esa bulletin

number 110 - may 2002

European Space Agency
Agence spatiale européenne

european space agency

The European Space Agency was formed out of and took over the rights and obligations of, the two earlier European Space Organisations; the European Space Research Organisation (ESRO) and the European Organisation for the Development and Construction of Space Vehicle Launchers (ELDO). The Member States are Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Canada is a Cooperating State.

In the words of the Convention: The purpose of the Agency shall be to provide for and to promote for exclusively peaceful purposes, co-operation among European States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems.

(a) by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions:
(b) by elaborating and implementing activities and programmes in the space field;
(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
(d) by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

The Agency is directed by a Council composed of representatives of Member States. The Director General is the chief executive of the Agency and its legal representative.

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

THE EUROPEAN SPACE RESEARCH AND TECHNOLOGY CENTRE (ESTEC), Noordwijk, Netherlands.

THE EUROPEAN SPACE OPERATIONS CENTRE (ESOC), Darmstadt, Germany

ESRIN, Frascati, Italy.

Chairman of the Council: A. Bensoussan

Director General: A. Rodotà

agence spatiale européenne

L'Agence Spatiale Européenne est issue des deux Organisations spatiales européennes qui l'ont précédée – l'Organisation européenne de recherches spatiales (CERS) et l'Organisation européenne pour la mise au point et la construction de lanceurs d'engins spatiaux (CECLES) – dont elle a repris les droits et obligations. Les Etats membres en sont: l'Allemagne, l'Autriche, la Belgique, le Danemark, l'Espagne, la Finlande, la France, l'Irlande, l'Italie, la Norvège, les Pays-Bas, le Portugal, le Royaumi-Uni, la Suède et la Suisse. Le Canada bénéficie d'un statut d'Etat coopérant.

Selon les termes de la Convention: l'Agence a pour mission d'assurer et de développer, à des fins exclusivement pacifiques, la coopération entre Etats européens dans les domaines de la recherche et de la technologie spatiales et de leurs applications spatiales, en vue de leur utilisation à des fins scientifiques et pour des systèmes spatiaux opérationnels d'applications:

(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications;
(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

L'Agence est dirigée par un Conseil, composé de représentants des Etats membres. Le Directeur général est le fonctionnaire exécutif supérieur de l'Agence et la représente dans tous ses actes.

Le SIEGE de l'Agence est à Paris.

Les principaux Etablissements de l'Agence sont:

LE CENTRE EUROPEEN DE RECHERCHE ET DE TECHNOLOGIE SPATIALES (ESTEC), Noordwijk, Pays-Bas.

LE CENTRE EUROPEEN D'OPERATIONS SPATIALES (ESOC), Darmstadt, Allemagne.

ESRIN, Frascati, Italy

Président du Conseil: A. Bensoussan

Directeur général: A. Rodotà

bulletin

contents

number 110 - may 2002

Cover: ESA Astronaut Roberto Vittori aboard the International Space Station - see page 98 (photo NASA)

Editorial/Circulation Office
ESA Publications Division
ESTEC, PO Box 299, Noordwijk
2200 AG The Netherlands
Tel.: (31) 71.5653400

Editors
Bruce Battrick
Barbara Warmbein

Layout
Carel Haakman

Montage
Paul Berkhout
Isabel Kenny

Advertising
Barbara Warmbein

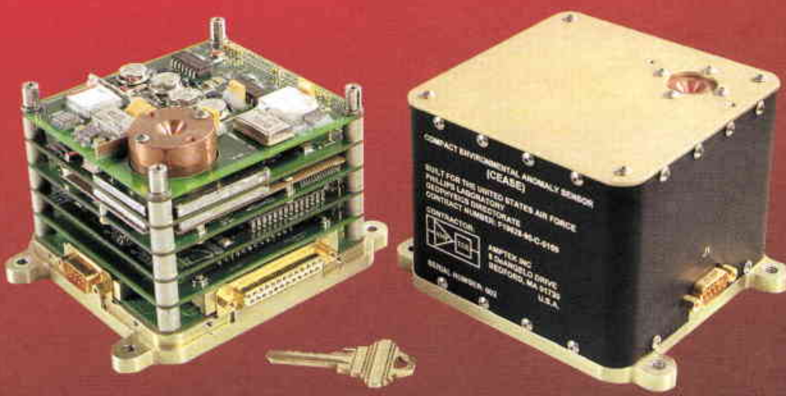
Printed in the Netherlands ISSN 0376-4265

European Space Agency
Agence spatiale européenne

Space Radiation Alarm

"CEASE"

COMPACT ENVIRONMENTAL ANOMALY SENSOR



FEATURES:

- Compact: 10 x 10 x 8.1 cm^3, 1 kg
- Low Power: 1.5 W
- Flexible I/O: Supports 1553B and RS422
- Full GSE and operational software
- On-board determination of hazardous conditions

CEASE is a compact, radiation hard, low power, space "weather" hazard sensor developed to monitor the local radiation environment and to provide autonomous real-time warnings of:

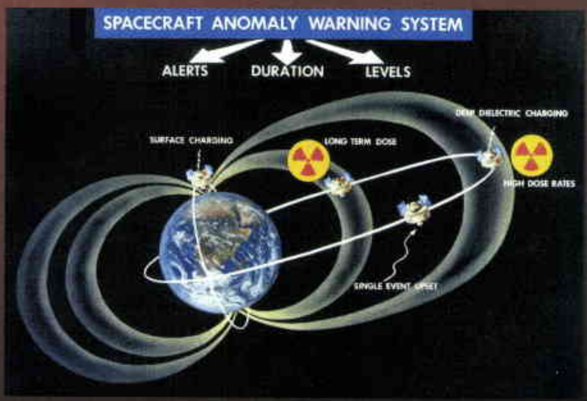
- Total Radiation Dose
- Radiation Dose Rate
- Surface Charging
- Deep Dielectric Charging
- Single Event Effects
- Solar Cell Damage.

CEASE detailed radiation data is used to pinpoint causes of spacecraft anomalies, and to forecast hazardous conditions before they affect the mission. The spacecraft, in turn, can re-prioritize its operations, inhibit any anomaly sensitive tasks such as attitude control adjustments, or initiate other prudent actions as indicated by the **CEASE** warning flags. Device degradation mechanisms and radiation tolerance of components can also be monitored.

The US Department of Defense has selected **CEASE** for several missions, including:

- **TSX-5**
- **STRV-1C**
- **SBIRS LADS**

and the **DSP** operational spacecraft.



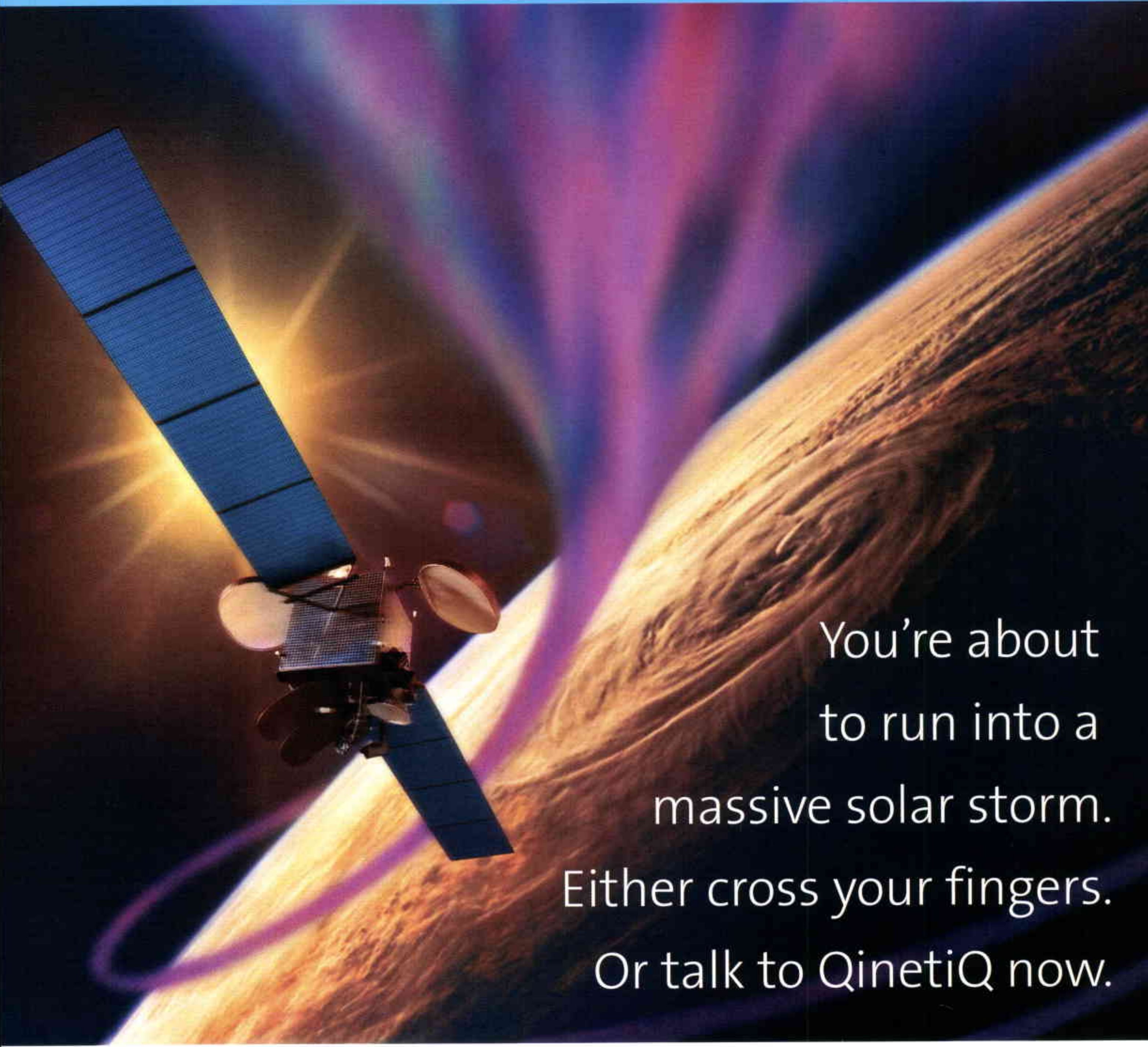
Amptek has a long and distinguished track record in the manufacture of space instrumentation. Mission examples include: DMSP, TIROS, CRRES, NEAR and APEX.

Current off-the-shelf Amptek sensors measure spacecraft charging, thermal and suprathermal, and high energy particles. In addition, Amptek provided the X-ray Detector on the Mars PATHFINDER Mission.

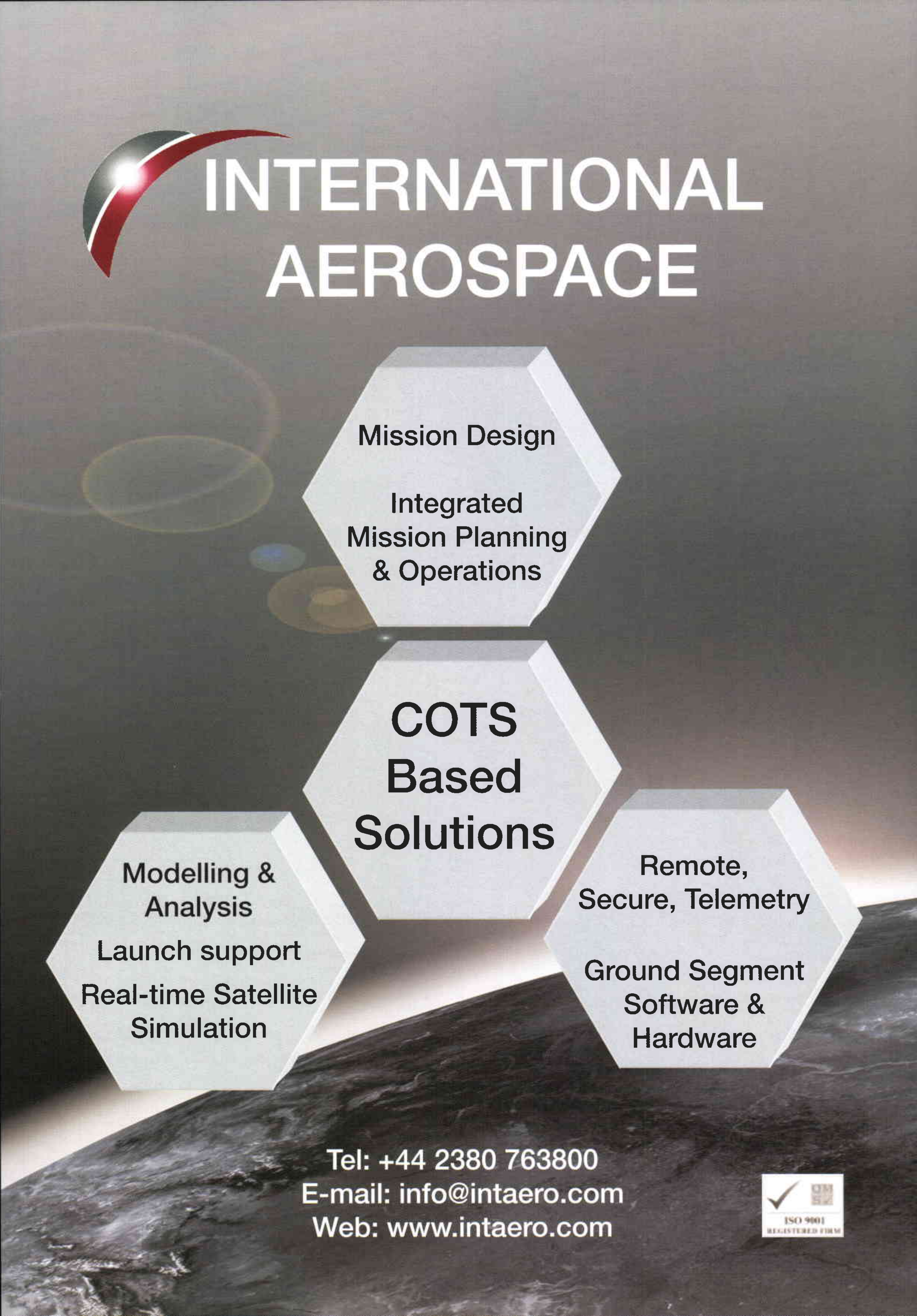
High reliability components from Amptek have been the number one choice of many missions, including: GALILEO, CASSINI, GIOTTO, AXAF, SUISEI, CLUSTER, SOLAR, GEOTAIL, SOHO, INTEGRAL, WIND and AMPTE.

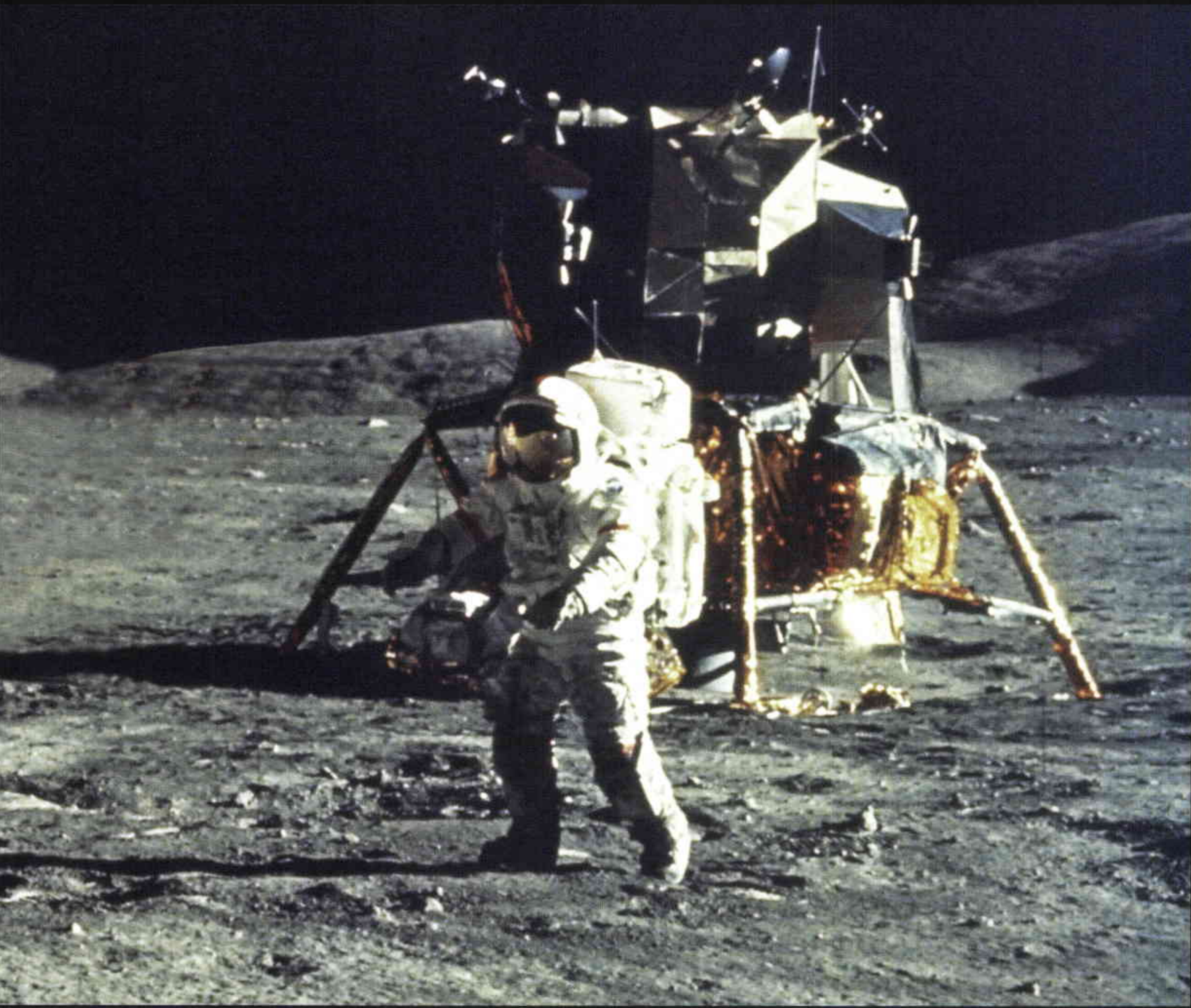
AMP TEK ®

AMPTEK INC.
6 DE ANGELO DRIVE, BEDFORD, MA 01730-2204 U.S.A.
Tel: +1 (781) 275-2242 Fax: +1 (781) 275-3470 email: sales@amptek.com http://www.amptek.com


You're about
to run into a
massive solar storm.
Either cross your fingers.
Or talk to QinetiQ now.


DISCOVERING
SPACE WITH YOU
Innovative solutions
for space missions.
Attitude sensors,
missions payloads,
RF equipment,
solar arrays,
power supply,
automation & robotics.
Galileo Avionica
A Finmeccanica Company
www.spazio.galileoavionica.com
Space Equipment Business Unit


INTERNATIONAL
AEROSPACE
Mission Design
Integrated
Mission Planning
& Operations
COTS
Based
Solutions
Modelling &
Analysis
Launch support
Real-time Satellite
Simulation
Remote,
Secure, Telemetry
Ground Segment
Software &
Hardware
Tel: +44 2380 763800
E-mail: info@intaero.com
Web: www.intaero.com
ISO 9001
REGISTERED FIRM




esa

Artemis

– 'A Lost Mission' on Course for a Full Recovery

G. Oppenhaeuser, A.G. Bird & L. van Holtz
Artemis Programme Office, ESA Directorate of Telecommunications, ESTEC, Noordwijk, The Netherlands

Artemis was launched on Ariane flight 142 from Kourou in French Guiana on 12 July 2001. Unfortunately, the second stage of the launcher did not perform to the full, resulting in an abnormal transfer orbit with an apogee of only 17 000 km instead of the nominal 36 000 km. For any other standard communication satellite this would have been the end of the mission. Indeed, for insurance purposes, Artemis has been declared a 'total loss'. However, thanks to the combination of technologies onboard Artemis, a recovery of the mission is possible. At the time of publication, the final phase of recovery has achieved 1100 of the 5000 km needed to reach geostationary orbit.

Introduction

Artemis is ESA's latest and most complex geostationary communication satellite. It carries a number of advanced communication payloads to support new communication services for mobile communication, data-relay and navigation services. In particular its L-band land mobile payload will be used to complement and augment the European Mobile System operated by Eutelsat, its data-relay payloads will provide operational support to Envisat and SPOT-4, and its navigation payload will form an element of the European Global Navigation Overlay Service (EGNOS).

The satellite will also demonstrate the flight-worthiness of a number of new technologies, the most significant being the electrical propulsion system for full north-south station-keeping and the SILEX optical inter-satellite data-transmission system.

The Artemis prime contractor is Alenia Spazio, responsible under contract to ESA for the development, assembly, integration and test, launch operations, and in-orbit operations of the spacecraft. Spacecraft operations from injection until end-of-life are managed by Telespazio from the Fucino Space Centre in Italy.

The choice of a launch vehicle for Artemis was a long and involved process. Initially it was planned to launch on an Ariane-4, but for funding reasons it was later slated for launch on the first, and then the second Ariane-5 APEX flights. When delays in the Artemis Programme made an APEX launch untenable, an agreement was reached between ESA and NASDA for a launch on the new Japanese H-IIA rocket. Following the failure of two H-II launch vehicles, NASDA announced significant delays in the H-IIA programme. In order to launch Artemis in time for its main customers, new funds were made available for a commercial Ariane-5 launch.

From injection to parking orbit

Following launch around midnight on 12 July, the operations team managed to establish TT&C (telemetry, tracking and command) contact with the satellite, despite the non-nominal orbit. The malfunction of the launcher was quickly reported and the first ranging results confirmed the orbit to be non-nominal. In particular, the apogee altitude was 17 487 instead of 35 853 km, the perigee was 590 instead of 858 km, and the inclination was 2.94 instead of 2.0 deg.

The satellite was placed in a safe Sun-pointing mode with its arrays partially deployed, and its systems were checked out. The battery charge cycle was adequate, but due to the relatively long and frequent exposure to the radiation belts in this orbit, a limit of 6 days was set for implementing a recovery .

The first meeting to assess recovery strategies took place on 13 July. The launch vehicle had shown a shortfall of some 500 m/s in injection velocity and it was apparent that, taking uncertainties into account, there was insufficient chemical propellant to reach geostationary orbit (GEO) and provide a useful station-keeping function. Therefore, three mission options were considered, based on making the most of the available chemical propellant, and included the use of non-geostationary orbits. Allowing for uncertainties and residuals, as a first approximation it was considered necessary to retain some 100 kg of chemical propellant for attitude and orbit control in the final orbit. This left about 1420 kg of chemical propellant for orbit recovery, equivalent to 1830 m/s.

The first two options considered were an elliptical orbit and a circular sub-synchronous orbit, respectively. They were aimed at providing a repetitive service coverage opportunity every 3 days by choosing an orbital period of some 18 hours, and were based on the use of chemical propellant only to reach those orbits. It was obvious that these orbits would only provide intermittent visibility of the satellite and would require investment in new ground networks. Moreover, it was quickly appreciated that, for frequency coordination reasons, the main payloads could not be operated in any other orbit than the geostationary orbit at nominal longitude. Consequently, it was GEO or nothing and all effort was concentrated on the practical aspects of achieving that solution.

The essential idea was to reach the nominal GEO by first using chemical propellant to reach an intermediate orbit and then using the ion propulsion system in a new attitude-control mode to transfer to GEO. In principle, the intermediate orbit could be either an elliptical orbit or a circular orbit, but the latter was preferred since the transfer time is shorter. Circular orbits with a radius of 32 000 – 35 000 km and transfer times of 450 – 300 days with ion propulsion were originally considered.

The energy-efficient solution to reach GEO is to provide one or more impulsive thrusts at perigee (correcting for the deficiency of the launcher), thereby raising the apogee to a suitable height, followed by an orbit circularisation (and inclination correction) using impulsive apogee thrusts to arrive at an intermediate parking orbit, from which the ion propulsion can be used to provide a continuous tangential thrust to raise the orbit to geosynchronous altitude. A balance had to be found between the chemical propellant remaining in GEO and the time taken to transfer to GEO using ion propulsion. These parameters determine the height of the parking orbit.

There were several practical problems to be solved in implementing the perigee impulse. It was first necessary to conduct a trial in orbit to verify that the earth sensor would operate at the low altitudes of the sub-standard injection orbit. Furthermore, the control modes for the apogee engine had been designed to operate in sunlight and the perigee was in eclipse. It was therefore necessary to investigate and simulate new mode-switching and operating procedures to operate the engine as close to perigee as possible in the interests of efficiency. It was also necessary to reduce arc loss by using several perigee burns and find a balance between efficiency and overall duration, taking station coverage opportunities into account.

Station coverage was also required to set up the apogee engine-firing attitude prior to perigee pass. This consisted of manoeuvres around apogee to calibrate the gyros and a further manoeuvre to an inertial Sun-pointing attitude to ensure a good state of battery charge. The station coverage constraint gave only two opportunities per day for perigee burns and they had to be executed without delay to avoid solar-array degradation in the radiation belts.

Activities during this difficult period were made easier by the faultless operation of the satellite and the extensive knowledge of the operations teams. Operation of the infrared earth sensor (Officine Galileo) well below its specified altitude was also a critical element in achieving success with these early perigee operations.

These efforts were concluded successfully, and an efficiency loss of only 8% relative to a single impulse was achieved. On 17 July, the final choice of strategy was confirmed.

This stated that the recovery mission would be based upon arriving in geostationary orbit at 21.5°E with a balance between the remaining usable mass of chemical propellant in GEO and the duration of orbit-raising with ion propulsion. Five perigee burns and three apogee burns using the liquid engine were to be used.

The final target height of the parking orbit was selected to be 31 000 km just before the final perigee kick, corresponding to a remaining chemical propellant after liquid-engine firings of 70 kg and an orbit-raising duration of 200 days with ion propulsion. The reduced transfer time with ion propulsion was due largely to the improved efficiency obtained with the perigee strategy and a revision of remaining chemical propellant to the bare minimum. The total impulse imparted during perigee and apogee burns was 1885 m/s and 1449 kg of chemical propellant was used during this phase.

In view of the non-nominal parameters of the injection orbit (inclination 2.9 deg, argument of perigee 151 deg), there was a limit to the inclination correction that could be made during circularisation at apogee. In fact, a parking orbit with a residual inclination of 0.8 deg was achieved. Some or all of this inclination can be reduced using the ion-propulsion thrust during the orbit-raising phase. This will, however, increase the overall duration of this phase by a few months.

The result of the overall strategy is illustrated in Figure 1, where the effect of the five apogee burns and three perigee burns, and the remaining band of altitudes to be served by ion propulsion is shown.

Shortly after the last apogee burn and confirmation of the new circular parking-orbit parameters, it was decided to proceed with the deployment sequence as foreseen for the nominal mission. Following battery and attitude-control system checks, the solar arrays, L-band reflector and S/K-band antenna arm and reflector were deployed. The two ion-thrust alignment-mechanism platforms, which allow the ion thrusters to be directed through small angles, were also released and the unified propulsion subsystem blow-down mode commanded, isolating the liquid-apogee engine and high-pressure tanks. The satellite was later commanded from Sun-pointing mode to Earth-acquisition, wheel spin-up and normal mode entry. This was followed by the initiation of the SILEX terminal's deployment and software loading.

All subsystems of the satellite performed excellently during the transfer-orbit operations. The solar-array outer panels, which provide 25% of the total power, have suffered some degradation due to radiation, but this amounts to only 2% of overall performance and is within the end-of-life margins.

Orbit-raising phase

New station network

Following the successful LEOP (Launch and Early Orbit Phase) recovery actions, Artemis was left in a safe condition in a parking orbit of some 31 000 km altitude and 0.85 deg inclination. Under natural perturbations, the semi-major axis and eccentricity of this orbit do not change significantly, but the inclination increases steadily. In this orbit, the drift rate of the satellite seen from a ground station is about 70 deg/day: the satellite is visible for about 3 days from an equatorial station every 5 days.

The original LEOP tracking network was no longer available to support Artemis long-term operations, so the first important activity was to arrange for a new network. Thanks to Telespazio's policy of deploying their own TT&C baseband equipment at the stations, a new network providing global coverage was rapidly set up. By September, a four-station network consisting of Fucino (Italy), Dongara (Australia), Southpoint (Hawaii) and Santiago (Chile) was fully operational.

So far this network has proved to be rather reliable, with only a few planned gaps in station availability of typically a few hours and a few communications outages of some minutes. However, there is no station redundancy and coverage is not guaranteed. This factor has led to the need for increased spacecraft autonomy as part of the new control concept.

New attitude-control mode

There are four ion thrusters on Artemis mounted in redundant pairs to provide north

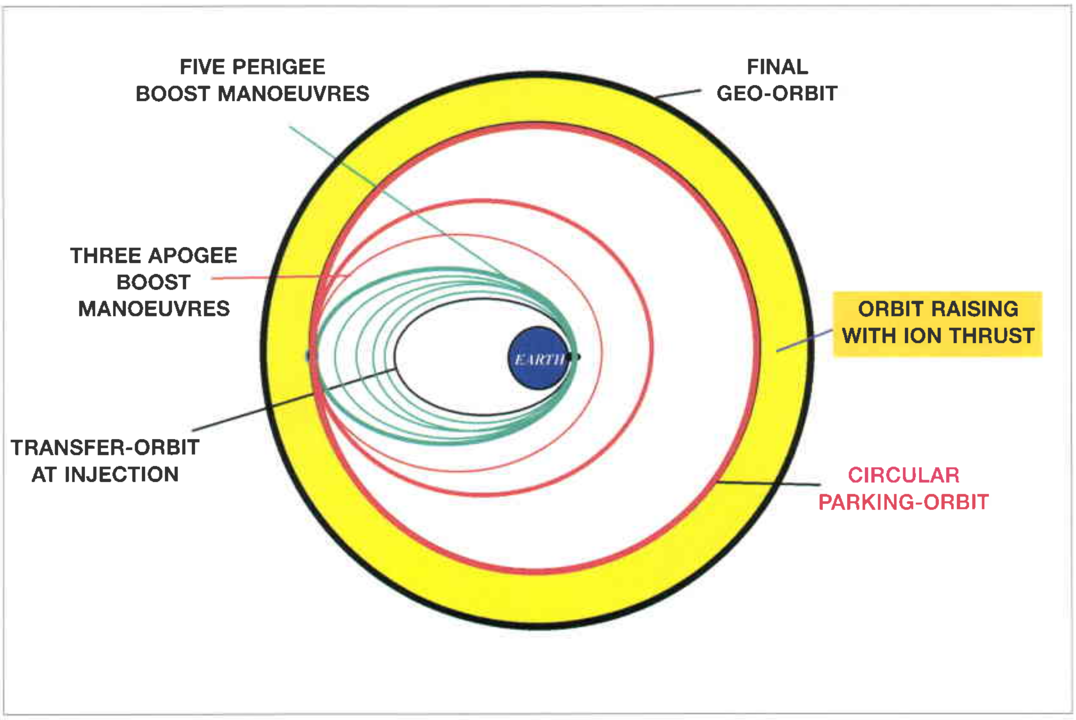


Figure 1. Overall manoeuvre strategy for Artemis recovery

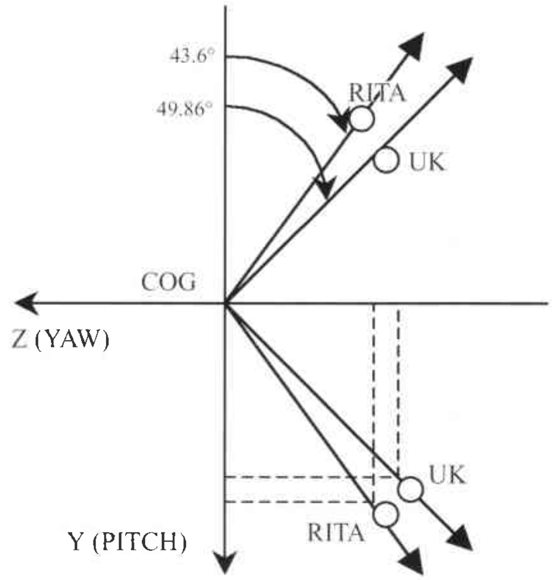


Figure 2. Ion-thruster orientation

and south thrusting for inclination control in GEO (Fig. 2). Due to their location, and because their thrust has to be directed through the spacecraft's centre of mass, there is a large (70%) thrust component along the spacecraft's z-axis, which points towards the Earth. During normal GEO operations, this component is unwanted and is cancelled by the alternate operations of north and south thrust arcs on opposite sides of the orbit. However, this is the very component required for orbit raising. By re-orientating the spacecraft's z-axis from being Earth-pointing to point along the direction of motion of the orbit (Fig. 3), the thrust will augment the orbit velocity and gradually lead to an increase in orbit radius.

Either two thrusters are fired together, in which case a maximum in-plane thrust component is achieved, giving orbit raising only, or a single thruster is activated, in which case both in-plane and out-of-plane components provide orbit raising and inclination control together. The current baseline strategy consists of switching between one- and two-thruster operations over four arcs of the orbit. With the correct choice of arc, the residual inclination (by now some 0.95 deg) can be removed at the same time as the orbit radius is increased to the geostationary value.

A similar scheme involving the modulation of thrust levels is under consideration. This would avoid switching between thruster combinations and relieve the operational workload. More powerful thrust steering strategies are also being analysed, involving spacecraft attitude changes as a function of orbital position.

The new attitude control mode (referred to as NM-ITN, or Normal Mode Ion Thruster Navigation) is similar to the Earth-pointing normal mode in geostationary orbit, in that it is based upon fixed momentum perpendicular to the orbit provided by a spinning momentum wheel. As the Earth is no longer visible, the attitude-

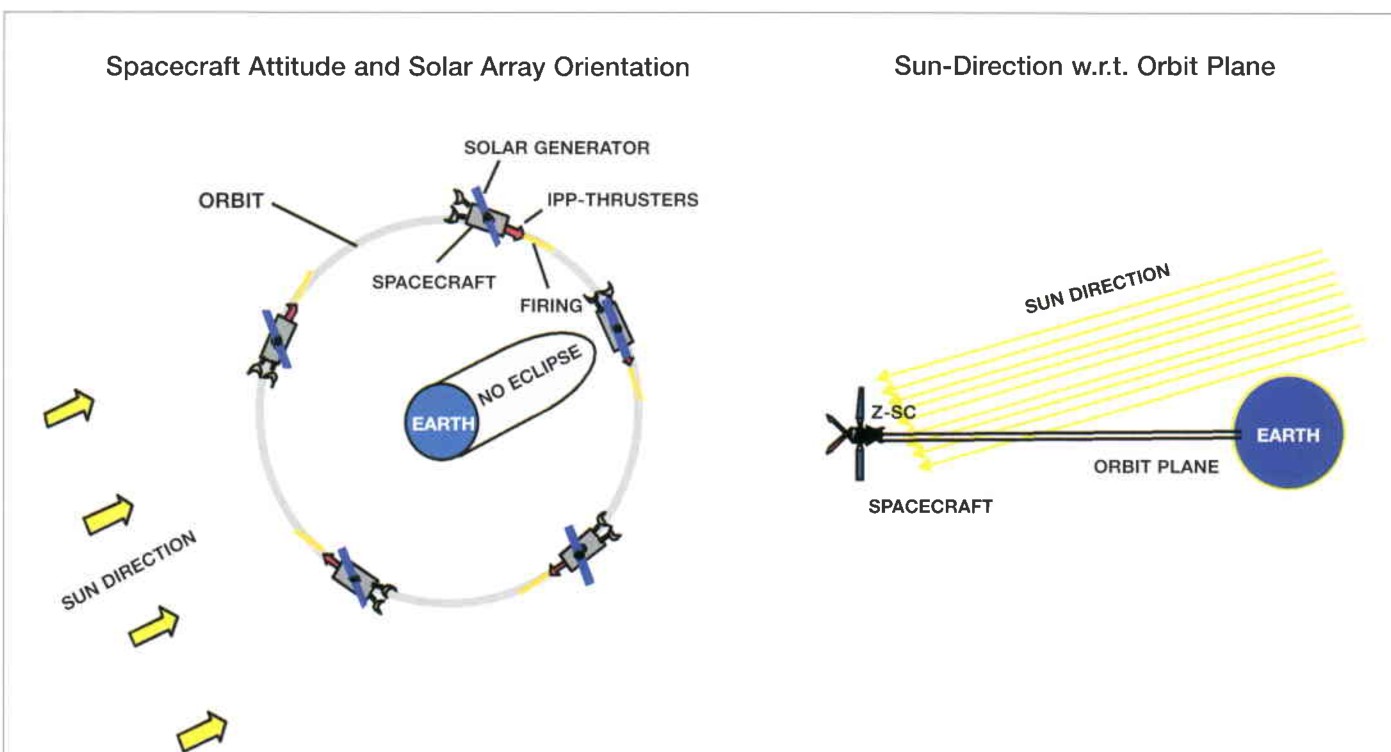


Figure 3. Principles of orbit raising when there is no eclipse

control reference in roll and yaw is provided by the Precision Sun Sensor (PSS) and the Rate Integrating Gyro (RIG). This is an entirely new mode, which has not been used on a spacecraft before, and it is thanks only to the re-programmable control concept (Integrated Control and Data Handling System, ICDS) that it is possible to implement it on Artemis.

The new control concept includes other additional attitude-control applications: a special orbit propagator to give the Sun reference direction in the new orbit; an automatic gyro drift observer-estimator; and a closed-loop system for the continuous pointing of the ion thrusters, using the Ion Thruster Alignment Mechanism (ITAM).

As the new mode relies upon the Sun for an attitude reference, during eclipse seasons the spacecraft has to return to Earth-pointing and ion thrusting has to be interrupted, for those arcs of the orbit in the Earth's shadow. This sequence is illustrated in Figure 4.

A number of the standard operational functions of Artemis have been designed under the assumption that there is permanent TT&C contact between spacecraft and ground, allowing ready evaluation and response from the Operations Control Centre (OCC). Due to possible TT&C outages during the orbit- raising phase, a number of the more critical functions have had to be upgraded or re-designed for autonomous onboard control. These include:

- ion-propulsion subsystem management
- battery-charge management
- solar-array pointing and drive management
- eclipse entry and exit management, including automatic return to Earth-pointing
- orbit propagator and gyro calibration
- closed-loop ion-thruster pointing control
- fault surveillance, detection and recovery.

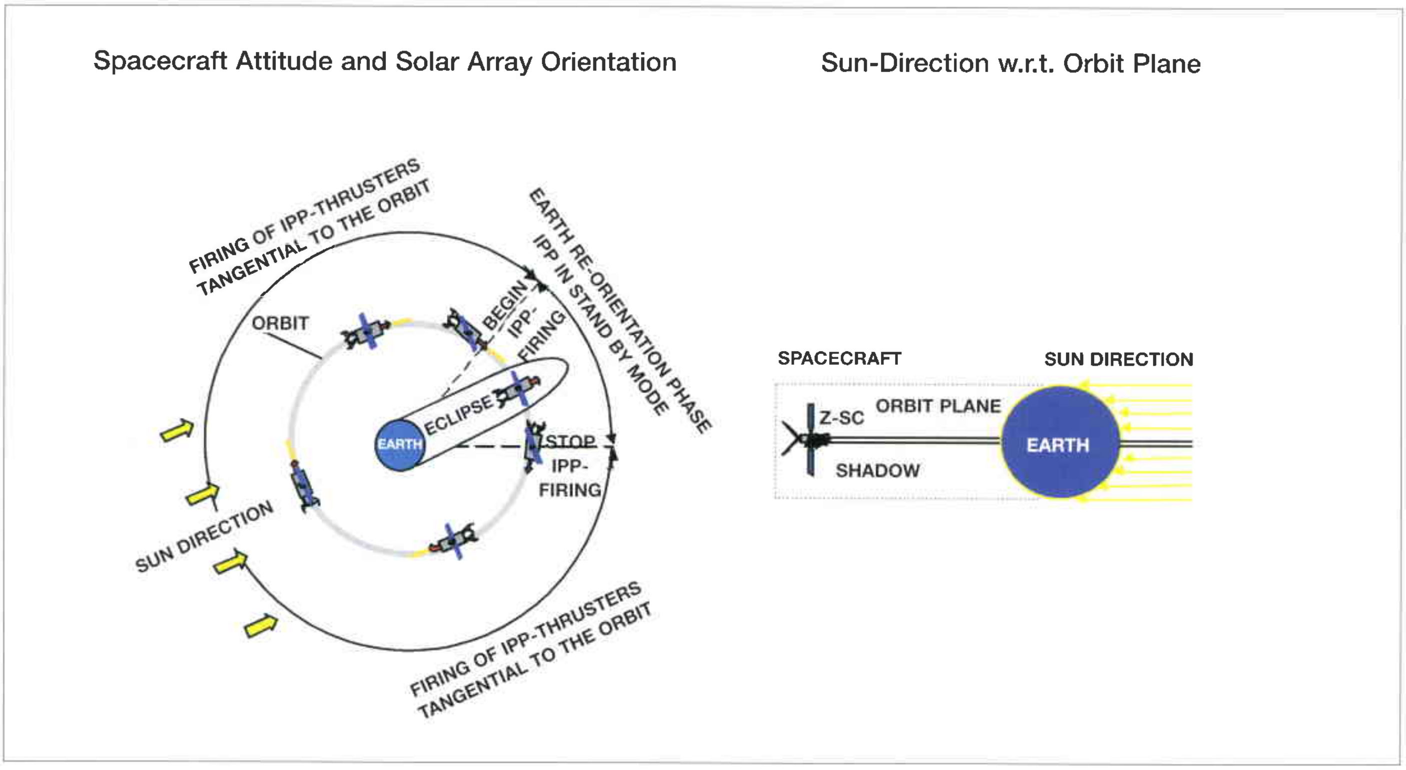
In addition, new telecommand, telemetry and data-handling interface functions for the above have been implemented.

In all, about 20% of the original ICDS (Integrated Control and Data Handling) software has been modified. These modifications have been effected by uplinking software 'patches' to the satellite amounting to 15 K-words, the largest ever for a telecommunications satellite.

Undoubtedly, the effort required for the design, development, test, integration and production of operating procedures was underestimated. But with so much at stake and with some early setbacks, it was considered prudent not to take shortcuts and make the most of the test models available. As it is, the new software has not been tested to the same level as existing functions and we are proceeding cautiously with activation of each sub-mode.

Nor has the development time for the new software been wasted at satellite operational level. The platform and payload functions have been commissioned and valuable in-orbit experience has been gained with the ion

Figure 4. Principles of orbit raising during the eclipse season



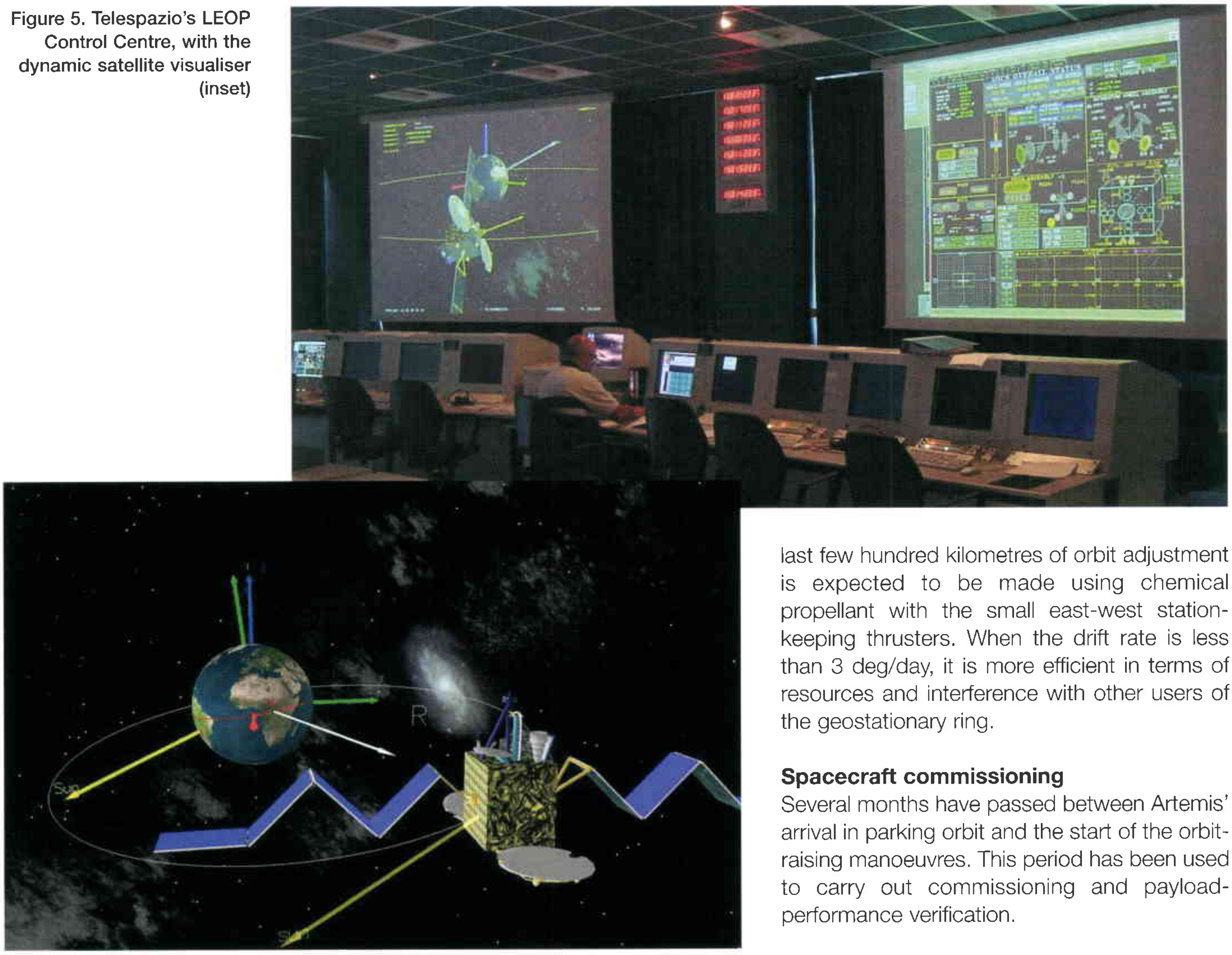


Figure 5. Telespazio's LEOP Control Centre, with the dynamic satellite visualiser (inset)

propulsion systems and ITAM control. During this same period, other operating modes of the satellite and the new ground facilities have also been exercised extensively. Moreover, very little propellant has been consumed during this phase.

Now the new mode is operational, but much observation and adjustment remains to be done in orbit. The eclipse season (which in this orbit starts around 22 February and lasts for some 50 days) will prove to be a testing time for the onboard autonomous functions and the operations team will be required to be vigilant around the clock.

Depending on the strategy and thruster combination used, we expect orbit raising to last about 200–250 days, representing an increase in orbit radius of about 20 km per day. Artemis carries two different ion-propulsion technologies – RITA and EITA – delivering slightly different thrust levels. The duration also depends upon the extent of inclination control applied during the raising process. In all cases, the xenon consumption is the same, about 16 kg or the equivalent of 4 years of normal north-south control in geostationary orbit. The last few hundred kilometres of orbit adjustment is expected to be made using chemical propellant with the small east-west station-keeping thrusters. When the drift rate is less than 3 deg/day, it is more efficient in terms of resources and interference with other users of the geostationary ring.

Spacecraft commissioning

Several months have passed between Artemis' arrival in parking orbit and the start of the orbit-raising manoeuvres. This period has been used to carry out commissioning and payload-performance verification.

Coming after the hectic transfer-orbit operations, platform commissioning was a relatively straightforward affair. Indeed, thanks to the many satellite reconfigurations needed during the LEOP operations, nearly all equipment and many spacecraft modes had already been exercised. It merely remained to test a few thermal configurations and initialise and configure payload equipment.

Payload performance testing was a more difficult matter. It required bi-directional RF links to be established between the spacecraft and the test and monitoring earth stations at ESA's Redu site in Belgium. Owing to the drift rate in parking orbit, link opportunities were limited to some hours every 5 days and special test methods and procedures were required. Moreover, use of the allocated radio frequencies is only allowed from the nominal orbital position at 21.5°E. This limitation was strictly respected for the 12 GHz band (Ku-band), which are widely used in the vicinity of Artemis' nominal position. For the Ka-band, there was more freedom to operate over the orbital arc from 10°W to 20°E in coordination with the relatively few Ka-band users in this region.

In order to cope with these constraints, a novel technique for performance measurement was devised to minimise transmit time and potential interference. This involved using very-low-power signal levels and rapid channel switching with computer-automated measurement and data logging on the ground synchronised with spacecraft switching operations.

The correct functional operation of all payloads was demonstrated, and payload performance was confirmed with satisfactory accuracy.

Two demonstrations are worth highlighting here. To establish a data link between with a user satellite in LEO, the 3 m SKDR steerable antenna on Artemis has to be pointed with high accuracy towards the user for the duration of the data transmission. Pointing can be performed in two ways:

- by programmed (open-loop) tracking: in this mode of operation, the antenna pointing angles are calculated using the orbit parameters of both Artemis and the user spacecraft and are updated every few seconds to maintain the required pointing accuracy
- by radio-frequency (RF closed-loop) tracking: in this mode of operation, the antennas of both Artemis and the user spacecraft are first pointed in open loop towards the partner; after an acquisition process both antennas track on the communications signal from the partner spacecraft.

Both modes of operation were demonstrated by maintaining antenna pointing and the communications link towards the earth station at Redu, with Artemis drifting in its parking orbit at a rate of 3 deg per hour.

Most impressive was the demonstration of the optical data-relay system SILEX between Artemis and SPOT-4, and as a preparatory exercise, between Artemis and the optical ground station in Tenerife (E). The art of establishing the optical data link consists of pointing a laser beam so accurately that the partner satellite is illuminated. The laser beam

The Principles of Ion-Engine Operation

EITA and RITA are both are 'gridded' ion thrusters, providing an impulse of about 3000 sec (approx. 30 000 Ns/kg) specific impulse, and for both engines the ion-beam neutralisation is provided by electrons delivered by a so-called 'neutraliser' electron source. Two separate developments have been pursued with industry to avoid the possibility of the incorrect application of a single technology jeopardising the future utilisation of electric propulsion in European space programmes.

The Electron-bombardment Ion Thruster Assembly (EITA) is a so-called 'Kaufmann engine', where the ionisation is performed by a DC discharge in a main cathode (Fig. 6a). The ions are focussed by means of magnets (solenoids) and accelerated in an three-grid system made of molybdenum. In contrast to other designs, the Astrium/DERA thruster utilises an inward dished grid. The innermost grid has the highest temperature and therefore due to the material expansion caused by the operating temperatures the dish will increase most for the hottest grid and less for the next grid. Thus the spacing between the grids increases when the thruster is operating, reducing the danger of a direct contact between grids.

With the Radiofrequency Ion Thruster Assembly (RITA), the ionisation is performed by a 1 MHz alternating field, induced by a coil surrounding the discharge chamber (Fig. 6b). Thus no main cathode or magnets are needed. The ions are again accelerated in a three-grid system, but the middle electrode 'acceleration grid' is made of graphite, providing greater resistance to material loss due to sputtering effects caused by the ions. Due to the relatively high specific resistance of graphite compared to metals like molybdenum, a potential graphite bridge between two grids is cleared by a substantially lower current than is required to clear a metal bridge.

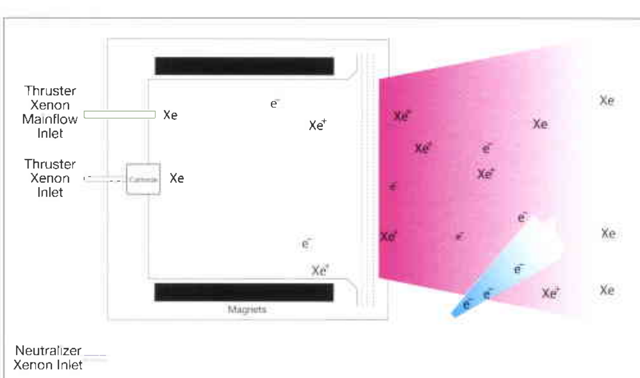


Figure 6a. Principles of EITA thruster operation

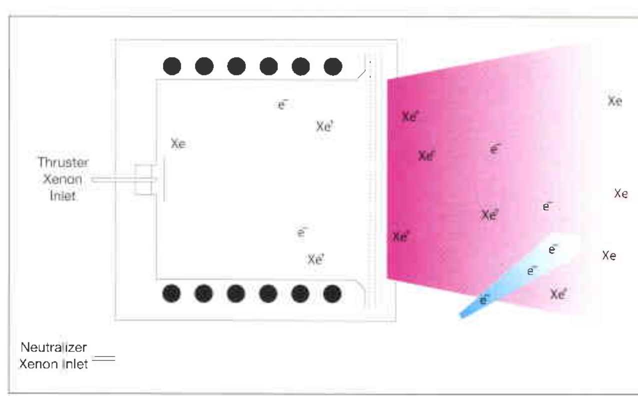


Figure 6b. Principles of RITA thruster operation

has a width of only 300 m after travelling 40 000 km through space while the LEO satellite has a relative velocity of several km/s.

Up to now, we have attempted to establish 26 optical links and all of them were successful. Once the link was acquired it was always maintained for the pre-programmed time, and no loss of link has ever occurred.

The communication link quality is remarkable. Quality measurements for the overall link, including the feeder link from Artemis to Redu, resulted in a Bit Error Rate (BER) of better than 1 in 10^9, i.e. when transmitting 1 billion bits, only one was erroneously received.

SPOT-4 image data has been relayed in real-time via Artemis to the data-reception centre in Toulouse. The picture quality was almost perfect, providing a convincing demonstration of the advantages of a data-relay system.

Outlook

The Artemis project has suffered many significant delays, initially for programmatic reasons and later due to an uncertain launch scenario. Now the rescue operation has added to this overall delay. Nevertheless, considerable progress has been made towards recovery. If the experimental ion propulsion system performs as planned, we expect the spacecraft to arrive on station in geostationary orbit in the latter half of this year and with sufficient propellant (chemical propellant and xenon) to support a nominal GEO mission for 5 to 7 years.

In parking orbit, the correct functioning of the communication payloads has already been demonstrated and Artemis will be able to provide its main services as planned:
- the L-band mobile communication payload will be used commercially by Eutelsat
- EGNOS will use the navigation payload, first experimentally, and later operationally
- SPOT-4 will use the SILEX optical data-relay payload for at least 5 orbits per day
- Envisat will use the Ka-band data-relay service for at least 3 hours per day.

It is to be hoped that Artemis will continue to stimulate European data-relay services, with the Space Station and other users who have shown an interest in this potential.

A lost mission is on course for a unique recovery. In terms of a reversal of fortune, it bears comparison with the earlier rescues of ESA's Olympus and Hipparcos missions. It will set new standards for the use of ion propulsion and re-programmable data-handling and attitude-control systems.

Acknowledgements

With operations of this kind, it is common to stress the need for teamwork. In this case we can honestly say that the team skills and close cooperation of Alenia and its subcontractors, Telespazio and ESA were essential for all aspects of this novel recovery mission. Astrium, Fiat Avio, Officine Galileo and Vega deserve special mention for their vital support during the critical LEOP activities. We would also like to pay tribute to the inspiration of Alenia and Astrium (D) engineers in conceiving of the new attitude- control mode and their perseverance during its development and testing. The ground operation teams, Telespazio with Alenia project support, have exhibited a command of procedures, facilities, flight dynamics and knowledge of the satellite that has been exemplary. We would also like to thank ESOC's flight-dynamics personnel for their timely and spontaneous advice, and the ESOC network team for extending LEOP services.

The spacecraft itself has performed well beyond its normal design specifications in many critical areas, and the accompanying panel provides a list of the major industrial participants in its realisation. esa

The industrial organisation for Artemis

– System	Alenia Aerospazio (I)
– ICDS	" "
– Thermal Control	" "
– Structure	Casa (E)
– Power Subsystem	Fiar (I)
– Solar Array	Fokker (NL)
– Solar-Array Drive Assembly	Astrium (UK)
– Batteries	Saft (F)
– Unified Propulsion System	Fiat Avio (I)
– Ion Propulsion: RITA	Astrium (D)
EITA	Astrium (UK)
– LLM Payload	Alenia Aerospazio (I)
– SKDR Payload	" "
– IAPS/IOL Antenna	" "
– Forward Repeater	Alcatel Espace (F)
– Return Repeater	Bosch Telecom (D)
– TT&C and Comms.	Alenia Aerospazio (I)
– OPALE (SILEX)	Astrium (F)
– System MGSE	ORS (A)
– System EGSE	Laben (I)
– Parts Procurement	TOP-REL (I)
– Ground Segment and Operations	ALTEL (I), INDRA (E), RYMSA (E), Laben (I), Vega (UK), GMV (E), ESOC

ESA Web Mapping Activities Applied to Earth Observation

C. Caspar & I. Petiteville
Ground Segment Engineering Division, Earth Observation Application Department, ESA Directorate of Earth Observation Programmes, ESRIN, Frascati, Italy

G. Kohlhammer
Mission Management Office, Earth Observation Application Department, ESA Directorate of Earth Observation Programmes, ESRIN, Frascati, Italy

G. Tandurella
SERCO, ESRIN, Frascati, Italy

Thousands of Earth Observation satellite instrument products are generated daily, in a multitude of formats, using a variety of projection coordinate systems. This diversity is a barrier to the development of EO multi-mission-based applications and prevents the merging of EO data with GIS data, which is requested by the user community (value-added companies, service providers, scientists, institutions, commercial users, and academic users). The web mapping technologies introduced in this article represent an elegant and low-cost solution. The extraordinary added value that is achieved may be considered a revolution in the use of EO data products.

Introduction

Every day, ESA ground stations and processing centres acquire and process several gigabytes of raw instrument data, sensed by a wide variety of both ESA and non-ESA Earth Observation (EO) satellites, including Envisat, ERS, Landsat, Spot, JRS, NOAA AVHRR, Terra Modis, MOS, SeaWIFs and soon the Earth Explorer missions. While ESA has long and solid experience in the development of ground-segment systems (data acquisition and processing), the weakest elements in the end-to-end chain from satellite to user remain the user services, the product distribution, and the product handling by the users themselves.

Until recently, users have spent a significant amount of time developing their own software routines to read the products from each satellite mission, instead of focusing on the data exploitation. With the development of the Internet, our user community (scientists, institutional organisations, value-adding companies, services providers, private users, etc.) requires faster and easier access to the satellite instrument data products generated, as well as standard commercial or freeware tools to easily display and analyse those products. Taking advantage of the number of satellite missions now flying simultaneously, more and more user applications (e.g. oil-spill monitoring or Charter for Disaster Management tasks) require the combination of various instrument data products from several satellite missions, as well as their merging with both in-situ data and Geo-referenced Information Services (GIS) layers.

After presenting the typical problems encountered when trying to distribute satellite data, and browse products in particular, without relying on web mapping techniques and standards, this article describes how some of the OpenGis Consortium (OGC) services may streamline this activity. A description of the roles and functions supported by the main OGC components follows, including Web Map Servers (WMS), Web Feature Servers (WFS) and Web Coverage Servers (WCS). A practical implementation of a WMS at ESRIN is then described and examples are given of several further activities conducted following the successful outcome of the initial test case, including putting online a large database of active fires detected by ERS-2's ATSR-2 instrument.

A barrier to the full exploitation of ESA's EO products

In recent years, a large quantity of EO satellite products and associated information (e.g. catalogues of products, browse images) has been accessed by a wide community of users via the Internet. This includes, for instance, browse images from optical and radar sensors as well as higher level EO products such as global-ozone or sea-surface-temperature maps. Before the emergence of standard web mapping technologies, it was often the case that each category of product corresponding to different sensors and different projects was distributed via dedicated web sites through heterogeneous and non-standard user interfaces based on a wide variety of proprietary software, imposing limitations on both data providers and users.

Data providers without web mapping servers
In the absence of a standard approach for accessing and distributing data, each new project team and application implementer had to 're-invent the wheel', designing in particular new interfaces between the user's web client and the provider's data server. The lack of powerful and re-usable mapping components also resulted very often in web sites with a static representation of the data and required trade-offs on geographic projections and – in the case of temporal datasets – on the time slices (weeks, months, years) used to display these data. The frequent overlaying of GIS information (coastlines, political boundaries, etc.) and annotations to support the data interpretation made the maps of little use beyond the mere scope of visualisation.

Furthermore, the scattering of products from a single distributor across different web sites using different interfaces and protocols has made it difficult to exploit the synergy between different sensors (e.g. active fires from an infrared sensor such as ATSR and NO_2 tropospheric emissions from a spectrometer such as GOME), making the whole dataset less attractive to the user community.

Users without web mapping support
Users needed to discover, search and access EO and GIS information spread over many different information systems, sometimes even when generated by the same data provider. They also needed to learn how to use the various corresponding user interfaces.

Often the information presented within a web site was self-standing and could not be combined with that from other data providers or with the user's own data for several reasons, such as different geographical projections, different sampling rates, and different formats. In the best case, when available, users had to download the raw data (ASCII tabulated values, binary products, etc.) and regenerate specific views suiting their purposes. Therefore, it was often simpler for users to discard data that were not crucial for them, as they could not be easily handled.

Breaking the barrier with web mapping services

Web mapping services provide an answer to most of the above problems by enabling a basic interoperability of simple map servers and clients. For the first time, users can access Geo-referenced Information Services in real-time, obtaining in a transparent way, space and non-space data coming from various data providers around the World. With access via the World Wide Web, users need no longer worry about the original formats of the data accessed, its location or its geographical projection. The data may be delivered to the users either in graphical form, as metadata or as binary data using either a Web Map Server (WMS), a Web Coverage Server (WCS), or a Web Feature Server (WFS). There are other types of services being offered by the OpenGis Consortium (OGC) TC211 group, but these are the main ones.

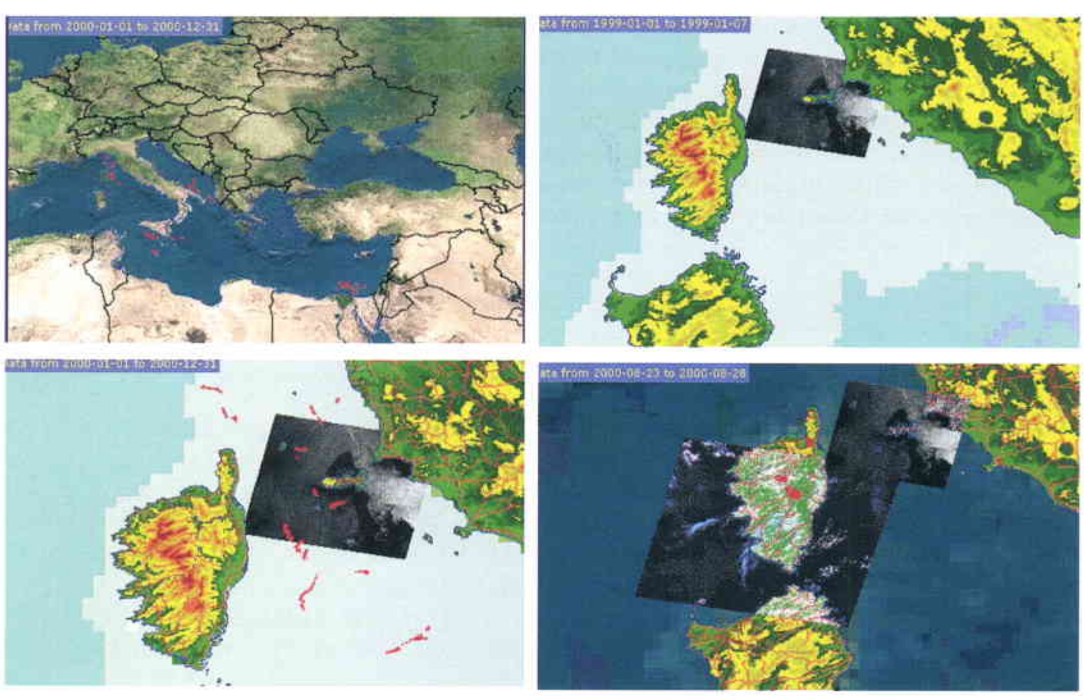


Figure 1. Examples of the combination of up to 7 GIS and EO satellite (Landsat TM, ERS-2 SAR) layers

They provide in particular:

- An easy and standard interface, allowing a simple web-browser client to access EO and GIS data distributed worldwide using a common and simple protocol. The interface is also well suited for automatic data retrieval (no need to manually interact via a web interface).
- Zooming, resampling, filtering and on-the-spot re-mapping of data with support for the most common geographical projections (Mercator, Lambert, UTM, Plate-Carrée, Orthographic).
- Separated thematic layers: the final overlaying is performed on the client side, allowing users to combine individual layers as needed for their particular application.

Being based on an Open Standard supported by a growing community of vendors such as Ionic, Cubewerx or ESRI, the list of distributed OGC-compliant servers is increasing, and already includes the larger space agencies such an NASA, NASDA and ESA, as well as international and national organisations such as USGS and JRC. Given data providers need only care for their own data, knowing that its users will automatically benefit from the wealth of additional GIS and EO information available from distributed servers around the World.

The OGC web mapping services

Standards and interoperability are becoming key factors in the development of information servers and services. In particular, the web mapping services as specified by the OpenGis Consortium (OGC) provide a flexible and low-cost method of combining data from several sources and presenting the combined information in a unified way, bringing significant added-value to the interpretation of satellite products.

Data visualisation: the Web Map Server (WMS)

In response to requests from a web client, a Web Map Server (WMS) generates 'pictures' of geo-referenced data, including EO data, in the form of images with standard formats. Independent of whether the underlying data are simple features (such as points, lines and polygons) or coverages (such as gridded fields), the WMS produces an image of the data that can be directly viewed with a graphical web browser or other picture-viewing software.

A WMS should handle at least two kinds of requests, to:

- list its capabilities (formats and projections supported, layers available, ..) (GetCapabilities request)
- deliver graphic files corresponding to one or more layers (GetMap request).

An additional type of request, GetFeatureInfo, that may provide additional information for a user-selected point of interest on a given layer, may also be included. We will now look at these three requests in more detail.

List of capabilities

In reply to the GetCapabilities request, a map server returns the list of all supported layers. This list is written in XML following strict rules (document type definition), so that besides being readable by a human, it can also be parsed by a catalogue system that could automatically index and update a set of available layers from a pre-defined list of Web Map Servers. For a given layer, the capabilities file specifies in particular the name of that layer to be used in subsequent queries, the geographic spread in one or more projection systems, and possibly the various representation styles available, and states whether the layer is queryable or not (see GetFeatureInfo below). Table 1 shows a fragment of a capabilities file for a layer providing coastlines.

```
<Layer queryable="0">
   <Name>COASTLINES</Name>
   <Title>Coastlines</Title>
   <Abstract>Coastlines from Digital Chart of the World</Abstract>
   <LatLonBoundingBox minx="-180" miny="-90" maxx="180" maxy="90" />
   <Style>
      <Name>BLACK</Name>
      <Title>BLACK</Title>
   </Style>
   <Style>
      <Name> DOTRED</Name>
      <Title>DOTRED</Title>
   </Style>
</Layer>
```

Table 1. Example of a layer description extracted from a 'capabilities file'

Map requests

A WMS client can specify via a specific request (GetMap) the information to be shown on the map (one or more 'layers'), possibly the 'styles' of those layers, what portion of the Earth is to be mapped (a 'bounding box'), the projected coordinate system to be used (the 'spatial reference system'), the desired output format, the output size (width and height), and the background transparency and colour. Typical output formats include Portable Network Graphics (PNG), Graphics Interchange Format (GIF), Joint Photographic Expert Group (JPEG), and Tagged Image File Format (TIFF).

When two or more maps are produced with the same bounding box, spatial reference system and output size, the results can be accurately layered to produce a combined/composite map. The use of image formats that support transparent backgrounds (e.g. GIF or PNG) allows the lower layers to be visible. Furthermore, individual map layers can be requested from different servers. The WMS GetMap operation thus enables the creation of a network of distributed map servers from which clients can build customised maps.

Some geospatial information may be available at multiple times, such as an hourly weather map. Depending on the context, time values may appear as a single value, a list of values, or an interval.

A server may accept specific requests (e.g. for elevation or spectral band) as indicated in its capabilities file.

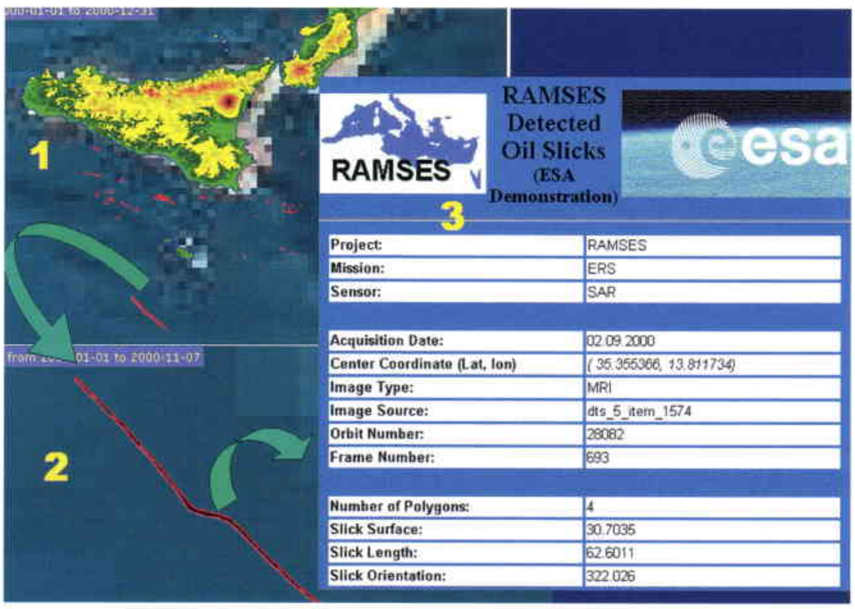


Figure 2. Feature information (3) relating to a specific oil slick (1 & 2)

Cascading Map Servers

Another very interesting feature of web mappers is 'cascading'. A Cascading Map Server can aggregate the contents of several distinct map servers into one service. It can also perform additional functions such as output-format conversion or coordinate transformation on behalf of other servers. If a client needs a layer from a provider in a projection not supported by that provider, the request may be issued to another WMS that will obtain the layer from the original provider and transform the image coordinates into the requested projection.

Information on a feature

Additional metadata information relative to a portion of a specific layer may be obtained. When invoking GetFeatureInfo, the client indicates which map is being queried and which location on the map is of interest. The source server is then queried to obtain the desired information. The WMS specification does not impose any specific constraint on the type of response to a GetFeatureInfo request. The decision is left to each particular application, which could, for example, return an image, an HTML or an XML file. An implementation of such a request is illustrated in Figure 2.

A WMS completely hides the underlying server architecture from the client, who always uses the same protocol to request layers. On the server side, GI data may be stored in several forms: database, flat files, images on a GIS server or generated by any program.

Because these servers are oriented towards web applications, where fast response times are expected, in order to give access to large data volumes, such as full-resolution EO images which can amount to several tens of megabytes per frame, some WMS implementations use various optimisation techniques including aggregation, i.e. the pre-calculation of the original image at various pre-defined scales in order to return any portion of the original image at any scale within a few seconds. The estimated overhead required by aggregation in terms of disk space is typically of the order of 20%.

Examples of requests

URL1 will return a map of the World consisting of a digital elevation model (GTOPO30) rendered with false colours, together with coastlines and political borders (digital chart of the World). For the sea surface, no data are requested and they will appear blue as requested by the BGCOLOR parameter. The map covers Europe as specified by the BBOX parameters. The projection is Plate-Carrée (EPSG code 4396). The returned image is reproduced in Figure 3.

URL1:
http://mapserv2.esrin.esa.it/cubestor/cubeserv/cubeserv.cgi?WMTVER=1.0.1&REQUEST=map&SRS=EPSG:4326&BBOX=-16.7,32.2,46.7,71.8&WIDTH=560&HEIGHT=350&LAYERS=GTOPO30:MapAdmin,COASTL_1M:MapAdmin,POLBNDL_1M:MapAdmin&STYLES=COLORMAP_GTOPO30,0X101040,BLACK&FORMAT=PNG&TRANSPARENT=FALSE&BGCOLOR=0x0000FF&EXCEPTIONS=INIMAGE

URL2 uses the same kind of layer combination, with just an extra bathymetry layer. The SRS parameter is AUTO:42003 this time, which corresponds to an orthographic projection. The centre point for the projection is 45ºN and 5ºE. For this kind of projection, the BBOX parameters express the map extent in metres from the centre point. Figure 4 shows the corresponding map returned by the server.

URL2:
http://mapserv2.esrin.esa.it/cubestor/cubeserv/cubeserv.cgi?WMTVER=1.0.1&REQUEST=map&SRS=AUTO:42003,9001,5,45&BBOX=-6400000,-6400000,6400000,6400000&WIDTH=300&HEIGHT=300&LAYERS=ETOPO5:MapAdmin,GTOPO30:MapAdmin,COASTL_1M:MapAdmin,POLBNDL_1M:MapAdmin&STYLES=COLORMAP_ETOPO5,COLORMAP_GTOPO30,0X101040,BLACK&FORMAT=GIF&TRANSPARENT=TRUE&BGCOLOR=0x0000FF&EXCEPTIONS=INIMAGE

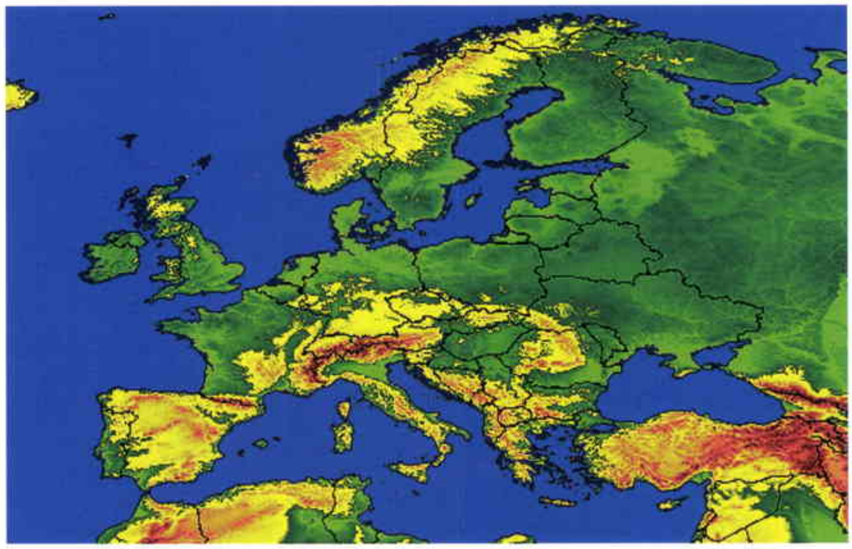


Figure 3. Image returned by URL1

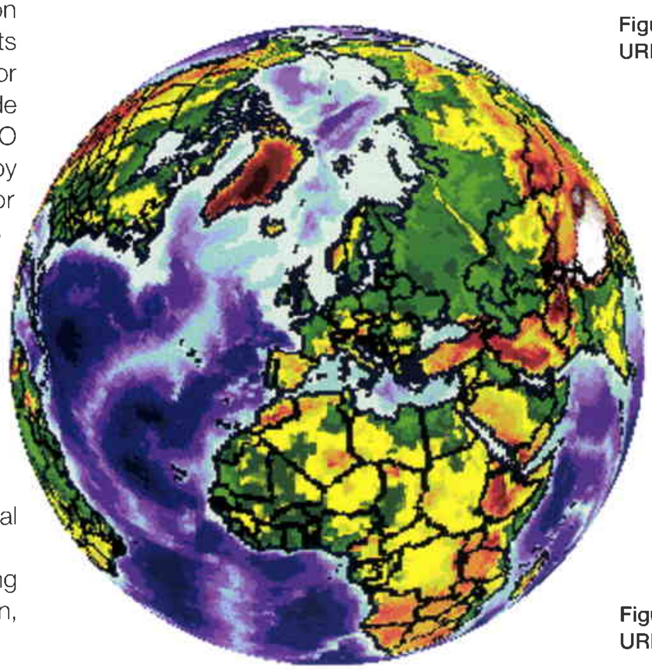


Figure 4. Image returned by URL2

Access to the product data and metadata
The WMS provides a graphical representation of GI and EO data in particular, using formats such as GIF or JPEG which are not suited for further processing because they do not provide the metadata available in standard EO products, lose track of engineering values by applying a simple colour code (GIF), or introduce degradation (JPEG). To allow users to access the underlying scientific data, the OGC introduces two additional components:

Web Feature Servers (WFS)
A WFS offers access to the geographic features (points, lines, and polygons) in a data store. In the context of EO applications, they may for example correspond to:
- the location of active fires with additional metadata (detection time, sensor, etc.)
- the detection of oil spills by remote-sensing radars (detection time, length, area, orientation, etc.)
- in-situ measurements.

A WFS does not provide a graphical representation of the requested features, but generally returns them in Geographical Markup Language (GML), which is XML based. For each feature, the GML structure provides the corresponding geographic information and associated metadata. The information returned to the user is extracted from a data store (e.g. Oracle database). The WFS also allows authorised users and applications to modify the server's database (create, update and delete records). In the case of active fire data, this GML content could be directly ingested into an atmospheric assimilation model.

As is the case for WMS, a WFS supports the GetCapabilities query with a similar syntax. The GetMap Query is replaced by the GetFeature query which, besides additional filtering specifications relevant to features only, accepts parameters very similar to the WMS GetMap, in particular for the specification of the time window and the geographic bounding box. It is therefore very easy to imagine a client that first allows a user to refine a particular query in a graphical mode relying on a WMS server, and then requests the data themselves in GML format, this time submitting the request to a WFS server, but using the same selection parameters as used with the WMS.

Despite being a rather recent specification, a WFS has already been implemented at ESRIN using commercial off-the-shelf (COTS) software from Ionic Software. This demonstration serving a large database of active fires detected by the ATSR-2 instrument onboard ERS-2 is further described below.

Web Coverage Servers (WCS)
A WCS offers access to the actual numeric values of gridded geo-referenced data or imagery (other, more sophisticated types of coverages are not addressed in the initial WCS specification). A WCS client can issue a

GetCoverage request to obtain these numeric values for further processing or rendering on behalf of the user. A WCS offers one or more layers, just like a WMS, but does not render them for the user and therefore does not offer 'styles'. GetCoverage includes the desired SRS, bounding box, and output format, but does not include a width or height because these apply only to images.

Possible output formats include GeoTIFF, NASA's Hierarchical Data Format implementation for the Earth Observing System (HDF-EOS), and an extension of GML for coverages that has been proposed to allow XML encoding of metadata about the coverage object and numerical values either stored online or referenced by link to an external file.

These servers allow users to request coverages directly, which in the case of EO could correspond to products from imaging sensors (including all bands) or level-3 products such as global ozone concentration maps (access to the ozone values and associated metadata). As in the case of the WFS, the WCS specification closely follows the one for Web Map Servers: i.e. it supports the GetCapabilities request and the GetCoverage request accepts parameters similar to the WMS GetMap request (BBOX, SRS ...). Moreover, the GetCoverage requests accept additional parameters for, for example, selecting a limited number of bands from spectral sensors.

Some current ESRIN application projects

The ERS ATSR Active Fires Atlas

To demonstrate the adequacy and the interest of web mapping for EO applications, ESRIN decided to implement a first prototype to access, from a standard web browser, a large existing database spanning over 5 years of active fires (> 300 000 fires), originally produced for the Global ATSR Fire Atlas project. The fire-detection algorithm uses the 3.7 micron band of the ATSR-2 instrument on the ERS-2 satellite.

The test implementation has been based on the COTS software from the Belgium company Ionic, which consists of a combined OGC-compliant WFS/WMS server written in Java and a client application written in HTML and Javascript. With their technical assistance, a first version of the complete server also supporting the GetFeatureInfo request was put in place in less than one working week. In addition to the short time needed, another important feature is that the original existing Global ATSR Fire Atlas system did not have to be modified. Only a very basic and simple interface routine between the Global ATSR Fire Atlas and the Web Mapping Testbed had to be developed. The preserving of the original structure of the databases and the original formats of data/metadata is one of the strong features of the web mapping technology.

The individual ATSR fire hot spots are ingested into an Oracle 8i database. When receiving an OGC compliant query, the WMS/WFS performs the following steps:

- Extraction of fire data from the Oracle database according to the user-specified bounding box and time window, and generation of a GML (Geographic Markup Language) stream.
- Portrayal of fire hot spots: application of drawing or thematic rules (style sheets or other methods), which determine the graphical aspect of the geographic elements (point in this case). Several rules may be defined to allow different representations or styles of the same object, for example at different scales. The transformation also takes into account the requested projection. The output of the portrayal step is an SVG (Scalable Vector Graphic) stream. In the particular case of this demonstration, fires can be rendered as red dots, blue circles or small fire icons.
- Rendering of the SVG stream to generate a GIF or JPEG image that can be easily displayed on any web client.

Compliance with OGC standard interfaces (WMS, WFS) enables online access and the combination of map information coming from one or more distributed Web Mapping Servers. It only takes a few minutes to configure the client application to access new layers from any OGC-compliant server.

The GetFeatureInfo is supported, and by simply clicking on the map a user can obtain the metadata information relating to a particular fire. The fire information is returned in the form of a dynamically generated HTML page. The information page also provides geographical context maps which are themselves generated by additional calls to Web Map Servers.

An additional internal development is the link to the ESRIN Multi-mission User Services (MUIS) catalogue and browse servers, which include a large collection of browse images from ESA and third-party missions (more than 7 million entries and 200 000 passes of browse imagery). Using a dedicated bridge, the user can receive a list of all available browses within the MUIS catalogue that match a selected fire in time and geographical coverage. This system shows, in particular, the original ATSR frame used for the detection, but also the matching frames from other sensors (ERS SAR and Landsat TM), fostering the synergy between various missions.

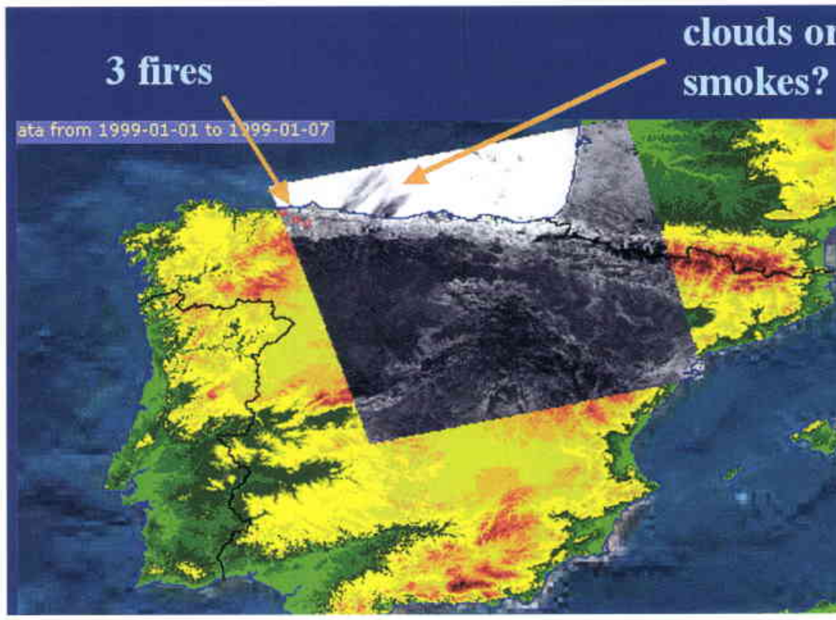


Figure 5. Possible case of misinterpretation: it is only by overlapping the ATSR frame with the detected hot spots that it becomes obvious that the cold features that are visible cannot be smoke from the detected hot spots

Eventually, browse satellite images can be directly overlayed on a map, providing a quick and easy way of performing a first interpretation of satellite data by combining it with online GI context information. To illustrate the benefits of such a function, Figure 5 shows a typical case that could easily result in a misinterpretation. The image shows three fire hot spots detected in Northern Spain. Looking at the corresponding ATSR frame initially leads to the conclusion that the smoke from the fires was visible on the image. It was only after integrating the frame into the Web Map Server that it became obvious that the cold features that are visible do not actually match up with the locations of the hot spots and are more likely to be clouds.

Following the successful initial test using the ATSR active database, further activities have been conducted using web mapping techniques, examples of which are described below.

Detection of fires In Southeast Asia

In October 2000, the CEOS Working Group on Information Systems and Services (WGISS) established, in collaboration with GOFC (Global Observations of Forest Cover), a task team (WGISS Test Facility GOFC) to prototype and demonstrate the use of inter-operable data and services to improve the work of the GOFC scientists. The 2000 fire season in Southeast Asia, and in particular Northern Thailand, was selected as the demonstration area. ESRIN participated in the activities of this team, bringing the ATSR fire database served by the IONIC WFS/WMS server and by ingesting into the server additional active-fires information derived from NOAA/AVHRR and DMSP/OLS provided by other WTF/GOFC participants. The integration of external data from NOAA and NASDA was completed in a few hours thanks to the standard and simple web mapping protocol.

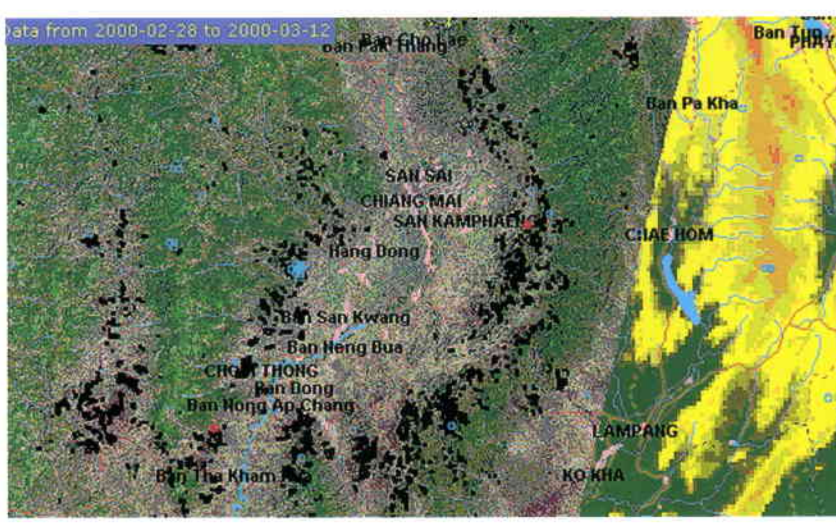
The ESRIN WMS client was also used to combine dynamically in a single map the active fire information from these various sensors, as well as layers from remote WMS servers, including in particular fire-risk maps and burn scars available from a NASDA server and a full-resolution Landsat image over Northern Thailand from a USGS server. Figure 6 is an example of such a combined map, which also includes extra layers taken from servers not linked to the WTF/GOFC activities. These extra layers include in particular the city names from a server in the Netherlands (DEMIS) and water bodies and roads from a Canadian server (Cubewerx). An interesting piece of information, unknown until the implementation of the Web Map Server, was discovered thanks to overlaying the three fire-detection layers (ERS ATSR, NOAA/AVHRR and DMSP/OLS). The spots discovered by each sensor did not correspond to those detected by the other two. This is vital information for scientists and engineers that remains to be explored and explained.

The ESA Web Mapping Testbed constitutes the cornerstone of the demonstration given at the last CEOS Plenary meeting, in Kyoto in November 2001. The success of that demonstration shows that the various CEOS members certainly appreciate the great benefit and added value of web mapping technology in the promotion and greater use of EO data.

Oil-spill monitoring in the Mediterranean

RAMSES is a project financed by the European Commission, the main objective of which is to detect oil slicks over the Mediterranean Sea using ERS SAR medium-resolution images. Over more than two years, SAR images have been acquired on an almost daily basis over seven regions of interest in the Mediterranean Sea. A database of over 500 oil slicks has been

Figure 6. Example of a map generated by the ESRIN WMS client in the framework of the WTF/GOFC activities. It combines ATSR fires (red dots) and AHVRR (light-blue dots), and black areas correspond to burn scars. ATSR and AVHRR fires cover the period 28 February to 12 March 2000



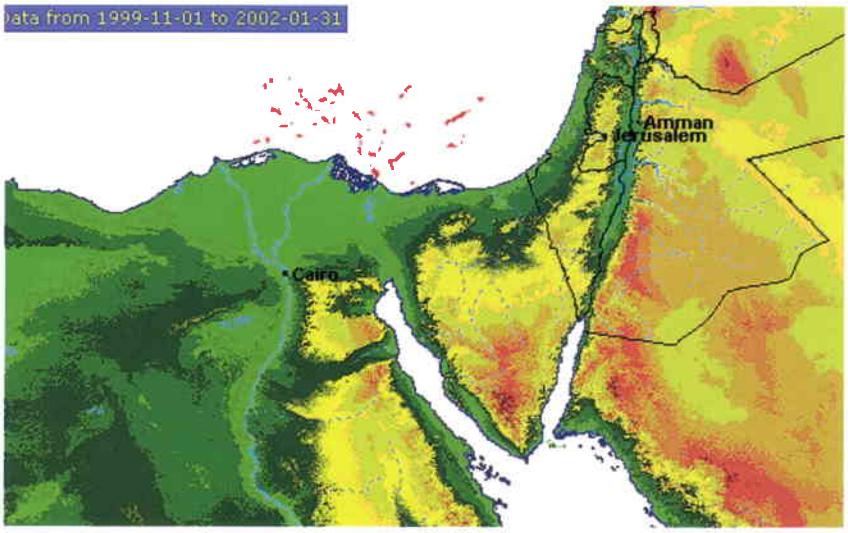


Figure 7. RAMSES oil-slick database for the Egyptian region of interest as seen from the ESRIN map server

built up, providing for each slick its geographic coverage in the form of a polygon as well as metadata (area, main orientation, radiometric values, etc.).

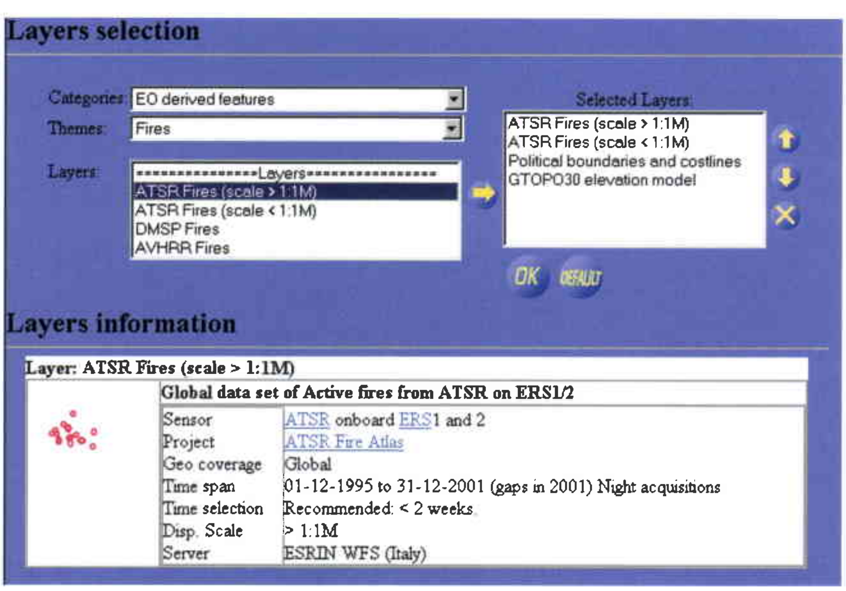
In the framework of this project, a dedicated browser application has been developed in Java. Despite providing the required functionality, this solution presents several problems: not least the interface between the client and the RAMSES server is proprietary and relies on a CORBA/IIOP protocol, which may cause access problems for users behind firewalls and makes it very difficult for these users to develop their own client application in order to merge the RAMSES oil-slick information with their own data, for example.

Considering the above limitations, the complete RAMSES database was ingested into the ESRIN WFS/WMS server. Data can now be viewed from anywhere using a simple web browser. Users can access metadata for each individual oil slick simply by clicking on that particular slick. Users can also download the 'raw' data in GML format. Another interesting advantage of the web mapping services is that the same software and hardware architecture used for the two projects described previously (Global ATSR Fire Atlas and the CEOS WGISS WTF GOFC) is fully reusable. The great strength of web mapping is that it is universal and can be used for a multitude of applications.

Once again, making the oil-slick information available online took less than one working week.

Client improvement
The improvement of the Web Mapping Testbed client interface is an on-going activity, reflecting the evolution of our Web Map Server environment. For instance, the selection of layers, illustrated in Figure 8, has been organised into categories and subcategories to cope with the ever-growing number of available layers. The selection window now also provides layer background information specifying geographic and time coverage, as well as hyperlinks to the projects from which the data originate.

Figure 8. The selection window in the ESRIN WMS with background information on the ATSR fire layer



The ESA EO Multi-Mission User Services

EOLI is the Java-based web interface to the ESA Earth Observation Multi-mission User Services (MUIS, URL: http://odisseo.esrin.esa.it/eoli/eoli.html). Via EOLI, users may query the Product Catalogue and the Browse and Product servers, which contain millions of products. Authorised users may then order products using EOLI.

The EOLI interface (client and server) has been chosen for the Envisat User Services. DLR (D) has also installed the MUIS suite of servers and is currently adapting the EOLI interface for its own User Services. MUIS and EOLI will become the nucleus of a multi-provider distributed system. In its original version, the EOLI interface overlays the frames of the various instruments matching the request, on a layer providing basic and fixed information including land/sea masks, political borders, major city names, hydrology.

Thanks to the simplicity of the OGC web mapping technologies, it was possible within just a few working days to extend the range of thematic backgrounds, as shown in Figure 9. Each background is itself made up of a combination of several layers provided by both local and remote OGC-compliant Web Map Servers. The possibility to choose various thematic backgrounds will help the user in the selection of particular EO frames. For example, the provision of a soil-moisture layer may be useful for the selection of an ERS SAR frame for particular applications, whereas a daily-cloud-cover layer may help a user to select data from optical sensors when only footprints and no browses are available to perform the selection.

Future evolution

Our servers are now ready to be fed with a wider range of data. Short-term and mid-term future activities include:

- Extending data sets offered by the WMS, in particular:
  - Adding a basic WMS wrapper layer to the MUIS catalogue and browse servers to provide a OpenGis-compliant access to all Envisat, ERS, Landsat, MODIS and other browse products available in native projection in the MUIS Product and Browse Data Server. This concerns in particular the Envisat ASAR, MERIS and AATSR browse products.
  - Transparent access to data from meteorological organisations.
- Integrating level-3 and higher products from the various data-processing servers located at ESRIN in order to provide a single uniform and harmonised client to access all kinds of data such as:
  - ERS/ATSR SST (Sea-Surface Temperature)
  - ERS/GOME global ozone and nitrogen maps.
- Visualisation of ESA and non-ESA satellite ground tracks and sensor swaths.
- Improving the time selection of datasets by:
  - Generating animation for a specified time window and periodic interval.
  - Performing on-the-spot averaging of datasets (e.g. monthly average ozone figures starting from daily datasets).
- Improving the user interface, by providing:
  - Legends.
  - Custom user interfacing for layer selection (possibility to discover, add and remove) from the selection window.
  - The possibility to navigate by specifying geographic names (cities, regions, countries ...).
  - A 'layer search' function, allowing users to discover layers by specifying thematic keywords.
- Performing an automatic indexing of selected WMS and WFS to extend and update the list of worldwide available GI and EO layers. The automatic parsing of capabilities files from a pre-selected list of Web Map Servers in order to offer users an up-to-date list of most layers available worldwide, as well as providing the possibility for users to customise their layer selection to best suit their field of application.

Figure 9. Selection of a thematic background generated by OGC Web Map Servers for the EOLI interface

- Implementing simple online post-processing functions that may be triggered by the user, e.g. data-format conversion allowing users to select the format for data to be retrieved via the WCS from those most commonly used (ERS and Envisat formats, HDF-EOS, GeoTIFF, ..).
- Implementing web registry services allowing users to discover more easily the web mapping services available at ESA and to build their own applications, chaining the basic services available at ESRIN.

Conclusion

The prototypes developed at ESA using the latest OpenGIS-compliant web mapping techniques have demonstrated the promising benefits for Earth Observation. The use of web mapping technology may be considered a small revolution in terms of the habits of the EO user community and a boost for EO exploitation. Essentially, users (value-adding companies, service providers, scientists, institutions, commercial users, academic users, etc.) no longer have to worry about the location, the format or the projection of the original data. The web mapping technologies now available enable the development of new multi-mission-based applications, for instance in the field of disaster management. Never before have users been able to combine space, geographical and in-situ data so easily. For both the data providers and the application developers, there are obvious advantages in using a standard and powerful technology that preserves the existing infrastructures and allows the quick development of new solutions.

Knowledge-driven Information Mining in Remote-Sensing Image Archives

M. Datcu
Remote Sensing Technology Institute, German Aerospace Centre (DLR), Oberpfaffenhofen, Germany

K. Seidel
Computer Vision Laboratory, Swiss Federal Institute of Technology (ETH), Zurich, Switzerland

S. D'Elia & P.G. Marchetti
Earth Observation Applications Department, ESA Directorate of Earth Observation Programmes, ESRIN, Frascati, Italy

Information mining/knowledge discovery and the associated data management are changing the paradigms of user/data interaction by providing simpler and wider access to Earth Observation (EO) data archives. Today, EO data in general and images in particular are retrieved from archives based on such attributes as geographical location, time of acquisition and type of sensor, which provide no insight into the image's actual information content. Experts then interpret the images to extract information using their own personal knowledge, and the service providers and users combine that extracted information with information from other disciplines in order to make or support decisions.

In this scenario, the current offering, which is 'data sets' or 'imagery', does not match the customer's real need, which is for 'information'. The information extraction process is too complex, too expensive and too dependent on user conjecture to be applied systematically over an adequate number of scenes. This hinders access to already available or new data (data accumulation rate is increasing), penalises large environmental-monitoring type projects, and might even leave critical phenomena totally undetected. Emerging technologies could now provide a breakthrough, permitting automatic or semi-automatic information mining supported by 'intelligent' learning systems.

The EO information burden and the technological challenges

Users in all domains require information or information-related services that are focused, concise, reliable, low cost and timely and which are provided in forms and formats compatible with the user's own activities. In the current Earth Observation (EO) scenario, the archiving centres generally only offer data, images and other 'low level' products. The user's needs are being only partially satisfied by a number of, usually small, value-adding companies applying time-consuming (mostly manual) and expensive processes relying on the knowledge of experts to extract information from those data or images.

In the future, these processes will become even more difficult to perform and to manage because of the growing diversity of the user communities, the greater sophistication of user needs requiring, for example, the fusion of multi-sensor or EO and non-EO data, and the exponential increase in the volume and complexity of the data archives, due to the rapid increases in:
- number of missions (even constellations)
- number of sensors
- kinds of sensed data
- sensor resolution
- number of spectral bands
- number of data formats
- number, type and size of distributed archives.

Today's Synthetic Aperture Radar (SAR) and optical sensors generate 10 – 100 Gbytes of data per day, so that in a multi-sensor spacecraft scenario the volume of data to be archived annually easily reaches 10 Tbytes. However, this figure can sometimes be at least one order of magnitude larger: the Shuttle Radar Topography Mission (SRTM) provided about 18Tbytes of SAR data in just 11 days, and ESA's Envisat spacecraft launched on 1 March 2002 is going to collect about 80 Tbytes of multi-sensor data per year! Future European programmes like GMES (Global Monitoring for Environment and Security) will be even more challenging, unless major progress is achieved soon. Emerging technologies for the automatic extraction, classification and easy provision of information, from EO data alone or after fusion with data and information from other fields, could provide this breakthrough.

After 30 years of remote sensing, for almost any site on Earth there are data takes piling up. They contain valuable information that is not being fully exploited because of the lack of automated tools. New technologies are required to automatically analyse such data and data series to detect changes and trends, for example, which could otherwise remain hidden forever or be detected only by chance.

From data to information

In recent years, our ability to store large quantities of data has greatly surpassed our ability to access and meaningfully extract information from it. The state-of-the-art of operational systems for remote-sensing data access, particularly for images, allow queries by geographical location, time of acquisition or type of sensor. This information is often less relevant than the content of the scene, i.e. structures, objects or scattering properties. Meanwhile, many new applications of remote-sensing data require knowledge of the complicated spatial and structural relationships between objects within an image. This knowledge is 'hidden' in the image's structure and must be 'mined' to retrieve meaningful spectral or polarimetric signatures or objects of higher-level abstraction, such as cities, roads, rivers, forests, etc. The hidden information can relate to very localised phenomena, such as subsidence or even to the structural stability of individual buildings, but can also include phenomena related to global change.

Knowledge-driven information mining from EO archives requires the exploitation of a family of methods for knowledge discovery, learning and automatic information extraction from large amounts of data. It may be performed with the identification of a specific feature and application in mind, such as the high density of strong scatterers and structures in SAR images to detect settlements, hot spots in ATSR products to detect fires, etc. Alternatively, it may be used to identify key features without having a specific application in mind at that very moment.

Companies and research centres around the World are devoting a large effort to the second approach through the design and production of Content-Based Image Retrieval (CBIR) systems. Several attempts have already been made to apply the CBIR approach to EO archives, but difficulties have been encountered in applying searching by global image similarity (the basic concept of CBIR tools) because of the predominance in the EO domain of grey-scale and false-colour imagery. The problem of how the system might remember particular features so that it gets 'smarter' with increasing use is also being addressed.

In Europe, IMF-DLR has been working since 1993 in collaboration with ETH Zurich on developing and refining a novel image information mining concept. Unlike traditional feature-extraction methods that rely on analysing pixels and looking for a predefined pattern, it is based on extracting and storing basic characteristics of image pixels and areas, which are then selected (one or more and weighted) by users as representative of the feature being searched for. This approach has a number of advantages:

- there is no need to re-scan the entire image archive to detect new features
- the selected feature can be closer to the user's expectations and perceptions (the same feature can have different meanings for different users: e.g. a forest for an environmentalist, a forest ranger, a geologist, or an urban planner)
- the system can learn from experts' knowledge.

Drawing upon the research experience of IMF-DLR and ETH Zurich and the systems engineering competence of Advanced Computer System SpA, an ESA Technology Research Programme (TRP) project has been started in ESRIN with the title: 'Knowledge-driven Information Mining in Remote-Sensing Image Archives'. This KIM project takes all of the above background into account, as well as the facts that:

- The huge and exponentially growing volumes of existing and new EO data archives need to be more fully exploited in terms of their true information potential.
- Human-centred computing will play an increasing role in the design of EO data exploitation, i.e. intelligent man/machine interfaces, systems that infer and adapt to user needs, etc.
- Fusion of sensor data with non-EO data and information will be used to better understand the identities of the observed scenes and the Earth cover structures.
- Information mining, knowledge discovery and other exploratory information-retrieval methods should be used to try to fully understand highly complex data, phenomena or global observations.
- There is a need to enlarge and reinforce the reconnaissance/surveillance applications spectrum.
- It is necessary to migrate (adopt and promote) from data to information management and dissemination.

KIM tries to satisfy the requirements of the various communities including:

- End users (access to basic information in a simple way).
- The EO value-adding industry and service providers (access to data and information for enhancing existing and providing new services).
- The scientific community (access to large information sets, e.g. for the analysis of global change).
- Civil protection agencies (access to specific information in support of their operational activities, directly or through service providers).
- Institutions involved in education (access to various data and information types to be used as examples or training cases).

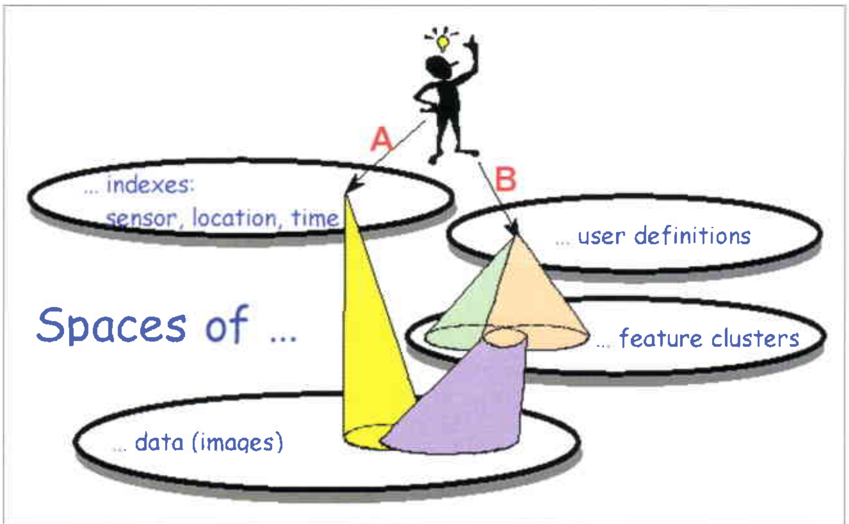


Figure 1. Schematic of current (A) and future (B or A&B) search methods

Table 1. Classification of query attributes

Attribute Type	**Description**
Basic attributes	Sensor, time, latitude, longitude (or location name), directly related for example to raw data or geocoded products
Primitive features	Intensity, texture or shape, for example: attributes that are both objective, and directly derivable from the images themselves, without the need to refer to any external knowledge base
Derived features	Sometimes known as logical features, these are objects of a given type (e.g. 'mountains') or specific objects (e.g. 'Jura-like mountains'). This level involves some degree of logical inference about the identity of the objects and permits searches in user semantic terms (which can be assigned during system training to weighted combinations of primitive features)
Abstract attributes	Involving a significant amount of high-level reasoning about the meaning and purpose of the objects or scenes depicted (e.g. illegal plantation). They are outside the scope of the current research activity.

A better grasp of user interaction

In today's EO ground segments, the retrieval of images is mainly based on sensor, location and time criteria (Case A in the schematic of Fig. 1). A more user-friendly interaction model would also permit searches using other attributes of the image or its parts (Cases B or A&B in Fig. 1). Access to a desired image from the archive might thus involve a search through:
- mission attributes such as sensor, time and location
- the presence of a particular combination of intensity, texture and shape
- the presence of specific 'object' types, e.g. forest, rice field, etc.
- the presence of a particular type of event, e.g. burnt forest, flood.

This list of possible queries represents an increasing level of abstraction, complexity and answering difficulty (requiring more and more reference to some body of external knowledge), corresponding to the increasing complexity of the related attributes, which can be classified as shown in Table 1 (from low to high complexity).

A model based on primitive and derived features would also require semi-automated extraction of primitive features, image annotation in terms of primitive and derived features, and the capability to select, weight and combine primitive or derived features during the query process.

A logical representation of the above classification of attributes is reflected in the model of Figure 2, where the arrows represent logical flows. The upward arrows represent unsupervised algorithmic flow, while the downward one describes the creation of the basic attributes or the user's subjective classification. In fact, the identification of derived features is supposed to be performed only via user subjective classification of objects of a given type. Figure 2 appears to include an additional level with respect to the above classification: the 'primitive feature clusters'. This level is necessary only to reduce the data volume, by grouping into clusters primitive features that show similar behaviours (values). In reality, 'primitive features' and 'primitive feature clusters' pertain to the same level.

First step: extraction of primitive features

The IMF-DLR/ ETH Zurich concept applied in KIM is aimed at building a system free from application specificity, so as to enable its open use in almost any scenario, and also to accommodate new scenarios required by the development of new sensor technology or growing user expertise. Its first step is the extraction of primitive features and the reduction of the resulting data into primitive feature clusters.

The primitive features to be extracted need to be carefully selected, since they mainly determine the quality and capabilities of the resulting system. SAR and optical images, for example, will have to be handled differently and texture primitive features will have to be extracted at various resolution levels, since different textures can dominate at different scales.

The steps necessary to properly extract primitive features in the EO context are shown in Table 2. The steps need to be repeated iteratively for each band of the image.

Primitive feature extraction generates a huge amount of data, which cannot be handled in practice and therefore has to be compressed somehow. This process is represented in the left part of Figure 3, which depicts the result of the scanning of two images (or of two bands of the same image). Each pixel of the image will be located in n-dimensional space in the position determined by the values of the contributing primitive features (their units are non-commensurable, e.g. texture and spectral features). The pixels will tend to group themselves into specific regions of this space. Through clustering (right part of Fig. 3), the 'clouds' of image primitive features are replaced by parametric models of their groups, which can be represented in more compact forms. This reduces the precision of the system, similar to a quantisation process, but permits its practical use thanks to the huge data reduction obtained. The primitive features are compressed into clusters using the K-means approach.

The clusters (condensed representation of primitive features) have no direct meaning, since they group points in an n-dimensional space of non-commensurable variables. Still they represent characteristics of the image seen as a multi-dimensional signal. It is possible to associate meaning with these clusters through training. A user can tell the system that a specific, weighted combination of some clusters represents a derived feature of the image. By making this association, it is possible to select all images in the database that have that specific combination and may therefore contain the feature that the user is searching for. This step is discussed below in more detail.

Second step: information mining

The second step in KIM is aimed at assigning physical meaning to the primitive features, i.e.

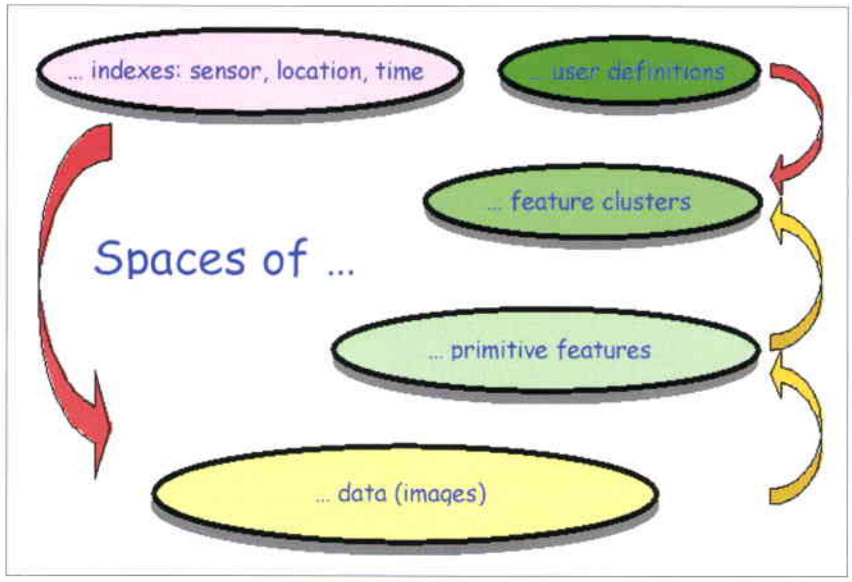


Figure 2. Logical representation of data and derived attributes

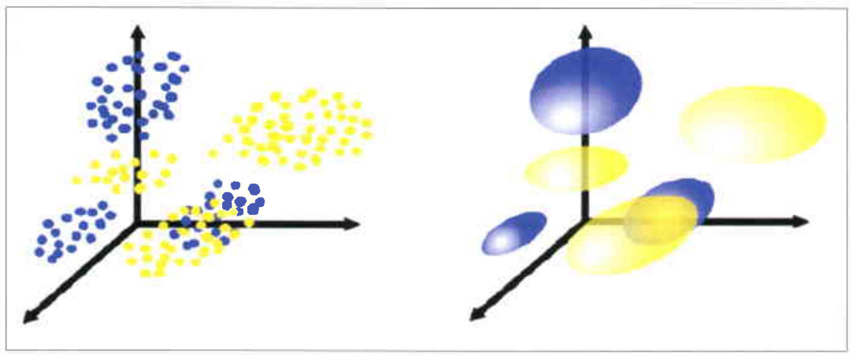


Figure 3. Unclustered and clustered primitive features

Table 2. Steps for primitive feature extraction in the EO context

Step	**Objective**
Image geo-coding	Permit co-registration of different images and absolute geographical reference of the features
Segmentation by geometry	The homogeneous areas that can be detected in the full geo-coded image are assimilated to reference shapes and related to an absolute coordinate system
Sub-scenes	Large images are split into sub-scenes to reduce the probability that an image item contains all the primitive features and therefore that it is always retrieved during a search
Sub-sampling	Perform progressive sub-sampling of each sub-scene to ensure that the various textures are identified at the related scale
Texture analysis:	
Optical image	Extract primitive features using the Gibbs Random Field approach
SAR image	De-speckle the image and extract primitive features using the Gauss-Markov Random Field approach

at identifying 'derived features'. This information-mining step involves a learning phase. The system presents sample images in which the user marks areas with positive and negative traits, refining the definition of the derived feature through an iterative process. Once this process/system training has been satisfactorily completed, the definition can be saved and used by other users, who then will have only to request images containing the derived features corresponding to that definition.

The information-retrieval process is divided into two steps:
- objective information extraction
- semantic representation.

The objective information extraction requires signal modelling as a realisation of a stochastic process. A library of stochastic and deterministic models is used to infer the signal model. The resulting objective features are interpreted according to user conjecture. The interpretation process relies on restructuring (using a certain syntax) of the signal feature space according to the semantic models of the user. Augmentation of the data with meaning can be seen as a data-encoding task including the modelling of the user's understanding.

The source manipulates the information input and provides a filter, which may however also add some process-induced noise. If the user is an expert, he/she plays an active role in training the system, to create relationships between primitive features and definitions. If the user is not an expert, he/she can just use the definitions prepared by other experts for retrieving images from the database.

The expert can train the system by pointing and clicking via a graphical user interface on 'positive' and 'negative' image-structure examples (and therefore the corresponding clusters), in two steps:
- first of all to identify specific broad 'cover-type' definitions, related to broad domains of possible user interest (e.g. geology, forestry, ...)
- therafter to create from the aggregation of the above definitions, and the possible use of additional 'training' pixels, more precise definitions with semantic meaning (i.e. 'concepts', like wood, water, grass, urban area, etc.).

A simple Bayesian network links primitive feature clusters and definitions and these associations can be stored and made available to users for subsequent interactive sessions.

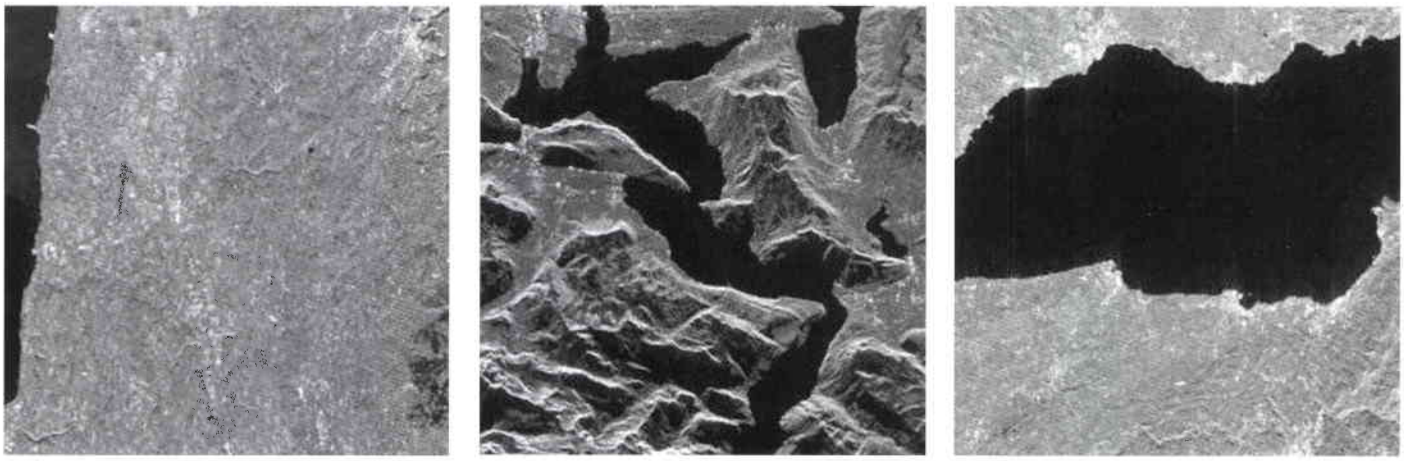
With this approach, we are modelling and learning about the user's interests and actions. We are implementing machine-learning methods to answer the question: What is the user trying to do? We are exploring ways to design an information mining and interpretation system that adapts to the user's particular interests and incorporates contextual information to determine the user's intentions and degree of satisfaction with the results. It should provide a breakthrough by establishing a new pattern for user-EO system (archive) interaction, and a quantum leap with respect to the more traditional feature-extraction systems. The aim with KIM is to help users uncover the most relevant image information content, by providing an 'eye' with which to delve into multi-sensor and multi-temporal image data archives.

Figure 4. Lake Constance on the Swiss-German border (Landsat TM)

Examples of application scenarios

The KIM system provides a wide variety of 'mining' tools, including semantic querying by image content and image example, and interactive classification and learning of image content. As an example, we can take an archive of Landsat TM and Space Radar Laboratory X-band SAR SRL/X-SAR images covering the whole of Switzerland, one of which is shown in Figure 4. The Landsat and X-band SAR scenes have been partitioned into sub-scenes of 2048 x 2048 pixels, with all data geo-coded in a pre-processing step. The user has available a catalogue list of semantically valid land-cover structures, e.g. lakes, forests, alpine valleys, cities, etc. A study of the dynamics of inhabited areas, for example, requires the detection of built-up areas as a first step. The KIM system can search for all SAR images likely to contain settlements larger than a specified threshold, returning the set shown in Figure 5.

Figure 6 shows the result of a search for the cover structure 'glacier'. Each image has associated with it a classification map identifying the structure of interest and a table recording all



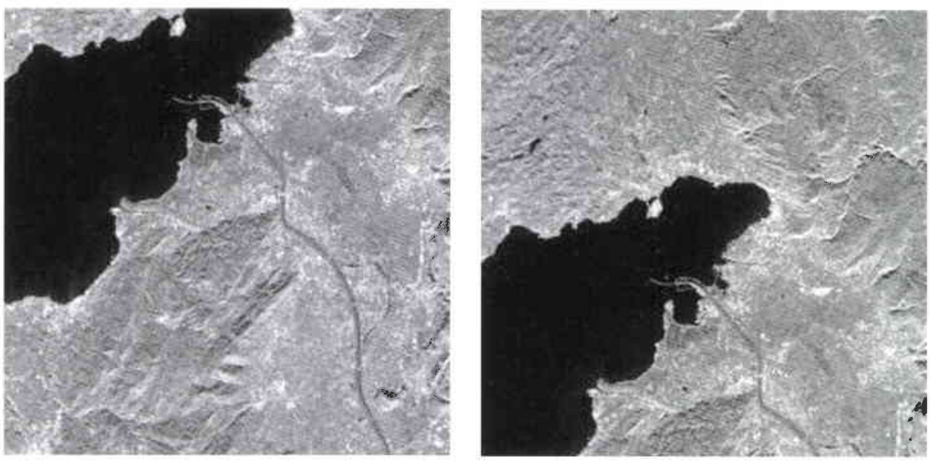
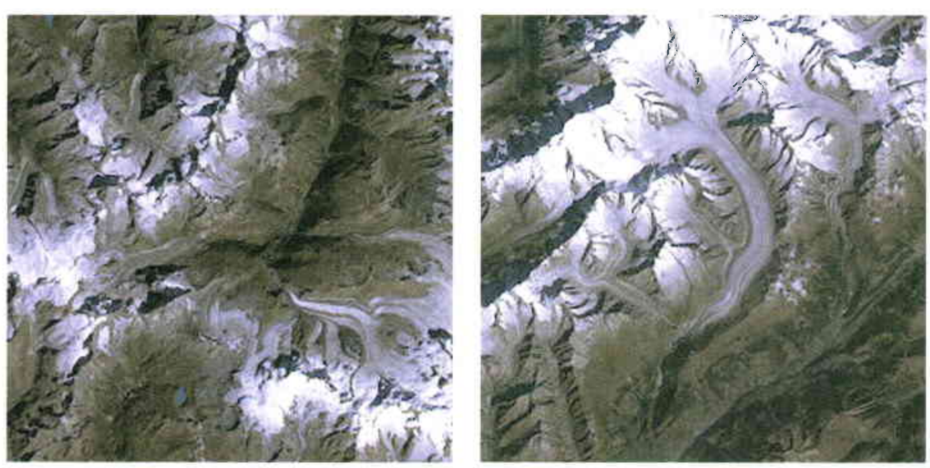


Figure 5. X-SAR images containing built-up areas

Figure 6. Result of a search for cover type glaciers



of the 'structures' that the users have searched for in this image. The latter is a record of the 'image content' seen from the perspectives of users with different interests or backgrounds. The record is created during the interactive learning step.

The interactive learning function is a valuable mining tool for exploring the unknown content of large image archives. A Graphical User Interface (GUI) enables the user to select, by clicking on the image, those structures of greatest interest, which then appear in red on a gray-scale visualisation of the relief

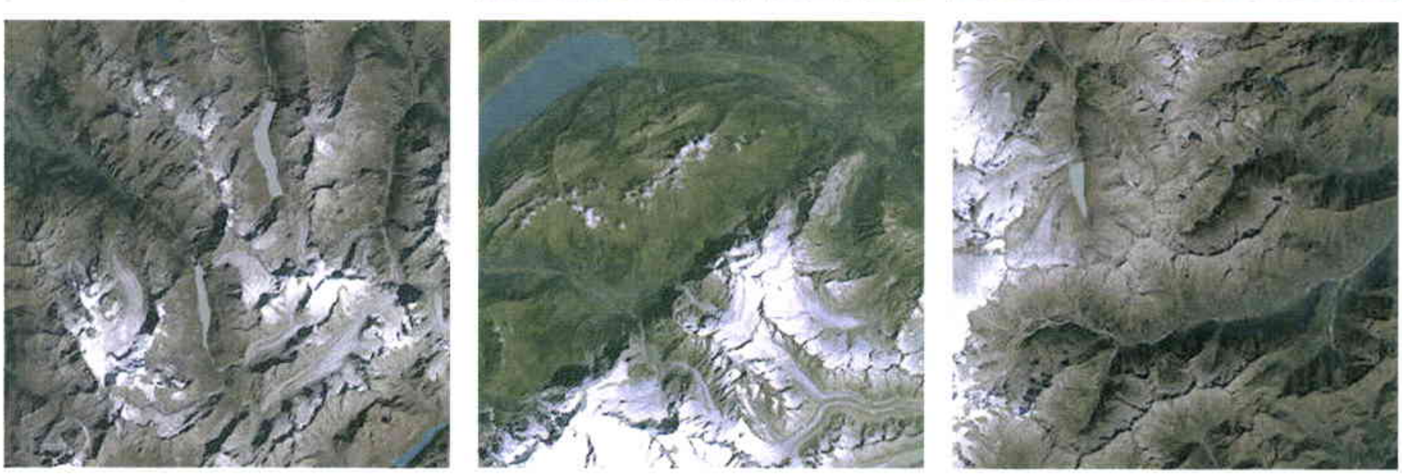
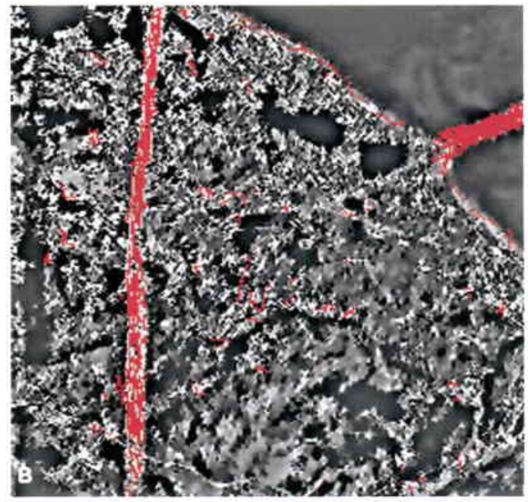


Figure 7
(A) Jet condensation trails in a Landsat image
(B) The user selects the 'interesting' pixels by pointing and clicking
(C) The result of a search for similar features after the selection performed in Figure 7B

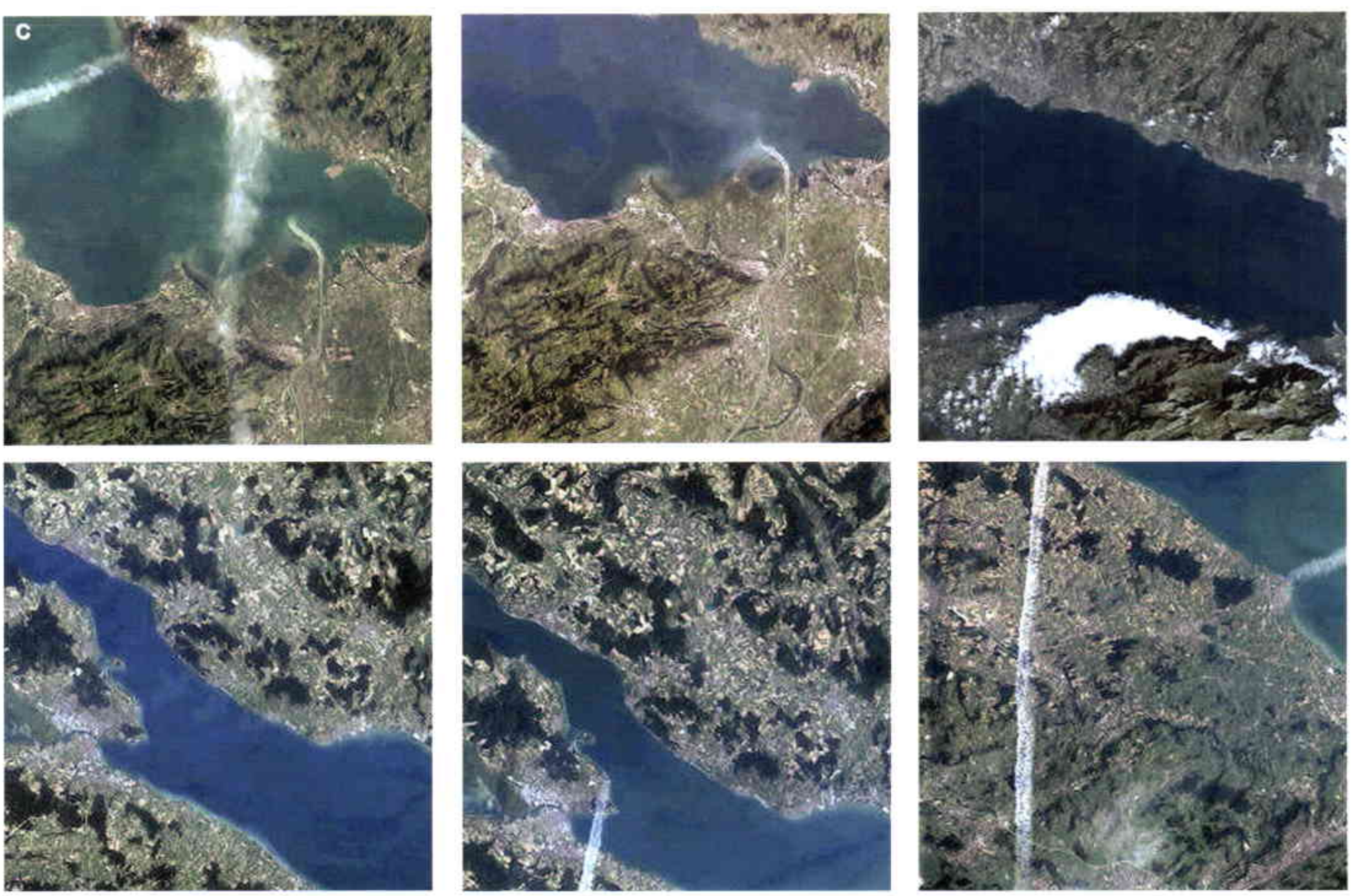


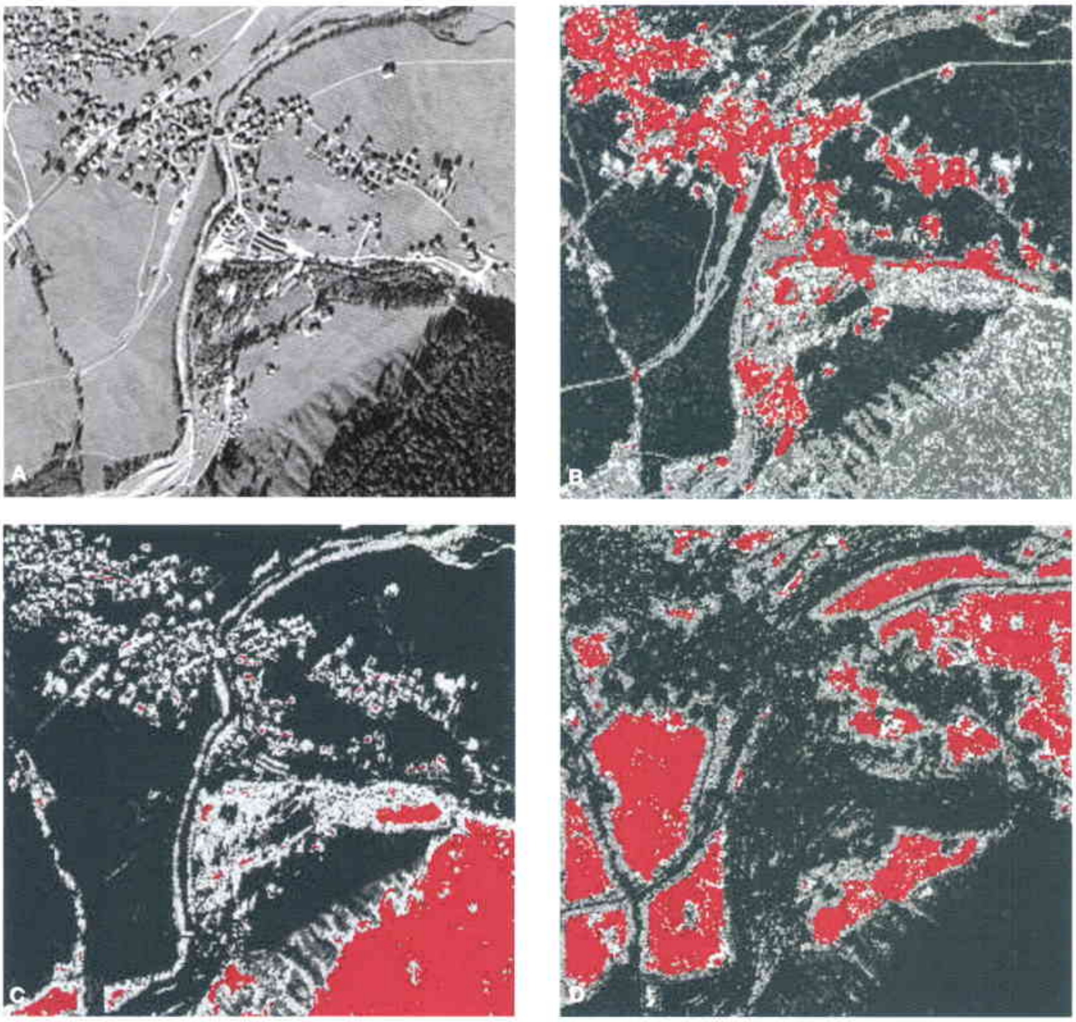
according to the Bayesian learning of the structure recognition (Figs. 7A and B). The scenario in which Figures 7A,B have been produced assumes that the user is interested in finding/studying the condensation trails produced by jet aircraft. The classification is based on the fusion of the image information that best explains the selected structures, i.e. spectral and textural image parameters. KIM thereby provides the user with those images most likely to contain similar structures (Fig. 7C), ranked according to their relevance.

The last examples, in Figure 8, are based on an aerial photograph of a small Swiss village and show how the user can explore the image, marking by pointing and clicking the features of interest. In this case, the red areas associated with 'built-up areas' (Fig. 8B), 'forests' (Fig. 8C), 'meadows' (Fig. 8D) and 'roads' (Fig. 8E), have been generated by a previous user clicking on the image, the KIM interactive learning module being able, in real time, to generate a set of supervised image classification maps. The interactively induced image classification is generalised over the entire image archive.

Conclusions

The technologies for knowledge-driven image information mining are reaching a sufficient level





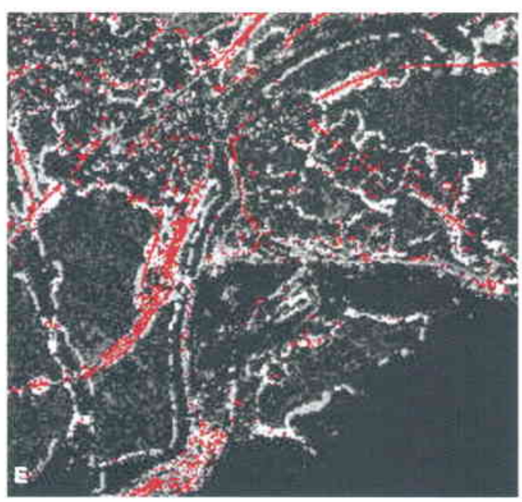


Figure 8.
(A) Aerial photograph of a Swiss village
(B) Selection of built-up area
(C) Selection of forest
(D) Selection of meadows
(E) Selection of roads

of maturity for their integration into commercial products, as has been demonstrated here for a variety of remote-sensing applications. This opens new perspectives and offers huge potential for correlating the information extracted from remote-sensing images with the goals of specific applications.

These technologies shift the focus from data to information, meeting user needs, promoting scientific investigations, and supporting the growth of the value-adding industry, service providers and market, by permitting the provision of new services based on information and knowledge. They will also profoundly affect developments in fields like space exploration, industrial processes, exploitation of resources, media, etc.

The KIM prototype has demonstrated that:
- the results of advanced and very highly complex algorithms for feature extraction can be made available to a large and diverse user community
- the users, who can access the image information content based on their specific background knowledge, can interactively store the meta-information and knowledge
- a new paradigm for the interaction with and exploitation of EO archives can be implemented, paving the way for much easier access to and much wider use of EO data and services.

Acknowledgements
The authors are very grateful to J-L. Valero and H. Touron from the European Union Satellite Centre for their support and comments provided during the preliminary evaluation of the KIM prototype.

"La Vie Commence dans l'Espace"

Pierre Brisson & Frederic Loeb

La conquête spatiale est un rêve et en tant que tel,personne ne saurait se l'approprier. L'essence même du rêve tient dans son existence: on le réalise mais on ne le possède point! Les auteurs s'attachent dans cet ouvrage à répondre aux multiples interrogations suscitées par la conquête spatiale, nouvelle dimension infinie de liberté et de paix, mais également à l'exploitation d'un espace utile, composante stratégique de notre futur. Comment vivre ailleurs que sur notre fragile planète, à échéance de vingt ou trente ans? Qu'en seraient alors les conséquences au niveau de notre vie de tous les jours? Outre un rappel historique des différentes étapes de la conquête spatiale la vie commence dans l'espace, et le rêve peut devenir réalité...

Prix spécial ESA: 30 Euro

ESA Chairs the Committee on Earth-Observation Satellites (CEOS)

J. Achache, CEOS Chairman
Director of Earth Observation Programmes, ESA, Paris

J. Aschbacher, CEOS Secretariat
Directorate of Earth Observation Programmes, ESA, Paris

S. Briggs
Head of Earth Observation Applications Department, ESA Directorate of Earth Observation Programmes, ESRIN, Frascati, Italy

ESA is a founding member of the Committee on Earth Observation Satellites (CEOS) and a permanent member of the CEOS Secretariat. Established in 1984, today CEOS has 23 Members, representing all nations with major Earth-observation programmes, and 20 Associates, who include representatives of the international user community. In November 2001, at its 15th Plenary Meeting in Kyoto, Japan, ESA was elected to chair the Committee. This one-year CEOS Chairmanship is combined with the Co-Chairmanship of the Integrated Global Observing Strategy Partnership (IGOS-P).

CEOS has identified two specific priorities during ESA's Chairmanship, in addition to the overall objective of coordinating Earth-observation missions and activities between the CEOS members. The first is the promotion of sustainable Earth-observation services in support of international policy requirements, such as those arising from the preparation of and follow-up to this year's World Summit on Sustainable Development in Johannesburg (26 August – 4 September), and the second is to develop a long-term strategic plan for CEOS for the next five years.

What is CEOS?

Objectives
The Committee on Earth Observation Satellites (CEOS) was created in 1984 in response to a recommendation from a Panel of Experts on Remote Sensing from Space, under the aegis of the G7 Economic Summit of Industrialised Nations Working Group on Growth, Technology and Employment. This Group recognised the multidisciplinary nature of satellite-based Earth observation and the value of coordinating international mission plans. CEOS has since established a broad framework for coordination across all space-borne Earth-observation missions.

Today, CEOS has three primary objectives:

- to optimise the benefits of space-borne observations through the cooperation of its members in mission planning and in the development of compatible data products, formats, services, applications and policies
- to aid both its members and the international user community by, inter alia, serving as the focal point for the international coordination of space-related Earth-observation activities, including those relating to global change
- to exchange policy and international technical information to encourage complementarity and compatibility among space-borne Earth-observation systems currently in service or being developed, and the data received from them; issues of common interest across the spectrum of Earth-observation satellite missions will also be addressed.

The individual members of CEOS apply their best efforts to implement CEOS recommendations in their respective Earth-observation programmes.

CEOS is currently revisiting its strategy and ESA has been asked, during its chairmanship, to coordinate the development of a long-term strategic plan for CEOS for the next five years.

Membership
Since its inception, CEOS's membership has grown to encompass all of the World's civil agencies responsible for Earth-observation satellite programmes, along with agencies that receive and process data acquired remotely

from space. At its 1990 Plenary Meeting in Brazil, CEOS extended its outreach to include international user organisations – including scientific, policy and inter-governmental groups such as the World Meteorological Organisation and the global Climate Observing System, which now have Associate status. Governmental organisations that are developing a space segment or have significant ground-segment activities can also become Associates. Currently, CEOS has 23 Member organisations and 20 Associates.

Structure
The central structure of CEOS includes a Plenary Assembly, which meets every twelve months (Fig. 1). The CEOS Secretariat takes care of business between plenary sessions. It is comprised of members of ESA, NASA, NOAA, MEXT/NASDA, and the Working Group Chairs, as well as one member from each of the past, current and future CEOS chair organisations. The Chairmanship of the Plenary rotates every year: INPE in 2000, NASDA/MEXT in 2001, ESA in 2002, NOAA in 2003 and China in 2004.

CEOS Members

Organisation		*Country / Countries*
ASI	Agenzia Spaziale Italiana	Italy
BNSC	British National Space Centre	United Kingdom
CAST	Chinese Academy of Space Technology	China
CNES	Centre National d'Etudes Spatiales	France
CONAE	Comisión de Actividates Espaciales	Argentina
CSA	Canadian Space Agency	Canada
CSIRO	Commonwealth Scientific and Industrial Research Organisation	Australia
DLR	Deutsches Zentrum für Luft- und Raumfahrt	Germany
EC	European Commission	Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Norway, Portugal, Spain, Sweden, United Kingdom
ESA	European Space Agency	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom
INPE	Instituto Nacional de Pesquisas Espaciais	Brazil
ISRO	Indian Space Research Organisation	India
KARI	Korea Aerospace Research Institute	Korea
NASA	National Aeronautics and Space Administration	United States of America
NASDA/MEXT	National Space Development Agency of Japan/ Ministry of Education, Culture, Sports, Science and Technology	Japan
NRSCC	National Remote Sensing Center of China	China
NSAU	National Space Agency of Ukraine	Ukraine
NOAA	National Oceanic and Atmospheric Administration	United States of America
ROSHYDROMET	Russian Federal Service for Hydro-meteorology and Environment Monitoring	Russia
ROSAVIAKOSMOS	Russian Aviation and Space Agency	Russia
SNSB	Swedish National Space Board	Sweden
USGS	United States Geological Survey	United States of America

Figure 1. The delegates to the 15th CEOS Plenary, which took place in Kyoto, Japan, on 6/7 November 2001

CEOS Associates

Organisation		*Country / Organisation*
CCRS	Canada Centre for Remote Sensing	Canada
CRI	Crown Research Institute	New Zealand
CSIR	Satellite Applications Centre (SAC)/ Council for Scientific and Industrial Research	South Africa
ESCAP	Economic and Social Commission of Asia and the Pacific	UN
FAO	Food and Agriculture Organization	UN
GCOS	Global Climate Observing System	International Programme
GISTDA	Geo-Informatics and Space Technology Development Agency	Thailand
GOOS	Global Ocean Observing System	International Programme
GTOS	Global Terrestrial Observing System	International Programme
ICSU	International Council for Science Unions	International Programme
IGBP	International Geosphere-Biosphere Programme	International Programme
IOC	Inter-governmental Oceanographic Commission	UNESCO
IOCCG	International Ocean Colour Coordinating Group	International Programme
ISPRS	International Society for Photogrammetry and Remote Sensing	International Programme
NRSC	Norwegian Space Centre	Norway
OSTC	Federal Office for Scientific, Technical and Cultural Affairs	Belgium
UNEP	United Nations Environment Programme	UN
UNOOSA	United Nations Office of Outer Space Affairs	UN
WCRP	World Climate Research Programme	International Programme
WMO	World Meteorological Organisation	UN

CEOS develops many of its activities through a number of Working Groups.

Working Groups

Working Group on Calibration and Validation (WGCV), and its subgroups
The Working Group on Calibration and Validation (WGCV) was established in 1984. It resulted from the recognition that calibration and validation activities should play a key role in all satellite Earth-observation missions to ensure a clear and quantitative understanding of the data that they generate. The goal of the WGCV is to promote international co-operation in the calibration of data from space-borne sensors and in the validation of associated geophysical parameters and derived products. The WGCV comprises six sub-groups: (i) Infrared and Visible Optical Sensors, (ii) Microwave Sensors, (iii) Synthetic Aperture Radar, (iv) Land Product Validation, (v) Terrain Mapping, and (vi) Atmospheric Chemistry.

The WGCV's activities are described in a three-year work plan approved by the CEOS Plenary and comprise technical work and workshops of subgroups, a calibration/validation dossier, pilot projects and the organisation of WGCV meetings. Recently, the focus has intensified on the validation of geophysical parameters and derived products to support the CEOS involvement in developing IGOS. WGCV outreach is ensured through the WGCV newsletter, a new web-site (http://www.wgcvceos.org) and publications from subgroup workshops (e.g. ESA SP-450).

Working Group on Information Systems and Services (WGISS), and its subgroups
WGISS has the goal of coordinating and standardising Earth-observation data management and services. The group addresses the needs of data providers by assisting them in improving the efficiency of their operations and maximising the utilisation and benefits of the EO data that they gather, and in supporting data and information users by providing simpler and wider access to the resources that they acquire. WGISS is currently supported by three subgroups, dealing with access, data and networks.

WGISS places great emphasis on the use of demonstration projects involving user groups to solve the critical interoperability issues associated with the achievement of global services. WGISS has both developed a number of tools and services and contributed to the development of standards to assist access to and use of Earth-observation data resources available on-line.

Ad-hoc Working Group on Disaster Management Support (DMSG)
The aim of the Ad-hoc DMSG is to develop and refine recommendations for the application of satellite data to natural and man-made disasters. Particular emphasis is placed on working closely with space agencies, international and regional organisations, and commercial organisations, on the implementation of these recommendations. The continuation of the Ad-hoc DMSG has been renewed on an annual basis and will conclude its activities at the 16th CEOS Plenary in November 2002.

Ad-hoc Working Group on Education (WGEdu)
The goal of the WGEdu is to promote access to and use of Earth-observation data and services for a wide community of existing and potential users. Particular emphasis is put on servicing the education and training needs of developing countries. A three-year strategy was adopted at the last CEOS Plenary in November 2001. To highlight the importance of training activities in Earth observation, the WGEdu plans to organise an 'Education and Training Summit' in conjunction with the next CEOS Plenary in November 2002 at ESRIN in Frascati (I).

Relationships with IGOS-P and SIT

IGOS and IGOS-P
CEOS has embraced the concept of an Integrated Global Observing Strategy (IGOS), primarily to fulfil its own set of objectives and to derive greater benefit from both already operating and planned observing systems. IGOS intends to unite the major satellite and ground-based systems for global environmental observations of the atmosphere, oceans, land and life.

Today, the IGOS Partnership (IGOS-P) has 14 Members, from both the supply and demand sides. CEOS is one of the Members of IGOS-P. To underline the importance of space observations as part of an integrated global observing system, CEOS is providing one of the two Co-Chairs of IGOS. IGOS-P Plenary Meetings are scheduled once per year, normally around end-May/early-June, and are hosted by one of the two Co-Chairs. The 9th IGOS Plenary Meeting is scheduled for 31 May 2002, at UNESCO in Paris. UNESCO and ESA are the Co-Chairs of IGOS-P for 2002.

Strategic Implementation Team
In order to prepare the IGOS issues on the CEOS side, the Strategic Implementation Team (SIT) was established in 1996 to assess the maturity of CEOS demonstration projects for transition to IGOS themes, which require some commitment in terms of resources from space

agencies in support of agreed themes. As an ad-hoc group, the SIT's mandate has been renewed annually. The SIT played an important role in shaping the development of the IGOS Partnership in 1998, and it has provided the necessary forum for senior members of space agencies to engage in the CEOS process. SIT was confirmed as a permanent group at the CEOS Plenary 2001, with a revised mandate to focus on the interfacing of CEOS with IGOS-P.

Eumetsat is chairing the SIT for a period of two years, from November 2001 to November 2003.

Implementation of IGOS through 'themes'
With a view to broadening IGOS to include the observing activities of all partners, the 'themes' concept was developed to provide a more coherent focus for its definition and implementation activities. Both IGOS-P and CEOS endorsed the theme approach.

The themes have been debated at length in the SIT. The Global Ocean Data Assimilation Experiment (GODAE) and the Global Observation of Forest Cover (GOFC) project, which were in the original list of CEOS/SIT projects, are already providing concrete results. The GOFC WGISS Test Facility, which was demonstrated at the CEOS Plenary 2001, is based largely on web-based data-access tools developed by ESA.

ESA is involved in all of the above projects, experiments and theme preparations.

ESA's involvement in CEOS

Objectives of ESA's involvement
ESA's involvement in CEOS is driven by five main objectives, derived from the objectives of the Committee itself:
– *Mission co-ordination:* ESA wants to ensure that its current and planned missions are well co-ordinated with those of other space agencies around the World. This includes the space as well as the ground segment. Through CEOS, ESA is in a good position to learn about the upcoming Earth-observation missions of other space agencies at an early (planning) stage. CEOS has frequently served as a forum where ideas have been exchanged informally, resulting in separate, sometimes bi-lateral agreements thereafter (e.g. GCOM/SWIFT between NASDA and ESA).

– *Standardisation:* ESA is interested in exchanging information on current data access and distribution standards in order to allow a seamless exchange of data between its own missions and those of other space agencies. This task, which is extremely important for users from the scientific, commercial and public sectors, aims at facilitating and promoting a wider use of Earth-observation data. ESA, together with partners from other European organisations and its own Member States, has been very active in establishing common data-exchange and data-access formats. One example is the CEOS Catalogue Interoperability Protocol (CIP), which was co-led by ESA and the European Commission, and which serves as the basis of today's main Earth-observation catalogue interoperability protocols.

– *Sensor calibration, validation and inter-comparison:* ESA has a need to calibrate, validate and compare data from its own missions and sensors with those of other, sometimes similar or related sensors. This facilitates the access and exchange of data from various Earth-observation missions for scientists and commercial users alike. Again, this enables a flexible and wider use of ESA's data, thereby contributing significantly to the development of sustainable Earth-observation-based information services. Good examples are several major sensor calibration and validation experiments, which have been carried out in the (active and passive) microwave, optical and infrared domains in support of ESA's ERS sensors, as well as preparatory experiments in support of Envisat's new suite of sensors. A new subgroup on atmospheric chemistry has been adopted within the WGCV, which is of particular relevance for the calibration, validation and inter-comparison of sensors onboard Envisat.

– *International co-ordination:* Through its participation in CEOS, ESA acts as a focal point for its members in the international co-ordination of space-related Earth-observation activities. Examples include the presence of CEOS in international user communities or organisations, such as in IGOS, in the global observing systems (G3OS), or, more importantly for the future, in the UN Framework Convention on Climate Change (UNFCCC) at its Committee of Parties (COP), the World Summit on Sustainable Development (WSSD) or similar committees and forums.

– *Development of sustainable EO services:* ESA has, like other space agencies, expressed an interest in developing long-term, sustainable information services based on Earth-observation data. The monitoring of the implementation of the Kyoto Protocol is but one of the many examples at stake. ESA, in concert with its international partners, will work at the policy as well as the technical level to achieve this goal, which is also one of the guiding principles of GMES.

ESA's support to the CEOS process

ESA contributes to CEOS by playing an active role in the CEOS Plenary and Secretariat. It is one of the three permanent members of the Secretariat (the others are NOAA/NASA and NASDA/MEXT), which works through frequently held formal meetings (approx. one every two months, mostly via teleconferencing) to discuss and harmonise the various issues at stake. Informal correspondence is exchanged on a daily basis in making progress between these meetings.

In addition to the work of the Secretariat, a large amount of technical work is carried out in the Working Groups. ESA currently holds the chair of the Working Group on Calibration and Validation (WGCV) for a period of three years, and has an active representation in the Working Group on Information Systems and Services (WGISS), as well as the ad-hoc Working Groups on Disaster Management (DMSG) and Education (WGEdu). In addition, ESA representatives lead several sub-groups within the WGCV and WGISS. ESA has also hosted and/or organised several of the CEOS Working Groups and their sub-groups (e.g. the WGCV Plenary in July 2001 and the WGISS-14 Subgroup meeting in April 2002, both at ESRIN).

ESA, together with CNES and CSA, has established the 'Charter on Disaster Management', which co-ordinates the (operational) provision of space data in the event of natural or man-made disasters. CEOS has invited other members to join the Charter, some of whom have already joined or expressed interest (i.e. NOAA, NASDA, etc.).

CEOS and the World Summit on Sustainable Development

The World Summit on Sustainable Development (WSSD) is being organised by the United Nations from 26 August to 4 September 2002 in Johannesburg, South Africa, with representation at Head of State level.

The CEOS member organisations have requested that this event become the main focus of CEOS during ESA's Chairmanship in order to support one of its main goals, namely the development of long-term, sustainable EO-based information services for the international user community. Earth observation has been proven to be an efficient tool for monitoring the state of the global environment, which is one of the leading themes of the Earth Summit. Hence ESA will take this opportunity to advance these objectives, in close cooperation with its Member States, its European partners, the CEOS partners and IGOS.

CEOS presented a statement at the recent 2nd Preparatory Committee Meeting (PrepCom II) of the WSSD held in January/February 2002 in New York, whereby the national delegates were invited to:

1. ACKNOWLEDGE the high importance of Earth observation from satellites for the provision of operational services and information in support of sustainable development.
2. RECOGNISE the progress made in the capability and responsiveness of Earth observation since the Rio Earth Summit in 1992.
3. ENCOURAGE the space organisations, through their member states, to ensure the long-term continuity of Earth-observation systems, which are of relevance to sustainable development – using appropriate mechanisms to achieve this goal.
4. RECOGNISE the potential benefits of partnership with CEOS, as the international forum responsible for the coordination of international needs for space-based Earth-observation data and information in support of international treaties and conventions relating to sustainable development; this includes, in particular, the activities arising from the World Summit on Sustainable Development.
5. ENCOURAGE an intense dialogue between decision makers involved in the follow-up of the outcome of the WSSD (representing the demand side) and the international Earth-observation community (representing the supply side) in order to ensure that Earth observation can best be put at the service of sustainable development.

CEOS Secretariat Contacts

ESA
8-10 rue Mario Nikis
75738 Paris Cedex 15
France

josef.aschbacher@esa.int

NASA/NOAA
300 E Street, SW
Washington DC 20546
USA

leslie.charles@hq.nasa.gov
brent.smith@noaa.gov

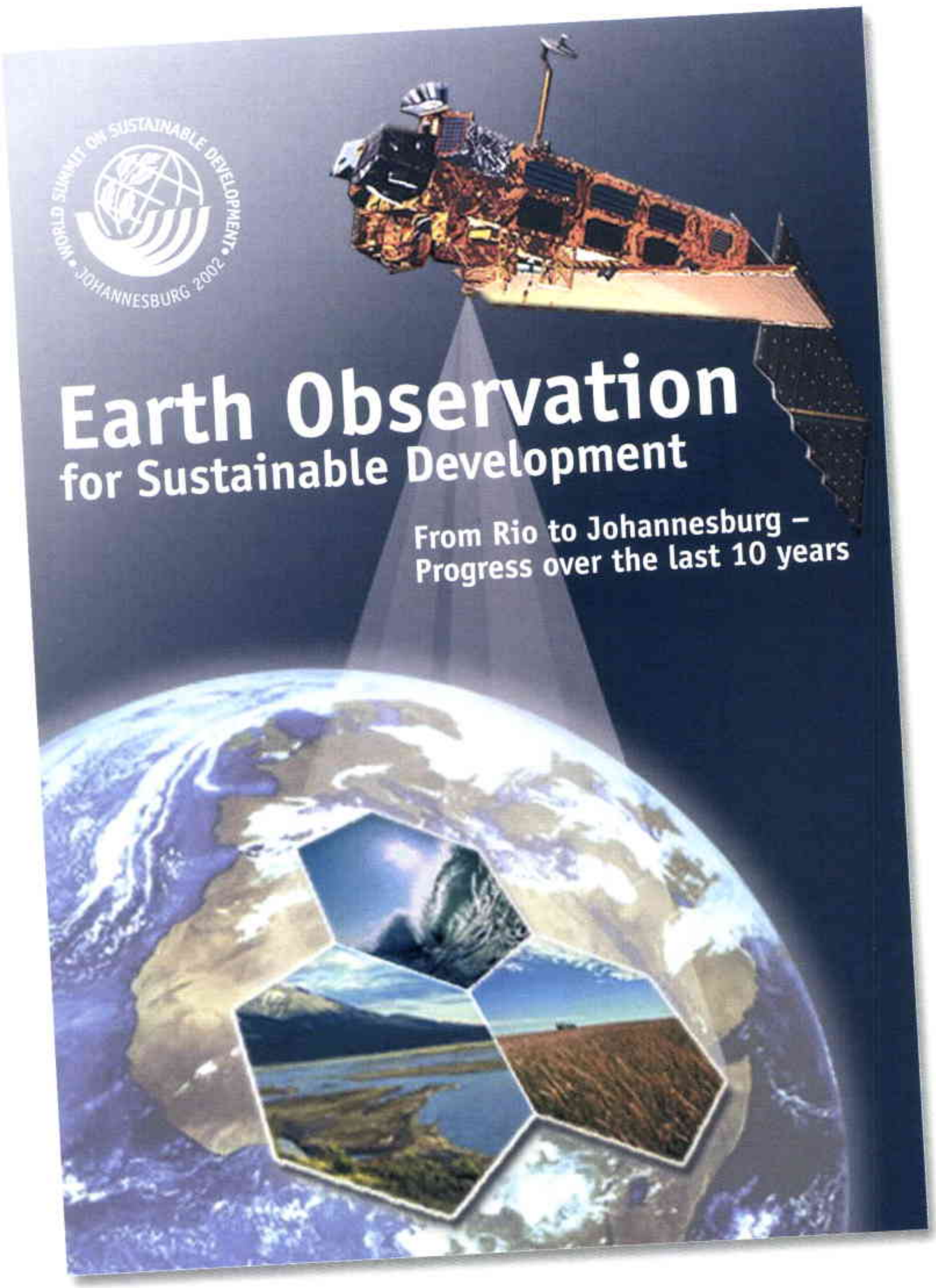
NASDA/MEXT
2-4-1Hamamatsu-cho,
Minato-ku, Tokyo, 105-8060
Japan

ishida.chu@nasda.go.jp

The aim is that information retrieved from Earth observation should be recognised as a key information source in support of sustainable development.

CEOS Plenary 2002

The concluding event of ESA's CEOS Chairmanship, the next CEOS Plenary, will be organised at ESRIN Frascati (I), from 19 to 21 November 2002. It will be accompanied by an 'Education and Training Summit' as well as a 'WSSD follow-up event', which will be open to a wider audience including high-level decision makers. At this 16th CEOS Plenary, ESA will hand over the Chair to the next incumbent, NOAA.



Industrial Cost Auditing at ESA

D. Greves
Cost Analysis Division, ESA Directorate of Industrial Matters and Technology Programmes, ESTEC, Noordwijk, The Netherlands

The industrial cost audit function is of vital importance for an organisation like ESA, which dispenses of the order of 88% of its annual budget in placing contracts with space-sector contractors. As an intergovernmental organisation spending tax-payers' money, ESA has an obligation to ensure that it has an effective procurement process and to obtain value for money, and the audit activity is an essential part of this process. By obtaining value for money, ESA not only obtains a proper return for its Member States' investments, but also ensures that the maximum can be achieved in terms of the challenging missions that the Agency undertakes.

What is auditing?

In a wider context, the term auditing is used for a number of different activities, which can be quite different in nature, namely:
- financial statement audits
- operational/management audits
- compliance audits.

Most companies and associations in most countries are required to have their financial statements audited by independent auditors. The auditors will issue a formal statement that the accounts presented are (or are not, as the case may be) in compliance with generally accepted accounting standards, and that they represent (or do not represent) a fair and true view of the situation. In view of recent events in the commercial world, and the unexpected failure of a major US corporation, the performance of auditors in this capacity has been called into the question, in particular because of possible conflicts of interest and the extent to which auditors whose firms also provide consultancy services to the same companies can be said to be able to offer a truly independent audit service to those companies.

Operational/management audits involve an investigation of the operating procedures and processes of an organisation in order to assess their efficiency and effectiveness. This will result in a report of the findings and recommendations to the management for improving the operations.

Compliance audits are for the purpose of determining whether an organisation is properly following specific rules, procedures or regulations laid down.

The ESA Audit Commission and Internal Audit

In the ESA context, there is the Audit Commission and the Internal Audit Section, as well as the industrial cost-auditing activity. The Audit Commission is appointed by the ESA Council and the Internal Audit Section is responsible to the Director General. The main responsibility of the Audit Commission is auditing the Agency's financial statements and verifying the adequacy of internal controls, including the internal audit. Both the Audit Commission and the Internal Audit Section are concerned with operational and compliance audits, looking at individual aspects of the way ESA conducts its business, reporting on findings and making recommendations for improvements.

Industrial cost auditing

The Industrial Cost Auditing Section is part of Cost Analysis Division, which is now in the recently formed Industrial Policy and Cost Analysis Department, after previously being in the Contracts Department for many years. There are many synergies to be exploited between the industrial-policy and cost-analysis functions and Cost Analysis retains close working relations with the Contracts Services, both being in the Industrial Matters and Technology Directorate. The other main activity of Cost Analysis Division is cost engineering, which is not considered here.

The industrial cost audit activity differs from that of the Audit Commission and of the Internal Audit Section in that it is totally in support of the procurement function and as such is focused completely on the operations of ESA contractors and their costs. The main tasks of the industrial cost auditors are therefore as follows:

- Verification of contractor cost accounting systems in order to ascertain compliance with generally accepted accounting principles and with the ESA General Clauses and Conditions. Also, where applicable, to establish adequacy of the accounting system for cost-reimbursement contracts.
- Audit of direct expenditure on cost-reimbursement contracts.
- Audit of direct expenditure and verification of sources of company contributions on co-funded contracts.
- Ascertaining the financial viability of contractors (on an ad-hoc basis).
- Special audit and cost-analysis exercises (on an ad-hoc basis).
- Verification/negotiation of industrial hourly labour rates and overheads, other overheads, and unit rates, such as facility charges. This task involves liaison with national authorities, where applicable.
- Where audits are not conducted by ESA or audit results are not available from national authorities, making judgements on request regarding the acceptability of quoted rates and overheads based on an expert-judgement approach.
- Agreement of price variation formulae for contract elements on a 'fixed price with variation basis.
- Advice on the conversion of fixed prices to firm fixed prices.
- General advisory service on financial matters in contracts, e.g. currency-related matters, finance and payment schemes, company cost-allocation structures, business plans, etc.
- Participation in evaluations.
- Inputs to negotiations.

The first five of these tasks are of the traditional auditing kind involving verification and assessment, whereas the remainder are associated with establishing prices, which is rather more of a commercial-type activity.

Verification of accounting systems
The first task of an auditing nature, the verification of the contractors' accounting system, is akin to the type of quality audit

carried out by our ESA Product Assurance Department colleagues when they check that an adequate system is in place to ensure that certain processes will be carried out properly on a consistent basis. Any such system should have adequate controls and safeguards, and this is certainly true of accounting systems.

Audits of cost-reimbursement contracts
For cost-reimbursement contracts, audits are performed at the end of the contract, or in the case of major contracts on an annual basis. The audit is usually carried out by a team comprised of the industrial cost auditor and project representatives, usually a project controller. The involvement of project personnel is usually regarded as being essential as they are familiar with the work that has been performed under the contract. However, the formal audit does not in any way obviate the need for active cost control during the contract on the basis of regular cost reports submitted by the contractor. This can be expected to give rise to queries, which should be investigated at the time to obtain satisfactory explanations from the contractor or, in some cases, to permit remedial action to be taken in good time. In such cases, if queries are not pursued, it will normally be too late to do anything if it is left until the time of the audit to raise the matter with the contractor. Nevertheless, some project related queries have to be dealt with at the time of the audit because it may not be possible to make a meaningful assessment until the total costs for a particular aspect are known, and because information available at the time of the audit, although only a sample of the total cost, is usually much more detailed and accompanied by full supporting vouchers and accounting source documents.

Audit findings vary significantly from contractor to contractor, and even sometimes from project to project within a particular contractor. This will depend on the quality of the company accounting system and the rigor with which it is applied and also, to some extent, on the particular accountants and project personnel involved.

Typical irregularities identified during audits are the following:
- Charging direct to contract items that are included in the overheads.
- Charging capital items to contract.
- Charging the cost of fixed-price activities to a cost-reimbursement area.
- Wrong bookings, in terms of charging to the wrong work package or contract.
- Charging proposal costs direct to the contract.
- Charging other un-allowable expenditure as per the General Clauses and Conditions.
- Charging other un-allowable expenditure as per the contract.
- Lack of agreement on special arrangements, e.g. for staff working away from the home base.
- Unsubstantiated travel costs.
- Travel costs exceeding limits in the company regulations or in the contract.
- Unsubstantiated purchases.
- Partly allowable costs being charged in full to contract.
- Expenditure incurred outside the period of authorization.
- Incorrect application of overheads.

In order to ensure, as far as possible, that cost claims are valid, and to help improve the efficiency of the audit process, the Agency requires that before establishing the final claim contractors carry out an internal audit and that the Financial Director or his authorised representative makes the following certified declaration:

"I ...., do hereby certify that the costs presented on the above statement are, to the best of my knowledge and belief, a true statement of the costs incurred, an internal review of the costs having been conducted to verify that the company's accounting system and rules and the Agency's requirements in Annex 1 to the General Clauses and Conditions, ESA/C/290, rev. 5, have been observed."

Co-funded contracts

A variation of a cost-reimbursement contract is the co-funded contract. In standard ESA procurements the Agency pays for 100% of actual allowable cost within the financial limit of liability on a cost-reimbursement contract, and also 100% of the agreed estimated cost on a fixed price contract. In a co-funded contract, the Agency pays for only part of the total cost,

this typically being 50% but with higher percentages sometimes for Small and Medium-sized Enterprises (SMEs) and for academic institutions. These percentages are specified in the programme Implementing Rules. Above a certain financial threshold, most of the co-funded contracts are awarded on the basis of a ceiling price to be converted to a firm fixed-price basis on completion of the work and acceptance by the Agency of the final costs. The Agency is entitled to have full visibility of costs incurred and to conduct audits, as in the case of the traditional cost-reimbursement contract.

An audit of a co-funded contract has the same objective to verify that costs have been incurred as claimed and that they are allowable. In addition, the contractor is required to make a certification with respect to the contractors' own contribution to confirm that it has not been provided by another public body, in which case it would be considered to be a 'State Aid', and also that it will not be recharged to the Agency through being included in the overheads.

Contractor financial viability

The question of ascertaining contractors' financial viability is a difficult one. With well over one thousand contractors with whom it regularly places contracts, it is not possible for ESA to do this systematically. This is partly because the Agency does not have the resources to do so, but it would anyway not be cost-effective as it is a relatively small minority of companies who get into financial difficulties, and any assessment can only represent a snap-shot of the situation at that time whereas circumstances can change rapidly. It is true that there may be indications of financial instability of a more permanent nature such as under-capitalisation, but more often the problems are a consequence of specific events.

The main means for identifying financial problems are from:
- the visibility provided by performing verification of rates and overheads or audits of cost-

reimbursement contracts and consideration of certain financial ratios
- credit-rating agencies
- notification of problems by the companies themselves or by third parties
- reports in the financial press.

The fact is that it is inevitable that, from time to time, problems of this nature of which there has been no prior warning will occur. In such cases, Cost Analysis Division investigates the situation and works in close collaboration with the contracts services to asses what the implications are and to see what action has to be taken. It is important in this process to maintain strict confidentiality and to only involve those who would be impacted by a financial failure. Unsubstantiated rumours in this respect can be very damaging and a loss of confidence concerning the financial viability of a company can lead to actions which become self-fulfilling prophesies.

The concept of 'fair and reasonable prices'
Apart from specific audits undertaken on an ad-hoc basis, most of the remaining tasks undertaken relate in some way to pricing and are of a more commercial nature, as opposed to classical auditing activities. However, an important aspect of the way in which industrial cost auditors perform their duties is that they are seeking to establish fair and reasonable prices, which does not necessarily mean the cheapest price.

The ESA pricing approach is based on the concept of full recovery of 'reasonable costs', defined in the General Clauses and Conditions as being 'those costs which would be accepted by a prudent person in the conduct of competitive business'. This means that cost claims have to be compatible with certain minimum requirements such as acceptable levels of productivity and of facility utilisation. Thus costs that have been incurred and which are normally regarded as being allowable may nevertheless be regarded as resulting from inefficiency, which is not acceptable and which has to be corrected. Such aspects, together with estimated or budgeted cost elements, are negotiable and can represent a significant cost in the context of the company's business with the Agency. Even with companies familiar with the Agency's policies and approach, this process can result in significant reductions in the amounts proposed, but with contractors new to this sort of scrutiny the reductions can even be spectacular. In a few cases, contractors, particularly small companies, sometimes unwittingly submit rate proposals that would significantly under-recover costs and which are therefore unsustainably low. In such cases, there can be agreement of unexpected rate increases which are, perhaps not surprisingly, criticised by the uninformed.

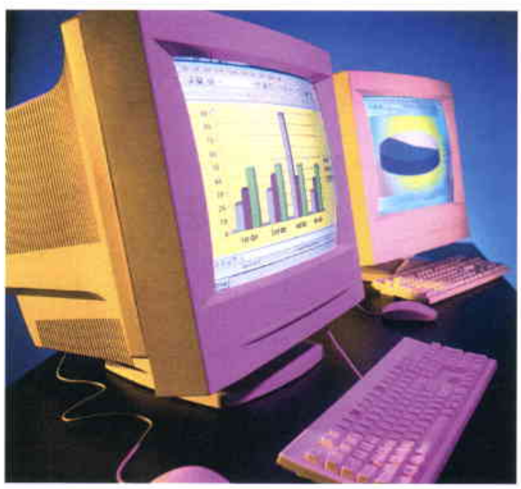
However, apart from any industrial-policy considerations with respect to ESA's obligation under its Convention to support the development of industry, the policy of agreement of fair and reasonable prices would certainly have been endorsed by the English writer John Ruskin (1819-1900), who wrote:

"It's unwise to pay too much, but it's worse to pay too little. When you pay too much, you lose a little money, that is all. When you pay too little, you sometimes lose everything, because the thing you bought was incapable of doing the thing it was bought to do. The common law of business balance prohibits paying a little and getting a lot - it can't be done. If you deal with the lowest bidder, it is well to add something for the risk you run, and if you do that you will have enough to pay for something better."

Agreement of rates and overheads
The verification of rates and overheads and other unit charges is, in financial terms, the most important task of the auditors, but the nature, importance and complexity of the task is often not fully understood or appreciated. The rates and overheads are the basic building blocks of the price. For major companies there are enormous numbers of hours involved, and relatively small variations in the rates or apparently minor changes in the allocation of costs to specific cost centres can have a significant impact on the overall costs. The complexity of the rate structures can vary considerably, with some major companies having well in excess of 60 cost centres. In some cases, final rates are agreed taking account actual costs in the past and a budget prediction for the future. Alternatively, they may be agreed on a provisional basis, based on

budget predictions and then on a final basis retroactively once actual costs and utilization are known. There are also cases where rates for a particular year are determined by extrapolating previously approved rates, but this approach will usually only be valid for a short time and provided there are no changes in the company's accounting structure.

The process of establishing rates and overheads is an active control function rather than simply being an arithmetic or 'bean-counting' exercise. There are judgments to be made and key points to be negotiated, particularly with respect to allowability of costs, utilisation/productivity levels, inter-company charges and extraordinary charges and allocation of shared costs. At this juncture it should be pointed out that many people are not aware of the fact that as far as 'rules' are concerned, cost accounting permits great flexibility of approach. Whilst there are international accounting standards and



generally accepted accounting principles that must be adhered to, there are many options which may be adopted with respect to different accounting issues. Even in France where the 'Guide Comptable', imposed a large measure of standardisation with respect to the accounting structures for French aerospace companies, this approach has now been abandoned in recognition of growing internationalism and the need for greater flexibility with cross-border mergers. The ESA General Clauses and Conditions, which have to be applied to companies in the fifteen Member States, whilst being very specific about certain aspects such as the exclusion from the overheads of imputed interest and limitations with respect to R&D expenditure, only contain three pages defining allowable cost, partly allowable cost and non-allowable cost. Within certain boundaries, there is therefore considerable scope for interpretation of specific provisions and their application.

In the negotiation of rates and overheads, contractors are often represented at a senior level, typically by Financial and Commercial Directors, reflecting their awareness of the importance of these aspects to pricing. Furthermore, it has been observed that with the increasing pressures of having to demonstrate increased 'shareholder value', the process of reaching agreement is becoming more intense and difficult. As a consequence mainly of resource limitations, the Industrial Cost Auditor is usually the sole ESA representative in the discussions being faced with challenging situations and often considerable pressure. It is unusual that individuals are placed in a position where they are regularly expected to address such important matters with industry at senior management level on their own rather than as part of a team. With the emergence of the large international companies and the increased complexity, it will be the policy to send two auditors for major rate verifications. However, this will inevitably mean that the general coverage will be reduced and more companies will remain uncontrolled in terms of active control, in the absence of other measures being taken.

Agreement of firm fixed prices and price-variation provisions

It is the Agency's policy to agree firm fixed prices where appropriate. However, sometimes it is necessary to place contracts on a cost reimbursement basis and where fixed prices are agreed for activities for more than say a three year period, such prices are often with 'variation of price' provisions. This means expressing the fixed price at specific economic conditions and defining a mechanism, usually a formula, to subsequently adjust the price according to prevailing economic trends. The formula contains a fixed element, typically 10-15%, not subject to change, a labour element, typically 65-70%, and a non-labour element of say 20%. The non-labour element varies according to an appropriate materials index, and the labour element traditionally to a labour earnings index. The formula is usually applied to a milestone payments plan taking the arithmetic mean of the index value at the nominal (contractual) milestone date and that of the previous milestone. No matter how delayed achievement of the milestone may be, the index value considered is always that at the nominal, or in other words, contractual date.

As many major programmes are of long duration, fixed prices with variation have often been agreed. However, the traditional approach, and in particular the indices applied in the formulae, is now being questioned and a review is being undertaken to assess whether this approach still leads to fair results.

General financial advisory service

Industrial cost auditors are frequently consulted by contracts officers and project personnel to give an opinion on a variety of matters with financial implications. Such advice is given on the basis of experience, general knowledge of financial matters, and knowledge of companies and circumstances in particular countries. In support of this type of advisory activity, in addition to making reference to its own databases and analysis, the Division is also taking steps to increase its access to external databases providing both economic and company information.

The auditing of SMEs

Economic considerations necessitate the Agency giving priority to auditing the larger companies with whom a high value of contracts is placed, and it is simply not possible to audit many of the hundreds of SMEs who also receive contracts. Sometimes coverage of such companies is achieved by auditing them less frequently, at intervals of say two or three years. Most people consider audits in terms of the financial results, but there is another aspect to the auditor's role with respect to SMEs. In the ESA situation, auditors have an almost unique insight into the way in which a large number of companies are organised and conduct their business. In this respect they have a good appreciation of 'best practice' with regard to matters with cost and financial implications and knowledge of accounting systems and software packages.

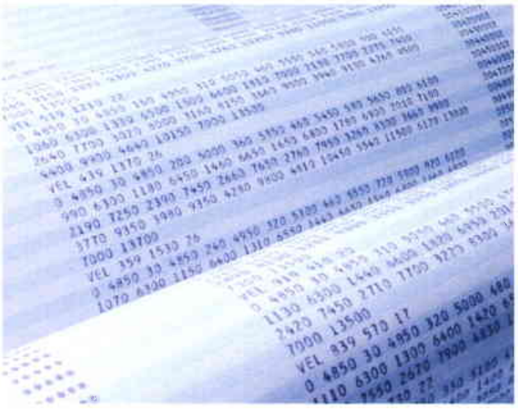
In addition to their official duties, they are also sometimes able to suggest to companies approaches that would reduce costs and increase efficiency, as well as being able to comment constructively on accounting aspects and accounting systems. Such advice can be of particular benefit to SMEs, many of which have meagre resources for support functions, which can lead to problems or inefficiencies. Sometimes SMEs actively seek advice, particularly when reaching stages in the company's evolution where significant administrative and organisational changes have to be considered. Furthermore, many start-up companies or other companies wishing to enter the space market seek advice from industrial cost auditors on a wide range of financial aspects.

Confidentiality

The question of the confidentiality of information provided by companies is of paramount importance. In the case of verifications of rates and overheads and cost-reimbursement audits, it is possible to do some preparatory work at ESTEC based on inputs received from the contractor. For the most part, however, it is necessary to verify the facts in-situ at the contractor's premises, with direct access to the accounting system and to highly sensitive financial information that has important commercial implications as far as the company is concerned. Understandably, contractors require auditors to maintain strict confidentiality with respect to such information and it is vital that their trust is fully respected.

Trends or issues with implications for auditing activities

There are a number of changes taking place which represent challenges to the industrial cost auditor. There are some new companies entering the space domain, but also some leaving. There has also been the closure of one major site as a consequence of a rationalisation process. Such closures raise particular accounting issues, and these situations can be expected to occur more frequently in future. The consolidation of European space industry and the emergence of large, multi-national groups is giving rise to additional complexity and change.



Companies are also changing their cost-accounting and cost-allocation structures more frequently due to modernisation initiatives and the wish to have a more precise cost allocation than hitherto. Mergers and the resulting need to have a unified approach to accounting structures and of accounting software is also playing a role. The need for companies to achieve increased 'shareholder value' also results in greater difficulty in reaching agreement on rates and overheads. There is an increase too in the number of companies showing very low profitability or even making losses, which also has an influence on attitudes. Co-funding arrangements, which are gaining in popularity, involve significant additional work.

However, there are other developments that are, at least in principle, making life simpler. They include an increase in the number of fixed-price contracts placed and a corresponding reduction in the number of classical cost-reimbursement contracts. There is also a general reduction in currency-exchange risks as a result of introduction of the Euro (but due to the weakness of the Euro, increased risk with some other currencies outside of the Euro zone). The generally lower levels of inflation have encouraged more firm fixed-price agreements, although some countries within the Euro zone still have relatively high rates of inflation. The improvements in data transmission are leading to more companies submitting accounting data electronically in spreadsheet form. In the case of smaller companies in particular, this is facilitating the process of agreeing rates remotely, without conducting a physical audit. This trend is likely to continue and will permit an extension of audit coverage.

Training and cost awareness

Part of the remit of Cost Analysis Division is to promote cost awareness and expertise in cost-related aspects of the procurement process. For many years, the Division has organised an internal training course entitled 'Cost and Financial Aspects of ESA Contracts'. It focuses on the ESA environment and is given by members of the Division and experienced colleagues from other Directorates. It was found necessary to develop this course because of the lack of a suitable alternative, most courses available externally being either too general or too specific. The course has attracted a lot of interest and sessions held at ESTEC have typically involved around forty-five participants. An abbreviated version of the course has also been given several times at ESRIN.

In addition, the Division has organised, from time to time, courses on accounting topics, delivered in ESTEC under the banner of the Chartered Institute of Management Accountants (CIMA) in the UK. These have primarily been for the benefit of the Division, but with the invited participation of colleagues from finance and project control.

Conclusion

Industrial cost auditing is not, in any way, regarded as being a glamorous activity, but it is a challenging and vital function for a professional procurement agency such as ESA. The irony is that the greater recognition and respect for the function is in industry, which fully appreciates the financial significance of agreements made in this respect. The scope of activities is also quite wide, ranging from classical audit exercises to activities of a more commercial nature. There are important principles to be observed, in particular the concepts of fairness and confidentiality, which underpin all activities. It is underlined that whilst there are significant cost savings resulting from audit activities, this is not the goal, the real objective being to agree 'fair and reasonable' prices.

The general perception is that in the space sector, ethical standards are high. This is something we should be grateful for, but human nature being what it is, we should remain aware of the temptations to depart from high standards for the purpose of short-term gain, and the deterrent factor in the role of the industrial cost auditor (as well as of other staff members) should not be underestimated.

As in other domains, the audit function is very much affected both by changes in the industrial environment, giving rise to new challenges, and by advances in the software support tools now available, which offer new possibilities for improving the efficiency of operations. These improvements, together with a small but significant increase in audit resources that has recently been approved in the Agency, can be expected to increase the effectiveness of ESA's audit activities and consequently the cost effectiveness of its programmes, thereby increasing the value for money for the Member States.

High-Energy Astronomy with the International Space Station

A.N. Parmar
Research and Scientific Support Department, ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

G. Gianfiglio, J. Schiemann
Microgravity and Space Station Utilisation Department, ESA Directorate of Manned Spaceflight and Microgravity, ESTEC, Noordwijk, The Netherlands

Europe is one of the major partners building the International Space Station (ISS) and European industry, together with ESA, is responsible for many Station components including the Columbus Orbital Facility, the Automated Transport Vehicle, two connecting modules and the European Robotic Arm. Together with this impressive list of contributions, there is a strong desire within the ESA Member States to benefit from this investment by using the unique capabilities of the ISS to perform world-class science. Indeed, ESA has ambitious plans to utilise the ISS for future high-energy astronomy missions.

Introduction

Currently, the ESA Manned Spaceflight and Microgravity and Science Directorates are studying three potential high-energy astronomy missions, in close cooperation: Lobster-ISS, an all-sky imaging X-ray monitor, the Extreme Universe Space Observatory (EUSO), which will study the highest energy cosmic rays using the Earth's atmosphere as a giant detector, and XEUS, the X-ray Evolving Universe Spectroscopy mission. This mission, as the name implies, will do more than use the ISS merely as an observation platform, but rather as a critical element in the construction of a world-class high-energy astrophysics observatory. As such, it will be the potential successor to the present generation of X-ray observatories, such as ESA's XMM-Newton and NASA's Chandra.

A mission is studied to allow its overall design to be elaborated, the scientific and technical feasibilities demonstrated and most importantly the costs evaluated and commitments obtained for all of the necessary elements. These activities are normally part of a so-called 'Phase-A Study', following a successful outcome of which, a project can move forward into the detailed definition and build phases as an approved mission. Each of the three missions described here utilises different aspects of the ISS in order to achieve its scientific goals in a timely and cost-effective manner.

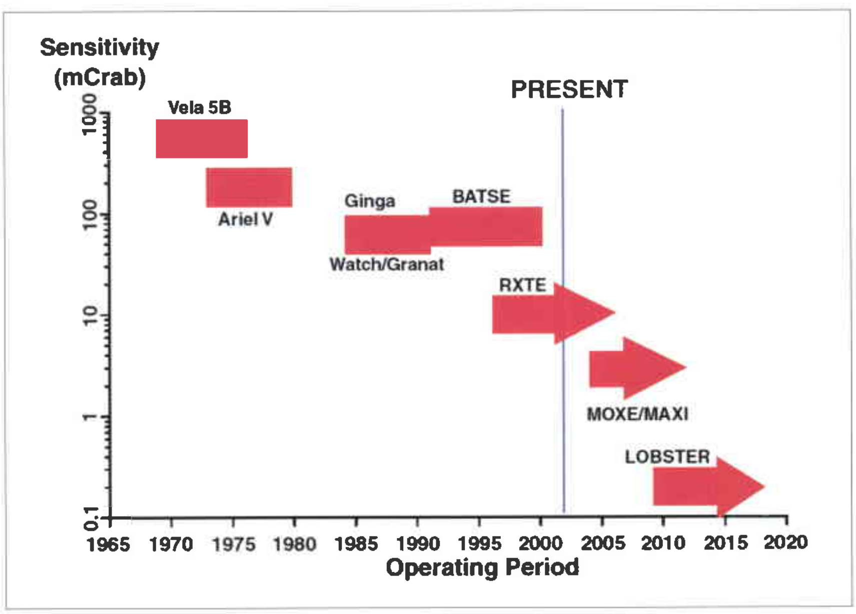


Figure 1. The sensitivity of X-ray all-sky monitors versus operating period. The large increase in sensitivity of Lobster-ISS compared to previous missions is clearly evident.

Surveying the X-ray sky – Lobster-ISS

The X-ray sky is highly variable and unpredictable. A new X-ray source may suddenly appear in the sky, out-shine its contemporaries, and then disappear a few days later. Sometimes an 'old favourite' will surprise everyone by behaving in a totally new and unexpected way. A highly sensitive X-ray mission such as ESA's XMM-Newton observatory only observes a small region of sky at any one time and could easily miss such unpredictable events. This is where an all-sky X-ray monitor, such as Lobster-ISS, can play a vital role. By alerting astronomers to important events occurring anywhere in the sky, powerful observatories can be rapidly re-pointed to take advantage of new opportunities. The importance of this capability was recognised as early as the 1960s and the sensitivity of all-sky monitors has steadily improved (Fig. 1). Currently,

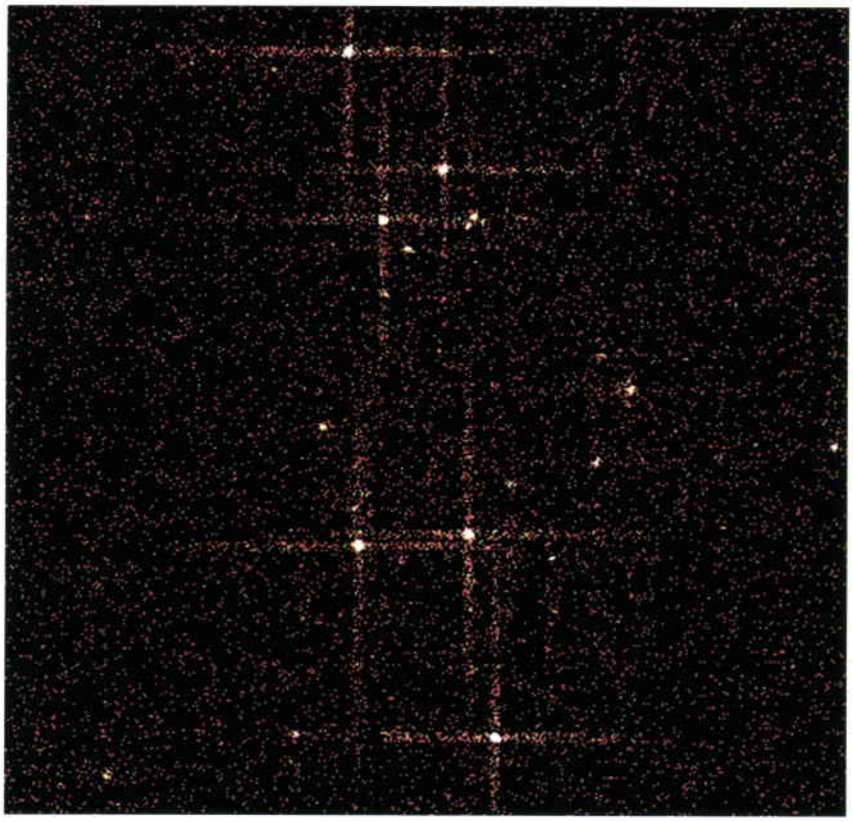


Figure 2. A simulated image of a 10 x 10 deg^2 region of the Large Magellanic Cloud as observed by Lobster-ISS in one day. A total of 22 X-ray sources are clearly detected. The distinctive crosses are a characteristic of the lobster-eye X-ray optics, which focus approximately half the photons into the four arms and the rest into the central point source.

astronomers benefit from the all-sky monitor on NASA's RXTE satellite and from the Wide-Field Cameras (WFCs) on the Italian/Dutch BeppoSAX satellite. Even though the WFCs have large, rather than all-sky, fields of view, their ability to provide accurate source positions rapidly played a crucial role in the discovery of X-ray afterglows to gamma-ray bursts. This discovery led to the confirmation that gamma-ray bursts occur in the distant Universe and are one of the most energetic events known. These instruments will be followed in 2004 by the MAXI all-sky X-ray monitor on the Exposed Facility of the Japanese Experiment Module on the ISS. MAXI will offer around a factor 10 improvement in sensitivity, compared to RXTE.

ESA is proposing to fly an even more sensitive (by another factor of 10) all-sky monitor on the ISS in around 2009 called Lobster-ISS. The Lobster-ISS proposal was submitted to ESA's Directorate of Scientific Programmes in response to the Call for Flexi-Mission Proposals (F2 and F3) issued in October 1999. In this Call, proposals based on the utilisation of Columbus and other ISS elements were invited. The Principal Investigator is Prof. G.W. Fraser from the University of Leicester, UK, with co-investigators from the Los Alamos National Laboratory, the NASA Goddard Space Flight Center, the Institute of Astronomy Cambridge, the University of Southampton, the University of Melbourne, and the University of Helsinki.

Lobster-ISS will utilise a novel form of micro-channel plate X-ray optics developed within the ESA Technology Research Programme to provide this unprecedented sensitivity. Lobster-ISS will be the first true imaging X-ray all-sky monitor and it will be able to locate X-ray sources to within 1 arcminute to allow the rapid identification of new transient sources. Lobster-ISS will produce a catalogue of 200 000 X-ray sources every two months, which will be rapidly made available to the astronomical community via the Internet. As well as providing an alert facility, the high sensitivity will allow many topics to be studied using Lobster-ISS data alone. These include the long-term variability of active galactic nuclei and stars, the mysterious and difficult to study X-ray flashes, and the highly topical X-ray afterglows of gamma-ray bursts.

Figure 2 shows a Lobster-ISS image of part of the Large Magellanic Cloud obtained in a 1 day simulated observation. All the bright X-ray binaries, supersoft sources and supernova remnants are visible and their intensities and overall spectra could be monitored on a daily basis. The distinctive 'crosses' visible in Figure 2 are a characteristic of the novel lobster-eye optics. The advantage of this type of optics for an X-ray all-sky monitor is its extraordinarily large field of view. This is achieved by accurately bending the thousands of tiny glass pores that make up each micro-channel plate by exactly the right amount, in order to focus incident X-rays like a telescope. This explains where the name 'Lobster' comes from, since this is similar to how the eye of a crustacean works.

In order to provide the best possible view of the sky, the optimum location for Lobster-ISS is on the zenith pointing of the External Payload Facility (EPF) on ESA's Columbus module (Fig. 3). An initial ESA feasibility study showed that Lobster-ISS could be comfortably accommodated on the standard ISS ExPRESS Palette Adaptor. Unlike a conventional satellite,

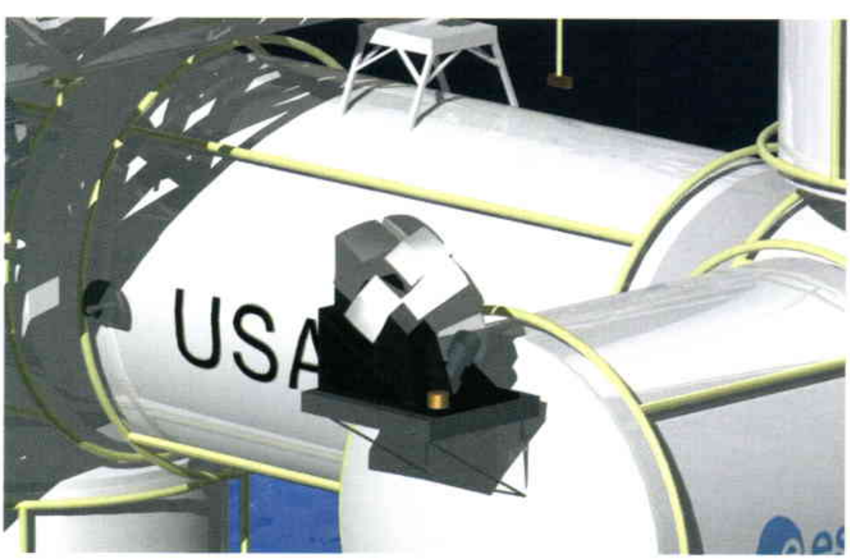


Figure 3. Lobster-ISS mounted on the zenith pointing platform of the Columbus External Payload Facility. The main truss of the ISS runs along the top left of the image, and ESA's Columbus module is visible to the lower right.

which orbits the Earth pointing in the same direction, unless commanded otherwise, the ISS orbits rather like an aircraft, keeping its main axis parallel to the local horizon. This is a great advantage for an all-sky monitor since it means that the field of view will automatically scan most of the sky during every 90 minute ISS orbit. A 12-month ESA Phase-A study is expected to start later this year. This will concentrate on the overall instrument design, ISS accommodation, robotic handling, and end-to-end operations.

Probing the highest energy phenomena in the Universe – EUSO

The Earth is being continuously bombarded by high-energy particles known as cosmic rays. While cosmic rays with energies up to 10^{15} eV almost certainly originate from comparatively well-understood objects in our own Galaxy, such as the expanding shocks of exploded stars, understanding the origin of the highest energy cosmic rays with energies above 5×10^{19} eV is one of the great challenges in astrophysics. Although these extreme energy cosmic rays (EECRs), believed to be probably mostly protons, are very rare – only around 1 per square kilometre per century! – they are the most energetic particles known in the Universe, with energies one hundred million times greater than produced by Fermilab's Tevatron, the world's most powerful particle accelerator. Because they are so rare, only about 30 such events have been detected using different ground-based air-shower detectors in the past 30 years. There has been no convincing identification of any of these events with a likely astronomical source.

At such extreme energies, cosmic-ray protons interact with the cosmic microwave background that permeates space, and the distance that an EECR can travel is limited to our galactic neighbourhood. Intriguingly, all the astronomical objects that could conceivably produce EECRs, such as massive black holes, colliding galaxies, or gamma-ray bursts, are all much further away than this. This has led to the idea that the decay of topological defects, or other massive relics of the Big Bang, may instead produce EECRs. If this is indeed the case, then it implies the existence of 'new physics'. These paradoxes are at the heart of the ambitious EUSO mission, to study EECRs from space by using the Earth's atmosphere as a giant cosmic-ray detector. EUSO will observe the flash of fluorescence light and the reflected Cherenkov light produced when an EECR interacts with the Earth's atmosphere (Fig. 4). Direct imaging of the light track and its intensity variations will allow the sky position of the event, as well as the overall energy to be reconstructed. In the same way that Lobster-ISS will benefit from the scanning offered by its proposed zenith location, EUSO will take advantage of the continuous nadir pointing provided by the lowest location of the Columbus EPF. By looking down from here with a 60 deg field of view, EUSO will detect around 1000 events per year, allowing a sensitive search for the objects producing EECR to be made.

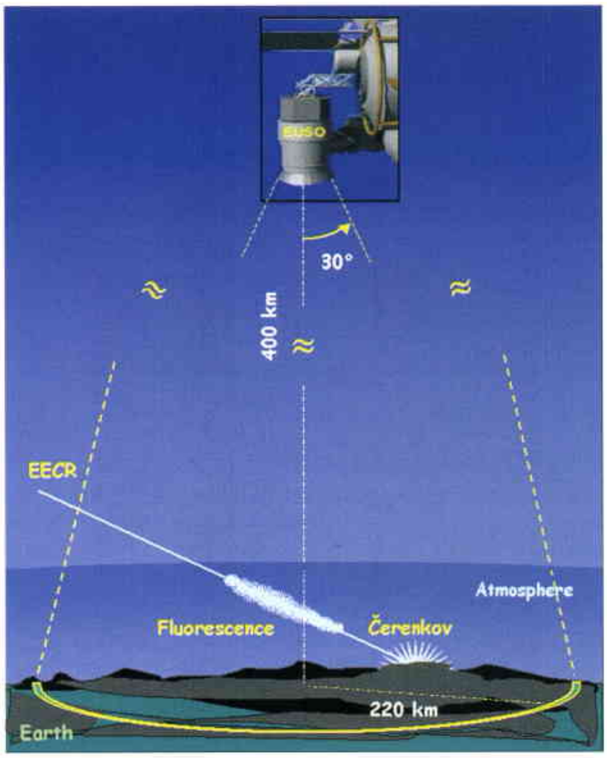


Figure 4. EUSO will observe downwards from the ISS at a height of 400 km with a wide 60 deg field of view and detect the fluorescent and reflected Cherenkov radiation produced when an Extreme Energy Cosmic Ray interacts with the Earth's atmosphere.

Protons are not the only type of extreme-energy particle that will be observed by EUSO. Many models for the production of EECR indicate that large numbers of neutrinos should also be produced. Since neutrinos propagate, on average, much deeper into the atmosphere than protons before interacting, EUSO will be able to distinguish between the two types of particles by selecting on interaction depth and so potentially opening up the new field of high-energy neutrino astronomy (Fig. 5). Since most sources of EECR are expected to be transparent to their own neutrinos, these particles would allow us to observe deep inside a source to view the particle acceleration mechanism directly.

The EUSO proposal was submitted to ESA in response to the same Call for Flexi-Mission Proposals (F2 and F3) as Lobster-ISS. The Principal Investigator is Prof. L. Scarsi from IASF-CNR in Palermo, Italy, who leads a large

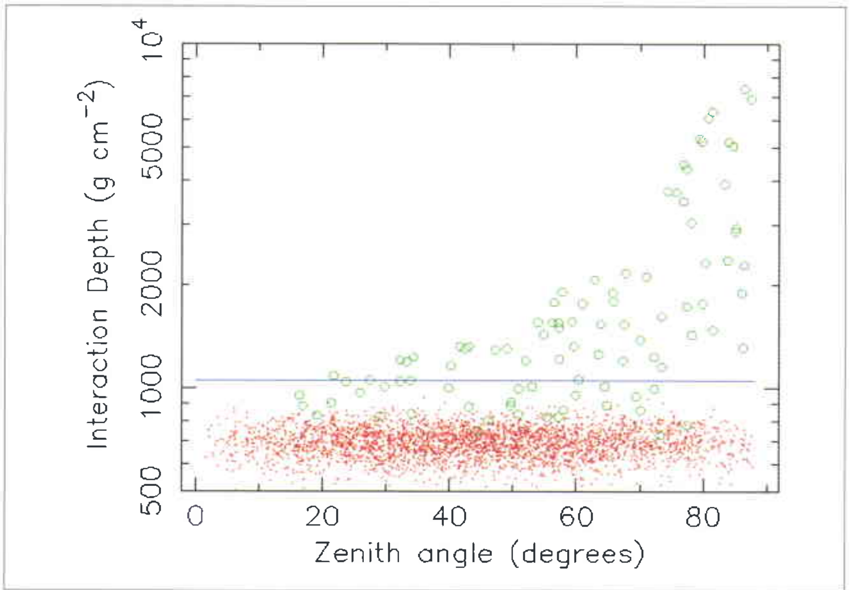


Figure 5. Extreme-energy cosmic-ray interaction depth simulations showing how particle-induced (green circles) and neutrino-induced (red points) events can be distinguished. Any events detected at high interaction depths (corresponding to low altitudes) and high zenith angles will almost certainly be produced by neutrinos.

Figure 7. Here EUSO is the cylindrical structure attached to the left side of ESA's Columbus External Payload Facility. From this location it will have an unobstructed view towards the ISS nadir. The docking port for the Space Shuttle and the Japanese module can be seen to the right of the Columbus module.

Table 1. The EUSO consortium – Participating Nations and Institutes

France:	APC, Paris; LAPP, Annecy; ISN, Grenoble; CERS, Toulouse; LPTHE; LAPTH; College de France; Observatoire de Paris
Italy:	CNR-IASF, Palermo; CNR-ISAO, Bologna; University/INFN at Catania, Firenze, Genova, Palermo, Roma, Torino, Trieste; Osservatori Astronomici/INAF at Arcetri and Catania, Istituto Naz. Ottica, Firenze; CARSO
Portugal:	LNP, Lisbon
UK:	University of Leeds
Germany:	MPIfR, Bonn
Japan:	Riken; ICRR/Univ. of Tokyo; KEK; NASDA; Univ. Saitama, Aoyama, Kinki, Seikei and Konan
USA:	NASA/MSFC, Huntsville; Alabama University at Huntsville; UCLA, Los Angeles; Univ. California at Berkeley; Vanderbilt University; University of Tennessee; University of Texas at Austin

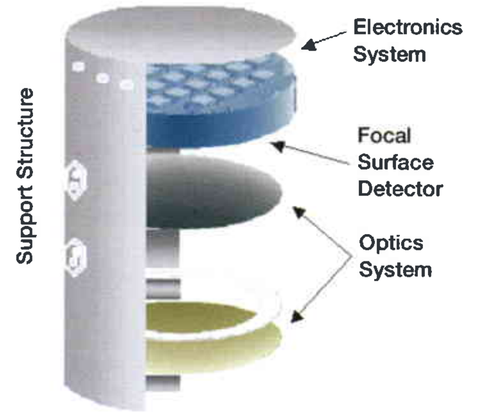


Figure 6. The proposed EUSO layout showing the principal components, including the double Fresnel lens optics and the highly modular focal surface.

consortium of astronomers, cosmic-ray and particle physicists (Table 1). EUSO will consist of a UV telescope with a large collecting area and field of view utilising a lightweight double-Fresnel-lens optics system, a highly segmented focal-surface detector array and sophisticated onboard image processing. The image processing will provide a sensitive discrimination between EECR and other forms of UV radiation such as lightening, meteoroids, aurorae, and man-made illumination. Unlike Lobster-ISS, which fits neatly into the approximately cubic-metre volume provided by the standard ExPRESS Pallet Adaptor, EUSO will need a larger carrier such as the Integrated Cargo Carrier (ICC), due to its 2.5 m diameter and 4 m long cylindrical dimensions (Fig. 6). Following an initial feasibility study, the best way of accommodating such a large and heavy payload on the ISS is one of the key topics of the 12-month ESA Phase-A study started in March 2002 by Alenia Spazio. Figure 7 shows EUSO attached to the Columbus module.

Studying the evolution of the hot Universe – XEUS

The third high-energy mission under study as part of ESA's long-term Horizons 2000 science programme is the X-ray Evolving Universe Spectroscopy mission, or XEUS.

A key goal of this mission is nothing less than the study of the hot matter and unseen dark matter when the Universe was very young by spectroscopic investigations of the first massive black holes. These are believed to have formed when the Universe was only a small fraction of its current age and they may have played a crucial role in the formation of the first galaxies. XEUS will have sufficient sensitivity to derive their masses, spins, and distances by observing X-ray intensity variations and emission lines that have been broadened and distorted by the effects of strong gravity close to the event horizon.

By studying how black-hole masses and spin rates evolve with cosmic time, astronomers will be able to investigate how they grow and the role that they play in the evolution of the galaxies such as our own. One of the most surprising discoveries of the past decade is that the stuff that we are made of, 'normal' matter, makes up only about 5% of the content of the Universe. Most of Universe is made up of mysterious dark matter and dark energy that are not explained by our current understanding of fundamental physics. Most of the normal matter in the Universe is trapped in a dark matter 'cosmic web' as a hot tenuous intergalactic medium (Fig. 8). XEUS will have sufficient sensitivity to characterise the mass, temperature and density of this material using X-ray absorption-line spectroscopy. As well as allowing the nature of the dark matter to be probed, these studies will allow the cosmic history of common elements such as C, O, Ne and Fe to be investigated. Another key science goal for XEUS is to study the formation of the first gravitationally bound, dark-matter-dominated systems (small groups of galaxies) and investigate how these evolved into the massive clusters of galaxies that we see today.

XEUS will be a long-term X-ray observatory consisting of separate detector and mirror spacecraft flying in formation and separated by the 50 m focal length of the optics (Fig. 9). XEUS will be launched by an Ariane-5 sometime after 2012 and will therefore have an initial mirror diameter of 4.5 m, limited by the

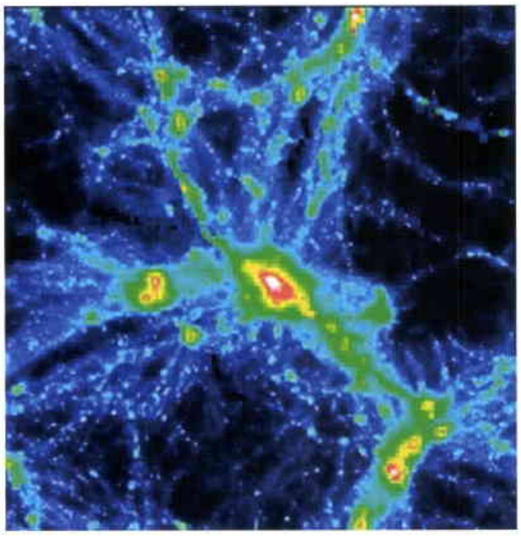


Figure 8. Most of the visible matter in the Universe is trapped in a dark-matter-dominated 'cosmic web' as a hot intergalactic medium. The 'hot spots' visible in this simulation are the building blocks of the Universe, clusters of galaxies.

Ariane shroud's diameter. XEUS requires a revolutionary extension of the technology devised for the X-ray telescopes on XMM-Newton. X-rays are focussed by glancing them off the inside faces of bucket-shaped mirrors through which they pass. To increase the effective area, each of XMM-Newton's three 0.7 m diameter mirror modules consists of 58 individual mirrors. For XEUS, around 500 mirrors will be needed. To achieve the much bigger size and sharper vision required, they will be divided into segments, or 'petals' (Fig. 10). Each petal will be individually calibrated and aligned in orbit to provide a spatial resolution of between 2 and 5 arcsec half-energy width. Narrow- and wide-field imagers will provide fields of view of 1 and 5 arcmin and energy resolutions of 500-1000 and 20 at 1 keV, respectively. It is likely that the narrow-field imager will be a cryogenic detector such as an array of bolometers or super-conducting

Figure 9. XEUS observing the deep Universe. The detector spacecraft (foreground) maintains its position at the focus of the X-ray mirrors 50 m away to within ±1 mm. The eight sets of thrusters, one at each corner of the rectangular detector spacecraft, are used to maintain alignment and for orbital manoeuvring. The radiator used to cool the cryogenic instruments is located on the upper surface. The cylindrical mirror spacecraft is slowly rotating to minimise the thermal gradients across the highly sensitive mirror surfaces.

tunnelling junctions, and the wide-field device will be based on advanced semiconductor technology. The detector spacecraft will have a sophisticated attitude and orbit control system, manoeuvring itself to remain at the focus of the optics.

After using most of its fuel, the detector spacecraft will dock with the mirror spacecraft and the mated pair will transfer to the same orbit as the ISS. The mirror spacecraft will then dock with the ISS and additional mirror segments that have been previously transported to the ISS will be robotically attached around the outside of the spacecraft (Fig. 11). This will increase the mirror diameter to 10 m and the effective area at 1 keV from 6 to 30 m^2 (Fig. 12). The dramatic increase in sensitivity associated with this expansion means that once the mirror spacecraft has left the ISS to be joined by a new detector spacecraft, complete with the latest generation of detectors, the study of the early X-ray Universe can begin in earnest. The 0.1–2.5 keV limiting sensitivity of XEUS will then be 4 x 10^{-18} erg cm^{-2} s^{-1}, approximately 200 times better than ESA's current X-ray observatory, XMM-Newton, and comparable to those of the next generation of ground- and space-based observatories such as ALMA and NGST (Fig. 13). However, even this figure under-estimates the increase in performance offered by XEUS for high-resolution imaging spectroscopy since it does not take into account the high-spectral-resolution and simultaneous-imaging capabilities of the cryogenic detectors.

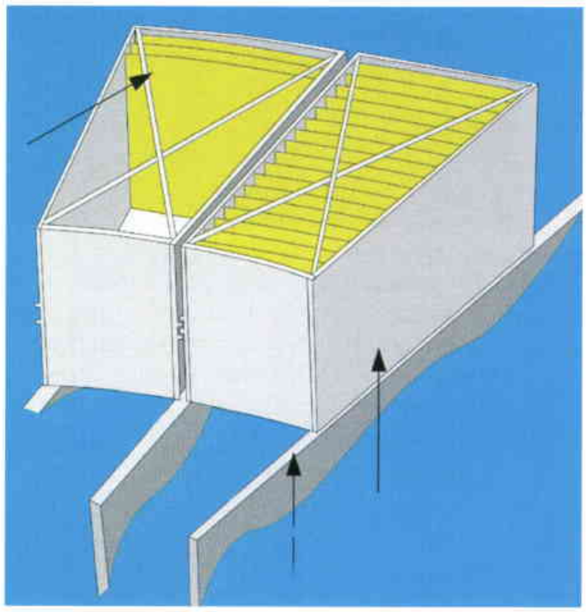


Figure 10. The overall design of the XEUS mirrors showing how the X-ray mirrors will be divided into segments, or 'petals'. The left-hand container is only partially filled with mirror plates.

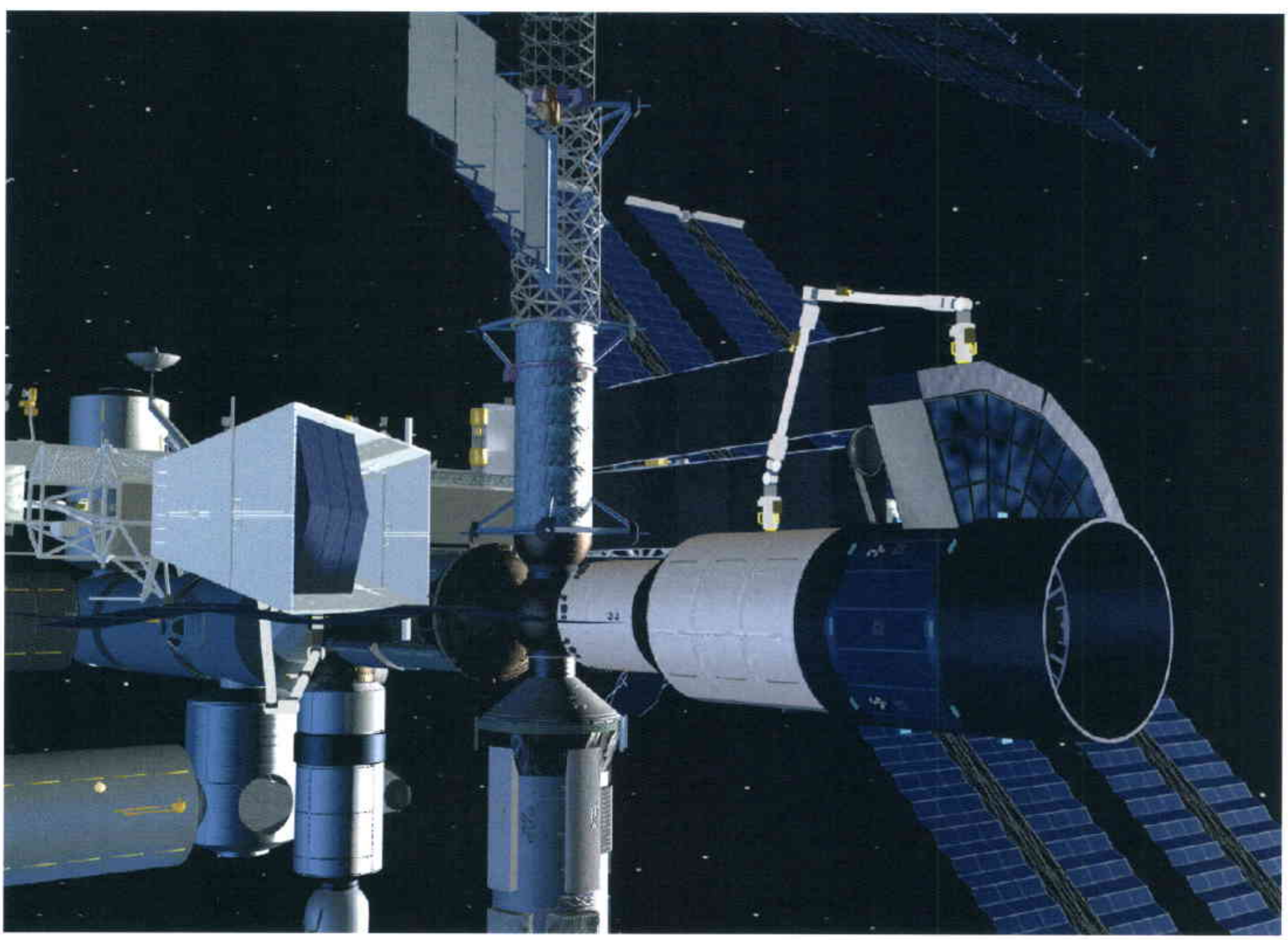


Figure 11. Using the European Robotic Arm (ERA), additional mirror segments are added to the XEUS mirror spacecraft while it is docked at the Russian ISS port. As each segment is added, the mirror spacecraft is rotated to allow easy access by the ERA. The three mirror segments that are waiting to be mounted can be seen in their white transport container on the left.

The scientists and engineers studying XEUS believe that, besides its unprecedented scientific capabilities, one of its strongest selling-points is the imaginative use of the unique capabilities of the ISS to develop a new approach to space astronomy. Following an initial feasibility study, the many new and challenging technologies that are needed for XEUS are being studied in Europe and Japan. It is hoped that in the future Russia and the USA will join this partnership to build the first truly global X-ray observatory. There are many advantages to the phased development afforded by the ISS: detector development can continue even after the launch of XEUS, and the simplicity of the mission design means that the instruments could be repeatedly upgraded during the long lifetime of the telescope. The use of two cooperating spacecraft not only avoids the use of a massive connecting structure, but also means that the detector spacecraft can be upgraded at any time without revisiting the ISS. There is already a great deal of interest from around the World at the prospect of a mission with a sensitivity and spectral capability far exceeding those of XMM-Newton, ESA's current X-ray observatory, which is already producing many exciting new results.

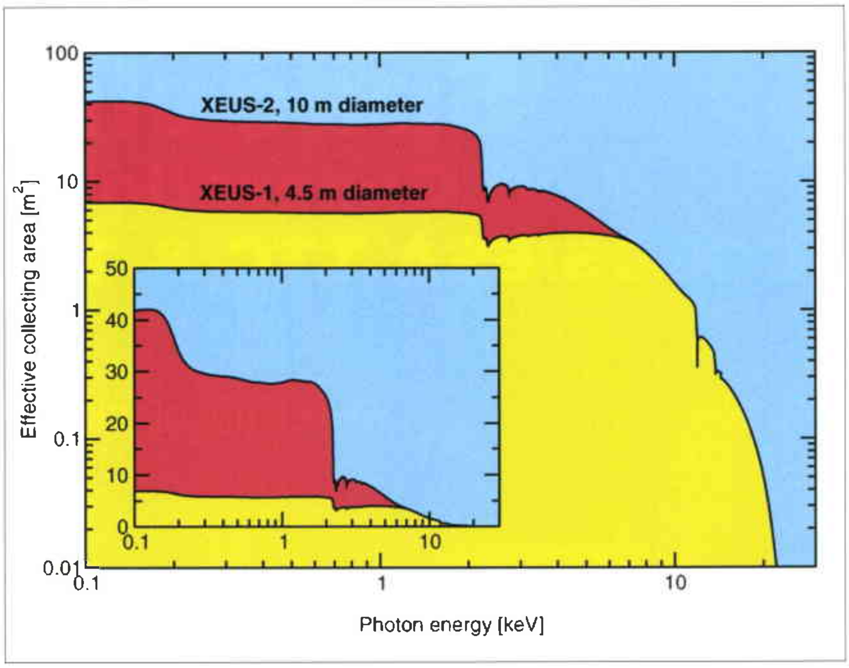


Figure 12. The XEUS mirror effective area at different energies. Directly after launch, XEUS would have a mirror diameter of 4.5 m (XEUS-1). XEUS-2, extended with additional mirror modules by a visit to the ISS, would have a diameter of 10 m and a considerably larger effective area below 5 keV. The inset shows, on a linear scale, the dramatic increase in affective area from XEUS-1 to XEUS-2.

Conclusion

The Lobster-ISS and EUSO studies demonstrate that the ISS is an excellent platform for certain types of astronomical payloads. In the case of XEUS, the ISS provides the only in-orbit infrastructure able to perform the complex operations needed to increase the X-ray mirror diameter from 4.5 m to the 10 m required to meet the science objectives. These capabilities, together with an increasing awareness within the scientific community of the potential of the ISS as a platform for space research, means that many other innovative astronomical applications of the ISS are expected in the next few years.

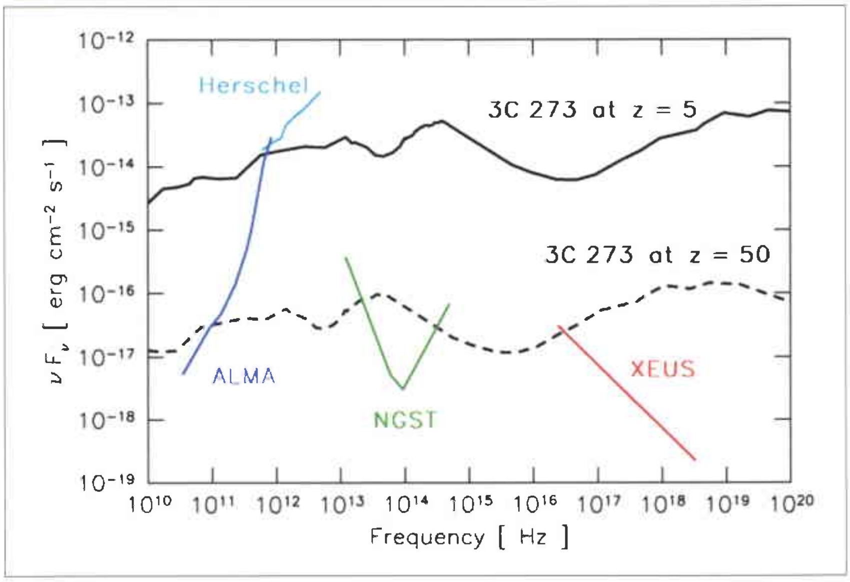


Figure 13. A comparison of the sensitivities of some future missions and facilities. A horizontal line corresponds to equal power output per decade of frequency. For ALMA, an 8 h integration was assumed, for Herschel a 5σ detection in 1 hour, for NGST a 5σ detection in 10 000 s, and for XEUS a 100 000 s exposure following growth at the ISS.

Acknowledgments

The EUSO and Lobster Principal Investigators and the XEUS Steering Committee (M. Turner, University of Leicester; M. Arnaud, CEA Saclay; X. Barcons, CSIC-UC Santander; J. Bleeker, SRON; G. Hasinger, MPE Garching; H. Inoue, ISAS; and G. Palumbo, Bologna Observatory) are thanked for their contributions.

M.C. Maccarone, N. Bannister, A. Reynolds, M. Türler and M. Polletta helped with the production of the illustrations.


SpacelinkNGT
Next Generation Technology
CCSDS/ESA TTC & TM/TC equipment
www.SpaceLinkNGT.com
SpaceLinkNGT - TM/TC Front-End
Satellite Services BV
www.satserv.nl
Satellite Services BV

ESA's Response to the Challenges of Developing X-ray Optics

M. Bavdaz & T. Peacock
Science Payloads Technology Division, ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

ESA is currently developing the X-ray optics for its future astrophysics and planetary missions, following on from the highly successful XMM-Newton mission. The next generation of astrophysics missions such as XEUS will require dramatic improvements in the performance, size and mass of the telescope, which is the heart of any high-energy astrophysics mission. This article highlights the challenges and identifies some possible technology solutions.

Introduction

Europe has a strong heritage in X-ray optics, with X-ray astrophysics missions such as Exosat (ESA), Rosat (D), Beppo-SAX (I) and XMM-Newton (ESA), but a further major evolution of the technology is required to satisfy growing future demands. The main technological drivers remain a dramatic increase in effective area, coupled with good angular resolution of order 1–10 arcsec. These two parameters are coupled, but must be improved while ensuring a reduction in mass as well as an overall reduction in X-ray mirror fabrication costs.

Since there is no material that efficiently refracts X-rays, reflection optics are used for astrophysics and possible future planetary space missions. The reflection occurs efficiently over a large range of photon energies only if the X-rays are reflected with a small grazing angle - typically below 1 deg. The geometry of choice is known as a Wolter-I configuration for X-ray energies from 0.1 to 10 keV, i.e. photon wavelengths of 10 – 0.1 nm. This configuration comprises, as a basic element, a paraboloid (P) coupled to a hyperboloid (H), as shown in Figure 1. To achieve a reasonably large collecting area, pairs of shells (P+H) are stacked inside each other, like Russian dolls, and the mirror system is said to be 'nested'. To ensure an adequate imaging resolution, these shells must be stiff and well-aligned, leading to bulky and heavy optics. Table 1 summarises the major characteristics of the Wolter-I mirrors flown to date.

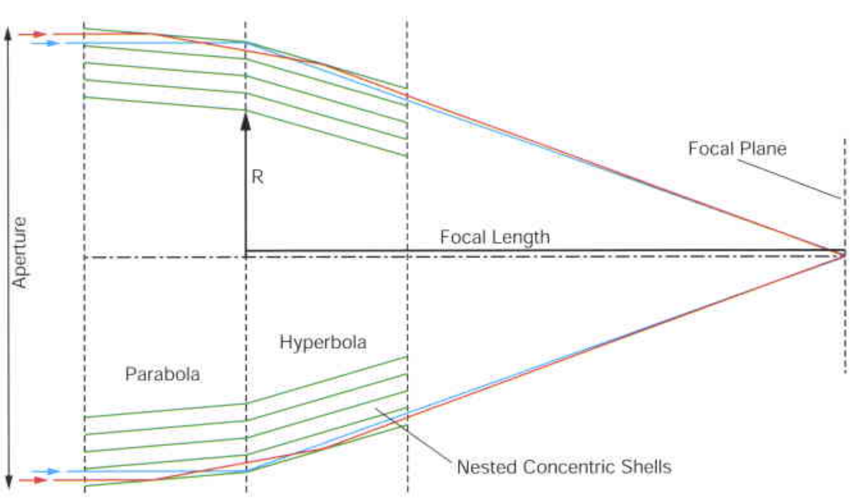


Figure 1. Schematic of a Wolter-I X-ray telescope showing the key characteristics

In Table 1, FOV refers to the field of view of the X-ray mirror system, while R is the imaging resolution on- axis. The effective area is also provided at a nominal energy of 1 keV (1 nm). All data refer to a single mirror module. In the case of some mirror systems, more than one module was flown to achieve an increase in collecting area. This duplication of mirror modules, however, requires the same duplication of focal-plane instruments.

A few issues are immediately evident from Table 1. Firstly, since the first imaging telescope for cosmic X-ray astronomy was flown (the Einstein Observatory) in 1978, the capabilities of the telescopes have evolved enormously, particularly with respect to focal length, which governs the upper energy (short wavelength) cut-off threshold of the mirror, and collecting area. The two current major observatories in orbit, NASA's Chandra and ESA's XMM-Newton, drive technology in two different directions. For Chandra the emphasis is on imaging resolution at the expense of collecting area, while for XMM-Newton the imaging capability has been relaxed while the collecting area has been increased. In fact, the collecting area in the case of XMM-Newton was achieved through the dramatic increase in the nesting of the shells together with the fabrication of three

*Table 1. A summary of the principal characteristics of Wolter-I X-ray mirror systems flown to date**

Mission	Agency	Launch (yr)	Lifetime (yr)	Mass (kg)	Nest	Focal Length (m)	Number Modules	Aperture (cm)	FOV (arcmin)	R (arcsec)	Area (cm^2) (@ 1 keV)
Einstein	NASA	1978	2.5	~ 460	4	3.5	1	56	75	~ 2	1x200
Exosat	ESA	1983	3	7	2	1	2	30	120	~ 18	2x35
Rosat	DLR	1990	9	950	4	2.4	1	84	120	1.7	1x400
BeppoSax**	ASI/NIVR	1996	6	13	30	1.85	4	16	30	60	4x80
Chandra	NASA	1999	~5–10	956	4	10	1	120	30	0.5	1x750
Newton	ESA	1999	~5–10	350	58	7.5	3	70	30	12	3x1500
XEUS	ESA	>2012	~25	?	?	50	1	1000	5	2–5	1x300 000

* No-foil optics, which also use a conical approximation to Wolter-I optics, are included here because they provide resolutions above 1arcmin.

** Conical approximation to Wolter-I optics.

identical modules. Figure 2 shows one such XMM-Newton module prior to integration into the spacecraft. Each mirror module manufactured from electro-formed nickel shells has a mass of 350 kg. The masses of the Chandra and XMM-Newton mirrors are essentially the same, with the ratios of the key parameters for the two missions, namely collecting area and resolution, being about 6 and 20, respectively. Figure 3 illustrates the importance of resolution to separate faint discrete X-ray sources versus collecting area. A large collecting area allows sufficient X-ray photons to be detected to allow the spectra of X-ray sources to be determined, while good spatial resolution ensures that overlapping sources are not confused.

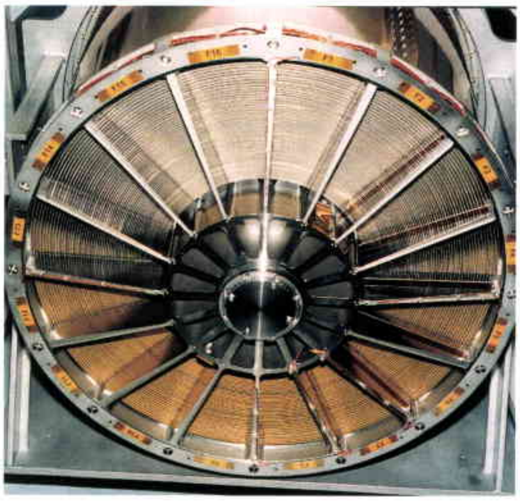


Figure 2. A single XMM-Newton flight-model mirror prior to integration into the spacecraft. The 58 mirror shells with diameters ranging from 30 to 70 cm, each manufactured from electro-formed nickel with a typical thickness of 1 mm from a high-quality mandrel, are stacked like Russian dolls inside each other with an inter-shell spacing of typically a few mm. These shells have to be aligned and fixed rigidly with respect to each other and the nominal X-ray focus, to achieve the high overall system resolution of 12-15 arcsec

For predicting the main evolutionary factors required of X-ray mirror systems over the next few years, we use the requirements for XEUS, an ESA mission under study as the potential successor to XMM-Newton in partnership with Japan. Here, the requirements have increased enormously, the mirror having a diameter of 10 m and a focal length of 50 m, but the collecting area and resolution are now 30 m^2 and 2 arcsec, respectively. To build such a huge mirror system and still achieve such a high image quality is a real challenge. A figure of merit that demonstrates both the optic and programmatic challenge is the collecting area to mirror mass ratio, which is shown in Figure 4 for the missions listed in Table 1.

Alternative technologies

ESA, together with European industry and research institutes, is exploring the X-ray optics technologies for the next generation of space astrophysics and planetary missions currently being designed. A number of technologies are

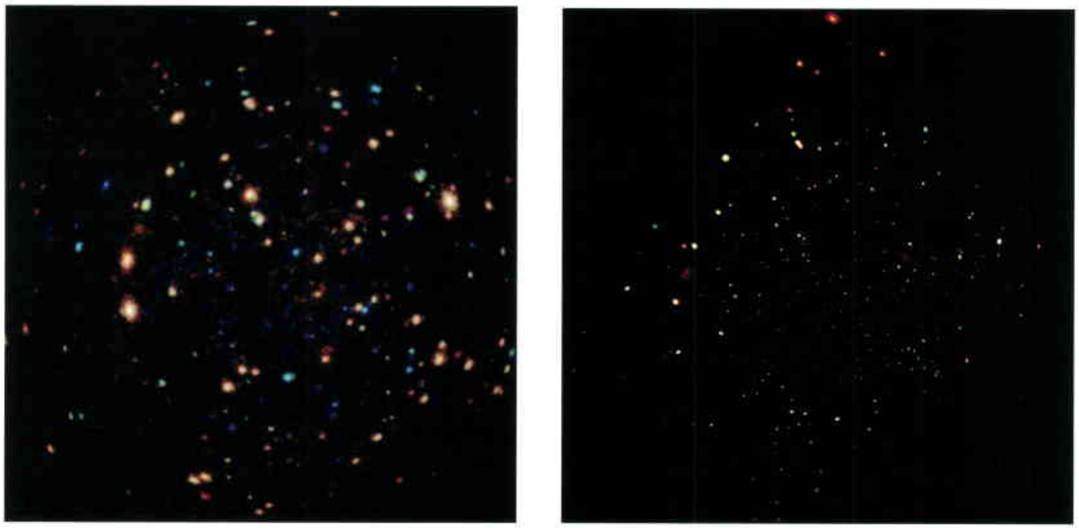


Figure 3. Images of a deep field – a region of blank space – observed with XMM-Newton (left) and Chandra (right). XMM-Newton detects many more photons so as to measure the source spectra, while Chandra ensures that overlapping sources are clearly separated. Both complement each other in resolving and understanding the discrete sources that form the X-ray background. This background is of major cosmological importance. Future generations of X-ray mirrors will need to do the same as these two missions, but with a single mirror system having even more (~ 200 times) collecting area to probe even deeper into the Universe and thereby look back in time to when it was very young

under study, ranging from low-mass replication processes built around conventional Wolter-I nested geometries to radically different approaches. In the latter case, the technology used to produce glass micro-channel plate (MCP) image intensifiers is used to produce X-ray optics with very thin reflecting surfaces, of the order of only a few microns. This results in an MCP optic that is far lighter and smaller than would be possible with conventional grazing-incidence optics. As shown in Figure 5, a conical approximation to the Wolter-I geometry is employed, and a radial arrangement of the MCPs is required. In a sense, the nested shell set of Russian dolls has been replaced by a massive set of micro-shells, all configured to focus X-rays at the same spot.

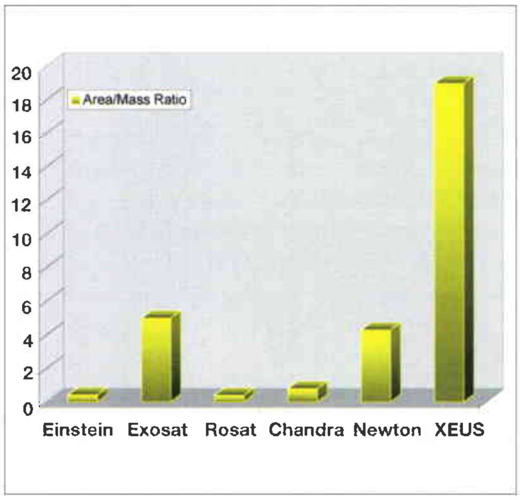


Figure 4. The mirror area-to-mass ratio, a figure of merit that illustrates the improvement in performance of X-ray mirrors over the last twenty years or so and the huge strides still needed to satisfy the requirements of future X-ray mirror missions such as XEUS. Care must, however, must be exercised when making comparisons between the various missions because imaging resolution is another merit parameter that needs to be considered

For the first time such a compact and light lens has been made with a geometry that produces true X-ray imaging. This lens has been manufactured under ESA contract by Photonis (F) with support from Leicester University Space Centre (UK). Testing has been performed by ESA staff and COSINE Research BV (NL) in collaboration with the Bessy PTB synchrotron facility in Berlin (D) and the European Synchrotron Radiation Facility (ESRF).

Microchannel plates have been developed for image intensifiers and photon-counting detectors, and their mass production has reached a high level of optimisation. Due to the production process, which involves severe stretching of the glass fibres, very smooth walls are obtained, which are arranged in a regular geometry. Starting with a slab of material, the glass is drawn into long thin fibres, which are then grouped into multi-fibres and drawn again. Finally, these multi-fibres are stacked with the desired geometry and then fused to form a monolithic block. The block is then cut into slices, which are etched to form pores. Finally, the resulting plates are slumped into the required shape.

To adapt the MCPs for use as X-ray optics, it was necessary to change and improve the multi-fibre geometry and reduce the surface roughness, which scatters X-rays and thereby degrades the image quality. The later has been achieved by polishing the starting blocks of glass used to produce the fibres. The geometry was a greater challenge because traditional MCPs are based on round fibres. For imaging applications, square fibres are required, which in turn require modifications to the drawing towers and the introduction of appropriate on-line metrology. The resulting optics are, however, very rigid, extremely light and very robust, since the specific mass and the corresponding forces during vibration are low.

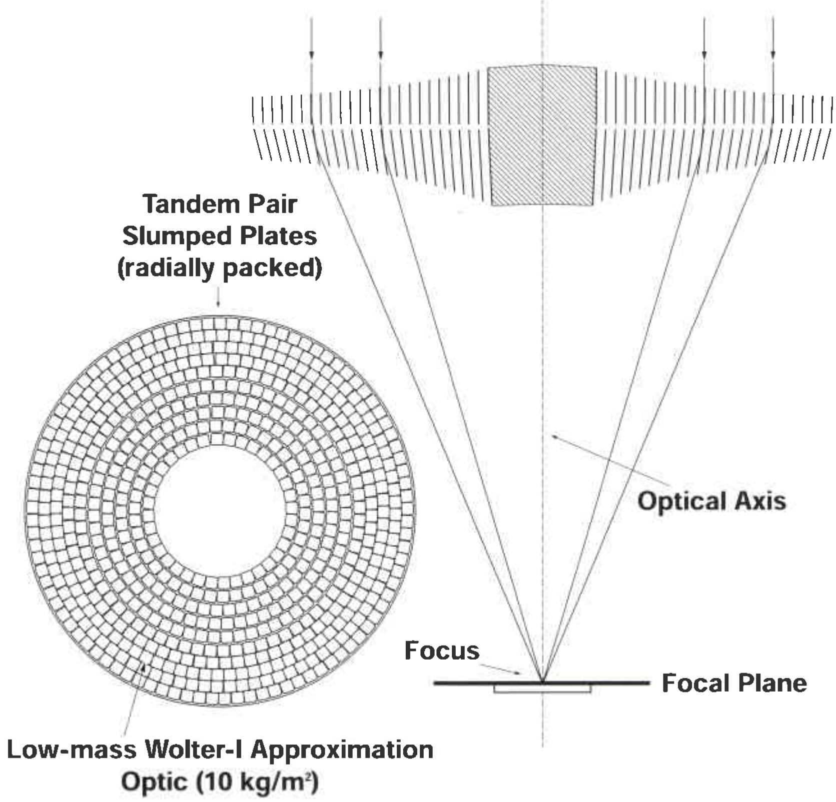


Figure 5. Schematic of an MCP-based optic. The microchannels are arranged in a radial geometry with a solid core. Two plates are required for the conical approximation of the Wolter-I geometry

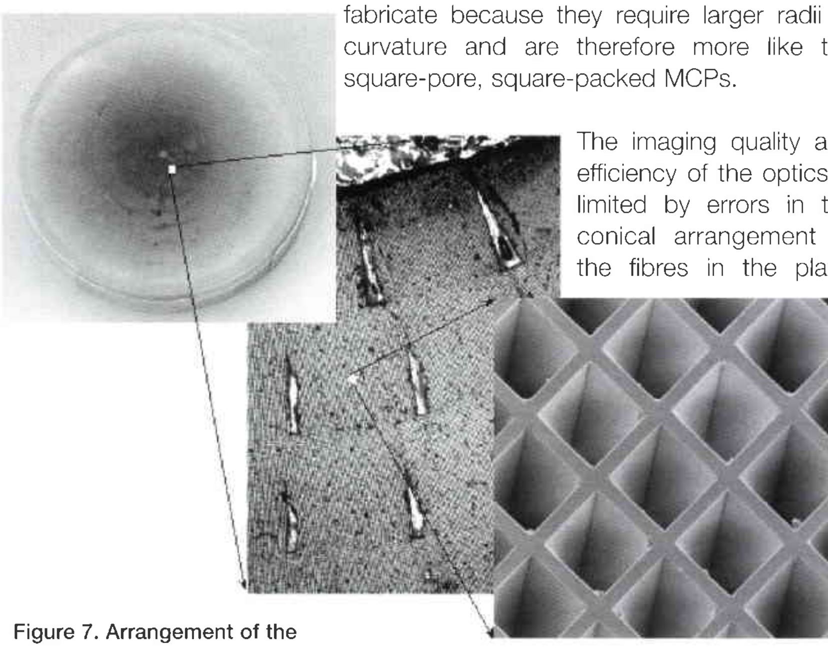
A prototype X-ray optic consisting of two circular plates of 60 mm diameter, each 5 mm thick, was produced, as shown in Figure 6. Each plate contains 20 million almost perfectly square holes, each 10 microns in diameter, with a wall thickness of a micron. The MCP plates are made of glass with a high bismuth content, to increase the X-ray reflectivity and improve the processing of the glass. To achieve the conical approximation to a Wolter-I geometry, one plate is slumped to a spherical profile with a radius of curvature of 20 m, the other to a radius of curvature of 6.7 m. In combination, this doublet has a focal length of 5 m, which was chosen to facilitate X-ray testing. Figure 7 shows the hierarchical structure of the radially packed square multi-fibres in the MCPs of this optic. The RMS surface roughness is 10 A

Figure 6. X-ray mirror doublet, conical approximation to a Wolter-I design - diameter 60 mm, thickness 2 x 5 mm, focal length 5 m. This is effectively an X-ray lens, analogous to its optical counterpart in the visible regime. Its mass is 28.5 g

(measured between 20 and 2000 mm^{-1}), which is sufficiently smooth to reflect medium-energy X-rays.

This X-ray optic behaves in the same way as a normal bi-convex lens in the visible range - it is effectively an X-ray lens. The lens is compact, robust, easy to mount and very light. The mass of the 60 mm-diameter prototype is 28.5 g (corresponding to 10 kg/m^2). This is to be compared with a value of ~900 kg/m^2 for XMM-Newton.

For practical optics of larger sizes, off-axis modules would be used. These are easier to fabricate because they require larger radii of curvature and are therefore more like the square-pore, square-packed MCPs.



The imaging quality and efficiency of the optics is limited by errors in the conical arrangement of the fibres in the plate.

Figure 7. Arrangement of the square multi-fibre bundles in the radial stack for the doublet. Each square bundle consists of 55 x 55 single square fibres. The gaps between the bundles can be filled prior to etching the plates. The multi-fibre bundle size projects to 20 arcsec in the focal plane. The single fibres have pores of 10 x 10 μm^2

A misalignment of the pores in the first plate compared to the second plate can block part of the rays and blur the focus. Since the two plates of the doublet were cut adjacent to each other, most of the alignment errors are present in very similar amounts in both plates. Consequently, the errors in the two plates compensate each other to a large extent, and only increase the vignetting.

Figure 8 shows the first true image of a point-like X-ray source taken with the prototype MCP optics of a Wolter-I configuration at the ESRF facility. The X-ray radiation of the source located 20 m from the optics, emitting photons of 8 keV (0.15 nm), is focused by the glass X-ray lens. Half the focussed radiation falls within a circle with a diameter of 1.0 arcmin. This is only a factor of 4 larger than the imaging resolution of XMM-Newton, with a much larger specific mass (with 350 kg at a diameter of 700 mm, i.e. 910 kg/m^2). If this imaging quality were to be further improved, it might be possible to build an XMM-Newton comparable mirror system with a mass of ~10 kg, with accompanying savings in mission costs.

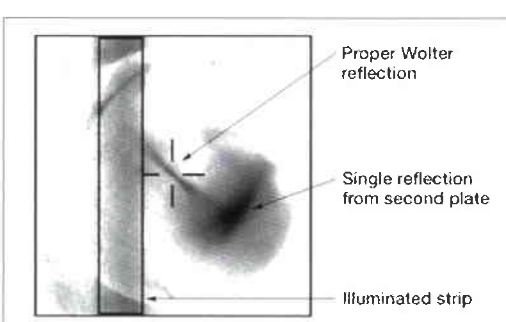


Figure 8. The first true X-ray image taken with the compact, MCP-based 'X-ray lens'. Only a strip of the optics is illuminated by the synchrotron radiation

Conclusion

A number of different technologies are being studied by ESA for the development of X-ray optics with a view to maximising the area/mass ratio whilst still maintaining image quality. The applications are very diverse, ranging from high-performance large-area mirrors, such as those required for the next generation of astrophysics missions such as XEUS and all-sky X-ray survey missions such as Lobster-IS, to very lightweight medium-resolution optics for planetary geology mapping through remote X-ray fluorescent imaging. Within this broad approach, MCP mirror technology is providing very attractive lightweight optics for mass-critical missions. Scattering and surface roughness are comparable to traditional X-ray optics, but the resolution is currently limited to about 1 arcmin. Square pores are used, which are perfectly square and straight at a level of 20 arcsec. The production of off-axis elements would allow the building of a segmented optic with a large diameter and collecting area. The challenge for Europe will be to pursue this and other novel technology further by improving the image quality and overall energy response.

Acknowledgements

We would like to express our thanks to G. Fraser and his group at Leicester University for their significant contributions in the collaborative effort to develop MCP optics for planetary missions, and to the companies involved in the production of the test mirrors for the ESA X-ray optics programme, namely Carl Zeiss (D), Media-Lario (I) and Photonis (F). esa

The ISS Operations and Exploitation Programme

R. Chesson
Operations Management Division, ESA Directorate of Manned Spaceflight and Microgravity, ESTEC, Noordwijk, The Netherlands

The assembly of the International Space Station (ISS) is well under way, with a crew of three in permanent residence. A significant step in the utilisation of the ISS was made with the launch of the US laboratory 'Destiny', which is now outfitted with a number of scientific payloads that, despite the limited resources of the current Station, are providing NASA with a valuable initial research programme. With Europe's main contributions to the ISS, the Columbus laboratory and the Automated Transfer Vehicle (ATV), scheduled for launch in 2004, ESA's ISS Exploitation Programme has already begun and the operations preparation for the ESA programme elements is gaining momentum.

ESA's rights and obligations in the ISS Operations and Utilisation Programme

By providing the Columbus laboratory, ESA contributes to the overall utilisation capabilities of the ISS. In return, Europe receives the right to use 50% of the payload accommodations afforded by Columbus (i.e. four payload rack positions and two external payload sites) and 8.3% of the total resources of the non-Russian part of the ISS. The latter is the result of the application of a complex formula that takes into account the contributions to the ISS infrastructure made by the different International Partners.

The ISS resources consist primarily of astronaut crew time and electrical power to perform payload operations. However, to exercise the right to use these resources Europe must also pay 8.3% of the cost for the 'common operations' of the ISS. Europe also has the right to purchase 8.3% of the services provided by the Space Shuttle for transportation of payloads, and 8.3% of the payload high-rate data services provided by NASA's Tracking and Data Relay Satellite System (TDRSS).

Rather than pay for ISS resources and NASA services in cash, ESA has elected to offset the charges by transporting cargo (spares, payloads, crew supplies, propellant, gases and water) to, removing trash from and raising the altitude of the ISS by means of the ATV. Current estimates show that between seven and eight ATV missions from 2004 to 2013 will be required to completely offset ESA's obligations.

Another key aspect of the ISS Programme is the principle that each Partner is responsible both financially and operationally for the operation and maintenance of the elements it brings to the Station. Consequently, the so-called 'common operations' relate mainly to the transportation and maintenance in orbit of the ISS crew as well as ground operations involving several Partners. An extension of this principle is that each Partner is responsible for training ISS astronauts on its elements and payloads.

ESA's ISS ground segment

As part of ESA's ISS Development Programme, a set of ground facilities are being developed to support the operations of the European ISS elements. Those for in-flight operation of the European elements are derived from the overall operations concept for ISS. At the outset of the ISS Programme, a concept of operations fully centralised at the Mission Control Centre, Houston (MCC-H) was envisaged whereby all International Partner elements of the ISS were controlled by a single, international Flight Control Team and all payloads operations were coordinated from the Payload Operations Integration Centre (POIC) at NASA's Marshal Space Flight Centre (MSFC) in Huntsville, Alabama. However, as a result of the extensive ISS redesign activity that took place in 1993 and brought the Russians into the Programme, ESA together with the other Partners insisted on a more devolved concept in which each Partner controls its own elements and payloads from its own facilities. In this concept, NASA coordinates the activities of the Partner centres and looks after safety-critical operations. The resulting ESA ground segment for flight operations, which is part of the overall ISS ground segment, is illustrated in Figure 1 and is comprised of the following major elements:

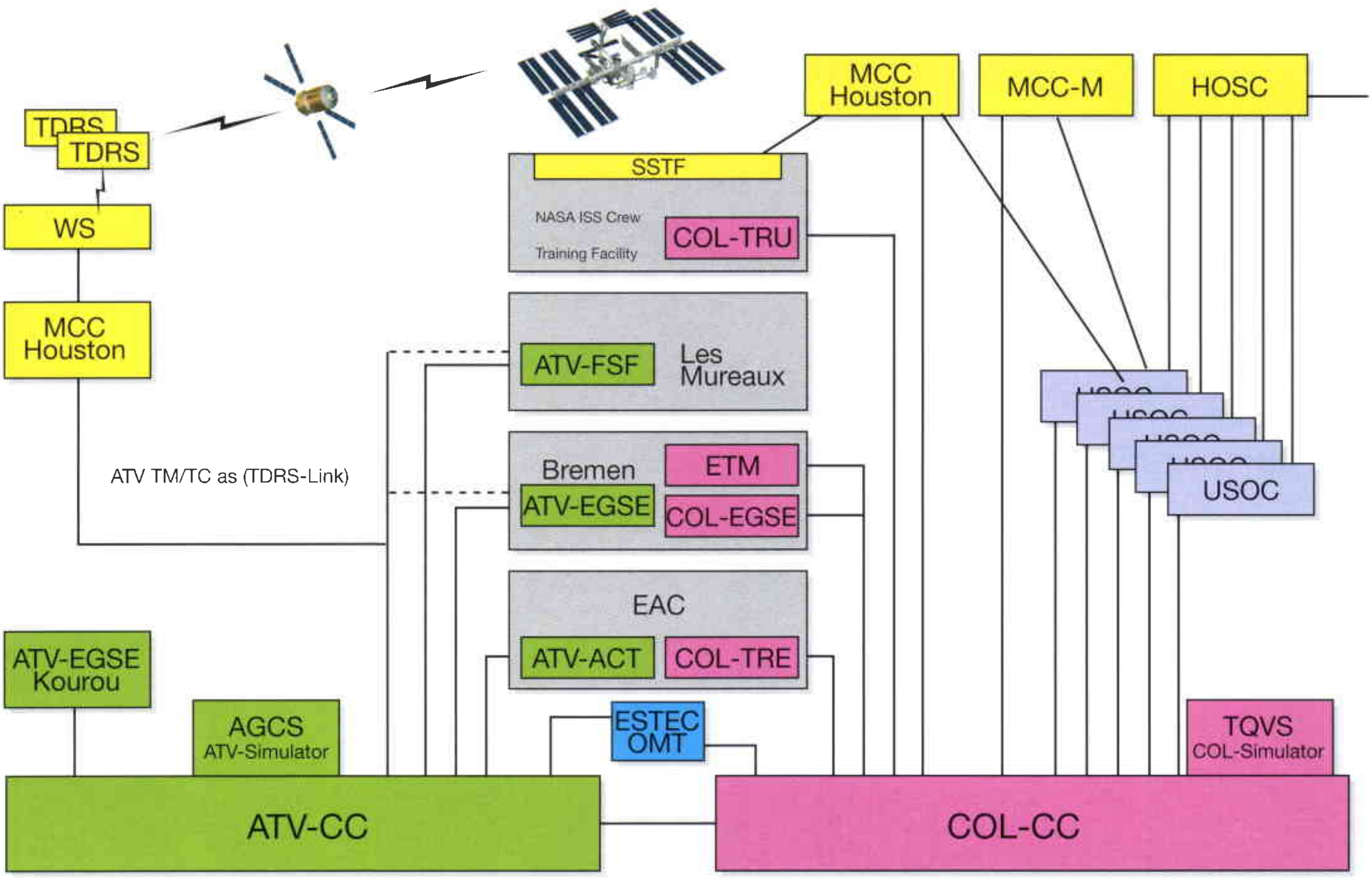


Figure 1. The overall ISS ground-segment architecture

The Columbus Control Centre

In 1997, the decision was taken by the ESA Council that the control centres for the main ESA ISS elements should be located at DLR/GSOC in Oberpfaffenhofen (D) for Columbus and at CNES in Toulouse (F) for the ATV.

The Columbus Control Centre (COL-CC) is housed in the facilities constructed originally to support the German Spacelab-D2 mission, but consists of a totally new development of the constituent systems. Of special note is the design of the Monitoring and Control System, which is based on the Columbus Ground Software (CGS) system. CGS has been developed from the outset of the Columbus Programme as an end-to-end data system from which all the Columbus software development, simulation and test facilities have been derived. In particular, CGS uses a single Mission Data Base (MDB) as a repository of the key Columbus data throughout the programme, thereby ensuring consistency and configuration control through development, integration and testing, and finally operations. So successful has this concept proved that NASA has adopted the CGS MDB software for its Mission Build Facility in which the entire ISS data is stored.

At the time of the decision on the location of the control centres, it was also decided that the development and operation of the ESA ISS ground communications network or IGS (Interconnection Ground Sub-network) should also be carried out by DLR/GSOC. The IGS is a Wide Area Network (WAN) using ATM technology that connects via relays the data sources and command destinations at MCC-Houston (MCC-H), MCC-Moscow (MCC-M) and the POIC with the European sites consisting of the ATV and Columbus Control Centres, engineering support sites, the launch sites, the User Support and Operations Centres (USOCs) and the European Astronaut Centre (EAC). On top of the basic network communications services, the IGS also provides high-quality secure data, voice and video infrastructure services.

The development of the Columbus Control Centre is now well under way, with the procurement of most subsystems already started. According to the current ISS Assembly Sequence, the first major operational event for COL-CC will be the support of the first ATV mission in August 2004, for which the IGS-related elements of the COL-CC must be at flight-readiness status.

The ATV Control Centre

The ATV-CC is under development at CNES in Toulouse, and in this case even the buildings are being newly constructed. The ATV-CC relies for its communications services on the

COL-CC, with the internal voice conferencing system and the IGS communications node being purchased under the umbrella of the COL-CC contracts. In common with the Columbus Programme, the ATV also uses the CGS and in particular the MDB. However, although the ATV-CC uses the MDB provided by the ATV developer as its basic data source, the ATV-CC monitoring and control system is not CGS-derived. A particularly important part of the ATV-CC is the flight-dynamics subsystem, which is used to compute trajectories and manoeuvres for the ATV during its free-flying phase and to monitor its trajectory during the critical rendezvous and docking sequence.

The ATV-CC will be completed in early 2004 to support validation testing, training and simulations prior to the first mission.

The User Support and Operations Centres

From the outset of the ISS Programme, a decentralised scheme for the utilisation of European payloads on board the ISS has been envisaged. USOCs located in various participating countries will act as the link between the user community and the ISS utilisation organisation.

During the pre-launch phase, the USOCs will be concerned with activities such as ground-model operations, experiment-procedure development, payload and experiment optimisation and calibration, and support to crew training activities. During the in-orbit payload operations, the USOCs will receive facility and experiment data and perform, in coordination with the Columbus Control Centre or the POIC, the operations of the payloads for which they are responsible. In addition, the USOCs will be responsible for the interaction with the scientists in the User Home Bases in disseminating experiment data to them, and receiving and processing requests for experiment scheduling and direct commanding.

Depending on the scope of the task assigned to a USOC, it can assume three basic levels of responsibility. The first level is to operate in support of users from the country in which the USOC is situated, in preparing and conducting an experiment. The second level is to operate as a Facility Support Centre (FSC) supporting particular functions of an Agency-provided multi-user facility. The third level is to operate as a Facility Responsible Centre (FRC) with full responsibility for the operation of a payload facility. The assignment of USOCs to ESA payload facilities is summarised in Table 1.

ESA provides the standard communication facilities and payload ground models (engineering models and/or science reference models) of the facilities for which a USOC is responsible as an FRC or is supporting as an FSC.

Engineering Support Centres

The main development facilities at Astrium (Bremen, D) for Columbus and EADS (Les Mureaux, F) for the ATV will be used during the operations phase to develop operations products and to support the control centres in troubleshooting and anomaly resolution. In particular, the software development and integration facilities at each site will be used to generate and test the respective flight software and data loads and the Electrical Test Model (ETM) for Columbus and the Functional Simulation Facility (FSF) for the ATV will be used for verification of software/data loads and troubleshooting problems during the respective missions. Both Bremen and Les Mureaux will be capable of receiving telemetry from the spacecraft via connections to the IGS.

ALTEC Logistics Centre

The ALTEC Centre is a joint venture between the Italian Space Agency (ASI) and Italian Industry. It has successfully supported the missions of ASI's Multipurpose Logistics

Table 1. Assignment of USOCs to payloads

	USOC	
Model Type/Facility	**Facility Responsible Centre (FRC)**	**Facility Support Centre (FSC)**
Pressurised Facilities		
BIOLAB	MUSC, Cologne (D)	Biotesc, Zurich (CH)
FSL	MARS, Naples (I)	Inst. DaRiva, Madrid (E)
EPM	CADMOS, Toulouse (F)	DAMEC, Copenhagen (DK)
EDR	ERASMUS, Noordwijk (NL)	B-USOC, Brussels (B) DUC, Emmeloord (NL)
MSL – SQF	CADMOS, Toulouse (F)	MUSC, Cologne (D)
MSL – LGF	MUSC, Cologne (D)	CADMOS, Toulouse (F)
EMCS	BPS, Trøndheim (N)	- / -
Unpressurised Facilities		
ACES	CADMOS, Toulouse (F)	- / -
SOLAR	B-USOC, Brussels (B)	- / -
EuTEF	ERASMUS, Noordwijk (NL)	- / -
SPORT	MARS, Naples (I)	- / -
EXPOSE	MUSC, Cologne (D)	- / -

Module (MPLM) and will be used to support the logistics of all ESA's ISS elements. The Centre has facilities that can be used for warehousing, packing and shipping of spare parts, depot maintenance activities, logistics planning and is also capable of receiving telemetry and processed ISS data to support real-time logistics activities.

ATV Production Facilities

The main facilities and ground-support equipment used for the manufacture, assembly, integration and testing (MAIT) of the ATV protoflight unit, will be maintained and used for the subsequent production programme, which is planned to span at least nine years. These include MAIT facilities for the integrated cargo carrier at Alenia in Turin (I), for the propulsion module structure at Contraves in Zurich (CH), for the avionics bay at Astrium in Toulouse (F), for the propulsion module and overall spacecraft integration and test at Astrium in Bremen (D), and for final spacecraft assembly and check-out at the launch facilities in Kourou, French Guiana.

Figure 2. The European Astronaut Centre (EAC)

Crew Training Facilities

ESA is responsible for training ISS astronauts to operate the European elements and payloads. To increase the efficiency of a desperately congested training programme for Station crews, the European training facilities are centralised at the European Astronaut Centre (EAC) in Cologne, Germany. These facilities consist of: the Columbus Trainer, which is a high-fidelity software simulation of the Columbus module systems housed in a mechanical mock-up; the ATV Crew Trainer, which is a software simulator of the ATV, which together with a simulation of the Russian Service Module crew workstation, provides an environment for training ISS crews on the ATV rendezvous operations; a high-fidelity mock-up of parts of the Columbus module for maintenance training; a high-fidelity mock-up of the ATV interior for training of cargo-transfer operations; and high-fidelity training models of the Columbus payload facilities.

In addition, a replica of the Columbus Trainer is installed in the Space Station Training Facility in Houston to support integrated ISS training, and a Russian-developed ATV training facility at the Gagarin Crew Training Centre will provide additional training capability for ATV rendezvous operations.

ISS operations preparation and integration

Although more modest schemes are currently being discussed in the light of the NASA budgetary problems, the nominal scenario for steady-state ISS operations foresees a crew of seven astronauts operating a fully complete Station, serviced annually by a total of five US Space Shuttles, two Soyuz and four Progress Russian vehicles, two Japanese HTV cargo vehicles and one ATV. During steady-state operations, three of the crew are Russian cosmonauts dedicated to operating the Russian part of the ISS, whilst the remaining four US, European, Japanese and Canadian astronauts are charged with operation of the non-Russian segment. The flight opportunities available to the non-Russian Partners are proportional to their contributions to the ISS. Europe's share of 8.3% buys approximately one flight for one ESA astronaut per year.

Whereas the Russian crew is rotated twice per year via the two Soyuz missions, a more complex scheme is planned for the rotation of the four non-Russian crew members via the Shuttle. The five Shuttle flights comprise four equally spaced (i.e. every three months) MPLM missions and one carrying only unpressurised external cargo. On each MPLM flight, three crew are rotated, leaving the fourth ISS crew member in orbit as the Commander for the next 'Increment', which is defined as the mission period between two crew-rotation flights of the Space Shuttle. The advantage of such a scheme is that it provides crew continuity from Increment to Increment.

The notion of the Increment is a key part of the overall ISS operations preparation and planning process. This is largely due to the fact that the Shuttle takes some 8 metric tons of dry cargo to the ISS with each MPLM flight and this cargo, which consists of payloads, spare parts and crew supplies, has a strong influence of the activities that will be carried out during the following Increment. Much of the preparation of an Increment is therefore related to the definition and preparation of the Shuttle cargo, as well as the cargo carried by some of the smaller vehicles visiting the Station during the course of an Increment.

Planning for a given increment starts five years before with the development of the strategic plan, which defines the resources available for the increment as well the planned utilisation. The strategic planning is progressively refined until two years before the Increment start, at which time the tactical planning process develops a set of detailed requirements for the Increment. These detailed requirements, which are baselined 18 months before Increment start, address the payload-utilisation and system-maintenance activities to be accomplished within the Increment, together with the associated resource requirements (crew time, electrical power, heat rejection, data and communications), the payload and system cargo items to be transported to and from the ISS, Extra Vehicular Activities (EVAs) to be performed, etc.

Based on these requirements, a detailed plan for the preparation of the Increment is drawn up by each Partner in line with a template, by means of which the overall ISS operations integration is carried out. The Increment operations preparation and integration covers the following activities:

- development and qualification of new payload hardware and software
- procurement and preparation of spare parts
- ground processing and cargo integration of flight hardware to be transported to the ISS
- analytical accommodation and engineering analysis of the compatibility of new payloads including the derivation of operational constraints
- preparation of flight and ground databases defining the telemetry and telecommands and associated data to be used during the increment
- preparation of flight and ground procedures and displays
- configuration of the ground segment and its facilities for the specific requirements of the increment
- training of the astronauts to operate the payloads and carry out the maintenance activities planned for the increment
- training of the flight-control and other ground-operations personnel on the specific increment operations
- detailed executional level planning of the activities scheduled for the increment
- simulations involving both ground- and flight-operations personnel.

To ensure that each of the above activities has been successfully concluded, a process called 'Certification of Flight Readiness (CoFR)' is employed. This process, which relies on a series of reviews, detailed status checks and inspections, is carried out by each Partner for its own part of the Programme. Overall certification is achieved via a series of ISS level reviews at which the status of Partner certification is incrementally checked. These reviews culminate in the Flight-Readiness Review at around launch minus 3 weeks, at which the final certification is achieved.

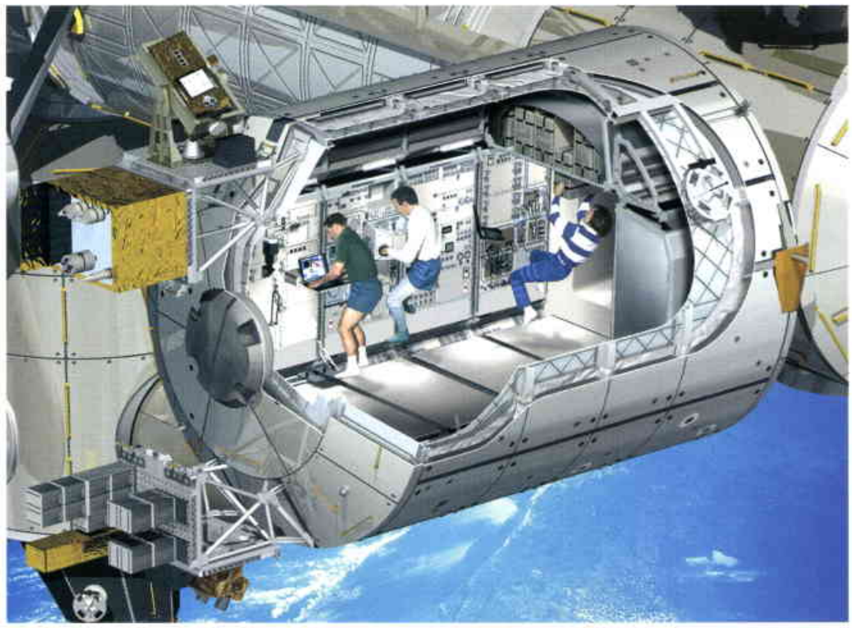


Figure 3. The Columbus laboratory

Although the operations integration activities described above relate mainly to the ESA elements that form an integral part of the ISS, i.e. Columbus and the payload facilities, this process also includes the following aspects of ATV operations:

- Since the ATV cargo is completely determined by the ISS manifesting process and the cargo items are provided by all international Partners, the entire ATV cargo integration process becomes entwined with the ISS operations integration. ISS databases interact with ATV cargo information systems to provide essential information on cargo items, ATV cargo layouts become an integral part of the ISS cargo operations procedures, ATV inventories are entered into the ISS Inventory Management System and the safety of the ATV cargo becomes part of the overall ISS safety review.
- Since the ATV has to rendezvous and dock with the ISS, ATV flight-dynamics operations and mission planning have to be integrated with those of the ISS so that the ATV launch windows can be properly computed and ATV flight trajectories designed and executed to achieve RVD opportunities compatible with ISS operations.
- The ISS crew and the MCC-M, and to some extent the MCC-H, flight controllers have to be trained to support the ATV operations. Due to the six months stay time at the ISS, at least two ISS crews have to be trained for

most ATV missions, and this has to be carefully planned into the Increment preparation schedule.

Sustaining engineering

ESA's ISS Operations and Exploitation Programme is the most extensive, long-term operations support undertaking ever attempted by the Agency. The flight elements that have to be supported for 10 years or more are:
- the Columbus laboratory
- the Microgravity Facilities for Columbus (MFC), consisting of the Biolab, the Fluid Science Laboratory (FSL), the Material Science Laboratory (MSL), the European Physiology Module (EPM) and the European Drawer Rack
- the Laboratory Support Equipment (LSE), comprising the Minus Eighty Degree Freezer (MELFI), the Microgravity Science Glove Box (MSG) and the Hexapod
- the Cupola
- the European Robotics Arm (ERA)
- the Data Management System for the Russia Service Module (DMS-R)
- the Automated Transfer Vehicle (ATV).

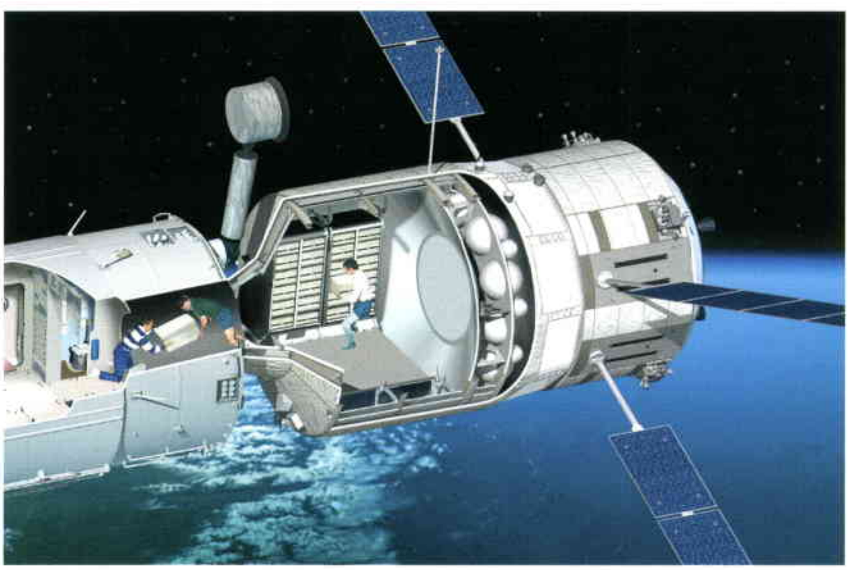


Figure 4. The Automated Transfer Vehicle (ATV)

In addition, the ground facilities supporting each of these flight elements have to be supported for the same period.

For each element, sustaining-engineering services have to be bought from the appropriate industrial contractors. However, the type and extent of the sustaining engineering varies greatly from element to element, depending on its complexity and in particular ESA's role in and obligations to its operation.

The simplest form of sustaining engineering is the on-demand provision of engineering expertise to support troubleshooting and anomaly resolution. This type of support is typically required for those elements such as the Laboratory Support Equipment that have been provided to NASA as constituents of a barter deal. However, even in these cases it is not straightforward to obtain commitments from the companies involved to maintain the necessary expertise for more than 10 years. Even if the Prime Contractors are willing to do this, the subcontractors are often not interested and so transfer of expertise, equipment and documentation is inevitable in most cases. Furthermore, due to the limited budgets available for sustaining engineering and the limited interest of staff in this type of work, companies cannot in general keep staff working full-time on these activities. Consequently, the access to experienced staff for troubleshooting and anomaly resolution is difficult to guarantee.

The Columbus laboratory represents the other extreme in sustaining engineering. In addition to the ad-hoc type of support required for troubleshooting described above, a more continuous effort is required to: prepare software and data updates for each Increment; perform analyses of the integrated payload and system performance to ensure that the planned payload complement can be operated and to derive operational constraints; develop and update operations procedures; and carry out software maintenance as well as maintenance of the Columbus ground facilities. A number of the facilities used in the Columbus development programme are maintained and used for sustaining engineering. These include the Electrical Test Model used for troubleshooting, software, data and procedure qualification, and the Software Development and Integration facilities.

Software maintenance over such a long period presents some challenges of its own, especially where commercial COTS products have been chosen. Due to the sometimes unpredictable evolution of the commercial markets, essential on-board software products may eventually no longer be supported by the vendors. A typical example of this is the on-board display software (SAMMI) chosen for Columbus, which even before launch has become obsolete. As a consequence, the opportunity is being taken to review the entire Columbus laptop display architecture with a view to implementing XML technology.

Owing to the significant delays in the ISS Programme, several ESA flight elements that should already be in orbit have completed development but have not yet been launched. Nevertheless, their sustaining-engineering programmes have already started and in particular software maintenance is being carried out.

Logistics and maintenance

Most of the ESA elements listed above are maintained in orbit by exchanging failed equipment with working units. To facilitate this, the design of each element includes a number of Orbit Replaceable Units (ORUs) that contain the parts most likely to fail and require replacement. Each ORU has its own maintenance concept supported by the required stock of spares, EEE parts, maintenance tools and facilities, test equipment, documentation and trained personnel.

The maintenance approach for each ORU has been arrived at as a result of logistics analyses, and negotiations with equipment and parts vendors with regard to their willingness to support a long-term maintenance programme. Maintenance concepts range from buying sufficient spare ORUs to cover all failures throughout the lifetime and thereby avoiding the need for long-term vendor support, to purchasing two ORUs and sufficient EEE parts and/or pre-assembled PCBs to allow the repair of the ORUs for 10 years. The latter concept relies on exchanging one ORU for the other in orbit following a failure, and transporting the failed ORU to the appropriate maintenance site for repair so that it is then available for exchange should the other ORU fail.

One of the problems with ISS maintenance is the access to launch services for transporting spares to the Station. The manifest for any flight is decided by prioritising cargo items based on their criticality, so that it is unlikely that a unit that fails in Columbus or a payload towards the end of an increment will be replaced during the following two increments.

A major problem influencing maintenance approaches and spares procurement is that of parts obsolescence. Due to the length of the ISS Development Programme, most of the designs that are now qualified use technologies that are out-of-date and parts that are either now obsolete or will become so in the near future. As a result, difficult decisions are currently being taken as to whether to make lifetime buys of obsolete parts or to plan on upgrading the technology. Such decisions are complicated by the quality of the data on which such decisions have to be based. This is mainly the failure-rate data, which is notoriously inaccurate due to the lack of real statistics based on large sample sizes.

The procurement of most spare parts has already been initiated due to the cost benefits of manufacturing them together with the initial flight units. In general, sufficient spares are being procured to support lifetime operations although in one or two cases, e.g. upgrading of mass storage technology from Winchester disk to solid-state devices, it has been decided, due to the low risk involved, to implement newer technology.

The ALTEC Centre in Turin will be the focal point for all European logistics activities for the ISS Exploitation Programme. ALTEC is currently supporting the MPLM logistics operations, but will gradually take on the role of integrated logistics operations for all European elements of the ISS.

Columbus flight operations

In-orbit operation and control of the Columbus laboratory systems will be conducted by flight controllers in the Columbus Control Centre (COL-CC) at DLR/GSOC in Oberpfaffenhofen. Because Columbus will be outfitted with a mixture of European and US payload facilities of various disciplines and consequently a wide range of operating periods and degrees of interaction, it is a priori impossible to predict when COL-CC be required to change the system configuration. Consequently, it is planned to operate for 24 hours per day, 7 days per week using three shifts per day. The flight controllers will be supported in their operations by on-site engineering support personnel provided by the development contractors. These engineers will provide a deeper level of knowledge of the Columbus systems and will play a major role in key system operations, such as assembly and activation as well as system-maintenance activities. They will also perform troubleshooting and anomaly resolution for failures that cannot be handled by the flight control team.

In addition to its system-management role, the COL-CC flight control team also coordinates the operations of the Columbus payload facilities and the experiments conducted within them. Operations of the Columbus payload facilities and their experiments are conducted from the 11 User Support and Operations Centres (USOCs).

The Columbus flight-control team works in close cooperation with the NASA ISS flight-control team at MCC-Houston for all operations that affect overall ISS resource management and multi-element and safety-related operations, and with the POIC flight controllers for overall ISS payload coordination.

The overall compatibility of the distributed operations carried out by the different Partner Control Centres is ensured by the use of a single integrated execution-level plan. This plan is integrated by NASA based on the Element-level plans provided by Russia, ESA and Japan. The Partner plans are compiled using a common tool, which is also used by NASA to perform the integration into a single 'Short Term Plan' (STP). The STP nominally spans one week of activities comprising both system and payload operations. The COL-CC flight control team's main objective is to execute the STP within the approved flight rules, and within this domain it can operate more or less autonomously. However, if malfunctions or significant changes in payload objectives cause significant deviations from the STP, the Programme Operations Management will be called upon to decide on how to continue operations.

The COL-CC also manages the ESA ISS ground communications network, which in addition to providing operational data to the Control Centres and engineering support sites, also provides higher rate scientific data to the USOCs.

ATV flight operations
The ATV will be operated and controlled by a team of flight controllers in the ATV Control Centre (ATV-CC) at CNES in Toulouse (F). Similar to Columbus, the ATV flight controllers will be supported in their operations by on-site engineering support personnel provided by the development contractors. The ATV-CC flight control team will interface closely with the MCC-M flight controllers during the final stages of rendezvous, at which time commands and telemetry will be routed either via the TDRSS or via the MCC-M and the Russian ground stations.

The level of interaction between the ATV and its Control Centre varies greatly with the phase of the mission. During the free-flying phases, the ATV-CC is responsible up to the final approach for determining the ATV trajectory and for calculating and executing the manoeuvres required to rendezvous with the ISS at the planned time and coordinates. During the final approach, the ATV trajectory is controlled by the ATV on-board software, which receives inputs from the ATV rendezvous sensors. During this phase, the ATV-CC monitors the vehicle's trajectory and attitude to ensure that it is within the allowed safety envelopes. After docking, the ATV-CC monitors the vehicle's systems and supports cargo transfer, ISS reboost and propulsive attitude-control operations. Finally, after undocking of the ATV from the ISS, the ATV-CC controls the destructive re-entry manoeuvre operations.

Like the Columbus Control Centre, the ATV-CC will operate 24 hours/day, 7 days per week during an ATV mission.

Operations management
To coordinate, integrate and manage the various operations activities described above, an Operations Management function led by ESA has been implemented. In addition to managing the operations phase programme, Operations Management: performs operations planning; organises and conducts ESA-level technical reviews and operations boards; participates in the ISS operations and utilisation control boards; coordinates and consolidates data and products provided to the ISS Partners and other external interfaces during operations preparation and execution; manages the procurement of ATVs and Ariane launch services; manages the user interfaces and coordinates payload data collection; performs science coordination; and manages the training activities, as well as ESA crew operations and medical-support activities. In particular, Operations Management oversees the overall ESA Certificate of Flight Readiness process.

During operations, Operations Management representatives will be stationed at the Control Centres to provide rapid Programme-level decision-making capabilities to support the ATV or Columbus Flight Directors and ISS Control centres in the event that the operations can no longer be carried out within the established plans, procedures and flight rules. Operations Management at the Columbus Control Centre will also be responsible for coordinating the real-time scientific objectives and for ruling on conflicts, should they arise. This function will also support the operations of ESA payloads in the US Segment.

Organisation of the Exploitation Programme
The intention is to eventually conclude a single contract with Industry to carry out the operations activities described in this article as a set of end-to-end services. However, due to the uncertainties in the scope of the activities, the transition from Development to Exploitation Programme, as well as overall programme situation, the risks are currently too great for Industry to enter into such a service contract. This will therefore be postponed until steady-state operation of both Columbus and the ATV has been achieved.

In the meantime, ESA, in addition to managing the overall Exploitation Programme, will take responsibility for the Operations Management and integration functions.

Operating the European Drawer Rack on the ISS

J.C. Degavre, C.Taylor, J. Miro
ESA Directorate of Technical and Operational Support, ESTEC, Noordwijk, The Netherlands

E. Kuijpers, P. Dujardin
National Aerospace Laboratory (NLR), Emmeloord, The Netherlands

L. Steinicke
Space Applications Services, Zaventem, Belgium

H. Koenig
ESA Directorate of Manned Spaceflight and Microgravity, ESTEC, Noordwijk, The Netherlands

The Erasmus User Centre, located at ESTEC in Noordwijk, will have overall responsibility for the preparation and execution of operations for the European Drawer Rack (EDR) facility in the European Columbus laboratory on the International Space Station (ISS). Together with the national User Support and Operations Centres (USOCs) involved in the operation of experiments on the ISS, it will form the network conducting the decentralised payload operations baselined for the European elements of the ISS.

The European Drawer Rack (EDR)

Utilisation features

The European Drawer Rack, housed within the Columbus laboratory, is a multi-user facility supporting and providing services to experiments accommodated in three ISIS (International Sub-rack Interface Specification) Drawers and four ISS Lockers (Fig. 1). It is a flexible, multidisciplinary experiment carrier. The scientific and observation instrumentation is provided by the experiment developer and integrated into the Drawers and Lockers, which are provided by ESA. Several experiments can be monitored and controlled in parallel, autonomously or with ground intervention, and with or without ISS crew intervention, as required. They share the electrical power, data and video services, cooling and venting capability provided by the EDR.

An experiment in the EDR can be accommodated within a single Drawer or Locker, or may occupy a combination of both. As the individual Drawers and Lockers are exchangeable in orbit, this allows for the exchange of a complete experiment in the former case, or of only one subsystem of an experiment in the latter.

**Experiment volume ISS Locker: 57 litres, W = 440 mm, H = 253 mm, D = 516 mm
Experiment net mass: 28 kg max.**

**Volume 8-PU ISIS Drawer: 72 litres, W = 387 mm, H = 327 mm, D = 574 mm
Experiment net mass: 39.5 max.**

Figure 1. The European Drawer Rack (EDR) can accommodate two types of experiment containers: the ISS Locker (left) and the ISIS Drawer (right)

The ISIS Drawers and ISS Lockers provide mechanical compatibility with the NASA Express Transport Rack. The ISS Lockers are also mechanically compatible with the interfaces on the Space Shuttle's mid-deck (e.g. DC voltage supplies), where it is planned to transport Locker inserts. This facilitates flexible experiment turnaround, with exchanges of experiment samples or diagnostic instruments. The data handling is also standardised and complies with the NASA Express Rack Protocol, allowing standardised integration test procedures.

The EDR provides the Drawers or Lockers with the following Columbus system resources:
- DC power (28 and 120 V)
- data exchange (RS-422 and Ethernet)
- high-speed telemetry or digital video interfacing
- vacuum, venting and nitrogen gas supply.

These resources are provided by the following subsystems:
- Power Distribution Unit (PDU)
- Process Control and Command Unit (PCCU)
- Ethernet Hub for Payload LAN Connection
- Video Management Unit (VMU)
- Avionics Air Assembly (AAA) for air cooling
- Water Cooling
- Utility Distribution Panel (UDP)
- Laptop Computer.

The EDR's scientific capabilities were described in ESA Bulletin 108 (November 2001 issue).

Table 1. EDR facility resource consumption estimates used for operations reference-scenario development

Facility	Characteristic	Resources needed
PCDF	Mass	66 kg 28(L) + 38(D)
	Crew	< 2 hrs/week
	Power	< 330 W
	Data	2 Mbit/s
FAST	Mass	56 kg
	Crew	< 2 hrs/week
	Power	< 130 W
	Data	1 Mbit/s
BMTC	Mass	< 81 kg
	Crew	< 2 hrs/week
	Power	< 550 W
	Data	2 Mbit/s
MSF	Mass	< 48 kg
	Crew	< 2 hrs/week
	Power	< 700 W
	Data	0.02 Mbit/s

Payload capacity

The following experiment configuration has been used as a working reference payload complement for
performing operational analyses (see Table 1):
- PCDF: Protein Crystallisation Diagnostic Facility (accommodated in 1 Drawer and 1 Locker)
- FAST: Facility for Adsorption and Surface Tension (accommodated in 2 Lockers)
- BMTC: Biotechnology Mammalian Tissue Culture facility (accommodated in 1 Drawer and 1 Locker)
- MSF: Materials Science Facility (a hypothetical payload, assumed to be accommodated in 1 Drawer).

This payload complement would occupy all the accommodation space available in the EDR, i.e. 3 Drawers and 4 Lockers.

At the time of writing, one facility has already been officially selected and is under development, namely the PCDF, while the FAST is currently under consideration. The likely initial configuration for the EDR to be launched with the Columbus laboratory itself is shown in Figure 2.

ESA is also pursuing the selection of experiments to be uploaded and integrated into the EDR once the Columbus laboratory is in orbit. These include experiments on thermal-transport phenomena in magnetic fluids, diffusion and Soret coefficient measurements, metal foams, and space combustion research, fundamental and applied studies of emulsions, biotechnology mammalian tissue cultures and critical-point phenomena, which are the subject of Announcements of Opportunity. In addition, approximately one-third of the utilisation opportunities will be reserved for commercial applications.

Under the terms of the ISS Utilisation agreement, 8.3% of the Station's overall resources will be available to ESA and hence the European users. This extends to all types of resources, such as power, crew time, visibility periods, and data downlinking and uplinking capacity. If one assumes that the resources available to Europe are distributed evenly between the five most resource-demanding European facilities, namely the Materials Science Laboratory (MSL), the Fluid Science Laboratory (FSL), Biolab, the European Physiology Modules (EPM), and the European Drawer Rack (EDR), then the resources specifically available for the EDR will be as indicated in Table 2. This means, however, that at this stage the ISS resources required by the EDR to support and operate the payloads listed above, and have them operating in parallel, would considerably exceed the projected utilisation share.

Ground segment

The EDR ground segment will be connected with the Erasmus User Centre in Noordwijk, designated as the Facility Responsible Centre (FRC) for the EDR, via the Interconnection Ground Subnetwork (IGS). The IGS facilitates all data exchange (science data, voice, video, telemetry/telecommand) between the Columbus Control Centre (Col-CC) and all of the User Support and Operations Centres (USOCs). The EDR ground segment will include three co-operating USOCs.

As discussed above, the Erasmus FRC will take full responsibility for the EDR as a system, but may delegate EDR experiment operations to the Belgian User Support and Operation Centre (B-USOC) and to the Dutch Utilisation Centre (DUC). The B-USOC and the DUC will assume responsibility for multi-user facilities accommodated within the EDR in one or more Drawers/Lockers, as Facility Support Centres (FSCs). The B-USOC will have permanent FSC responsibility for the Protein Crystallisation Diagnostic Facility and will focus on science mission planning and operations (Figs. 3 & 4).

The role and responsibilities of the Erasmus User Centre

The Erasmus User Centre will be responsible for EDR operation during both the mission-preparation and mission-execution phases, covering a variety of tasks:
- strategic and tactical planning
- payload integration
- payload operations preparation

Figure 2. The probable configuration of the European Drawer Rack (EDR) to be launched with the Columbus laboratory

Table 2. EDR resource allocations as a function of total ESA resources on the ISS

Type of constraint		EDR resource budget estimate	Estimate ESA resources on ISS	Unit
Mass	Envelope	500 (launch) < 650 (in orbit)		kg
	Upload, pressurised	200.0	1000.0	kg/year
	Download, pressurised	156.00	780.00	kg/year
	Upload, unpressurised	60.00	300.00	kg/year
	Download, unpressurised	60.00	300.00	kg/year
Crew		0.5 (empty) to 2 (full)	1.4-2.6 (initial) to 12.5 (steady phase)	hours/week
Power	Average	0.5 (< 3kW)	2.49 (30 kW for ISS)	kW
Data	Average data rate	< 0.71	3.57 (43 Mbps ISS)	Mbps
	Maximum low and medium rate	1.5	1.5	Mbps
	Maximum high rate	30	30	Mbps

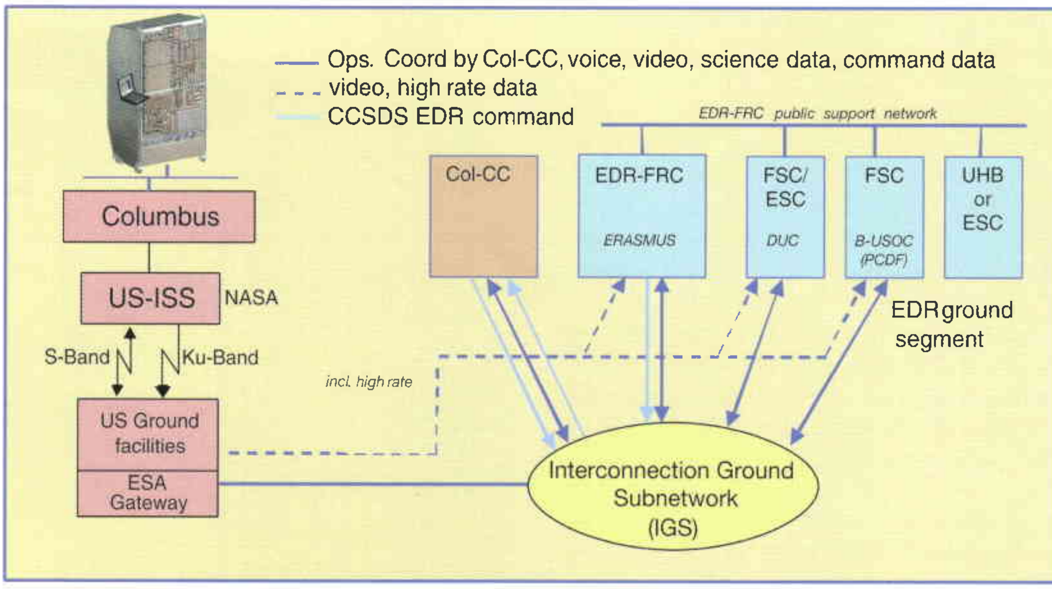


Figure 3. Connection of the EDR experimenter teams to the Erasmus User Centre

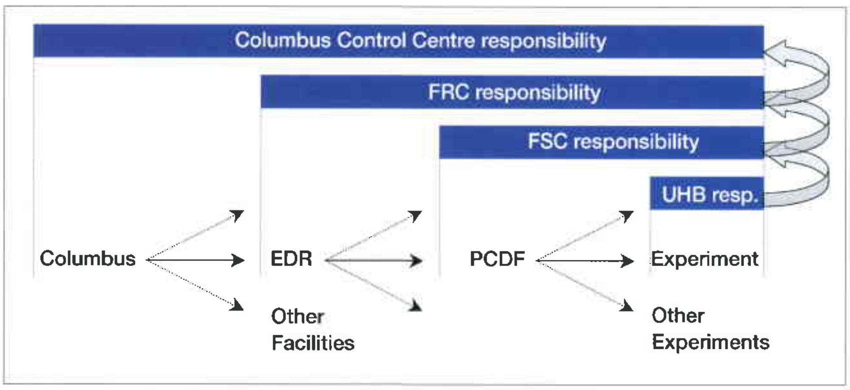


Figure 4. Division of responsibilities between the various EDR-involved centres

- operations support training
- payload execution-level planning
- payload operations execution
- facility health and status monitoring
- post-mission evaluation and post-mission-Increment operations
- reports and configuration management
- experiment preparation and promotion
- logistic support for experiment up- and down-loading.

Operational products will be an output from these tasks to the Columbus Control Centre prior to each new mission Increment.

Predefined resource envelopes will be allocated as part of the scheduling of experiments. Depending on the specific resource demands of the various experiments, several may be operated in parallel, or operations may be reduced during certain phases to a subset of the Drawers/Lockers. There may be up to four mission Increments (uploads) each year.

The EDR industrial developer will perform the initial payload integration for the Columbus launch, with the participation of the Erasmus FRC. For all subsequent Drawers and Lockers prepared during the in-orbit lifetime of the EDR, responsibility for flight acceptance will lie with the Erasmus FRC. The latter will also support the scientific investigators and payload providers during the development of their payloads, including provision of technical support for interface specification, operation concept definition and test verification.

The Erasmus FRC is responsible for analytical integration of each new Drawer payload, to ensure that the specifications and design will enable safe and correct interfacing with the EDR. The final step in the acceptance process is the physical integration of the Drawer/Locker instrument into the EDR engineering model located at the FRC. Once this final step has been completed and all associated tests passed successfully, the Drawer/Locker will be loaded into the relevant space-transportation vehicle that will bring it to the ISS. For Drawers, this is the MPLM which is launched in the Space Shuttle's cargo bay, whereas Lockers are launched in the Shuttle's mid-deck.

Workload

Utilisation bounded by 75% of EDR payload capacity during steady-state operation has been used to dimension the EDR support services. This is deemed to be a reasonable envelope based on the current EDR resource constraints and the assumption that continuous and simultaneous use of all Drawers will not be feasible:

- Most of the proposed experiment facilities for the EDR comprise more than one ISIS Drawer/ISS Locker, and typically use two. With seven slots for Drawers/Lockers, the number of teams that can operate in parallel will be three on average, and be limited to four.
- The number of Drawer/Locker exchanges is limited by the up- and down-load constraints

and limited crew availability for installation. With 200 kg of up-load capacity and 156 kg of down-load capacity available per year, this limits the annual exchange capacity to a maximum of three ISIS Drawers or four to five ISS Lockers.
- Crew time is an additional parameter that limits the number of exchanges that are feasible per year.
- The peak power and the communication bandwidth available are limited and have to be shared between the Drawers and Lockers being hosted.

A reasonable workload for the EDR ground-segment team has been estimated to consist of:
- The monitoring of two double Drawer/Locker and one single Drawer/Locker payload.
- The preparation of one Drawer exchange per mission Increment.
- The acceptance of one novel payload upload per year.

This overall workload will be shared between the Erasmus FRC and the B-USOC and DUC Facility Support Centres.

Special facilities
To support the development, qualification and in-orbit maintenance of EDR and its payloads, the Erasmus FRC will make use of the Payload Integration and Operation Reference Facility (PIORF). The PIORF is a representation of the end-to-end data-management system as seen by EDR and its payloads. It incorporates the EDR Electrical Engineering Model and provides a simulation of the Columbus data transmission protocols and support services. The Electrical Ground Support Equipment used during the development of EDR and of its payloads is used to operate them. Using the PIORF, it will be possible to validate changes to operations procedures, software updates or new payload experiments prior to deployment in the EDR flight segment.

The EDR FRC also plans to have at its disposal a number of items of transportable Experiment Ground Support Equipment (ExGSE) able to stimulate the power, cooling, and command and data interfaces of an experiment under development. These ExGSEs will be used to test and verify – without the need for access to the EDR flight or engineering models – that an experiment, once accommodated in the EDR, will work correctly and also respect the applicable interface and operational specifications and constraints. It is the intention that the ExGSEs will also be used to develop and test ground and on-board software.

An EDR and PCDF Virtual Model and Software Simulator will provide a flexible tool for the preparation and validation of EDR operational plans and experiment procedures and for the training of ground operators. As a secondary objective, it will help in the presentation and demonstration of the EDR's capabilities to potential users.

An EDR Multimedia Web Server will provide user-friendly access to:
- all the technical documentation required by the experiment developers

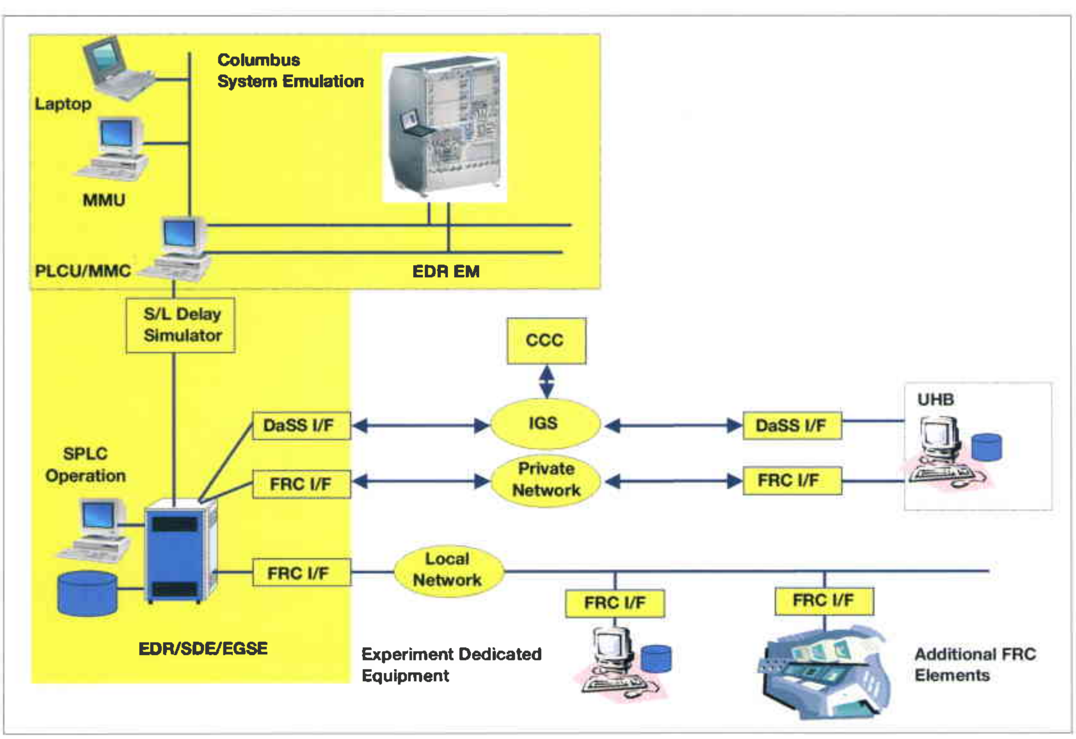


Figure 5. Ground Payload Integration and Operation Reference Facility (PIORF) to support the development and qualification of new EDR payloads

- the records of EDR flight events and of its in-orbit performance
- experiment data and video buffers and replays
- the knowledge acquired during the integration of EDR Drawers or Lockers
- EDR utilisation planning
- user training materials and plans
- an archive of valuable products and data.

The Server will also give access to multimedia products, such as 3-D animations, simulation videoclips, and 3-D images.

The above facilities will be developed under ESA's technical management by Belgian and Dutch industry.

Operating concept
The following functions will be executed by the EDR Facility Responsible Centre within the Erasmus User Centre at ESTEC:
- control over access to the ground and on-board services and resources
- monitoring of experiment resource consumption
- formatting and transmission of experiment commands, and generation and transmission of facility commands
- reception, archiving, display and distribution of housekeeping and science data
- generation, validation and uploading of experiment operation procedures and schedules
- integration and distribution of planning information.

The EDR experiments themselves will be designed to operate autonomously under the control of the experiment computer or EDR computer, which provide the means for experimenter intervention by telecommand (e.g. start/stop/suspend/resume experiment procedure, switch power supply on/off, switch cooling system on/off, upload files, etc.).

The principal elements involved (Fig. 6) are:

- the EDR PCCU based on the ESA Standard Payload Computer (SPLC) with its interface to EDR subsystems and Drawers/Lockers

- the EDR crew laptop computer

- the Electrical Ground Support Equipment (EGSE) of the SPLC providing the basic software environment for medium-rate telemetry and commanding via the ground-to-space link

- the Erasmus FRC server

- one or more clients at remote user locations, linked via the EDR FRC public support network or the IGS.

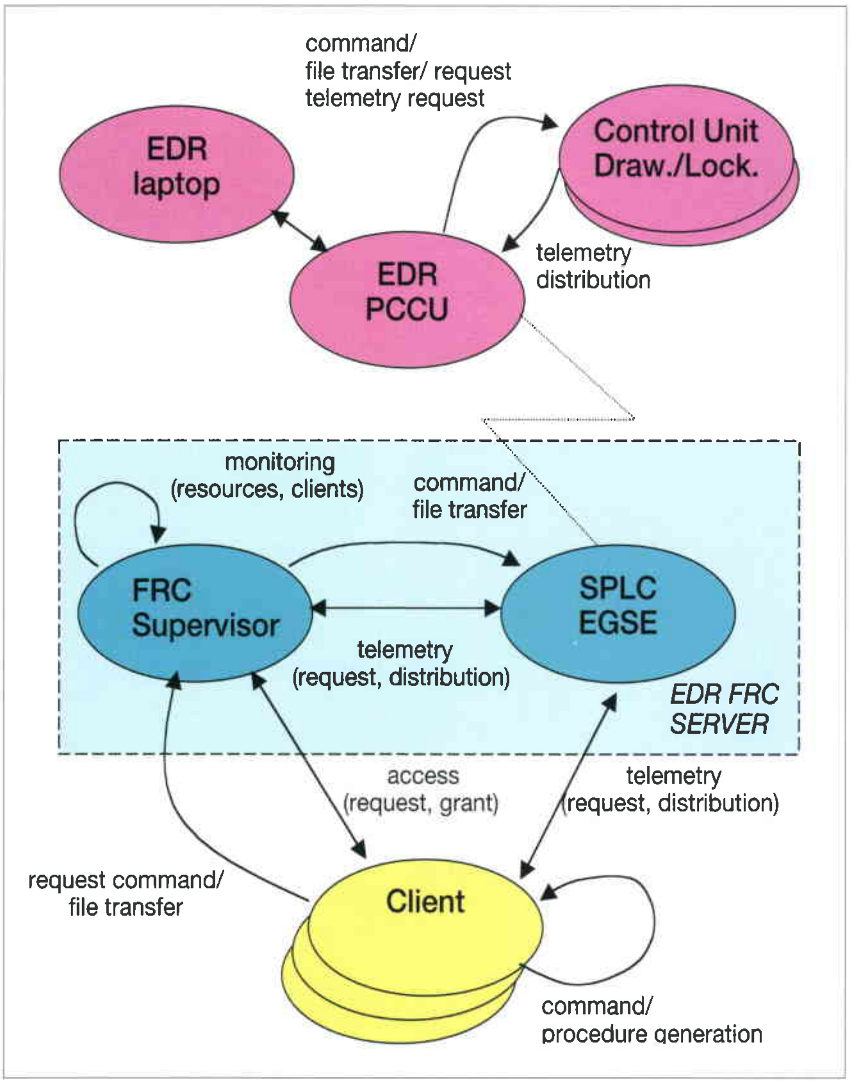


Figure 6. The concept of distributed EDR experiment operations using the client-server paradigm

Acknowledgements
The authors gratefully acknowledge the contributions of Mrs M.Cl. Limbourg from the Belgian USOC, Mr D. de Hoop from the Netherlands Agency for Aerospace Programmes (NIVR), and Mrs B. Taglienti, a trainee at ESTEC, in the preparation of this article.

SUCCESS 2002 STUDENT CONTEST

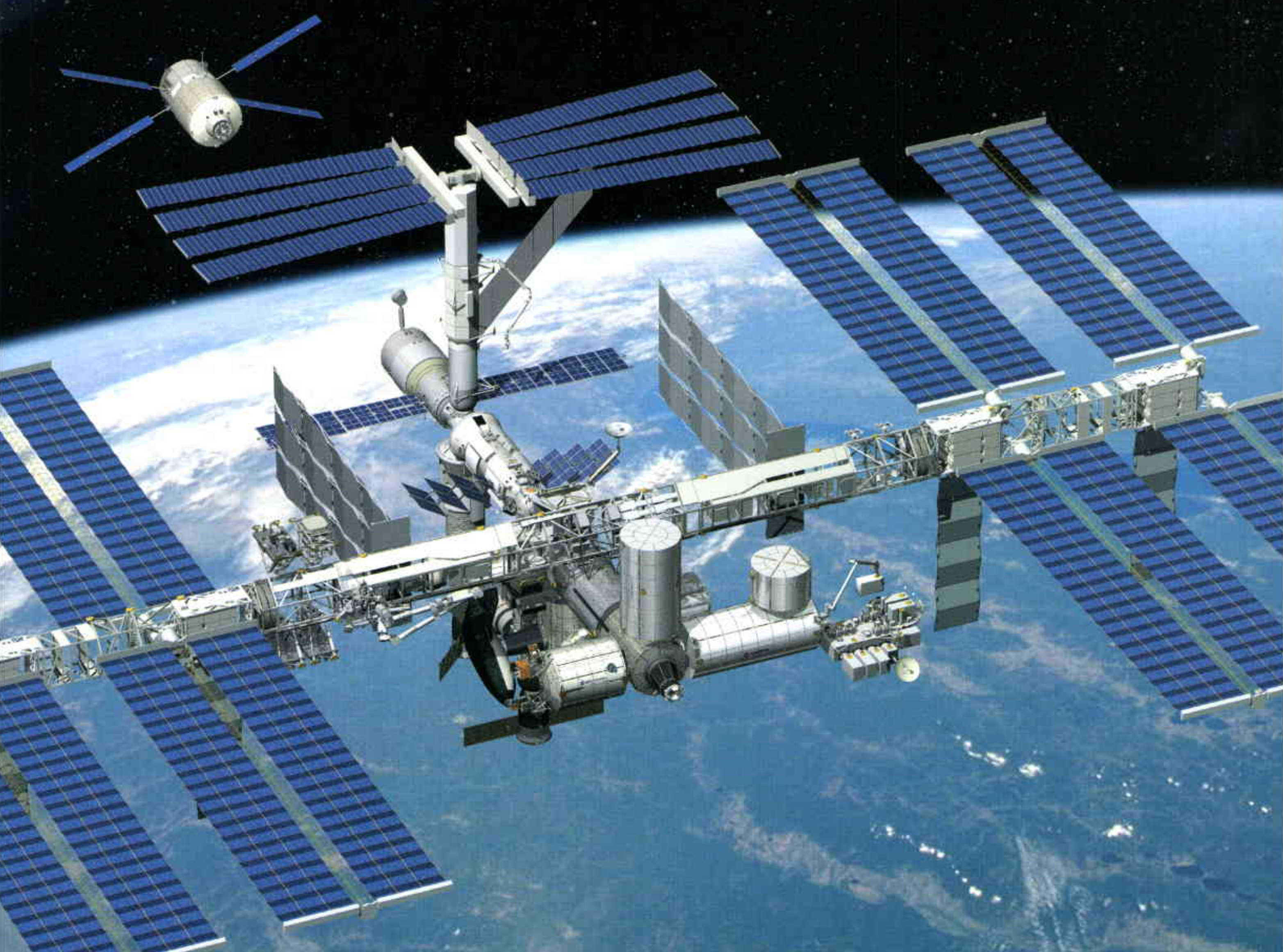
A competition for European university students to propose an experiment for the International Space Station

How can you participate?

More information on the competition and how to enter can be found on the SUCCESS 2002 web page:

www.spaceflight.esa.int/users/success

As a first step, register before 2 September via the web page and revisit it frequently to monitor progress and spot the latest news.



www.spaceflight.esa.int/users/success

Alternative Approaches to International Space Cooperation

M. Ferrazzani
Senior Legal Administrator, ESA, Paris

Introduction

Recent geopolitical developments, combined with the funding constraints of the various participating nations, have made it clear that greater international cooperation is the way forward for major space activities. Space activities have reflected a constant theme of evolving relationships and political agreements between space agencies over the last few years. The single most prominent issue in international relations, certainly since the events of 11 September, is security, which can benefit greatly from the further development of cooperation in space, something that has already been recognised for some years*.

During their recent history, space activities have experienced sizeable growth in terms of institutional involvement, State investment, and technological effort. There is a greater international presence in outer space than ever before, which in many cases is the result of alternative and innovative methods of international cooperation. Several new forms of international relations and institutions have appeared recently, and seem to be fast-growing. This trend encourages us to take a fresh look at some of these international cooperative practices, which are valid alternatives to the classical legal instrument largely used so far, namely the 'International Agreement', defining a formal relationship and containing binding obligations. One such alternative practice is the provision of international multilateral instruments containing non-binding principles of ethics, charters or terms of reference for specific groups involved in space activities, to give visibility and shape to existing relationships.

Mankind is already committed to the use of outer space for, for example, scientific research, operational telecommunications, living in space stations, exploiting launching systems, and studying the environment here on Earth. Civil missions carried out on a purely national basis are more and more a thing of the past, certainly in terms of the utilisation of the data acquired and the exploitation of the results. States can no longer initiate and carry out a significant space programme without some element of foreign participation. Indeed, national space programmes, although an expression of the particular State's technological capabilities, are increasingly being conducted under some form of international cooperation, either bilateral or multilateral, not least to maintain credibility. Space cooperation remains, however, an exercise of State sovereignty, in pursuance of defined political interests and shaped by very specific objectives.

As far as the definition, content and political evolution of international cooperation in space activities are concerned, a recent and relevant guideline, adopted by the UN General Assembly at its 51st Session in 1996, is the 'Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interests of all States, taking into Particular Account the Needs of Developing Countries' – UNGA(A/51/20). In Article 2 it is recalled that: 'States are free to determine all aspects of their participation in internationalcooperation in the exploration and use of outer space on an equitable and mutually acceptable basis'.

Examples of alternative methods of international cooperation in space activities

Because of the recent explosive growth in space activities containing elements of international cooperation, various forms of establishing such relations have flourished. The competences involved respect the traditional boundaries in terms of the peaceful uses of outer space, as they relate to astronomy, space exploration, space debris, use of the radio-frequency spectrum, remote sensing and environmental research, meteorology and microgravity. However, the emerging trend towards addressing more general issues has an obvious impact on mandates and political objectives. The following are some examples of how new cooperative endeavours in space are being formed and formulated:

* See Secretary General's Report to the UN General Assembly, 'International Cooperation in Space Activities for Enhancing Security in the Post-Cold-War Era' – 48th Session, 1993, Doc.A/48/221

SFCG: Space Frequency Coordination Group
The SFCG was created in 1980 as an ESA initiative to coordinate official government positions on frequency matters to be discussed at ITU and ruling conferences such as WARCs. The Terms of Reference for the Group have been accepted by all participating agencies. Almost all are space agencies or government space offices, which have some interest in using space frequencies. There are several Observers, among them the Radiocommunication Bureau of the ITU.

The Group has successfully conducted coordination and applied a common policy approach through its annual meetings since 1980, on the basis of a rotating chairmanship. There is a permanent Secretariat (provided by ESA) and it issues Decisions, Resolutions or Recommendations covering the objectives and functioning of the Group. Under a 'less formal and more flexible environment compared with the official organs of the ITU', representatives define common positions for frequency allocations. Members coherently follow its work and Resolutions and the joint working produces smooth and effective international coordination for frequency allocation and use.

IACG: Inter-Agency Consultative Group for Space Science
The IACG was created in 1981 by four member agencies to maximise the opportunities for coordinating multilateral space-science missions recognised as being of common interest. The present members are ESA, Rosaviacosmos of Russia, ISAS of Japan, and NASA of the USA (for the history of the Group, see ESA Bulletin No. 51). The IACG provides an international forum in which space-science activities are reported by member agencies and proposals are elaborated for possible future collaborations at different levels. Since 1981, the IACG has been responsible for the coordination and common planning of several space-science missions and is considered a successful model for other disciplines.

CEOS: Committee on Earth-Observation Satellites
CEOS was created in 1984 following a recommendation expressed at the G-7 Economic Summit, on the initiative of US Government representatives inviting other governmental organisations to contribute to international cooperation on space-borne Earth-observation systems. The CEOS Terms of Reference were first adopted on 25 September 1984 in Washington DC, and have since been amended several times by consensus of the members. The Committee has achieved wide participation by interested government representatives and has become a major reference forum for the exchange of information and the issuing of recommendations regarding current and future remote-sensing programmes. The CEOS Plenary session approves Resolutions establishing definitions and policy principles widely recognised in the space community. It has created several Working Groups to address specific topics. Its technical standards, procedures and practices for accessing Earth-observation data are strongly followed for the great majority of the Earth-observing missions and have proved essential for successful international cooperation.

IPOMS: International Polar Orbiting Meteorological Satellites Group
IPOMS was created in 1983 under the auspices of a G-7 Economic Summit, with the scope of fostering exchanges and new initiatives for polar-orbiting meteorological satellites to be built and operated by others besides the US Government. The group served as an information-exchange forum for governments and space agencies, until its scope was embodied in that of CEOS.

CGMS: Coordination Group on Geosynchronous Meteorological Satellites
CGMS was established by the governments and international organisations either managing or having an interest in geostationary satellites for meteorological applications. For over 20 years, the Group has served as the focal point for this application and has reflected fairly the setting up and updating of international standards for meteorological data, which are uniformly and consistently applied by practically all governments.

IGOS (International Global Observing Strategy) Partnership
The IGOS group was created as a result of an informal meeting held in Paris in 1998 between representatives of international governmental programmes studying the environment, named

IGOS

as 'partners'. Their aims are to provide a comprehensive international framework in which to harmonise long-term strategies, and to coordinate resources devoted to conducting observations, either space-based or in-situ. A document 'constituting an authoritative statement on the procedures for the IGOS partnership', contains structures and procedures for proposing and agreeing common themes and activities. The partners, who hold regular meetings and publish their conclusions, which constitute a reference to harmonise the work of Earth-observation missions, maintain an active Secretariat.

Inter-Agency Space Debris Coordination Committee

IADC: Inter-Agency Space Debris Coordination Committee
The IADC's terms of reference were approved in October 1993 and updated in March 1995, by countries and national or international space organisations that are carrying out space activities, either through manufacturing, launching and operating spacecraft, or manufacturing and launching rockets. Members are: DRA (UK), CNES (France), CNSA (China), ESA (Europe), ISRO (India), NASDA (Japan), NASA (USA), and RA (Russian Federation). Each is represented both on the Steering Committee and in the Working Groups. The purpose is to exchange information for cooperation purposes on space-debris issues, to identify debris-mitigation actions, and to recommend possible international norms. It provides the only informal opportunity at international level for regular debates about space-debris issues, which are now high on the agenda of the UN Committee for the Peaceful Uses of Outer Space (COPUOS).

International Space Life Science Strategic Planning Working Group
A Charter was adopted on 15 March 1980 by space agencies having significant programmes in the life sciences. Like the IACG, the Group has already served for a long time as an international forum for planning scientific experiments and possible cooperative endeavours. Its participants consider it a success, as its working results are the de facto guide for the future plans of each member agency when deciding on and funding life-science activities.

SAF: Space Agency Forum
The SAF was created in Rome on 23 April 1993 by government representatives of countries conducting space activities, with the intention of having a forum for exchanging views, following the positive experience with its predecessor SAFISY set up for the International Space Year (ISY) in 1992. For practical reasons, it is convened alongside the annual Congress of the International Astronautical Federation (IAF) and the chair rotates annually. It is considered a very useful forum, especially by those with medium-sized and small space programmes, for establishing international relations and coordination. A major declared objective of the SAF is cost-effective international cooperation between space agencies.

ESCAP Region: Committee on the Asian Remote Sensing Programme
This Committee was created by some government members of the UN Economic and Social Commission for Asia and the Pacific (ESCAP). Initially, the Governments of China, Indonesia, Malaysia, Nepal, the Philippines, Singapore, Sri Lanka and Thailand adopted the Terms of Reference of an Intergovernmental Consultative Committee on the Regional Remote Sensing Programme in Jakarta on 26 May 1984, providing for decision by consensus, or even by majority, of the members present and voting. Since then several sessions have been held and an active regional remote-sensing programme has been created.

APC-MCSTA: Asia-Pacific Conference on Multilateral Cooperation in Space
APC-MCSTA is a recent and interesting effort to create a new form of regional cooperation for space missions, following the success in Asia of the ESCAP regional remote-sensing programme. The Asia-Pacific Conference adopted by consensus at its Plenary session recommendations creating a Liaison Committee that is explicitly mandated to play an institutional role between the parties involved. The scope of its activities includes the promotion of multi-lateral cooperation projects. Indeed, beyond the traditional space-faring nations, Asia is living proof of developing countries entering the space business and contributing to the future growth potential for space cooperation. The ASEAN group of countries could serve as a political example for organising space cooperation among emerging space countries.

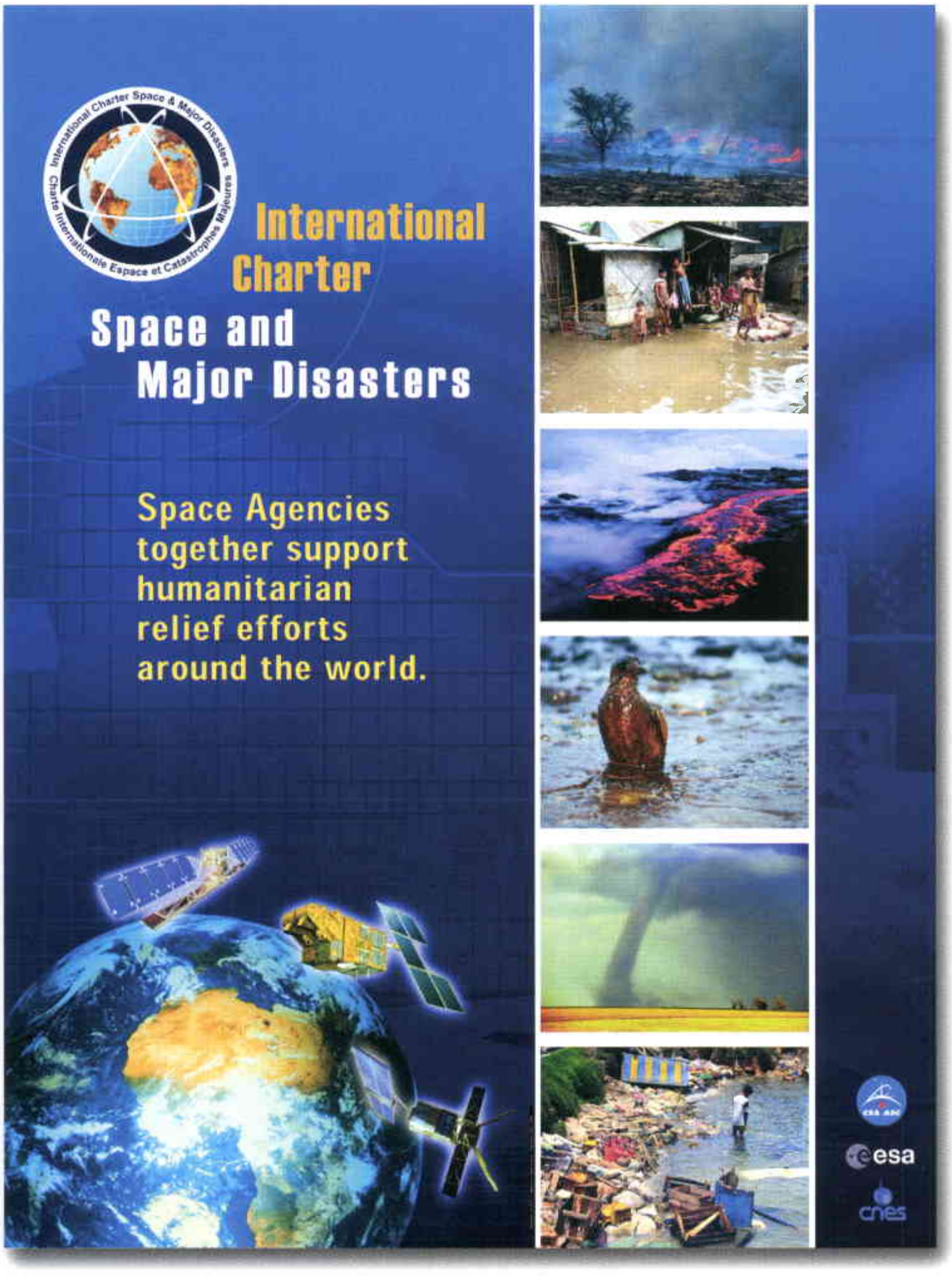
International Charter on Space and Major Disasters
On 20 June 2000, a 'Charter on cooperation to achieve the coordinated use of space facilities in the event of natural or technological disasters' was signed by its founding members.

The goal is to promote cooperation between space agencies and space-system operators in the use of space facilities as a contribution to the management of crises arising from natural or technological disasters. It brings together space agencies having significant remote-sensing activities that may be readily deployed in the event of a crisis. It also sets up a common mechanism for supplying, during a period of crisis, all available space data and facilities to States or communities whose population, activities or property are at risk. The present members are ESA, CNES, the Canadian Space Agency (CSA) and the Indian Space Research Organization (ISRO). Without becoming members, other entities may be called to be cooperating or associated bodies to contribute to the coordination mechanism, or else be a beneficiary body to receive data, associated information and services.

Common issues associated with alternative methods

In addition to the above bodies, there are many more examples of committees, working groups or academic relationships created by virtue of technical cooperation arrangements. There are many such schemes covering institutional relations for space activities, either bilateral or multilateral, sometimes with substantial decision-making authority delegated to ad-hoc bodies.

In the space-relations arena, there is also a growing range of somewhat informal mutual institutions able to put forward the views of and to act for and represent the positions of the participating States. Members work in close collaboration, comfortable in the fact they still maintain a distinct identity but have well-coordinated access to shared data and results to be utilised for the maximum benefit of all



participants. For many countries, these organisations are the only means for defining and implementing their space-cooperation links.

Coordination mechanisms work on the declared basis of no exchange of funds and no transfer of technology. A good demonstration of the seriousness of benefit-sharing circle is provided by the fact that a non-participant who wishes to access the pooled results has to apply to join the Charter, to be accepted by general consensus of the members, and to bring a worthwhile contribution.

States representatives meet regularly, convened with the declared intention of formulating and following the ground rules that they have established for themselves. The results of space missions, which often require vast investments, are freely exchanged between the participants for the purposes determined in the founding act. Reports of all these activities are openly published and often made available also to non-participants. Several of the above-mentioned groups make their proceedings and acts public via dedicated web sites.

Such practices are founded on the recognised need for greater cooperation and flexible methods of coordination. However, such coordination between actors, whether 'technical only' or 'purely scientific', still establishes far-reaching relationships and practices, which in themselves constitute an alternative form of international space cooperation. Whether created for reasons of scientific progress or for the general exchange of information, the legitimacy, stability and success of these relationships endows them with both political and economic importance.

Today the scientific and space community, in practising such international cooperation, is becoming more and more receptive to the common values and working methods contained in these charters. The more effective the informal character and behaviour agreed by the parties proves to be, the more this practice becomes recognised as perfectly and politically authoritative. This is where the border begins to blur between the classical binding agreements and the newer, less formal alternatives. General political statements in the founding charters and acts indicating that participation in activities is not considered binding upon governments, indicate how these methods are helping government representatives to access international space cooperation, in a manner that is flexible in form but still powerful in terms of achievable results.

Conclusions

This article has hopefully provided a useful overview of the general frameworks of some of the more recently formulated space relationships and the various motivations: result of unwritten long-enduring relations, wish to raise profile, quest for a political role, international effort to legitimise a project, good means of gaining approval for funding that it would otherwise be difficult to obtain. Such interests produce informal yet effective multilateral arrangements under politically relevant circumstances, resulting in the drafting of charters and other texts, none of which requires binding recognition. The objectives pursued, the meanings expressed, the methods used and the consistent behaviours of the actors and creators of international space cooperation are converging on methods delivering practical cooperation.

Realising alternative methods of cooperation is a positive step, but one that may not be conclusive in itself. Some still need to be formalised by subsequent government Agreements of a binding nature. However, the reality is that the intermediate phases are already producing political benefits, which are often not immediately apparent. Such alternative methods, along with growing international relations, are helping to cement the cooperation process by:

- favouring the development of easier, wider and more meaningful international relations
- facilitating the early elaboration of focussed political objectives, subsequently formalised under international Agreements; this has been the historical process that led to the Space Station Agreements, and might be a useful framework for early informal work leading to an international cooperative mission to Mars
- establishing some light norms of a substantive nature (as in the case of CEOS)
- defining common objectives, along with obligations of a procedural nature (as in the case of SFCG, IGOS, and the International Charter on Space and Major Disasters)
- assisting in the interpretation and application of space-law treaties and other binding agreements.

Whatever path the future evolution of cooperation in space takes, the alternatives that have been described in this article are already making an important contribution to the establishment and growth of international space relations. esa

MegaCities

L. Beckel
Geospace GmbH, Salzburg, Austria

A. Kühnen,
Hugin AG, Jena, Germany

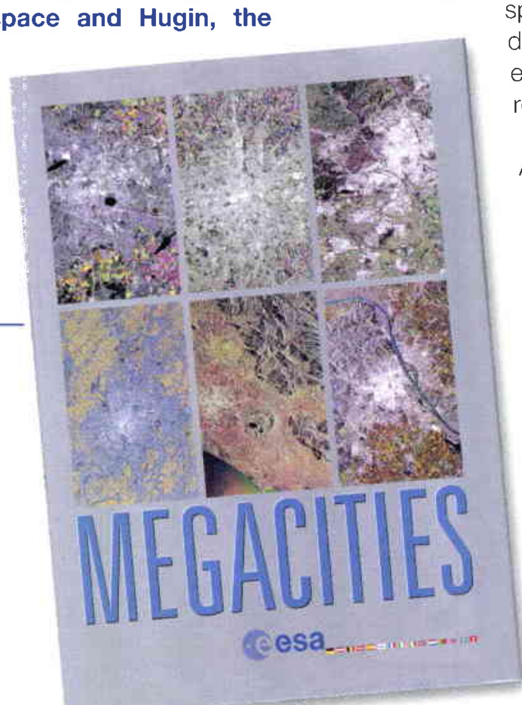
A. Siebert
Munich Re, Munich, Germany

J. Lichtenegger
ESA Directorate of Earth Observation Programmes, ESRIN, Frascati, Italy

F. Gampe & P. Brisson
ESA Directorate of Industrial Matters and Technology Programmes, ESTEC, Noordwijk, The Netherlands

Remote-sensing satellites are a truly global tool for addressing 'global challenges' and 'global concerns'. To increase public, political and industrial awareness of their real potential, the ESA Technology Transfer Programme office chose to support the United Nations' 'Urban 21' Programme, and as part of that initiative the MegaCities book project. The goal in collecting scenes from as many satellites as possible to show the prevailing situations of 42 'MegaCities' around the World, including potential threats and hazards, was to contribute to a better understanding of the global challenge that they pose.

Through a public-private partnership involving the remote-sensing value-adding companies Geospace and Hugin, the reinsurer Munich Re, and the Austrian Space Agency as co-sponsors, a first English edition of 3500 copies of the MegaCities book has been sold and distributed. A second printing is now in process and a German edition is also available.



Introduction

By 2005, about two thirds of the World's population will live in cities, and about 50 MegaCities will sprawl across the Earth's surface. New methods and tools will be needed to address the multidisciplinary problems that they will face. Space technologies will be instrumental in providing the greater understanding and insight needed to manage these huge conurbations on our 'blue planet'. Remote-sensing satellites, with their many very specialised instruments, provide the precise data that is needed to unravel the complex ecological interdependencies on the global, regional and local scales.

As the initiator of the MegaCities book project, the ESA Technology Transfer Programme is targetting both businesses and the public to promote the application of remote sensing by satellite. As well as demonstrating the value of satellite technology to the European taxpayer at a glance, the book is also seen by ESA as a means of generating more business for the European Earth-observation value-adding community by drawing attention to the global markets associated with the huge application potential of satellite imagery. Insurance companies too, with their economic and regulatory powers, are also considered a valuable target audience, and one that might rely more in future on 'satellite truth' rather than on 'ground truth' alone in conducting its business.

In 1996, the idea was hatched to approach non-space industry directly at higher management level to improve awareness of Earth observation from satellites and the potential applications for their businesses. To prepare the ground, some exploratory activities were undertaken to assess such things as the potential for and limitations on the integration of Earth-observation (EO) technologies into the planning and development strategies for MegaCities. These were followed in 1997/99 by an ESA-sponsored study entitled: 'Demonstration of the Potential Value of ESA EO Data and Products – End-to-End Demonstrator: Mega-Cities'. During the UNISPACE III Conference in Vienna in July 1999, various speakers from the satellite remote-sensing community expressed their disappointment at the 'very limited impact' that the latest EO satellite-based technology had so far had on decision-making in the upper echelons of industry, administration and politics.

Urban Agglomeration	Population (Mio.)		Annual Growth Rate	
	5 10 15 20 25 30		1985-1995	2005-2015
Africa				
Lagos	10,287	24,437	5.68%	3.61%
Cairo	9,656	14,494	2.28%	1.97%
Asia				
Tokyo	26,836	28,701	1.40%	0.10%
Mumbai	15,093	[illegible]	4.22%	2.55%
Shanghai	15,082	23,382	1.96%	1.85%
Jakarta	11,500	21,170	4.35%	2.34%
Karachi	9,863	20,616	4.43%	3.42%
Beijing	12,362	19,423	2.33%	1.89%
Dhaka	7,832	18,964	5.74%	3.81%
Calcutta	11,673	17,621	1.67%	2.33%
Delhi	9,882	17,553	3.80%	2.55%
Tianjin	10,687	16,998	2.73%	1.91%
Metro Manila	9,280	14,711	2.98%	1.75%
Seoul	11,641	13,139	1.98%	0.32%
Istanbul	9,316	12,345	3.68%	1.45%
Lahore	5,085	10,767	3.84%	3.55%
Hyderabad	5,343	10,663	5.17%	2.83%
Ôsaka	10,601	10,601	0.24%	-
Bangkok	6,566	10,557	2.19%	2.51%
Teheran	6,830	10,211	1.62%	2.30%
South America				
Sao Paulo	16,417	20,783	2.01%	0.88%
Mexico City	15,643	18,786	0.80%	0.83%
Buenos Aires	10,990	12,376	0.68%	0.50%
Rio de Janeiro	9,888	11,554	0.77%	0.84%
Lima	7,452	10,526	3.30%	1.32%
North America				
New York	16,329	17,636	0.31%	0.39%
Los Angeles	12,410	14,274	1.72%	0.46%

In mid-2000, therefore, the Technology Transfer Programme office initiated the idea of a book devoted to MegaCities, presenting satellite remote-sensing scenes and their interpretations in an easy-to-understand manner. Geospace GmbH in Salzburg was chosen as prime contractor, based on its reputation in publishing EO-type books. A 'pre-print' containing 24 draft pages of the planned volume was exhibited during the Frankfurt Book Fair that autumn, with sufficient success for the project to be pursued.

Deciding on the final content of the book, which not only had to be suitable for a wide audience, but also had to present well-supported factual data that would influence decision makers, posed several challenges for the editors. This also meant striving to convey a clear message, with both the images and the text, and avoiding

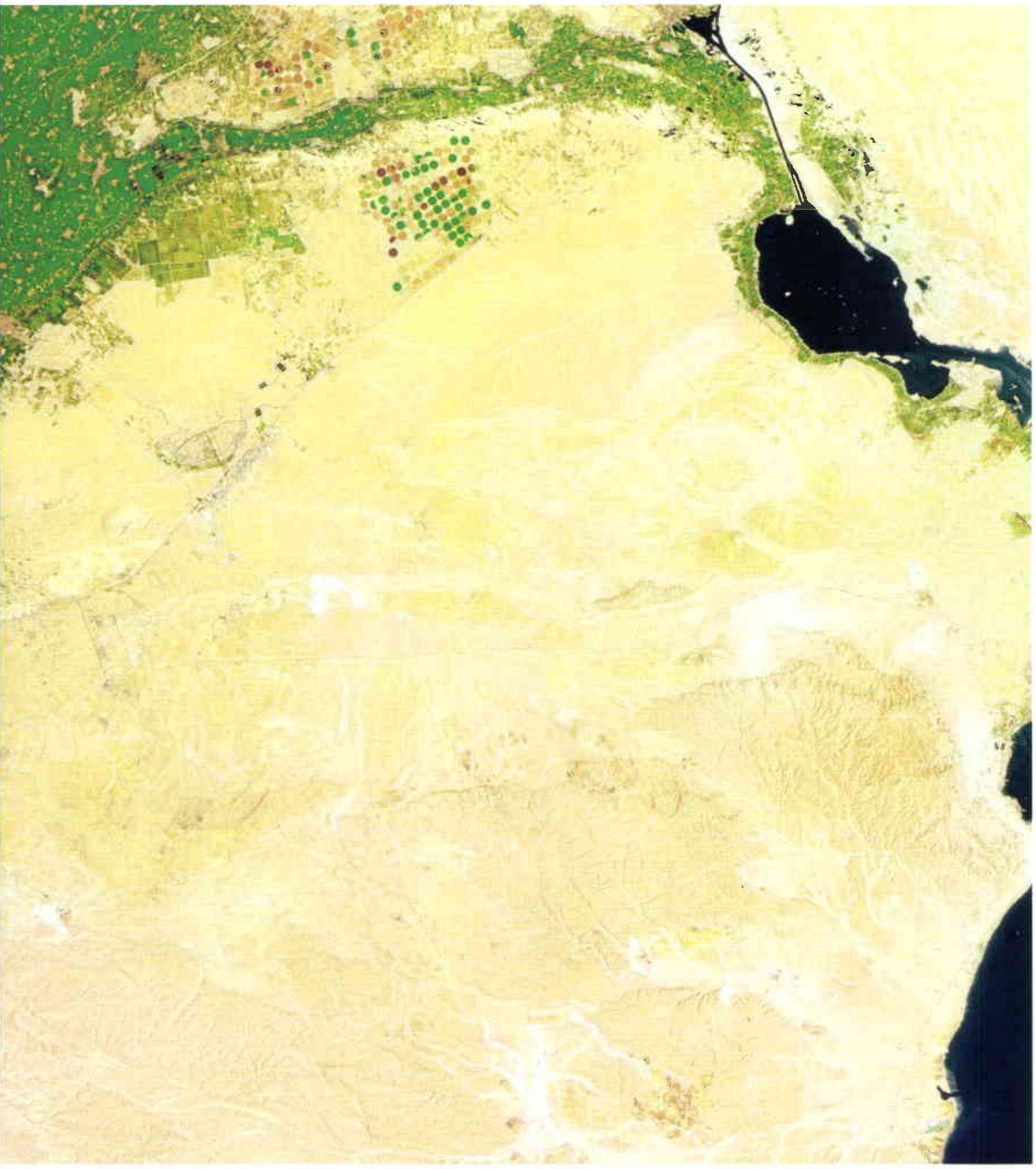


Figure 1. Cairo, seen from Landsat (courtesy of Geospace/EDC)

any biased characterisation of the chosen MegaCities. Geospace achieved this by asking different suitably academically qualified, and wherever possible locally based, authors to formulate the texts for each city. The final choice of images was also not made lightly, with every effort being made to strike a balance by selecting images with high visual impact from virtually all available civilian satellite sources. Last but not least, there were the usual economic constraints that shape the final form of such a book.

Economic considerations

It was decided at the outset that the price of the book should not exceed 50 Euro, despite the need for first-class layout and print quality to attract customers. This meant:

- the number of pages and thus the number of MegaCities portrayed had to be strictly limited
- the number of 'expensive EO scenes' had to be limited
- the 'partners' involved had to contribute some 50% of the total budget.

It was therefore clear that major support was needed from the industrial user side, from one or more ESA Member States, and from ESA's own Earth-Observation Department in contributing the ESA satellite scenes, before the Technology Transfer Programme could commit to undertake the project. In other words, several sponsors were needed to make the MegaCities book a reality.

The industrial sponsor

The search for, and finally the contractual involvement of, an industrial sponsor was the most critical aspect of the whole enterprise. After several initially promising contacts had

failed to materialise into financial contracts for a variety of reasons, the 24-page MegaCities preprint displayed at the Frankfurt Book Fair attracted the attention of staff from the Georisks Research Department of Munich Re, which deals with insurance covering earthquakes, floods, storms, hail, draughts, etc. Munich Re gave an immediate positive commitment, on condition that it would remain the exclusive sponsor and the wish that its CEO could contribute an appropriate introduction.

Munich Re's sponsorship took the form of the purchase of 2000 copies to be distributed to VIPs at the end of 2001, thereby promoting greater awareness regarding megacities and their associated risks, exactly in accordance with the original goal that had been set for the book.

The institutional sponsors

The Austrian Space Agency, in partnership with the Austrian Federal Ministry for Transport, Innovation and Technology, was instrumental in making the book happen by providing unwavering support from the start. Mr Klaus Töpfer, Executive Director of the United Nations Environment Programme (UNEP), was also asked to contribute to the book by writing a foreword. This he accepted to do without hesitation, acknowledging the great potential of satellite remote-sensing technologies to contribute to better urban development. Last but not least, ESA can be counted among the institutional sponsors in terms of using the book as a 'public relations tool' by buying some 650 copies. It distributed the book for the first time at the ESA Council at Ministerial Level in Edinburgh, in November 2001.

The industrial sponsor's viewpoint

Reinsurance companies form the backbone of the insurance industry, particularly for the high-risk sectors involving natural and man-made hazards and disasters. MegaCities are vulnerable man-made constructions that are very often located in areas prone to natural hazards such as river and sea flooding, earthquakes, tsunamis, and very high winds. Certain combinations of man-made and natural circumstances can aggravate the potential danger far beyond the risk of the individual hazards. Satellites very clearly show this, for example where earthquake fracture zones and large settlements coincide geographically,

Figure 2. Berlin, seen from IKONOS (courtesy of Geospace/SpaceImaging Europe)

whether it be the San Andreas Fault and Silicon Valley, or the fact that Istanbul sits on top of a major fracture zone.

In the industrialised societies, it is often the wealthier people and the industrial companies that settle in 'attractive high-risk areas', like Silicon Valley, as they can afford the necessary insurance cover. By contrast, in the Developing Countries it is usually the poorest people who are forced to live in such areas, because the safer zones are already fully occupied or building land there is unaffordable. The potential loss of life and infrastructure remains unacceptably high in both cases.

Preventive measures need to be organised at the economic, social, technical and legal levels in order to defuse and mitigate some of the potential disasters that threaten the MegaCities around the globe today. Disaster management after the event – whether it be a flood, a heat wave, a drought or an earthquake – is a particular challenge in MegaCities due to their complex and sprawling structure. The opportunity to look at all of these cities from a satellite tells the insurer that, despite their beauty and fascination, MegaCities harbour mega-risks, and this is a subject of great concern to the insurance industry as a whole. It is what the satellite images of the MegaCities tell us, qualitatively and quantitatively, that has prompted Munich Re to sponsor this book and distribute it to its clients, and why it is engaging more and more in the exploitation of 'remote sensing by satellite'.

A typical user's viewpoint

Hugin AG has presented copies of the ESA MegaCities book to its various customers in national and international planning authorities, as well as in industry. The overall feedback from all sides has been very encouraging. Those receiving the book were immediately more aware of the potential of EO technology and its applications to urban management. Comments have been especially positive concerning the fact that the book not only contains 'nice pictures', but also meaningful data and thematic information derived from the satellite image data. Some of the most enthusiastic responses have been from the environmental and planning authorities of MegaCities in the developing countries, such as Lagos in Nigeria.

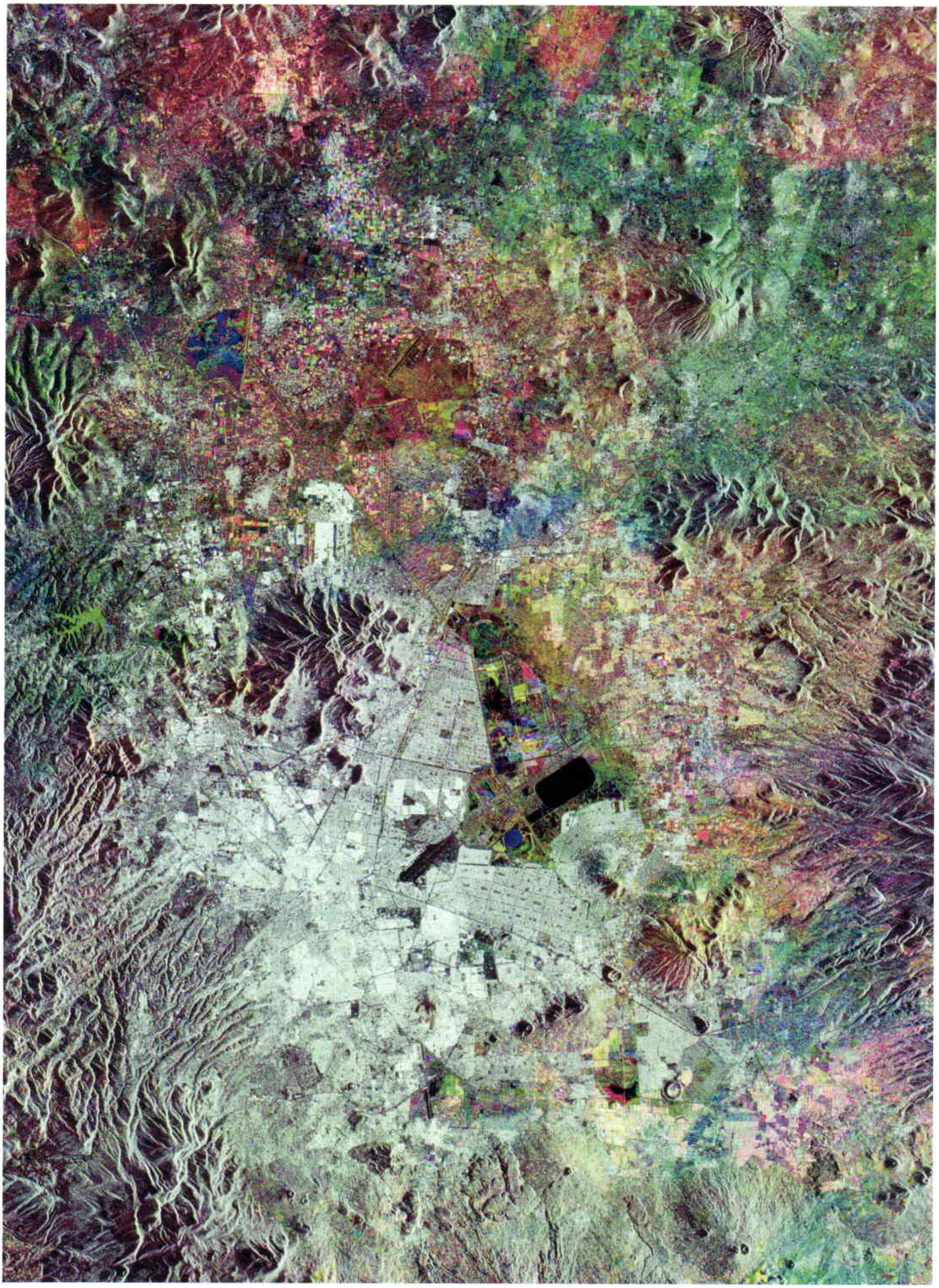


Figure 3. Mexico City, seen from ERS (courtesy of Eurimage/ESA)

Hugin had been engaged in a study on behalf of the European Commission (JRC) titled 'Development of Reference and Historical Databases for the Lagos Area'. The main goal of this project was multi-temporal land-use mapping in four time periods from 1962 to 2000, but also the collection and processing of ancillary data. A population estimation on the basis of Ikonos data was also carried out. This is believed to be the first such detailed multi-temporal study for a MegaCity. It demonstrated the importance of up-to-date high-quality satellite imagery and GIS products as a basis for planning and decision-making at the local-authority level for the management of one of the fastest-growing cities in the world. The fact that the Nigerian authorities were thoroughly convinced by the study results of the benefits of EO and GIS technology and are already committed to applying these techniques must be considered the most important outcome of the project and one that guarantees a real sustainable effect.

Outlook

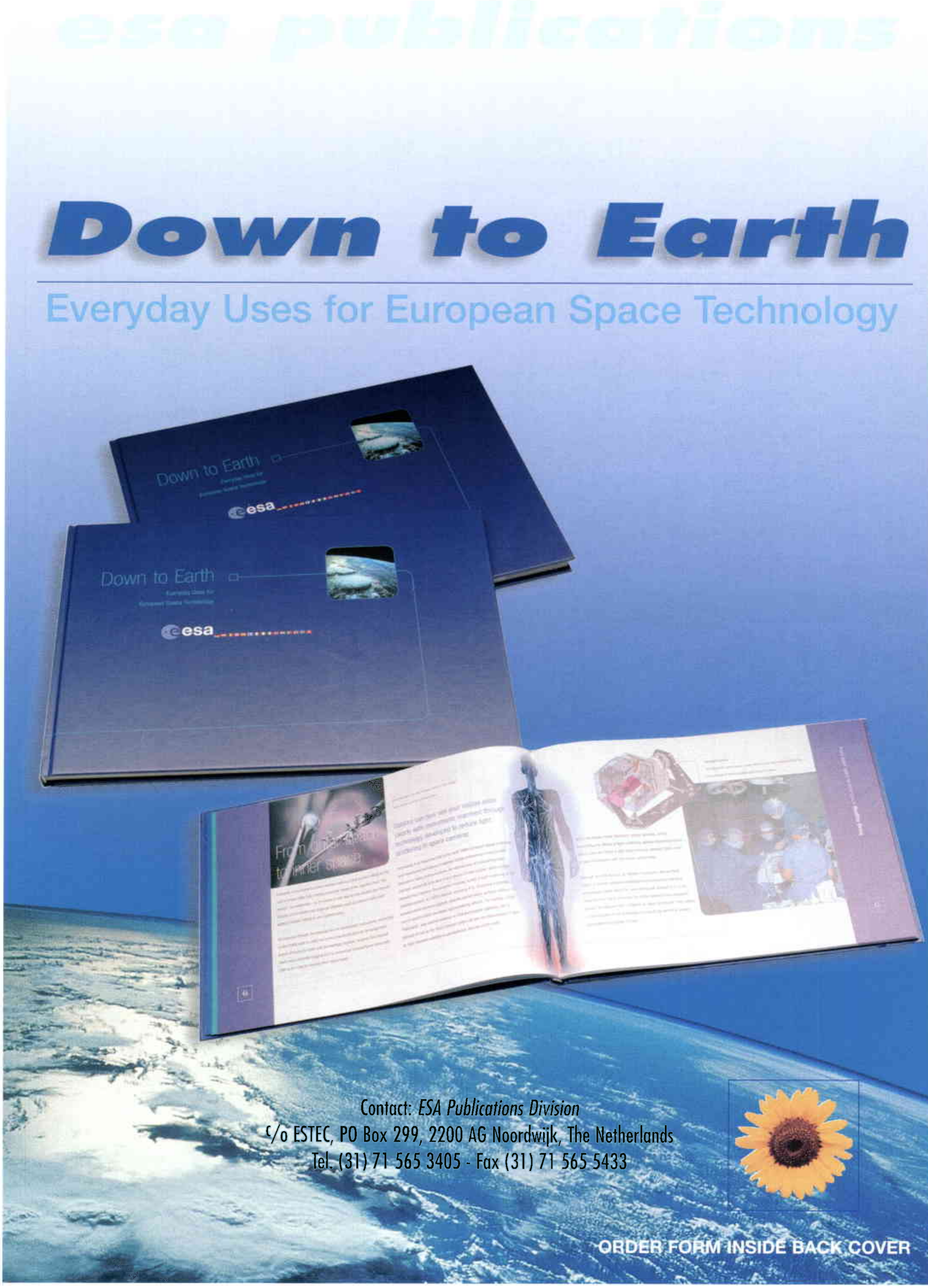
Given the encouraging user responses received so far, there is good reason to believe that the MegaCities book will prove a commercial success in the public domain also. Specific marketing efforts will be made by the TTP in the future, targeting city planners, architects and building companies to promote the application of 'remote sensing by satellites' in their businesses.

Some of the MegaCities book customers have already asked what the theme of the next book will be! A satellite remote-sensing book addressing another 'global concern' identified by the United Nations, or one addressing 'the enlarging Europe' might be a possiblity. esa

To order a copy of the MegaCities book, contact:

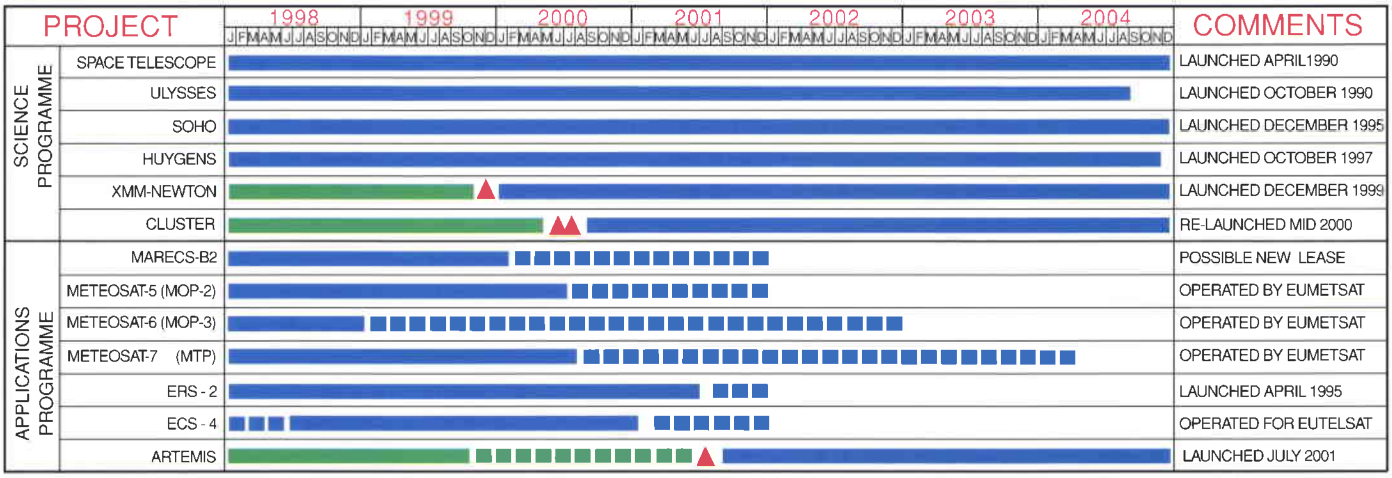
Geospace GmbH
Attention Dr. L. Beckel
Jakob-Haringer Strasse 1
A-5020 Salzburg
Austria

Tel. 00 43 662 458115-0
Fax: 00 43 662 458115-4
E-mail: office@geospace.co.at

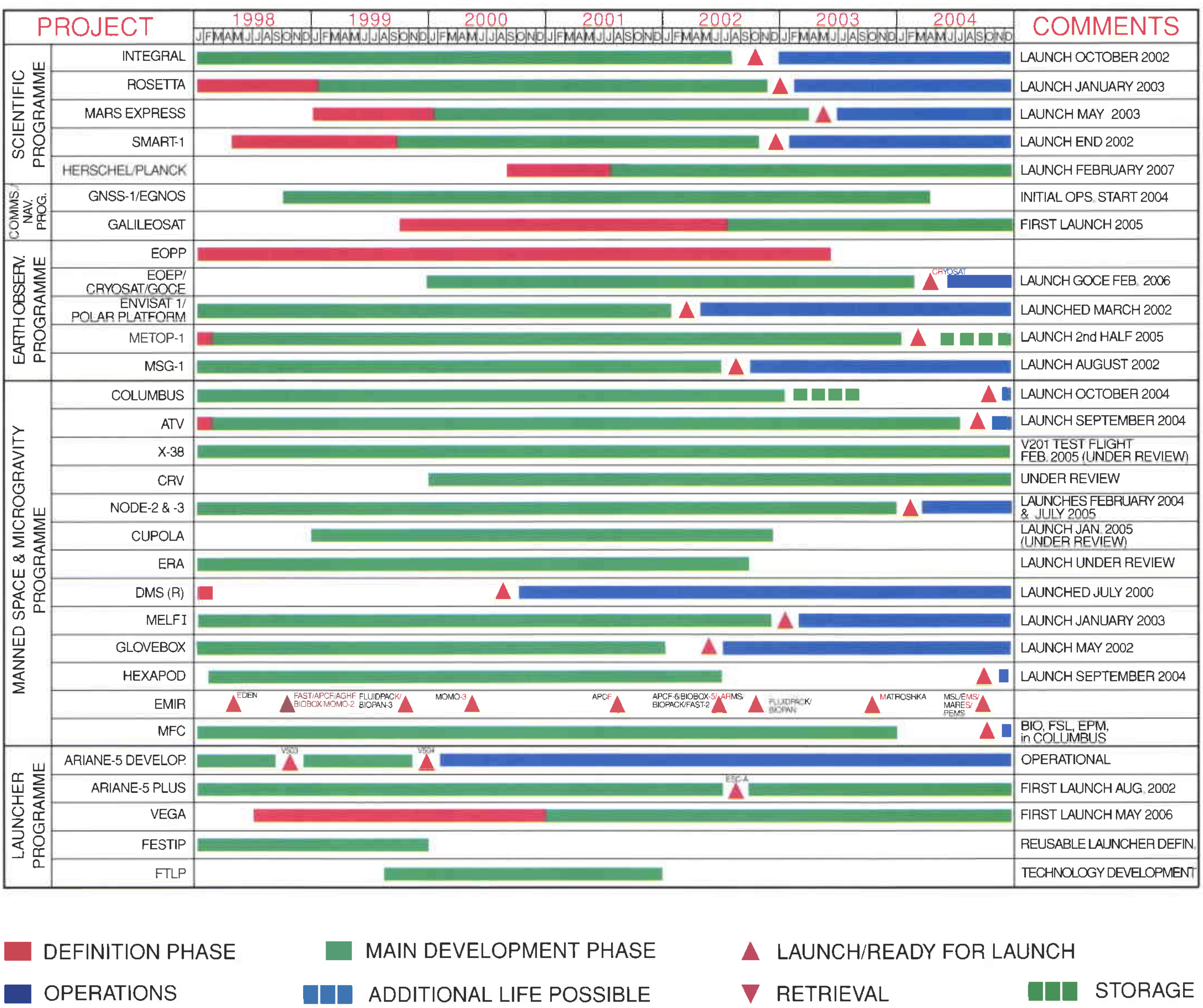

esa publications
Down to Earth
Everyday Uses for European Space Technology
Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel. (31) 71 565 3405 - Fax (31) 71 565 5433
ORDER FORM INSIDE BACK COVER

Programmes under Development and Operations
(status end-March 2002)

In Orbit



Under Development



XMM-Newton

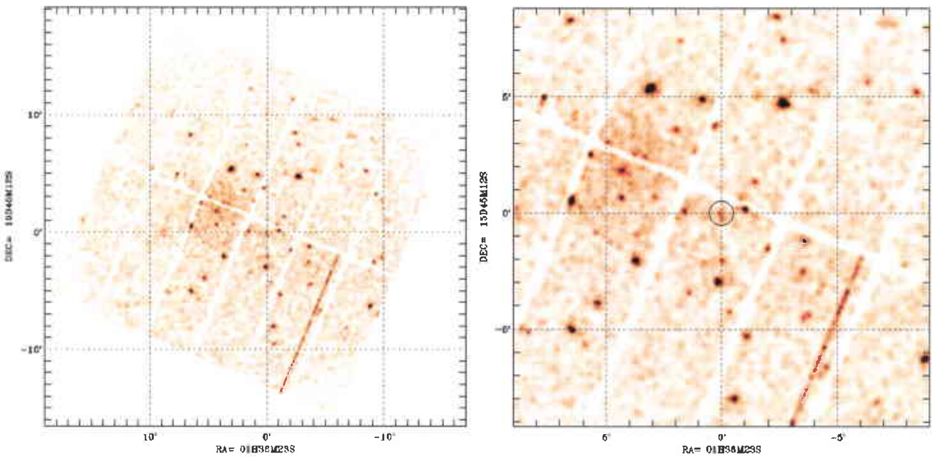
The XMM-Newton operations continue to run smoothly. During the first quarter of 2002 some science time was lost, partly due to high solar activity and partly to the fact that the regular XMM-Newton ground stations were needed to support the launch of Envisat.

The fifth eclipse season for the spacecraft passed without any problem. Some instrument-related problems that occurred during previous eclipses did not recur this time.

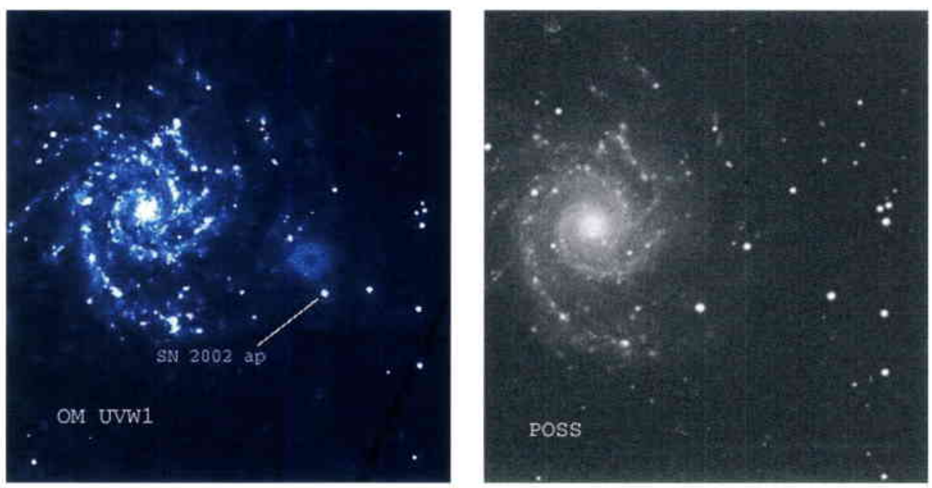
A number of successful observations have been made of so-called 'Targets of Opportunity' and the early quick-look results have been made public via the Web (see http://xmm.vilspa.esa.es/external/xmm_news/items/sn_2002_ap/index.shtml, and http://xmm.vilspa.esa.es/external/xmm_sched/too/index.shtml).

XMM-Newton data processing and data shipment is also running according to plan. A total of 1635 observation sequences have been executed, and the data for 1511 of these have already been shipped. A new and much improved version – especially in terms of calibration – of the XMM-Newton Science Analysis Software (SAS), a co-development between ESA and the Survey Science Centre (SSC), has been released.

Work on the first phase of development of the XMM-Newton Science Archive (XSA) is nearing completion, with public release scheduled for April 2002.



Supernova SN 2002 ap was observed by XMM-Newton on 2 February 2002 for a total of 37 ksec.
Left: EPIC PN full image centred on SN 2002
Right: Closeup of a circle of 30 arcsec radius around the supernova



The left image of the M74 host galaxy taken in the near-UV with the Optical Monitor (OM) on board XMM (UVW1 filter: 2450-3200 Å) clearly shows the presence of the supernova. On the right is the optical Palomar Sky Survey image of M74. Both images are 10x10 arcmin. The bluish ring-like structure in the UV image north of the SN is an instrument artefact

Integral

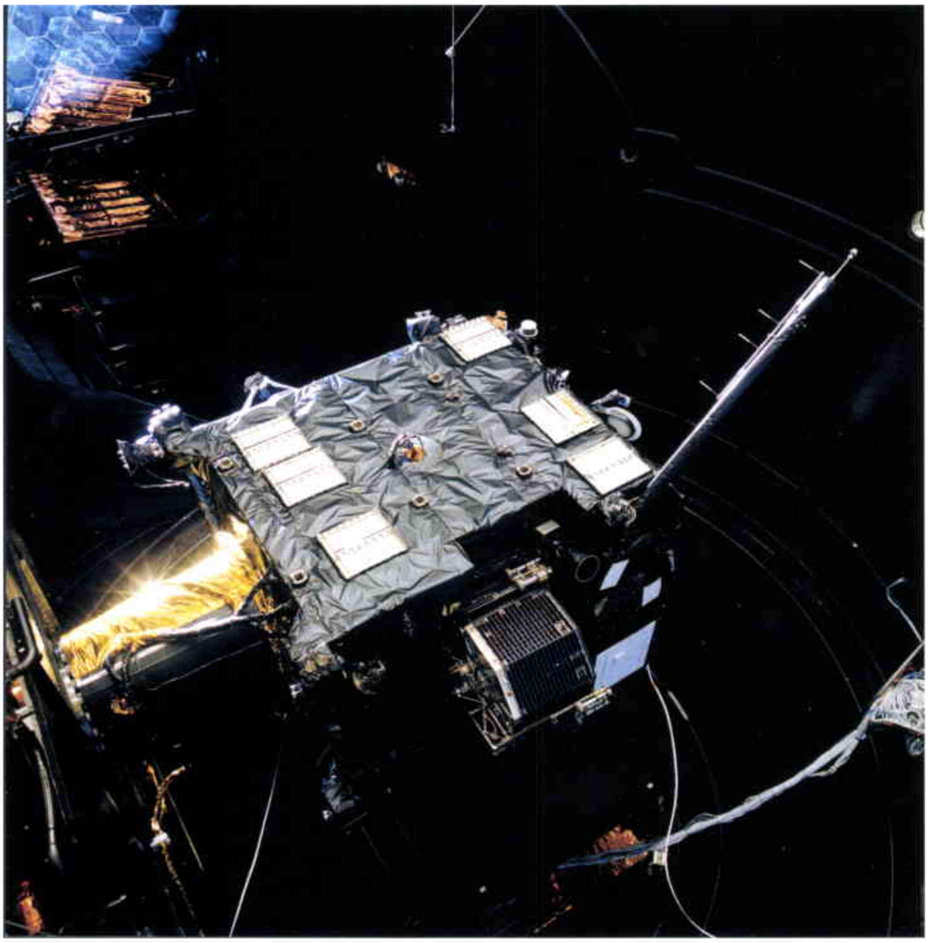
Integral flight model being moved to the Large Solar Simulator at ESTEC (NL) for thermal-vacuum testing

The Integral spacecraft has completed its acoustic vibration test campaign without any major problems. The flight-model environmental test campaign in the ESTEC facilities is continuing with the thermal-vacuum and thermal-balance testing. This challenging test is the last environmental checkout before final functional verification. Everything is therefore on track for the Flight Acceptance Review scheduled for July. The current plan is to ship the spacecraft to the launch site in August for a launch in October 2002.

The payload calibration campaign, during which the performance of the scientific instruments was verified using radioactive sources, has been successfully completed. The instrument flight-acceptance review is progressing satisfactorily and is scheduled to be completed in May.

The mission Final Design Review has been successfully completed. Production of the Proton launcher system for Integral is proceeding according to the agreed master schedule. However, due to delivery delays, the engines and certain control-system elements are now on a critical path.

The final ground-segment integrated test has been successfully completed. This test involved the Integral Science Operations Centre at ESTEC (NL), the Mission Operations Centre and spacecraft simulator at ESOC (D), and the Integral Science Data Centre in Geneva (CH).



The Rosetta flight spacecraft in the Large Space Simulator (LSS) at ESTEC in February 2002

Rosetta

The flight-model spacecraft has successfully undergone thermal-vacuum testing in February/March. This has demonstrated that the spacecraft can function nominally in vacuum at extreme hot and cold temperatures, as well as that the thermal-control system will keep the units within acceptable temperature limits during the near-Sun and deep-space phases of the mission.

The spacecraft is now being prepared for its mechanical acceptance testing, and the complete environmental test programme should be completed by the end of July 2002. After some refurbishment, the flight spacecraft will be shipped to the launch site in September. All subsystems are functioning nominally and the flight transponders, which were previously a very time-critical item, have now been delivered. The electrical qualification model programme is continuing in parallel and is being used to verify all software functions and operational procedures.

The scientific payload is continuing to operate nominally on the flight-model spacecraft. Two experiments are requesting to exchange their detectors, which will be performed during the refurbishment phase. The Experiment Flight Operations Review (EFOR) process will take place for each payload during the second quarter of 2002.

The Lander was successfully separated from the Orbiter after the thermal-vacuum test, underwent a set of modifications, and was then re-installed. An independent working group has studied the previously critical landing gear and has made various recommendations regarding its design and verification in order to improve the gear's robustness.

The ground segment's development is progressing according to plan. The New Norcia ground station is still on schedule to be ready by August 2002. Various validation tests have taken place, whereby ESOC has directly commanded both the proto-flight and electrical-qualification spacecraft. Radio-frequency (RF) compatibility tests using a spacecraft RF suitcase and a reference ground station are underway. So far, no new problems with the overall RF system, including the transponder, have been detected.

The Rosetta Science Operations Centre has undergone an implementation review and is on course for verification after the payload commissioning in orbit during 2003.

Detailed preparations are progressing for the launch campaign in Kourou, French Guiana. The manufacture of the Ariane launch-vehicle is going according to plan and the unique Rosetta requirements, due to the escape mission scenario, are being addressed between the project and Arianespace.

Herschel/Planck

The system-design activities for both spacecraft have progressed well, with the main emphasis on instrument-interface definition and subsystem and unit specification. The procurement activities were very intense during the quarter. Subcontractors were brought on board at a high pace as result of the successful completion of various proposal evaluations and decision processes.

The first tests of the radio-frequency characteristics at 30 and 100 GHz of the Planck telescope and baffle designs were successfully carried out at the end of March in the high-frequency test facility at Alcatel in Cannes (F).

The development of the large, 3.5 m-diameter, Herschel silicon-carbide telescope has also progressed according to plan, working towards a planned Critical Design Review in April 2002. Progress in the development of the Planck reflectors has also been nominal.

The development statuses of four of the five instruments were reviewed as part of the Instrument Baseline Design Review. This review resulted in many actions to be followed-up by the instrument development teams, but also in a good baseline for convergence of the instrument interface documentation. Manufacture of the first hardware development models has also been started. The fifth instrument, LFI, has gone through a de-scoping exercise in order to stay within the budget constraints and is now being prepared for its Baseline Design Review in June 2002.

The launcher interface definition exercise with Ariane resulted in confirmation of compatibility in terms of ascent and injection trajectories, mechanical environment and pre-launch operations.

RF testing of a Planck development model

Meteosat Second Generation

Preparations for the launch of the MSG-1 spacecraft are proceeding on schedule. Based on the non-availability of a co-passenger for an Ariane-4 launch in July 2002, Arianespace has committed to an Ariane-5 launcher that will provide a shock environment as smooth as Ariane-4. This is being accomplished by the introduction of a series of three specific shock-absorbing devices, mounted on the launch vehicle. Following a successful shock analysis, the launch date has been set for 13 August 2002, on Ariane flight V513. To meet this launch date, the MSG-1 spacecraft will be flown from Cannes (F) to Kourou (Fr. Guiana) on 13 May 2002 aboard a Russian Antonov aircraft.

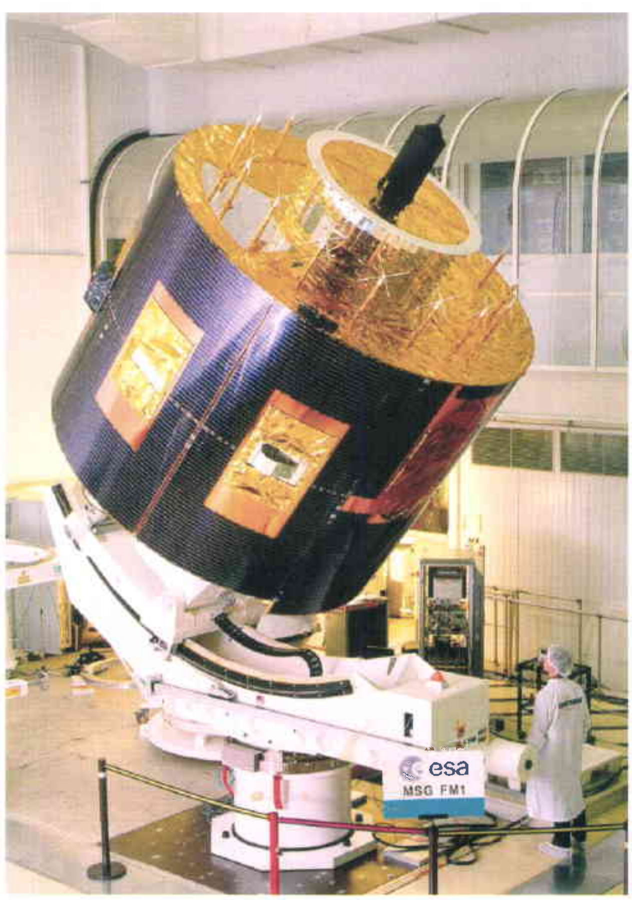
The MSG-2, MSG-3 and engineering-model spacecraft will remain in storage until after the MSG-1 launch.

MetOp

Following the consolidation of the restructured Assembly, Integration and Verification (AIV) programme, activities at Astrium in Friedrichshafen (D) have generally proceeded as planned. Evidence of the 'interleaving' approach now being taken can be found in the Astrium integration facilities, where the three Payload Modules – MetOp-1, -2 and -3 – are presently in various stages of integration.

The flexibility allowed for in the revised approach could accommodate, with minimum impact, unanticipated delays in the delivery of some customer-furnished instruments. In particular, the AVHRR and HIRS instruments are currently being reworked, and the A-DCS instrument experienced functional problems during acceptance testing, which have since been resolved with a work-around solution.

During the reporting period, Service Module (SVM) integration has been started at Astrium in Toulouse (F). The first GOME-2 flight model has completed its acceptance testing at Galileo Avionica in Florence (I), and is now undergoing calibration in TPD-TNO in Delft (NL). The first ASCAT flight model has been successfully acceptance tested and is now being integrated with the Payload Module. Good progress was also made in debugging the complex on-board software of the GRAS instrument, which has allowed the commencement of the acceptance testing.

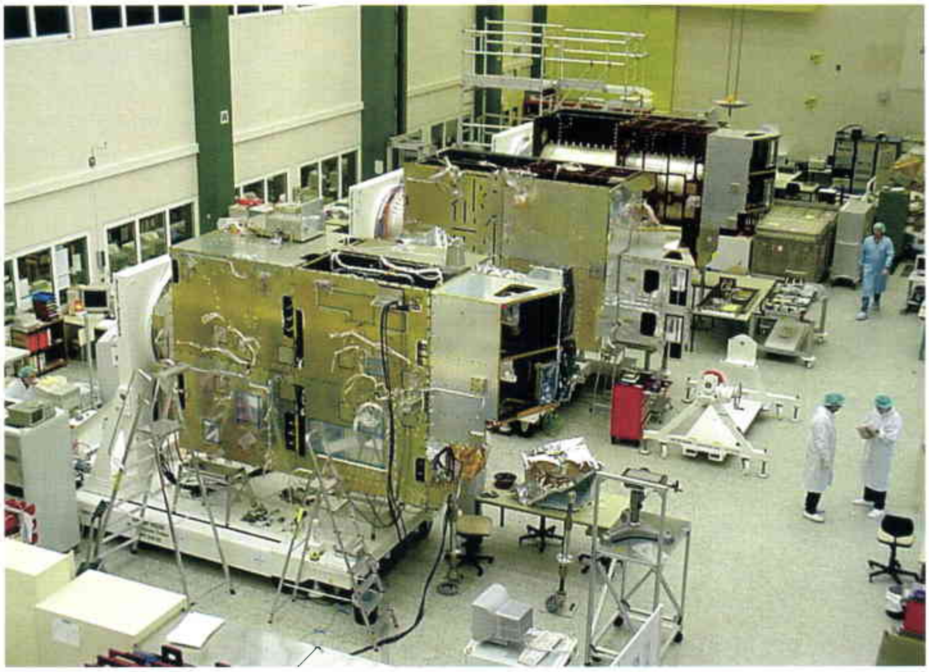


Testing of MSG-1 at Alcatel Space Industries

The IASI instrument has entered a very important phase with the starting of its Critical Design Review, which will hopefully have a successful outcome. Nevertheless, the IASI delivery schedule remains critical for the programme.

Work continues with Starsem and Astrium on finalising the launcher/satellite interface documentation and the associated industrial design dossier for MetOp.

Eumetsat is currently finalising, with ESA involvement, the wrap-up of the System Preliminary Design Review. The Core Ground-Segment Critical Design Review is planned for this coming summer.

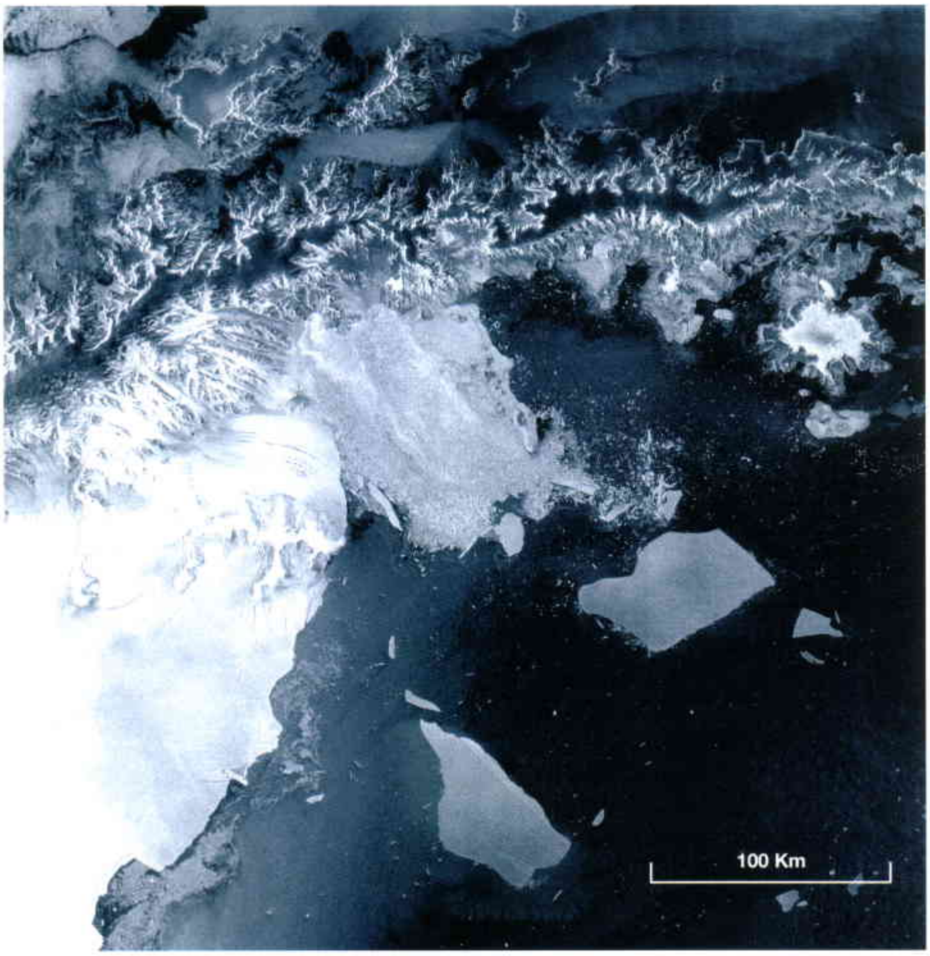


The Metop-1, -2 and -3 Payload Modules in the clean room at Astrium in Friedrichshafen (D)

Envisat

Following the successful launch of the Envisat satellite on 1 March 2002, the solar-array deployment and the attitude acquisition were performed within less than one and a half hours after launch. Less than two days after launch, orbit manoeuvres were performed to set Envisat drifting towards its final orbit, 30 minutes ahead of ERS-2 and with the same orbital ground track. This was achieved by 3 April.

The Launch and Early Orbit Phase (LEOP) was completed on schedule. By 4 March, the ASAR antenna deployment had been completed, and the Artemis Ka-band antenna mast was deployed on 7 March. All Instrument Control Units were switched on in the following days and the X-band link, plus on-board recording capabilities, activated.



All instruments were then progressively switched on and data taking activated successfully for all of them. The last two instruments, AATSR and Sciamachy, for which part of the activation process was different to avoid contamination during satellite outgassing, were fully operational by the end of April.

Data acquisitions by the Kiruna (S) and Matera (I) ground stations were performed successfully and the data were delivered via landlines and via the Data Dissemination Satellite System (DDS) to ESTEC, ESRIN and the ESLs (Expert Support Laboratories) participating in this phase. These data transfers, and the processing at the various sites, permitted the timely production of several ASAR and MERIS images for the first Envisat press event, which took place at ESRIN in Frascati (I) on 28 March.

This Envisat ASAR image taken on 18 March 2002 shows the disintegration of the Larsen B ice shelf in Antarctica, in which 3300 sq km of ice was lost. Envisat is making regular all-weather observations of the Antarctic ice shelves, which a key area of interest for global-change research

The Flight Operation Segment (FOS) and the Payload Data Segment (PDS) supported all of the early manually controlled operations very well. The automatic planning by the corresponding mission-planning subsystems has been progressively activated in moving towards the nominal operations scheme for the Envisat mission. While this activation has not hampered the full recovery of the instrument data, it has highlighted several software weaknesses, which are now being corrected to achieve the required operational robustness.

The Switch On and Data Acquisition Phase (SODAP) was satisfactorily concluded on 16/17 April and the calibration activities are currently in progress. The product release to the users will take place in a staggered manner, and as soon as the engineering products (Level-1B products) are declared calibrated, the corresponding service will be opened to users.

Altogether, the first two months of the mission have been highly successful: the satellite is healthy and the data analysed so far are showing very promising performances for all instruments and supporting onboard services.

CryoSat

The major event during the first quarter of 2002 was the signature of the contract between ESA and Astrium GmbH for the development and delivery of the CryoSat spacecraft. The project has now entered the main development phase (Phase-C/D) and work is progressing according to plan. A breadboard version of the onboard computer (CDMU) and its associated software has already been delivered to the satellite Prime Contractor for evaluation.

Offers concerning the CryoSat launcher are expected by the end of April 2002 and a decision should be taken before the summer.

The development of the CryoSat ground segment is also progressing according to plan, both at ESOC in terms of the preparation of the flight operations, as well as in industry in terms of the development of the Payload Data Segment.

Within the framework of the Announcement of Opportunity (AO) for the calibration and validation of the SIRAL instrument, proposals have been received from some 13 countries.

GOCE

The GOCE Preliminary Design Review (PDR) presentation by Industry and delivery of the related data package took place on 22 February. The PDR Board is scheduled to meet on 9 April. Successful conclusion of the GOCE PDR will be the milestone marking the end of the project's design phase (Phase-B).

Good progress has been achieved in the competitive selection process for the various equipment suppliers, but the selections in the micro-propulsion and solar-generator areas remain on hold.

The majority of the actions resulting from the Gradiometer PDR have been addressed and an updated data package is now under review. It is expected that this will result in a proper close-out of the review. However, the Gradiometer's development remains the most critical item in terms of the GOCE schedule, as the delay in flight-model delivery can only be partially recovered at system level. There is therefore a resulting delay of about four months in the Final Acceptance Review, leading to a current predicted launch date of mid-February 2006.

Activities have been started with ESOC to prepare for the GOCE Flight Operations Segment (FOS) Requirements Review, currently planned for the third quarter of 2002.

International Space Station

ISS Overall Assembly Sequence

During the first quarter of the year, one logistics Progress flight was launched to the ISS from Baikonur on 21 March.

Columbus Laboratory

Integration work has been finalised, with the exception of rack D1 and some external equipment, and the module has now been closed on the starboard side. Qualification testing on the electrical test model is continuing.

Columbus Launch Barter

Nodes-2 and -3

The Node-2 flight-unit integration has continued, but delivery to NASA's Kennedy Space Center has been delayed by three months, to end-February 2003. Assessments of test/verification activities have been initiated by NASA and the Italian Space Agency (ASI) in order to maintain the launch date of February 2004.

The last Node-3 primary structure weld is in progress and options to Europeanise Node-3 are being studied as part of the overall exercise to find an acceptable ISS 'end state'.

Crew Refrigerator/Freezer (RFR)

NASA has cancelled the Refrigerator/ Freezer Racks project. Activities will cease following qualification-model verification and delivery to NASA in April 2003.

Cryogenic Freezer (CRYOS)

Following the kick-off meeting for the Cryo-Freezer early in February, the Contractors have started activities on the specifications set-up. The first progress meeting with Industry is scheduled for mid-April.

Cupola

The new flight-unit dome forging has been manufactured and delivered for final machining, and the manufacture of the flight-unit shutters, harness and window frames is in progress. An instrumentation error during vibro-acoustic test preparation has caused a delay in the delivery of the Structural Test Article (STA) to NASA's Johnson Space Center until not earlier than June 2003.

Automated Transfer Vehicle (ATV)

Modal-survey tests on the structural/ thermal model (STM) have continued at ESTEC.

The proto-flight model (PFM) avionics-bay structure was delivered on schedule and avionic integration and tests on the avionics electrical test model (ETM) have started.

Preparations for propulsion-subsystem qualification testing have restarted.

Artist's impression of the Cupola

X-38/CRV and Applied Re-entry Technology (ART)

Work on the European contributions to the X-38 vehicle has continued. In March, NASA postponed indefinitely the flight date for the X-38 vehicle V201 and further drop tests, but intends to continue integration and system testing at Johnson Space Center until autumn 2003, leaving the possibility for NASA management to reconsider the flight demonstration open. All remaining work on the European contributions to the X-38 vehicle will be completed, but shipment to NASA-JSC will be put on hold pending clarification.

No further CRV activities will be initiated until the vehicle's future is clarified. Current activities will be completed within 2002.

Ground-segment development and operations preparation

The Request for Quotation (RfQ) for the main development phase (Phase-C/D) for the ATV Control Centre (ATV-CC) has been finalised and the pre-TEB (Tender Evaluation Board) held to review and release the RFQ. Individual Columbus Control Centre (COL-CC) subsystem offers have been evaluated and the subsystem contracts incrementally kicked-off.

Utilisation

Preparation

The Space Station User Panel meeting in February was attended by two officials from the European Commission, and focused on increased cooperation between ESA and the EC.

Detailed work on the plans for the implementation of User Support Operations Centres (USOCs) is in progress.

Of the 44 Microgravity Application Projects (MAP) originally planned, 42 are now ongoing; one has been cancelled due to lack of funds and one is still under negotiation.

Payloads and their integration

Negotiations with industry for the main development phase (Phase-C/D) for the atomic-clock instrument ACES are being finalised. Development of the external payloads Solar/Export and EuTEF is ongoing. The Space Science instruments EUSO and Lobster are in the design phase (Phase-A), and preparations for the Phase-A/B for the RapidEye commercial Earth observation payload are continuing. The Preliminary Design Review (PDR) for the European Drawer Rack (EDR) has been completed. Following the kick-off meeting for the Cryo-Freezer in early-February, activities have started on the specifications set-up. The ESA Microgravity Science Glovebox (MSG) was integrated into the Multi-Purpose Logistics Module (MPLM) on 4 March, ready for flight.

Flight Unit 1 of the –80 degC Freezer (MELFI) was delivered to Kennedy Space Center by the end of March. Launch to the ISS is foreseen for January 2003.

The qualification test campaign for the Hexapod pointing system should be completed in April.

The Global Transmission System (GTS) functional verification testing has revealed a potential failure and further detailed checkout tests are planned prior to activation.

Astronaut activities

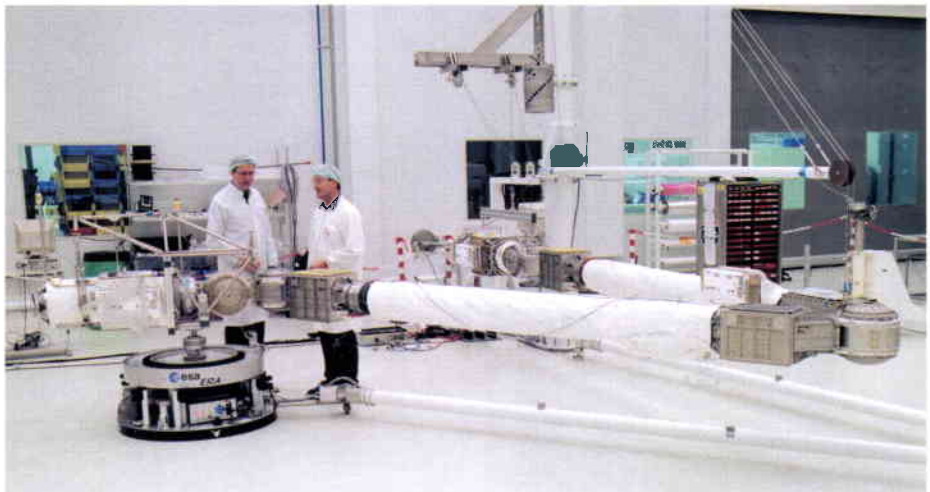
Roberto Vittori has been nominated as Soyuz Board Engineer for the Russian taxi flight 'Marco Polo', sponsored by the Italian Space Agency (ASI), in April. Negotiations with Rosaviakosmos regarding a Soyuz taxi flight in November 2002, sponsored by the Belgian Office for Scientific, Technical and Cultural Affairs (OSTC), are close to conclusion. The training of Frank De Winne in Star City continues and the experiment training, managed by the European Astronaut Centre (EAC), started on 11 March in Brussels. Christer Fuglesang has been assigned to ISS Assembly Flight number 12A.1, currently planned for May 2003. He will perform three EVAs during the mission (see page 98 for latest news).

The ISS Advanced Training continued with the first training period at NASDA in February 2002, with one week's training for each of the four ESA astronauts (P. Duque, L. Eyharts, P. Nespoli and T. Reiter), each with one NASDA colleague. This Advanced Training class, together with six astronauts from NASDA and one from NASA, will visit the European Astronaut Centre (EAC) for the first Columbus Systems Training in August 2002.

Launch of the Marco Polo Mission with ESA astronaut Roberto Vittorio on board

The Columbus Trainer Mechanical Configuration has been installed at EAC and will be outfitted in the coming months. A second unit has been installed at NASA-JSC as part of the Space Station Training Facility (SSTF). The first training with the Columbus Trainer at EAC will be provided in August 2002 to the ISS Advanced Training class.

A meeting of the European Astronaut Corps took place in Brussels from 4 to 8 March, and was accompanied by high-level public-relations-oriented events, with the participation of Crown Prince Philippe of Belgium.



ERA Robotic Arm flight model at Fokker Space

Early deliveries

Data Management System for the Russian Service Module (DMS-R)
As a result of an ISS computer problem, control of the Station's orientation was lost for several hours on 4 February. Initial indications from the investigation of this problem have identified the application software and/or its interface with the DMS-R operating system as the cause.

European Robotic Arm (ERA)
The functional qualification testing of the ERA flight model at the Prime Contractor's flat-floor facility is in progress. A delay in the completion of the Mission Preparation and Training Equipment (MPTE) has delayed the ERA system-level qualification and acceptance, which will now take place in October/November 2002.

ISS Exploitation Programme
The Cooperation Agreement for Implementation of Commercial ISS Utilisation Preparation has been signed by all parties permitting an incremental implementation of the cooperation as a function of the ESA financial commitment, which will be matched by the Partners in terms of firm commitments at the same level. All ISS partners have agreed to initiate the ISS global branding programme, and the target date for having the programme in place is end-2002.

In Europe, the Sponsorship Programme has been initiated with the flight opportunity of R. Vittori. Commercial blood-pressure-measurement equipment has been transported to the ISS on the Progress flight in March and an in-orbit demonstration will take place in April-May. Agreement has been reached with Industry on a transitional approach towards implementing the Industrial Operations end-to-end service contract.

A Rider to the Preliminary Authorisation to Proceed (PATP) has been developed and will be released to Industry in April. The main articles of the contract have been negotiated and the Rider will be finalised in the near future.

Work on the CCN-3 Early ATV Procurements is continuing according to plan. The updated Production Concept Review documentation has been delivered and is being reviewed.

The preparation of the RFQ for ATV production has been started.

Microgravity

An adapted proposal for the programme contents of the European Life and Physical Sciences (ELIPS) programme, aligned with the subscription level of 171.4 MEuro, was endorsed by the Life and Physical Sciences Advisory Committee (LPSAC) and subsequently approved by the relevant ESA authority.

Preparation of ESA's payloads (APCF, Biobox, ERISTO, FAST, ARMS and Biopack) for their July 2002 flight on STS-107 is ongoing.

The refurbishment of facilities and experiments for the Russian Foton M1 recoverable capsule mission is in progress and the implementation of new experiments is under negotiation.

The Maser-9 sounding-rocket flight on 16 March was only partially successful due to problems with some of the biology experiments.

The 32nd Parabolic Flight Campaign was conducted between 18 and 21 March.

Various payloads for the ISS are under development, including the European Modular Cultivation System (EMCS) biology facility, due to be launched mid-2004, and the Expose facility for exobiology, for which a launch date has not yet been set by NASA. Delivery to NASA of the HGD/PFD and PEMS physiology instruments is imminent completion, but at present there is no utilisation planning on the NASA side.

Development of the MARES (physiology) and Matroshka (radiation) facilities for the Russian module and of the PCDF (proteins) continues.

Microgravity Facilities for Columbus (MFC)
The flight-model subsystem procurement and manufacturing for Biolab are progressing and have reached 70% completion. The close-out of the Critical Design Review (CDR) for the Fluid Science Laboratory (FSL) has been successfully completed and the engineering-model system test campaign is approaching completion. The engineering-model system test campaign for the Material Science Laboratory (MSL in US Lab) is also in progressing, and the crew review with ESA and NASA astronauts has been successfully completed.

Engineering-model manufacturing of the European Physiology Modules (EPM) is nearing completion, Standard Active Container engineering and flight models have been delivered to the national agencies, and interface compatibility testing with the science modules has been successfully completed.

Ariane-5 Plus

The flight hardware for the first Ariane-5 Plus flight (V517), now scheduled for end-August 2002, will be acceptance tested in early April. All of the V517 EPC flight hardware has been delivered, except for the engine, which will arrive in mid-May. In parallel, the activities concerning the definition of the 'standard 6' oxygen turbo-pump are progressing; the Critical Design Review for this new definition was held successfully in March and the first test model will be available at the end of July, the objective being to equip the third Vulcain-2 engine to this new standard. The qualification reviews for the Vulcain-2 engine subsystems are planned for April. For the solid booster (EAP), qualification reviews have been held for the attachment devices and the solid motor, and similar reviews have started for the front skirt and the stage.

The first simulation of the launch chronology with the filling (MR) model of the ESC-A stage was performed as planned on 25 March in Kourou, French Guiana. The detailed analysis is still in progress and preparations for the next chronology, which will take place in mid-April, are being implemented.

Concerning the dynamic mechanical stage model, the pyrotechnic separation tests for the upper stage and its lower skirt (ISS) have been successfully performed; the last step will be the separation test for the acceleration rockets. The rupture test on the structural model, including the engine thrust frame, a LOX tank dummy and the inter-tank structure, showed that the safety margins are good. The stiffness test on the hydrogen tank showed a higher stiffness than predicted.

The characterisation tests on the Vinci hydrogen turbo-pump are pending, awaiting definition of the speed limitation on the pump's impeller, which has not yet reached final manufacturing standard. The ESC-B System Concept Review (RCS) may take place early in 2003.

Vega / P80

A proposal for the full Vega small-launcher development contract is expected on the basis of the Request for Quotation (RFQ) sent to industry (ELV) in February. Close-out of the System Preliminary Design Review (SPDR) actions has been completed within the framework of the current contract with ELV for initial development activities.

On the P80 side, the Preliminary Design Review kick-off meeting took place in March, followed by two working meetings during the month. The final report is about to be submitted to the Review Board, which will meet in April.

Ground facilities

Following its first use during the Envisat launch campaign, the new CCU3 payload-preparation facility in Kourou (Fr. Guiana) is undergoing some improvement work in order to achieve full operational status prior to a technical review scheduled for April.

In the Vega ground-segment area, the Procurement Plan and the set of Procurement Proposals have been approved by the ESA Industrial Policy Committee (IPC). A Vega Ground Segment Industry Day, in which around 100 invitees participated, was held at ESRIN on 19 March, in order to present the activities to be performed to potential contractors. On the technical side, activities have concentrated on the actions resulting from the Ground Segment Key Point review held in February, in preparation for the Preliminary Design Review next June.

Artist's impression of Vega

In Brief

Vittori, taxis and tourists

A mission to the International Space Station (ISS) returned to Earth on 5 May after successfully delivering a new 'lifeboat' to the Station. The members of the Marco Polo flight were ESA's Italian astronaut Roberto Vittori, Russian mission Commander Yuri Gidzenko, and South African 'space tourist' Mark Shuttleworth. The Marco Polo crew safely descended to Earth in a Soyuz capsule, ending a 10-day mission with a textbook landing on the plains of Kazakhstan at 10h55 local time (04:55 GMT).

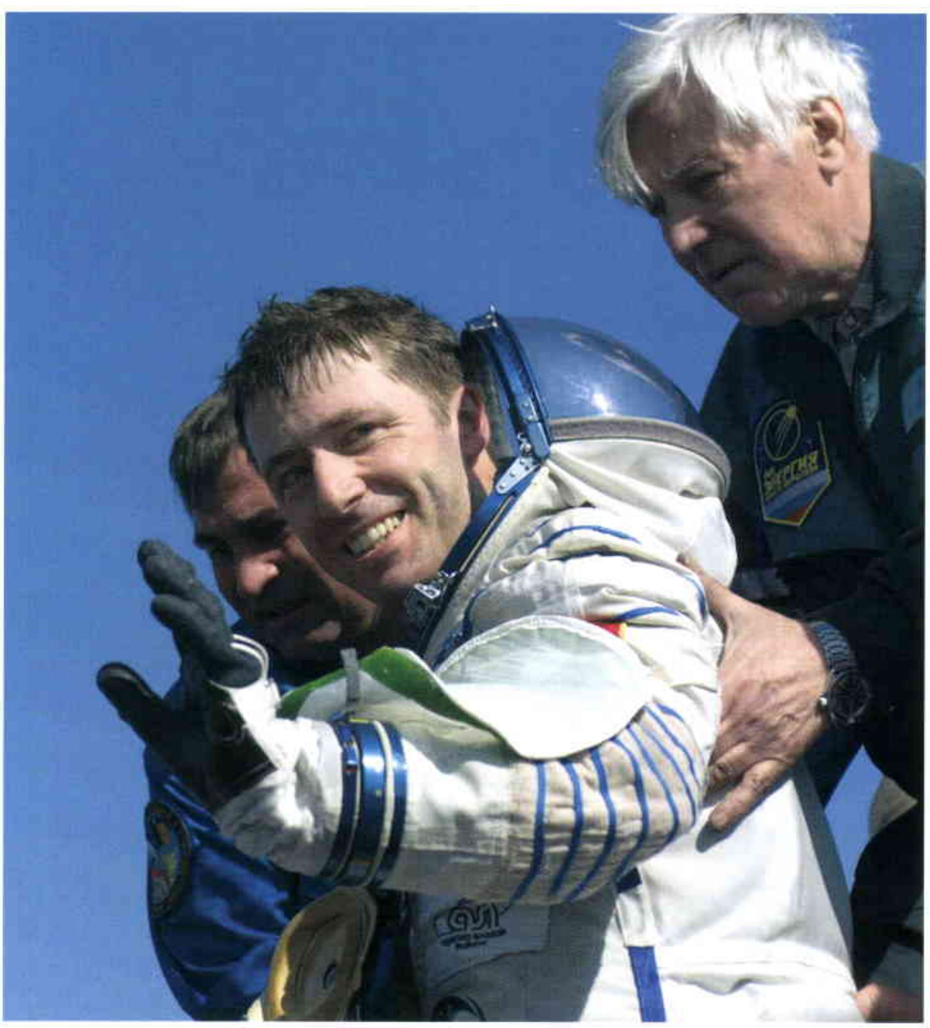
Vittori, a former Italian Air Force test pilot, described his maiden voyage into space as "the most exciting and challenging experience of my life". After Umberto Guidoni and Claudie Haigneré, he is the third European astronaut to visit the Space Station in a year. During his eight-day stay he worked alongside the resident crew on the ISS – Expedition Four commander Yuri Onufrienko and flight engineers Dan Bursch and Carl Walz – overseeing four European scientific experiments.

The perfect lift-off of the Marco Polo flight from Baikonur, Kazakhstan on Thursday 25 April 2002, at 12:26 local time (06:26 GMT).

The experiments examined the forces involved in moving around in microgravity and the effects on humans of cosmic particles during long missions, assessed newly developed clothing, and tested a non-intrusive blood pressure monitoring device.

Marco Polo – following the equally successful Andromède mission last October with ESA's French astronaut Claudie Haigneré – was the latest in a series of European manned missions to the Space Station.

Belgian ESA astronaut Frank De Winne has already started training for a similar 'taxi' mission in October and Sweden's first astronaut Christer Fuglesang will be on the Space Shuttle for an important assembly flight next spring. esa



Roberto Vittori returns to Earth after spending eight days on the ISS.

Ariane-4 safe deliveries

Since the beginning of the year, six Ariane rockets have been successfully launched from Europe's spaceport in French Guiana, marking a record-breaking number of 112 launches for the most successful Ariane launcher ever built. The latest passenger was the French CNES SPOT-5 satellite, others included Dutch and Japanese telecommunications satellites and a pair of mini-satellites for amateur radio. Flight 152, the next launch from Kourou, is scheduled to take place on 5 June.

esa

Ariane 4 flight 149

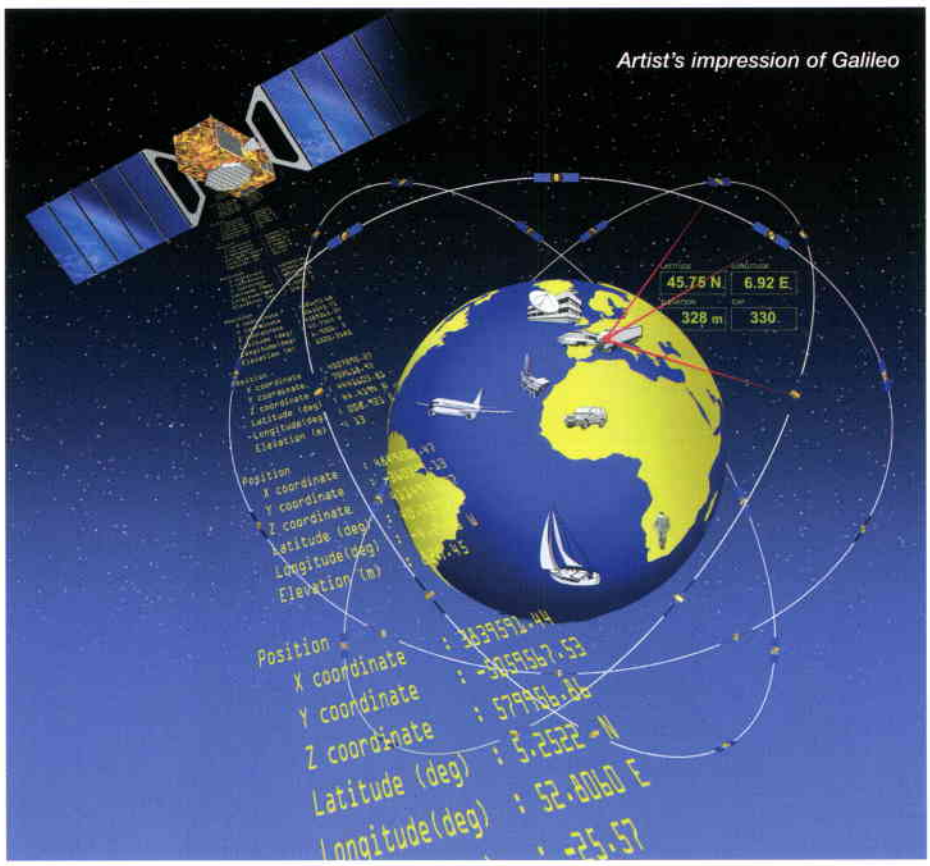
Go, Galileo!

Galileo is definitely going to happen. The European Union Transport Ministers gave the final go-ahead at a meeting in Brussels on 26 March.

Developed by ESA in collaboration with the European Union and co-funded by the two organisations on a 50-50 basis, Galileo is a complete civil system, designed to be operational from 2008 to provide the world in general and Europeans in particular with an accurate, secure and certified satellite positioning system. It is the first project to be conducted jointly by ESA and the European Union.

The go-ahead for Galileo is particularly important for European industry, which will now be able to develop the advanced technologies required not only for the purposes of the satellite network and its ground support system, but also for the numerous applications associated with it.

esa



Artist's impression of Galileo

TESEO: helping to safeguard the environment

Maybe "Treaty Enforcement Services using Earth Observation" (TESEO) is not one of the catchiest titles but the work it does is more interesting – and useful – than it sounds. A new website now helps to spread the word about the project *(http://earth.esa.int/teseo)*.

Earth observation satellites can play a useful role in ensuring that international conventions and treaties are respected and put into effect. To follow through this idea, in 2001 ESA set up TESEO, which is also part of its contribution to Europe's Global Monitoring for Environment and Security (GMES) initiative.

The four areas of environmental protection with which TESEO is presently concerned are marine pollution (MARPOL 73/78 and regional conventions related to marine pollution), wetlands (Ramsar Convention), forest monitoring (Kyoto Protocol to the UN Framework Convention on Climatic Change), and desertification (UN Convention to Combat Desertification).

Although ESA's Earth observation satellites are not there to police the skies, TESEO can help to implement treaty objectives. Together with the local, national and international organisations involved in treaty enforcement, TESEO project teams will assess and evaluate ways in which existing and future Earth Observation technology can help to implement international agreements, particularly those of interest to Europe. An added benefit is that this will also increase awareness of how Earth observation satellites can help in environmental monitoring.

esa

Envisat's spectacular view of the Earth

A major new health check on the Earth got under way on 1 March 2002 with the launch of ESA's Envisat, the largest and most sophisticated Earth-observation satellite ever built. From its vantage point in Sun-synchronous orbit, Envisat is tirelessly sweeping the Earth's land surfaces, oceans and atmosphere, using a suite of ten highly sophisticated scientific instruments.

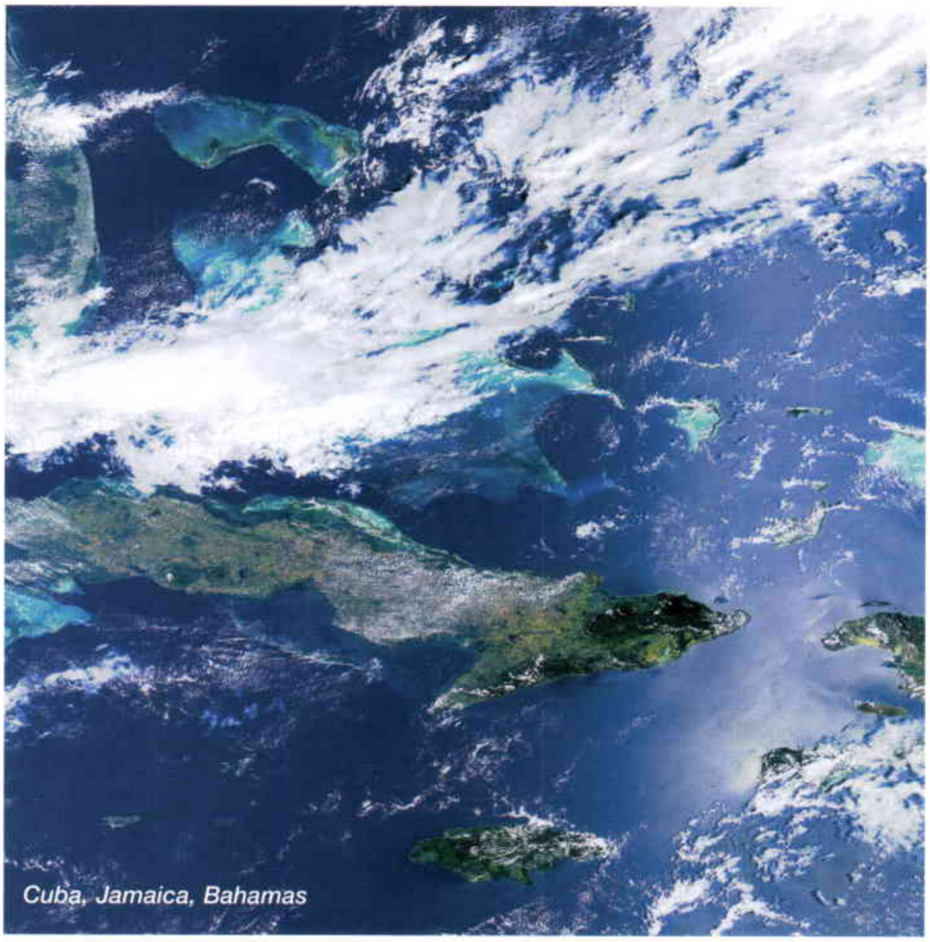
The first images from Envisat's Medium-Resolution Imaging Spectrometer (MERIS) and Advanced Synthetic-Aperture Radar (ASAR) instruments are of exceptionally high quality. The first data available from the satellite were acquired via the Kiruna station in Sweden and processed at the ESA/ESRIN establishment and the processing and archiving centres throughout Europe.

West African Coast
MERIS, 22 March 2002


West African Coast

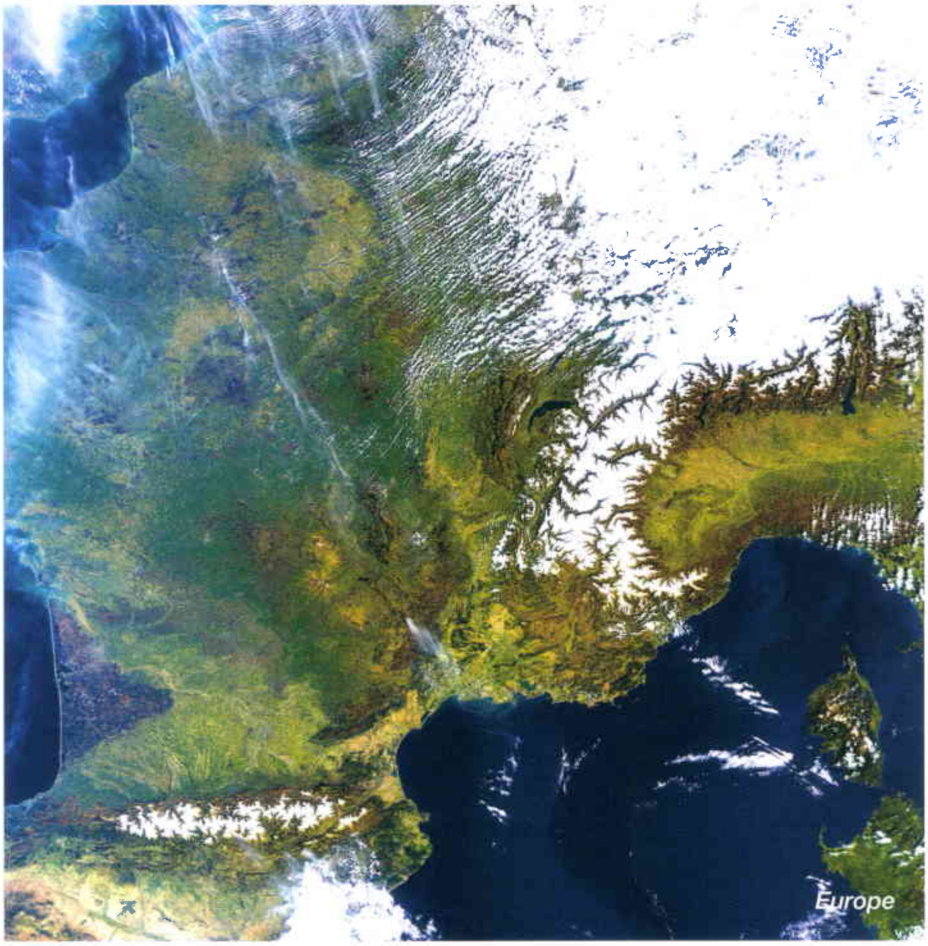
This MERIS image shows the complex river system of Caramance, with its heavy discharge into the sea. Series of such images are needed to monitor the transport of the sediment, which originates from inland soil erosion. The overall scene covers the transition between savannah in the north and tropical vegetation in the south. MERIS can also monitor the intensification of land use, which leads to increased erosion and soil loss.

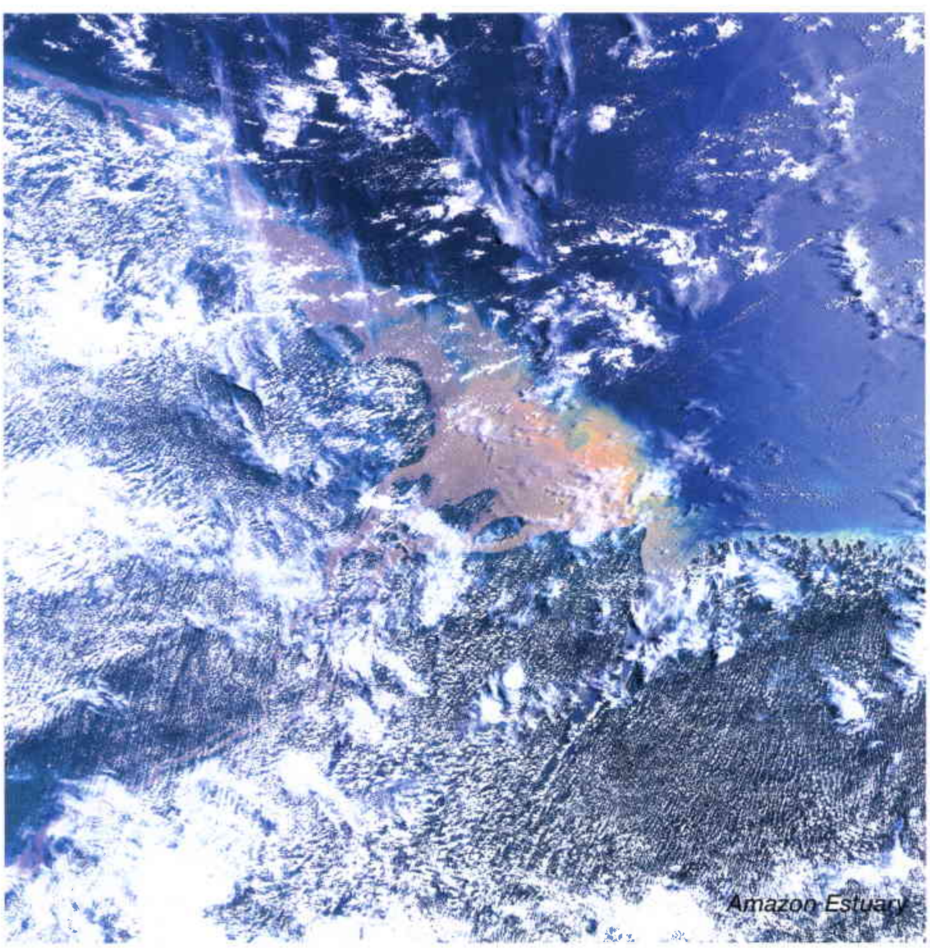
Cuba, Jamaica, Bahamas


Cuba, Jamaica, Bahamas

Central in this image is Cuba, the largest and most westerly of the Caribbean islands. Cuba's 3735-km coastline has coral islands, and white sandy beaches to the north.

South of Cuba lies Jamaica. The highest point on the island is Blue Mountain Peak (2256 m). Jamaica has a high degree of biodiversity, with some three thousand





species of plants, about a quarter of which are unique to the island.

To the north, but unfortunately lying beneath the clouds, the Bahamas comprise an archipelago of about 700 islands extending from Florida to Cuba's eastern tip. The beautiful turquoise colour of the waters around these islands is due to the shallowness of the water, and the presence of coral reefs, which are the only active ones in the Atlantic Ocean.

Europe
MERIS, 24 March 2002

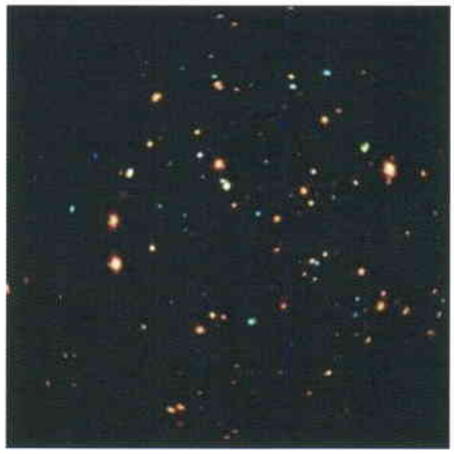
In this image one can distinguish several European countries as seen from space by MERIS: Andorra, Austria, Belgium, England, France, Italy, Spain, Switzerland... Two mountain ranges covered with snow are clearly visible: the Pyrenees and the Alps, with their highest points at 3404 m (Aneto peak) and 4807 m (Mont Blanc), respectively. The image also shows all of the major French cities and their surroundings: Paris, Lyon, Marseilles, Bordeaux and Toulouse. The Rhone, the Seine and the Garonne rivers are pouring large quantities of sediment, visible as green plumes, into the Mediterranean Sea and the Atlantic Ocean.

Amazon Estuary
MERIS, 25 March 2002

Flowing more than 6400 km across Brazil, the Amazon River originates in the Peruvian Andes. It is second in length only to the Nile among the World's rivers. The Amazon discharges huge amounts of sediment, carried away from the vast lands that it crosses, depositing an estimated daily average of 3 million tons of sediment near its mouth. The outpouring of water and sediment is so vast that the salt content and colour of the Atlantic Ocean are altered over distances of several hundred kilometres from the estuary.

XMM-Newton proves supernovae can cause gamma-ray bursts

New results from the XMM-Newton space telescope confirm the theory that the death of very massive stars in supernova explosions can cause gamma-ray bursts. Gamma-ray bursts are the most powerful explosions ever detected in the Universe. They are also one of the greatest mysteries of modern astronomy, since so far no clear evidence has existed to prove what causes them.


A gamma-ray burst

By analysing the afterglow of a gamma-ray burst that occurred last December in X-ray light, scientists have produced the first ever evidence of the presence of chemical elements which are the unmistakable remnants of a supernova explosion that had occurred just a few days before. *"We can now confidently say that the death of a massive star, a supernova, was the cause of a gamma-ray burst. However we still don't know how and why these bursts, the most energetic phenomena in the Universe, are exactly triggered,"* says ESA astronomer Norbert Schartel, a co-author of the original paper, published in Nature in April.

The observations revealed two important facts: first, the material in the source was moving quickly towards Earth, at 10% of the speed of light; and second, the chemical analysis of this material showed that it had to be the remnant of a supernova explosion.

XMM-Newton detected large amounts of magnesium, silicon, sulphur, argon and calcium, but very little iron. This is the kind of material a massive star would produce shortly before exploding as a supernova. Nuclear reactions in the stars' cores fuse light chemical elements into heavier ones, a process that generates the energy needed by the stars to shine; different elements are synthesised at each stage of the stars' evolution. The supernova explosion would have ejected this material into the surrounding environment, producing the sphere subsequently illuminated by the gamma-ray burst afterglow seen by XMM-Newton.

ESA's International Gamma-Ray Astrophysics Laboratory, Integral, to be launched in October 2002, will be the most sensitive gamma-ray observatory ever built. It will be able to detect radiation from the most distant violent events and hopefully answer some more of the many remaining questions in the 'case of the gamma-ray bursts'. esa

ESA and CNES sign contract on CSG


Jean-Jacques Dordain (seated left), ESA's Director of Launchers, and Gérard Brachet, CNES's Director General, signing the contract at Guiana Space Centre.

ESA and CNES signed a contract at the Guiana Space Centre (CSG) in Kourou, French Guiana, on 2 May that assures funding to cover the fixed costs of the 'CNES/CSG facilities'. The total amount of these fixed costs over the five years from 2002 to 2006 is put at 617.4 million Euros.

This contract, signed by Mr Jean-Jacques Dordain, ESA's Director of Launchers, and Mr Gérard Brachet, CNES's Director General, follows on from the decision on Guiana Space Centre (CSG) funding taken by the ESA Council meeting at Ministerial Level in Edinburgh, under which the Agency will cover two-thirds of the fixed costs, amounting to 411.6 million Euros. The other third is being met by CNES out of its budget for national activities, bringing the overall French contribution to 56% of the total.

Under the contract, the term 'CNES/CSG facilities' means the CNES facilities at the CSG and those belonging to ESA made available to CNES for the purposes of carrying out the contract (the downrange stations and the payload preparation complexes operated by CNES). The contract does not however cover the Ariane launch sites in French Guiana made available by ESA to Arianespace. It is Arianepsace that is responsible for meeting the variable costs, which depend on the number of launches carried out.

Gérard Brachet took pride in the fact that *"Europe has, in the CSG, one of the best equipped and most efficient launch bases in the world. The service to users is universally recognised as outstanding. The costs of operational upkeep are well below those of the American bases funded by the Department of Defense and, with productivity gains already identified, they will be reduced by over 15% between now and 2006".*

"The process of Europeanising the CSG set in train under the previous contracts is going to be continued through cooperation between the ESA and CNES teams", said Jean-Jacques Dordain after the signing ceremony, *"especially in the field of industrial policy, the target being to ensure that every ESA Member State has a satisfactory industrial return by the end of the period 2002-2006."* esa

Hubble's new camera unveils a new view of the Universe

Jubilant astronomers unveiled humankind's most spectacular views of the Universe as captured by the NASA/ESA Hubble Space Telescope's new Advanced Camera for Surveys (ACS) on 30 April. They also reported that Hubble is operating superbly since the March servicing mission and are looking forward to more pictures from the newly revived NICMOS camera.

The camera's tenfold increase in efficiency will open up much anticipated new 'discovery space' for Hubble. *"ACS will allow us to push back the frontier of the early Universe. We will be able to enter the 'twilight zone' period when galaxies were just beginning to form out of the blackness following the cooling of the Universe from the Big Bang,"* says Johns Hopkins University astronomer Holland Ford, the lead scientist in the ACS's seven-year development.

Among the suite of four 'suitable for framing' ACS science demonstration pictures is a stunning view of a colliding galaxy, dubbed the 'Tadpole', located 420 million light-years away. Unlike textbook images of stately galaxies, the 'Tadpole', with a long tidal tail of stars, looks like a runaway pinwheel firework. It captures the essence of our dynamic, restless and violent Universe.

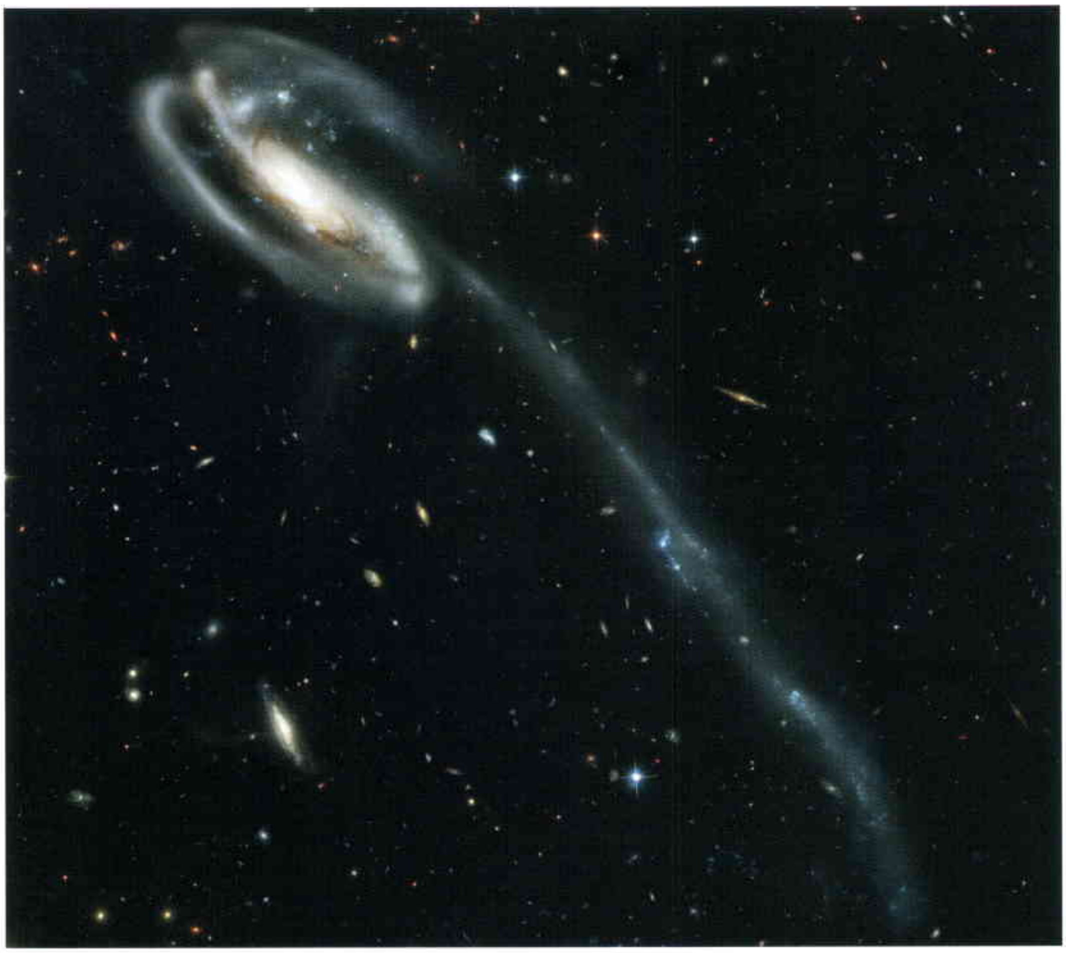
But what came as an unexpected bonus is the enormous number of galaxies behind the Tadpole galaxy – as many as 6000, twice the number in the legendary Hubble Deep Field (HDF) in 1995. Amazingly, the ACS picture was taken in one-twelfth the time it took for the original HDF, and in blue light it shows even fainter objects than the HDF. Like the HDF, the galaxies stretch back to nearly the beginning of time and contain myriad shapes that are snapshots of galaxies throughout the Universe's 13 billion-year evolution.

The ACS images are so sharp that astronomers can identify 'building blocks' of galaxies, colliding galaxies, an exquisite 'Whitman's Sampler' of galaxies, and extremely distant galaxies in the field. The ACS image of the Tadpole illustrates the dramatic gains over the Wide Field Planetary Camera 2 that were expected from doubling the area and resolution, and the five times improvement in sensitivity.

The other pictures include a stunning collision between two spiral galaxies – dubbed 'the Mice' – that presage what may happen to our own Milky Way several billion years in the future when it collides with the neighbouring galaxy in the constellation Andromeda. Looking closer to home, ACS also imaged the Cone Nebula, a craggy-looking mountaintop of cold gas and dust that is a cousin to Hubble's iconic 'pillars of creation' in the Eagle Nebula, photographed in 1995.

Mounted aboard the world's premier optical-ultraviolet telescope, the ACS is a camera of superlatives. It is expected to go beyond the sensitivity of the largest ground-based telescope to eventually see the very faintest objects ever. Its camera delivers a panoramic crispness comparable to that of a wide-screen IMAX movie, a staggering 16 million picture elements (megapixels) per snapshot (typical consumer cameras are 2 to 4 megapixels).

esa



This picture of the galaxy UGC 10214 was taken by the Advanced Camera for Surveys (ACS), which was installed aboard the NASA/ESA Hubble Space Telescope in March during Servicing Mission 3B. Dubbed the 'Tadpole', this spiral galaxy is unlike the textbook images of stately galaxies. Its distorted shape was caused by a small interloper, a very blue, compact, galaxy visible in the upper left corner of the more massive Tadpole. The Tadpole resides about 420 million light-years away in the constellation Draco. Credits: NASA/ESA-ACS Science Team

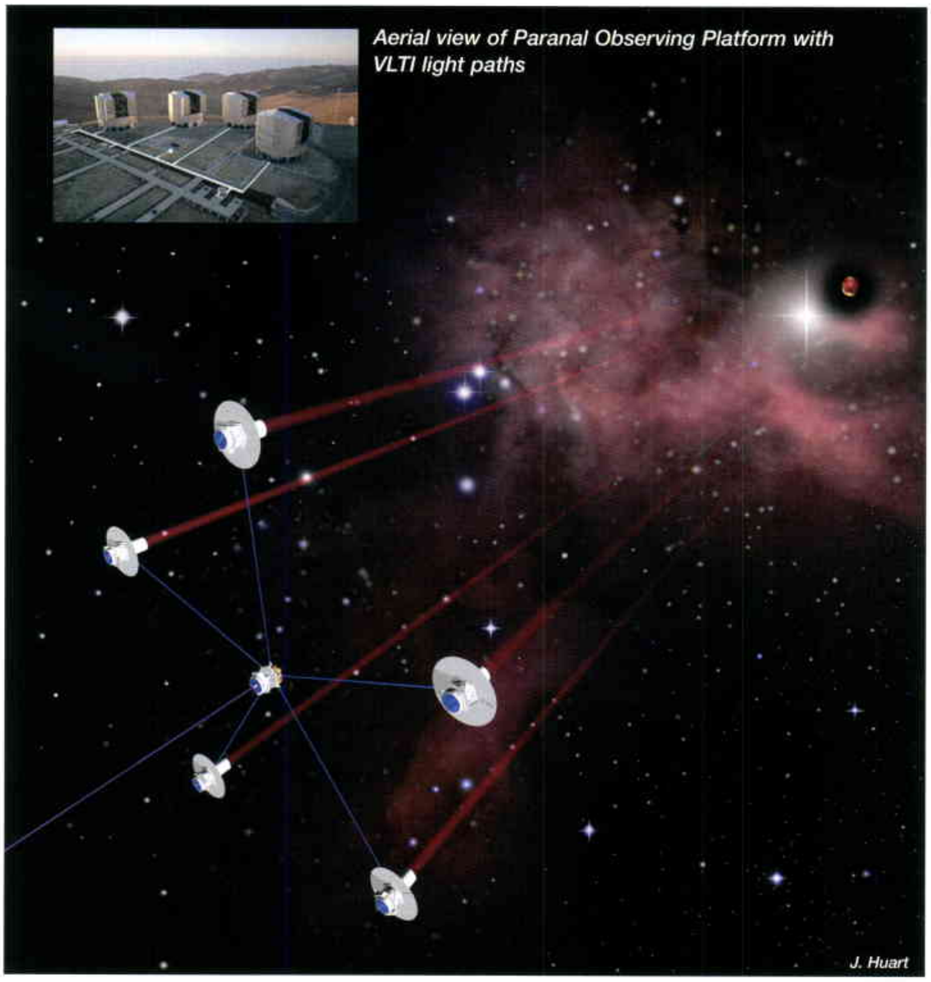
ESA to test the smartest technique for detecting extrasolar planets from the ground

ESA and the European Southern Observatory (ESO) are going to build a new instrument to test nulling interferometry from the ground before ESA applies it in space. Nulling interferometry combines the signals from a number of different telescopes in such a way that the light from the central star is cancelled out, leaving the much fainter planet easier to see.

ESA and ESO will build the new instrument called GENIE (Ground-based European Nulling Interferometer Experiment) using ESO's Very Large Telescope (VLT), a collection of four 8-metre telescopes in Chile. It will be the biggest investigation of nulling interferometry to date.

Using GENIE to perfect this technique will provide invaluable information for engineers about how to build the 'hub' spacecraft of the Darwin flotilla. Scheduled for launch in the middle of the next decade, Darwin is a collection of six space telescopes and two other spacecraft, which will together search for Earth-like planets around nearby stars. The hub will combine the light from the telescopes.

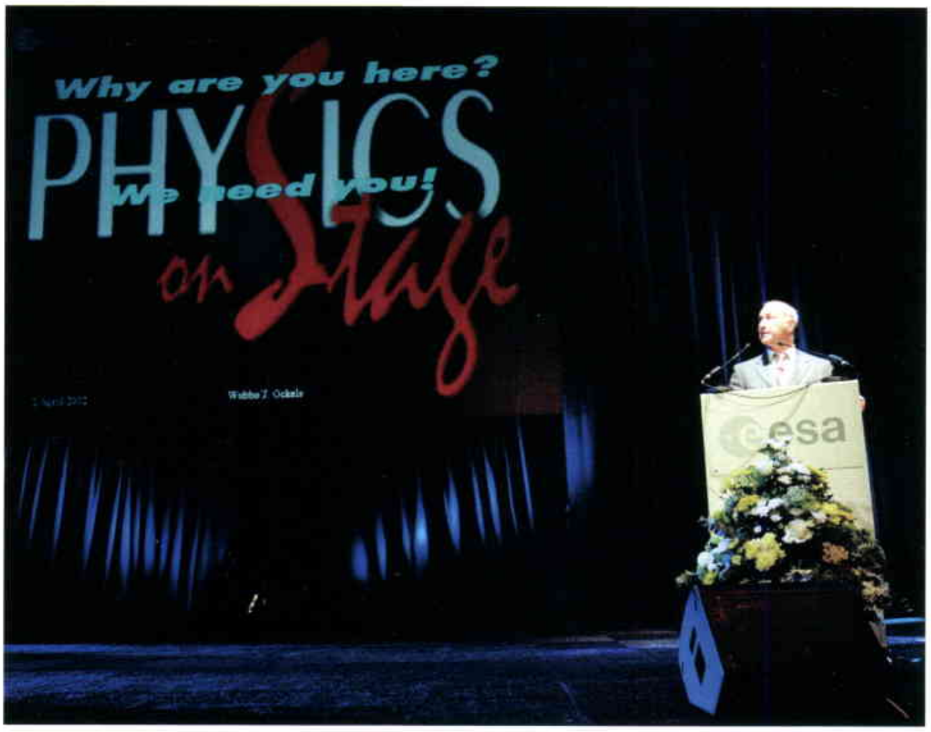
GENIE will see failed stars, known as brown dwarfs and, if the instrument performs to expectations, may also see some of the already-discovered giant planets. So far, these worlds have never been seen, only inferred to exist by the effect they have on their parent stars.



Artist's impression of the Darwin space telescopes.

Focus on teachers

The Physics on Stage 2 festival was held at ESTEC from 2 to 6 April 2002. It was a great success, with over 400 teachers and educational experts from 23 countries taking part in the intensive programme of presentations, workshops, performances and lively fair sessions. They all had a common goal: to solve the current crisis in physics education by making physics more attractive for schoolchildren and to address general European-wide curriculum issues. The participants showcased a large number of exciting and inspiring physics teaching projects, and made many constructive recommendations, which will allow ESA and its EIROFORUM



Wubbo Ockels, Chairman of Physics on Stage 2, gave the opening speech.

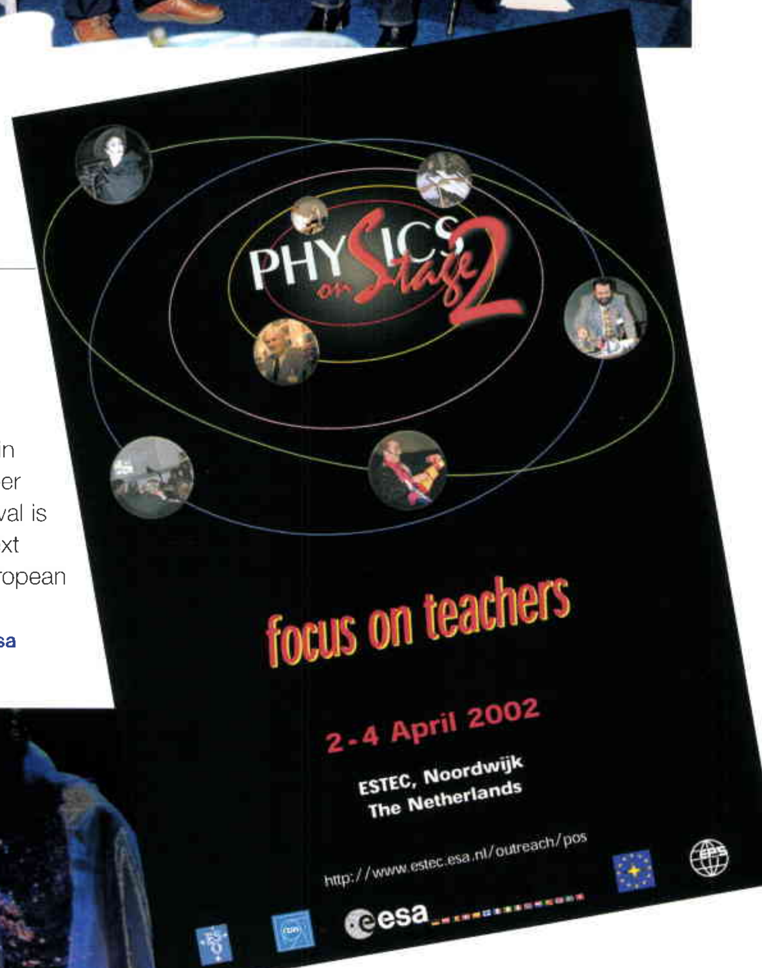
partners to better target future educational projects. The experiments and projects presented ranged from measuring the speed of light with the help of grated cheese and a microwave oven, a walk-in pinhole camera and a transportable planetarium in a tent, to textbook development and teacher training.

The Education Office welcomed several VIP guests to the festival, including Dutch Minister for Education Loek Hermans, Spanish senators Josep Varela and Carlos Bonet, and the Austrian Minister for Education, Science and Culture, Christian Dorninger. Philippe Busquin, European Commissioner for Research, arrived on the last day to listen to all of the recommendations from the workshops and to present recognition awards for teaching excellence, inspiration and motivation of young people, at the festival's Farewell Dinner. Another guest of honour at the dinner was Gerard t'Hooft, winner of the 1999 Nobel Prize for Physics.

"I got a lot out of it and felt fortunate to be involved. In fact, as the week progressed and I became more and more aware of the high quality of the conference, I realised that I was indeed lucky to be talking with some of the leading physics educators from the various ESA countries", says Jim Tisel, a participant from the Netherlands.

The Physics on Stage network continues to be active, with national events and activities taking place in many of the 23 member countries. A third festival is already planned for next year as part of the European Week for Science and Technology 2003. esa

Miguel Cabrerizo from Spain won the first prize for his entertaining range of experiments called 'Recreational Physics XXL'.



The Bulgarian performance 'A Restaurant at the End of the Universe'

Space Walking at ILA2002

The ILA 2002 international aerospace exhibition took place between Monday 6 and Sunday 12 May at Berlin Schoenefeld Airport in Berlin, Germany. "With contracts and cooperation agreements running into billons of Euros, 1,067 exhibitors from 40 countries, 90,000 trade visitors from Germany and abroad, and 215,150 visitors in total, the International Aerospace Exhibition ILA2002 reconfirmed its status as a major European marketplace for the entire aerospace industry", says the official ILA press release.

Photo: FOTAC/Kirst

German Minister for Research and Education, Mrs Edelgard Bulmahn, poses 'on Mars' with ESA astronaut Gerhard Thiele and children from a German TV programme.

1600 square metres of European space activities ranging from space science, Earth observation, telecommunications, satellite navigation, launchers and the International Space Station to industrial matters and technology programmes were on show in Hall 2, the 'Space Hall' with ESA, DLR (the German Space Agency) and the German space industry as exhibitors.

Main attractions were the German-developed Phoenix model and ESA's models of the ISS and the ATV. A daily live video link in 3D to the Columbus module under construction at Astrium in Bremen also drew many visitors.

The ILA was opened by German Chancellor Gerhard Schröder, and many prominent guests including Mrs Edelgard Bulmahn, Minister for Education and Research and Chair of the ESA Ministerial Council and ESA's Director General. Directors and Astronauts talked to the large number of international journalists present, who showed great interest in the development of the Galileo programme and the International Space Station. esa

Publications

The documents listed here have been issued since the last publications announcement in the ESA Bulletin. Requests for copies should be made in accordance with the Table and Order Form inside the back cover

ESA Annual Report

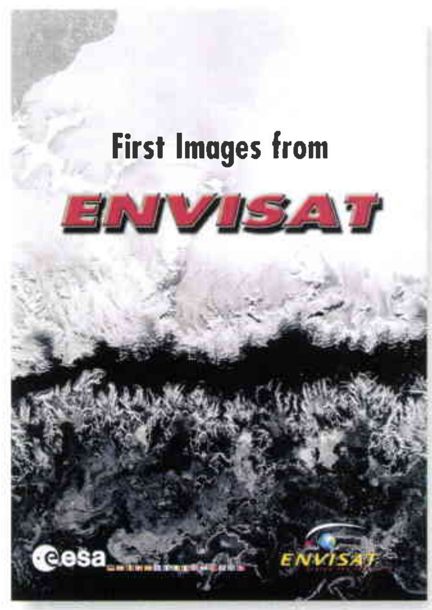
ANNUAL REPORT 2001 (ENGLISH EDITION, JUNE 2002)
ED. BATTRICK B.
NO CHARGE

ESA Newsletters

EDU-NEWS, NO. 2 (MARCH 2002)
ED. WARMBEIN B.
ESA EDU-NEWS, NO. 2 // 16 PAGES
NO CHARGE

ESA Brochures

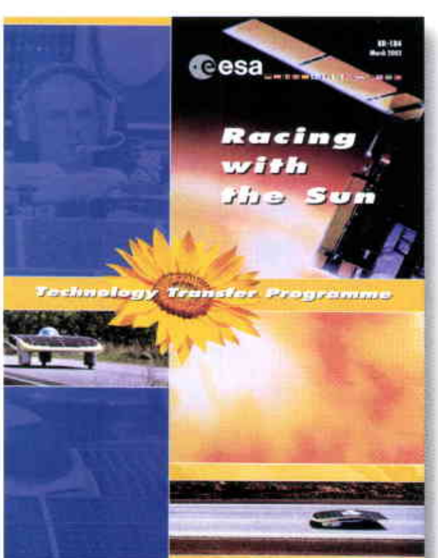
FIRST IMAGES FROM ENVISAT (MAY 2002)
ED. BATTRICK B.
8-PAGE FOLDER
NO CHARGE

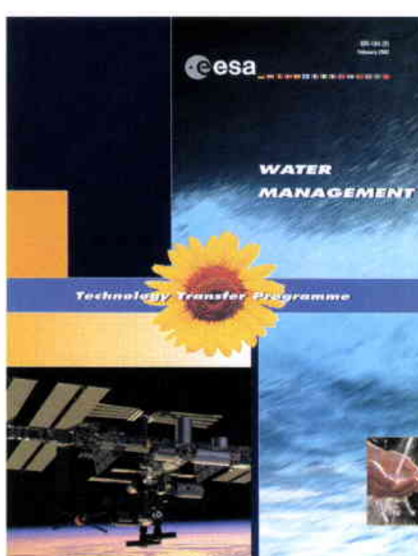


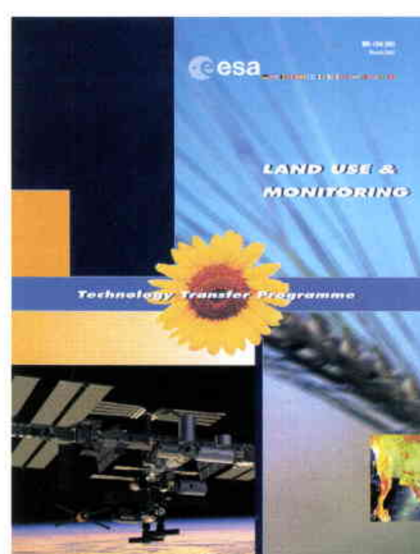
RACING WITH THE SUN – THE ESA TECHNOLOGY TRANSFER PROGRAMME (MARCH 2002)
ED. BATTRICK B.
ESA BR-184 (I) // 8 PAGES
NO CHARGE

WATER MANAGEMENT – THE ESA TECHNOLOGY TRANSFER PROGRAMME (FEBRUARY 2002)
ED. BATTRICK B.
ESA BR-184 (II) // 6 PAGES
NO CHARGE

LAND USE AND MONITORING – THE ESA TECHNOLOGY TRANSFER PROGRAMME (MARCH 2002)
ED. BATTRICK B.
ESA BR-184 (III) // 6 PAGES
NO CHARGE







GALILEO – THE EUROPEAN PROGRAMME FOR GLOBAL NAVIGATION SERVICES (MAY 2002)
ED. WILSON A.
ESA BR-186 // 32 PAGES
PRICE: 10 EURO

ESA Special Publications

BIOLOGICAL EXPERIMENTS ON THE BION-10 SATELLITE (MAY 2002)
ED. PERRY M.
ESA SP-1208 // 125 PAGES
PRICE: 30 EURO

SWITZERLAND, EUROPE AND SPACE (JUNE 2002)
ED. HARRIS R.A.
ESA SP-1261 // 228 PAGES
PRICE: 40 EURO

SOLSPA 2001 – PROCEEDINGS OF THE SECOND SOLAR CYCLE AND SPACE WEATHER CONFERENCE, VICO EQUENSE, ITALY 24-29 SEPTEMBER 2001 (MARCH 2002)
ED. SAWAYA-LACOSTE H.
ESA SP-477 // 637 PAGES
PRICE: 60 EURO

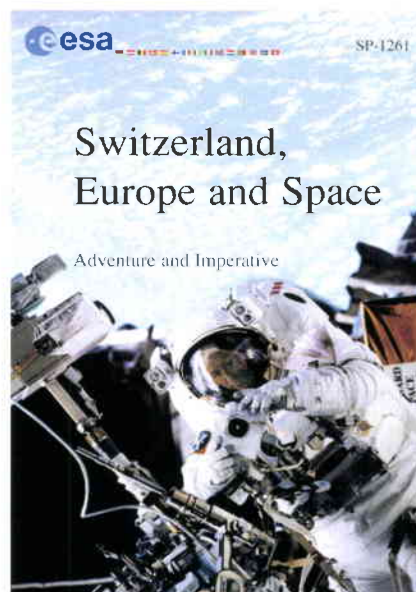
AEROTHERMODYNAMICS FOR SPACE VEHICLES – PROCEEDINGS OF THE FOURTH EUROPEAN SYMPOSIUM, CAPUA, ITALY, 15-18 OCTOBER 2001 (FEBRUARY 2002)
ED. HARRIS R.A.
ESA SP-487 // 767 PAGES + CD-ROM
PRICE: 50 EURO

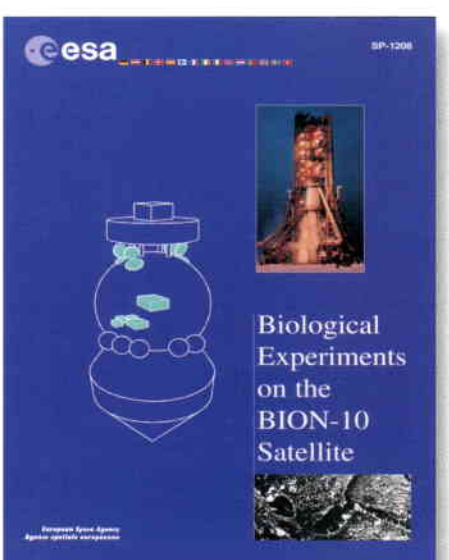
TEACH SPACE 2001 – PROCEEDINGS OF THE INTERNATIONAL SPACE STATION EDUCATION CONFERENCE, ESTEC, NOORDWIJK, THE NETHERLANDS, 26-28 OCTOBER 2001 (FEBRUARY 2002)
ED. WARMBEIN B.
ESA SP-491 // 115 PAGES
PRICE: 20 EURO

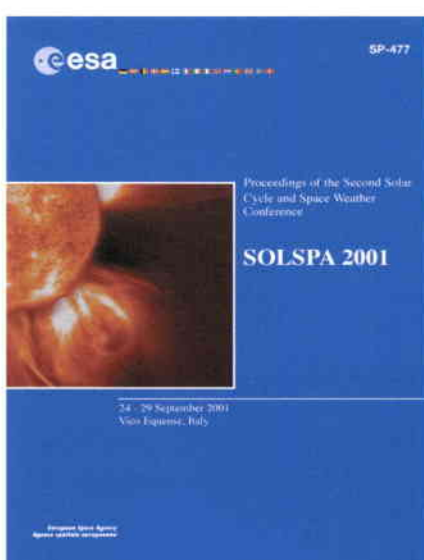
SPACE POWER – PROCEEDINGS OF THE SIXTH EUROPEAN CONFERENCE, PORTO, PORTUGAL, 6-10 MAY 2002 (MAY 2002)
ED. WILSON A.
ESA SP-502 // 751 PAGES + CD-ROM
PRICE: 65 EURO

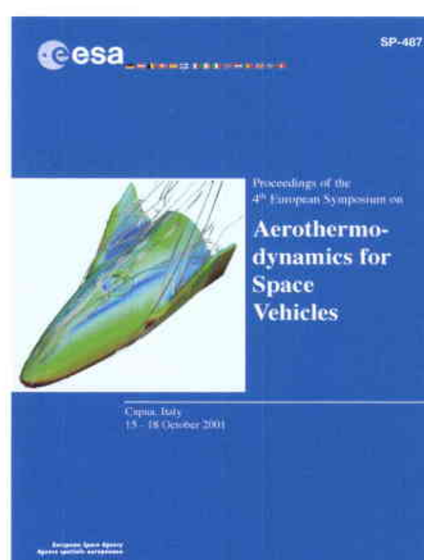
ESA History Study Reports

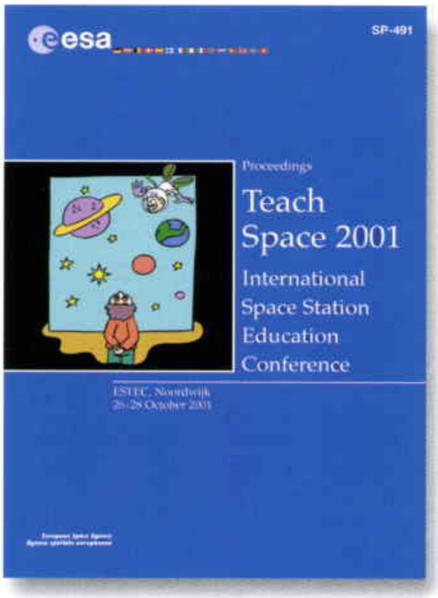
CANADA AND THE EUROPEAN SPACE AGENCY – THREE DECADES OF COOPERATION (MAY 2002)
ED. HARRIS R.A.
ESA HSR-25 // 27 PAGES
PRICE: 10 EURO

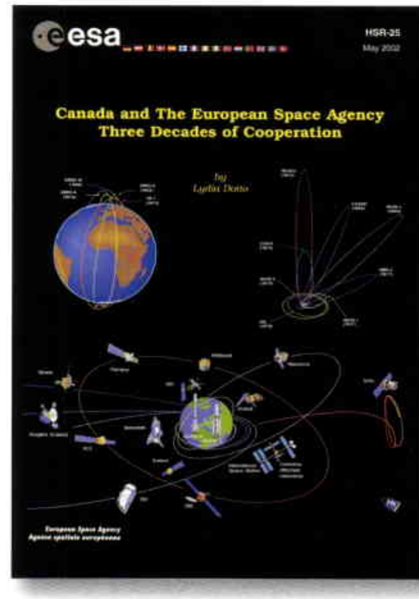












ESA Procedures, Standards and Specifications

SPACE ENGINEERING – TESTING (FEBRUARY 2002)
ECSS SECRETARIAT
ESA ECSS-E-10-03A // 160 PAGES
PRICE: 30 EURO

SPACE PRODUCT ASSURANCE – QUALITY ASSURANCE (MARCH 2002)
ECSS SECRETARIAT
ESA ECSS-Q-20B // 76 PAGES
PRICE: 20 EURO

SPACE PRODUCT ASSURANCE – NONCONFORMANCE CONTROL SYSTEM (MARCH 2002)
ECSS SECRETARIAT
ESA ECSS-Q-20-09B // 38 PAGES
PRICE: 10 EURO

Credit Card Payments for ESA Publications

The Agency's publications can be purchased from the ESA Publications Division 'Bookshop' using your corporate or your personal credit card (Eurocard/ Mastercard, Visa or American Express).

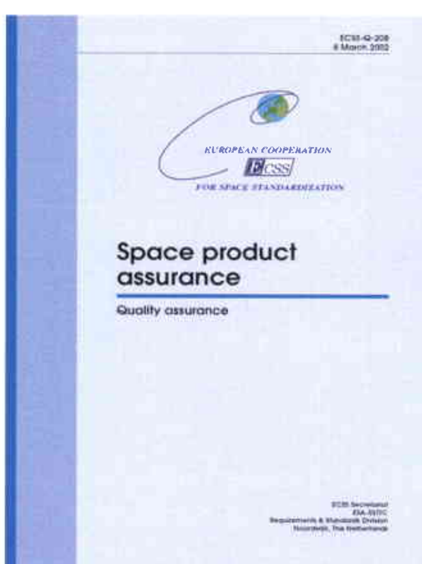
You can telephone or telefax your orders to the numbers given below, quoting your card's number, security code (where applicable), and its expiry date.

The Bookshop (attn. Mr Frits de Zwaan)
ESA Publications Division
ESTEC
Keplerlaan 1
2200 AG Noordwijk
The Netherlands

Telephone: (31) 71 5653405 – Telefax: (31) 71 5655433

Other methods of payment are also accepted. Please call or fax for details.

A list of the latest publications can be accessed via the ESA Publications Division's Home Page at: *www.esa.int*



Available from ESA Publications Division

Publication	Number of issues per year	Scope/Contents	Price	Source
Periodicals				
ESA Bulletin	4	ESA's house magazine	Free of charge	ESA Publications Division
Earth Observation Quarterly	4	Remote-sensing newsletter	"	"
Reaching for the Skies	4	Space Transportation System newsletter	"	"
On Station	4	Space Station and Microgravity newsletter	"	"
Preparing for the Future	4	Technology Programme newsletter	"	"
ECSL News	4	News from the European Centre for Space Law (under ESA auspices)	"	"
Monographs	**Code**			
Conference Proceedings	(SP-xxx)	Collections of papers presented at ESA conferences	Prices vary	ESA Publications Division
Special Publications	(SP-xxxx)	Detailed monographs on ESA programmes/projects	"	"
Brochures	(BR-xxx)	Concise summaries on ESA programmes/projects	"	"
Scientific & Technical Reports	(STR-xxx)	Reflecting ESA's position on a given subject	"	"
Scientific & Technical Memoranda	(STM-xxx)	Latest but not finalised thinking on a given subject	"	"
Procedures, Standards & Specifications	(PSS-xxx)	Definitive requirements in support of ESA contracts	"	"
Training Manuals	(TM-xxx)	Series for education of users or potential users of ESA programmes, services or facilities	"	"
Public-relations material		General ESA literature, posters photographs, films, etc.	ESA Communication Dept. 8-10 rue Mario-Nikis 75738 Paris 15, France	

All periodicals are also available via the Internet at:

http://esapub.esrin.esa.it/

Public-relations material and other ESA information is available at:

http://www.esa.int

Order Form for ESA Publications

No publications sent before receipt of payment in Euros (€).

No. of copies	ESA reference no.	Title	Price per copy/€	Total €
			Total amount:	

Mailing Address *(please print carefully):*

Name

Function Organisation

Address

Post Code Country

Date Signature

Payment *(please tick as appropriate):*

❍ Cheque enclosed (made payable to ESA Publications Division)
Return Order Form with cheque to: ESTEC – Finance Division (ADM-FT)
P.O.Box 299 – 2200 AG Noordwijk – The Netherlands

❍ Items ordered are free of charge

Charge to: ❍ Eurocard/Mastercard* ❍ Visa ❍ AmEx

Card No. Expiry date:

*Mastercard: include Security Code located on back of card above signature - 3 digits

Card Holder's Name

Return Order Form to: The Bookshop (attn. Mr Frits de Zwaan) – ESA Publications Division – ESTEC
P.O.Box 299 – 2200 AG Noordwijk – The Netherlands; Fax: +31 (0)71 565 5433

Telephone orders (and further information): +31 (0)71 565 3405

Information via e-mail: Frits.de.Zwaan@esa.int
Internet – list of the latest publications: http://esapub.esrin.esa.it/

Member States

Austria
Belgium
Denmark
Finland
France
Germany
Ireland
Italy
Netherlands
Portugal
Norway
Spain
Sweden
Switzerland
United Kingdom

Etats membres

Allemagne
Autriche
Belgique
Danemark
Espagne
Finlande
France
Irlande
Italie
Norvège
Pays-Bas
Portugal
Royaume-Uni
Suède
Suisse

European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel (31) 71 565 3400 - Fax (31) 71 565 5433
Visit ESA Publications at: http://www.esa.int