Technical and Quality Management

The main tasks in a very busy year included:

- A review of the laboratories, the investment plan, and updating the positioning of and strategy for of the different laboratories and the ESTEC Test Centre, both internally and vis-a-vis industry.

- Defining a strategy for the evolution of concurrent engineering.

- Analysis and redefinition of technology programmes and processes in the Agency.

- Improvement of the Directorate's internal reporting on activities, both on-going and planned.

- Significant achievements in the many technology activities in the various disciplines, some of which are mentioned below.

- Commencement of the Proba-2 project dedicated to in-orbit technology demonstration and the scientific solar-science experiment.

- Renewal of framework contracts for contractor support.

- A review of workforce and recruitment management.

- Re-organisation of the Directorate teams and the creation of a Systems Engineering Support Department.

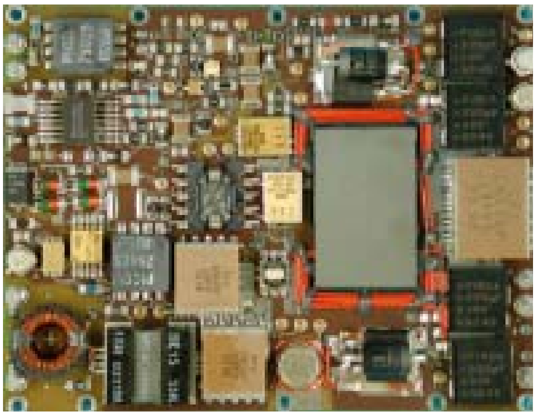
Electrical Engineering

Power Systems

The development of high-efficiency European solar cells has achieved the important milestone of 28% efficiency for 150 micron-thick triple-junction cells, comparable to the worldwide state of the art. In parallel, the development has begun of thinner, 100 micron germanium epi-ready wafers, which are used as substrates for multi-junction solar cells. Their reduced thickness will allow mass savings of the order of 30%.

A 100 micron germanium epi-ready wafer (Courtesy of Umicore)

The number of spacecraft flying European lithium-ion batteries, both small-cell (AEA Technology) and large-cell (SAFT), has continued to increase. ESA's Proba-1 spacecraft has completed three years of operation with such batteries, and the first two Eurostar-platform-based commercial telecommunications missions in the World to use this technology were launched.



Top view of the engineering-model low-voltage converter board (Courtesy of Austrian Aerospace)

Advances in digital payloads require lower voltages (reducing firstly from 5 V to 3.3 V, and later to 1.8 V) for logic circuits to increase their speed. The average load current is also rising sharply, in step with more demanding dynamic requirements. Achieving high efficiency at very low voltages is quite a challenge, and the development of an optimal concept for a standard very-low-voltage converter was pursued for ESA by Austrian Aerospace in 2004. Having selected two promising concepts for prototyping, the best-performing topology was subsequently manufactured as an engineering-model printed- circuit board. Its conversion efficiency of better than 87% in the 18 to 30 W range surpasses the original design objective and the board's thin profile and small area (less than 100 cm^2) make for easier integration.

Development and qualification of a failure-tolerant Power Conditioning Unit (PCU) for Field-Emission Electrical Propulsion (FEEP) with a 0.1 to 150 microNewton thrust range was completed by Galileo Avionica (I) during the year.

Data Systems

Much work was done on streamlining the design and implementation of onboard data systems, following a top-down approach. Particular attention was devoted to reducing onboard cabling through the standardisation of existing interfaces, complementary developments for SpaceWire onboard networks, and the potential integration of optical and RF wireless interconnect solutions.

After a long development phase, the LEON2FT 32-bit processor reached the point of prototype manufacture and will be tested on the Proba-2 satellite in 2006. The LEON2FT (AT697 from Atmel (F)) can handle 100 million instructions per second, while still maintaining compatibility with its ERC32 and ERC32SC predecessors (limited to typically 25 MIPS). Flight components will be produced with support from the European Space Components Initiative.

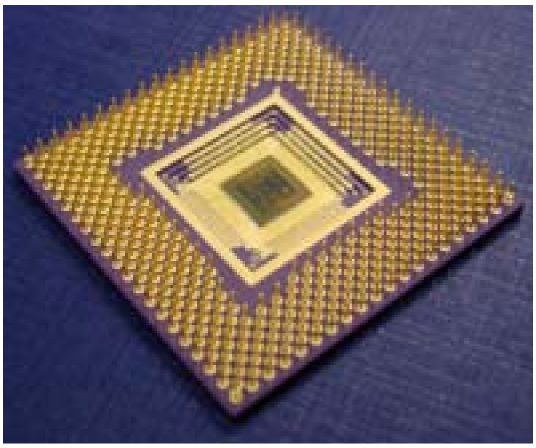
The FEEP Power Conditioning Unit
(Courtesy of Galileo Avionica)

Control Systems

Significant milestones were achieved in the development and validation of cutting-edge guidance, navigation and control (GNC) system technologies to support future ESA missions. They include the breadboarding of an autonomous vision-based camera for planetary soft landing, hardware-in-the-loop testing of a control-moment gyro-based attitude-control system for future agile Earth-observation satellites (e.g. Spectra), in-flight validation of autonomous onboard navigation algorithms for interplanetary missions (SMART-1), and environmental testing of a high-performance inertial sensor to be flown on LISA Pathfinder.

Three new integrated-circuit technologies for space applications, all promoted and co-funded by ESA, became available in 2004. The first Application-Specific Integrated Circuit (ASIC) prototypes developed under the new ESA - Atmel Space Multiproject Wafer Programme were manufactured using the new 0.18 micron radiation-hardened Atmel technology. In addition, the first large telecommunications ASIC manufactured using the new Design Against Radiation Effects (DARE) technology proved to be fully functional and to have excellent radiation hardness. Last but not least, the first European radiation-hard, reprogrammable Field Programmable Gate Array (AT40KEL040 from Atmel) was brought to market.

AOCS sensor technology developments in support of a variety of Science, Earth Observation and Telecommunications missions also made good progress. The miniature 1.5 kg star-tracker unit developed for BepiColombo will be flight-tested on Proba-2 in 2006. Pre-developments have confirmed Active Pixel Sensors (APS) as a promising technology also for future geostationary platforms, cutting costs by at least by 30% compared with CCD-based star trackers. Digital Sun sensors are ready for test flights on GOCE and Proba-2. A novel European magnetometer (Anisotropic Magneto-Resistive technology) is also being manufactured and will flown on ADM-Aeolus in 2007.



The first large (750 kgates, 438 pins @ 105 MHz) telecom ASIC developed using the new DARE technology by Alcatel Space (F) and IMEC (B). The package is just 40 mm x 40 mm

APS-based star tracker (centre) for the Bepi-Colombo mission, shown between a precursor Cassini Stellar Reference Unit (right) and Rosetta's CCD-based Autonomous Star Tracker

Control-moment gyroscope for high-agility Earth Observation satellites

Radio Navigation

Performance assessment for Europe's Galileo navigation system was a major task in 2004. The GSTB-V1 and GSSF tools were deployed in the European Navigation Laboratory at ESTEC, where joint ESA-Industry teams worked closely together to determine the system's end-to-end performance, validate the integrity-computation algorithms, and evaluate the orbit-determination models. Successful completion of these tasks by year's end was instrumental in the preparations and negotiations for Phases-C/D/E1 of the Galileo In-Orbit Validation (IOV) activities kicked-off at the end of December.

The pre-development of Galileo receivers was initiated to help prepare European industry for the technical challenges associated with their development and the fierce competition expected.

2004 also saw the system validation, ground infrastructure deployment and demonstration outside Europe (China, South Africa) of the European Geostationary Navigation Overlay Service (EGNOS). In collaboration with the European Commission, ESA is actively contributing to the development of EGNOS and Galileo applications in the road, rail, maritime and aeronautical sectors.

Communications

During the year ESA completed the acceptance of a comprehensive mobile testbed that allows faithful laboratory emulation of a complete third-generation satellite system based on adaptation of the terrestrial 3G Universal Mobile Telecommunication System (UMTS) standard. Multi-beam satellite constellations, traffic interference and mobile fading channels can be realistically emulated in real time. It also allows over-the-air experimentation and demonstration of S-UMTS services using Artemis's L-band payload. Specific 3G applications, such as location-based services and reliable digital multimedia multicasting, have also been developed, in addition to other interactive applications. The public-service demonstrations that took place in 2004 were supported by ESA's advanced multimedia van.

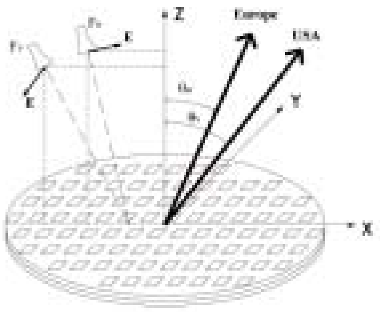
Telemetry, Tracking and Command

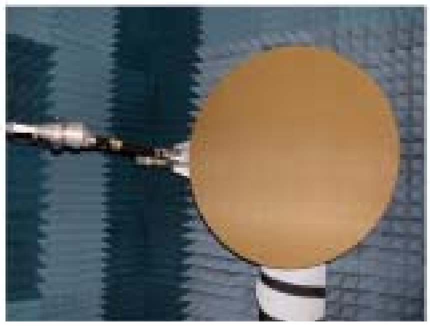
Development of the Galileo TT&C transponder is progressing well. It is a key element of the Programme as it will provide secure satellite commanding and control, as well as satellite time synchronisation. Its unique features include multi-mode operation and in-orbit reconfigurability.

The Ka-band Transponder Experiment (KaTE) on SMART-1 in 2004 was the first in-flight demonstration of deep-space telemetry transmission at 32 GHz. Its success means that KaTE is paving the way for future deep-space science missions, the first being BepiColombo.

Electromagnetics and Antennas

As part of the Technological Research Programme (TRP), a three-layer printed 'reflectarray' dual-polarisation antenna, providing different coverages for each polarisation, has been designed, manufactured and tested by Universidad Politécnica de Madrid (E), Lehrstuhl für Leichtbau, TU Munich (D), KRP-Mechatec Engineering, Munich (D) and Alcatel Space, Toulouse (F). The reflectarray can replace a dual-grid-shaped reflector on a telecommunications satellite to generate a





Geometrical features of the patented reflectarray antenna, and its breadboard model. The dimensions of the rectangular printed patches can be adjusted to achieve the required phase shift for each beam at several frequencies in the operating band

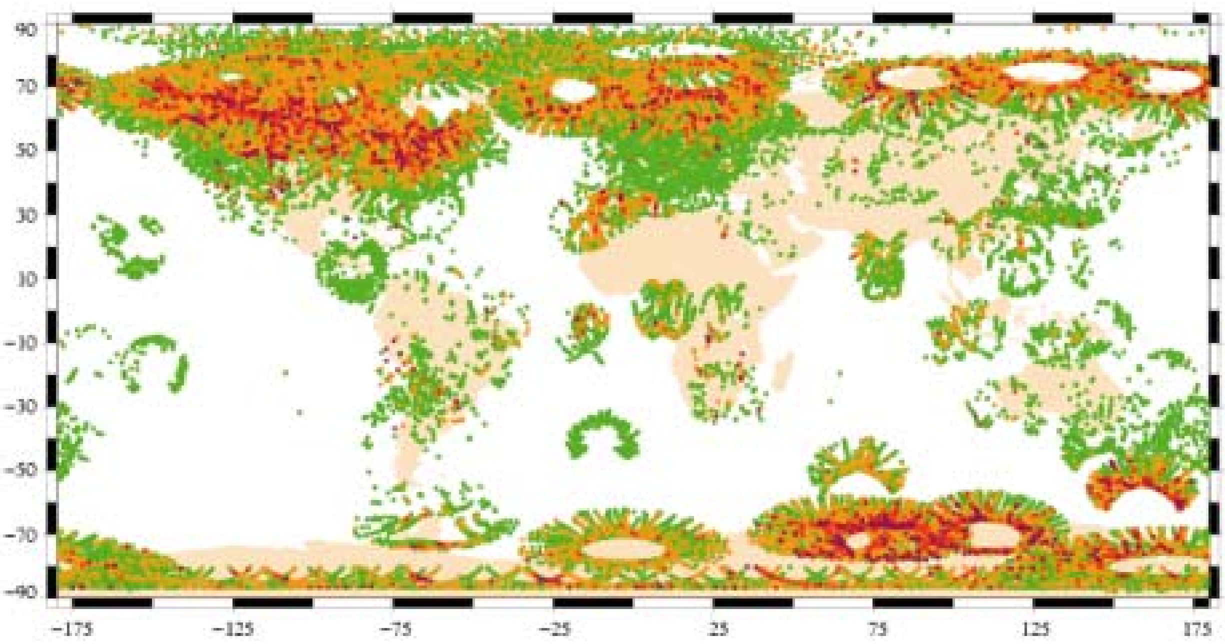
contoured Ku-band beam for Europe in H-polarisation and a pencil beam for the US East Coast in V-polarisation. It also occupies less volume due to its flatness and is some 20% lighter.

Space-Environment Effects

A European network of space-weather services is being developed through the Space Weather Applications Pilot Project, and will be used to assess the benefits of a possible future space-weather programme for Europe. Other European and International space-weather activities in which ESA is collaborating include the COST Action 724 'Developing the Scientific Basis for Monitoring, Modelling and Predicting Space Weather' (EU), the E-STAR Eurocores Programme (ESF), the International Living with a Star End-Users Task Group, and the International Space Environment Service. They came together in 2004 for the first 'European Space-Weather Week', a workshop covering a broad range of science and applications topics and attended by 200 scientists, engineers and industry representatives.

Software Systems

As the coordinator of 29 partners from 11 countries in Europe, ESA was awarded the ASSERT Project (Automated proof-based System and Software Engineering for Real-Time applications) in the context of the European Commission's 6th Framework Programme. A 15 million Euro project in the area of 'embedded systems', ASSERT brings together academic and industrial expertise in Europe to establish a new process for building design-proven computer systems.



Space Weather Applications Pilot Project estimation of the scintillation index for a given day, which allows prediction of the effects of space-weather-induced changes to the Earth's external magnetic field on, for example, GPS signal quality

The latest version of the Simulator Handling Module, SHAM6

Low-cost Software Validation Facilities (SVF) containing a hardware-in-the loop emulator have been developed to support the validation of onboard software for the microprocessors used on ESA spacecraft. The latest in the series, the SHAM6, is a revolutionary and compact design that allows the processor emulator to be installed in a standard workstation.

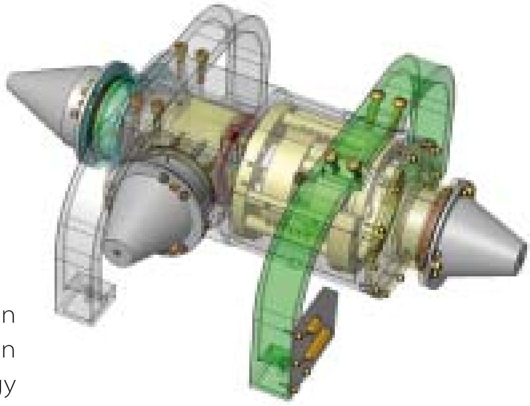
In-Orbit Technology Projects

The Proba-1 mission has completed three years in orbit with all subsystems still in good health. All of the mission's technology-demonstration activities have been successfully completed, including the demonstration of Earth-observation manoeuvres using only the attitude provided by the star tracker. The imaging success rate proved that it was a viable solution in terms of both performance (rates up to 1 deg/s) and availability (no specific area where the number of stars would be insufficient). Also, Proba-1's lithium-ion battery, which is based on commercially available cells, has now achieved 17 000 cycles without significant degradation in performance. The Earth Environment instruments – SREM and MRM for radiation measurements and DEBIE for debris monitoring – have also been working extremely well. With the dedicated ground segment at ESA's Redu (B) station also performing nominally, the mission has been extended for another year.

The follow-on Proba-2 micro-satellite mission, to be launched at the end of 2006, entered its main development phase (Phase-C/D) in 2004. It will demonstrate new propulsion, battery, star- and Sun-sensor technologies, and its payload complement also includes plasma measurement instruments, a UV Sun imager and a radiometer.

Two images of Dubai taken by the Proba-1 imaging spectrometer with motion compensation (colour image) and the miniature telescope (black and white) with point-and-stare manoeuvring

Mechanical Engineering



High-resolution optical filter for narrow-bandwidth filtering of light in Lidar applications, based on a capacitance-stabilised Fabry-Pérot etalon

Mechatronics and Optics

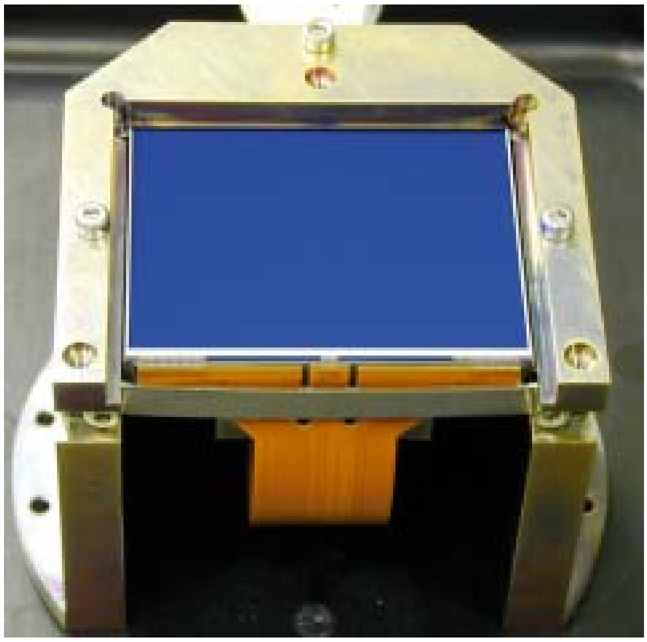
Engineering expertise in these areas was again in high demand to support advanced mission studies, ongoing projects, technology developments and external customers. Intense optical-engineering effort was directed towards the scientific missions, with the testing of the Planck reflectors at cryogenic temperatures and infrared wavelengths, the evaluation of sintered ceramic mirror materials for the James-Webb Space Telescope, and the assessment of ultra-stable optical benches for Gaia and LISA. Accompanying technology developments included the realisation of a monolithic ultra-stable glass interferometer for the LISA Pathfinder mission, the development of a tunable, high-resolution optical filter for advanced Lidar instruments, and the fabrication of single-mode optical fibres for mid-infrared light guides for Darwin, which represented a 'World first' technology breakthrough.

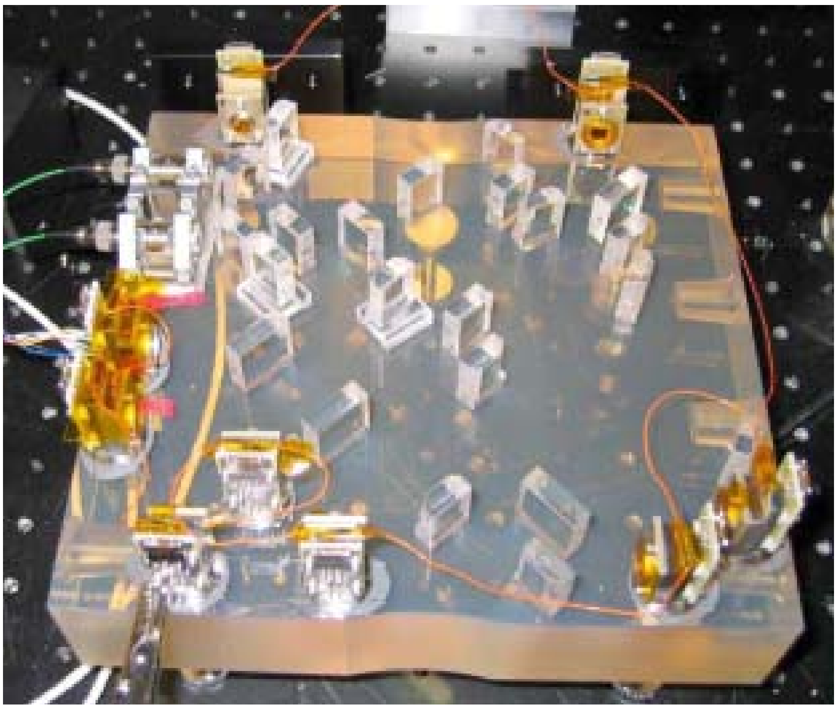
Many external customers called upon ESA's optical communication expertise for help, in particular Germany's DLR and Japan's JAXA for their TerraSAR-X and OICETS laser-communications projects, respectively. Early studies were also initiated on security-relevant space technologies, such as dual-use optical communication systems and quantum-optical encryption for secure communications.

Related efforts in the opto-electronics area included the realisation of a full-size, back-illuminated Charged-Coupled Detector (CCD) demonstrator for the demanding Gaia mission, which requires maximum efficiency to detect faint stars whilst still being able to handle very bright objects.

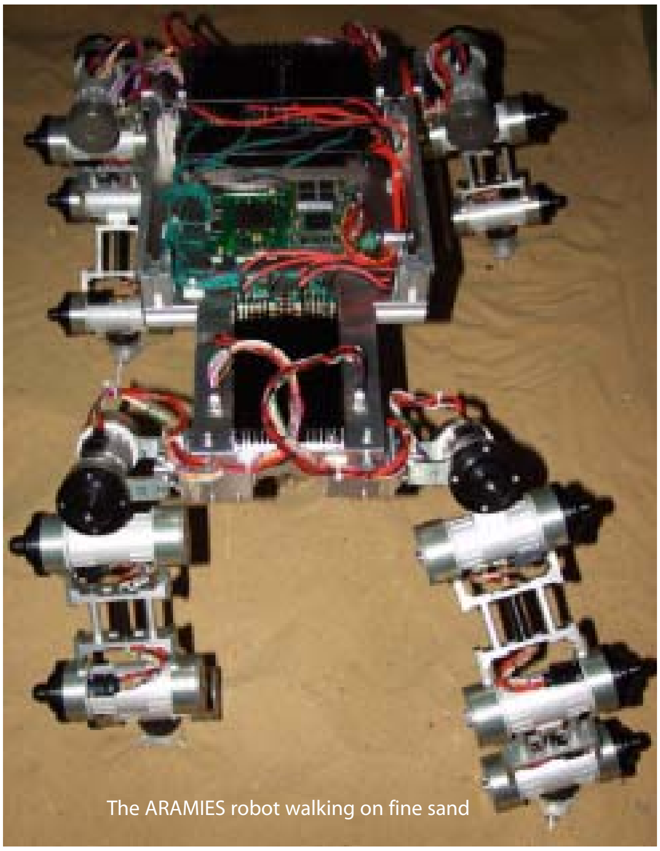
Activities in the robotics field concentrated on advanced elements for future science and exploration missions, including navigation systems for aerobots, advanced locomotion systems for Mars, and micro-probes for Venus. Development of a rover terra-mechanics tool kit was initiated to allow the performances of the ExoMars prototype rovers to be assessed for terrains with different soil conditions and inclinations.

Engineering model of Gaia's ASTRO thinned and back-illuminated CCD

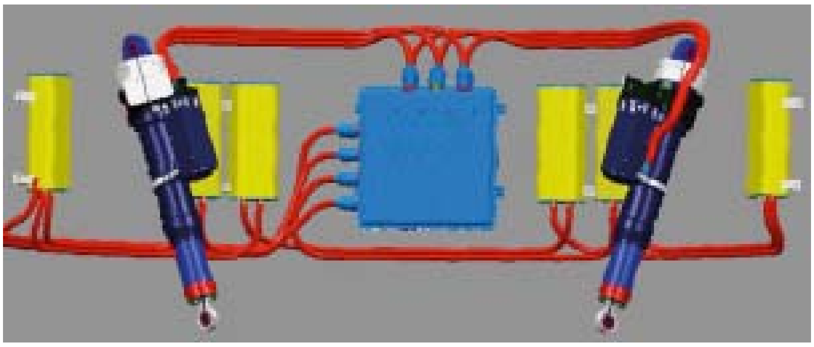




Monolithic, ultra-stable glass interferometer for the LISA Pathfinder mission



The ARAMIES robot walking on fine sand



The multi-purpose integrated motor controller (HBRISC 2) for launcher thrust-vector control

Breadboard model of the SONOS scanning-probe microscope

New activities were initiated in the payload-automation field in support of the Foton-M3 mission, to enable the scientists to interact with their payloads during flight.

Major development efforts in the space-mechanisms domain focused on strategic European products such as solar-array drives, control momentum gyroscopes, antenna-pointing mechanisms and launcher mechanisms. The HBRISC 2 multipurpose integrated motor controller, for example, will be a key component in realising the fully electrical – as opposed to hydraulic – thrust-vector control systems needed for future-generation launchers, including Vega.

The development of a family of analytical tools was further extended with the completion of the SONOS system, a scanning-probe microscope for applications down to the nano-technology scale, with early application potential in the ISS environment and good prospects for use in extraterrestrial invest-igations.

Thermal and Environmental Control

Structures and Pyrotechnics

New technology-demonstrator activities were initiated to support the development of large flexible structures, such as solar arrays, antennas and shields. The feasibility of using piezo-patches to control the alignment, stability and shape of structures was demonstrated, paving the way for their application in future spacecraft instruments.

A lightweight equipment housing made from composites rather than aluminium has been developed and will be used for the first time in Proba-2's data- and power-management system. It provides significant mass savings whilst still meeting the mechanical, thermal, radiation and EMC requirements.

Thermal Control and Life Support

Cryo-cooler R&D activities were initiated in line with the Technology Harmonisation roadmap, and a new vibration-free cooler design for missions such as Darwin has been finalised. An in-orbit demonstration experiment, called

Composite equipment box breadboarded by Verhaert (B), Helsinki University of Technology and Componeering (SF)

The ANITA air-quality monitoring instrument destined for the ISS

'MiniTherm', consisting of miniature two-phase heat transport devices was developed in cooperation with CNES for flight on Foton M2 in 2005.

Cryogenic nitrogen slush has been successfully produced in a test phase, as a first step towards producing hydrogen slush for future launchers.

In the life-support area, due to the very strong interest expressed by NASA's ISS Human Factors Office, ESA's planned 10-day in-orbit technology demonstration of ANITA (Analysing Interferometer for Ambient Air) has been extended to a six-month experimental validation in support of atmosphere monitoring inside the ISS. ANITA will be uploaded to the ISS with the first ATV flight.

Thermal Analysis and Verification

A thermal-analysis model-exchange facility (TASverter) that converts ESARAD and THERMICA thermal models through the open STEP-TAS standard developed by ESA/ESTEC was released and is already being used successfully by industry. ESA co-organised the 6th NASA-ESA Workshop on Product Data Exchange with EADS/Astrium GmbH, and continued its role as Aerospace Industry Coordinator (together with EADS/Airbus) in the EU Thematic Network 'FENET' on the dissemination of engineering-analysis technology. This activity is facilitating the exchange of analysis and modeling knowhow between 110 European engineering entities.

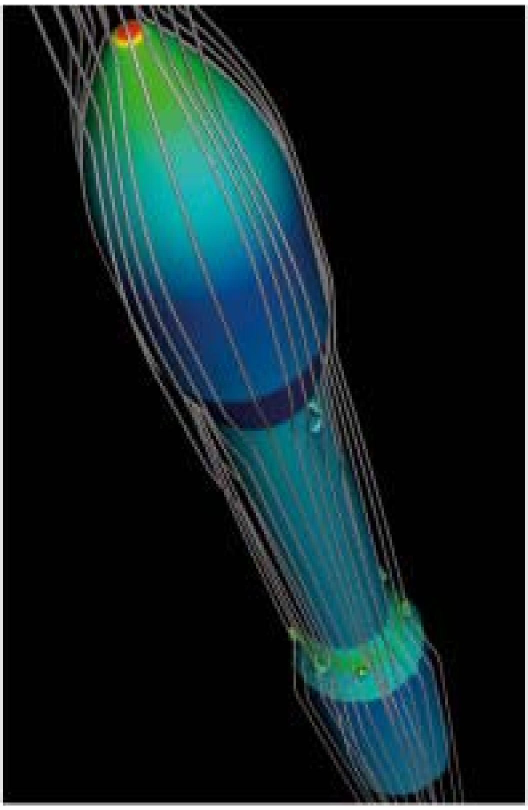
A new cryogenic-cycling facility providing a minimum temperature of less than 10 K was developed by the Mechanical System Laboratory for testing materials for the Planck satellite. The performance of the Multi-Layer Insulation (MLI) for the Venus Express mission was measured at 250°C, and a new MLI test setup was designed to cover the BepiColombo requirement of 350°C. The accreditation of five test methods under ISO 17025 was also successfully completed.

Propulsion and Aerothermodynamics

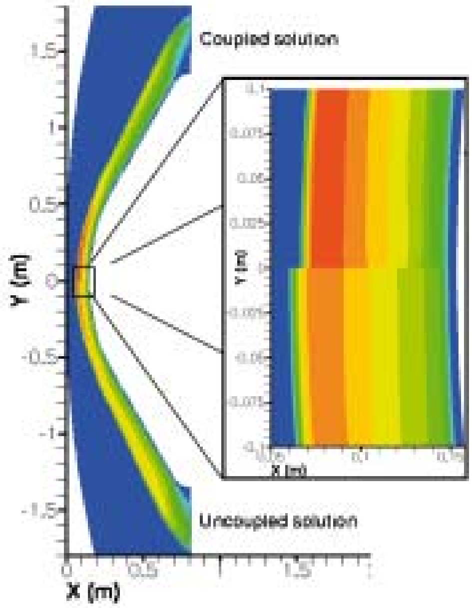
The development and qualification of European ITAR-free chemical-propulsion components and advanced materials progressed. The AlphaBus system development effort addresses the need for higher-performance chemical propulsion for the next generation of telecommunications platforms, whilst also enabling further improvements at component level. Investigation of the replacement of the classical highly toxic liquid propellants with non-toxic 'green' propellants is another ongoing ESA initiative.

The arrival of SMART-1 in lunar orbit at the end of 2004 clearly demonstrated electric propulsion's ability to serve as the primary propulsion system for future interplanetary missions. At Industry's request, a Working Group was formed to exploit SMART-1 experience in terms of performance evaluation, lifetime estimation and assessment of spacecraft/ propulsion-system interactions, for future telecommunications missions.

The 5000-hour ion-engine qualification test for the GOCE mission was successfully completed. The AlphaBus project has selected electric-propulsion systems for station-keeping (NSSK) on its telecommunications platforms. ESA is also providing the FEEP (Field Emission Electric Propulsion) micro-thrusters for CNES's Microscope mission, and ESA's LISA-Pathfinder



Simulation of Vega launcher flight at Mach 2: streamlines and surface-pressure modelling computations used to assess the effect of the attitude control system, wiring channel, and retro-motor firings on the vehicle's aerodynamics



Predicted radiative flux emission around the Huygens Probe during its entry into Titan's atmosphere

project is closely monitoring this technology for its own use.

Turning to aerothermodynamics, support for Ariane-5 focused on numerical and experimental modelling of the first-stage engine's interaction with the ambient base flow. Support for Vega concentrated on the prediction of external pressure loadings for a variety of flight conditions, including the effect of the attitude control system, wiring channel, and retro-motor firings on the launch vehicle's aerodynamics.

The effects of engine and thruster plume impingement were also analysed numerically for the Aeolus, CryoSat and SMART-1 spacecraft.

In the re-entry domain, the aerothermal environment of the Huygens Probe was assessed to support the final phase of the mission during its entry into Titan's atmosphere. Such evaluations are benefitting from recent advances at ESTEC and other European laboratories in the study of non-equilibrium plasma radiation.

Development of flight experiments is being pursued with two vehicles, the Inflatable Reentry and Descent Technology Demonstrator (IRDT) and the European Exerimental Re-entry Testbed (EXPERT). The IRDT is a probe protected by an inflatable shield during re-entry. EXPERT is an Earth re-entry capsule being developed to gather flight data on critical aerothermodynamic phenomena by means of several scientific payloads onboard.

Concurrent Engineering

Concurrent Engineering (CE) methods and tools were applied to an even wider range of applications in 2004 in support of various Directorates. Efficiency measurements on the Concurrent Design Facility's (CDF) conceptual studies indicated savings of at least 75% in time and 50% in cost compared to other approaches.

The CDF provided effective multidisciplinary support to many Programmes, including Aurora, Science, Human Spaceflight, Microgravity, General Studies and Launchers. Several potential future missions were also studied and designed at conceptual level: Lunar Exploration, Mars Demo Lander, Solar Orbiter, X-Ray Evolving Universe Spectrometer (XEUS), and Near-Earth Objects. The CDF also hosted several reviews of industrial design work and preparations for the next industrial phases of such projects as ExoMars, Mars Sample Return, and Human Missions to Mars.

The models and tools developed and used by the CDF are being shared with ESA's institutional partners, and activities initiated to encourage their wider application. The Concurrent Engineering Team also helped several other organizations during the year, including CNES and ASI, to implement similar design facilities of their own. The CDF also played an active role in ESA's Education and Technology-Transfer initiatives by hosting several studies and reviews, presentations and workshops.

A CDF Study Report on the definition and design of a Low Resource Radar for a mission to Jupiter's moon Europa (ELRR)

More than one hundred participants from space agencies, industry and academia attended the first 'Concurrent Engineering for Space' Workshop held at ESTEC. The two-day programme contributed to the sharing of CE experience and know-how with other European and international partners. The Workshop highlighted the wide interest in the CE approach and confirmed the CDF as a centre of excellence in Europe.

Product Assurance and Safety

European Component Initiative

Global trends in the Electrical, Electronic and Electromechanical (EEE) components industry over the past decade have resulted in critical dependence of the European space user community on non-European component manufacturers and products, which are often the subject of export controls. A dedicated programme known as the 'European Component Initiative (ECI)' has therefore been put in place to ensure the timely and unrestricted availability of enabling, space-qualified components for European projects, and to improve the global competitive position of the European space industry. Supported by national space agencies, in its first phase ECI will provide new European manufacturing capabilities for a range of radiation-hardened, space-qualified components such as power MOSFETs (Metal Oxide Semiconductor Field-Effect Transistors), low-power digital devices, FPGAs (Field-Programmable Gate Arrays), memories and high-performance microprocessors.

Russian and ESA engineers working in the CDF on 'Human Missions to Mars'

EEE Components

The Components Division supported the ESA projects and the European space community in the areas of EEE component evaluation and qualification, and the resolution of reliability and application problems experienced in the field. Tantalum capacitors, for example, may constitute a reliability hazard under certain conditions, and are the subject both of a systematic test evaluation activity and an ESA Alert prescribing corrective actions. Working closely with the national agencies, industry and academia, component and technology needs were updated to reflect changing requirements and industrial conditions to ensure their timely availability for inclusion in the next generation of European equipment and missions. The focus remained on mission-critical technology and component developments such as the radiation-hardened submicron and deep-submicron silicon technologies, wide-band-gap semiconductors, Micro-Electro-Mechanical Systems (MEMS) and nano technologies, as well as three-dimensional packaging concepts.

Particular efforts were also directed at the continued provision and enhancement of ESCIES, the European space-component community's on-line information system (https://escies.org). Now in its fourth year of operation, it has become the major European space-component data repository.

Materials and Processes

The growing number of activities carried out in the Materials and Processes Laboratory confirmed the importance of having a fast-reaction capability to support ESA's Programmes as well as European industry. The laboratory supported several failure investigations during the year, not least for the future scientific missions. Venus Express posed one of the major challenges due to its short development schedule, and imminent launch in October 2005.

In addition to the qualification to ECSS Standards of printed-circuit-board manufacturers as in previous years, the qualification of surface-mount-technology lines was also pursued. Two of the Standards published in 2004 are already highly valued by industry: ECSS-Q-70-71 on 'Data for selection of space materials and processes', and ECSS-Q-70B on 'Materials, mechanical parts and processes'.

Some 300 material-analysis and technical-assessment reports were published in 2004, on subjects ranging from outgassing and contamination analyses, thermo-mechanical characterisation, inspection of small surface-mount devices, to large cold plates for the Columbus laboratory.

A growing part of the Materials and Processes Division's workload results from so-called 'third-party activities' in support of ESA's industrial partners. Twenty-six contracts were placed by industry with ESA for such services as dynamic outgassing tests, environmental exposure to ultraviolet radiation or atomic oxygen, thermal-cycle testing, and examinations using the laboratory's C-mode scanning acoustic microscope. The laboratory also cooperated with industrial and research facilities in the development and performance characterisation of advanced materials and processes in such high-potential areas as nano-structured, self-healing and hybrid materials, and new joining and manufacturing processes.

European Cooperation for Space Standardization (ECSS)

The ECSS recognises that industry needs to deliver quality products and services to its customers in an efficient and cost-effective manner. This requires stable, qualified processes that can be operated with the minimum of variation to meet all customer requirements. ECSS Standards are therefore developed according to strict rules to ensure that they are both transparent and fair.

The good progress of ECSS Standards and the growing awareness of them in the project teams had led to a sharp increase in their use. This was reinforced by the publication in March of a new Administrative Instruction titled 'Application of ESA Approved Standards', to clarify the Agency's implementation of the ECSS and other ESA approved standards. It stipulates that the related documents shall serve as a common reference for formulating contractually binding requirements on suppliers, together with the programme/ project-specific requirements.

Altogether work has progressed on 142 standards (not including revisions and document requirements definitions), which are either already published, under review or in the drafting stage (see table).

	Engineering (ECSS-E Series)	Management (ECSS-M Series)	Product Assurance (ECSS-Q Series)
Published	27	11	42
Under review	14	1	13
Drafting	36	3	10
TOTAL	77	15	65

In addition, 46 ECSS standards were approved as European Standards (ENs) and three as International (ISO) Standards.