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number 130 - may 2007

bulletin

SPACE FOR EUROPE

INSIDE: stereoscopic DVD, images and pull-out poster of the International Space Station

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, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Canada is a Cooperating State.

In the words of its Convention: the purpose of the Agency shall be to provide for and to promote for exclusively peaceful purposes, cooperation 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 coordinating 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 the 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:

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

ESRIN, Frascati, Italy.

Chairman of the Council: S. Wittig

Director General: J.-J. Dordain

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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, la Grèce, l'Irlande, l'Italie, le Luxembourg, 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.

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ESRIN, Frascati, Italy.

Président du Conseil: S. Wittig

Directeur général: J.-J. Dordain

Editorial/Circulation Office
ESA Publications Division
ESTEC, PO Box 299,
2200 AG Noordwijk
The Netherlands
Tel: +31 71 565-3400

Editors
Andrew Wilson
Carl Walker

Design & Layout
Isabel Kenny

Advertising
Lorraine Conroy

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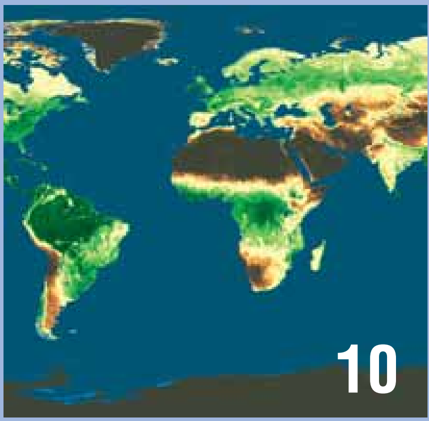
The image released to mark the 17th anniversary of the launch of the NASA/ESA Hubble Space Telescope shows the giant star-forming Carina Nebula in stunning detail. The fantasy-like landscape of the nebula is sculpted by the winds and scorching ultraviolet radiation from the monster stars that inhabit this inferno. In the process, these stars are shredding the surrounding material that is the last vestige of the giant cloud from which they were born. The image was recorded in the light of ionised hydrogen, while colour was added from data taken at the Cerro Tololo Inter-American Observatory in Chile. Red corresponds to sulphur, green to hydrogen, and blue to oxygen emission. *(NASA; ESA; N. Smith, Univ. of California, Berkeley; The Hubble Heritage Team, STScI/AURA)*



GMES
The Second European Flagship in Space

ATV Ahoy
Final Preparations for the First Flight of Europe's Space Ferry

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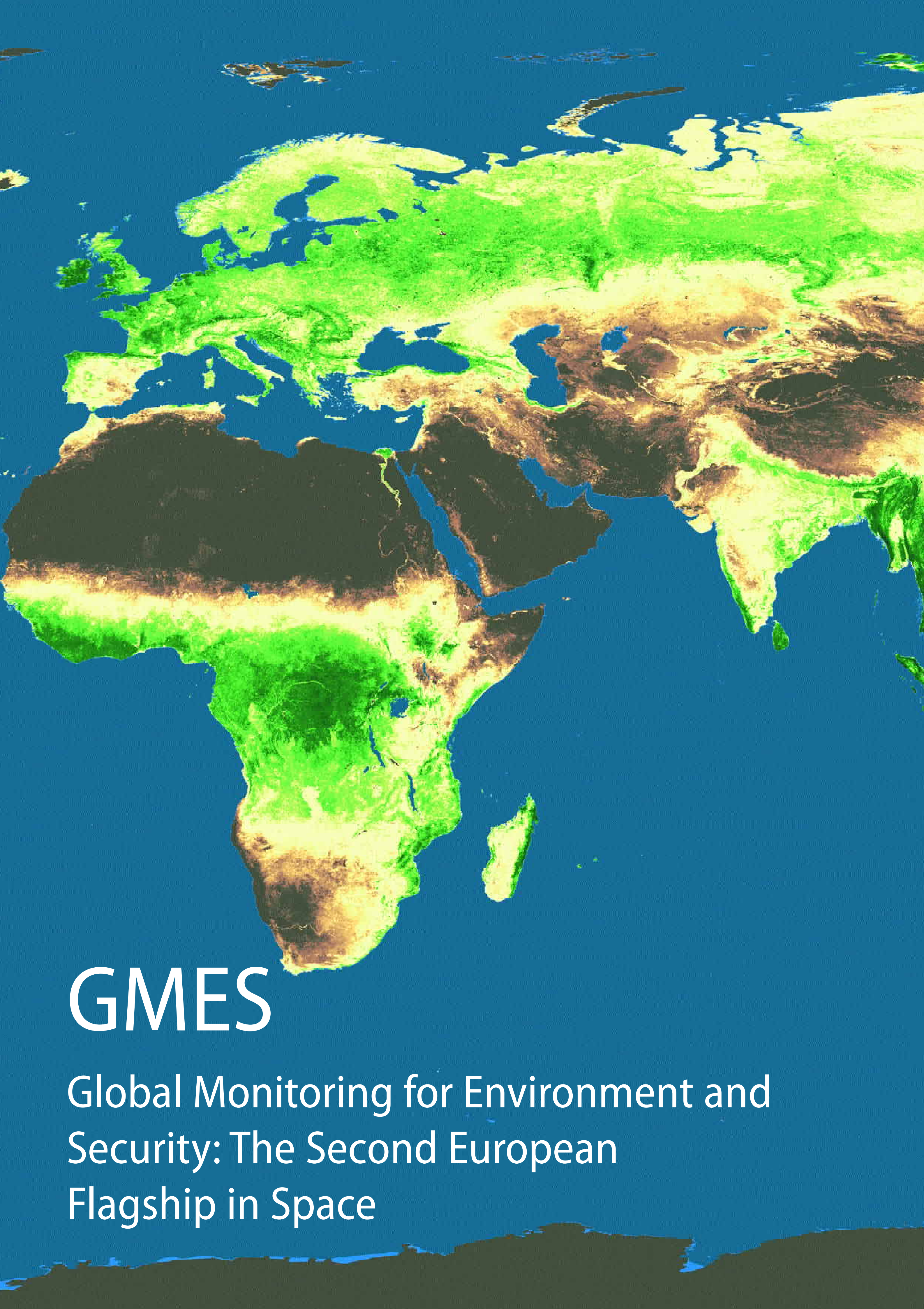
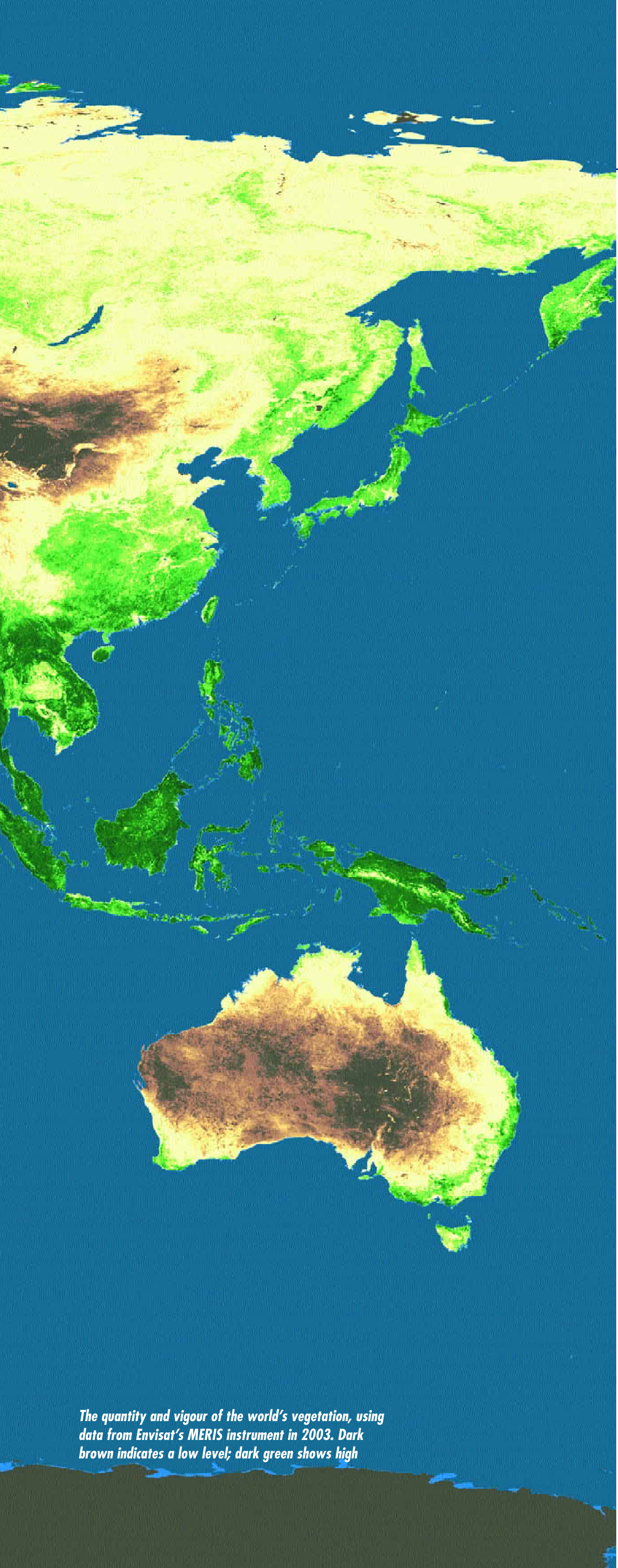


GMES

Global Monitoring for Environment and Security: The Second European Flagship in Space

Volker Liebig, Josef Aschbacher,
Stephen Briggs, Gunther Kohlhammer
& Reinhold Zobl
Directorate of Earth Observation Programmes,
ESRIN, Frascati, Italy

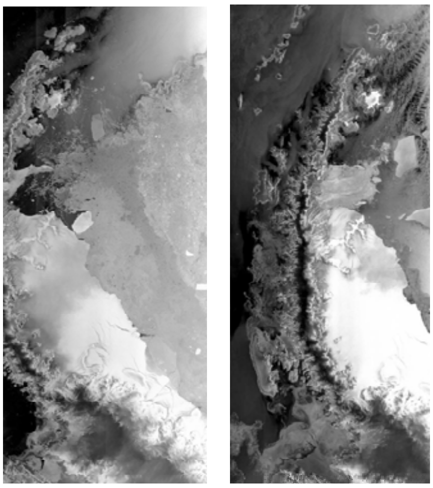


The quantity and vigour of the world's vegetation, using data from Envisat's MERIS instrument in 2003. Dark brown indicates a low level; dark green shows high

Society and politicians are demanding operational information services in order to manage our planet's environment, understand and mitigate the effects of climate change, and ensure civil security for Europe's citizens. GMES can respond to these challenges by providing accurate, up-to-date and globally available information on an operational basis to European, national, regional and local entities. Important decisions are expected in the next two years on the future of GMES, including finalisation of the funding scheme for developing the infrastructure, and progress in setting up its long-term governance and funding. ESA's responsibility is to provide the GMES satellites, which includes developing a dedicated space infrastructure and coordinating the space contributions from all the partners.

GMES Political and Strategic Goals

The Intergovernmental Panel on Climate Change, at its recent meeting in Paris, concluded that global temperatures will increase by 1.7–4.4ºC and sea levels by 21–48 cm by the end of this century. Heat waves and tropical storms will likely intensify and Arctic summer sea ice will disappear in the second half of the century.



Captured by Envisat on 22 February 2007, this radar image (left) highlights changes in the Antarctic ice shelf since the image of 18 March 2002 (right)

Climate change will affect developing countries most. They are already under stress through large increases in their populations; the global population will rise from 6000 million today to 9000 million by 2050. Shortages of food and clean water will lead to conflicts and large-scale emigration to wealthier regions such as Europe and North America.

Environment and security are intimately linked and will become major political issues in the coming decades. The command of information has geostrategic implications. The political mandate for the Global Monitoring for Environment and Security (GMES) programme was expressed at the 2001 Gothenburg European Union (EU) Summit, stating the need to "*achieve by 2008 an operational and autonomous European capacity for global monitoring for environment and security*". This was transformed into an Action Plan 2004–2008, endorsed by the European Parliament. Further, the second Space Council, combining the EU Competitiveness and ESA Councils, stated that GMES will be the second flagship of EU space policy, after the Galileo navigation system.

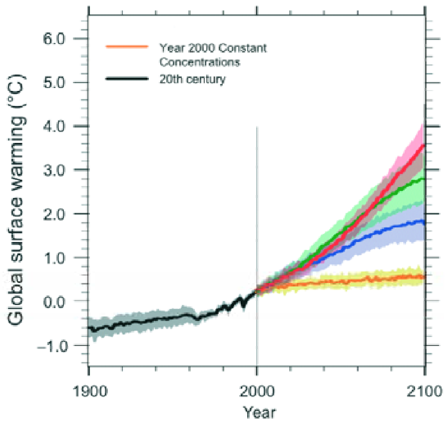
GMES will provide critical environment and security information to European and national policy-makers. Satellites will be a critical component, assuring autonomous, up-to-date and globally comparable information.

A secondary objective of GMES is to provide a coherent European contribution to international efforts such as the Global Earth Observation System of Systems (GEOSS), which was established in 2005 through an international Ministerial Summit. GEOSS is largely modelled on GMES in terms of overall objectives, but totally relies on participants' contributions. GMES will be one of the most significant contributors to GEOSS.

GMES: A European Project in the Making

GMES began in 1998 through the 'Baveno Manifesto', which states the need for a global satellite-based monitoring system for Europe. It attained political momentum in 2000 when it first appeared on the agenda of several EU Presidencies. In 2001, both ESA and the EC obtained approval for some EUR100 million each to initiate GMES services and build up a sustainable user community.

GMES comprises four main, interdependent, elements: services, space observations, *in situ* observations, and data management, integration and modelling. The last is particularly important because it allows forecasts of critical parameters for environment and security.

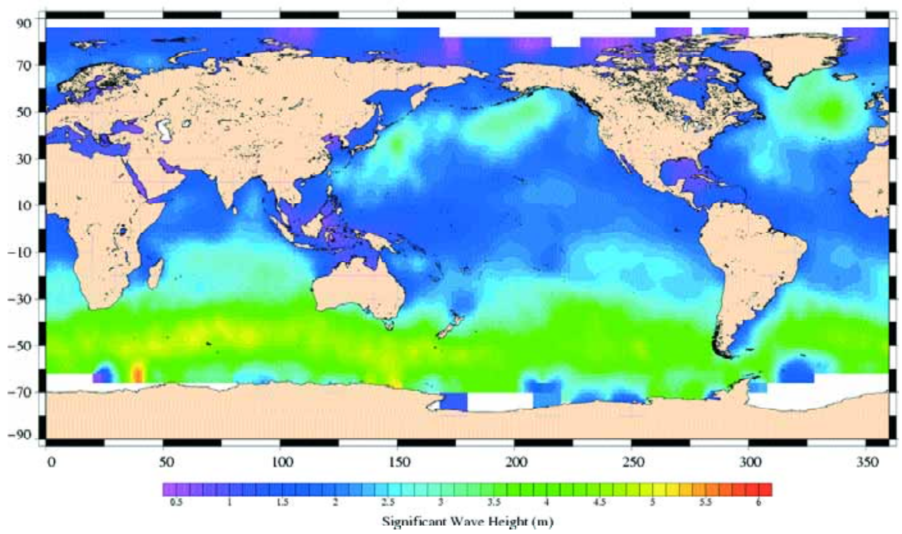


Predicted global warming, depending on different levels of greenhouse gases (red, green, blue). The orange curve predicts the increase if the levels did not rise after year 2000. (Adapted from the Intergovernmental Panel on Climate Change)

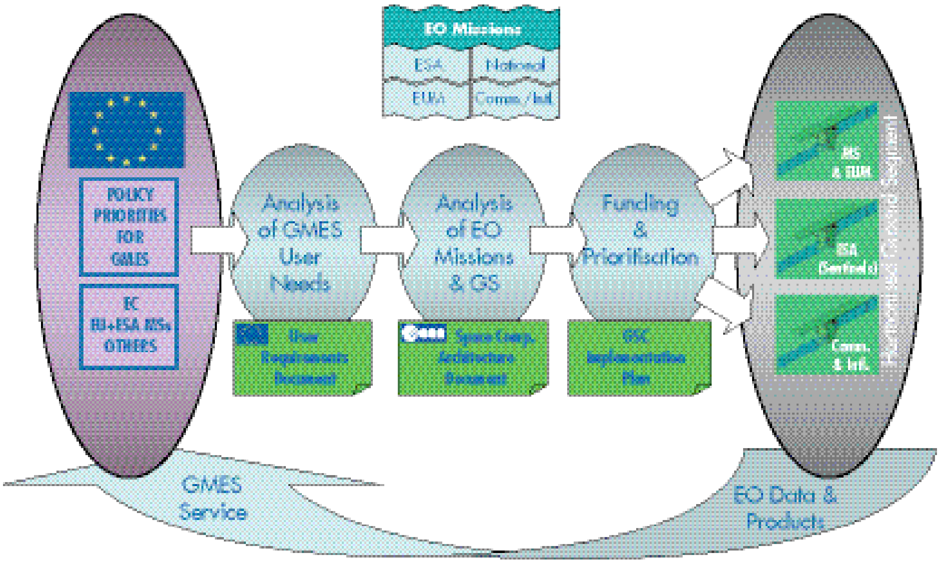
In 2005, the European Commission (EC) assumed political leadership of GMES and took responsibility for the development of services, including the definition and setup of a sustainable governance structure.

ESA is responsible for the space component. This role comprises two basic functions, confirmed by Member States, according to which ESA is responsible for:

– the end-to-end definition and implementation of the space component. Some of elements will be provided



Global wave height measured by Envisat's radar altimeter, 4 September to 10 October 2006. (CNES-CLS)



The process leading to the GMES satellites

through national entities or Eumetsat;
- the development of space and ground infrastructures through ESA programmes, complementing national and Eumetsat contributions.

The elements developed through ESA programmes – the Sentinel satellites and the ground segment and operations – complement Member State contributions.

Responding to User Requirements

GMES satellites are responding to user requirements. The Sentinels, approved at the Berlin Ministerial Council in December 2005, were defined by a 'gap analysis', which analyses user requirements based on policy needs, derives space observation requirements, and compares them with available and planned missions from EU/ESA Member States and Eumetsat.

The EC was closely involved in defining the specifications of these Sentinels. It provided an assessment of the Mission Requirement Documents (MRDs) of Sentinel-1, -2 and -3 through the GMES Fast-Track Implementation Groups on emergency management, marine and land monitoring. The recommendations led to design changes of these missions. The EC further prepared a synthesis report on space infrastructure needs, which endorsed the designs. The report also states that the Sentinel-1, -2 and -3 missions need two satellites each to meet the observation coverage and repeat cycle requirements.

GMES Services

ESA and the EC began developing GMES information services as early as 2002. Under the ESA GMES Service Element, approved in November 2001, ten service portfolios were developed. Each responds to user needs in a specific sector of environmental or security policy. They address domains such as polar monitoring, forest monitoring, marine and coastal monitoring, flood, fire and geo-hazard risk assessment, air-quality monitoring and forecasting, and land-cover mapping and urban development monitoring, as well as information services to support humanitarian aid and development and food security actions.

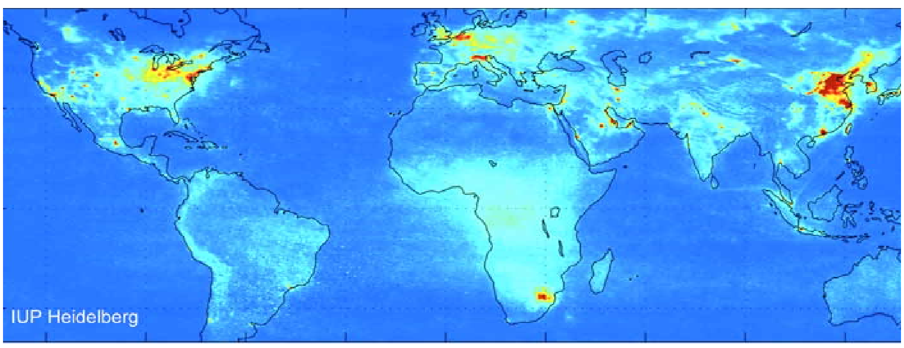
In parallel, the EC undertook a series of large integrated projects within its 6th Framework Programme to address the underlying research issues. Together, these activities engaged more than 300 organisations from 35 countries as end users of GMES. This enabled ESA and the EC to identify the key requirements for the GMES space element, and led to specifications for the Sentinels and access to national missions.

Building on this, the EC organised major consultations with user organisations in Europe and is now dedicating significant resources of the 7th Framework Programme to develop three Fast Track Services: The Land Monitoring Service; The Marine Service, and The Emergency Management Service. These will enter their pre-operational stage in 2008.

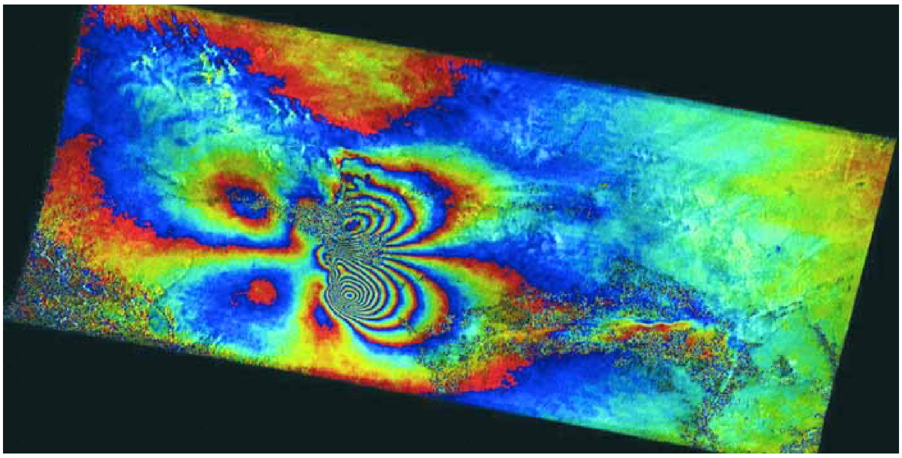
Two other pilot services are planned: the GMES Atmospheric Service, and a service dedicated to Security. A set of core, pan-European or global services will be established first. Later, more specialised services (at national, regional or local levels, for example) will be introduced.

National and Eumetsat Contributions

In line with the GMES Declaration, the space component comprises shared



Nitrogen dioxide pollution measured by Envisat's SCIAMACHY instrument from June 2003 to January 2004. (Univ. Heidelberg)



Envisat radar images of Bam (Iran) from before and after the Earthquake of 26 December 2003 are combined in this 'interferogram' to reveal the ground movement. (Polimi/Poliba)

infrastructure provided by national, European and other contributors as well as the dedicated Sentinel satellites developed by ESA.

Today, a number of national, Eumetsat and commercial Earth observation (EO) missions are being developed in Europe. They primarily serve their respective operator's strategic priorities but are also of interest to GMES.

The candidate EO missions listed in the GMES Declaration will be the starting point for determining these contributions. The list will evolve as new missions become available. Priority will be given to European data sources, to underline the principle of independent data access.

Sentinel-2 will provide high-resolution multispectral imaging. Shown here is the Barrax test site in La Mancha (E), imaged by Proba-2's CHRIS compact high-resolution imaging spectrometer in 19 of its 62 spectral bands

Currently, the missions identified as potential contributors are (in alphabetical order): Altika, Cosmo-SkyMed, DMC, EnMap, Envisat, ERS, Jason, Meteosat, MetOp, Pleiades, Proba, Radarsat, RapidEye, SeoSat, Spot, Tandem-X, TerraSar-X and TopSat.

In order to assure the sustainability of those national and multinational missions that are required for GMES (based on a formalised user endorsement process), a high-level coordination group, the GMES Space Component Partnership, will be set up by ESA with the stakeholders involved.

Sentinel Missions

Based on the gap analysis, five observation capacities have been identified that need to be developed for GMES, in addition to national and Eumetsat missions:

- Sentinel-1: high-resolution synthetic aperture radar (SAR) imaging;
- Sentinel-2: high-resolution multispectral imaging;
- Sentinel-3: global ocean and land monitoring;
- Sentinel-4: geostationary atmospheric monitoring;
- Sentinel-5: low-orbit atmospheric monitoring.

Sentinel-1 carries a SAR in a precise dawn-dusk Sun-synchronous orbit at 700 km altitude with an exact repeat of 12 days for multi-pass interferometry. With a SAR swath width of about 240 km, 12-day quasi-global coverage is ensured. The ground resolution of about 5 m exceeds that of the ERS and Envisat satellites in imaging mode. The 2.1 t satellite is built around the large SAR instrument, which features a phased-array antenna with 5 kW total radiated power. It is designed for launch on Soyuz and a lifetime of 7 years.

Sentinel-2 carries a medium- to high-resolution push-broom multispectral imager operating in the visible and near-

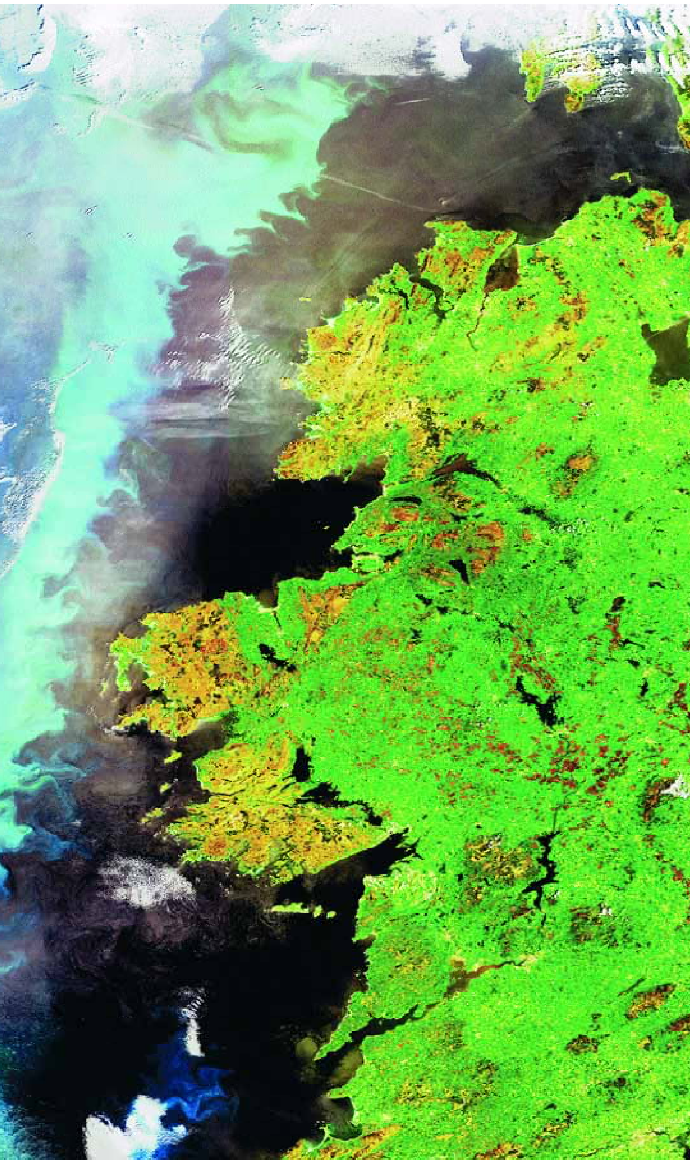
infrared and shortwave infrared in an Envisat-like orbit. The ground resolution is 10, 20 and 60 m, depending on channel. The swath width of the multispectral imager is about 280 km, which ensures systematic acquisition of all land surfaces every 10 days. The 850 kg satellite will fit a small launcher (Vega) and has a 7-year design lifetime.

Sentinel-3 carries a CryoSat-derived microwave altimeter (including a microwave radiometer and precise orbit-determination device) and two imagers, for ocean/land colour observations (MERIS-like) and for sea/land surface temperature observations (AATSR-like) into an Envisat-like orbit. The imager also provides continuity of the Spot/Vegetation mission. The 1.3 t satellite will use a small launcher (Vega). The design lifetime is 7 years.

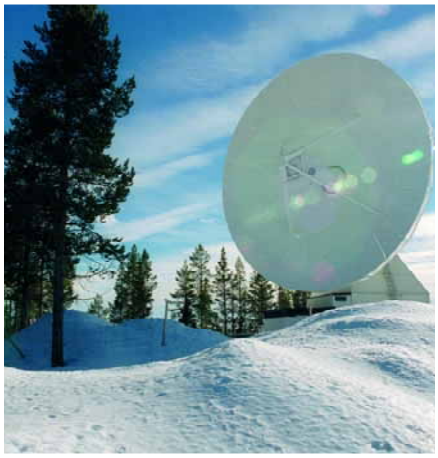
Sentinel-4 and -5 are atmospheric chemistry missions, details of which are being defined through pre-Phase-A studies. The baseline assumption is that they will be instruments aboard the Meteosat Third Generation (MTG) around 2017 (Sentinel-4) and on post-MetOp around 2019 (Sentinel-5). Their use, if confirmed in the above configuration, will be closely coordinated with Eumetsat, who will operate the MTG and post-MetOp satellites.

Long-term continuity of Earth observation data is a prerequisite for GMES services. It is therefore assumed that the baseline technology for the satellites will remain stable for a long period, such as 15 years per satellite generation, which is similar to operational programmes like Meteosat, Spot, Landsat and NOAA/AVHRR. This assumption does not exclude some evolutionary improvements in, for example, in-orbit performance. The ground segment will have shorter renewal cycles of technology to absorb better computing, telecommunication, software systems and user interface technologies.

The strategy and phasing of the procurement process will significantly influence the overall programme's financial profile and cost. The satellite deployment schedule, lifetime, overall funding and the use of new or existing technology are key parameters affecting global cost. For this reason, the technology should be chosen to keep the cost of the overall system low rather than to increase performance. Technology has to be mature before entering engineering and system development.



Sentinel-3 will provide ocean and land monitoring, similar to this image from Envisat's MERIS instrument, a dedicated ocean-colour sensor able to identify phytoplankton concentrations. On 6 June 2006 it found a plankton bloom (pale blue) stretching the length of Ireland in the Atlantic Ocean



An integrated network of receiving stations will ensure the operational supply of Sentinel data to users

Replenishment of Sentinel-4 and -5 would follow the MTG and post-MetOp schedules if they are indeed carried by those satellites.

Ground Segment and Operations

The ground segment will control and exploit the ESA Sentinels-1/2/3 satellites and manage, plan and monitor the overall GMES space component, including access to the other missions.

The Payload Data Ground Segment is distributed, reusing existing facilities, infrastructure and expertise. Furthermore, it will link and share the infrastructure already developed for national missions.

Sentinel operations and utilisation will have a higher degree of automation compared to, for example, ERS and Envisat, but near-realtime requirements and operational reliability will put higher demands on the development of the ground segment.

From 2008 onwards, pre-operational support of GMES services will start through coordinated and harmonised

EO data provision from national, Eumetsat and other third-party missions, all referred to as GMES Contributing Missions.

Routine operations cover all missions. These include mission planning, a distributed user service shared with all partners, coherent quality assessment and the monitoring and control of the end-to-end data provision for the entire GMES space element.

Socio-Economic Benefits of GMES

A consortium led by Price Waterhouse Cooper has analysed the potential socio-economic benefits of GMES over 2006–2030, following wide-ranging consultations with stakeholders and authorities in the policy sectors addressed by GMES.

The study demonstrated that GMES can lead to significant benefits in environment and security policies, because decision-making will be able to draw on better, more complete, consistent, timely and reliable information. Significant benefits were quantified in the following policy areas:

– Europe as a global partner (climate change adaptation, global environment protection, humanitarian response);
– preservation and management of natural resources (air quality, marine environment, forest ecosystem management, civil protection).

Significant benefits were also identified, but not allocated a monetary value, in the following domains:

– Europe as a global partner (climate change mitigation, development and aid);
– preservation and management of natural resources (urban and rural policy, agricultural policy, water quality, management of wetlands).

GMES strategic and political benefits were grouped as:

– *efficiencies in implementing existing policies.* These benefits could, in principle, be realised almost immediately. They represent a value of the order of EUR100 million per annum;
– *European policy formulation benefits.* Since they depend on future policy evolution, these benefits would accrue later, typically a decade hence. Price Waterhouse Cooper estimates the potential magnitude of these benefits to be at least ten times greater than the first category;
– *global action benefits.* Since they depend on new international policy agreements, these benefits would accrue later. The external dependencies and uncertainties in their realisation are greater. However, by virtue of their global scope, they hold the greatest potential benefits. These are estimated to be at least ten times greater than the previous categories.

The potential GMES benefits accumulated from 2006 to 2030 were estimated to be around 0.2% (about EUR80 000 million) of the EU's current annual gross domestic product.

The study highlighted the fact that the mere availability of information does not in itself produce benefit. The GMES benefits will materialise only when the information is used. Hence, during its implementation, major emphasis is being placed on integrating GMES information into future policy and decision-making processes within Europe.

Phased Funding Approach

Up to 2013

The funding required for the build-up of the GMES space component is being obtained in a phased fashion. ESA funds are complemented by EC funds.

Several funding steps are planned during the period 2006–2013. On ESA's side, the 2005 Ministerial Council provided EUR257 million for the first phase. This is expected to be complemented by EUR430 million in 2007 for Phase-2 and then, at the 2008 Ministerial Council, by the amount required to complete the build-up of the space component.

The EC foresees a total of EUR780 million through its 7th Framework Space Work Programme for 2007–2013. Future contributions will be necessary to cover the operational phase of GMES beyond 2013 and to complete the initial operational validation (IOV) of the current Sentinels (such as Sentinel-4/5, launched in 2017–2019). These figures are subject to negotiations with ESA Member States and the EC.

Long-term funding considerations

For the space infrastructure, the longer term funding sources have to move from research & development to infrastructure budget lines. The current share of the investment made via ESA Member States for the build-up of the GMES space component (the IOV) is expected to decrease, while the EC is expected to replace its R&D contributions increasingly through infrastructure budgets to support the operations (including recurrent spacecraft).

The goal should be to follow the example of meteorology, where ESA develops and finances (with a suitable contribution from Eumetsat) the prototypes based on the requirements defined by the users, who are responsible for funding recurrent units, operations and services.

Funding through ESA will focus on technology evolution and upgrades as well as the overall coordination of the space component.

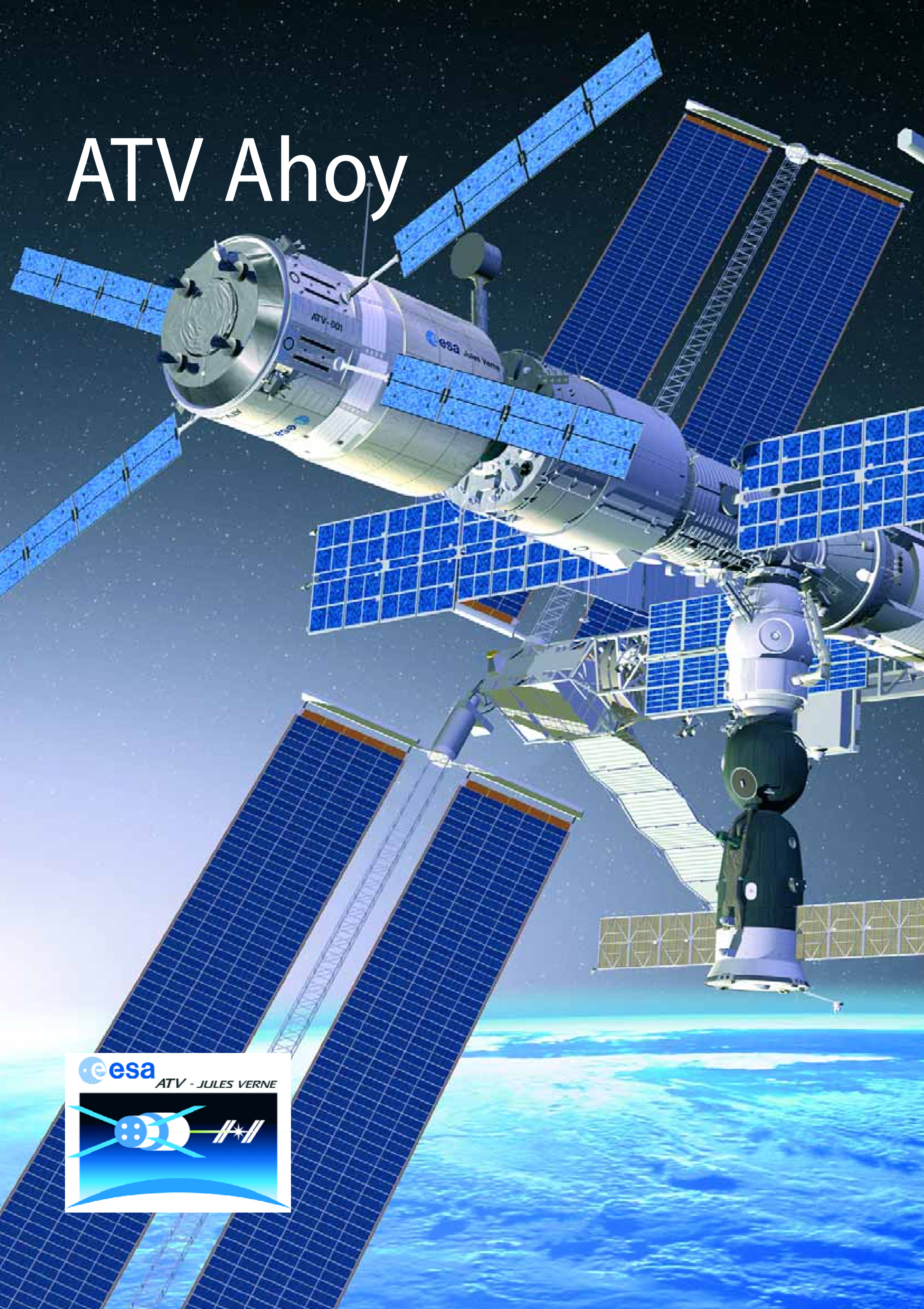
The development of funding sources along these lines would allow GMES to become an operational system that provides critical information to support European policy.

Acknowledgements

The authors wish to thank the staff of the GMES Space Office, the EO Services & Exploitation Division and the Communications Department staff at ESRIN for their support in the compilation of this article and the provision of figures and diagrams. esa

Further information on GMES can be found at www.esa.int/gmes

ATV Ahoy



Final Preparations for the First Flight of Europe's Space Ferry

John Ellwood
Project Manager, ATV, Directorate of Human Spaceflight, Microgravity & Exploration, Les Mureaux, France

Jean-François Clervoy
ATV Senior Advisor Astronaut, Directorate of Human Spaceflight, Microgravity & Exploration, Les Mureaux, France

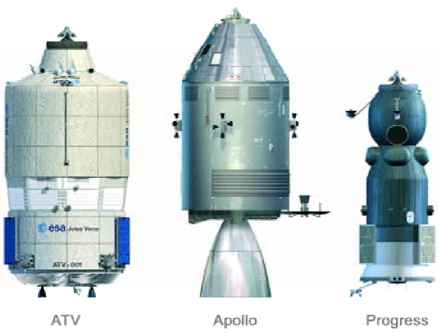
Frederic Castel
ATV Support, Les Mureaux, France

Jules Verne, the first of five Automated Transfer Vehicles (ATVs), stands on the brink of flight. Its inaugural mission, set for the second half of 2007, will conclude an extensive 3-year test campaign. During the coming crucial months, the programme faces three key objectives: prepare for flight, fine-tune the interfaces with the International Space Station and the ISS partners, and ready Ariane-5 for launching its largest payload to date.

Introduction

The ATV marks a new step for European space transportation and lays a cornerstone for human spaceflight. It is the most versatile spacecraft ever developed, uniquely able to self-navigate in orbit and control its own rendezvous. It is a critical resupply tool for the ISS and for the Station partners, especially after Shuttle flights end in 2010 and the ISS must rely on ATV for reboost and disposal at the end of its life.

With ATV technology, ESA has the capacity for automatic rendezvous between spacecraft – crucial for robotic sample-return missions, assembling



ATV's complexity is comparable to that of the Apollo craft that took mankind to the Moon. (ESA/D. Ducros)

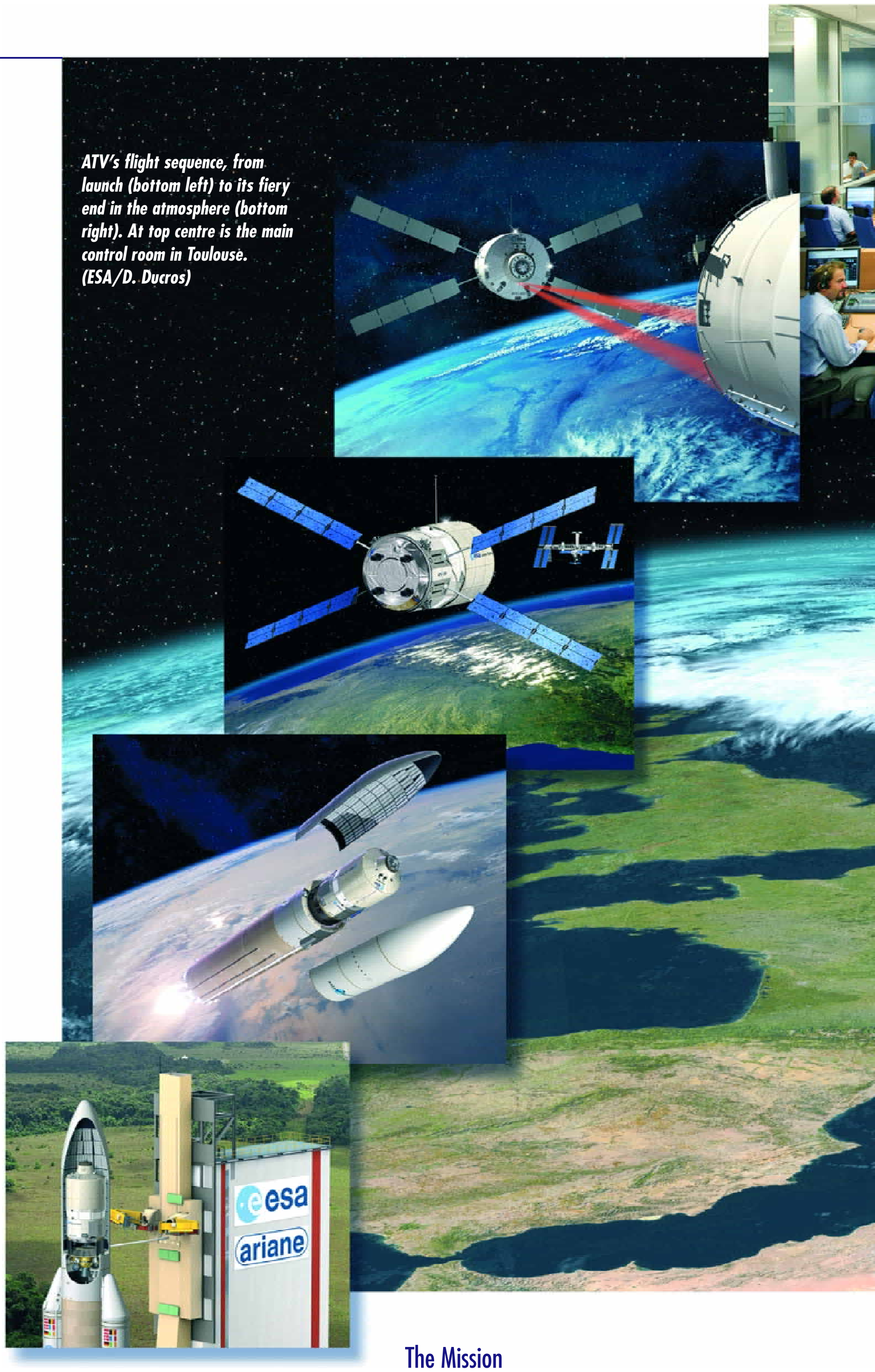
complex spacecraft, and future human planetary exploration.

Several European countries made the political commitment in 1988 to participate in the Station by signing the Inter Governmental Agreement with the USA and other participants. In 1992, ESA began a joint study with NASA to define ATV missions to what was then Space Station *Freedom*. The following year, ESA and the Russian space agency agreed to study possible ATV missions to Mir-2 and, later, to the Russian segment of the ISS.

After numerous political changes in the former USSR and following a US decision in 1993 to include Russia in building the Station, it was finally decided in 1994 to build ATV. In February of that year, the 111th ESA Council Meeting in Paris agreed to the Manned Space Transportation Programme, including ATV. At the Ministerial meeting in Toulouse in October 1995, ATV's full development won formal approval.

For more than a decade, ATV has involved dozens of companies and thousands of engineers from 10 European countries under the prime contractorship of EADS-Astrium Space Transportation (F). The companies include Alcatel Alenia Spazio, Contraves Space, Dutch Space, Snecma, Alcatel Espacio, Crisa and MAN. Eight Russian companies are also involved, with the main contractor, RSC Energia, in charge of building 10% of ATV.

The 19.4 t *Jules Verne* is the most complex space vehicle ever developed in Europe. Since summer 2004, it has been assembled and tested at ESTEC, at times requiring new technical solutions, minor changes and a lot of fine-tuning. The technical complexity of the programme has led to a 3-year delay in the inaugural launch. Now, after meeting numerous challenges, *Jules Verne* is in the home strait, aiming for launch in the second half of 2007.



ATV's flight sequence, from launch (bottom left) to its fiery end in the atmosphere (bottom right). At top centre is the main control room in Toulouse. (ESA/D. Ducros)

The Mission

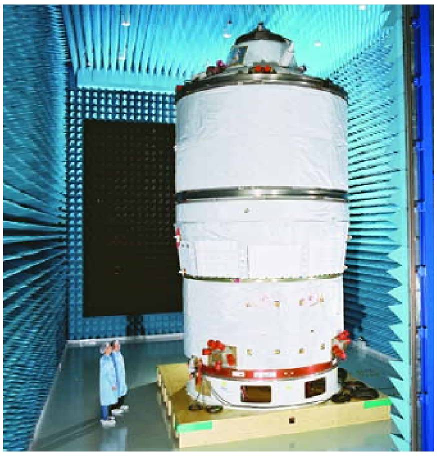
A typical ATV mission begins with launch into a circular orbit atop a new version of Ariane-5 from the French Guiana equatorial site. It is injected into the Station's orbital plane, inclined at 51.6° to the Equator. Under the responsibility of the ATV Control Centre (ATV-CC) in Toulouse (F), it separates from Ariane after 70 minutes and activates its navigation systems,

which fire thrusters to begin its move towards the ISS.

After several days of raising its orbit, ATV comes within sight of the ISS and begins navigating relative to its target, from about 30 km behind and 5 km below. The computers begin final approach manoeuvres over the next two orbits, closing in at a relative speed of a few cm per second while both craft are flying around the Earth at 28 000 km/h.

The approach and docking are fully automatic. If there are any problems, either the ATV computers or the Station crew can trigger one of three programmed anti-collision manoeuvres.

With ATV securely docked, the Station crew enters the cargo section and removes the payload: supplies, science hardware and lightweight bags with fresh food, mail and tapes from their families. Meanwhile, ATV's supply tanks connect to the Station plumbing and discharge their contents. The 100 kg of air for breathing is manually injected by the crew into the ISS atmosphere. For up to 6 months, ATV remains attached mostly dormant, with the hatch open into the Station. The crew gradually fill the cargo section with unwanted equipment and rubbish. Every 10–45 days, ATV fires its thrusters to boost the



Electromagnetic testing at ESTEC in 2005

Station's altitude, which is naturally degraded by the faint but continuous atmospheric drag.

Once its resupply mission is accomplished, and it is filled with discarded items, ATV is closed off by the crew and automatically separates. Its thrusters use their remaining propellants to drop out of orbit – not at a flat angle used for the smooth reentry of manned vehicles, but as steeply as possible for a controlled and safe destructive reentry high above the Pacific Ocean.

From its first operational flight, Europe's most challenging spacecraft will play a vital role in Station servicing. It is also a way for Europe to pay its share in ISS running costs by spending money within European industry rather than by cash transfers to its ISS partners.

The Challenges

ATV is the most versatile spacecraft ever built – it first acts as the upper stage of Ariane-5, then it is a fully independent spacecraft, and, after docking with the Station, it is a supply, life-support and reboost module. Finally, it provides waste-disposal.

Its unique level of autonomy and safety makes it the first fully automated resupply spacecraft of its kind. Even with a malfunction, ATV does not rely on human intervention to ensure mission success and Station safety.

The ATV's design respects a tough requirement: even with any combination of two possible onboard failures, the craft must still be safe for the crew and for the Station itself. It must also tolerate one failure and still complete its mission. This high level of autonomy, courtesy of several layers of safety and failure management, allows ATV to fulfil the entire mission on its own, from navigation in orbit to rendezvous manoeuvres and finally docking with the Station. The whole software package, the most complex ever developed in Europe, has a million lines of code.

ATV's main computer and its three independent sub-computers act as the pilot, controlling the mission. In the event of a major failure during the critical approach phase to the ISS, or if any manoeuvre endangers the Station, a dedicated backup computer will intervene using highly reliable and robust software.

This backup computer isolates ATV's normal system and commands a special 'retrieve' manoeuvre to take the vehicle into a safe trajectory. This independent mode relies on separate computers, separate software, separate batteries, separate trajectory-monitoring sensors, and separate thrusters; only the propellants are shared. This backup system is so segregated from the main ATV systems that it is like a copilot responsible for safety hidden inside the automated spacecraft.

Preparations and Tests

2005 saw small technical problems and failures late in the processing of *Jules Verne*, including a small fatigue failure in a propulsion valve and an anomaly in the drive mechanism of the crucial solar arrays. Together, they snowballed into a launch delay of more than a year.

By the end of 2006, the complex environmental test campaign, including the main acoustic and thermal

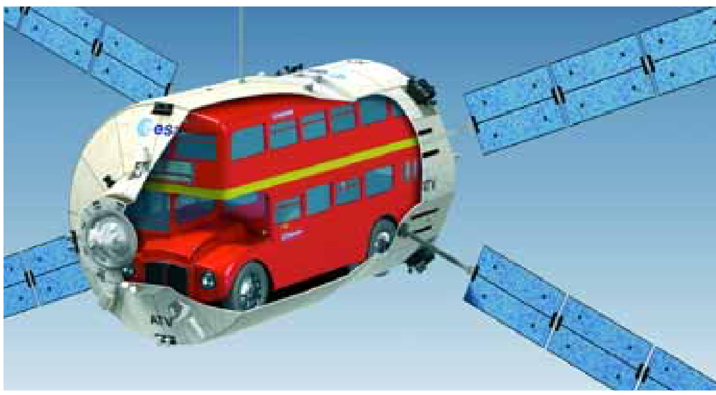
Preparing for acoustic tests at ESTEC

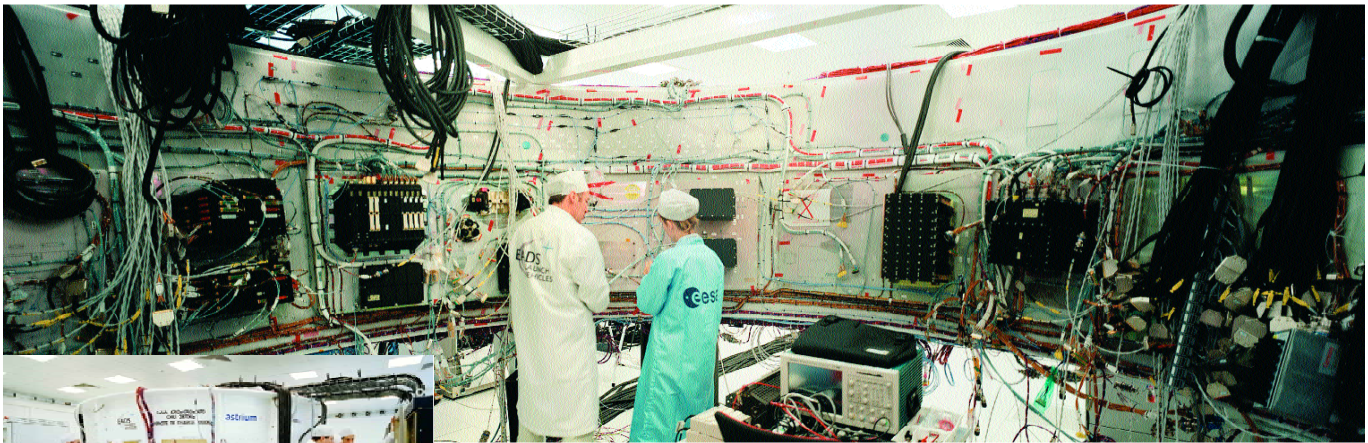
tests, had concluded successfully. In parallel, functional and operations tests were performed at both the ATV-CC in Toulouse and the Functional Simulation Facility (FSF) at EADS-Astrium in Les Mureaux, 50 km west of Paris.

Acoustic and thermal testing

The Large European Acoustic Facility at ESTEC simulated the stress that ATV will encounter during the first 3 minutes of flight atop Ariane-5. The entire ATV structure – the size of a double-decker London bus – must withstand frequencies up to 8 kHz at 143 dB, a level lethal to the human body.

In the second half of 2006, *Jules Verne* completed a series of critical thermal vacuum tests that replicated the harsh





The Functional Simulation Facility in Les Mureaux is replicating the flight of Jules Verne

temperature environment of space. These were the most critical environmental tests for ensuring that all the systems are robust enough to withstand the 6-month orbital mission.

Since early 2006, a primary goal of the *Jules Verne* campaign at ESTEC has been to test the full interaction between the extensive flight software and the real flight hardware of the spacecraft as a whole. Using the Electrical Ground Support Equipment of hundreds of cables and dozens of computers, the flight was replicated.

Similar testing also began early last year at the FSF. This facility housed actual mechanisms from *Jules Verne* and replicas of its electronic 'brain' and 'nervous system' plus ground equipment to simulate all the external interfaces, including up to 60 electronics racks. To be sure that the Facility exactly replicates *Jules Verne*, however, the results from the two campaigns will be closely compared. To make the tests even more realistic, the control centre in Toulouse was added into the loop in early 2007. The preparations and the successful closed-loop simulations with *Jules Verne* took more than 3 months of intense work.

Now that all the numerous tests and campaign challenges are nearing completion, *Jules Verne* should be ready for shipping in summer 2007. The transportation of ATV and its 400 t of support equipment from The Netherlands to French Guiana will take 2 weeks by sea aboard the ship *Toucan*.

Testing the links with the ISS

For the past several months, the challenge has been to run parallel test campaigns in different countries and sites. The primary goal of this complex and time-consuming strategy is to ensure that ATV hardware and software can handle all the possible nominal and off-nominal scenarios that *Jules Verne* might face during its demonstration flight.

For instance, at the RSC Energia plant outside Moscow, home of the ATV docking mechanism, the refuelling system and the complex associated electronics, major computer simulations were underway from December to March. The objective was to test the final version of the software that will link ATV and the Russian Zvezda module during rendezvous and docking. Tests included actual communications hardware and GPS simulators. During ATV's stay at the Station, Zvezda's computers will order the ferry to fire its thrusters to boost the Station's altitude.

At this 'Ground Debugging Complex', a powerful simulator could introduce several failure scenarios and create degraded situations that the ATV architecture had to cope with while respecting the tough safety requirements of human spaceflight.

At the same Moscow plant, a 2-month campaign began in April to test ATV's physical interfaces – the docking system, the complex associated electronics and the refueling system with real fluids and pressurised tanks. *Jules Verne* has the unique capability to refuel the Station with 860 kg of propellants and remove 840 kg of liquid waste.

In summer 2006, thanks to the Europe's largest ship hull test facility at Val de Reuil, west of Paris, it was possible to replicate the rendezvous successfully. For the first time, the system worked under complete closed-loop conditions where all aspects of the spacecraft were either represented for real – software, sensors, trajectories – or simulated, such as thruster firings.

In 2006, ATV's computer and sensors mounted on a mobile platform (left) proved they could approach and dock with the ISS (right) from 250 m out

This rendezvous test campaign brought the different systems together perfectly by using real ATV flight sensors under life-size rendezvous conditions and feeding measurements into the flight control computer. At the same time, a simulator calculated the movements of the vehicle in space. A third system physically translated these computations into a relative motion between the sensors, carried by an industrial robot, and their targets on a huge mobile platform representing the ISS. The integration of all these systems into a closed-loop test worked as planned from some 250 m out all the way to docking.

Astronaut Jean-Francois Clervoy demonstrates the loading of late cargo into ATV

Further information on ATV can be found at www.esa.int/SPECIALS/ATV/

Facing page: ESA's ATV team in Les Mureaux, November 2006. Holding the ATV display photo are Daniel Sacotte (left, Director, HME), Jean-Jacques Dordain (centre, Director General) and John Ellwood (right, ATV Project Manager)

Getting Ready for Operations

Under a contract signed with ESA in 2003, CNES has developed the ATV Control Centre, responsible for monitoring and controlling the vessel during its mission. Since early 2006, dozens of simulations to monitor the *Jules Verne* approach to the Station have required a high degree of technical skill never seen before in European operations.

While attached for up to 6-months, ATV will not only resupply, refuel and boost the ISS, it will also be used to desaturate the Station's control gyros and, if necessary, manoeuvre the complex to avoid space debris.

Several mission scenarios require complex interactions and shared responsibilities between ATV-CC and the Mission Control Centres in Moscow and Houston. For the first time, three space centres around the globe must work together. Special high-level 'Multi-Element Procedures' have been developed, allocating the tasks to be performed sequentially to the centres involved. A dozen simulations involving the three centres are under way to fine-tune the range of possible scenarios, from perfect to degraded missions.

During the flight's highly critical phases, from launch to docking and from departure to reentry, the entire 60-person team in the ATV-CC will work in three adjacent control rooms separated by large glass walls. The main room provides mission execution and management, performed by CNES. In the second room are the flight dynamics engineers. An Engineering Support Team occupies the third, with experts from ESA and EADS-Astrium ready to help in case of a problem.

There is no CapCom (Capsule Communicator) in the ATV-CC but, in case of emergency, the flight director can contact the crew in orbit. The official language during all ATV operations is English, including the communications with Moscow and Houston.

The Extensive Launch Campaign

Since ATV is the heaviest and most challenging spacecraft ever developed in Europe, together with the demanding requirements of manned spacecraft safety, the launch campaign at Kourou will take 3.5 months.

First, in the EPCU S5 (Ensemble de Préparation de Charges Utiles) building, where satellites are prepared for launch, a major leak test will check ATV's 48 m^3 pressurised section and all other pressurised components such as water and gas tanks and the propulsion and the refuelling systems.

Then comes the loading of the dry cargo, in white standard bags of different sizes, stored in the racks of the pressurised section. Most of the 1610 kg of dry cargo carried by *Jules Verne* will be loaded horizontally through the large opening at the aft end of the pressurised module. At this stage, the ATV service module, housing the avionics and the propulsion systems, will not yet be mated to the cargo section. For flexibility, a small fraction of the dry cargo can be loaded through the docking hatch up to 8 days before launch, when the craft is undergoing final preparations on top of the Ariane-5.

The first ATV flight is a demonstration mission, so it will carry a heavier propellant load than subsequent missions. The extra load will allow several scenarios and manoeuvres to be tested, such as retreating into a parking orbit and delaying rendezvous until the following day. The rest of *Jules Verne*'s payload will be 860 kg of refuelling propellants for the Station's own propulsion system, 280 kg of drinking water, 20 kg of oxygen and the 2010 kg of reboost propellants. The extra propellants not consumed for unexpected scenarios during free-flight will be used for additional Station reboosting. All the fluids and gas will be loaded following strict safety rules.

In parallel, the special version of the Ariane-5 will undergo its own launch preparations.

Ariane's Largest Payload

Jules Verne will be launched by a modified version of Ariane-5 known as

the 'Ariane-5 Evolution Storable' (A5 ES-ATV). It comes equipped with the powerful Vulcain-2 main engine and features the storable-propellant upper stage (Etage à Propergols Stockables, EPS) and its reignitable Aestus engine. On subsequent flights, the launcher will inject the 20 750 kg ATV into the ISS orbital plane at around 300 km altitude. For *Jules Verne*, with a mass of 19 400 kg, the circular orbit is at 260 km.

This first ATV is more than double the heaviest single payload ever lifted by Ariane-5. To handle such a heavyweight, the Vehicle Equipment Bay, supporting the ATV atop the launcher, has been significantly strengthened.

The second major change is the modified path taken by the 775 t Ariane-5 during ascent and insertion, allowing for the more severe aerodynamic and thermal demands and the different centre of gravity.

About 3.5 minutes after lift-off, the fairing protecting the ATV is ejected. Five and a half minutes later, the cryogenic main stage (Etage à Propergol Cryogénique, EPC) separates, leaving ATV with its the upper stage. This ATV will reach its initial circular orbit using two burns separated by a 45 minute coast. The first EPS burn lasts about 9 minutes, over the Atlantic Ocean, followed by a ballistic coast half way around the world. Passing over south-east Australia, Aestus reignites for 40 seconds to circularise the orbit at 260 km. Four minutes later, ATV separates over the southwest Pacific and becomes an independent spacecraft. On its own, the EPS reignites an orbit later to deorbit and burn up safely during a precise reentry.

The Launch Date

From April to mid-summer, an extensive review is being conducted with NASA and the Russians to be sure that *Jules Verne*, the facilities and the trilateral procedures are ready to support the inaugural mission.

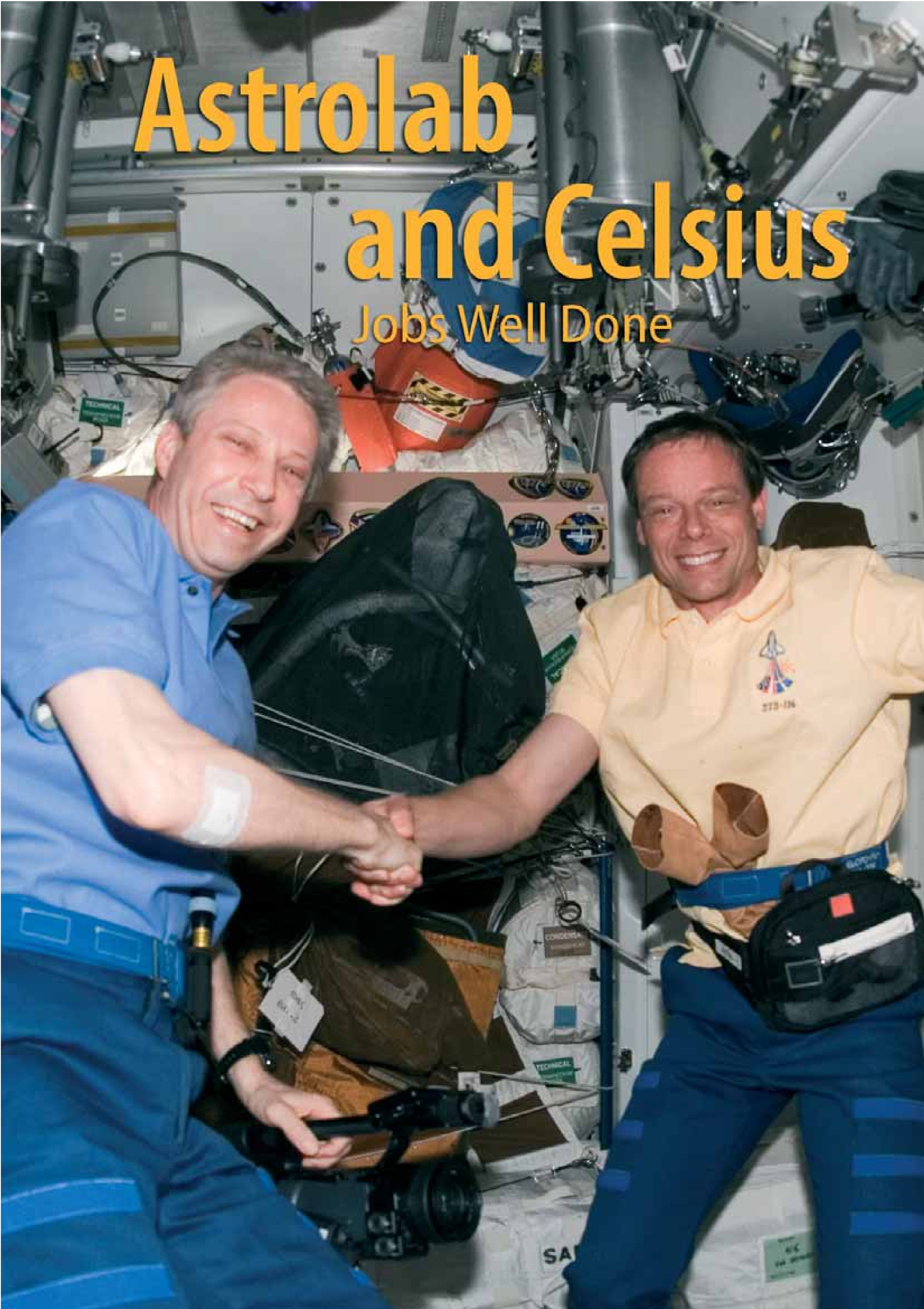
Whatever happens, the mission will not depart earlier than the second half of 2007. Once *Jules Verne* is ready to go, the launch window depends on several factors such as the angle of the Sun at the time of docking, spacecraft traffic and availability of the ISS aft docking port, Station requirements for cargo and reboost and, finally, Ariane-5 constraints from its own busy commercial manifest.

Finally, all the international partners must agree upon the best date among the possible windows to resupply the Station with up to 6 t of cargo.

The ISS Expedition-16 crew, Yuri Malenchenko (right) and Peggy Whitson (left) began ATV training at the end of February 2007 at the European Astronaut Centre

Astrolab and Celsius

Jobs Well Done



Dieter Isakeit
Head, Erasmus Centre, Directorate of Human Spaceflight, Microgravity & Exploration, ESTEC, Noordwijk, The Netherlands

The landing of Space Shuttle Discovery in December 2006 marked the end of two successful ESA missions: Thomas Reiter's 171-day 'Astrolab' and Christer Fuglesang's 13-day 'Celsius'. These were the first in a new series of ESA missions to the International Space Station (ISS), as Europe fulfils its duty as a fully-fledged partner, contributing to assembly and maintenance of the space outpost.

Introduction

Thomas Reiter and Christer Fuglesang undertook a wide range of work in orbit as Russian Expedition and NASA Shuttle crewmembers, respectively. The ESA programme of scientific, technical and educational experiments was highly successful. Astrolab and Celsius were good opportunities to promote ESA's human spaceflight programme to the general public, media and political and industrial decision-makers.

Furthermore, Astrolab involved the ESA mission management, integration and operations teams for the ISS, providing them with valuable hands-on experience before the missions of ESA's own spacecraft and Station elements, particularly the Columbus module and the Automated Transfer Vehicle (ATV) this year.

Flight Engineer and Mission Specialist

Although the experiments by Reiter and Fuglesang were important, the emphasis of both missions was on their roles as ISS Flight Engineer and Shuttle Mission Specialist, respectively.

On 6 July 2006, *Discovery* docked with the ISS and Reiter and his six colleagues were welcomed by the Station's crew of Commander Pavel Vinogradov (Russia) and Flight Engineer Jeffrey Williams (NASA). The pair had been aboard as Expedition-13 since their arrival in the Russian Soyuz-TMA 8 spacecraft in March 2006. Reiter became the third member of Expedition-13, marking the return to a permanent crew of three after the reduction in May 2003 as a result of the *Columbia* accident.

After the docking of *Discovery*, one of the main tasks for the combined crews was transferring items between the Station, Shuttle and the *Leonardo* multi-purpose logistics module (MPLM, in the Shuttle cargo bay). The MPLM acts as a cargo container for the ISS, ferrying experiments and crew supplies from and to Earth.

Once unloaded, *Leonardo* was repacked with 2 t of experiment results, unused Station items and waste material for return to Earth. Reiter was closely involved in this work. This experience is very useful to ESA in preparing for similar operations when its own resupply craft, ATV *Jules Verne*, visits the Station later in 2007.

While Reiter remained aboard the Station, his Shuttle colleagues left on 15 July and landed safely in Florida on 17 July.

Wearing a Russian Sokol pressure suit, Reiter checks the seat fit in the Soyuz-TMA8 spacecraft

Shuttle Mission STS-115

The next Shuttle, *Atlantis*, arrived at the Station on 11 September 2006. Three spacewalks installed the 'P3/P4' assembly, a new 14 m-long segment of ISS Truss with a set of solar wings spanning more than 70 m.

The new solar array doubled the available energy on the Station to 60 kW, preparing for the Columbus and Japanese Kibo laboratory modules. However, the new assembly could not produce power immediately, since the electrical connections on the Truss needed to be rerouted; this was a task for upcoming Shuttle mission STS-116.

Fuglesang moves his EVA suit into Destiny as he prepares for his first spacewalk

Crew Exchange

Atlantis departed on 17 September and made way for Soyuz-TMA 9 three days later with Russian cosmonaut Mikhail Tyurin and NASA astronaut Michael Lopez-Alegria, accompanied by Iranian-born US citizen Anousheh Ansari as the first female 'spaceflight participant'.

Together with Thomas Reiter, Lopez-Alegria and Tyurin formed the new Expedition-14 crew, with Lopez-Alegria as Commander and Tyurin as Flight Engineer. Expedition-13's Vinogradov and Williams left on 28 September, with Ansari, in Soyuz-TMA 8 and landed safely in Kazakhstan.

More Cargo Arriving

On 10 October, the resident trio boarded their Soyuz to transfer it from the Zvezda rear docking port to the forward Zarya position. The flight itself took less than half an hour, but it required them to go through the same lengthy procedure as if they were leaving for good. Before entering the Soyuz in their Russian Sokol pressure suits, they had to switch the Station systems to standby in case some problem forced them to return to Earth.

The Soyuz repositioning freed up the docking port used for the unmanned Progress-M 58 ferry on 26 October, which brought more than 2 t of fresh supplies, including fuel, water, oxygen, food, spare parts, life-support system components and experiment hardware.

The new arrival was the twenty-third Progress to visit the ISS – a new one visits every 4–5 months. Its predecessor remained docked to the Pirs port until 17 January 2007 to provide additional storage space.

Operations and Maintenance

Station operations and maintenance took up a considerable proportion of Reiter's time. In his role as Flight Engineer in the Expedition-13 and -14 crews, he carried out numerous tasks to operate and maintain system equipment in the US and Russian elements of the ISS. This included inspection, reconfiguration and repair, if necessary. He had been in training for this work since 2001.

The ISS and STS-116 crews enjoy a meal together

His responsibilities included the Russian docking mechanisms, guidance and control systems, environmental control and life-support systems, safety equipment, power control and communications systems, crew health equipment and logistics management, including the food supplies and waste.

When Fuglesang arrived aboard STS-116 on 11 December 2006, it was the first time that two ESA astronauts had worked aboard the Station together. Most of Fuglesang's time was taken up with Station assembly tasks, but his role as a NASA Mission Specialist included securing the Shuttle's docking with the ISS, assisting in the retraction of one of the 34 m solar wings, transferring supplies and equipment between the vehicles, and releasing three microsatellites from the Shuttle's cargo bay after undocking.

In addition to the supplies delivered inside the pressurised Spacehab module, STS-116 also carried new space debris-protection panels for the Zvezda module.

On 19 December, the STS-116 crew, including Fuglesang and Reiter, bade their farewells. *Discovery* touched down in Florida on 22 December.

The Legacies of Astrolab and Celsius

The two missions served to promote human spaceflight in Europe. This was achieved through the distribution of comprehensive information material, promotional campaigns, events and exhibitions throughout Europe, and special events when participants could talk to Reiter and Fuglesang in space.

With an average of one call per week, Reiter was able to hold 22 video and three audio conference calls with young people, the media, celebrities, scientists, engineers, politicians and decision-makers, and many other European citizens who took an interest in his mission. He was particularly pleased with the widespread enthusiasm shown by university students and school children in these events, as this is likely to motivate their future studies. Human curiosity is a prime motivation for space exploration.

European Mission Control

Astrolab was the first time that a European control centre was used for a long-duration ISS mission. ESA set up a dedicated European Payload Operations Centre (EPOC) to coordinate space and ground experiment and payload operations, and to monitor the activities of Thomas Reiter on the ISS.

EPOC was based at the Columbus Control Centre in Oberpfaffenhofen near Munich (D). It was the hub of European activity and the ESA control centre for the duration of Astrolab and Celsius. It reacted to any changes during the missions, coordinating decisions and establishing priorities when these changes interfered with the experiment programmes.

Any issues arising were coordinated closely with the mission control centres of NASA in Houston and Roscosmos in Moscow, and with NASA's Operations Support Centre in Huntsville, which is responsible for the experiment activities in the Station's US segment. ESA's Crew Medical Support Office at the European Astronaut Centre (EAC) in Cologne (D) was staffed by medical doctors and biomedical engineers to provide Reiter and Fuglesang with medical advice and monitoring aboard the ISS.

A team of specialists worked on the mission consoles 13 hours every day to support Reiter in orbit, starting and ending their work around the daily morning and evening planning conference between US, European and Russian mission controllers and ISS astronauts. ESA Operations Manager (ESA astronaut Reinhold Ewald) and four ESA Operations Directors organised the daily operations for the ESA experiment programme and ensured that Reiter received the necessary support from the ground team.

Six 'Eurocom' European astronauts led by Claude Nicollier were in charge of all communications with Reiter. They worked mainly from EPOC but could also communicate with the Station from EAC.

EPOC was responsible for coordinating the work of the various User Support and Operations Centres (USOCs). These are national centres throughout Europe responsible for specific ESA experiment facilities and experiments on the ISS. In these centres, scientific investigators can monitor, or be linked to, their experiments. Experiment data are distributed to these centres and information received from them, such as requests to reconfigure experiments and facilities. For Astrolab, six USOCs were active in receiving science results from the Station: DAMEC in Odense (DK), CADMOS in Toulouse (F), MUSC in Cologne (D), MARS in Naples (I), N-USOC in Trondheim (N) and BIOTESC in Zurich (CH).

Mission Objectives and Science

Astrolab had five major ESA objectives: increase European experience in human spaceflight; conduct an experiment programme; gain experience for operating Columbus; promote human spaceflight activities in Europe; expand international cooperation. Celsius added the promotion of human spaceflight with a focus on Scandinavia.

Experiment programmes

Weightlessness is a unique environment for scientific research, giving an unusual opportunity to answer questions that would be impossible to tackle on Earth. Many more processes in physics, chemistry, biology and physiology are affected by gravity than was expected in the early days of spaceflight. Research in weightlessness leads to high-level discoveries or changes of commonly accepted scientific understandings. Even Nobel Prize-winning research, such as that of eye movement reflexes, have been found to be partly erroneous thanks to experiments made during spaceflights.

Astrolab's set of scientific experiments were peer-reviewed and recommended by ESA's Advisory Committee for Life and Physical Sciences. Other experiments covered technology, education and commercial activities. The research programme came mainly from scientific institutions across Europe, and included experiments in human physiology, biology, physics and radiation dosimetry. Most were performed by Reiter, with some by Russian and US crewmembers.

Fuglesang with the Altcriss cosmic-ray detector in the Pirs module

Apart from the direct benefits of the resulting data, Astrolab's experiments provided Europe with operational experience in planning and carrying out a long mission. This is helping the work on the utilisation programme for Columbus. Astrolab marked the first time that a European scientific programme has been composed for a long-duration ISS mission. Reiter's arrival also marked the return to a permanent crew of three, which increased the time available for research.

Human physiology

Reiter's human physiology experiments have three-fold importance. They are helping to understand the effects of spaceflight on the human body and psyche, which is of fundamental scientific interest. They are important for maintaining the health of astronauts aboard the ISS and on future missions to the Moon or Mars. Finally, the results are finding their way into clinical practice, such as in new ways for diagnosing, preventing or treating diseases of age or disability. Reiter conducted eight experiments:

'Card' and 'Cardiocog-2' investigated how weightlessness affects cardiovascular and respiratory systems, as well as the cognitive, physiological and stress reactions of an astronaut in orbit;
'Chromosome-2' looked into chromosome changes and sensitivity to radiation in the white blood cells of astronauts;
'Cult' is a continuing long-term study of cultural aspects and leadership styles of ISS crewmembers;
'Eye-Tracking Device' uses cameras and sensors to record eye and head movement to understand how our balance system works;
'Immuno' and 'Leukin' aim to understand the immune system during long missions;
'Nitric Oxide Analyser' is a European device to measure nitric oxide levels in astronauts' lungs. Elevated levels are believed to be an early and accurate sign of airway inflammation.

Reiter works with the Cardiocog-2 experiment in Zvezda

In addition, Reiter also participated in a series of NASA experiments on measures to prevent the formation of kidney stones.

Space biology
Space biology studies the effects of the space environment on organisms and cells. Reiter's experiments are important for future exploration missions. They looked into the behaviour of bacteria and yeast and into possible biological hazards in a closed spacecraft:

'Ying' studied the influence of gravity on the formation of organised cell structures using yeast cells;
'BASE' studied how bacteria adapt to weightlessness, cosmic radiation, electromagnetism and ISS vibrations.

Radiation dosimetry and monitoring the electromagnetic environment
Studies of cosmic rays are important for determining the effect inside and outside the ISS, as well as for quantifying the potential impact on the human body on long missions to the Moon or Mars. Reiter looked after four experiments:

'Altcriss' is a continuing experiment to study the effectiveness of various shielding materials against space radiation;
'EuCPD' is testing ESA passive dosimeters. All ISS astronauts carry dosimeters at all times, but only US and Russian versions have been used so far. With the increased presence of European astronauts in future, ESA has begun a project to use its own devices;
'Altea' is a continuing experiment to look at the effects of cosmic rays on the brain;
'Lazio' measured the electromagnetic environment of the ISS resulting from man-made emissions on Earth and from natural phenomena such as thunderstorms, earthquakes and volcanic eruptions.

Physics
'PK3plus' is a fundamental-physics experiment for studying complex plasmas, a state of matter that is not fully understood.

Technology demonstrations
Three Astrolab experiments focused on making use of the physical and operational environment on the ISS to test new technologies:

'Erasmus Recording Binocular' is a new 3-D video camera to improve the existing virtual-reality simulation models of the ISS and to share the experience of life and work in space with the general public;
'Special Event Meal' is part of a plan to develop a European capability to produce, analyse and certify food for astronauts;
'Skincare' is aimed at characterising the different parameters of human skin in weightlessness with non-invasive medical equipment.

Fuglesang takes pictures through the Shuttle's overhead windows on the third day of his flight

Education
Reiter also performed some experiments, demonstrations and live events for educational purposes. Two were selected from a contest among European university students:

'Casper' evaluated a new method of monitoring sleep disturbance and sleep stability in weightlessness;
'UTBI' measured the background radiation inside the ISS with a new type of radiation sensor.

Three other educational activities were designed for teachers and pupils in European schools:

'Oil Emulsion' demonstrated to 11–14-year olds how an oil/water emulsion behaves in weightlessness;
'ARISS' allowed children in Greece, Switzerland and Germany to ask Reiter questions via amateur radio equipment about his life and work on the ISS;
the filming of robotic equipment and demonstrations on the ISS for the fourth edition of an educational DVD series that will be produced in all ESA Member State languages for use in European schools.

Celsius experiments and educational activities
Most of Fuglesang's time at the ISS was taken up with assembly tasks, but he was still able to perform three experiments in human physiology and radiation dosimetry, and perform some educational activities. Like Reiter, he participated in Chromosome-2; he also carried the new ESA EuCPD dosimeters.

Fuglesang also took part in Altea. He was filmed during the experiment session for later use in ESA's series of educational DVDs. Altea continues similar studies on Mir, which Fuglesang initiated as a particle physics scientist while training for the Euromir-95 mission. He also participated in NASA medical experiments.

New European scientific gear
The Shuttle that delivered Reiter to the Station in July 2006 also carried three European experiment facilities: the Minus Eighty-Degree Laboratory Freezer (MELFI); the European Modular Cultivation System (EMCS); and the Pulmonary Function System (PFS) upgrade. Jeffrey Williams and Reiter installed and successfully tested them in NASA's Destiny laboratory.

Various human physiology and biology experiments, such as ESA's 'Immuno', made immediate use of MELFI to store samples. Reiter conducted the first sessions with EMCS. This facility allows plant-growth experiments to be carried out at various gravity levels. Experiments with insects, amphibian and invertebrates as well as studies with cell and tissue cultures are planned. The first experiment in EMCS was NASA's 'TROPI', which will provide insight into how plants can be grown in space to develop sustainable life-support systems for long-term space travel.

Reiter also upgraded the PFS for respiratory analyses and used it for the first time in the periodic fitness evaluations that determine the cardio-vascular health of ISS crews. The astronauts measure their oxygen uptake during exercise on a cycle ergometer. It was installed in July 2006 and used once a month by Reiter for his health checks. The PFS, installed in NASA's Human Research Facility, arrived at the Station in July 2005 for research. Upgraded, it is now also used for medical purposes.

Reiter was also the first to use the European Portable Glovebox, with the ESA 'Leukin' experiment. The glovebox is a small hermetically-sealed facility for safely handling biological and physical experiments.

Reiter serviced the larger Microgravity Science Glovebox (MSG), a research facility in Destiny, replacing its large main window and seals. All facilities on the ISS need regular maintenance so they can continue to be safely used in orbit. In 2002, MSG was the first European rack-size facility to be delivered to the ISS and has been successfully used for ten different experiments. It provides a fully sealed and controlled environment, isolated from the rest of the ISS, allowing the astronauts to perform a wide variety of materials, combustion, fluids and biotechnology experiments.

The Origins of Astrolab and Celsius

The Astrolab and Celsius missions had their roots in agreements between ESA, NASA and the Russian space agency Roscosmos.

In the ISS global cooperation scheme, ESA represents Europe, which is one of the five International Partners that are united by the Intergovernmental Agreement (IGA), signed in Washington, D.C., on 29 January 1998.

The IGA, together with others between the partners' space agencies, confers rights and obligations on the participants, including the right to send astronauts to the ISS. However, there is a prerequisite: contribution of a Station element. Europe's element is the Columbus laboratory module, which is scheduled for permanent attachment late in 2007.

Until then, Europe depends on other agreements with NASA and Roscosmos for an ESA astronaut to occupy a Station place that would normally would be taken by a US or Russian crewmember. One way for ESA to send astronauts to the ISS was opened by a 1997 Memorandum of Understanding between ESA and NASA on 'Early Utilisation Opportunities of the ISS'. It provided two flight opportunities for ESA astronauts before the addition of Columbus, in exchange for the delivery to NASA of scientific facilities and other equipment for the ISS. Christer Fuglesang's flight on Shuttle STS-116 was the first under this agreement.

Another route to the Station for European astronauts before Columbus is the ESA/Roscosmos Agreement on participation in Soyuz crew-exchange missions. ESA pays for the training and flight opportunity. Initially, the agreement involved only shorter flights (typically 10 days) that deliver fresh Soyuz craft to the Station, and returned the old vehicles. These not only return the crew to Earth at the end of the mission, but also serve as lifeboats to evacuate the ISS in case of emergency. They are guaranteed for 6 months and then must be exchanged.

After six very successful flights on Soyuz crew exchange missions, this type of ESA-astronaut mission was to come to an end in 2004, when Columbus was due for launch. However, the tragic loss of *Columbia* dictated a serious delay.

As an alternative to missing utilisation opportunities on Columbus, ESA worked out an 'Interim Utilisation Activity Plan' to bridge the gap until Columbus. This included an additional flight of an ESA astronaut on a Soyuz crew exchange. Based on the good experience with the Soyuz short missions, ESA and Roscosmos looked at an ESA astronaut performing a long mission by replacing a regular Russian Station crewmember.

The discussions concluded in 2005 with the signature of the 'ISS Flight Order Contract concerning the Cooperation on the Implementation of an ISS Flight Opportunity for an Expedition Flight involving an ESA Astronaut'. This became the Astrolab mission with Thomas Reiter.

The contract stipulated that Reiter would perform all the ISS system tasks of the Russian cosmonaut, plus 156 hours of ESA experiments. The other Russian cosmonaut would contribute about 20 hours to ESA's experiments.

The mission was initially planned for 2005, during Expeditions 11 and 12. However, further Shuttle delays meant that Reiter flew with Expeditions 13 and 14 in 2006.

While previous flights of ESA astronauts under the ESA/Roscosmos cooperation agreement used Russian Soyuz-TMA vehicles launched from Baikonur, Reiter flew on the Shuttle. This was the result of a separate NASA/Roscosmos agreement that shares some Shuttle-Soyuz seats.

A separate agreement was made between ESA and NASA for Reiter's use of NASA-owned research facilities in the US Destiny laboratory.

Reiter and Williams prepare for their spacewalk in August 2006

The Spacewalks

A high point of Reiter's mission was his extravehicular activity (EVA) on 3 August 2006 with Jeffrey Williams. He was the first ESA astronaut to perform a spacewalk from the Station. Reiter was already experienced in EVAs, having performed two during his Euromir mission aboard Mir in 1995–1996.

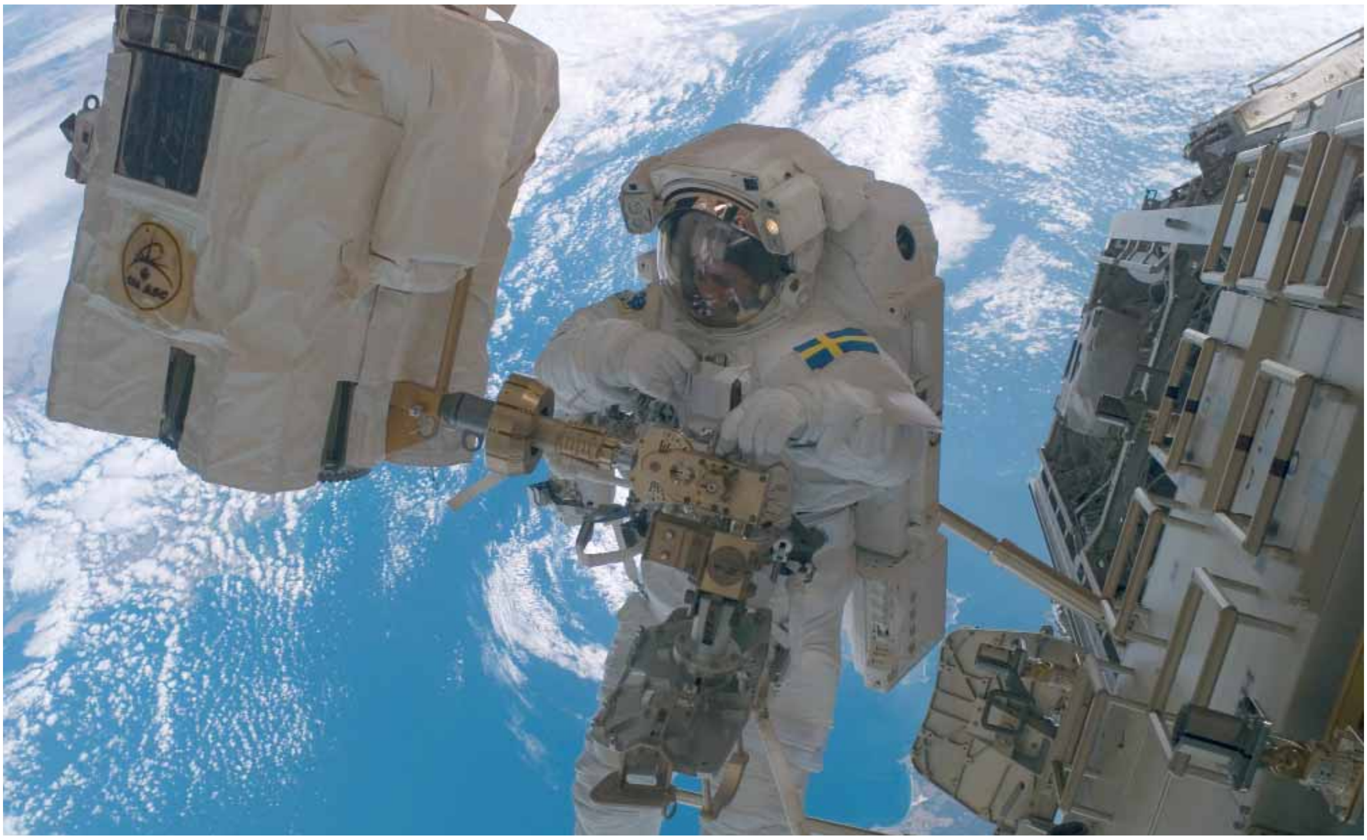
Together with Williams, Reiter set up hardware that included the Floating Potential Measurement Unit (to monitor electrical charging to ensure safety during dockings and EVAs) and the MISSE-3 and -4 materials experiments.

The astronauts then prepared ISS Truss components for future assembly work by installing a computer for the external thermal control system, and deploying a new EVA infrared camera to evaluate its possible use for inspecting the heatshields of visiting Shuttles. The EVA lasted nearly 6 hours.

Fuglesang's EVAs

Fuglesang's most important role during his mission was to perform three highly demanding EVAs. The first two, during the nights of 12/13 and 14/15 December 2006, were part of the original mission plan for Fuglesang and NASA astronaut Robert Curbeam to carry out several important Station assembly tasks. The third EVA, during the night of 18/19 December, was added only during the mission.

During the first EVA, the pair connected the P4 and P5 Truss elements on the Station's left side. Joan Higginbotham and Sunita Williams, inside the Station, used the Canadian robotic arm to steer P5 into place alongside P4.



Fuglesang on his second spacewalk. The end of the Station's Canadarm2 is at left

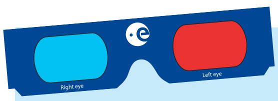
At this time, the astronauts set a record: they were working furthest from the airlock than any crew since Station construction began. Fuglesang and Curbeam had to tighten the bolts securely by hand using a battery-driven wrench. The other major task during the first EVA was replacing a broken camera on the S1 Truss element.

On their second EVA, they changed many of the electrical connectors at several sites. They had to reconnect two of the Station's four power channels, during which almost half of the power had to be switched off. Finally, Fuglesang and Curbeam were carried on the Canadian robotic arm to move two tool carts to new positions for the next EVA.

The third EVA, by Curbeam and Williams, reconfigured the other two power channels and transferred three packs of debris panels from the Shuttle cargo bay to a storage location on the ISS.

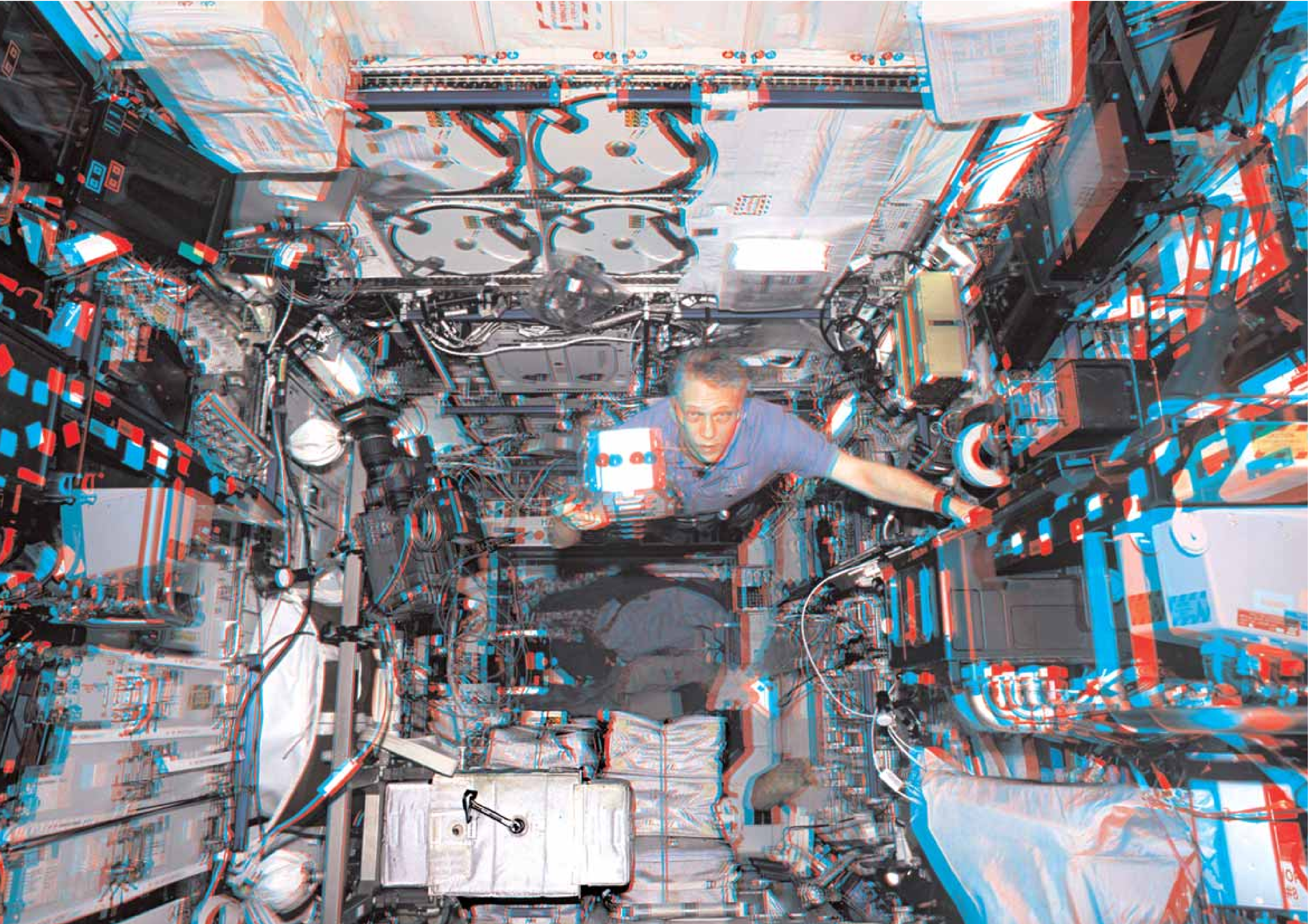
Fuglesang then unexpectedly had the chance of a third EVA after one of the original solar wings refused to retract and fold up when commanded by the crew inside. Fuglesang and Curbeam had to venture outside again and help the solar array manually. This was challenging work because they had not trained for the job. But helped by experts on the ground, Fuglesang and his colleagues choreographed a complex EVA at short notice and built a new tool.

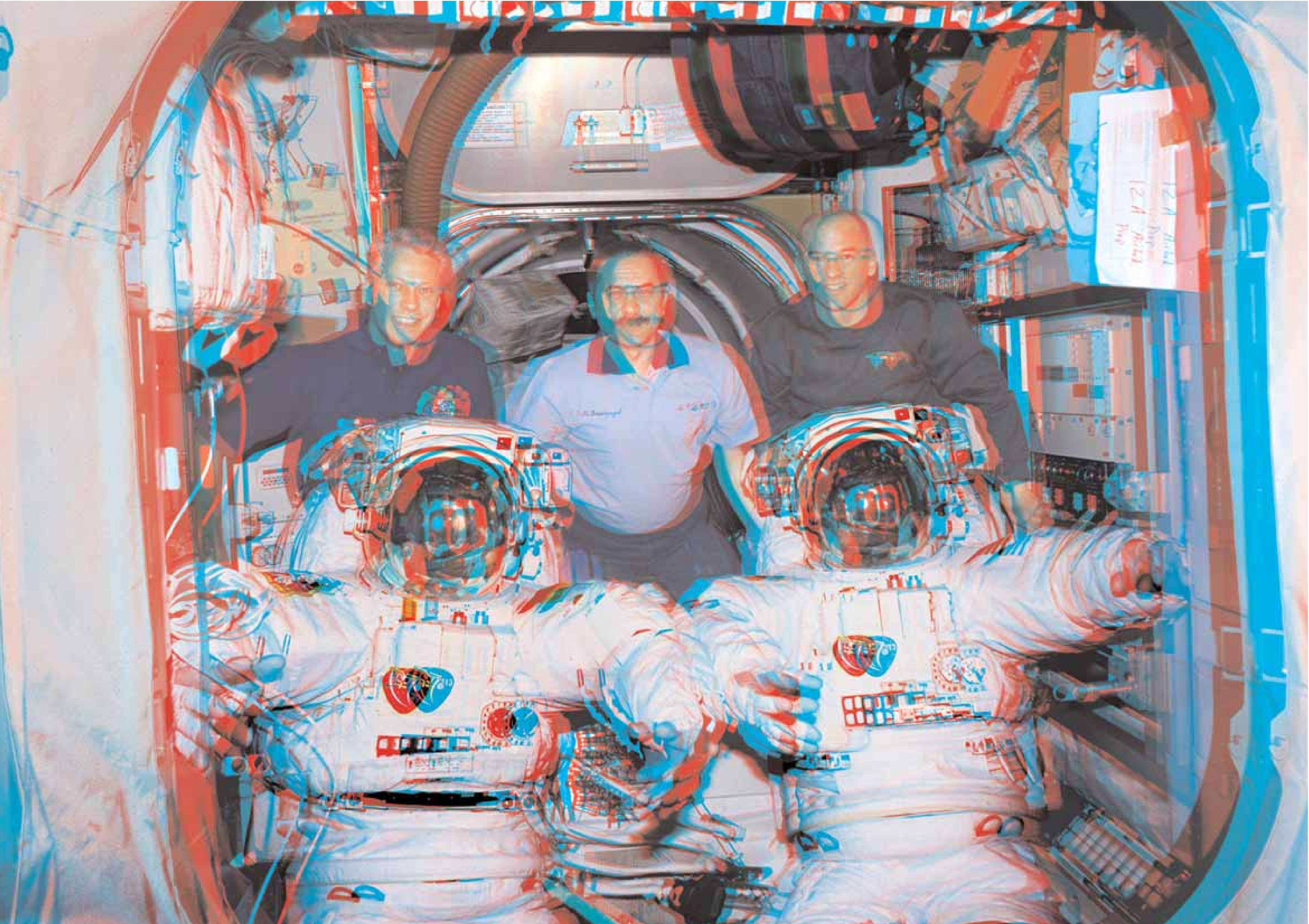
In 6.5 hours, they succeeded in freeing the jammed array to allow full retraction. The wing had been operating for 6 years but has to be moved to complete Station assembly and also would have interfered with the rotation of the new wings installed in September 2006.

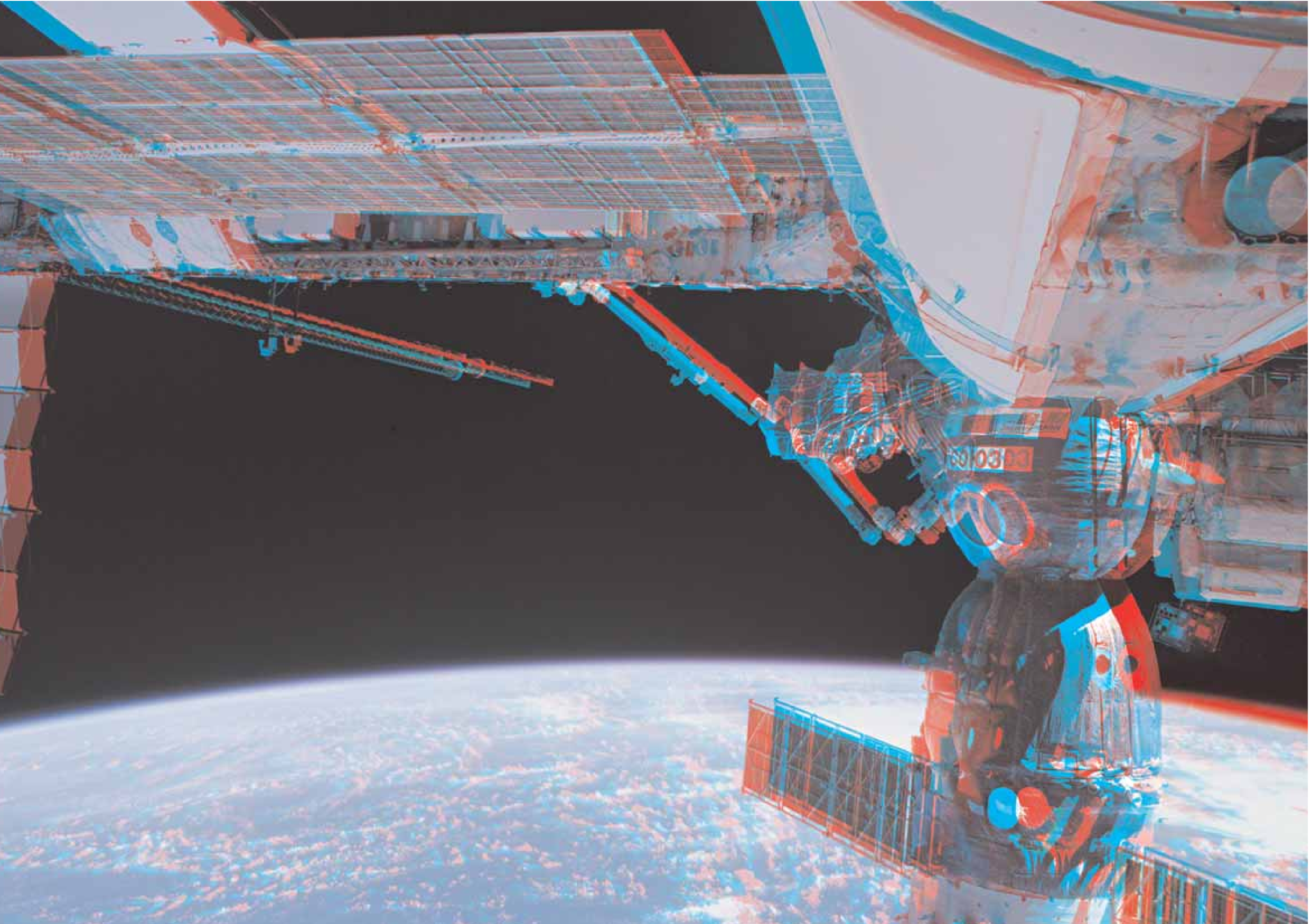


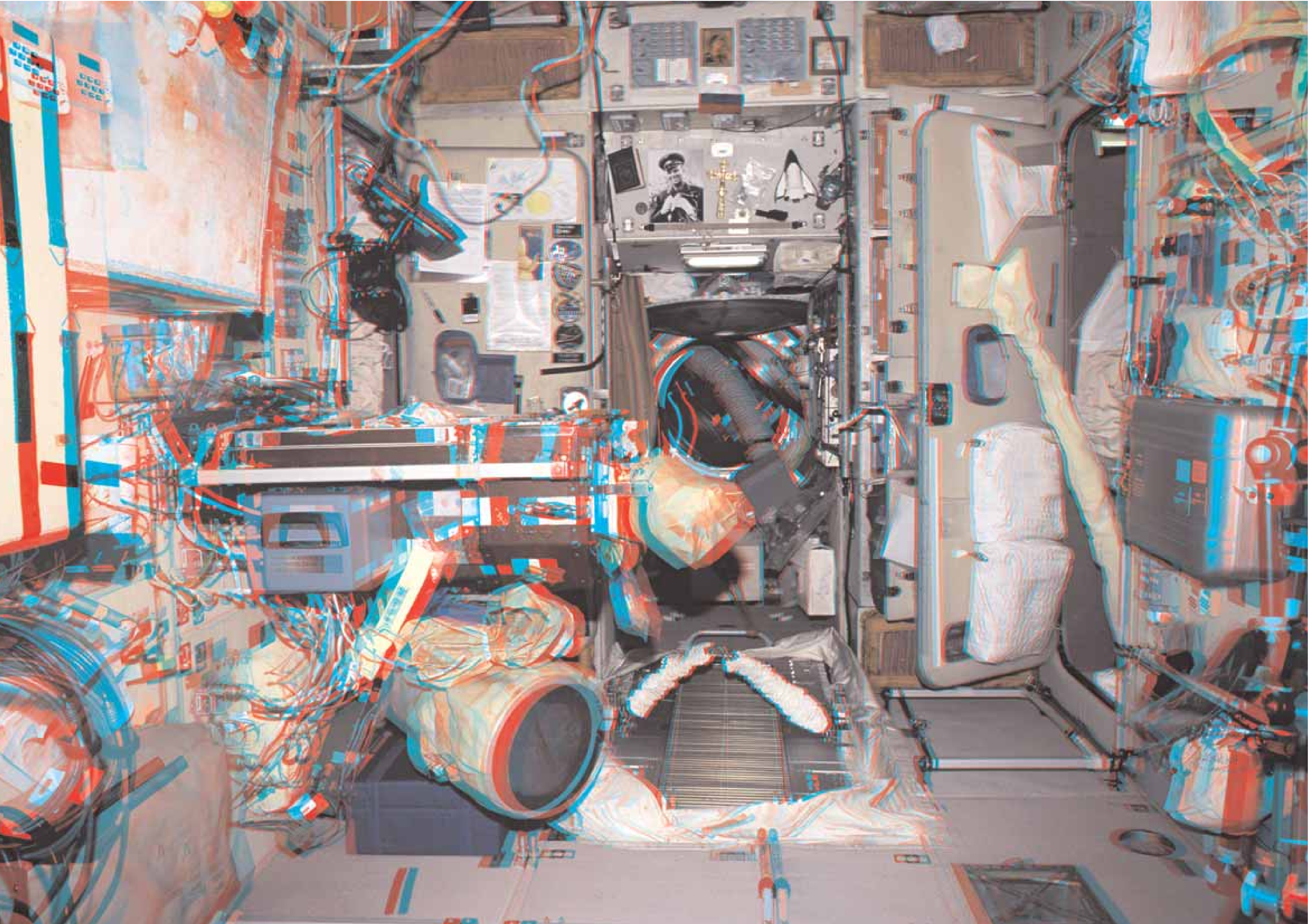
Use the stereo glasses provided in this issue to view the DVD, poster and the eight stereo images from the Astrolab and Celsius missions on the following pages:

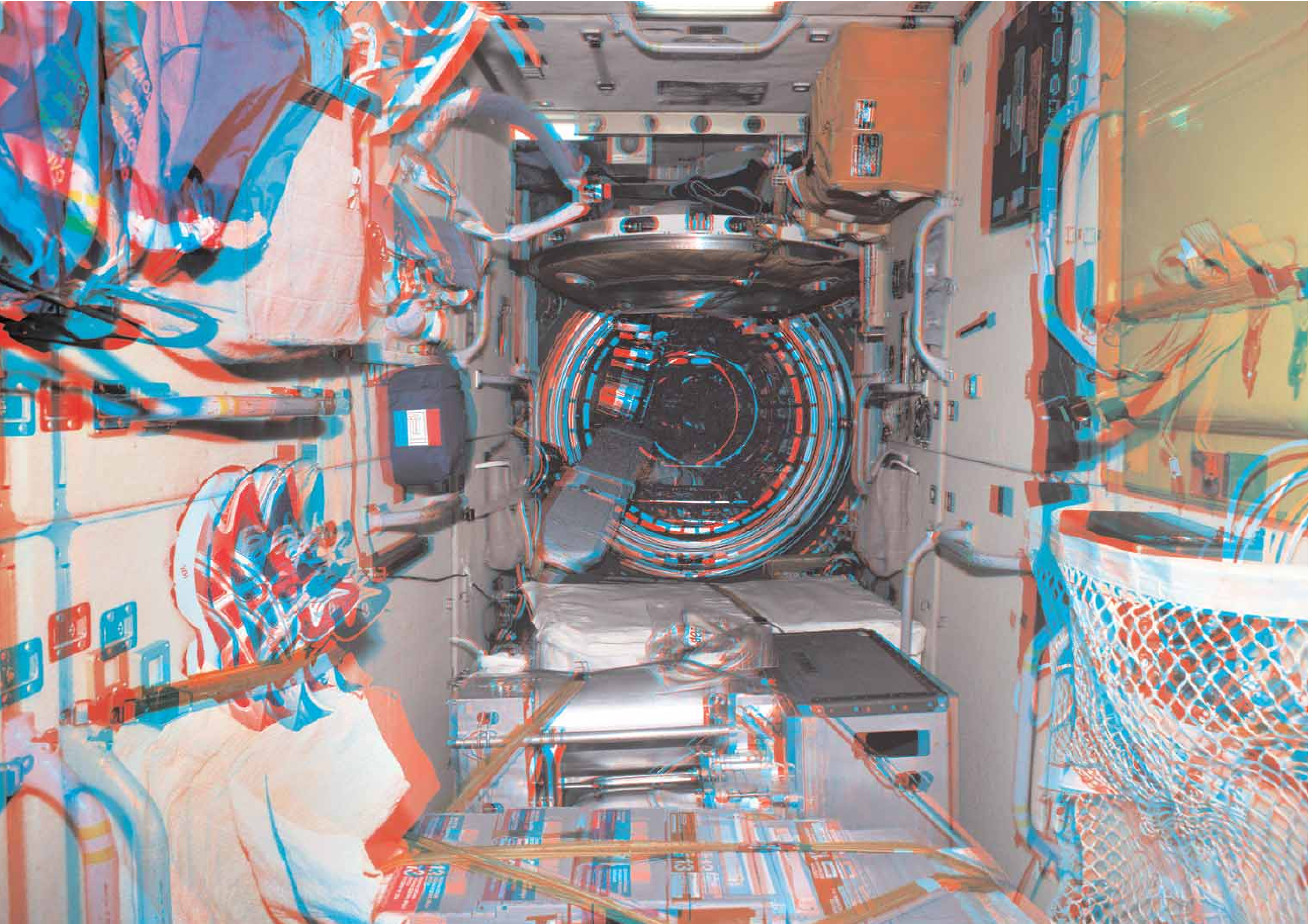
1. Reiter with ESA's stereo videocamera in the US Destiny laboratory module.
2. The Expedition-13 crew (from left): Reiter, Vinogradov and Williams.
3. Reiter filming through the Destiny window with the stereo camera.
4. The view from the Russian Pirs EVA/docking module, looking towards Soyuz-TMA 8, the robotic arm and the Station Truss.
5. The Russian Zvezda habitation module, with the work and dining table.
6. The Russian Zarya module is used for storing spare parts, food and clothes.
7. Fuglesang prepares to enter the airlock for an EVA.
8. Fuglesang in the Shuttle simulator in Houston.

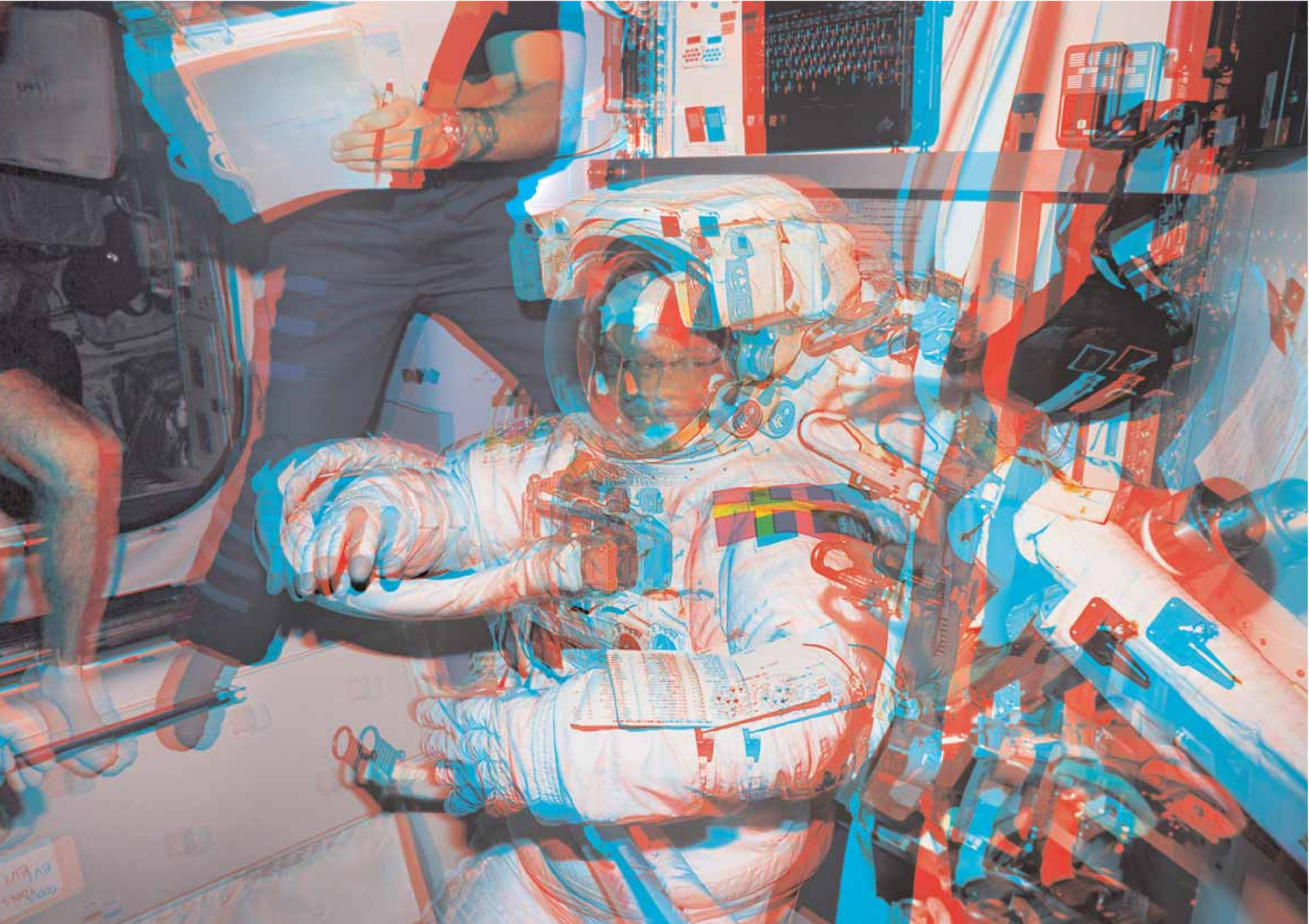










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ESA and Television

Bringing Space to Europe's Television Viewers

Claus Habfast
Television Executive Producer, Media Relations Office, Communication Department, Directorate of External Relations and Security Office, ESTEC, Noordwijk, The Netherlands

Getting ESA into the TV news of its Member States is an important element of the Agency's communication strategy. TV news engages the public in space activities, leading to political support and, ultimately, funding for future programmes. 'ESA TV' is a trusted source of space images and stories for Europe's broadcasters. Space is too good a story not to be part of the news.

ESA and Television News

On 3 September 2006 controllers of ESA's SMART-1 probe confirmed its successful impact with the Moon, at the chosen site near the Lake of Excellence. Some 14 hours later, French broadcaster France 2 opened its flagship evening news show with the story. TF1 and France 3 also covered SMART-1 in their lunchtime and evening news. This is how up to 20 million viewers in France alone saw the tension of mission controllers give way to applause as the impact was confirmed. The audience figures in other ESA Member States were comparable.

Admittedly, ten news items of about 90 seconds each on that day in a major

Member State cannot be compared with the coverage on 21 July 1969 when humans set foot on the Moon for the first time. Mankind followed Neil Armstrong and Buzz Aldrin round-the-clock as the networks provided televised coverage with an intensity no longer seen in today's broadcasting. What they have in common, however, is that television was in 1969 – and still is in 2006 – the only medium able to tell a significant fraction of the population in real time that something important is happening.

Compared to 20 or 30 years ago, ESA has made headway. Throughout the Apollo era and the first Shuttle missions, European space activities were virtually absent from television. Since the 1990s, ESA launches have found their way into the news and, since 2003, have regularly reached cumulative audience figures of more than 200 million across the Member States (see 'Television Monitoring', p 47).

This article outlines why getting into the television news has a prominent place in ESA's communication strategy, what has been done in this area for some 10 years, typical problems encountered when striving to maximise television coverage, and an outlook on the job ahead.

Television and Other Media

Newspapers and radio delivered news to people long before television, and the internet entered our homes at the end of the 20th century with a force similar to that of television in the 1960s. Today, the number of Europeans listening to radio is about the same as those watching television, reading a daily newspaper or browsing the internet.

Television and radio, however, are broadcast media, whereas print and the internet are not. Why is this difference important? A newspaper buyer reads only a small proportion of the articles; the same holds for visitors to internet sites. In contrast, viewers of television news tend to watch every item the broadcaster has chosen to air.

Television, therefore, is much more selective than print and the internet. This is why, despite identical distribution figures, television reaches many more people. Broadcasters are the first to be aware of this and zealously study the news audience figures. The style and content of these programmes are under continuous scrutiny in the effort to attract the best ratings, making it difficult for every story to get into the news. Only stories fulfilling specific criteria will succeed.

Indeed, broadcasting is considered to be the most important medium for reaching out to 'everybody'. The organisers of tennis tournaments, electoral debates and lottery shows, for example, must ensure they appear on television – above all, on television news.

A few figures illustrate the impact of television. In 2006, the average German spent 30 hours per month on the internet, and three times more in front of the television (for youngsters, the ratio is more like the reverse). However, whereas eight channels accounted for 70% of the television audience in Germany, surfing the internet was distributed among thousands of sites: travel bookings, e-Bay, MSN, personal blogs, movie theatre schedules, and so on, with each site offering possibly thousands of pages.

The internet is not (yet) the medium to carry the news. Although ever more people take news from the internet, they total less than 10% of the viewers of TV news and, more importantly, the type of news they get is of a different nature.

This is why established news media invest heavily in internet news portals to provide viewers or readers with information updated in real-time and with additional content with special appeal to online audiences.

The sites of the main players in the online world indeed feature quite different news than the front pages of established media. A click on the 'most popular' tab in the left column of Google News reveals that internet users make radically different choices than mainstream media.

The internet sites of established media have their finest days when big news is breaking during work hours. On

the day of the London bombings on 7 July 2005, the number of visitors to the BBC News Website equalled the figure for a typical month. But these people were interested in just one story. Every editor of a news portal will confirm that anything beneath the front page gets little or close to zero page views.

24-hour news and night television face a similar dilemma. The millions-of-viewers figures of the main 8 o'clock evening news melt away to tens of thousands, thousands and even hundreds of viewers.

For ESA's communication strategy, television therefore has its place whenever ESA generates headline news with satellite launches and astronaut missions, plus certain science results and technological breakthroughs.

However, television must not be seen in isolation. ESA's broadcast media relations are embedded in the wider context of media activities addressing all media – print, online and broadcast – in a coherent way, delivering to each medium the content best suiting its viewers, readers or users. Well-managed different media mutually amplify coverage of a story from day to day, eventually culminating in major news coverage across all media, as with SMART-1's lunar finale.

Why Space on Television?

There are many areas in society that are poorly covered by television news, or even not at all. Why should 'space' be favoured with coverage?

If political decision-making were an isolated process entirely inside parliamentary debate and government activity, there would indeed be little need for ESA to care about TV coverage of its activities. However, political decision-makers use the media as one platform (others are lobbying and research) to judge a healthy balance among the various policies and political choices favoured by the different components of modern society.

If space were absent from television, it would deprive the space sector of a route into the political decision-making process in its Member States, and it would ultimately lose opportunities for funding its future programmes. In a nutshell, TV news engages the public in space activities, which in turn leads to political support.

However, the 'beauty contest' for appearing in the news should not be confused with policy-making. The 30-second soundbite delivered by a politician at a party conference or in parliament has little in common with the balanced and elaborated point of view the same politician will develop in policy-making circles. It is the capability to engage the public in a 30-second statement or news item on a complex issue that makes the difference in shaping positive public opinion.

Nobody can expect a Long-Term Plan or all the results from a scientific symposium to feature prominently on television. ESA's capability to simplify complex stories with the potential to make them appear on television is a decisive factor for successful broadcast media relations. Television focuses on human stories, daunting challenges ahead, the next open question, fighting a competitor … this is why astronauts and planetary missions are so well-suited to television.

This does not mean that other space activities are condemned to be totally absent. If a story is developed in a way to meet the requirements of television, many areas of spaceflight have the potential to make the news.

However, a single TV appearance is of little use. Despite the selective character of television, making a real impact requires a long-term commitment to serving television with news stories. At ESA, this commitment dates back to the 1990s, when the ESA TV Service was set up.

ESA TV Service – Not a European NASA TV

In the late 1980s, NASA provided several hours per week of NASA TV to Europe via satellite and in some countries fed it into cable networks. Though 'NASA Select' disappeared from Europe many years ago, proposals for a 'European space channel' still abound to provide the aficionado with round-the-clock coverage of space. Actually, there is such an ESA space channel, but it is online – the ESA web Portal puts together news, topical stories, background information,

multimedia content and interactivity under a single roof. Thanks to live streaming, NASA TV is also back in Europe today for those wishing to watch the daily International Space Station Mission Commentary and Shuttle launches.

Without the internet, reaching out to every citizen would be impossible for ESA. So what is ESA TV about, if not televising ESA stories to people?

To understand the role ESA TV plays in Europe's television world, it has to be put into the context of TV news generation, production and exchange. At least 50% of TV news programming on a given day is made up of the same pictures on all national channels – international conflicts, government meetings, disasters – with a voiceover from a journalist and perhaps completed by an interview with an expert or by a piece to camera.

The moving pictures to illustrate the news are exchanged among broadcasters and global news organisations like the European Broadcasting Union (EBU) and Reuters. It is on this level that ESA TV comes into play: it is a trusted channel through which newsworthy space images and stories are injected into the global news exchange mechanism. There are two physically distinct means of transport for this process: satellite feeds and video tapes.

Just as ESA publishes hundreds of web stories and dozens of press releases every year, it releases about 60 'TV Exchanges' every year. A TV Exchange is a story documented by a package of video images lasting typically 15 minutes. Journalists can re-edit the story, insert their own images or sound bites and use the piece on the day of its release or keep it for later.

Every TV Exchange is fed two or three times during one week into 'Europe by Satellite', the satellite news service of the European Commission, and then entered into the ESA video archive from where journalists can request videotape copies or a feed via ftp transfer. A list of more than 2000 contacts is informed via email 24 hours ahead of the release of a new Exchange. All scheduled feeds are listed, along with a content description of the archived tapes, on *http://television. esa.int*

Every new story also enters ESA's web Portal multimedia gallery, where it often illustrates web stories.

It takes a long time to build confidence with broadcast media and the reputation as a reliable and trusted news-provider.

Pitfalls on the Way into the News

In addition to strict technical constraints on format, packaging and delivery methods, the true difficulty in placing space stories in TV news lies in the fact that the television media have a specific view of what makes a story worthy of using, and when and how this happens. The space community is not alone in having a different view on this. All company executives and politicians want to get on television at the very moment they have success stories to tell; and they also want the cameras turned off in the event of problems.

Unfortunately, TV viewers consider nothing more boring than 'corporate success' stories. An athlete winning a race or breaking a record will make it onto the news. The athlete's story is not only one of success but also of the drama of possible failure, of frustration in the fight against fatigue or a strong competitor. It is this aspect of the success that TV viewers want to know more about.

Without drama, ideally focusing on a human effort, a space story will not make it very far. This is why ESA astronaut missions always attract such high media attention.

If there is no drama, a story must at least have a strong forward-looking element. Today's news are followed by tomorrow's and so on. Stories without the potential to be another news story tomorrow are less attractive to the media than if they have at least an angle pointing towards the future. Many satellite launches attract media attention because the drama of a possible launch failure can be combined with the promise of exciting scientific discovery or benefits.

However, these requirements do not mean a story should be invented – its characters must always be real and the facts correct and complete. The trustworthiness of a news source is rapidly eroded if its output turns out to be biased or loaded with spin.

Also, although news is inherently international in nature, its delivery is largely a national business. The ratings of the CNN International, BBC World and EuroNews pan-European cable news channels are at best a few percent of their national terrestrial counterparts. Also, internet news delivery is focusing increasingly on national, regional or even local stories. Most international stories without a national angle will therefore miss the news.

Television Monitoring

Two different figures can be used to measure television coverage: the total number of viewers ('ratings'), and the number of times a story is mentioned in different news shows.

Ratings are suitable if only a handful of news shows picks up a story. When many programmes cover it, the number of times this has happened is even more useful, because the ratings of a news programme on a given day also depend on other factors: the number of important stories that day, whether other TV networks show a block-buster movie at the same time, and even the weather. How many times a given story has found its way onto television is a better measure than total audience figures (to obtain these, it is always possible to multiply the number of times the story was in the news by the average rating figures). This is why all the figures given here refer to the numbers of TV news programmes covering an event.

Since 1999, ESA has measured these figures for its main events – satellite launches, manned missions and orbit insertions plus some press conferences. For all of these, news coverage by the 38 major TV networks in seven ESA Member States (D, F, I, UK, E, NL, B) is screened over 1–2 weeks, plus the pan-European CNN, BBC World and EuroNews.

Whenever the targeted event features in a TV news show, a 'hit' is added into a database, along with some 'event data' on the TV channel, the date and time of the broadcast, etc. More than 7000 hits have been registered in the last 7 years, corresponding to a total audience of several billion viewers (in the larger Member States, a news show on a main network is always good for a million viewers, and more often for 2 or even 3 million).

These data are used to analyse whether ESA has increased its TV coverage in recent years. Between June 2003 and April 2006, ESA had the privilege of eight main events linked to planetary missions: the launches of Mars Express, SMART-1, Rosetta, Venus Express, and the arrival at their destinations of Mars Express, Venus Express and Huygens. They had much in common, notably in terms of television: all were equally good stories in all Member States, all occurred either on a fixed date or within a relatively short launch window, and all benefited from a similar approach to broadcast media relations, including media events at many different sites across Europe. So the monitoring data provide a good sample to identify any common trend over time. For this analysis, only mainstream (terrestrial) broadcasters were taken into account, not 24-hour news because of their lower ratings.

The analysis shows that the coverage increased by 55% between the first four events (Mars Express, SMART-1 and Rosetta launches, Mars Express arrival) and the second four (Cassini-Huygens Saturn orbit insertion, Huygens landing, Venus Express launch & arrival). It can therefore be said that, in 3 years, ESA's TV coverage for comparable events increased by some 50%.

Also, the events interested broadcasters roughly equally across all Member States.

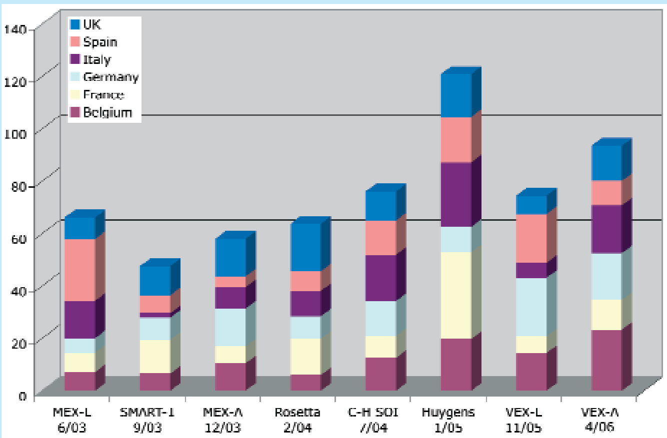
Is this increase reflected by less comparable events during that period? These were the launches of Integral, Envisat and MSG-1 in 2002–2003, and of CryoSat, SSETI Express and GIOVE-A in 2005, European observations of NASA's Deep Impact comet strike in 2005, and SMART-1's lunar end in 2006 (which was excluded from the list of planetary missions as atypical since only ESOC hosted an event and media relations began only the week before).

The analysis shows they were not of equal interest to TV media in all Member States: Italy and France took most notice, and Belgium least. And there was clearly an increase in interest from the 2002–2003 period to 2005–2006.

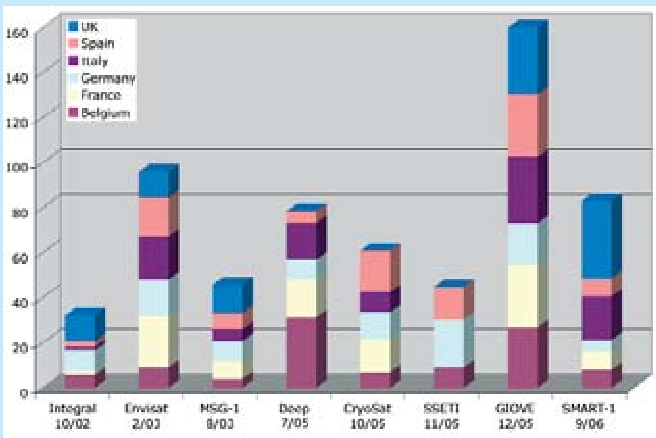
The launches in 2002–2003 were of major ESA projects, whereas the European observations of Deep Impact and the launch of SSETI Express in 2005 had lower significance for the Agency. Nonetheless, they attracted comparable TV coverage.

Overall, ESA succeeded in the last 5 years in increasing the TV coverage for its main events, and in catching opportunities that were unused in the past for additional coverage.

Continued TV monitoring is helping to formulate a strategy to maintain this achievement and to identify areas where coverage can be expanded.



The distribution of 'hits' (mentions in news programmes) among six Member States for eight events. The figures have been 'normalised' to allow for the fact that some countries have more news programmes than others. A general increase with time is evident; the sum for the first four events is 235, compared to 365 for the second four – an increase of 55%. A: arrival; C-H SOI: Cassini-Huygens Saturn Orbit Insertion; L: launch; MEX: Mars Express; VEX: Venus Express



The normalised hit totals for a more disparate range of events. Although less evident than in the first graph, there was an increase in interest between 2002–2003 and 2005–2006

Above all, newsrooms and journalists must know when a new story is coming, whether it carries a national angle or not. ESA has a two-pronged approach for this information provision.

For large events like launches and manned missions, an 'advisory document' is sent out a few weeks ahead to the TV newrooms of all ESA Member States. It includes a story summary and a list of broadcaster opportunities, notably details of the ESA-provided launch transmission, of launch events at ESA Establishments and Member State space agencies, of background video images and a list of interview partners in various languages. The advisory enables a broadcaster to plan ahead for the story and to make the necessary arrangements, for example, for travelling to the launch site or for shooting additional video images covering a particular national angle.

For smaller events, a TV Exchange is released, often together with a web story or a press release. The day before the release, a mailing makes the newsrooms aware of the upcoming story. Written background information and even a preview clip of the Exchange are featured in the mail so that the journalists have 24 hours to prepare their story, ahead of the official release.

This is mainly because turning a story into TV news is more time-consuming than writing a newspaper article and above all requires video images on the edit machines of the broadcaster. Without planning and sharing this planning information with the broadcast media, even the best story will not make it on air.

Despite careful preparation, a human angle and proactive media relations, not every story make it into the news. In fact, many stories will find just one or two broadcasters to use them. This has to do with the selectivity of TV news as mentioned earlier and with the trend that TV news is focusing increasingly on two complementary types of story: main news stories and soft news. Main news stories cover major international conflicts, issues of national politics, some sports, murder trials, elections, and sometimes ESA launches. Every broadcaster must cover these. Soft news is normally exclusive to a given news programme and tells a story that is more interesting trivia than hard news: the discovery of a hidden treasure, a crazy world record, a scientific discovery nobody else is aware of – anything with a wow factor.

The Way Ahead

Soft news does not necessarily mean low quality. It is like tabloids and broadsheet newspapers: they address different needs. Just as today's broadsheets are increasingly taking up tabloid content, TV news is becoming more 'popular'.

One way ahead for space stories in TV news is through soft news. Space exploration is fascinating and there are so many facets interesting to people that it is worth the effort to look into these stories. Very often, they will be interesting to regional broadcasters. For example, when a student participates in a parabolic flight or a scientist has published a major paper in *Nature* or *Science*.

A major obstacle to delivering news to regional broadcasters and producers of current affairs programmes is that they often do not have the technical capability to receive satellite feeds but require expensive videotapes in a professional format. ESA always considered that tape duplication and shipment should be paid by the requestor, which *de facto* puts a limit on the distribution of ESA stories.

This is why new ESA footage and an increasing range of archived stories have been made available to broadcasters since February 2007 on a server via FTP transfer. Although 15 minutes of broadcast-quality footage requires 1 GB, this method is rapidly replacing videotape delivery. A full-scale test was run in December 2006 during the STS-116/Celsius mission of Christer

Fuglesang, as Scandinavian broadcasters are particularly advanced in the use of online broadcast resources.

A second axis of development involves 24-hour news broadcasters. Their ratings are relatively low, so where does the interest in 24-hour news stem from? All print and broadcast newsrooms sport banks of TV monitors showing the country's 24-hour news programme, plus possibly EuroNews and CNN. 24-hour news broadcasters have an important role as drivers and multipliers of news. Just like any news programme, they take up a mix of hard and soft news content. In this capacity, they can reach media that ESA cannot easily, if only because of the sheer number of national and regional print media across Member States.

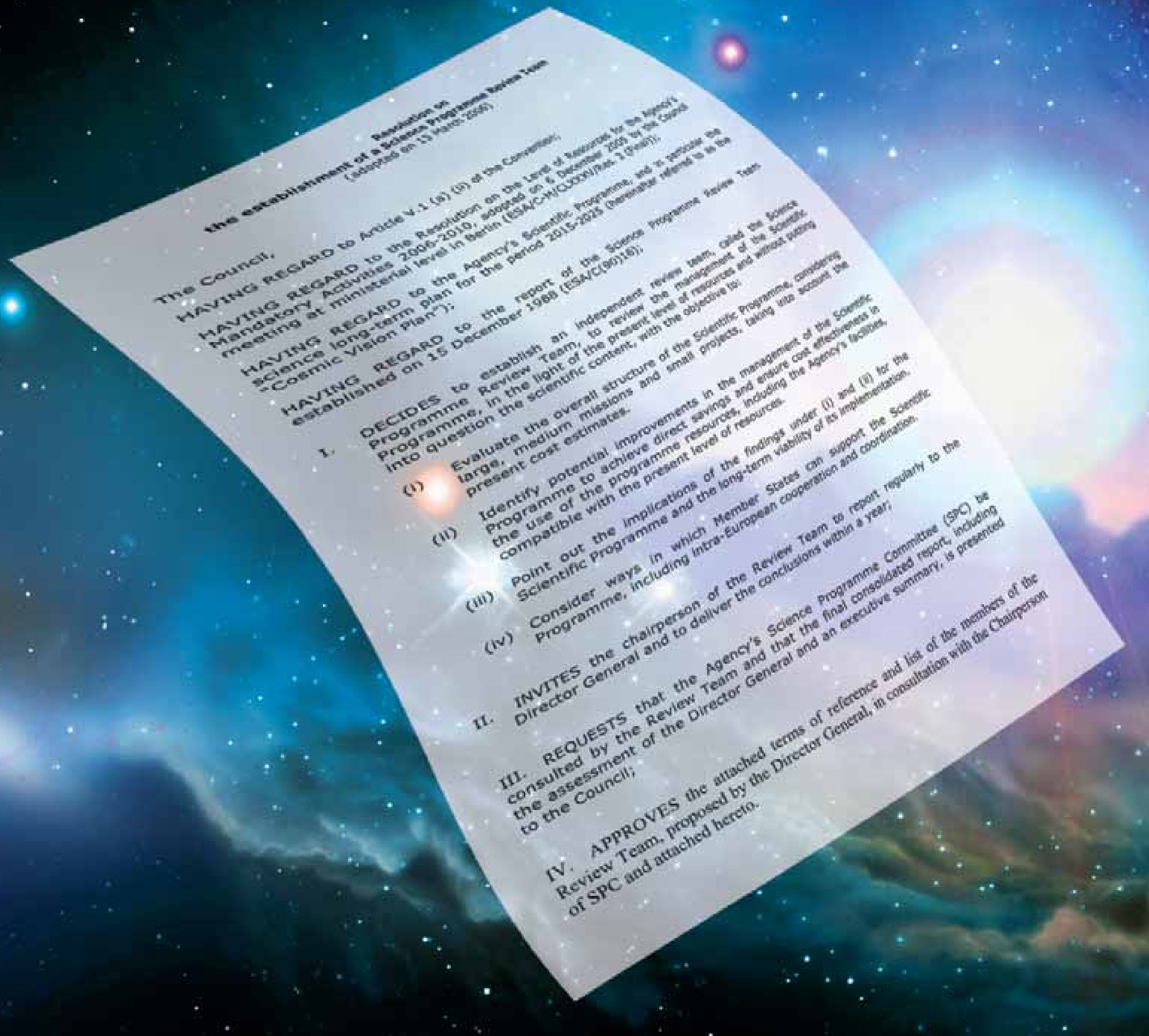
Since 2000, Italian news broadcaster RAI24 has broadcast a periodic space magazine. Since 2004, EuroNews has had the biweekly SPACE magazine. Both are produced with editorial support by ESA and both focus on space activities and stories that are not in the spotlight of hard news but have the potential for making it onto television.

The EuroNews stories enter, via the EBU news exchange, the newsrooms of most of Europe's public broadcasters. This is how stories on space law and space tourism found their way to large audiences in 2006. The ratings for the European Commission's 'Futuris' magazine on EuroNews are measured at 15 million, compared with 1.5 million actual viewers for the channel. The multiplication factor for 'space' on EuroNews will be similar.

Television has never been static since its beginnings in Europe at about the same time as the first Sputnik. Neither has space exploration. ESA's strategy towards the world of broadcasting has to evolve with it, because others would fill the gap if European space programmes were absent. Space is too good a story not to be part of the news.

Reviewing the Future

The 2006 External Review of the Science Programme

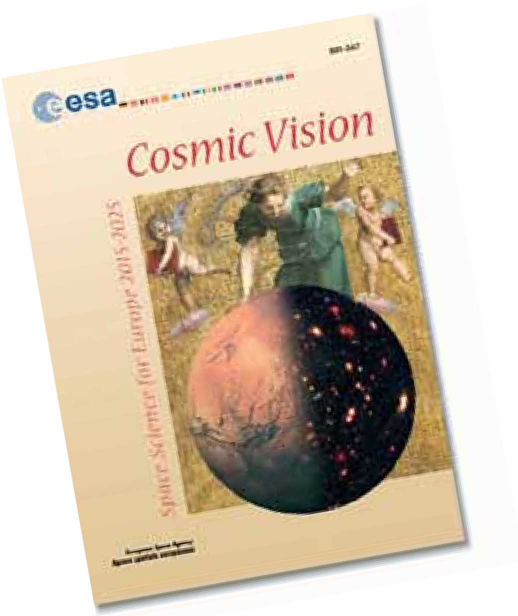


Leo Hennessy
Executive Secretary, Science Programme Review Team / Head, Programme Policy & Coordination Unit, Directorate of Scientific Programmes, ESA Headquarters, Paris, France

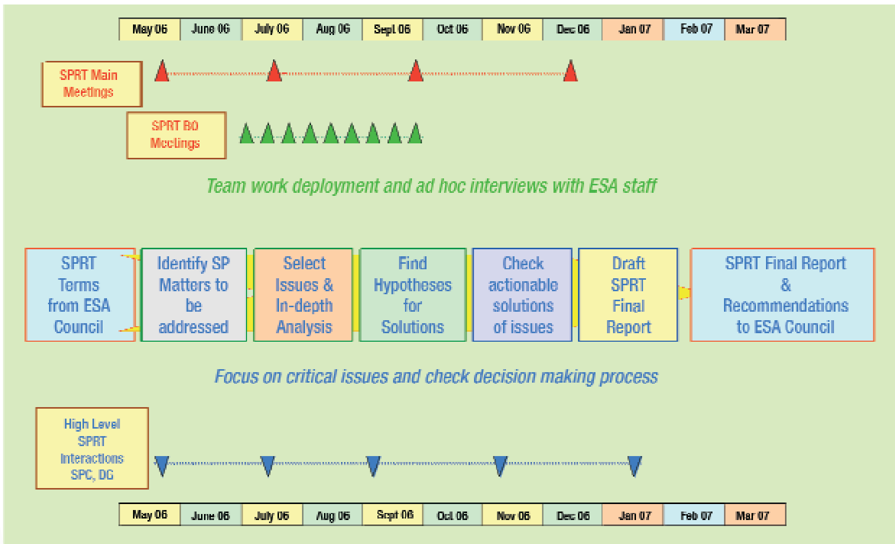
ESA's hugely successful Science Programme is facing flat budgets for the foreseeable future. The resources will be insufficient to satisfy all of the science community's wishes for new missions. As a result, the Science Programme Review Team (SPRT) was established to recommend ways for the Programme to meet its obligations to current and approved missions and to support new projects to the greatest extent possible.

Introduction

As has been stated many times, the Science Programme is the 'backbone' of ESA. 'The Case for a Strong ESA Scientific Programme' (ESA/(C2005)157), presented to the Ministerial Council of December 2005, puts this point in context: "*The Science Programme of ESA is a successful programme. Over the last twenty years, its missions have gained leadership or co-leadership in most space science research areas such as cometary science (Giotto, 1985; Rosetta, 2004), astrometry (Hipparcos, 1989), Infra-Red astronomy (ISO, 1995), X-Ray astronomy (Newton, 1999), magnetospheric physics (Cluster, 2000; Double Star, 2003 and 2004, in cooperation with China), Gamma-Ray astronomy (Integral, 2002, in cooperation with Russia) and planetary science (Mars Express, 2003; SMART-1, 2003). In joint missions with NASA, the leadership extends to Ultra-Violet Astronomy (IUE, 1978), Inter-planetary and interstellar medium (Ulysses, 1990), Optical Astronomy (HST, 1990), Solar physics (Ulysses, 1990; SOHO, 1995).*"



The Cosmic Vision report is available at: http://www.esa.int/esapub/br/br247/br247.pdf



The working process of the Science Programme Review Team

The paper continues, "*In addition to providing first class science and consuming only 12% of the total ESA budget, the Science Programme, nonetheless, employs about 25% of the ESA technical work-force, thereby keeping a pool of highly skilled technical labour at the Agency and its Member States' disposal. It pays more than 25% of the recharges, which maintain the Agency's core administrative and strategic capacity. With its 16 spacecraft presently in operation, the Science Programme gives work to a network of ground segments [and] provides about 80% of the operations workload for ESOC and close to 100% for ESAC, developing thereby a node for data exploitation and archiving for all European space astronomers. With its frequent missions, the Science Programme is also a sustaining customer of the spacecraft and launcher industries because its budget of one MEuro per day, albeit modest, is at present stable. The Programme has, up to now, used more Ariane-5 launchers than any other agency customer.*"

From this, it would seem that the Programme is in good shape, and, indeed, in most respects, it is certainly functioning in a highly efficient and effective way. However, it is a victim of its own great success in that, at present, it has the highest number ever of missions underway, more under development and a huge expectation, on the part of the European scientific community, of its delivering new missions, under the Cosmic Vision plan (ESA BR-247). Unfortunately, the budget is planned to be 'flat' into the future, and the resources at the Programme's disposal (financial and other) are, therefore, largely insufficient to be able to satisfy all of these demands.

The Science Programme Review Team

Towards the end of 2005, recognising the necessity to take action quickly to avoid further deterioration in the Programme's capability to satisfy the demands of the scientific community, the Chair of the Scientific Programme Committee (SPC) decided to call for an external review. Accordingly, the SPC proposed to Council that a Science Programme Review Team (SPRT) be set up. Its members would be recognised high-level experts from Industry and Science, with a mandate, later contained in a Council Resolution passed at the March 2006 Council, to conduct a detailed review of the Science Programme and to recommend ways by which the Programme could meet its obligations to current/planned missions as well as the legitimate desires of the community for new missions, to the maximum extent possible.

This is not the first such review. There was one in 1977 and another in 1988 when, at the request of Council, a comprehensive review of the management and the activities of the Programme was similarly carried out, by a group of high-level external experts.

The first review, led by Dr Harry Atkinson, turned in an 8-page report with 23 recommendations. The second, headed by Prof Klaus Pinkau, delivered a 237-page report, with 16 recommendations. The latest review, led by Dr Reinder van Duinen, recently presented its report (ESA/C(2007)13) of 366 pages, including 40+ recommendations and six formal observations. It contains more than 200 pages of references, compared to Pinkau's 120 and Atkinson's zero.

The 2006/2007 SPRT

Dr van Duinen and the rest of the team were appointed soon after the Council meeting of March 2006 and the setting-up process started immediately. The systems, process and organisational structures, the protocols for handling the Team's future interactions with the Executive and Advisory Structure, as well as the logistics needed to get things moving, had to be put in place very

The Team at work, with Dr van Duinen emphasising a point

quickly. During April, the Chairman and the Executive Secretary worked closely together to organise the first meeting of the Team, which was held at ESTEC on 18/19 May 2006.

Science Programme Self-Evaluation

At the request of the SPRT Chairman and with the full support of the Prof David Southwood, Director of the Scientific Programme, a self-evaluation was carried out by the Scientific Programme during March and April 2006. Senior staff of the Director's office worked with the SPRT Chairman to prepare a list of questions to be answered and topics to be addressed. A Directorate team then spent a number of hectic weeks producing detailed inputs, which were reviewed by the Director and senior managers, responding to the identified issues. The self-evaluation process was acknowledged by all involved to have been comprehensive and informative and to have delivered a response that was of value, not only for the SPRT, but also the Directorate. It was also seen as an excellent exercise in internal collaboration and sharing information across functions and gaining an understanding and appreciation of the work of colleagues from other parts of the Directorate. The final evaluation report, which is one of the Reference documents reproduced as an Annexe to the SPRT Report, was presented to the SPRT Chairman and Team at its first meeting and was heavily drawn upon in the initial stages of the SPRT's work.

The SPRT 'Problem-Statement'

Based, in part, upon a detailed review of the Self-Evaluation Report, the SPRT developed a problem-statement, to guide its future work: "*What opportunities exist for ESA to enable the scientific community to make significant advances in science through improvement of programme management, costs control, and better mission decision making processes?*"

Developing the problem-statement further led to the identification of a number of key points that would be focused upon during the SPRT's work. These key issues were initially identified as:

1: instrument development, risks and funding;
2: the decision-making process;
3: overhead charges and facilities;
4: advanced technology development;
5: 'overheating' of the Science Programme;
6: contingency management, risk- and budget-control;
7: mission mix and timescales;
8: operations and data centres.

The Science Programme Review Team

Dr Reinder van Duinen (Chairman)
Former President of the European Science Foundation (ESF) and former Vice-Chairman of Fokker; The Netherlands

Mr Alvaro Azcarraga
Former Managing Director of Aerospace, SENER; Spain

Mr Jean-Jacques Dechezelles
Former Director, Science Meteorology and Environment, Alcatel; France

Prof Therese Encrenaz
Director of Research at the Centre National de Recherche Scientifique, Laboratoire d'Etudes Spatiales et d'Instrumentation, Observatoire de Meudon, Paris; France

Prof Kerstin Fredga
Former Director General of the Swedish National Space Board (SNSB); Sweden

Mr Kurt J. Gluitz
Former Vice President and Managing Director Science and Earth Observation Division of DASA/Dornier Satelliten Systeme GmbH; Germany

Prof Michael Grewing
Former Director of the Institut de Radio Astronomie MilimOtrique (IRAM); Germany

Prof Luciano Maiani
Department of Physics, University of Rome 'La Sapienza' and former Director General of CERN; Italy

Prof Sir Martin Sweeting
Group Chief Executive of Surrey Satellite Technology Ltd (SSTL); United Kingdom

The reaction to the Report by the SPC and the Director General confirmed the validity of the majority of the recommendations, albeit with some reservations as to the applicability or indications of a requirement for a different approach on some issues. Overall, the Report was acknowledged as delivering a new and different perspective, a solid assessment and appropriate, actionable receommendations.

To address these issues, the Chairman created a number of 'breakout groups', essentially working groups consisting of subsets of the full Team, each concentrating on one or more of the eight issues. The structure of each subgroups ensured an equal number of members with backgrounds in Science and in Industry.

It is not hard to imagine the challenges involved in supporting eight simultaneous subgroups, composed of highly motiva-

A Real Team Effort

As well as bringing a huge range of individual experience and knowledge to the task, it was notable that, at a very early stage, the team members formed into a well-working and collaborative unit. Their approach, as could be expected, was both thorough and methodical but, equally, the general atmosphere was surprisingly and pleasantly informal. The Chairman certainly facilitated this, as he was strongly focused on ensuring the maximum participation and inclusiveness in the process, and he devoted considerable attention to achieving consensus in the team.

The SPRT meetings and off-site activities generated a large amount of administrative work. Support in handling this was provided by many colleagues in the Science Directorate and elsewhere. In particular, Asa Ericson and Valerie Lecuraud helped enormously with these often very complicated administrative arrangements. In addition, the responsiveness of other colleagues throughout ESA to requests, frequently at short notice, for them to be available to the SPRT, was excellent. This made a very positive impression of their professionalism and commitment on the members of the team.

ted, task-oriented and demanding top-level experts, in terms of organising meetings, arranging the (right) contacts when needed, providing background documentation, giving guidance and advice, ensuring the sharing of relevant information, keeping records and drafting reports. The sheer volume of documentation analysed (and produced) by the Team required the setting up of a dedicated document and reference library, allowing all Team Members to view any documents whenever needed.

The Team's Work

Since the deadline given to the Team to complete its mandate was the March 2007 Council and given that work could not begin before May 2006, the Team worked almost continuously for the next 8 months. During that period, four plenary meetings were held, three presentations were made to the SPC, two meetings were held with the Director General, a number of meetings

ESA's Rosetta comet mission passed close to Mars on 24 February 2007. (ESA © 2007 MPS for OSIRIS Team MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA)

took place with the Director of Science, and about 50 members of the Executive were interviewed. Numerous other meetings and interviews also took place with non-ESA experts, each meeting being led by individual members of the Team. For each, a summary had to be prepared, to ensure that the whole Team had access to the information gathered by the breakout groups.

Following a request from Council, the Chair of the SPC participated in all of the plenary meetings, although there were one or two closed sessions when only the Team was involved. The Executive was kept informed, when necessary and within the limits of maintaining the confidentiality of the SPRT activity, via the Chairman and/or the Executive Secretary. This led to the very positive situation whereby adaptations were made, both by the Executive and the SPC, to current procedures or practices, taking account of developments during the work of the SPRT. Examples of this include an adaptation of the documentation related to the Call for Proposals, the realigning of SPC agendas to separate decision points from information items, the issuing of a new strategy paper by the Executive, and other similar changes.

The Report and its Recommendations

By the end of August 2006, things were beginning to take shape on the direction in which the Team's recommendations were likely to go. The plenary meeting at the end of September, a huge amount of email traffic between then and the end of November and an intense pre-drafting session by the Chairman and Executive Secretary resulted in a 'preliminary content' paper – a draft structure for the Report and Recommendations. During early December, the thousands of pieces of the jigsaw puzzle, generated by all of the Members, had to be put together and developed into a cohesive and clear text, which was circulated in draft form to the Team. The last meeting, held at ESTEC in mid-December, put the finishing touches to the structure of the Report (if not yet the final content), and the drafting of the final Report could begin. The target was to have this issued to the Team before Christmas – and we made it, on 22 December, the last (official) working-day of the year! As expected, the Team Members were not idle during the Christmas holiday. All carefully read the entire text and made their comments – mostly editorial, but, nonetheless, crucial nuances and clarifications that added much to the first draft.

Having succeeded in pulling together all of the Team's comments, the final version of the Report was issued to the Director General, all SPC delegations and the Director of the Scientific Programme, early in January 2007.

Assessment of the Report

On the initiative of the SPC Chair, the Report's content and recommendations were 'dissected' by four working-groups composed of members of the SPC, during a 2-day meeting dedicated entirely to the Report, at ESTEC in the second week of January.

The recommendations contained in the Report were, by and large, well understood and the plenary meeting focused on addressing the issues where there were differing views as to how to find a solution to some of the problems

Areas Covered by the SPRT Report and Recommendations

(Given the Programme-specific nature of the recommendations and their relevance principally to the Science Programme and its Advisory Structure, the full recommendations are not reproduced here. Only the major topics and some examples are provided for illustration.)

Chapter 4. IMPLEMENTING COSMIC VISION
— The Call for new mission proposals
— Mission mix and international collaboration
— Payload development
— Block decisions

Examples: the SPRT Report called for the removal of EUR 200 million from the Programme, before issuing any new Call for Proposals. It also suggested the reopening of an option to have small missions (about EUR 75 million). The previous practice of making 'block decisions', which freezes the Programme for a period into the future, was considered no longer feasible or desirable by the SPRT.

Chapter 5. DECISION-MAKING AND MANAGING THE SCIENCE PROGRAMME
— Cost increases
— Technology readiness
— Core technology programme
— Cooperation
— Peer reviews
— Timing of mission selection and adoption by SPC
— Contingency in the Science Programme
— Extra demands on the Programme
— Operations and support costs
— Overhead charges
— Financial contributions to payload developments by scientific institutes
— Extensions of mission operations

Examples: decisions should only be taken when there is solid information available on the readiness of critical technology, as assessed by independent peer-groups. The projected Cost-at-Completion is exceeded, decisive actions need to be taken. Costs that are not directly associated with spacecraft procurement have to be reduced. The level of contingency margins at Programme and Project level have to be carefully determined and managed. The scientific return from mission extensions has to be carefully weighed against the potential cost of opportunities to the rest of the Programme.

Chapter 6. INDUSTRY
— Follow-up of payload instrument development and assessment of risks
— Procurement practice and development methodology
— Costs, contingencies and contractual terms
— Coupled missions and related potential cost savings

Examples: within the limits imposed by the ethics of competition, Industry experts should assist ESA experts and others in conducting a comprehensive assessment of mission-critical technologies, prior to the adoption of a mission.

Chapter 7. GENERAL
Examples: the SPC should become more fully involved in those decisions it is making but without micro-managing. A review of the effectiveness of the division of roles between the Executive and the SPC would be useful. *Ad hoc* SPC working groups, seconded by outside experts, could help in the preparation of difficult decisions.

identified by the SPRT. In parallel, the Chairman of the SPRT met with the Director General and the Chair of the SPC, in separate meetings, to discuss the Report in finer detail.

The outcome of the SPC Working Group review was presented at the February meeting of the SPC, in conjunction with a formal presentation and discussion of the Report, in the presence of the SPRT Chairman. The final stages of completing the SPRT mandate was achieved by the submission of the Report to the March 2007 Council, accompanied by the comments of the Director General and the observations of the SPC.

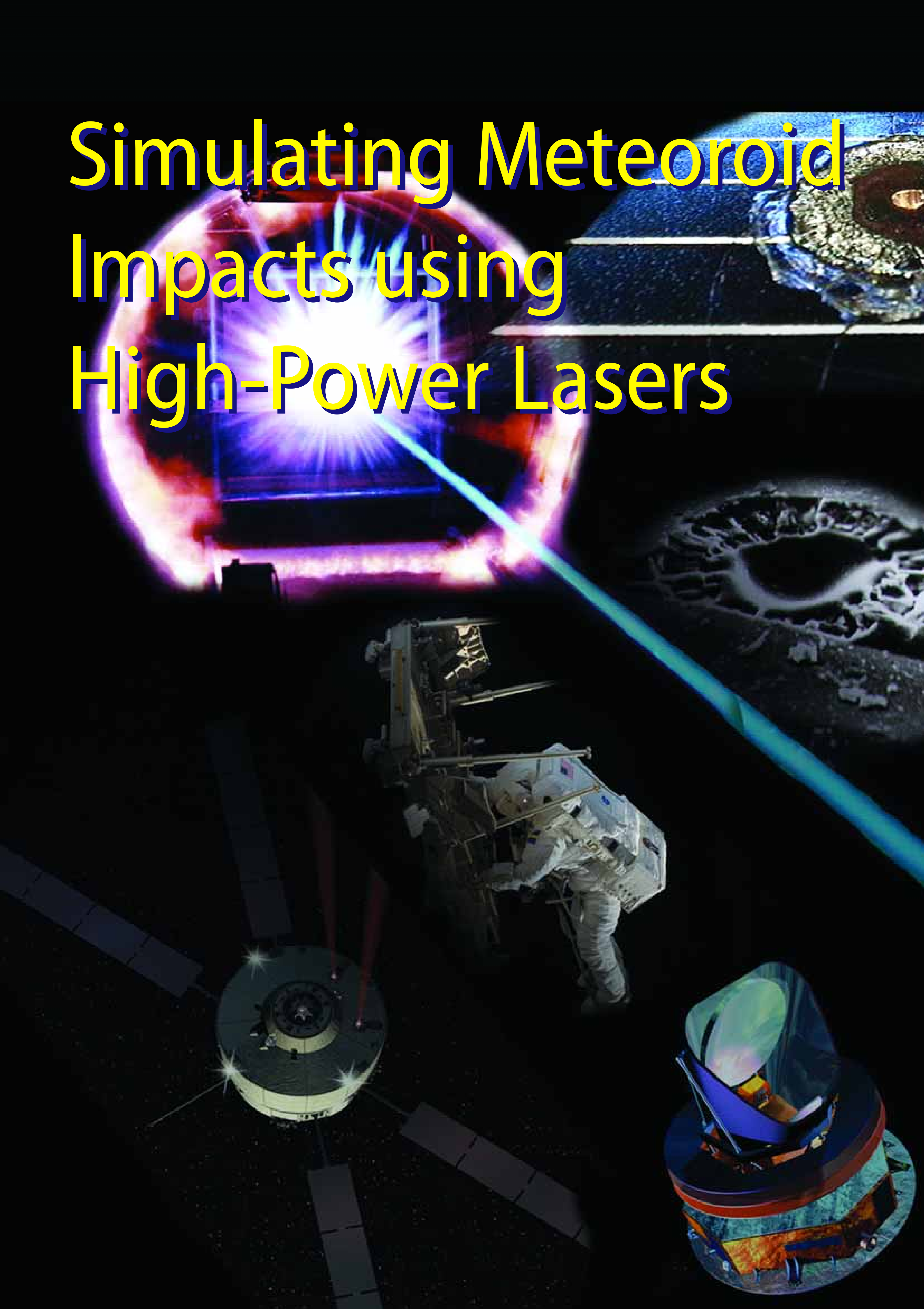
Conclusions

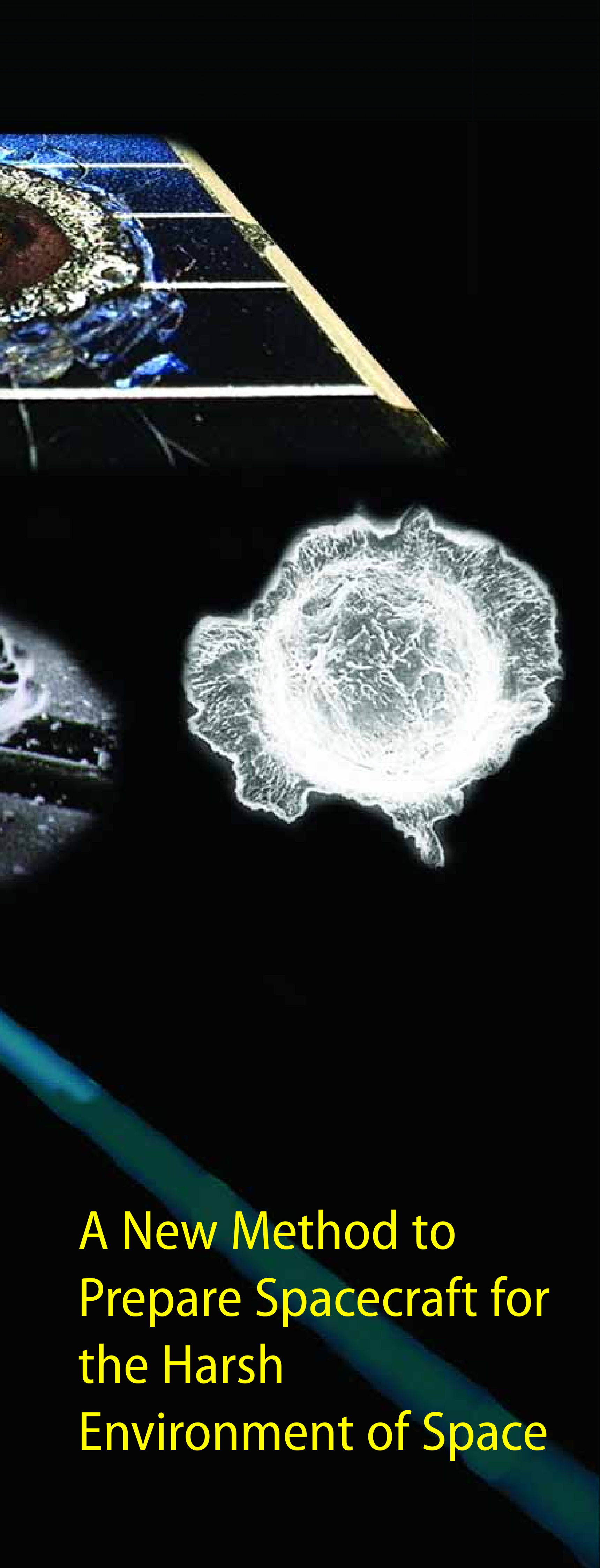
Both the SPC and the Executive have warmly commended the work of the SPRT and have stated that the work by Dr van Duinen and his Team was conducted very competently and comprehensively and to have resulted in a very good Report and set of recommendations.

The van Duinen Report should, therefore, mark a significant point in the history of the Science Programme. As well as indicating areas for improvement, it will help to highlight and recognise its successes, achievements and opportunities, so as to put it on an even better footing for the future. It may be useful to note that, whereas previous SPRT reports were produced assuming good growth potential in the future, this one was done from the perspective of a constrained budget.

As the Director General has remarked, the potential effects of the van Duinen Report's recommendations are not limited to the Science Directorate, since many comments and recommendations deal with facilities and services provided by other ESA Directorates to the Science Programme. Equally, therefore, the process and the main issues that have been highlighted are relevant right across the Agency. In effect, the outcome of the deliberations at the March Council can have consequences for activities/facilities that are not under the direct control of the Programme. A crucial aspect of dealing with the van Duinen Report is that both the Executive and ESA Delegate bodies are monitoring and evaluating the implementation of the recommendations. Within the Science Directorate, a member of the management team has been given specific responsibility for monitoring the implementation of the SPRT recommendations, but there is no doubt that this task requires the attention of all in the Directorate to ensure an effective response.

Simulating Meteoroid Impacts using High-Power Lasers





A New Method to Prepare Spacecraft for the Harsh Environment of Space

Markus Landgraf
Mission Analysis Section, Flight Dynamics Division, Directorate for Operations & Infrastructure, ESOC, Darmstadt, Germany

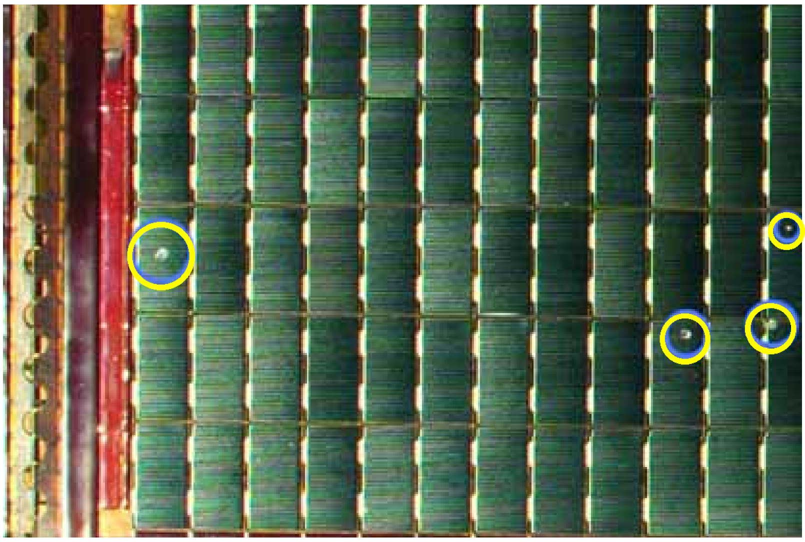
Gerhard Drolshagen
Space Environments & Effects Analysis Section, Directorate of Technical & Quality Management, ESTEC, Noordwijk, The Netherlands

Zoltan Sternovsky, Scott Knappmiller & Mihály Horányi
Laboratory for Atmospheric and Space Physics, University of Colorado at Boulder, USA

Meteoroids are one of the most damaging elements in space: at 20 km/s even one the size of a grain of salt can wreak the same damage as a cannonball fired at 1000 km/h. The solar wings of the Hubble Space Telescope returned from space are peppered with holes and craters from meteoroids and space debris. Satellites must be protected from such impacts through careful design and testing. In laboratory testing, firing a high-power laser at a satellite hull efficiently simulates all aspects of the impact: the cratering, the shock travelling through the material, and the impact cloud that can knock out electronics. It can also be used to calibrate detectors that characterise the meteoroid and debris environment, allowing sensitive instruments to be protected simply by carefully choosing a satellite's orientation.

Introduction

Hardware brought back from orbit bears the marks of meteoroid bombardment. ESA's Eureca retrievable carrier was returned from space by the Space Shuttle in 1993 after 10 months in low Earth orbit and showed numerous craters (*Bulletin* 80; *http://www.esa.int/*



Electron-microscope image of a crater in a Space Shuttle window. (NASA/JSC)

Left: a 26 x 13 cm piece of solar panel from the Hubble Space Telescope after more than 8 years in space. Only the larger craters are marked

esapub/bulletin/bullet80/ace80.htm). From Eureca and three sets of solar cells retrieved from the Hubble Space Telescope (HST) we know that meteoroid impacts cause structural damage as well as surface degradation. The craters are normally 10–20 times larger than the meteoroid itself. So, even a millimetre-sized particle can destroy structural elements or penetrate a pressure vessel such as a tank or a crew module. Careful design of the spacecraft structure – perhaps using meteoroid shields – must ensure that impacts are without serious consequences. For example, ESA's Columbus module and Automated Transfer Vehicle are protected by 'Whipple-shields', which fragment any impactor smaller than 1 cm before it can penetrate the hull.

Besides structural damage, which requires relatively large meteoroids, another effect is the continuous degradation of exposed surfaces. Optical surfaces like camera lenses are most sensitive to the large number of submillimetre craters that accumulate over time.

There are also more subtle, indirect consequences. The highly energetic impact creates a small cloud of electrically charged material that can disturb electrical systems onboard a satellite. For example, the loss of solar cells on HST has been linked to a discharge avalanche that could have been started by a meteoroid impact.

Satellites that must maintain very stable positions in space are also affected by meteoroid impacts. Subsatellites in interferometer astronomy constellations, such as ESA's proposed Darwin and XEUS, have to control their separations with other members of the formation to within a few millimetres. In these cases, a meteoroid could break the optical connection.

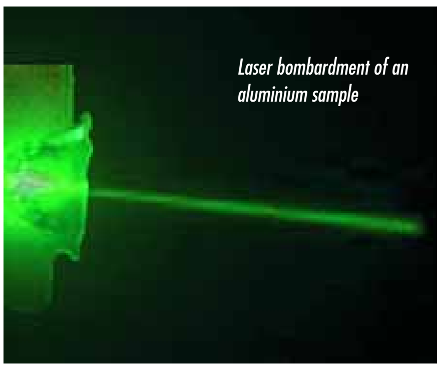
This list of effects shows that, while our current understanding of meteoroids certainly allows us to prepare missions for the space environment, it is imperative that we improve our understanding of the meteoroid environment and expand the Agency's testing capabilities to handle the more sophisticated and sensitive equipment of the future.

Classic Meteoroid Testing Methods

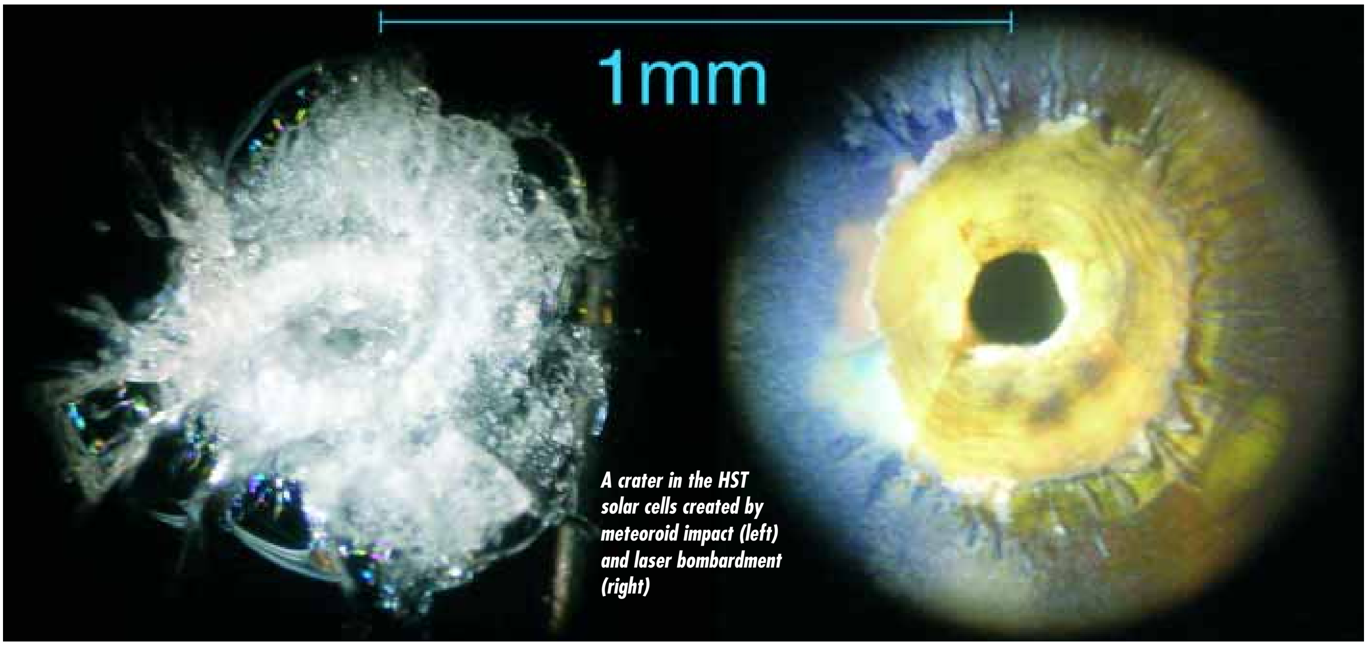
Recreating a meteoroid impact to test space materials in the laboratory requires a solid particle to be accelerated to the extreme speeds found in space. While there is a wide range of meteoroid speeds, they normally cluster around 20 km/s, which is more than twice the speed of vehicles in low Earth orbit.

Classically there are two methods to achieve high speeds: electrostatic acceleration using high-voltage Van de Graaff generators, and acceleration by 'gas drag', in which a gas is accelerated, either by a high-pressure piston in a light-gas gun or by electric forces in plasma guns. Europe has a number of these facilities, including the light-gas gun at the Center of Studies and Activities for Space in Padua (I), the Ernst-Mach-Institut für Kurzzeitdynamik in Freiburg (D), a Van de Graaff generator of the Dust Accelerator Facility at the Max-Planck-Institut für Kernphysik in Heidelberg (D), and both devices at the Open University in Milton Keynes (UK).

While Van de Graaff accelerators can deliver a relatively large number of test particles from 0.1 mm down to some nanometres (10^{-9} m) at 1–100 km/s, they can accelerate only particles with conducting surfaces. Iron grains are traditionally fired in these machines. In contrast, light-gas and plasma guns can accelerate larger particles of any material. However, the maximum speeds are normally lower and each shot has to be prepared carefully, so not many



Laser bombardment of an aluminium sample



A crater in the HST solar cells created by meteoroid impact (left) and laser bombardment (right)

experiments can be performed in a limited time.

Van de Graaff accelerators and guns together already allow a good amount of testing. However, they are fully-fledged laboratory devices surrounded by vacuum and high-voltage systems, with the associated demand on resources.

The Laser Approach

Even high-performance lasers are now widely available and are rather benign in their demand for resources. It is therefore desirable to use them to test space materials for sensitivity against meteoroids. In order to simulate surface impacts, a green 'neodymium-doped yttrium aluminium garnet' laser, commonly referred to as a Nd:YAG laser, has been tested. Every second, the laser pulses with an energy of 30 mJ for 7 ns. This corresponds to a power of 4 MW for a very short time. A simple optical setup with two lenses focuses the laser onto a spot smaller than 0.1 mm.

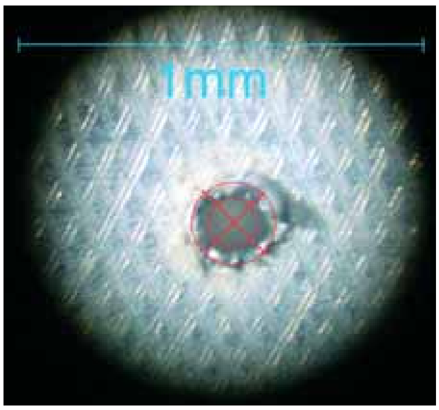
The aluminium or solar cell samples are first fixed in a holder on the optical bench. The red helium-neon guiding laser that runs parallel to the Nd:YAG beam is positioned on the target spot by adjusting the two mirrors in its path. The focusing lens is then adjusted to concentrate the laser on the target. The Nd:YAG laser then fires for the set number of shots. The whole procedure takes some 30 minutes.

Owing to the tightly focused laser creating a high energy density, the surface material is subjected to extreme thermal conditions, as in a high-speed meteoroid impact. The results are the same: the target material is evaporated (even ionised), a crater is formed and a shock expands through the material. Performing the experiments in air, the shock can be heard clearly as a click every time the laser hits the target. In the experiments at the Laboratory for Atmospheric & Space Physics (LASP), in Boulder, Colorado, USA, materials typically used in space manufacturing were laser-tested: aluminium and the composite material that makes up solar panels (using cells returned from HST in 1993). Afterwards, the materials were analysed under an optical microscope. The experiments showed that indeed the laser shots produced craters similar in shape to those from meteoroids, and that selecting the number of laser shots easily controlled the size of the crater. The empiric law is that an accumulated laser energy of 1 J created a crater 0.07 mm across; and each doubling of the laser energy increases the crater size by 17%. On average, each laser shot deepens the crater by 0.001 mm. Thus a 5 mm-deep crater normally created by a 0.5 mm meteoroid can be simulated by firing our laser 5000 times. Fortunately, the firing frequency can be set to 100 per second, so the whole procedure takes only 50 seconds.

The craters in aluminium were surrounded by white powder, which was interpreted to be aluminium oxide created by chemical reaction of the surrounding air with the hot gas. Of course, this reaction would not occur in vacuum.

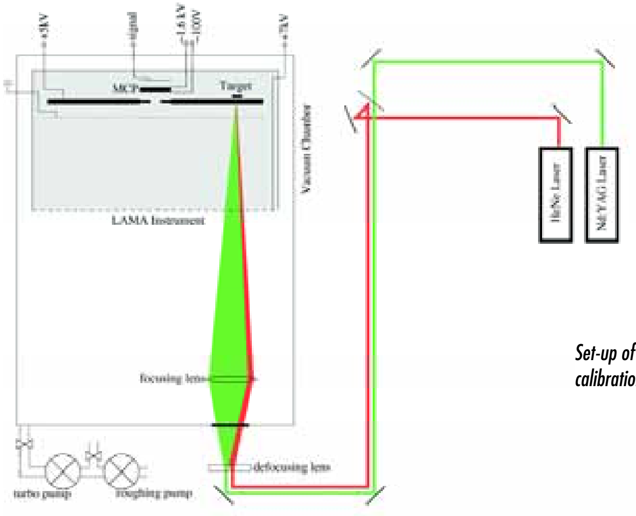
An obvious difference between meteoroid and laser craters on the solar cells is

Measuring the crater diameter in an aluminium sample



the amount of melting. This is because the low absorption of the cover glass lengthens the very brief laser shot, and the heated cell substrate (highly refractive silicon) transmits its heat to the amorphous glass. The result is a halo of melted and chemically altered material around the central hole.

Comparing the laser damage to the aluminium with that to the solar panel composite, it turns out that the craters in the composite material are about twice as deep for the same number of laser shots. This is because the shinier aluminium reflects more of the laser's power.



Set-up of the LAMA calibration experiment

Know Your Foe: Meteoroid Detectors

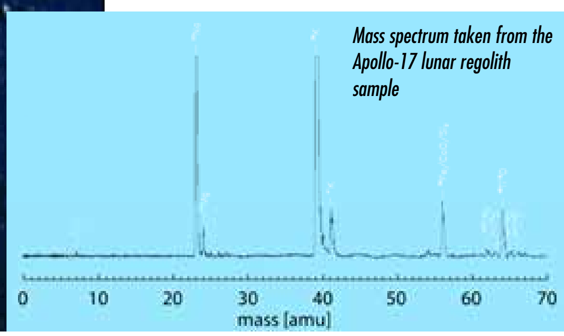
Satellites can be efficiently protected from the hazards of meteoroid impacts only if we know the number of meteoroids and their sources. Our current understanding of the meteoroid environment comes mainly from microcraters on the rocks brought back from the Moon by the Apollo astronauts, and by measuring meteoroids that enter Earth's atmosphere using highly sensitive radar equipment (*Bulletin* 113; *http://www.esa.int/esapub/bulletin/bullet113/chapter9_bul113.pdf*).

Meteoroids are also detected in space by instruments aboard satellites in geostationary and low Earth orbit. In order to improve our understanding of how many meteoroids there are and from which directions they come, more information about their sources, makeup and dynamics is needed.

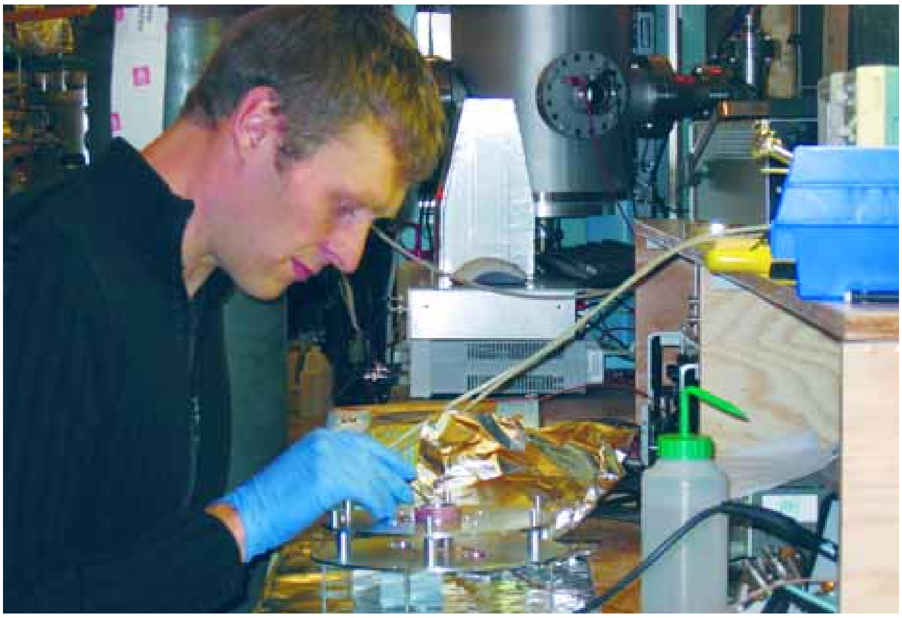
Thus, the other important application of the laser is to calibrate new instruments to detect meteoroids in space. The next generation of detectors is already working in the laboratory. One is the large-area mass analyser (LAMA), which can determine the chemical makeup of meteoroids when they hit its large (almost 1 m^2) target area. The instrument was conceived by the dust research group at the Max-Planck-Institut für Kernphysik in Heidelberg, which also developed meteoroid detectors for the Ulysses and Cassini/Huygens missions.

Because the laser shots are so similar to meteoroid impacts, the laser can be used to calibrate LAMA and to find out how meteoroids of different materials could be analysed. With LAMA, the high energy of the impact means the meteoroid is vaporised and its material is split into its chemical compounds. The impact is so energetic that the compounds are broken into individual atoms that are stripped of at least one of their electrons, making them positively charged ions. The target surface of LAMA is held at a high positive voltage (+5 kV) so that the ions are repelled

Apollo-17 astronaut Harrison Schmitt collects lunar rake samples of regolith at Taurus-Littrow in December 1972



Mass spectrum taken from the Apollo-17 lunar regolith sample



The procedure working on the LAMA instrument required some laboratory experience. Here, Markus Landgraf works on the sensitive micro-channel plate, which is at the heart of LAMA's ion detector electronics

from it. Using a careful design of the electric field inside LAMA, the ions are deflected towards an ion detector at the centre that produces an electrical pulse each time a certain species of ions hits it. Because each ion receives the same amount of energy from the electrical field inside LAMA, the ions of lighter elements like carbon or oxygen move faster than those of heavier elements like iron. The com-position of the meteoroid can then be determined by measuring the time of arrival of its compounds. We found that LAMA works equally well if the ions are created by a laser shot focused on a sample mounted on the LAMA target plate.

Meteorites recovered on Earth are made mainly of silicate minerals, such as olivine and pyroxene, and of carbon-rich material. To calibrate LAMA, metals (brass, stainless steel and lead), quartz (the simplest silicate) and graphite (the most common form of carbon) were analysed. In order to provide more realistic, astrochemically relevant materials, actual lunar regolith (dust) brought back from the Moon's Taurus-Littrow highlands by the Apollo-17 astronauts was analysed. This regolith is made up of simple silicon oxides, metal (calcium, magnesium, iron, sodium, titanium, potassium, chromium) oxides, and trace elements.

Rock samples (quartz) were ground down to powder for mixing with iso-propanol, and the mixture was inserted into the bowl-shaped sample holder. Despite the fact that the iso-propanol evaporated within a few minutes, the residual powder retained some structural strength and some adherence to the holder, so that it could even be turned upside down. This was important because some samples were coated with a thin gold layer in order to improve the electrical field directly above the sample. Once the sample was prepared, it was remounted on the target plate, LAMA was returned to the vacuum chamber, and the chamber was evacuated. Within a few hours, the optics could be adjusted and the laser switched on.

In general, the calibration experiments showed that LAMA is highly capable of distinguishing between carbonaceous material and silicates. It was found that not all of the material is broken up, but that some, especially graphite, remains in clusters of four or more atoms. The carbon clustering could be very useful when it comes to identifying organic compounds in real meteoroids. While more quantitative tests with a greater variety of materials are needed, the results so far show that LAMA can be used in space to analyse meteoroids and space debris and determine their sources.

More particularly, we have been able to identify, together with the ubiquitous contaminants sodium and potassium*, the most abundant copper and zinc isotopes in the brass sample, and the lead isotopes in the lead sample. The fact that the rather heavy lead isotopes (206, 207 and 208 atomic mass units) can still be resolved shows that LAMA can distinguish between a wide variety of chemical elements and molecules. With the Moon regolith, LAMA confirmed the very interesting abundance of titanium oxide, a chemical compound that is now being widely discussed as a good source of oxygen for future exploration missions. Singly oxidised species of all five titanium isotopes were identified.

Anti-Meteoroid Testing

The experiments at LASP provided confidence that the laser can be used for calibrating meteoroid detectors and testing meteoroid impacts on satellites and new materials at facilities in ESTEC. Such a facility requires fewer resources than a light-gas or plasma gun that are traditionally used in simulations. While a laser shot is certainly not perfectly analogous to a meteoroid impact, it is similar enough for routine testing.

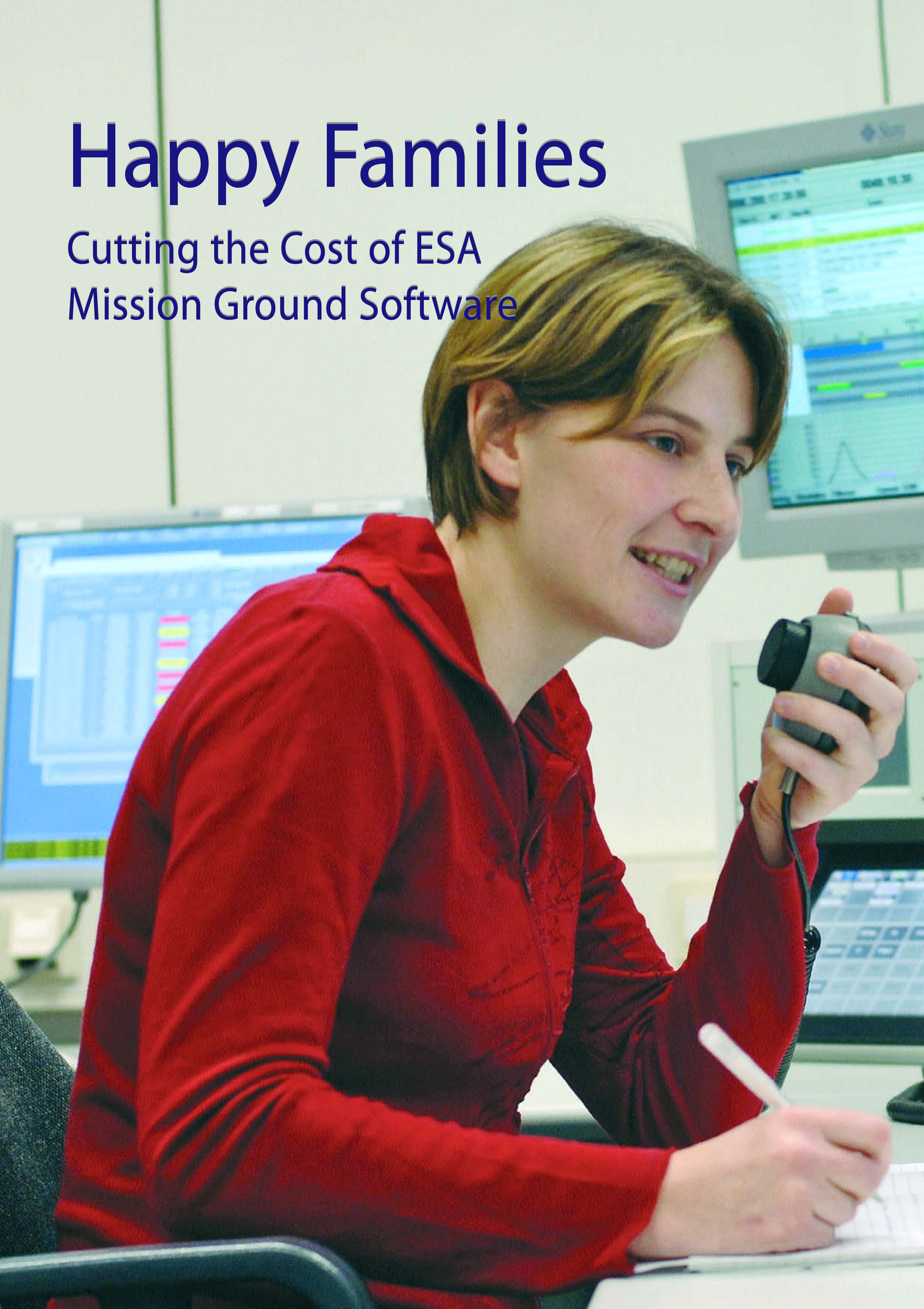
Acknowledgements

The work presented here was conducted under the Douglas Marsh Fellowship awarded to the principal author by ESA in 2004. He thanks LASP for its assistance and hospitality during the project, and NASA for providing a sample of lunar dust.

**sodium and potassium form ions very easily, so even minute traces of these elements, which cannot always be avoided under laboratory conditions, will show up as strong peaks in mass spectra*

Happy Families

Cutting the Cost of ESA Mission Ground Software



Mario Merri, Alessandro Ercolani, Damiano Guerrucci, Vemund Reggestad & David Verrier
Ground System Engineering Department, Directorate of Operations and Infrastructure, ESOC, Darmstadt, Germany

Pier Paolo Emanuelli & Paolo Ferri
Mission Operations Department, Directorate of Operations and Infrastructure, ESOC, Darmstadt, Germany

In recent years, ESA has adopted a new approach to reduce cost and risk in the development and operation of ground software. The 'mission family' concept is the basis for cost-effective mission control systems for monitoring and controlling spacecraft, and operational simulators for testing and training. This concept is complemented by exploiting reusable software using a 'delta' approach. Since families of missions have lifetimes much longer than the individual projects, the challenges of evolving ground software and hardware platforms over ten or more years must be met.

Introduction

Operating spacecraft is a demanding job, requiring a complex ground segment of stations, communications networks and computer centres hosting large software systems. It is an unforgiving undertaking – a satellite is launched only once and there may be no second chance if there are ground segment failures or operational errors that degrade the mission or even result in its loss.

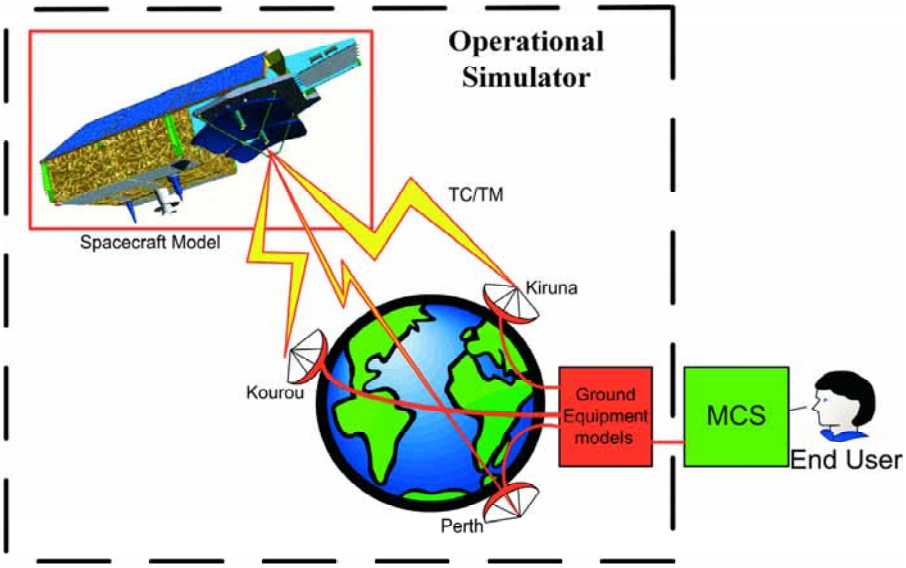
For more than 35 years, the European Space Operations Centre (ESOC) in Darmstadt (D) has accumulated extensive experience in the development, operations and maintenance of the ground software systems. Demanding levels of availability, reliability and maintainability imply high-performance technology and extensive validation, which drives up costs. Despite this, ESOC has succeeded in drastically reducing the costs of ground software systems for space missions. This has been achieved largely through reusing software that was designed and developed for reuse from the outset.

The first such reusable software system (now called 'infrastructure software') was the Multi-Satellite Support System (MSSS), developed in the 1970s and used for over 20 years. In the mid-1980s the first generation of the Spacecraft Control and Operations System (SCOS) was developed; it was succeeded by SCOS-2000 in the late 1990s.

In parallel in the simulation domain, infrastructure software included the General Purpose Software Simulator Package and then the first generation of SIMSAT. Both were based on the latest technology at the time. SIMSAT was then migrated to PC/Windows and converted to the more modern C++ language. More recently, it was made available under Linux, now the operating system of choice for simulators and MCS.

This infrastructure has thus continuously adapted to current technology, culminating in the ESA Ground Operations Software (EGOS), of which SIMSAT and SCOS-2000 are cornerstones. EGOS is an extensive suite of applications, middleware and lower level components covering all major software needs in the ground segment, including mission control software, software simulator infrastructure and ground station 'back-end' software. Naturally, this software has in effect encoded into it much of ESOC's accumulated operations expertise and knowledge.

In recent years, software reuse has been taken a step further, based on the observation that for related missions



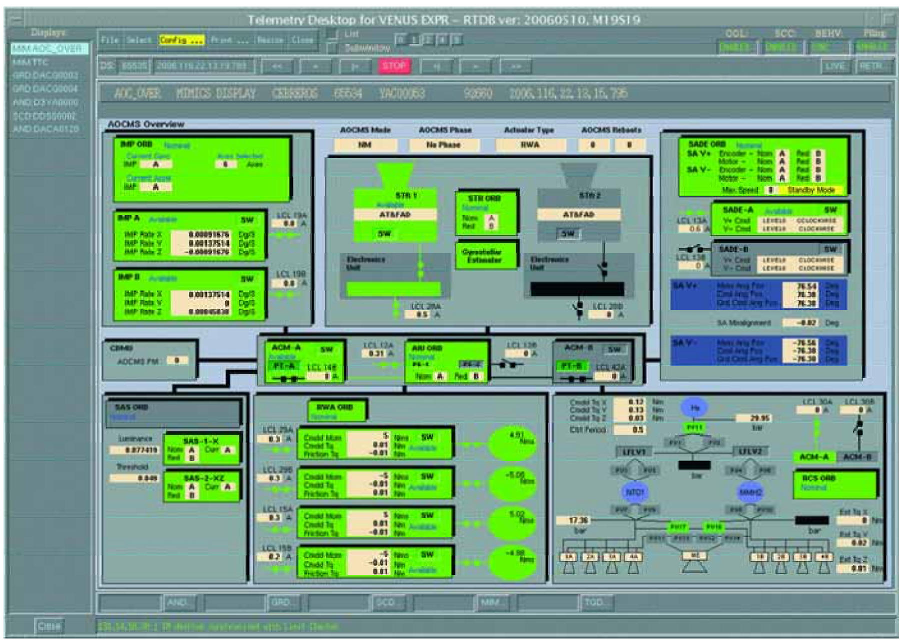
The Mission Control System (MCS) and Operational Simulator. TC: telecommand. TM: telemetry

– 'mission families' – the common characteristics between the family members can be exploited for further cost reductions.

The Mission Control System (MCS)

The MCS is a software system that enables the operators on the ground to interact with the satellite. It receives, interprets, analyses and archives telemetry, the data downlinked from the spacecraft used for monitoring its health and receiving its mission products. The MCS also generates, verifies and uplinks commands, transmitting instructions to the satellite to control all its operations.

Via the MCS, the Flight Control Team can assess the health of a satellite throughout its mission and command it to achieve the mission goals. The MCS is



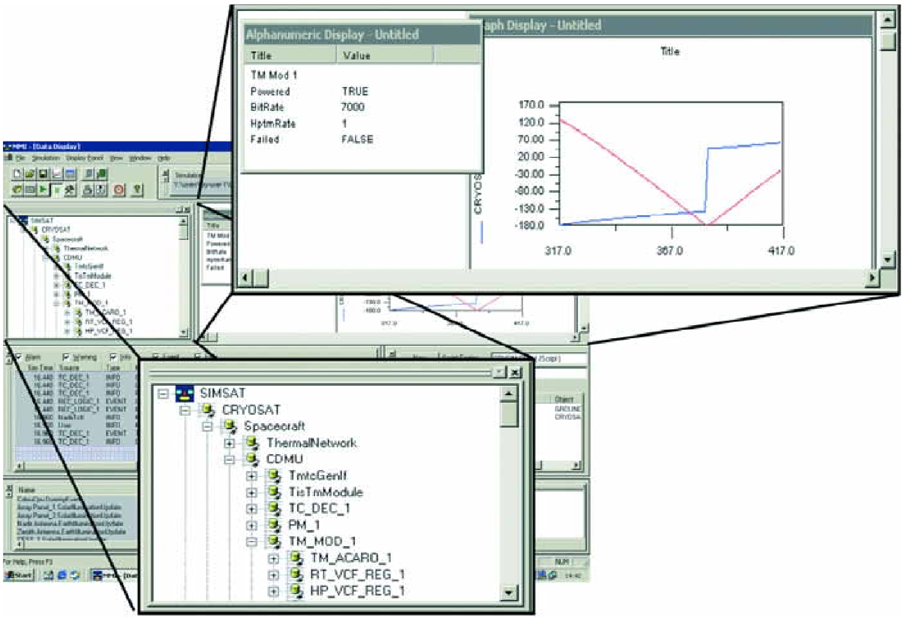
A typical Mission Control System display a critical system that needs to go through a comprehensive verification and validation process. This is not limited to the software itself, but extends to the operational data that are used to configure the MCS. It includes, for example, the database describing the spacecraft's telemetry and command data.

In addition to these functions, the MCS usually provides support for mission planning, data analysis and distribution, telemetry and command database management and onboard software management.

The Operational Simulator

The Operational Simulator is a software system that simulates the satellite, the ground stations and, to a certain extent, the space environment. An Operational Simulator is developed for almost every mission operated by ESOC. It is used to:

- support testing of the ground systems, including the MCS;
- support validation of operational data, including the operational database and the operational procedures;
- prepare the System Validation Test campaign, which contributes to the operational validation of the operations system that ground systems, procedures and personnel are able to operate the system successfully. This includes test and validation of the interfaces between ESOC and the satellite, confirmation of the correct functioning of the MCS and Flight Dynamics System and the validity of the operational procedures.
- support training of the Flight Control Team to make sure that everyone has the skills to ensure mission success under nominal and contingency situations. When something unexpected happens on the satellite or on the ground, it is extremely important to have a well-trained team of experts covering all areas and able to take timely decisions. Simulated failures in the space and ground segments test the team's responses to contingencies.



A typical Operational Simulator desktop, with graphs, displays and models

The ESOC Infrastructure Software

Most of ESOC's activities involve science and Earth observation missions. Such satellites are complex and every mission is different. At first sight, this would seem to prevent the reuse of tools and functions between missions, but software reuse has been achieved using various techniques, such as:

- changing configuration via setting different parameters in tables or databases;
- using appropriate software engineering technologies.

Two parts of EGOS are particularly relevant here:

- SCOS-2000 is the basis for mission-specific MCSs and covers most of the functions required for telemetry reception and processing, telecommand uplink and verification, data archiving, display and retrieval, and data distribution;
- the Simulus toolset is the basis for mission-specific Operational Simulators. It covers the SIMSAT simulator kernel and the Generic Models, including onboard processor emulators, orbit prediction and propagation (including environment perturbations), selected onboard subsystem models (such as thermal, electrical, telemetry/commanding) and ground system models.

Mission Families

A family is a set of satellite missions with a high degree of commonality in the spacecraft platform and/or in the operational profile. The families currently in use at ESOC are:

- interplanetary, in orbits not bound to Earth;
- Earth observation, in near-Earth orbits;
- observatory, with long visibility periods, high data rates and observation schedules proposed by users;
- navigation, typically a constellation of satellites in medium Earth orbits operated simultaneously.

There are requirements common to all mission families and these are generally supported by the infrastructure software. On the other hand, there are also requirements specific to one mission family only, and for which the supporting software has to be specifically developed. Further software reuse can be achieved by exploiting this 'intra-family' commonality.

Two mission families are considered further here: interplanetary and Earth observation, although significant levels of reuse have also occurred in others.

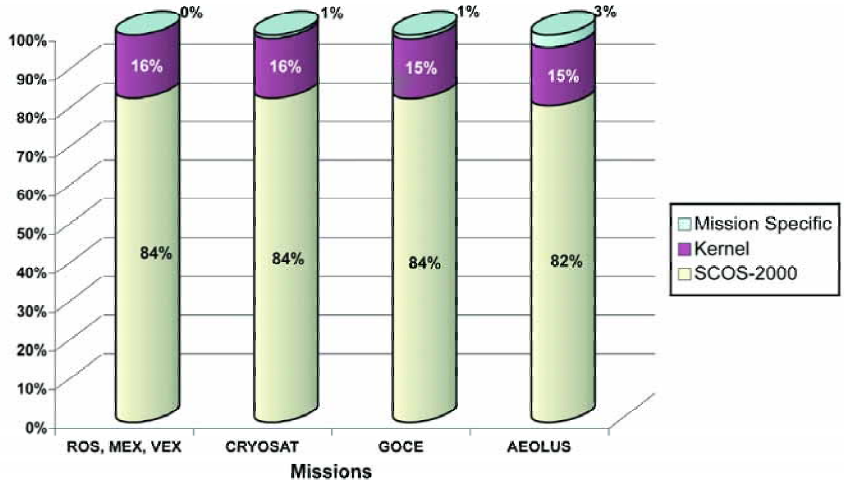
The interplanetary mission family

The interplanetary mission family comprises Rosetta (launched in March 2004 towards Comet Churyumov-Gerasimenko), Mars Express (launched in June 2003 and now orbiting Mars), and Venus Express (launched in November 2005 and now orbiting Venus). Two more missions are under preparation to join this family: BepiColombo (launch in 2013 to Mercury) and Solar Orbiter (launch in 2015 towards the Sun).

Missions that are launched on Earth-escape trajectories have operational characteristics significantly different from Earth-orbiting missions. Many of these directly affect the ground software systems. For example, the long radio signal travel delays must be taken into account in telecommand verification and telemetry time-stamping. Also, special commanding protocols (such as File Transfer) are needed to deal with the delayed space-ground interactions. The MCS has to cope with two or more parallel data streams, one for real-time telemetry and one or more transporting the telemetry recorded onboard during the long non-coverage period.

The unifying feature of these ESA interplanetary missions is their common spacecraft platform, leading to:

- the same types of processors and major software functions;
- similar orbit and attitude control sensors and actuators;
- similar interfaces to the Solid-State Mass Memories;
- reuse of payloads;
- similar satellite autonomy functions;
- identical operator interaction with the MCS.



The apportioned requirements for Mission Control Systems. ROS, MEX and VEX represent Rosetta, Mars Express and Venus Express, respectively

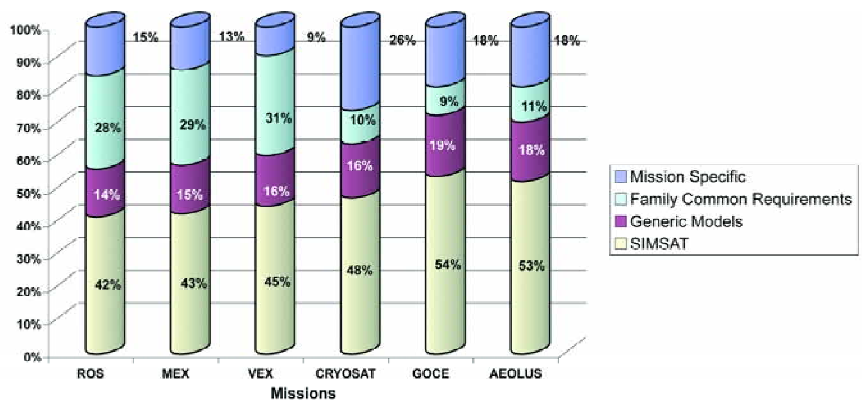
The Earth observation mission family

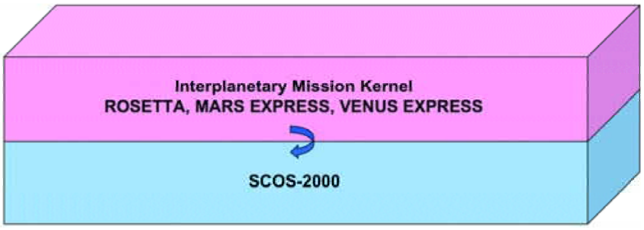
The Earth observation mission family consists today of CryoSat, GOCE and Aeolus. CryoSat was the first Earth Explorer Opportunity mission, which unfortunately suffered a launch failure in October 2005. GOCE is the first Earth Explorer Core Mission, with launch foreseen at the end of 2007. Aeolus is the second Core Mission, planned for launch in 2008. Future missions include CryoSat-2 (rebuild of CryoSat), Swarm, EarthCARE and the Global Monitoring for Environment and Security (GMES) initiative, comprising the Sentinel mission series.

Typically, these missions fly at low altitudes over the Earth (250–800 km), often in polar orbits, and their operational profiles provide frequent (about 15 times daily) and short passes (about 10 minutes) over a single ground station.

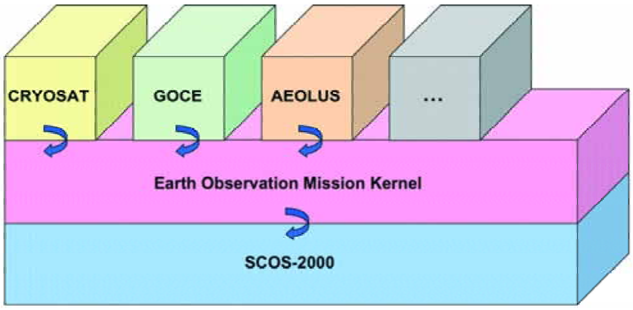
Despite the fact that the missions in this family have different spacecraft platforms and technologies, they all have very similar mission profiles and consequently very similar operational concepts. However, differences in satellite design can result in significantly different functions in the ground software. For example, onboard time is managed differently for the missions in the family. CryoSat uses the French payload DORIS to synchronise its time via a number of ground-generated microwave beacons, GOCE uses a simple onboard counter kept in synchronisation by the ground, and

The apportioned requirements for Operational Simulators

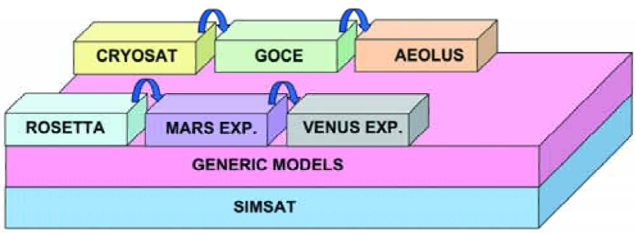




Typical software layering for reuse for Mission Control Systems in the interplanetary mission family. Arrow indicates possible path for requirements migration



Typical software layering for reuse for Mission Control Systems in the Earth observation mission family. Arrows indicate possible path for requirements migration



Typical software layering for reuse for Operational Simulators in the interplanetary and the Earth observation mission families. Arrows indicate possible path for requirements migration

Aeolus carries a Global Positioning System (GPS) receiver in addition to its counter.

The Delta Approach

The 'delta' approach isolates layers of software components that could be used as building blocks for mission-specific ground software (see illustrations). Three layers are identified:

- the lowest is the most generic and is reused across mission families. Typically, this is the infrastructure software;
- the middle increases the level of specialisation and is reused within a mission family;
- the upper is mission-specific and groups only those characteristics that are specific to a single mission.

Not all of these layers are needed every time, but a fundamental characteristic of this approach is that each layer is defined only in terms of the differences ('deltas') with respect to the layer below.

Requirements engineering

During requirements engineering, a 'delta requirements document' is produced that covers exclusively the mission-specific requirements. Since the majority of the requirements come from the lower layers, the document is slimmer and simpler. Experts can focus on what is unique in the mission, taking standard functionality for granted.

Clearly, a prerequisite for realising the full benefit of the delta approach is that the authors of the requirements document have a good knowledge of the functions of the reused software.

An important benefit in isolating the kernel requirements from the lower and upper layers is that it makes it easier to follow the evolution of the infrastructure software.

In fact, requirements common to missions in the same family will move down from the mission-specific context to the family kernel layer, while requirements generic enough to serve any type of mission can be moved down to the infrastructure layer. There is a similar process for Operational Simulators. The process of assigning or moving requirements between software layers is 'configuration-controlled': a control board ensures that the requirements are generic and stable.

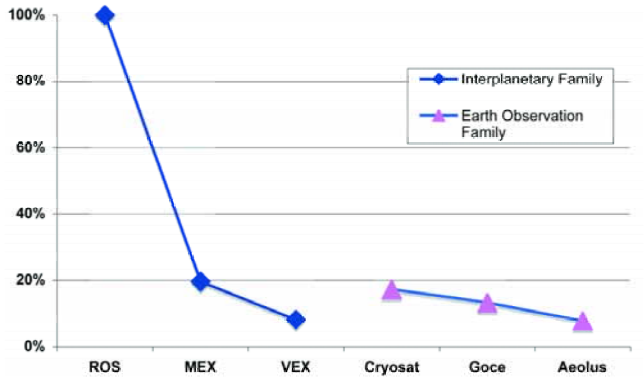
The rest of the lifecycle

The same basic idea applies to the rest of the lifecycle: concentrate on the differences and reuse as much as possible of what is already available.

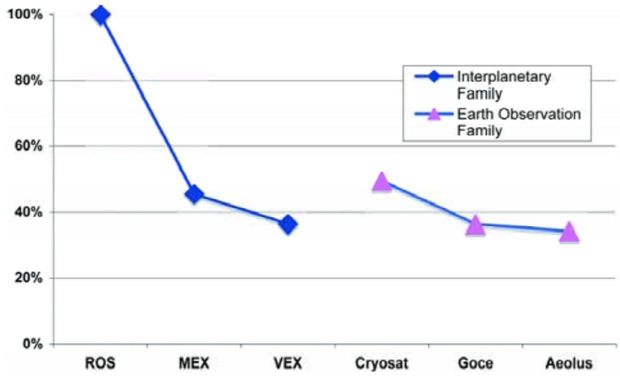
Specific to architectural design is the reuse of interface definitions along with the software at either side of these interfaces. For example, the interfaces between the MCS and Operational Simulator are based on generically defined file formats. For the Operational Simulator, ESA has defined a standard for the interaction between models and the simulation infrastructure. This Simulator Model Portability (SMP) standard encourages platform and infrastructure independence and permit the reuse of models both throughout the mission lifecycle and also from one mission to another.

During the implementation process, the software development team makes use of the fact that the infrastructure software and the mission family kernel are self-standing components to ensure maximum reuse. This also helps open industrial competition and extends the pool of contractors familiar with the software. This wide reuse creates a virtuous circle in which the software progressively improves as it is employed in more and more missions. In fact, fixes to software bugs found in one mission-specific system may be fixed in the other systems in the family at minimal effort.

In the maintenance phase, combined maintenance reduces costs. 'Combined maintenance' means that a single team maintains several data systems, such as



The development costs of the Mission Control Systems for the two mission families relative to the most expensive development



The development costs of the Operational Simulators for the two mission families relative to the most expensive development

all the mission control systems in a family. Overheads and maintenance manpower per mission are reduced: costs are shared among the missions and the engineers are given more interesting work through involvement in several missions. The delta approach also ensures that the amount of mission-specific software needing to be maintained is reduced.

The delta approach in practice

This approach achieves the best results when it is followed from the outset of a development. The later the start, the less effective it is.

For the MCS of interplanetary missions, a two-layer delta approach was used for all missions in the family, thus capitalising on the common spacecraft platform. Practically, this implied a single system that could be used for each of the three missions by simple reconfiguration. The effort usually required for one mission covered all three.

For the MCS of the Earth observation family, a three-layer approach was adopted to cope better with the spacecraft platform differences. Common functions in the family are separated in the middle layer. This is the Earth Observation Mission Kernel, lying between the mission-specific software (unique to each mission) and the infrastructure software. It is a self-standing piece of software.

For Operational Simulators, the tailoring is very similar for the two families. Heavy reuse is made of the infrastructure software (SIMSAT and Generic Models) and commonalities among spacecraft are exploited within each family by reuse of models from previous developments in the family. For interplanetary missions, near-identical spacecraft platforms means that the simulators are also almost identical. The teething problems of developing the simulator, such as immature or late onboard software and problems with early versions of spacecraft documentation, were mainly borne by the first mission in the family, Rosetta.

For simulators there are other aspects of reuse. Emulation of the onboard processors means that the actual onboard software can be reused, leading to iterative reuse from space to ground segments. The software Model Portability standard allows reuse of models (developed by the spacecraft manufacturer, for example) in the Operational Simulator. In fact, if common subsystems are used in different spacecraft, models developed in compliance with SMP can be used in any simulator, whether developed for spacecraft checkout by the spacecraft manufacturer or for operations training by the operations supplier.

These examples show how reuse is beginning to happen at the higher level of the space system lifecycle. A similar trend can be seen in mission control systems and operations preparation tools. For example, common tools for spacecraft checkout and operations preparation are promoting seamless transition from spacecraft manufacture to operations. This was exploited recently by Herschel and Planck.

The arrows in the illustrations show the typical direction of migration of functionality. Once stable, the more generic functions may migrate to the lower software layer (not shown for the Operational Simulator for simplicity).

Benefits for the infrastructure software

Evolution of the infrastructure software to cope with the needs for new generic features is a relatively slow process because it requires consensus across mission families. The mission family

kernel layer allows missions to build up initial operational experience on new features that are of general interest and could be introduced into the infrastructure software at a later stage. Thus the mission family kernel is like an operational laboratory where requirements are refined, experimented with and modified until they are mature and stable. At this point, the new generic features may be imported into the infrastructure software. A successful mission family kernel will thus be reduced to nothing as this importing process proceeds!

The infrastructure software must also evolve to take account of new versions of the operating system and commercial-off-the-shelf software, as well as changes resulting from fault correction during maintenance and, last but not least, major functional upgrades. Migration of ground software to new versions can be a major effort, involving extensive testing and validation by developers and the Flight Control Team. For missions in their operational phase, the effort and operational risks are often considered to be too high, so missions in their routine phase are usually reluctant to take new infrastructure versions. However, the mission family approach can help to remove this barrier. For example, when Venus Express was preparing for launch, its MCS was based on the most recent SCOS-2000 (at that time, version 3.1), whilst the already-flying Rosetta and Mars Express continued to use the previous version. Once the Venus Express project completed operational validation of the new system, migration of the Rosetta system to the new interplanetary kernel was straightforward, taking a few months. Following this, migrating the Mars Express MCS was even quicker, lasting only a few weeks.

Cost, schedule, quality and risk

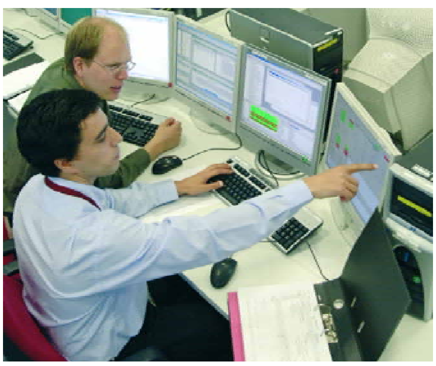
The delta approach achieves cost reduction by having:

– less system specification, design and development effort;
– less validation effort;
– shortened project elapsed time;
– higher software quality;
– lower risk because of the validation by earlier missions in the family.

The illustrations show that the development costs progressively decrease and that the earlier missions have to pay the price of an earlier (less rich and stable) infrastructure software and of being the first implementers of the mission family kernel. Clearly, one has also to factor into the interpretation of these figures the complexity of the spacecraft, which is certainly higher for the interplanetary family. Additional cost savings can be achieved during maintenance.

Conclusions

There are benefits in taking the delta approach to building mission control systems and simulators, and splitting the mission ground software into layers for progressive reuse. Software is systematically reused, focusing specifications, design and development on the differences. The new software may then itself be reused in a new layer, the Mission Family Kernel. This delta approach encourages new missions to make their new features or improvements generic. Migration to new versions of the infrastructure software can be done by one mission (say, a new family member), and the other missions in the family may then benefit from it with minimal risk and effort.



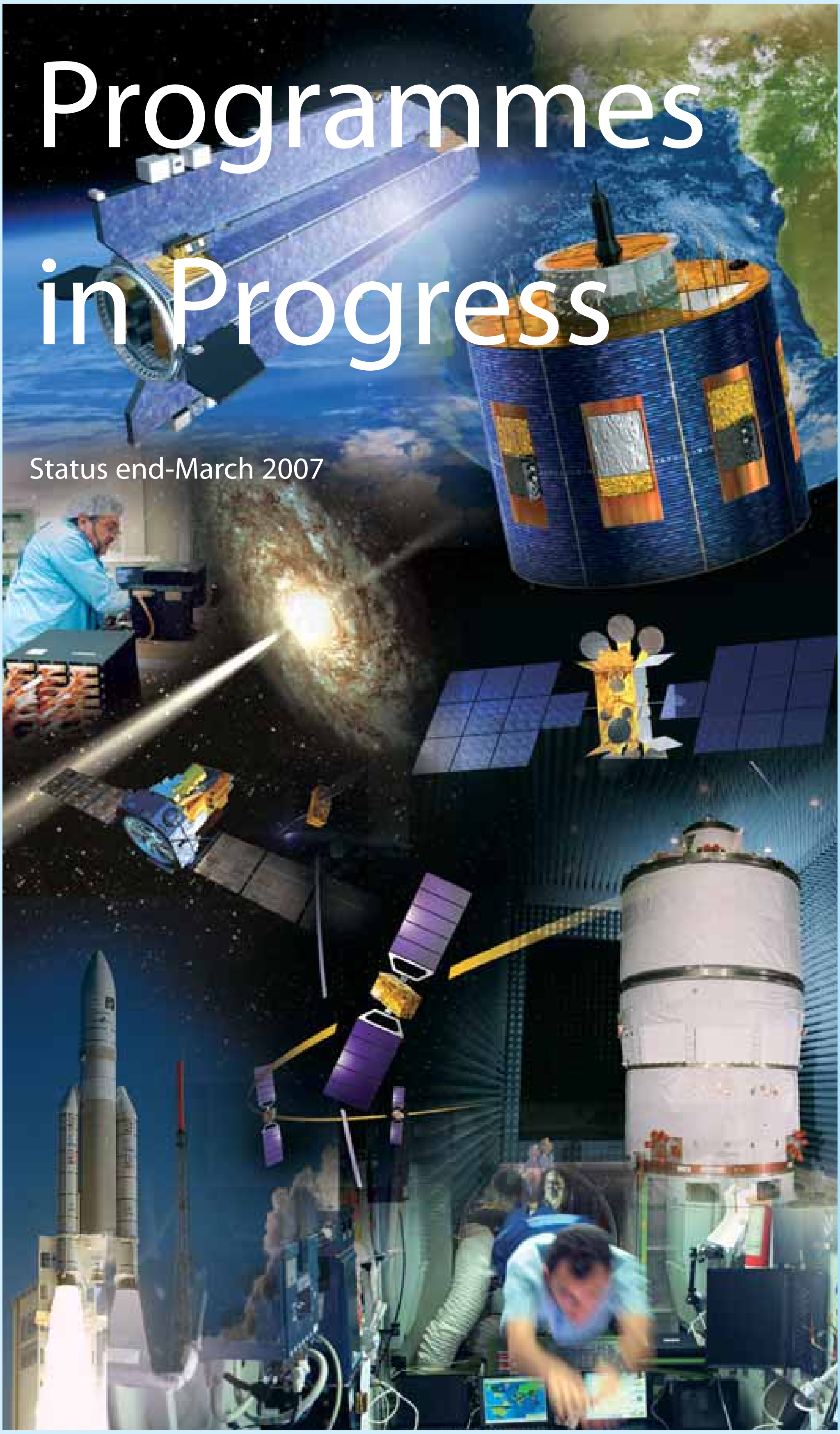
ESOC simulators have also benefited from this approach. With a common simulation framework, standardisation of external interfaces, internal interfaces and components, a high-level of reuse has been achieved. Simulator costs, however, remain sensitive to the differences between the spacecraft they simulate. By the same token, they are reduced as standardisation of space and ground segments subsystems, interfaces and processes consolidate.

ESOC has drawn its proven infrastructures for MCS and Operational Simulators together to provide the EGOS open, flexible infrastructure that stimulates reuse during all project phases and from one project to another. This provides a virtuous circle of improving quality and increasing reuse, which results in lower costs and improved service for the end users.

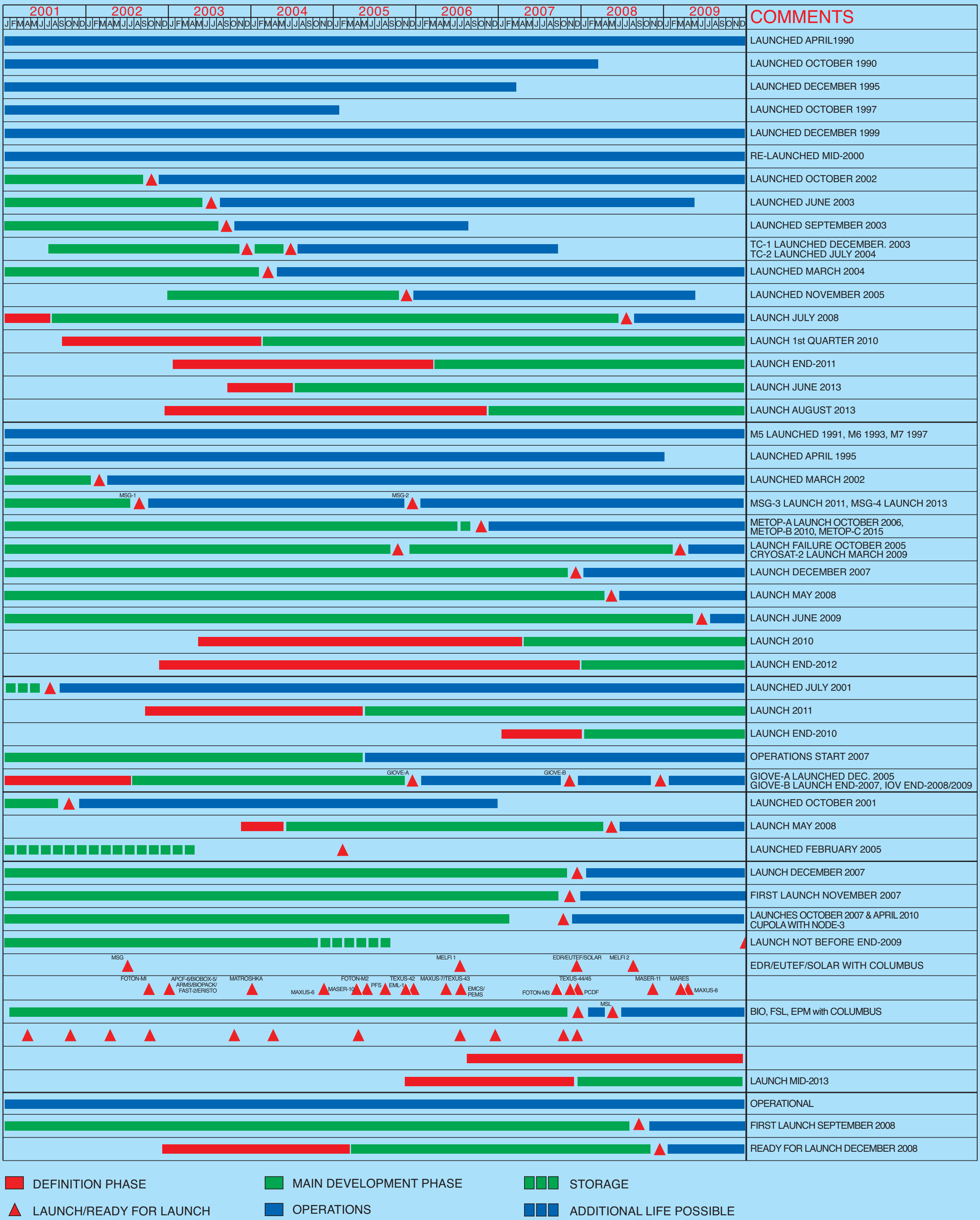
Last but not least, it is worth stressing that the whole field of ground segment engineering and operations benefits from the family mission approach. This allows combination or cooperation between teams for the individual families in all specialist areas, ranging from ground stations, mission data systems and flight dynamics to ground segment operations and spacecraft operations. On the operations side, similarities between missions and between the systems on the ground used to operate them save on training and operations costs, leading to fewer operations staff per mission, as well as facilitating mobility of staff between missions. In short, knowledge reuse within the various engineering teams and the infrastructure itself is maximised, with considerable benefits in cost and risk reduction.

Programmes in Progress

Status end-March 2007



	PROJECT
SCIENTIFIC PROGRAMME	SPACE TELESCOPE
	ULYSSES
	SOHO
	HUYGENS
	XMM-NEWTON
	CLUSTER
	INTEGRAL
	MARS EXPRESS
	SMART-1
	DOUBLE STAR
	ROSETTA
	VENUS EXPRESS
	HERSCHEL/PLANCK
	LISA PATHFINDER
	GAIA
	JWST
	BEPICOLOMBO
EARTH OBSERVATION PROGRAMME	METEOSAT-5/6/7
	ERS-2
	ENVISAT
	MSG
	METOP
	CRYOSAT
	GOCE
	SMOS
	ADM-AEOLUS
	SWARM
	EARTHCARE
COMMS./NAV. PROGRAMME	ARTEMIS
	ALPHABUS
	SMALL GEO SAT.
	GNSS-1/EGNOS
	GALILEOSAT
TECHNOL. PROG.	PROBA-1
	PROBA-2
	SLOSHSAT
HUMAN SPACEFLIGHT, MICROGRAVITY & EXPLORATION PROGRAMME	COLUMBUS
	ATV
	NODE-2 & -3 & CUPOLA
	ERA
	ISS BARTER & UTIL. PREP.
	EMIR/ELIPS
	MFC
	ASTRONAUT FLT.
	AURORA CORE
	EXOMARS
LAUNCHER PROG.	ARIANE-5
	VEGA
	SOYUZ AT CSG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COMMENTS
LAUNCHED APRIL1990
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LAUNCHED DECEMBER 1995
LAUNCHED OCTOBER 1997
LAUNCHED DECEMBER 1999
RE-LAUNCHED MID-2000
LAUNCHED OCTOBER 2002
LAUNCHED JUNE 2003
LAUNCHED SEPTEMBER 2003
TC-1 LAUNCHED DECEMBER. 2003
TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004
LAUNCHED NOVEMBER 2005
LAUNCH JULY 2008
LAUNCH 1st QUARTER 2010
LAUNCH END-2011
LAUNCH JUNE 2013
LAUNCH AUGUST 2013
M5 LAUNCHED 1991, M6 1993, M7 1997
LAUNCHED APRIL 1995
LAUNCHED MARCH 2002
MSG-1
MSG-2
MSG-3 LAUNCH 2011, MSG-4 LAUNCH 2013
METOP-A LAUNCH OCTOBER 2006,
METOP-B 2010, METOP-C 2015
LAUNCH FAILURE OCTOBER 2005
CRYOSAT-2 LAUNCH MARCH 2009
LAUNCH DECEMBER 2007
LAUNCH MAY 2008
LAUNCH JUNE 2009
LAUNCH 2010
LAUNCH END-2012
LAUNCHED JULY 2001
LAUNCH 2011
LAUNCH END-2010
OPERATIONS START 2007
GIOVE-A
GIOVE-B
GIOVE-A LAUNCHED DEC. 2005
GIOVE-B LAUNCH END-2007, IOV END-2008/2009
LAUNCHED OCTOBER 2001
LAUNCH MAY 2008
LAUNCHED FEBRUARY 2005
LAUNCH DECEMBER 2007
FIRST LAUNCH NOVEMBER 2007
LAUNCHES OCTOBER 2007 & APRIL 2010
CUPOLA WITH NODE-3
LAUNCH NOT BEFORE END-2009
MSG
MELFI 1
EDR/EUTEF/SOLAR
MELFI 2
EDR/EUTEF/SOLAR WITH COLUMBUS
FOTON-M1
APCF-6/BIOBOX-5/
ARMS/BIOPACK/
FAST-2/ERISTO
MATROSHKA
MAXUS-6
MASER-10
FOTON-M2
PFS
TEXUS-42
EML-1
MAXUS-7/TEXUS-43
EMCS/
PEMS
FOTON-M3
TEXUS-44/45
PCDF
MASER-11
MARES
MAXUS-8
MSL
BIO, FSL, EPM with COLUMBUS
LAUNCH MID-2013
OPERATIONAL
FIRST LAUNCH SEPTEMBER 2008
READY FOR LAUNCH DECEMBER 2008
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
STORAGE
LAUNCH/READY FOR LAUNCH
OPERATIONS
ADDITIONAL LIFE POSSIBLE

HST

A team of European and US scientists obtained this Hubble Space Telescope view (right) of the nearby barred spiral galaxy NGC 1672, showing details in the star-forming clouds and dark bands of interstellar dust. Some of the most striking features are the dust lanes that extend from the nucleus and follow the inner edges of the galaxy's spiral arms. Clusters of hot young blue stars are forming along the spiral and ionising the surrounding clouds of hydrogen gas (glowing red). Curtains of dust partially obscure and redden the light of the stars behind them by scattering blue light. Galaxies lying behind NGC 1672 give the illusion they are embedded in the foreground galaxy, even though they are really much farther away. A few bright foreground stars inside our own Galaxy appear as bright objects. As a prototypical barred spiral galaxy, NGC 1672 differs from normal spiral galaxies in that the arms do not twist all the way into the centre. Instead, they are attached to the ends of a straight bar of stars enclosing the nucleus. Viewed nearly face on, NGC 1672 shows intense star-formation regions, especially at the ends of its central bar.

The manifest for HST Servicing Mission 4, planned for September 2008, includes two new instruments: the Wide-Field Camera 3 and the Cosmic Origins Spectrograph, plus several life-extending items such as gyroscopes and batteries. The astronauts will also attempt to repair the Space Telescope Imaging Spectrograph, which failed in August 2004.

NGC 1672 imaged by HST in August 2005. See the In Brief news pages for a larger version of this photograph

Ulysses

During a ~4.5-day period starting on 5 February, Ulysses encountered the tail region of Comet C/2006 P1 McNaught. The probe was then at a heliocentric distance of ~2.4 AU and 79° south heliographic latitude. The region of disturbance in the solar wind produced by the comet was nearly 10 Mkm wide. During the encounter, the speed of the solar wind dropped from ~750 km/s to a minimum of 360 km/s, and the proton density dropped by more than two orders of magnitude. Simultaneously, very large fluxes of molecular and singly- and doubly-charged atomic ions of cometary origin were detected. Although no shocks were observed during the encounter, the magnetic field strength was slightly enhanced in broad regions at the leading and trailing edges of the comet's tail. This is the third confirmed crossing of a comet tail during the mission (the others being Hyakutake in 1996 and McNaught-Hartley in 2000).

SOHO

SOHO ran a highly successful and intense campaign with the Japanese Hinode satellite in April. More than 30 observing programmes addressed a large variety of solar phenomena, including explosive events, loop oscillations, MHD wave propagation, coronal hole structures, prominences, active region structures and dynamics, and coronal heating. This joint campaign will be followed by a 2-week high-cadence SOHO/STEREO campaign.

SOHO recently became the first solar physics mission to observe a complete mean solar cycle (11.1 years).

Solar energetic particle (SEP) events from the Sun are a major element of space weather. They can damage space missions and pose a serious hazard to humans in space. A new study based on COSTEP data demonstrates the possibility of short-term forecasting of the appearance and the intensity of SEP events by means of relativistic electrons, which arrive about an hour ahead of the more dangerous ions. The new method is already in trial operational use by NASA Johnson Space Center's Space Radiation Analysis Group for protecting astronauts aboard the International Space Station.

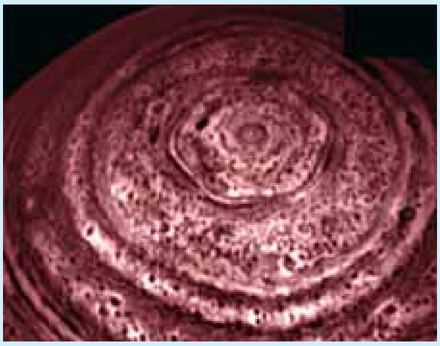
Cassini-Huygens

ESA, COSPAR and NASA have honoured Prof Hubert Curien's contribution to European space research by naming the Huygens landing site on Titan after him.

New images taken by Cassini's Visual and IR Mapping Spectrometer (VIMS) in October 2006 revealed a 6-sided feature almost 25 000 km across, circling the entire north pole of Saturn. Such a feature has never been seen on any other planet before and its nature is not yet understood.

The final presentation of the Huygens very long baseline interferometry activities took place at ESTEC on 8 February. The results concerning the Huygens trajectory are

This hexagon-like vortex in Saturn's atmosphere was captured by Cassini/VIMS on 29 Octover 2006. (NASA/JPL/Univ. Arizona)



excellent and indicate some meridonal drift of the probe that has yet to be explained.

Rosetta

The Mars swingby on 25 February was an excellent opportunity to make observations of Mars and its environment, although science was only a secondary objective of the gravity assist. OSIRIS, VIRTIS, ALICE and the Navigation Camera observed the planet over a broad range of wavelengths. RPC studied the solar wind interaction with Mars, while the Standard Radiation Monitor gathered valuable data on the radiation environment for future human missions.

Since the spacecraft passed through an eclipse during closest approach to Mars, the orbiter payload had to be switched off. However, the Philae Lander continued observations running on its own power. Stunning images of the Mars surface were taken by Philae's CIVA camera. ROMAP, the lander's plasma and magnetometer instrument, provided excellent data.

The flyby demonstrated the excellent capabilities and performance of both the Rosetta spacecraft and its scientific payload.

XMM-Newton

XMM-Newton and NASA's Chandra X-ray observatory have found evidence for a new class of supernova. Thermonuclear (Type Ia) supernova occur in binary systems when a white dwarf star becomes so massive as it accretes material from a companion star that it collapses and forms an incredibly dense neutron star. These supernovae are often used as 'standard candles', which help to investigate the nature of Dark Energy and Matter.

However, observations of two supernova remnants (SNRs) DEM L238 and DEM L249, have cast doubt on the standard models of Type Ia explosions. The observations revealed a bright central emission

The CIVA camera on Rosetta's Philae lander captured this image of Mars and the spacecraft itself just 4 minutes before closest approach on 25 February. The Mawrth Vallis region is visible on the planet's disc. (CIVA/Philae/ESA Rosetta)

surrounded by a faint shell. The central emissions show an overabundance of iron – a characteristic of white dwarf collapse (Type Ia) – rather than the more common Type II SNR due to the explosion of a massive star. However, the gas in the remnants is much denser and brighter in X-rays than expected from Type Ia explosions. This implies that the white dwarves exploded into very dense environments that could only be produced by the winds of very massive stars. Since such massive stars have very short lives, this means that Type Ia supernovae could occur much earlier in the Universe's history than expected. This means they can be used to probe the expansion of the Universe at these early epochs. Another possibility is that these Type Ia explosions differ in other properties. If so, the assumption they are standard candles may have to be revised, complicating the study of Dark Energy and Matter.

XMM-Newton completed 1338 revolutions on 31 March 2007. The winter 2007 eclipse season passed as expected.

Cluster

A paper published by Retino (IRF Uppsala) in *Nature Physics* using Cluster data showed, for the first time, magnetic reconnection taking place in a turbulent plasma. It had been predicted in theory but never seen before. The four Cluster spacecraft, with high time resolution measurements, could observe it for the first time.

Development of the Cluster Active Archive continues steadily; the archive now has 386 registered users. It will produce extensive sets of pre-generated plots from all spacecraft that illustrate the various data products. This work is approaching completion and is expected to be available in April 2007.

The Cluster fleet is now in the second mission extension phase and in its 7th year in orbit. The satellites are in a multi-scale arrangement, forming a 10 000 km triangle with two craft 500 km apart at one of the vertices.

Double Star

On 7 February, a team of Chinese and European scientists published a paper describing how Cluster and Double Star observed a flux transfer event (a huge magnetic tube where plasma from the solar wind enters the magnetosphere) for the first time at small- and large-scale simultaneously. All the observations, including magnetic fluxes, orientations and hot-ion velocity distributions, strongly suggest that Cluster and Double Star encountered the same flux tube at two different positions along its length. Such new results allow us to understand how the solar wind connects to the Earth's magnetic field.

In October 2007, TC-1 will enter the Earth's atmosphere. The Chinese have confirmed their intention to continue operating TC-2 after that. For ESA, TC-2 operations will be much simpler because it will involve only two instruments instead of the current eight.

Integral

Integral astronomers have detected what appears to be the fastest spinning neutron star yet. This tiny stellar corpse, probably only

20 km in diameter, is spinning 1122 times per second. XTE J1739-285 was discovered during an active phase in October 1999 using NASA's Rossi X-ray Timing Explorer (RXTE) satellite. In August 2005, while Integral was performing its regular monitoring of the central regions of our Galaxy, XTE J1739-285 was observed to be active again. About a month later, Integral saw X-ray bursts from it and alerted the RXTE team. In total, the two satellites observed around 20 bursts. Previous observations of other neutron stars have shown that the X-rays emitted during bursts can oscillate with the star's rotation rate. The team searched the XTE J1739-285 bursts for evidence of oscillations. What they found was astonishing; in the brightest burst there were indeed oscillations, but they were nearly twice as fast as any previously observed. The 1122 rev/s is very close to the fastest possible rate for a neutron star – much faster and it would fly apart.

Mars Express

A major Mars Express paper describing some of the more recent Marsis findings was published in *Science* on 15 March, entitled 'Subsurface radar sounding of the South polar layered deposits of Mars', by Plaut, Picardi and co-authors.

A Mars Express data workshop will be held at ESAC 11–15 June. This new initiative appears to be welcomed by the community. The first workshop will focus on (co-)analysing HRSC and OMEGA data.

Venus Express

Venus Express continues to perform its routine operations. A session dedicated to results from Venus Express was held at the 2007 European Geophysical Union meeting in Vienna. Preparations are under way for a special section in *Nature* on science results. The Science Team, at a meeting combined with a Venus science workshop, discussed potential future orbit changes to allow for new types of observations.

In operations, work focused on completing preparations for the quadrature phase operations (May–June 2007). A review is planned for April partly because the activities are complicated by new illumination constraints for one of the instruments.

With the support of the NASA Deep Space Network ground stations, a successful VIRTIS-movie observation was executed and downlinked. During earlier observations, VIRTIS detected oxygen-airglow on the nightside of Venus (see the In Brief news pages in this issue). This airglow is produced when oxygen atoms, 'migrating' from the dayside to the nightside of the atmosphere, recombine into molecular oxygen and in the process emit light.

Akari (Astro-F)

Since its launch in February 2006, Akari, a JAXA mission with ESA participation, is working almost flawlessly after a difficult start to operations and has already produced outstanding views of the infrared Universe. New results, presented in March 2007 at the annual meeting of the National Astronomical Society of Japan, provide unprecedented glimpses of regions of intense star formation, views of stars at the very ends of their lives, a supernova remnant never detected before in the infrared, distant galaxies and a galaxy harbouring a black hole surrounded by clouds of molecular gas.

About 80% of the entire sky has so far been imaged by Akari. The mission is currently in a phase dedicated to pointed observations, interleaved with survey gap-filling observations. It is expected that the liquid helium cryogen will last until at least September 2007, 4 months longer than post-launch expectations. ESA's contributions to the mission are working well: regular and efficient ground station coverage from Kiruna (S) and pointing reconstruction software, developed at ESAC, which is already providing the accuracy expected at the end of the mission. The ESAC team is in close contact with the Open Time users in Europe, to maximise the overall scientific return of

Star formation as revealed by Akari's wide-area survey in the reflection nebula IC4954/4955. The observations in seven different infrared wavelengths revealed a continuing cycle of star formation over three generations, across enormous spatial scales (the image is roughly 15 light years wide)

the pointed observations programme, despite increasing operational constraints. More than 200 European observations had been performed by the end of March. The Data Archive repository was opened to the Japanese, Korean and European users in early March, with a substantial contribution from ESAC, in the form of documentation and processing tools testing.

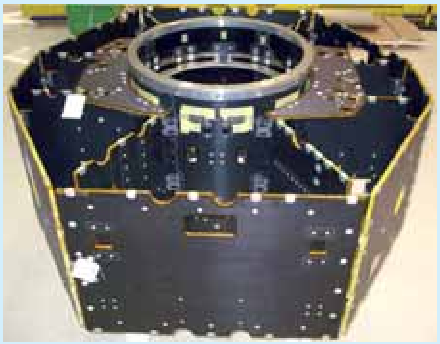
Herschel/Planck

The Herschel and Planck FMs are now in final acceptance testing. The Herschel cryostat completed its second cryogenic test phase, with the major test being the demonstration of the lifetime of the helium system under simulated orbital conditions in the Large Space Simulator at ESTEC. The cryostat was shipped back to Astrium for the FM instruments to be installed. The Herschel Service Module was delivered to Astrium at the end of 2007; the electrical and functional checkout in preparation for the mating with the cryostat this summer is progressing well. Herschel's scientific instruments are in the final stage of calibration testing and will be delivered in the coming months.

Planck spacecraft activities continue according to plan. The spacecraft is almost fully assembled and already under functional

The Planck Flight Model: the telescope in front and the spacecraft at the back, in the final stages of integration

The FM carbon fibre structure of the LISA Science Module (Oerlikon Contraves, CH)



testing, with final mechanical and electrical integration of electrical units of the scientific instruments to the satellite panels. A major milestone was mounting the focal plane units of the two instruments onto the spacecraft. The final mounting of the telescope and the alignment to the HFI and LFI focal plane unit are imminent and will complete the major mechanical integration activities.

The Herschel telescope is available and is in storage until its integration into the spacecraft.

LISA Pathfinder

The SMART-2/LISA activities are proceeding largely according to schedule. The main activity in the reporting period was the finalisation and consolidation of the spacecraft design, in preparation for the CDR. In parallel, all the spacecraft subsystems completed their PDRs and equipment underwent their Qualification Reviews. Some subsystems also had CDRs. The FMs of a few subsystems are already built, such as the primary structure of the Science Module and the Digital Sun Sensors. The two European micropropulsion technologies (needle indium thrusters and slit caesium thrusters) continue to be developed to prove the readiness of the technologies. The progress is apparent for both and the many difficulties encountered are being overcome. The technology suited to the need will be selected at the end of 2007.

For the LISA Technology Package, many subsystem CDRs have taken place and good progress is being made. Many electrical units have been built and delivered to Astrium GmbH for the Real Time Test Bench. The most critical subsystems are still the inertial sensor vacuum enclosure, the electrostatic suspension front-end electronics and the caging mechanism. Successful tests have been carried out on all these subsystems.

The launch is expected to take place in the first quarter of 2009.

Microscope

In January, CNES held three keypoint reviews on mission performances, satellite alternatives and payload. The Phase-C/D contract with ONERA for the development of the T-SAGE accelerometer was accepted and Phase-C kick-off is planned in May.

All FEEP electric propulsion activities are being performed under the LISA Pathfinder development activities Phase-1. CNES is studying in parallel the potential use of cold gas as a micropropulsion alternative, with access to the corresponding activities under way for Gaia.

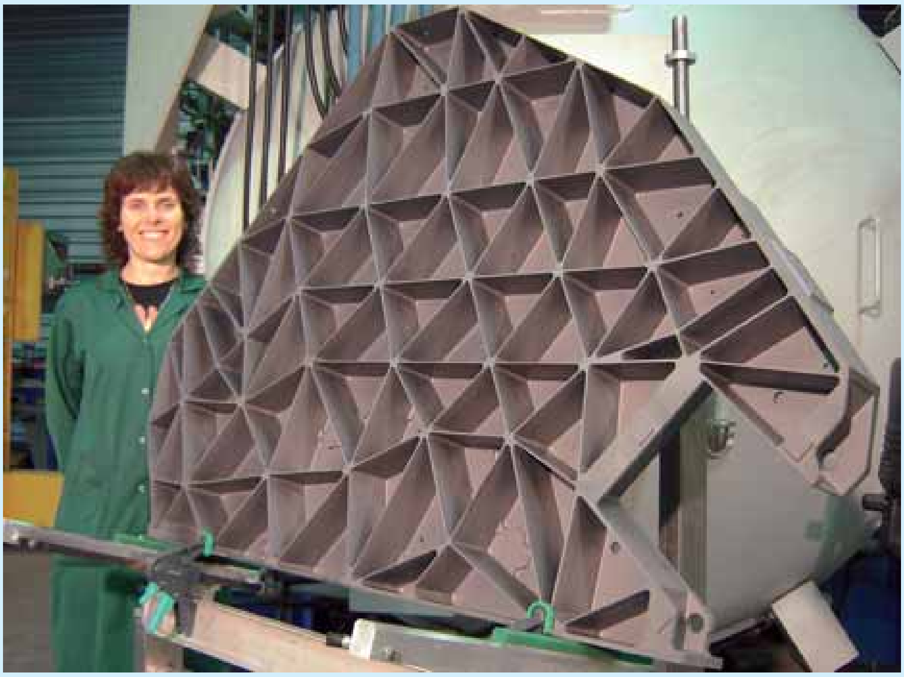
Gaia

Nearly all subcontractors for the flight hardware have been competitively selected; the last two procurements are in the final stage of proposal evaluation. A small amount of ground test equipment remains to be procured in the very near future.

Preparations for the Mission PDR are well under way and the spacecraft data package will be delivered by the Prime Contractor in April. Despite the fact that this system review has not yet been held, a significant number of subsystem reviews have already been held. In particular, the design review of the

The optical face of the first FM secondary mirror blank for Gaia. The optical surface accuracy of better than 50 µm rms will be improved by polishing to better than 10 nm rms

The silicon carbide baseplate of JWST's NIRSpec optical bench



Focal Plane Assembly, consisting of about 108 densely packed electronics boxes, ended successfully.

The first pieces of flight hardware are being delivered. The first set of silicon carbide flight mirror blanks has been received and forwarded to the subcontractor for polishing.

The response to the Announcement of Opportunity for the Gaia Data Analysis and Processing Centre submitted by a European consortium was analysed and the results of the evaluation discussed with the proposing consortium.

JWST

All the JWST critical technologies, including the MIRI cryocoolers, have passed the Technology Readiness Level 6. This status was confirmed by the JWST Independent Review Team. TRL-6 requires a system or subsystem model or prototype demonstration in the relevant environment (ground or space); it is one of the main criteria for formally passing into mission implementation (Phase-C).

All the primary mirror segments and the secondary mirror blank have finished their back and front face machining.

For NIRSpec, the detailed design phase of all the SiC ceramic parts was completed and the manufacturing of the remaining optical bench and camera optics ceramic blanks was released. The redesign of the grating and filter wheel assemblies is nearing completion, with a delta-PDR planned for the end of April.

MIRI's instrument-level CDR was concluded. Recovery of the filter wheel assembly design is nearing completion, with an anticipated close out in April. The Integration of the Instrument Verification Model (VM) kicked off. A split delivery of the JPL-provided detector and detector electronics will minimise impact on the VM programme. Firm plans for beginning Qualification Model and FM subassembly manufacture are established.

Preparation for the launcher PDR analysis campaign (RAMP) is under way, with a planned start in June.

BepiColombo

The contract proposal for the Implementation Phase was approved by the Industrial Policy Committee and the mission was then adopted by the Scientific Programme Committee. The Memorandum of Understanding with JAXA for the Mercury Magnetospheric Orbiter (MMO) was approved by the Council. The commitment from the Lead Funding Agencies to support the BepiColombo payload was formalised in a Multi-Lateral Agreement between ESA and the European Lead Funding Agencies. This agreement was approved by the SPC.

The instrument design and prototyping is proceeding according to plan. However, some instruments impose a high thermal load on the spacecraft and the overall payload mass is growing. This development is being closely monitored with the Principal Investigator teams.

A technology status review was held with the Industrial Core Team in order to confirm readiness for starting equipment procurement and high-priority development activities. The equipment procurement plan was consolidated and presented at the Industrial Space Day, which was attended by a large number of representatives from European industry.

The System Requirements Review was held and the Board concluded that the requirements specifications must be consolidated before beginning equipment procurement. This is planned to be completed before mid-May.

LISA

The Mission Formulation activity performed by Astrium (D) has been extended until July 2008 and is now in Phase-3, which includes a trade-off of the In-Field of View architecture with different positions of the test masses.

The analysis of alternative payload concepts proceeds and a telescope design was finalised, aiming at a simplified mechanical accommodation. The mechanical design of the alternative payload concept is being updated accordingly. The optical truss analysis and design is being tailored to the new telescope design.

The cooperation with NASA proceeds well on all fronts. The review for the prioritisation of the NASA 'Beyond Einstein' programme initiated by NASA HQ and performed by the National Research Council (BEPAC) is under way.

Owing to the revised implementation strategy of the Cosmic Vision 2015–2025 programme, LISA's status was modified. Programmatically, the launch of LISA earlier than 2017 is incompatible with the planned financial situation. LISA was therefore shifted to the Cosmic Vision planning window of 2015–2025, where LISA will compete as a candidate for the first large mission (L-class mission).

GOCE

Following the completion of the environmental testing and final functional verification of the sixth Accelerometer Sensor Head (ASH) Flight Models (FMs), the third and last pair of ASHs was delivered by ONERA in mid-February. The pair was then integrated in the Gradiometer Core Proto-flight Model (PFM), including the alignment of all six ASH FMs and one-axis gradiometer arms. This completes the integration of the Gradiometer Core PFM, which will be subjected to mechanical and thermal vacuum acceptance testing in April. The completion of all six ASH FMs and their integration in the Gradiometer Core carbon-carbon structure is a fundamental milestone for the GOCE programme.

Satellite PFM integration and testing activities continued, in double shifts, at Alcatel Alenia Space (AAS-I) in Turin. Integrated system tests were carried out on the two Satellite-to-Satellite Tracking Instrument (SSTI) FMs and on the Gradiometer PFM electronic units connected to the upgraded Gradiometer Core Structural & Thermal Model. Some anomalies were detected during final acceptance testing of the overall Ion Propulsion Assembly (IPA) FM when firing the thrusters close to their maximum level. This was solved by inserting filters between the thrusters and the power supplies. The investigation of the anomalies and the design, manufacturing and testing of the flight filters led to delays in the completion of the IPA final acceptance testing, which is estimated to last until the end of April.

For the launch vehicle, a delta-CDR was performed with Eurockot at the beginning of March. The primary objectives were the verification of the close-out of the corrective actions established after the CryoSat launch failure and the acquisition of the necessary confidence in the development, reliability and verification of GOCE mission-specific adaptations.

The GOCE Ground Segment Overall Validation activities are running nominally, with tests performed between the Reference Planning Facility, the Flight Operations Segment and the Payload Data Segment. In addition, a System Validation Test was performed, with exchange of commands/ telemetry between ESOC and the satellite FM in Turin. Work progressed nominally on the Calibration and Monitoring Facility, where factory acceptance testing of all tools was completed. The CDR of Version-3 of the Level-1 to Level-2 High Level Processing Facility of the European GOCE Gravity Consortium was completed as part of the bridging phase kicked-off last November.

CryoSat-2

The changes required to the design of CryoSat-2 were scrutinised from December 2006 to January 2007. This delta-CDR was completed on 1 February, with no significant points of concern found. In the meantime, the development of the satellite hardware continued and in March passed an important milestone: the delivery of the structure. This is the satellite's 'chassis' and its installation in the cleanroom at Astrium in Friedrichshafen (D) marks the real start of the integration of the satellite hardware. At the same time, the Engineering Model flight computer, refurbished to CryoSat-2 standard, was delivered and is now being integrated into the 'virtual satellite' set-up that will be used for test development.

The ground segment activities are also starting up. The first stage was the generation of the documentation that identifies the changes required induced by changes on the satellite. For example, the introduction of redundancy in the payload means that two sets of characterisation data have to be managed, which introduces some changes in the original concept. These documents will be reviewed in a Ground Segment PDR in May 2007.

SMOS

After delivery of all remaining subsystem units in late 2006, the payload PFM integration was completed in January, followed by full deployment tests of all three radiometer arms in February. The payload module with all Ground Support Equipment was transported to ESTEC for the environmental test programme.

Firstly, the payload mass, centre of gravity and moments of inertia were measured. This was followed by the acoustic test in the Large European Acoustic Facility. The payload was then transferred to the Large Space Simulator and fully deployed and suspended in a sophisticated zero-gravity jig. Chamber closure and pump-down took place on 14 April, with a programme of different illumination and thermal conditions expected to continue for the rest of April.

The Proteus platform dedicated to the SMOS mission has been formally accepted and is waiting to be integrated with the payload module once its test programme is

The SMOS payload ready for thermal testing in ESTEC's Large Space Simulator

completed. Validation of the flight software is continuing on a simulator bench with the payload Engineering Model.

Ground segment deliveries are progressing, with the most visible part being the 3.5 m-diameter dish antenna being installed at ESAC. Stepped integration testing has begun and will continue throughout the year as more facilities become available.

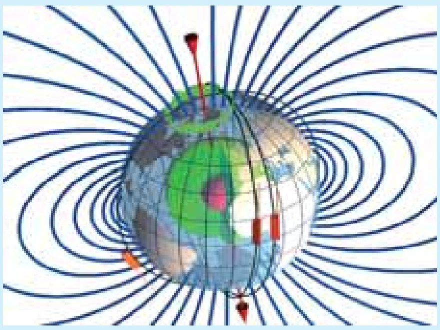
ADM-Aeolus

Progress has been made in improving the thermo-mechanical stability of the transmitter laser. Tests using a different adhesive to bond the laser mirrors to their mounts showed significantly improved stability in thermal tests and in vacuum. In a design review, it was decided to implement this process for the most sensitive mirrors of the flight laser together with some minor mechanical modifications in the Master Oscillator baseplate. The implementation of these changes and a parallel requalification programme for the new adhesive are under way.

A further step forward was the qualification of the laser diode stacks for the transmitter laser. Test data after 6 months of operation are available and show that the observed level of degradation of the laser diodes is fully compatible with a 3-year operation of the transmitter laser in flight. For additional confidence, the qualification batch of the laser diodes continues to be run to confirm the expected long-term behaviour.

Integration of the FM platform continues, and the onboard software is being tested on the satellite platform. The formal test campaign at platform level has started. The first versions of the L1B and L2B processors were completed and delivered for further testing with the science teams.

For the ALADIN Airborne Demonstrator, the data evaluation from the first ground-based campaign gave new insight and led to a refinement of some alignment procedures of the FM. In the meantime, the laser for the Airborne Demonstrator was modified to allow single-frequency operation in the environment of the aircraft. A proving flight will be performed before the first airborne campaign in autumn 2007.



The Earth's magnetic field is produced mainly by a self-sustaining dynamo in the fluid outer core. Swarm's 3-satellite constellation will measured this, together with other contributions. (GeoForschungszentrum Potsdam)

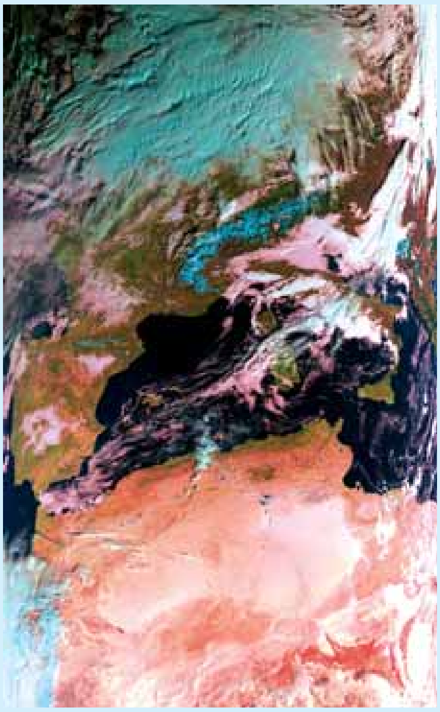
Swarm

The PDR was completed and the kick-off of Phase-C/D is planned for mid-April. The procurement activity for the satellites' instruments and equipment is near completion, with the remaining procurements to be completed within Phase-C.

Analyses are under way on the candidate launchers. The launcher performance for Eurockot and Dnepr were clarified, detailed accommodation design is under way on the satellite side, and the launch providers are studying the complex dispenser needed to carry the three satellites.

The PDRs of the Absolute Scalar Magnetometer and Electrical Field instruments are completed. The PDRs of the other instruments/spacecraft units are under way and will be finalised during Phase-C.

Preparation of the ground segment is progressing, with the mission implementation requirement documents being well advanced for both ESRIN and ESOC tasks. Definition of the Level-1b algorithms is under way. Preparation for Level-2 processing has begun, and several support studies are running.



MetOp AVHRR image from November 2006 during the System In-Orbit Verification campaign

MSG-4 in the Compact Antenna Test Range at Thales Alenia Space (Cannes, F) to check the performance of the antenna system

MetOp

MetOp-A, launched successfully on 19 October 2006, went through its early operations phase to 22 October 2006, under ESOC control, without incident. The In-Orbit Verification phase then began, with the successive switch-on and check-out of the instruments. By the end of 2006, all instruments had been switched on and 'first light' data were available. No major anomalies were encountered for the instruments; performance was as expected.

The System In-Orbit Verification phase successfully concluded on 29 March 2007. Eumetsat, supported by ESA, then began the Commissioning phase, including calibration/ validation, for the overall system. This should be completed in mid-May, so that routine operations can then begin.

The performance of the new instruments looks very promising, with results consistently better than specification. The ground segment has also largely worked very smoothly. Overall, the system should prove to be highly successful.

The project and industrial activities are now in a standby mode, with MetOp-1 (MetOp-B) and MetOp-3 (MetOp-C) in storage, waiting for the restart in 2009 for the next launch (MetOp-B), in 2010.

MSG

Meteosat-8/MSG-1

An east-west stationkeeping manoeuvre was performed on 20 February, with nominal satellite behaviour. It is planned that Meteosat-8 will operate in Rapid Scan mode once Meteosat-9 becomes the operational satellite. Instrument performance remains excellent.

Meteosat-9/MSG-2

East-west stationkeeping manoeuvres were performed on 6 February. Eumetsat is preparing Meteosat-9 to take over from Meteosat-8 as the operational satellite at 0º longitude by April 2007.

MSG-3

It is planned to move MSG-3 this summer from its intermediate storage in the Thales Alenia Space cleanroom into long-term storage. Launch is projected for early 2011.

MSG-4

After the completion of the environmental tests on at Thales Alenia Space, the Pre-Storage Review (PSR) cycle began. Following PSR, MSG-4 will be prepared for long-term storage. Launch is not expected before 2013.

Human Spaceflight, Microgravity & Exploration

Highlights
After the highly successful missions in the latter part of 2006 for Thomas Reiter (Astrolab) and Christer Fugelsang (Celsius), the post-flight reviews were held at ESTEC in February. Participating alongside the ESA astronauts were Russian and NASA representatives, scientists, User Support Operations Centre (USOC) and industry representatives, and ESA Staff. On 26 March Reiter, as part of a busy programme of events, delivered a well-received speech to the European Union Heads of State and Government in Berlin. Fuglesang's activities included events in Sweden and Rome, along with a crew trip to the NASA Marshall Space Flight Center.

The next ESA astronaut flight will be that of Paolo Nespoli (I), who will be part of the STS-120 Shuttle crew to install the European-built Node-2 on the ISS. Léopold Eyharts (F) is assigned as a member of the Expedition-16 crew. He will arrive on the ISS aboard Shuttle *Discovery* mission STS-122 together with colleague Hans Schlegel (D). Schlegel will help to install the Columbus laboratory and its external payloads on the ISS, involving two EVAs. Eyharts will help to commission Columbus before returning home, some 2 months later, aboard Shuttle *Endeavour* STS-123.

The launch schedule for 2007 is delayed because of damage to Shuttle *Atlantis* sustained during a severe hailstorm. As a result, the flights of Node-2, Columbus and their crews have moved by a few weeks. There is a possibility that this will also affect the launch window of ATV *Jules Verne*.

Space Infrastructure Development
ATV *Jules Verne* completed thermal vacuum testing at ESTEC and continued functional qualification testing in the Functional Simulation Facility (FSF) at the prime contractor's plant in Les Mureaux (F). Rendezvous and docking tests were completed in the Val de Reuil facility using a model of the ISS aft end and the ATV sensors. Several System Validation and Bilateral Interface tests (SVT, BIVP) were conducted using *Jules Verne* and/or the FSF, the ATV Control Centre and the Houston/Moscow ISS control centres. Joint integrated mission simulations are about to begin to validate the mission design and to train the flight and ground control crews. Discussions are under way with NASA on the potential purchase of one or more ATVs.

The Columbus module underwent a final functional system test at the Kennedy Space Center; payload rack final minor changes are being prepared before closing out the laboratory for flight. SVT2 was conducted for EuTEF, and SOLAR completed its qualification tests in readiness for a final SVT in late spring. Both payloads will be shipped to KSC by July in readiness for integration on the ICC-Lite carrier, to be launched with Columbus. Development of the other Columbus experiments, including GeoFlow, WAICO and FlyWheel are progressing well and are scheduled for delivery in time for installation in the module. The Columbus Control Centre and many of the USOCs have completed their qualification and acceptance processes (and supported Reiter's Astrolab mission).

Node-2 is in the final stages of preparation for launch in October, having completed the flush and fill of the Internal Thermal Control System. Node-3 completed its element leak test, Engineering Review and Preliminary Acceptance Review. Meanwhile, discussions concluded with NASA to transfer more work from KSC/Boeing to AAS-I in Turin. ATV *Jules Verne* underwent thermal vacuum testing at ESTEC. Phase-3 of the functional qualification programme began and 12 further tests were completed during February at the FSF. Node-3 will be launched, together with the Cupola (which is already at KSC), in early 2010.

Left: Thomas Reiter on his return to Germany after his 172-day mission. Right: Christer Fuglesang is greeted by Michel Tognini (Head of the ESA Astronaut Division) at the Kennedy Space Center following his landing after the Celsius mission

Rendezvous and docking tests were completed in the Val de Reuil facility using a model of the aft of ISS and the ATV sensors

SUCCESS student contest winners (from left): Daniel Brandt (second prize), Haakon Lindekleiv (first prize) and Cornelia Meyer (third prize)

Negotiations were completed covering the impact of a further delay to the launch of the European Robot Arm (ERA), which is now scheduled to be launched together with the Russian MLM module on a Proton rocket in late 2009.

The Technical Assessment Board for the Atomic Clock Ensemble in Space (ACES)-Space Hydrogen Maser (Swiss Clock, SHM) concluded, confirming SHM design feasibility and readiness to start development of the engineering and flight models. Close-out was concluded before the ACES Mission PDR board at the end of March. Phase-B began following negotiation on the proposal from Industry.

Utilisation

The first scientific reports from Astrolab indicate significant scientific achievements. Detailed data evaluation is in progress.

GRAVI, ESA's first experiment processed in the European Modular Cultivation System (EMCS) was successfully completed in Destiny. Development of the Multigen-1 experiment passed its Flight Safety Review and is on schedule for launch on Shuttle STS-118/13A.1. The experiment will investigate the effect of microgravity on *Arabidopsis thaliana* (thale cress) over a full life cycle, from germination to the next generate of seeds. Another challenging EMCS experiment, ROTIFIER-NEMATODES, is in Phase-C/D. It will study the developmental process in Nematode worms and Rotifers (small multi-cellular animals) through several generations onboard the ISS. Both experiments will use EMCS.

ANITA (Analysing Interferometer for Ambient Air) was removed from the ATV-1 manifest and formally manifested on STS-118 (13A.1). After testing at the NASA Johnson Space Center, ANITA was shipped to KSC for final 1F testing with the Express rack.

The first MELFI (Flight Unit-1, FU1) continues to operate normally in orbit. The draft Transfer of Ownership was delivered to NASA for review. Tests for certifying higher water inlet temperatures for FU2 and FU3 were completed.

A drop tower campaign for 'Miller-Urey in Microgravity Science Glovebox' experiments is earmarked for 29 May to 8 June at ZARM (D). The Catapult will be operational from mid-April, and will double the microgravity time available for study.

The SUCCESS contest, challenging European university students to think of original ideas for an experiment to fly on the ISS, was won by Haakon Lindekleiv (N). His planned research is into light flashes, the visual phenomena reported by many astronauts. He proposes to use a modified electroretinograph (ERG) to find out if the flash is caused by radiation passing through the eye or brain. Lindekleiv's prize is to spend a year working at ESTEC to prepare his experiment for flight on the ISS.

Astronaut Activities

Having been debriefed after their STS-116 mission, the crew visited Europe, starting in Sweden on 8 April and culminating at ESTEC on 18 April.

Training for Hans Schlegel is in full swing and included an EVA run with full Preparation and Post-EVA checks. He also completed a 6-hour Dual Glove Box run with a Shuttle thermal protection system repair in the vacuum chamber. Hans is slated to fly with Shuttle mission STS-122 to deliver Columbus to the ISS. Léopold Eyharts also continues training for launch on the same mission; STS-122 will deliver him to the ISS for a 2-month stay, returning on STS-123.

Paolo Nespoli is intensively training for mission STS-120, which will deliver and install Node-2 to allow further expansion of the Station. Launch is planned for October 2007.

Paolo Nespoli training at the NASA Johnson Space Center

Frank De Winne's training at the Johnson Space Center included specialist training on the Common Berthing Mechanism for docking Columbus.

The Expedition-15 crew continues ATV training at the Gagarin Cosmonaut Training Centre (Moscow). The Expedition-16 prime and backup crews underwent ATV part 1 training.

Exploration
ExoMars Phase-B1 continues apace, with Alcatel Alenia Space-Italy (AAS-I) building up its subcontractor team. Plans for a bridging phase from the end of B1 to the planned start of B2 were endorsed. The Systems Requirement Review was completed and preparations begun for the Implementation Review.

Discussion on Technical Assistance Agreements with NASA continues. Another ESA-Roskosmos interface meeting took place in March.

The Payload Confirmation Review for the Pasteur scientific payload was completed; model payloads were recommended to meet the different mass allocations associated with the various mission configurations. The proposal for the Geophysical Environment Package study began in mid-March; the contractors will present their findings during May.

A call for ideas for the NEXT exploration science and technology mission within the Aurora Exploration Programme was issued. A high number of proposals covering the different possible exploration targets were received. The outcome of the assessment will be presented to the HME advisory bodies before being submitted to the Programme Board. The selected ideas will be developed through internal ESA studies.

Vega

The Launch Vehicle CDR, the last major milestone of the Vega programme for 2006, began as planned on 20/21 December. The Zefiro-9, Zefiro-23 and Liquid Propulsion System CDRs have been completed.

Several development tests were performed during the reporting period: Upper Composite mechanical and acoustic tests; Zefiro-23 motor case hydro-proofing and mechanical test on the skirts; Fairing/AVUM separation test; preliminary phases of hardware-in-the-loop and Upper Composite electromagnetic compatibility tests.

The worksite in Kourou was opened and the first elements of the Mobile Gantry were delivered for integration to begin.

For the VERTA programme, a preliminary authorisation was issued to proceed for long-lead item procurement. This allows activities to begin aiming at the first VERTA flight, following the Vega qualification flight, by March 2009.

Soyuz at CSG

The Soyuz launch base construction site in Sinnamary, French Guiana, was officially inaugurated on 26 February.
A commemorative plaque was unveiled and a stone from the Soyuz pad in Baikonur was placed on the new site. Construction continues on schedule.

The CDR began on 5 March. This is a major milestone in the programme, to be followed later in 2007 by the Soyuz Ground Segment CDR.

FLPP

The Consolidated Contract integrating all remaining activities from FLPP-1 was signed in November 2006. The Authorisation to Proceed and the contract for the Expander Demonstrator were also signed.

For the IXV Experimental Vehicle, the sea landing option was finally chosen after a roundtable of European experts. IXV Phase-B2/C1 activities will soon begin, along with work on the Building Blocks System Concept Studies after industrial proposals have been received.

A review on Materials & Structures Part-2 activities at the end of October 2006 enabled the procurement of raw materials and the manufacture of various demonstrators.

In Brief

'Small GEO Satellite' Contract

ESA and OHB (D) signed the EUR100 million framework contract in Berlin on 28 March to develop the 'Small Geostationary Satellite' platform for telecommunication missions. The contract covers the first part of the initiative to define a general-purpose small geostationary platform that will enable European companies to compete in the commercial telecommunications market.

To achieve this, ESA has set up a new element under ARTES (Advanced Research in Telecommunications Systems). This ARTES-11 project was approved at the ministerial meeting of the ESA Council in December 2005.

Divided into two parts, the programme initially involves the development and manufacture of the first Flight Model of a generic bus. This work is included in the contract that was signed by Giuseppe Viriglio, ESA Director of Telecommunication and Navigation, and Prof Manfred Fuchs, CEO of OHB-System AG. The programme then involves the development, manufacture and launch of the first demonstration mission. The payload is due to be selected in late 2007 or early 2008 under an open tender process, for launch by the end of 2010.

The Small Geostationary Satellite will see its first launch by the end of 2010

The platform will accommodate a payload of up to 300 kg with power consumption of up to 3 kW over a 15-year mission.

The platform is being developed by a consortium headed by OHB that includes LuxSpace (L), the Swedish Space Corporation (S) and Oerlikon Space (CH). An industrial cooperation agreement between OHB and these companies was signed on 28 March in Berlin.

Mr Viriglio (far left), ESA's Director of Telecommunication and Navigation, congratulates Prof Manfred Fuchs, CEO of OHB-System AG, on the contract to develop a small geostationary platform

With this initiative, ESA is helping to broaden the product range of European industry by covering a market segment where there are no optimised European solutions.

esa

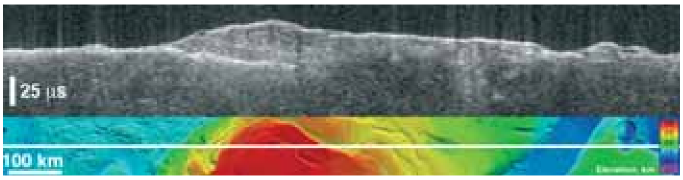
Mars Water

The amount of water trapped in frozen layers around Mars' south polar region is equivalent to a liquid layer about 11 m deep covering the planet. This new estimate comes from mapping the thickness of the dusty ice by the Mars Express MARSIS radar instrument that has made more than 300 virtual slices through layered deposits covering the pole. The radar sees through icy layers to the lower boundary, which in places is as deep as 3.7 km below the surface.

These deposits cover an area as wide as a big portion of Europe. The amount of water they contain has been estimated before, but never with the level of confidence this radar makes possible. MARSIS is also mapping the thickness of similar deposits at the north pole.

Polar layered deposits hold most of the known water on modern Mars, though other areas of the planet appear to have been very wet at times in the past. Understanding the history and fate of water on Mars is a key to studying whether the planet has ever supported life.

The deposits extend beyond and beneath a polar cap of bright-white frozen carbon dioxide and water at the south pole. Dust



The bright radar echo from Mars' south-polar layered deposits. The white line on the lower map traces the radar slice through the surface. (NASA/JPL/ASI/ESA/Univ. of Rome/MOLA Science Team)

darkens many of the layers. However, the strength of the echo that the radar receives from the underlying rocky surface suggests the composition of the layered deposits is at least 90% frozen water. One area with an especially bright reflection from the base of the deposits puzzles researchers. It resembles what a thin layer of liquid water might look like to the radar instrument, but the conditions are so cold that the presence of melted water is deemed to be highly unlikely. esa

Venus Express Milestone

Venus Express, Europe's first mission to Venus and the only spacecraft now in orbit around the planet, passed the first anniversary of its arrival on 11 April. In its first year of observations, Venus Express has been revealing details never seen before.

The orbiter is studying the noxious and restless atmosphere and the interaction with the solar wind and the interplanetary environment. It is also looking for signs of surface activity, such as active volcanism.

"*During one year of observations, we have already collected a huge amount of data, which is exactly what we need to decode the secrets of an atmosphere as complex as that of Venus*," said Håkan Svedhem, Venus Express Project Scientist. "*Analysing it is an extreme effort for all science teams, but it is definitely paying back in terms of results.*"

The stunning first global views of the double-eyed vortex at Venus' south pole, the first sets of 3-D data on the structure and the dynamics of the sulphuric-acid clouds surrounding the planet in a thick curtain, temperature maps of the surface and the atmosphere at different altitudes are a few of the results so far.

"*On the basis of what we were able to see so far, there is no doubt that Venus Express will eventually allow a better global understanding of this planet*," said Svedhem. "*Not only will planetary science in general benefit from this, but also understanding Venus – its climate and atmospheric dynamics –will provide a better comprehension of the mechanisms that drive long-term climate evolution on Earth.*"

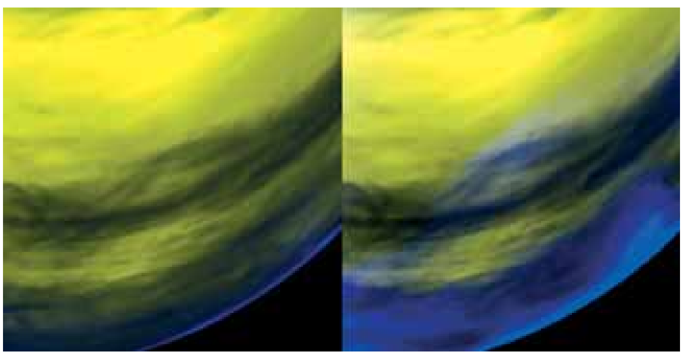
New infrared data are now available about Venus' oxygen airglow – a nightside feature that makes the planet glow like a 'space lantern'. "*The oxygen airglow was discovered by ground observations, and observed by other missions to Venus such as the Russian Venera spacecraft and the US Pioneer Venus Orbiter*," said Pierre Drossart, Co-Principal Investigator on Venus Express' VIRTIS instrument. "*However, the global and detailed view we are getting thanks to Venus Express is truly unprecedented.*"

The airglow is generated when oxygen atoms recombine into molecules and fluoresce in the process. At high altitudes on the dayside, the strong ultraviolet radiation from the Sun liberates oxygen atoms from the ubiquitous carbon dioxide. Atmospheric circulation spreads these atoms to the nightside, where they migrate down and combine into oxygen molecules.

Studying the airglow and its evolution is important. "*First, we can use the distribution and motion of these fluorescent oxygen 'clouds' to understand how the atmospheric layers below move and behave*," said Giuseppe Piccioni, the other Co-Principal Investigator on VIRTIS. "*In this sense, the airglow is a real tracer of the atmospheric dynamics on Venus.*"

"*Second, it provides new clues on how the global atmospheric chemistry works – a very challenging task indeed, and still an open field of research. By calculating the speed at which this chemical recombination takes place, we might be able to understand if there are mechanisms that favour it, and learn more about the production and recombination of the other chemical species.*"

"*Third, the observation of the airglow also allows a better understanding of the global energy exchange between the mesosphere, where the airglow occurs, and the thermosphere, an even higher layer directly influenced by the Sun.*" esa



This false-colour view from VIRTIS reveals the oxygen airglow (in blue) in the nightside atmosphere of Venus. (ESA/VIRTIS/INAF-IASF/Obs. de Paris-LESIA)

EO Symposium

In late April in Montreux (CH), more than 900 scientists attended 'Envisat Symposium 2007' to discuss results from ESA's Earth observation satellites, with the emphasis on Envisat. Generating some 280 GB of data products daily, Envisat has gathered 500 TB to date and recently achieved 5 years of operations.

Almost every field of Earth science was highlighted, including greenhouse gas concentrations, ozone hole monitoring, sea-level rise, sea-surface temperature, ice-sheet and sea-ice variations, volcanoes, earthquakes and land cover changes. Around 800 presentations were made during 54 themed sessions.

A session was dedicated to the use of Earth observation in support of International Environmental Conventions in close collaboration with United Nations agencies, the World Climate Research Programme and the International Geosphere-Biosphere Programme and other key international and European institutional actors, such as the European Environment Agency. A special session was held on the GMES programme. esa

Russian Cooperation

Europe and Russia are strengthening their cooperation in space. The Head of Roscosmos, Anatoly Perminov, ESA Director General, Jean-Jacques Dordain, and European Commission Director General, Heinz Zourek, met in Moscow on 21 March as part of the Tripartite Space Dialogue between the European Commission, ESA and Roscosmos.

Set up in March 2006 in Brussels, the Space Dialogue initiative encompasses space applications (satellite navigation, Earth observation and satellite communications), access to space (launchers and future space transportation systems), space science and space technology development.

"*Space cooperation is an important element in overall Europe-Russia cooperation. This meeting has proved very useful as concrete work plans have been established,*" said Mr Dordain. "*The cooperation between Europe and Russia in the area of launchers should serve as a model for cooperation in other areas such as exploration, space science and space applications. If the two sides pool their resources, the result will be even more outstanding than it is today.*"

In Earth observation, for instance, the parties engaged in setting up a specific data-exchange mechanism. For satellite navigation, compatibility and interoperability between Russian and European systems will be addressed. For space communications, the parties agreed to promote applications reaching out to other entities that are not necessarily involved in space.

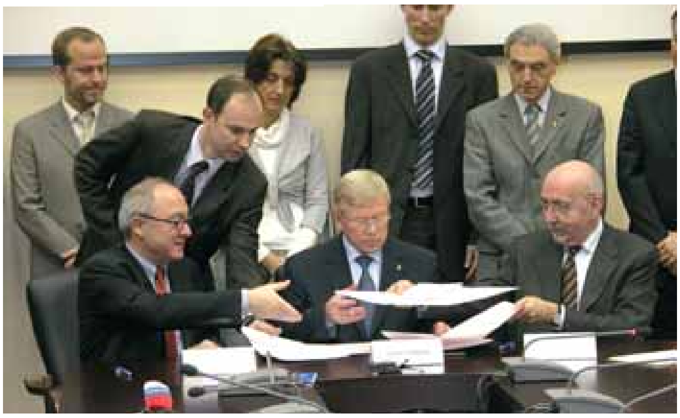
Russia will provide a gamma-ray and neutron spectrometer instrument to ESA's BepiColombo mission to Mercury. Russian scientists have been invited to respond together with European colleagues to the call for proposals for the first planning cycle of the new Cosmic Vision 2015–2025 issued by ESA (see below).

In the launchers domain, the two sides are concentrating on Soyuz launches from the Guiana Space Centre, while looking into technologies for future launchers.

Discussions are also being held on the next generation of crew vehicles, with possible ESA involvement in an Advanced Crew Transportation Vehicle to be tabled for decision at the ESA Ministerial Council in 2008.

The European Commission, within the European Union's 7th Research Framework Programme, will offer to provide targeted information on space-related topics to Russian space experts. esa

From left to right: Jean-Jacques Dordain, Anatoly Perminov and Heinz Zourek met at Roscosmos in Moscow



Closer to Cosmic Vision 2015–2025

Enthusiasm and a large number of responses from the European scientific community marked the first step in defining ESA's Cosmic Vision scientific programme for 2015-2025. "*The future starts today*," said Director General Jean-Jacques Dordain, addressing the community on 11 April.

By the end of March, ESA had received more than 60 'Letters Of Intent' from European space science teams expressing their intentions to submit detailed proposals for new missions by 29 June 2007.

The mission concepts range from the exploration of Jupiter and its satellite Europa, to satellites studying radiation from the Big Bang and testing theories concerning the inflation of the Universe. They include missions studying near-Earth asteroids, satellites looking for liquid water on Saturn's moon Enceladus and spacecraft to verify the truth about gravity as one of the fundamental forces of Nature.

"*Since the moment we consulted the scientific community to define the big scientific themes of our programme in 2004, it was clear that ESA – with its wealth of missions that came or are about to come to fruition – has been creating an incredibly positive momentum for space science in Europe and worldwide*," commented David Southwood, ESA Director of Science.

"*Successful scientific missions such as those we have flown so far have increased ESA's overall recognition and inspired the public. As such, they have made ESA a symbol of Europe's achievements*," said Mr Dordain during the opening of the briefing to the large group of scientists who had submitted their preliminary concepts.

ESA astronaut Hans Schlegel trains for his December Shuttle mission. A revised launch schedule announced in mid-April for the Space Shuttle provides confidence that Europe's Columbus laboratory module will be attached to the International Space Station before the end of the year. STS-117 is aiming for 8 June and STS-118 for August. Originally scheduled for August, the STS-120 mission with ESA astronaut Paolo Nespoli is now targeted for 20 October. He will accompany the Node-2 connecting module. STS-122, with Columbus and ESA astronauts Schlegel and Leopold Eyharts, is due for launch on 6 December. Eyharts will remain aboard the Station for a long-duration mission.

"*The future of European science is the result of successful alchemy between your ideas and competence, and ESA's ability to deliver within resources, space projects that make your ideas come true. Not only have we demonstrated that we are a reliable partner who always sticks to its commitments, but also we have become an example for the world through the European and international dimension we give to our projects.*

"*The future we are looking at also includes an ever improving relationship with you – European scientists – and with national and international agencies. We are also trying to convince our Member States to capitalise on the success of the scientific programme – the Agency's only mandatory programme – by creating new synergies with other ESA activities, such as technology and exploration.*"

ESA must receive the detailed mission proposals by 29 June. Starting in October 2007, until mid-2009, ESA's Space Science Advisory Committee and scientific working groups will assess the proposals and pre-select three 'class-M' and three 'class-L' missions. M missions are medium-size projects, where the costs to ESA do not exceed EUR300 million. L missions are larger projects, with cost envelopes not exceeding EUR650 million.

By the end of 2009, out of these missions plus LISA, two class-M and two class-L missions will be shortlisted for definition (Phase-A). This phase will be run by European industries on a competitive basis between the beginning of 2010 and mid-2011. By the end of 2011, one class-M and one class-L mission will be adopted for launches in 2017 and 2018, respectively.

Closer to European Space Policy

On 26 April, the College of European Commissioners in Brussels adopted a 'Communication' on the European Space Policy jointly drafted by the EC and ESA's Director General. Over the past 2 years, the two organisations have been working to establish a comprehensive political framework to develop and exploitat space technologies and systems, so that individual investment decisions can be taken to maximise the benefits from space. As a next step, the European Space Policy will be presented by ESA's Director General as a proposal at the next delegate-level meeting of ESA's ruling Council on 9 May. Finally, it will be tabled for endorsement by Ministers on 22 May in Brussels at the 4th Space Council.

Commenting on the adoption of the Communication, Commission Vice-President Günter Verheugen, responsible for enterprise and industry policy, said, "*Space is strategic for our future. It gives us the tools to address many challenges of the 21st Century. Space systems and satellites are key assets in assessing global problems and helping us overcome them. Space also contributes significantly to our daily life.*"

ESA's Director General, Jean-Jacques Dordain, said, "*For over thirty years, the Agency has been successfully developing space systems and infrastructures. We are eager to consolidate this success story in responding to the new challenges of the European Space Policy and in working with the European Commission to develop the application of space systems in support of Europe's policies.*"

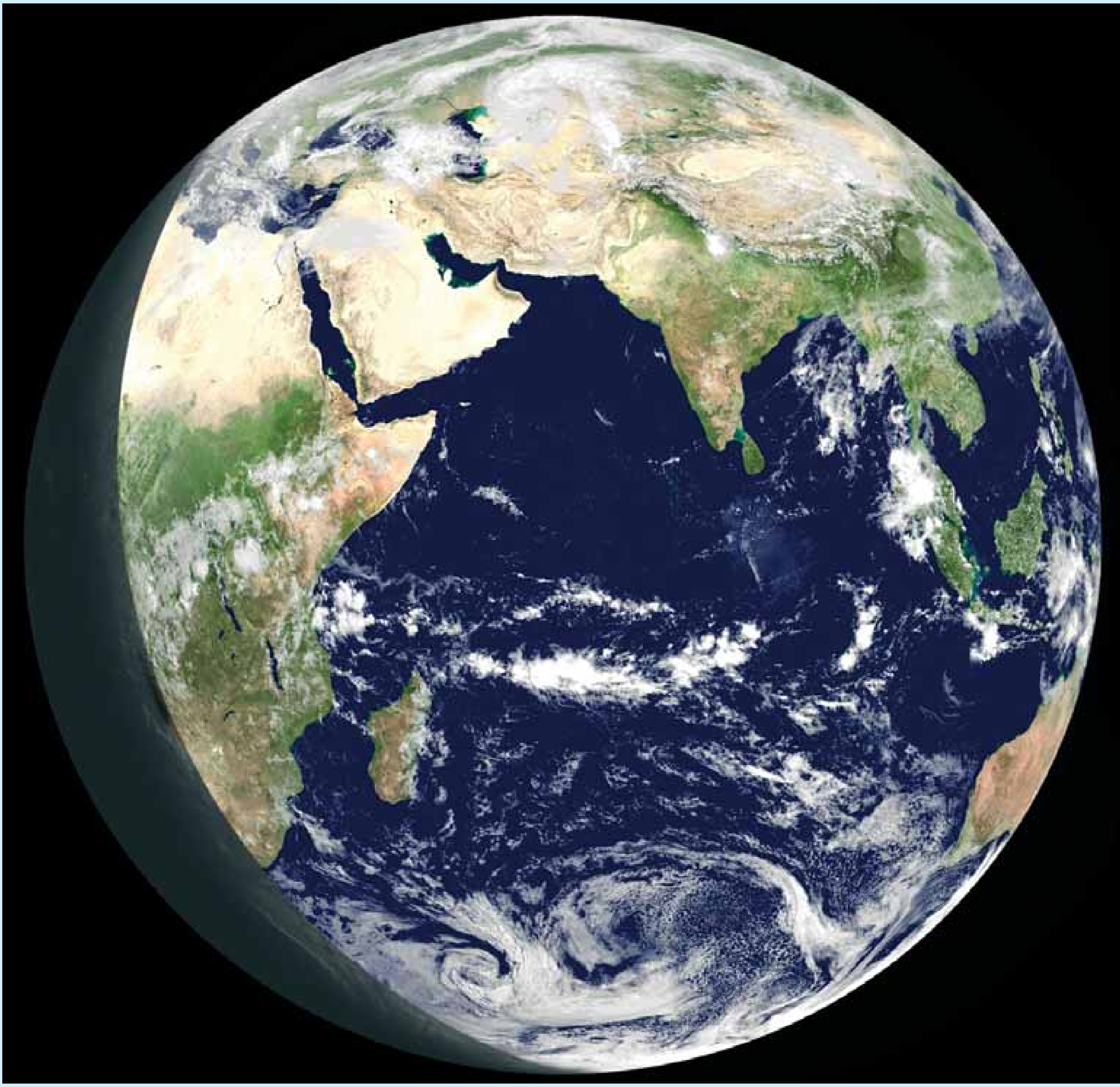
Europe is a global actor and is increasingly playing a leading role in global policies. Space will increasingly serve Europe's domestic and global policy needs and it can also help to achieve further important European policy objectives. Environmental policy and in particular the European response to global climate change is a striking example. Others are security, transport, research, agriculture, fisheries and development aid.

The Communication on the European Space Policy aims to:
- foster better coordination of civil space programmes between the EU, ESA and their respective Member States to ensure value for money and eliminate unnecessary duplication, thus meeting shared European needs;
- increase synergy between civil and defence space programmes and technologies, in particular interoperability of civil/defence systems;
- ensure sustainable funding for space applications, in particular the flagship Global Monitoring for Environment and Security;
- ensure that space policy is consistent with, and supports, the EU's external relations. The EU, ESA and their Member States will put in place a coordination mechanism to develop a joint strategy for international relations.

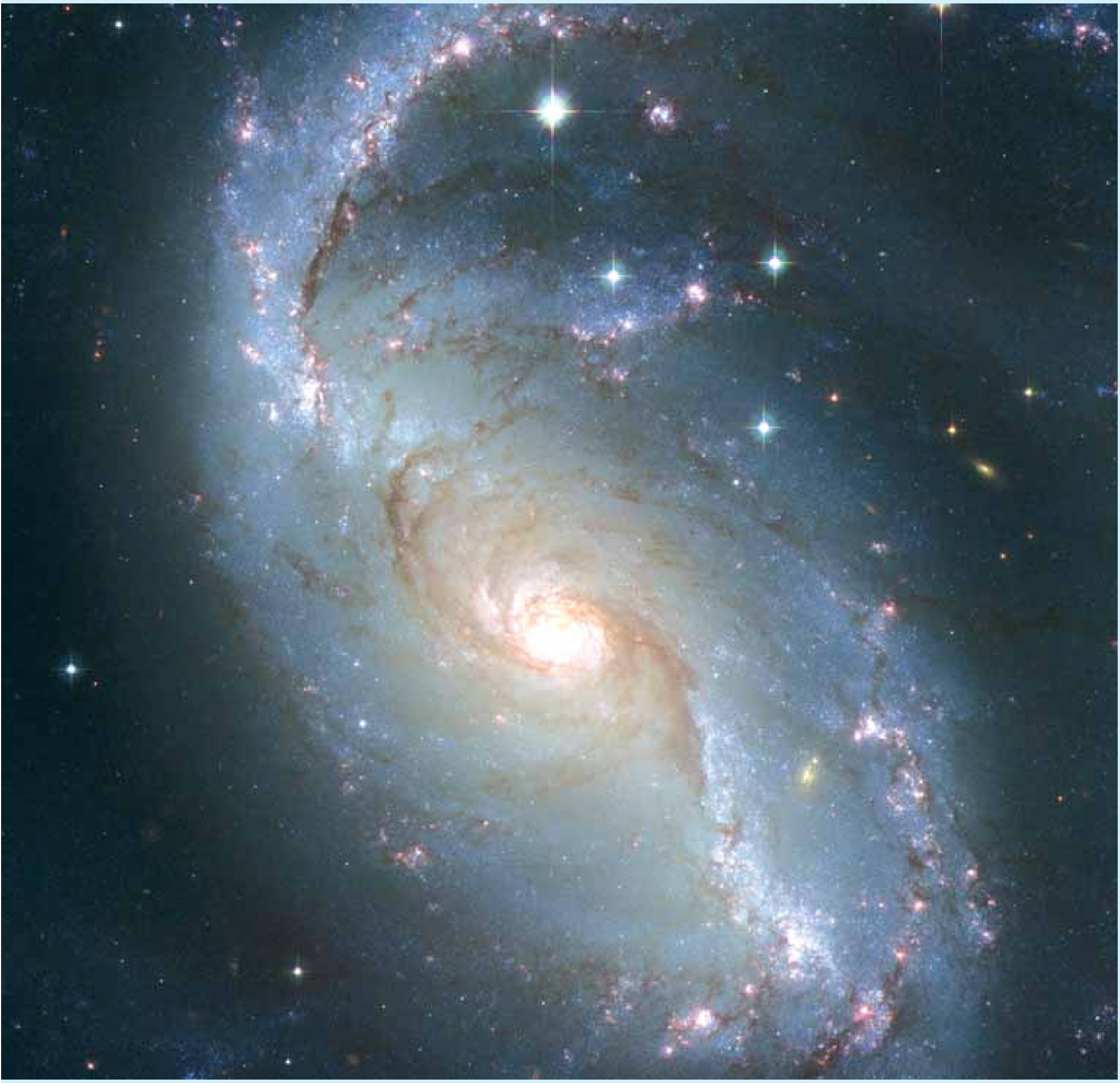
Space is also a high value-adding sector, a driver for growth and employment and a valuable opportunity-provider for European industry.

Vietnam's Mekong Delta is highlighted in this Envisat /MERIS image, captured on 6 February. The Mekong River is the longest in Southeast Asia and the twelfth in the world. Rising in the Himalayas, it flows through six nations on its 4800 km journey to the South China Sea, supporting around 90 million people. The river splits into nine arms, leading the Vietnamese to refer to it as Cuu Long, 'the nine-tailed dragon'. At the end of its course, the tropical wetlands of the Delta are supplied with rich alluvial deposits from the 475 000 cubic km of water the river discharges each year. This tannish-coloured silt is clearly seen flowing out into the sea. The Delta soil is so fertile that the area is home to 15 million people and Vietnam has become one of the world's leading rice exporters. The intense green of cultivated rice paddies can be seen across the Delta, threaded through by an intricate web of irrigation and drainage canals.

The first Ariane-5 launch of 2007 took place on 11 March, when the ninth Ariane-5 ECA vehicle (V175) lifted off from Europe's Spaceport in French Guiana at 22:03 UT on its mission to place two satellites into geostationary transfer orbits. The satellites were accurately injected into the correct transfer orbits about 30 minutes later. The payload comprised Skynet-5A, a secure telecommunications satellite for the British armed forces, and Insat-4B, which will provide fixed television and telecommunications for the Indian subcontinent. By the time this issue of the *Bulletin* is published, the tenth Ariane-5 ECA should have been launched. Galaxy-17 will provide telecommunications and television coverage over North America for Intelsat, while Astra-1L will provide direct-to-home TV coverage over Europe. Arianespace is targeting six flights in 2007 as it builds to a steady rate of eight annually by 2009. *(ESA/CNES/Arianespace-Service Optique CSG)*



The last operational image from Meteosat-5, taken on 16 April 2007. After more than 16 years in service providing meteorological data, the satellite retired on 26 April. Meteosat-5 served as the primary satellite over Europe until 1997; in 1998 it was relocated over the Indian Ocean where it provided valuable information for forecasting cyclones and severe storms affecting coastal regions. Following the Asian tsunami disaster at the end of 2004, Meteosat-5 was used in a new tsunami warning system: it relayed signals from several buoys placed in the Indian Ocean by the University of Hawaii. The new service was introduced only 2 months after the tragedy as a valuable contribution towards mitigating further disasters. By 20 April, the satellite had exhausted its propellant to raise itself 500 km above the geostationary ring so that it does not pose a collision threat to operating satellites. *(Eumetsat)*



This Hubble Space Telescope image of barred spiral galaxy NGC 1672 reveals clusters of hot young blue stars along the spiral arms and clouds of red-glowing hydrogen gas. Delicate curtains of dust partially obscure and redden the light of the stars behind them. Astronomers believe that barred spirals somehow channel gas from the disc towards the nucleus. This allows the bar portion of the galaxy to serve as an area of new star generation. NGC 1672 is a 'Seyfert' galaxy, which sometimes have nuclei that outshine their host galaxies. The active galaxy family include the exotically named quasars and blazars. Although each type has distinctive characteristics, they are thought to be all driven by the same engine – supermassive black holes – but are viewed from different angles. The image was recorded with Hubble's 'Advanced Camera for Surveys' in August 2005 but released only recently. *(NASA/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 Brochures

GOCE (German, April 2007)
H. Rider, M. Rast & B. Battrick (Eds.)
ESA BR-209/D // 16 pp
Price: 10 Euro

Galileo: I primi satelliti – GIOVE (Italian, March 2007)
A. Wilson (Ed.)
ESA BR-251/I // 20 pp
Price: 10 Euro

Mobile Multimedia for Cars (2007)
B. Battrick (Ed.)
ESA BR-264 // 4 pp
No charge

ESA Special Publications

Proceedings of the 3rd International GOCE User Workshop, 6–8 November 2006, Frascati, Italy (February 2007)
K. Fletcher (Ed.)
ESA SP-627 // CD
Price: 40 Euro

Proceedings of the 3rd International Conference on Green Propellant for Space Propulsion and 9th International Hydrogen Peroxide Conference, 17–20 September 2006, Poitiers, France (December 2006)
C. Walker (Ed.)
ESA SP-635 // CD
Price: 50 Euro

Proceedings of the Second Solar Orbiter Workshop, 16–20 October 2006, Athens, Greece (October 2006)
R. Marsden & L. Conroy (Eds.)
ESA SP-641 // CD
Price: 50 Euro

Proceedings of the Third Workshop on the Atmospheric Chemistry Validation of Envisat (ACVE-3), 4–7 December 2006, ESRIN, Frascati, Italy (February 2007)
D. Danesy (Ed.)
ESA SP-642 // CD
Price: 50 Euro

Workshop on Dust in Planetary Systems, 26–30 September 2005, Kauai, Hawaii (January 2007)
A. Wilson (Ed.)
ESA SP-643 // 264 pp
Price: 50 Euro

ESA Scientific & Technical Memoranda

The ACT Distributed Computing Environment v. 2.3 – Administrator's Guide and Instructions for Further Development (January 2007)
C. Walker (Ed.)
ESA STR-253 // 68 pp
Price: 20 Euro

ESA Training Manuals

InSAR Principles: Guidelines for SAR Interferometry Processing and Interpretation (February 2007)
K. Fletcher (Ed.)
ESA TM-19 // 246 pp
Price: 40 Euro

ESA Contractor Reports

Large 650 Litre Propellant Tank – Final Report (July 2006)
EADS Astrium, UK

ESA CR(P)-4569 // CD
Price: 25 Euro

RF Product Family for Telecommunications – Executive Summary (October 2006)
Alcatel Alenia Space, Belgium
ESA CR(P)-4570 // CD
Price: 25 Euro

Working with ESA Telecom V.3 – Executive Summary (January 2007)
ARTES E-Training
ESA CR(P)-4571 // CD
Price: 25 Euro

Cell Inspection Criteria based on Electroluminescence (CIEL) – Final Report (November 2006)
EADS Astrium, Germany
ESA CR(P)-4572 // CD
Price: 25 Euro

ESA Telecom ARTES-3 Project – PERUSE – Personal Safety System Utilising Satellite Combined with Emerging Technologies – Executive Summary (January 2007)
Securecom
ESA CR(P)-4573 // CD
Price: 25 Euro

Innovative Satcom Security Services for Ships – Executive Summary (January 2007)
Novacom Services
ESA CR(P)-4574 // CD
Price: 25 Euro

ConeXpress Orbital Life Extension Vehicle – Executive Summary (February 2006)
Dutch Space, The Netherlands
ESA CR(P)-4574 // CD
Price: 25 Euro

An Airborne Satellite Terminal for Navigation and Communication, BIRDCOM – Final Report (December 2005)
Space Engineering
ESA CR(P)-4567 // CD
Price: 25 Euro

ARTES 4 – ESA-Industry Partnership Programme – CASIMO – Carrier Signal Monitoring – Final Report (September 2006)
Siemens AG, Austria
ESA CR(P)-4577 // CD
Price: 25 Euro

750W ODU Satcom Amplifier Platform Development – Final Report (May 2006)
E2V Technologies, UK
ESA CR(P)-4578 // CD
Price: 25 Euro

Echostar LNB Phase 2 (March 2006)
Invacom, UK
ESA CR(P)-4579 // CD
Price: 25 Euro