser scanning microscope and the realisation of a gradient bioreactor. Technological preparations for a Pasteur-mission-related payload were heavily supported through work on the water sensor for Mars, the UV/Vis spectrometer, and the life marker chip.

Thermal and Environmental Control

In the structures domain, support was provided to almost all ESA programmes – e.g. Herschel-Planck, CryoSat, ADM-Aeolus, MSG, AlphaBus, Galileo, ATV, and Vega – ranging from conceptual-design phases in the Concurrent Design Facility (CDF), through to the actual design, test and validation phases. Further advances were made in terms of shock-load verification for spacecraft and payloads, applying new methodologies in support of various ESA projects, notably the MSG-2 spacecraft which was successfully launched in December.

Studies of loading interactions between launchers and spacecraft were further developed, establishing detailed dynamic models and applying advanced numerical-analysis methods in support of various ESA projects, including ATV, Vega and Aeolus.

The development of inflatable structures in Europe progressed well in order to demonstrate the feasibility of manufacturing, folding, deploying and rigidising large structures for satellite appendages, including possible in-flight demonstrations. The development of a large deployable antenna with 12 metre aperture for mobile communications advanced significantly, with two deployment tests successfully performed under gravity-compensation conditions.

Reflector surface-accuracy measurements in progress on a large deployable antenna (Courtesy of NPO-EGS, RSC Energia and Alcatel Alenia Space Italy)

Product Assurance and Safety

European Component Initiative

Launched in 2004 to ensure the timely and unrestricted availability of space-qualified components for European Industry by creating alternative sources for parts that are subject to export controls, this Initiative is supported both at ESA and national level, and coordinated with CNES and DLR. The first phase will provide new European manufacturing capabilities for a range of space-qualified components, from fuses to high-performance microprocessors. By the end of 2005, 15 of the 20 activities covered by the first phase were underway, with the first deliveries of qualified components expected during the fourth quarter of 2006. Preparation of the second phase has already been initiated in the framework of the Component Technology Board (CTB).

Global coordination of non-dependence programmes with non-European agencies was also pursued. As a first step, co-operation with the Japanese Aerospace Exploration Agency (JAXA) was initiated to establish mutually recognised procurement procedures for Japanese and European suppliers and to identify overlapping activities.

EEE Components

The main focus of the Components Division's support to ESA projects was on mission-critical technologies, such as the evaluation of a high-power laser diode that is a key component in the main instrument on the Aeolus satellite. Another example was a new thermal-management technique for hybrid microcircuits, which was flown on a Foton mission. Round-table events were organised on MEMS/nano-technologies and wide-bandgap semiconductors that are under development, attracting large numbers of European and overseas participants.

Wide-bandgap technology: a package containing two parallel, 12 x 125 micron, high-gain, high-efficiency microwave transistors

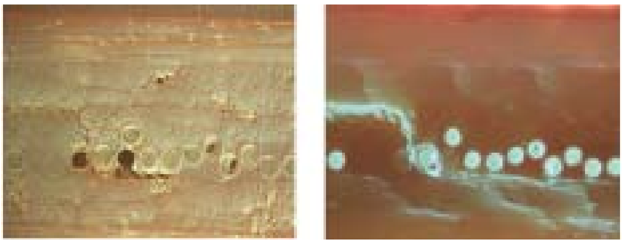
To cope with the growing demand for beam time for Single Event Effects (SEE) testing, in May the RADEF laboratory at the University of Jyväskylä in Finland was officially commissioned as the third ESA-supported external SEE radiation test facility.

The updating of the ECSS Standards and the Specification System under the European Space Components Coordination (ESCC) continued throughout 2005. Dossiers are in place that set the strategic aims for the next five years in each of the technology areas, and are closely coordinated with the European Component Initiative. The signing of executive implementation agreements by ESA, CNES, DLR and Enterprise Ireland was another highlight during the year, with commitments to the Annual Qualification Programme (AQP) for EEE parts.

Materials and Processes

A total of 304 Materials Reports were published – the largest number in the Division's history – covering such topics as the examination of rubber fuel-tank membranes, testing of solar cells and their coverglass adhesives, development of special cleaning methods for highly polished mirrors, and development of a shock-damper material for the ATV's solar-array drive mechanism. Failure investigations included an ATV latch-valve assembly that failed during acceptance vibration testing.

The Laboratory provided considerable support to the upcoming ESA science missions to the inner Solar System, namely Venus Express, Bepi-Colombo and Solar Orbiter. Due to their closer proximity to the Sun, these missions face severe challenges in terms of materials and processes. The Division also actively supported the Aeolus project by pulling together the main expertise on laser damage within Europe, setting up an internal ESA laser test facility in



Self-healing composite materials: Left, optical micrograph showing self-healing hollow fibres end-on; Right: UV light image, showing healing agent (in green) and healing of crack damage (courtesy of University of Bristol, UK)

collaboration with the Optical Division, and running a number of test programmes within established laser testing houses in Europe.

Work on advanced materials and processes covered nano-structured materials, self-healing materials, space-durable polymers and hybrid materials, new joining and manufacturing processes, etc.

The ESMAT website, created in 2005, contains the latest materials and processes data on outgassing, flammability and corrosion and a collation of special materials datasheets in a searchable format (they also exist as ECSS-Q-70-71, available as a hardcopy reference standard).

European Cooperation for Space Standardization (ECSS)

It was another productive year in the generation of ECSS standards, leading ultimately to the availability of a set of standards for almost all core space-related activities (see table).

The updated ESA Approved Standards list (version 1.8) containing 125 Standards (besides the core ECSS: ESA-PSS, MIL STD, CCSDS), was approved by the ESA Standardization Steering Board (ESSB) at its December meeting.

To facilitate the application of ECSS Standards, ESA has developed an automated tool, which was used during 2005 in a prototype form to support the tailoring of ECSS requirements to various Agency programmes. The ECSS Steering Board also set up a task force to revisit the present working modalities of the Standards.

An ECSS Developer's Day at ESTEC in September provided valuable feedback from the European space community involved in the development of the ECSS Standards. International recognition of the ECSS system and ESA's standardization activities was further enhanced in November by an exchange of views with a large Chinese delegation working in the field.

Systems, Software and Synthesis

Concurrent Engineering

Concurrent engineering continued to be used for the conceptual analysis of future missions, payloads and the impact of advanced technologies, in the Agency's Concurrent Design Facility (CDF). Lunar and planetary exploration missions, heavy-lift and Vega launcher missions, near-Earth-orbit missions, alternative energy-storage systems, and the Proba-3 mission for the demonstration of satellite formation flying were all studied. The CDF was also used extensively for education

	Engineering (ECSS-E Series)	Management (ECSS-M Series)	Product Assurance (ECSS-Q Series)	Total
Published	33	11	45	89
Under review	19	3	14	36
In drafting	34	0	12	46

ECSS Standards – status end-2005

and technology-transfer purposes, attracting considerable attention from both specialists and the media.

The process of consolidating the CDF integrated-design model and developing an open-source design server was started, the objective being to spread the Facility's expertise throughout Europe and Canada. The application of GRID technologies is also being explored with a view to setting up a Virtual Collaborative Facility to enable concurrent engineering activities by the geographically separated teams involved in international space projects.

A design session in progress in the Concurrent Design Facility (CDF) at ESTEC

Software Systems

Efforts continued in the critical area of system/software compatibility to prevent the occurrence of failures and to automate the design and verification process. The ASSERT initiative, which is coordinated by ESA and forms part of the EC's Sixth Framework Programme (FP6), draws together the academic and industrial expertise of 29 partners from 11 countries to improve the development process for critical embedded real-time systems.

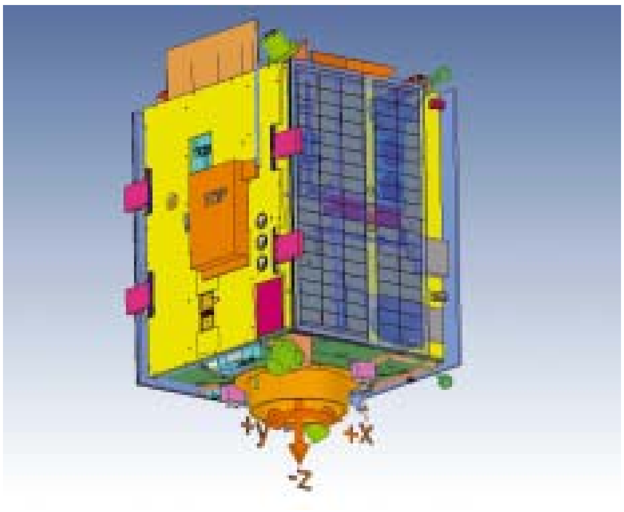
The prototype of the Generic Architecture for Mass Memory Access (GAMMA) was delivered in November. Running on the LEON-2 processor, its flexibility, scalability and file-management services allow multiple users to access mass-memory simultaneously and at high speed.

The GAMMA prototype (Courtesy of EADS Astrium SAS, France)

In-orbit Technology Projects

The Proba-1 mission has completed four years in orbit. All subsystems are in good health and no platform redundancy has had to be used. More than 10 000 images have been acquired by its Compact High-Resolution Spectrometer (CHRIS) for use by scientists around the World. The High-Resolution Camera and the Earth-environment monitoring instruments have also performed flawlessly. The mission has therefore been extended for a further year.

Proba-2, a microsatellite mission for technology demonstration, is in its main development phase (Phase-C/D), with launch planned for mid-2007. Most of the technology flight units have been delivered or are close to delivery. The payload instruments, a UV Sun imager (SWAP) and a radiometer (LYRA) will be delivered early in 2006.



The Proba-2 spacecraft concept (launch configuration)

Technology Programmes

Basic Technology Research Programme (TRP)

While TRP-initiated developments are at the root of today's major technological successes such as SMART-1's electric-propulsion system and Galileo's atomic clocks and new developments such as the LEON-2 processor are ongoing, the plan of work for the coming years has been thoroughly prepared in the context of the new Agency-wide approach to the definition of future technology programmes. This required extensive consultation with the users across Europe and the scrutiny of requirements by networks of expert groups, including representatives of technology users and developers and the relevant ESA Programme Boards.

NewPro

A thorough analysis of technology-development requirements and capabilities showed the need for a new technology programme, called 'NewPro', with three key objectives:

1. To ensure European independence in the critical technological capabilities required for space-based solutions.
2. To enable the use for space applications of multiple-use technologies, development of which is driven mainly from outside the space domain, through systematic spin-in.
3. To prepare the technological base for future civil security programmes and applications.

Conceived to be co-financed with the European Commission, a three-year interim period has been proposed for NewPro's implementation under the GSTP.

General Support Technology Programme (GSTP)

GSTP contracts worth more than 33 MEuro were awarded during the year. In addition, the GSTP provided special support to the SMOS Earth-observation mission and Vega, the European small launcher, worth nearly 15 MEuro.

Subscriptions to the 4th period of the GSTP had reached more than 90 MEuro by the end of the year, and an additional 215 MEuro were committed by Participating States during the Ministerial Council in December.

The O3-Ozonizer, to be marketed by the newly formed company DutchOzone BV

Technology Transfer Programme (TTP)

The TTP continued its efforts to open new markets for space technologies. Members of the Technology Transfer Network (TTN) added seven space spin-offs, with a total value of over 7 MEuro. More than 50 new space technologies were identified for potential spin-off, fifteen of which were eventually retained and commercial agreements signed. A further 64 new market needs on the part of non-space companies were also extracted. Similarly, non-space technologies were promoted to give their providers the opportunity to offer them to ESA and the space industry. A total of twelve spin-in technologies were extracted.

Eighteen start-ups or entrepreneurs were identified and/or assisted by the European Space Incubator (ESI), or one of the 35 incubators of the ESINET members in 2005. More than 80 proposals for new start-up companies were submitted to the ESI, 18 of which successfully passed the selection criteria and evaluation boards. Four selection committees sat during the year, resulting in the creation of 15 more start-ups, bringing the total number of companies within the Incubator to 38. During the year, three companies left the Incubator, and a further five are expected to 'graduate' at the beginning of 2006. The ESI is an integral component of ESINET – a network of incubators throughout Europe having a strong space connection and supported by both ESA and the European Commission.

One technology-transfer example is the O3-Ozonizer, derived from ESA's Microgravity Science Glovebox onboard the ISS. The Ozonizer is undergoing intensive validation and testing before technical certification for use as a steriliser by the medical and dental professions. Desert Seal is another example of the transfer of space technology to ground applications. This one-person tent for extreme environments borrows from space technologies for its inflatable structure and flexible solar panels.