Technical and Operational Support

The major highlights for the Directorate as a whole were the:
• successful extension of the operational lifetime of the ERS-2 satellite
• successful launch of the technology mini-satellite Proba
• raising of ESOC’s ISO 9001 certification to the new ISO 9001-2000 standard
• construction of the new 35 metre deep-space antenna structure and dish installation in Western Australia
• completion at ESTEC of the Envisat flight-model test campaign and commencement of the Integral and Rosetta flight-model test campaigns
• completion of a new large satellite-integration building adjacent to the ESTEC Test Centre.

ESOC External Services are currently provided to a number of European and non-European industrial and public entities – including CNES, Eumetsat, Eutelsat, NASA, NASDA, Comgen, Dataspazio, Newskies and Telespazio – mainly in the areas of station/network support, launch and early operations, and in-orbit testing. The current order book amounts to ca. 37.5 MEuro for some 20 customers, with annual orders having increased significantly from 6.9 MEuro in 1999 to 11.6 MEuro in 2001.

ESTEC Test Centre also continued to provide extensive test services to industry, with an order of magnitude increase in work conducted over the last three years, generating 7 MEuro of income for ESA in 2001. Prestigious external customer projects included Helios-2 (payload testing) and the Hubble Space Telescope (thermal-shock testing of the new solar arrays).

Mission Operations

ECS and Marecs
ECS-4 continued to provide successful communications services to Eutelsat throughout the year, with operations conducted from the Redu (B) ground station. Marecs-B2 mission-control operations also continued from Redu (B) throughout the year, using the C-band antenna at Villafranca (E).

Ulysses
Ulysses has now completed both the second south and north polar passages, the latter being completed in December. Spacecraft nutation was successfully kept within safe operational limits throughout the year, with first-class scientific data being acquired from all on-board experiments, which are still functioning flawlessly. The ESA flight control team, located at JPL in Pasadena (USA), manages the daily real-time operations and at year’s end was commencing the next phase of the mission during which Ulysses will descend from high latitudes to cross the ecliptic plane in mid-2004. Operations are currently scheduled to end in September 2004.

Huygens
The Cassini/Huygens spacecraft was performing well as it commenced the fifth year of its seven-year journey to reach Saturn in 2004. The in-flight checkout campaigns conducted in February and September indicated that the Huygens probe and experiments are in good health. The Huygens relay-link anomaly identified in 2000 was completely characterised by extensive testing with the probe in 2001. A new mission scenario agreed between ESA and NASA will require a substantial orbit change during the first eight
months of Cassini's Saturn tour. Huygens' delivery to Titan will now be from a high-altitude fly-by at 65 000 km, and not the original 1100 km. A new mission implementation team was established between ESA and NASA and its work, started in mid-2001, will continue until 2004.

**XMM-Newton**
On 10 December, XMM-Newton completed 2 years in orbit. All operations activities during the year were problem-free. The overall science-data return continued to be at the effective practical maximum, interrupted only by solar flares and instrument calibrations. All spacecraft subsystems are performing very well, providing high-quality science data. Predictions for the on-board consumables (solar-array power and hydrazine reserves) indicate that a 10-year extension beyond XMM-Newton’s planned operational lifetime is feasible. The nominal mission would terminate in March 2003, but a 4-year extension has already been granted.

**ERS-2**
Although it had started with poor mission prospects, it was ultimately a highly successful year, with raised expectations for mission operations for several years to come. This change in fortune was brought about by the implementation and operational validation of a new satellite operating mode, not relying on the ageing gyroscopes, through a team effort involving Astrium, ESTEC, ESRIN and ESOC. The pointing performance in this new gyroless piloting mode is fully compatible with mission requirements. At the same time, measures were taken to reduce gyroscope dependency in other modes, thereby reducing mission risk.

**Cluster**
The Commissioning and Verification Phase (CVP) was successfully completed in January, after which the nominal Mission Operations Phase (MOP) started. The first major scientific milestone occurred when the fleet of four spacecraft, specially configured with a 600 km inter-spacecraft separation, crossed the magnetosphere's central cusp area in January. For the tail constellation manoeuvre phase in May/June, the four spacecraft were put into a tetrahedron formation around apogee with an inter-spacecraft distance of 2000 km. Both the spacecraft and payload behaved well throughout the year, despite passing through the two eclipse periods, and the requested volume of data return to the science community was comfortably exceeded.

**Proba**
After the successful launch in September, the first phase of the mission proceeded very well, meeting all anticipated milestones. Operations continue to be conducted from the Redu (B) Control Centre.

**Artemis**
Responding to an urgent request from the Artemis project, ESOC was able to provide emergency ground-station telemetry tracking and command support from the satellite’s launch on 12 July until the end of the year. In addition, the expertise of ESOC’s flight-dynamics specialists was called upon to assist in defining the mission-recovery strategy.

### Missions in Preparation

**Envisat**
Preparation of the Envisat ground segment continued according to plan, in readiness for the anticipated launch in March 2002.

**Integral**
Integral ground-segment activities proceeded according to schedule for the spacecraft's launch in October 2002. Notable progress was made in the
operational validation of the new generation of ESOC infrastructure elements, including the Space Link Extension (SLE), the SCOS-2000 mission control system, and the IFMS ground-station frequency and timing system.

**MSG**
The ground segment and preparations for the launch of the Meteosat Second Generation spacecraft in July 2002 were nearing completion by the end of the year.

**SMART-1**
Work on the ground segment proceeded according to plan in readiness for a launch in December 2002.

**Rosetta**
Procurement activities for the new ESA 35-metre deep-space antenna progressed according to plan, and the Rosetta Ground Segment Implementation Review was successfully completed in December.

**Mars Express**
The ground-segment preparations progressed well, taking advantage of the synergy with systems under development for the Rosetta ground segment. The Ground Segment Implementation Review started at the end of the year and will be completed in January 2002.

**Herschel/Planck**
Support was provided throughout the year to the Herschel/Planck project and to the Science Operations Centre for the definition of the space and ground segments, mission analysis and related interfaces.

**Earth Explorer Missions**
Cryosat GOCE development work was started and is proceeding according to plan. The Cryosat Ground Segment Requirements Review was successfully completed in December.

**Ground Systems Engineering**

There were a number of significant achievements in the ground-segment domain in 2001. The design and construction of the first ESA deep-space antenna ground station at New Norcia in Western Australia progressed well. The antenna tower, the antenna backing structure and the panels were finalised according plan, and operational acceptance should take place soon. The latest high-performance IFMS (Intermediate Frequency and Modem System) spacecraft ranging system was successfully deployed for the first time at ESA’s Redu (B) ground station.

ESOC’s latest state of the art SCOS-2000 mission control system was successfully deployed for a number of missions, including ‘open source’ support for Member State missions. The First SCOS-2000 Workshop, held at ESOC, was attended by numerous companies intending to use the system. DLR is already using SCOS 2000 and Radarsat and Eutelsat have also baselined it for their new control centres.
Intensive mission-analysis support was provided to the Artemis mission through the rapid development of methods and software tools for low-thrust trajectory optimisation and navigation needed for mission recovery following the partial launch failure.

The Third European Conference on Space Debris was held at ESOC in March, in the same time frame as the Mir space station was being de-orbited, which ensured high interest. The follow-on Mir De-orbit Workshop at ESOC was also attended by all involved control centre representatives.

**Mechanical Engineering**

Satellite mechanical engineering and related disciplines saw significant advances in 2001, with very active progress in the mechanical-system, cryogenic, and electric-propulsion domains.

**Mechanical Systems**

The year’s major achievement was the completion, on behalf of the Applications Directorate, of the Optical Ground Station (OGS) at Izana, Tenerife (E). The station was then used successfully for commissioning the laser communication terminal on Artemis, by establishing a laser data link over a distance of 34 000 km through the Earth’s turbulent atmosphere. This paved the way for SILEX, the World’s first civilian laser communication link in space, between Artemis and France’s Spot-4 remote-sensing satellite, which took place on 20 November.

Much technology effort was also devoted to the miniaturisation of optical devices, including the development, breadboarding and testing of a Hadamard micro-spectrometer for ozone measurements. Its volume and mass could be reduced to one quarter of those of a classical configuration, without compromising the spectrometer’s performance.

The Science Directorate was provided with both technical guidance and project-management support, including the MIDAS science instrument development for Rosetta, and the Hubble Space Telescope Servicing Mission (SM3B) during which a new generation of rigid-panel arrays will be fitted and the solar-array drive mechanisms exchanged. The support for HST covered the production of the related flight hardware, the establishment of EVA procedures and the preparation of the contingency documentation to facilitate EVA replacement of the solar arrays. The development and successful testing of the MIDAS instrument flight hardware for the Rosetta spacecraft required important progress in mechanism miniaturisation to enable atomic-force microscope capabilities to be exploited in space for the micro-measurement of collected comet coma dust.
In the area of robotics and automation, support was provided to many projects in the Manned Space and Microgravity and the Science Directorates. For the International Space Station (ISS), a novel external robotic assistant, called ‘Eurobot’, was conceived for astronauts making ‘spacewalks’. Preparation of the new European Solar-System exploration programme, Aurora, was extensively supported and robotics was established as one of the key enabling technologies. A study of robotics for human Mars exploration was also completed. Support for the automation aspects of all Microgravity Facilities for Columbus (MFC) was continued. Following the success of the first Telescience Support Unit on the Foton-12 flight, a continuation for the Foton-M mission was secured and its development initiated. The formal agreement with the Italian Space Agency (ASI) on a cooperative technology-mission demonstration of ISS external payload-tending robotics, EUROPA, was concluded and the industrial contracts for the ESA contributions (ground control system, scientific and technology payloads, calibration subsystem) are in progress. As a major preparatory development, an end-to-end laboratory demonstrator of interactive autonomous robotic payload tending was completed and demonstrated, including a live demonstration via the Internet to the International Symposium on Artificial Intelligence, Robotics and Automation in Space (ISAIRAS 2001) in Montreal (Can). A medium-term strategy for European space-robotics-technology development was elaborated and agreed in the context of a Technology Harmonisation exercise with the European stakeholders.

In the area of instrumentation for life and physical sciences, the Microgravity Laboratory Facilities were heavily used for flight sequence and scientific verification tests for the ERISTO/OSTEO Payload and Biobox. The field of technology development was dominated by the consolidation and improvement of achieved results, for instance in the areas of ultrasound bone density monitoring, interferometric optical tomography, depolarization-sensitive dynamic light scattering and high-temperature sensing. Methods were developed for applying optical tomography to rectangular cells, as used in the Fluid Sciences Laboratory (FSL) experiment containers. These developments found immediate application in a fluid-science sounding-rocket experiment on Maser-9. Miniaturised depolarization-sensitive dynamic light scattering instrumentation was developed to allow shape resolution for biological macromolecules. The latter is a prime candidate for upgrading the Protein Crystallisation Diagnostics Facility (FCDF), together with newly developed highly miniaturised protein reactors. A small study applying high-resolution X-ray scattering to a stationary particle-production process was successfully completed, using commercial instruments, in preparation for future activities potentially enabling the in-situ observation of particle genesis and growth in the nanometre range. Many new activities were initiated to support the utilisation and future upgrading of ISS facilities.
and to prepare for new areas of research in this environment, including pyrolysis, combustion, jet-aerosol expansion, non-invasive diagnostics for clear and opaque media including X-ray technology, immuno-biochemical analysis, etc.

In the structures area, the Mechanical and Test Effectiveness Database (MATED) developed by Alenia (Italy) under ESA contract was delivered. Its purpose is to compile information on best engineering practice, anomalies, and non-conformances as experienced in spacecraft projects during development and the Assembly, Integration, and Verification (AIV) process, and during flight. In particular, cost and schedule drivers are identified, facilitating feedback from lessons learned to optimize the development approach for new programmes. The data collection and investigation is a coordinated effort, led by ESA and supported by several industrial partners.

A new version of ESAComp, a state of the art software tool for the design and analysis of structures made of composite materials was released during the year. Developed by the Agency and now distributed by Componeering (Fin), ESA Comp is widely used by the European space industry.

The Agency was assigned the leading role for aerospace activities, supported also by Airbus Industries, in FENET, which is part of the research and technology development programme ‘Competitive and Sustainable Growth’, funded under the European Union’s Fifth Framework Programme. More than 100 partners from a wide range of industrial sectors and universities are participating, and its goal is to promote the best-practice industrial application of engineering analysis methods in Europe.

**Thermal Control and Life-Support Technology**

Specialised thermal and ECLS support was again provided to Agency projects and technology programmes in 2001. In the field of cryogenic cooling the development of a NIS-chip cooler, for the in-situ cooling of scientific sensors from 0.3 to 0.1 K, was successfully completed, as well as a feasibility study of a vibration-free 4 K cooler for the proposed Darwin mission. Developments were initiated for an optimised 50 – 80 K pulse-tube cooler, aimed at maintaining a leading role for Europe in this important temperature range. More globally, steps were initiated to harmonise the landscape of 10–100 K cryo-coolers in Europe, to maintain and improve industrial capability and competitiveness. At the other end of the temperature scale, work continued to develop the technology needed for the BepiColombo...
mission. The major emphasis here was on MLI, heat-pipe, and louvre systems for operation in the high-temperature environment encountered in the vicinity of Mercury.

In the ECLS area, there was steady progress towards establishing the life-support technology needed to ensure a noble role for Europe in the ISS context, as well as for eventual manned Solar System exploration missions. The European ARES (Air REvitalisation System), proposed as an upgrade for the ISS, was being actively discussed, and an experiment (FAVORITE) to verify the zero-g compatibility of the electrolyser unit was in preparation for a flight in August 2003. Development of the FTIR-based trace-gas monitoring system, the development model of which performed very well in NASA-sponsored trials, continued, and a flight demonstration model (ANITA) is in preparation.

For the longer term, the advanced life-support technology effort centred on the MELISSA bio-regenerative project continued to progress well. Co-ordination of ESA’s advanced life-support activities with those of other international players was also actively pursued via the ESA-NASA co-chaired International Advanced Life Support Working Group, which met twice during 2001, in Canada and Japan.

New releases of ESATAN, with enhanced fluid-loop-analysis capabilities, and of ESARAD were distributed to industry, as well as a spreadsheet thermal-analysis tool, ThermXL, which had proved very useful for rapid conceptual design studies in the ESTEC Concurrent Design Facility.

Several important tests were performed in the Mechanical Systems Laboratory during the year to support the development and qualification of flight instruments. They included the successful deep thermal vacuum cycle testing of the Smart-1 solar-array coupons over the -215 to +60°C range using a liquid-helium shroud inside the vacuum facility. Other notable activities included the MIDAS qualification tests for MetOp, the Lockheed pulse-tube-refrigerator performance test for Integral, and a series of spectrometer measurements to identify changes in trace elements in the bacteria cultures of MELISSA experiments.

**Propulsion and Aerothermodynamics**

In the aerothermodynamics domain, the definition study for the development of the European eXPERimental Reentry Testbed (EXPERT) was initiated. A consortium of European industries and institutes is assessing the feasibility of the concept and the resources required for a low-cost flight-research vehicle for three missions on Russian Volna launchers. The intended activities cover the assessment and possible improvement of aerothermodynamic design tools by providing high-quality flight data, low-cost testing of selected aerothermodynamic phenomena, and new in-flight measurement systems.

Two major international conferences were organised during the year in cooperation with other European space agencies, to exchange information at international level: the First Green Propellants Conference, held at ESTEC (NL) in June, and the Fourth Aerothermodynamics Conference in Capua (I) in October. On the occasion of the latter, the powerful Scirocco plasma facility at the Italian CIRA Research Centre, realised with significant ESA financial and technical contributions, was inaugurated.
The launch of Artemis brought both technology highlights and new challenges due to the satellite’s delivery into a non-nominal transfer orbit. Its recovery necessitated the first European operational in-orbit use of electric ion thrusters which, although unplanned, played a key role in rescuing the mission.

Elsewhere in the electric-propulsion domain, the ROS-2000 and Smart-1 programmes (Hall-effect thrusters) progressed well, with successful production of the electrical qualification and flight-model propulsion units. The industrial contract for the first operational FEEP (Field-Emission Electric Propulsion) system, representing ESA’s contribution to the CNES Microscope mission, was awarded and development is progressing according to plan. The pilot technology-harmonisation activity explored various avenues and it was agreed to pursue a number of developments to enhance capabilities in this area, focusing in particular on new grid systems for ion engines, the double-stage Hall thruster, steering devices for electric-propulsion thrusters, and new electric-propulsion test methods and techniques.

Electrical Engineering

The ESTEC Electrical Engineering Department undertook a wide range of technology-development, hardware and satellite procurement, and engineering-support activities in 2001. Significant advances were also made in satellite and payload avionics.

Proba

The development of Proba, a 100 kg technology demonstration spacecraft, was completed. After its successful launch by an Indian PSLV-C3 rocket on 22 October, the first two months of commissioning activities confirmed that all spacecraft systems and instruments were working nominally, and the ground segment was fully operational.

This mission was funded mainly by Belgium, and Belgian industry played a major role in the development of the spacecraft bus, the satellite’s integration and its ground segment. The payload was provided by three ESA Member States: Belgium provided a compact telescope (HRC), which will be used in an educational initiative (EduProba) in that country, while Finland and Switzerland provided space-environment monitoring instruments (DEBIE and SREM). The United Kingdom provided the Earth-observation payload (CHRIS). This miniaturised hyper-spectral imager (500 bands and 19 m resolution) is providing data to 60 Principal Investigators worldwide via ESA’s Redu ground station in Belgium.
Power Systems
The development and qualification of a Power Control Unit for high-power telecommunications satellites with a 100 V regulated bus was completed during the year. It is a fully modular concept allowing one to build power systems providing from 7.5 to 20 kW. It found immediate application on the Alcatel Spacebus 4000 platform. In parallel, the development of the Power Processing Unit for the electric-propulsion thrusters on telecommunications satellites (also a 100 V bus) was also completed.

Proba, is the first spacecraft to rely entirely on a lithium-ion battery for its energy storage. The 9 Ah battery, manufactured by AEA Technology, uses specially selected commercial lithium ion cells and weighs less than one-third of an equivalent nickel-cadmium battery.

In the area of solar power generation, the European harmonization exercise that took place in 2000 was followed up with the first phase in the development of European high-efficiency triple-junction solar cells and the initiation of three parallel studies on the system aspects of low-cost thin-film cell technology.

On-Board Software
With many missions close to launch, the year was characterised by intense software testing and review activities. With the ever-growing computing power onboard spacecraft, software technology is being assigned more and more critical spacecraft functions, resulting in ‘software crises’ in several projects. As a result, new approaches and techniques are being investigated and implemented to resolve these often mission-critical issues. On the other hand, the benefits of the advances in software technology were again spectacularly demonstrated when the Artemis spacecraft was re-programmed in flight to cope with its non-nominal launch.

Ground-Support Equipment and Simulators
Simulation technology and test beds are increasingly being exploited in the early phases of spacecraft design, one of the major customers in 2001 being the Galileo Programme. Much progress was also made in exploiting the benefits of the growing commonality between the ground-support systems used for electrical integration and the systems required for mission operations. Commonality with SCOS 2000 was successfully introduced into several ESA spacecraft development programmes.

Space Weather
The DEBIE in-situ impact detector, launched on the Proba satellite in October, is measuring the sub-millimetre size meteoroid and space-debris population in space. Solid particles of these sizes are much more abundant than larger objects, but they cannot be detected from the ground. The data gathered will support the development of better flux models and impact risk-assessment tools.

With various activities addressing space weather, the dynamics of which are the result of complex solar and magnetospheric processes, ESA has been actively working to ensure the continuing success of its missions in the hazardous environment of space. These phenomena increasingly give rise to adverse effects on other sectors, such as communications here on Earth.
Two parallel studies of a possible future ESA Space Weather Programme were therefore funded by the Agency’s General Studies Programme in 2001. They analysed user requirements and the space-segment and ground-based service-segment options. This work was supported by an external Space Weather Working Team and a study by the Concurrent Design Facility at ESTEC.

**TT&C Equipment and Systems**

In August, the engineering model of the new X/X-Ka band deep-space transponder successfully passed its Critical Design Review. A protoflight model, known as KaTE, was manufactured for the SMART-1 spacecraft to demonstrate X/X-Ka band TT&C subsystem communications, as well as having the potential to demonstrate telemetry link turbo encoding and to support radio-science investigations.

**On-Board Data Systems and Control**

At the request of the Italian Space Agency (ASI), ESA made an evaluation of the viability of extending the SAX satellite mission, due to the considerable interest shown by the scientific community in such an extension. The main task was to assess the likelihood of continued gyro operation and the alternatives in case of failure. The ESA recommendation to continue the mission was subsequently adopted by ASI.

On the technology front, a number of advances were made in the areas of on-board computing, microelectronics and attitude-control systems. The ESA-developed, high-performance LEON onboard microprocessor, featuring an innovative fault-tolerant concept, was successfully tested and industrialisation of this product is now underway.

In the area of attitude control, the year saw the implementation and flight (on Proba) of the first machine-generated onboard AOCS software, thereby reducing the development time for complex onboard attitude-control and navigation systems. Development of the high-performance fibre-optic gyroscope, now planned to be flown on the Planck mission, was also finalised. At system level, considerable progress was made in formation-flying concept definition and agile control-moment gyro-based AOCS systems, technologies that are vital for future high-performance science and Earth-observation missions.

**Electromagnetics**

In the domain of satellite antennas, much progress was made with reflector and printed-radiator modeling, as well as low-mass designs. Such generic techniques and technologies are suitable for communications as well as remote-sensing and science applications.

Substantial progress was also made in the field of millimetre and sub-millimetre wave antennas and telescopes, through the challenging analysis and development efforts for the Herschel/Planck astronomy mission payloads. This progress is also relevant for future atmospheric-sensing missions operating at similar wavelengths.

Opto-electronics, which covers detectors and sensors, lasers, optical links and wireless interconnects, photonic processing, and superconducting...
devices, is a growing and strategic area of space research. In the sensor sector, a new gravity-gradient sensor for future gravimetry missions was successfully developed. Based on Niobium superconducting technology, this new sensor provides marked improvements in terms of gravity-gradient sensitivity, rejection of spacecraft disturbances, mission lifetime, and miniaturisation.

**Product Assurance**

**Quality Management Systems**

Following the successful ISO 9001 Certification of ESOC (D) in 1999, the next candidate for certification was the Earth Observation Applications Department at ESRIN (I). This major achievement was accomplished in less than two years and encompassed the definition, documentation and implementation of a Quality Management System (QMS) compliant with the ISO 9001 standard. In the course of the certification project, the working processes of the Department were analysed, improved as necessary to achieve compliance, and then described in more than 90 documents that constitute the QMS. A comprehensive training programme was supported by an extensive series of internal audits, leading to a successful certification audit in October. ESA’s Director General was officially presented with the ISO 9001-2001 Certificate by National Quality Assurance (NQA), the accredited third-party certification body, at ESRIN on 28 November.

**EEE Components**

The ESCC space-component cooperation initiative, involving manufacturers, user industries, national agencies and ESA, continued apace in 2001. Substantial progress was again made in the revision and updating of technical specifications and their subsequent adoption into the European Space Component Coordination (ESCC) system.

ESCIES, the European Space Components Information Exchange System introduced in 2000 and which serves as the principal information portal for providing component data and related information via the Internet (http://www.escies.org/), was steadily expanded during the year.

The third issue of the European Preferred Parts List (ECSS-Q-60-01) was released in November and is available on-line. The ESA Parts Derating Requirements were updated and readied for publication as ECSS-Q-60-11.

In the ESA Technology Programme framework, a number of substantial development and evaluation activities were initiated to implement the recommendations laid down in the strategic plans in the areas of Silicon Integrated Circuits (Si-IC), Monolithic Microwave Integrated Circuits (MMIC), and Hybrids and Micropackaging.

Throughout the year, the Components Laboratory provided crucial support to ESA’s projects and component technology programmes by performing numerous failure-analysis, constructional-analysis and electrical-characterisation activities. To keep pace with the growing use of very advanced integrated circuits, a new Field Emission Scanning Electron Microscope was commissioned that can provide high-resolution images of components manufactured using current and future deep sub-micron processes.

More than a dozen heavy-ion and proton irradiation test campaigns were performed at the ESA external test facilities – HIF (B) and PIF (CH) – and other accelerators in Europe, covering different groups of parts and different
types within each group. Major efforts were again devoted to the characterisation of memories, e.g. advanced DRAMS for solid-state data recorders, fast SRAMs and non-volatile EEPROMs. The investigation of proton-induced displacement damage to opto-couplers was of particular importance for Envisat.

Materials and Processes
The year saw the Materials and Processes Division devoting up to 60% of its specialist manpower to direct project-support activities. These varied from project reviews, to in-depth laboratory investigations to assess hardware quality and make failure analyses. One hundred laboratory reports were issued, including one on an important metallurgical investigation accounting for the apparent corrosion of the Columbus Heat Exchanger and detailing how it could be re-furbished to flight-worthy state using special surface treatments.

The availability of the Materials Laboratory and its services ensures selection of the most appropriate materials and processes for all ESA space projects. Analyses performed in 2001 included 3000 ultraviolet spectra for the measurement of thermo-optical properties, 400 infrared spectra for chemical analysis, 1500 thermal characterisations for investigating phase changes in materials and their expansion coefficients, 100 outgassing-under-vacuum tests, and 46 tests to measure the offfgassing of units to be installed in ESA’s manned spacecraft.

A growing number of evaluations were also made through third-party contracts. These mainly concerned the susceptibility of materials and space hardware to environments such as atomic oxygen, UV and particle radiation. Such tests require very special laboratory apparatus, which has been specially constructed for the ESTEC Materials and Processes Division and is not generally available within the space community.

New materials, such as a novel copper alloy developed by powder metallurgy for use in the construction of low-cost rocket combustion chambers, and new processes, such as the machine assembly of high-density electronic packages onto printed-circuit boards, continued to be developed, tested and qualified for space use.

With the growing need to be able to construct, repair and maintain manned structures in space, the Division assessed the various joining and cutting techniques that are used by astronauts. Friction stud welding was demonstrated as a successful means of ‘plugging’ simulated impact craters.

Work continued on MEDET, a material exposure and degradation experiment consisting of a collection of environmental sensors and material and coating samples that will be mounted externally on the ISS Columbus module. The results of these experiments will help in selecting more suitable materials for specific space applications.

European Co-operation for Space Standardization (ECSS)
The ECSS has now published 61 common European space standards and made them available via the ESA web site (www.estec.esa.nl/ecss). The major effort during the reporting year was the updating of the first series of standards published back in 1996, with redrafting and review of 8 ‘B’ versions, and the transfer of additional ECSS standards to CEN standards. The number of ECSS Standards approved as European (CEN) Standards grew during the year from 3 to 19.

During the year, an assessment panel composed of senior European managers assessed the general status of the ECSS and recommended ways to improve application of the ECSS Standards by space projects and to speed up the Standards development process.