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bulletin

SPACE FOR EUROPE

Cassini-Huygens Closes in on Titan

European Space Agency
Agence spatiale européenne

european space agency

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

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

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

The Agency is directed by a Council composed of representatives of 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:

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

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

ESRIN, Frascati, Italy.

Chairman of the Council: P. Tegnér

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, l'Irlande, l'Italie, la Norvège, les Pays-Bas, le Portugal, le Royaumi-Uni, la Suède et la Suisse. Le Canada bénéficie d'un statut d'Etat coopérant.

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

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

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

Le SIEGE de l'Agence est à Paris.

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

ESRIN, Frascati, Italy

Président du Conseil: P. Tegnér

Directeur général: J.-J. Dordain

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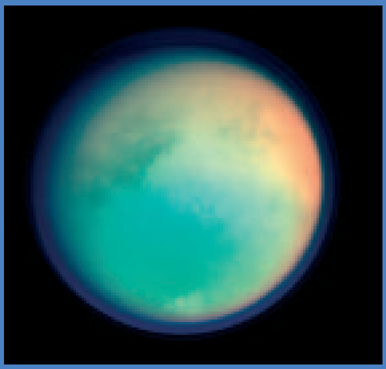
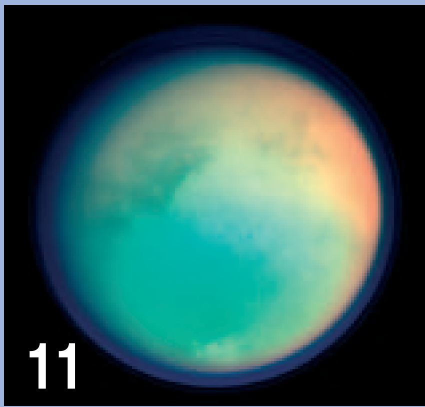
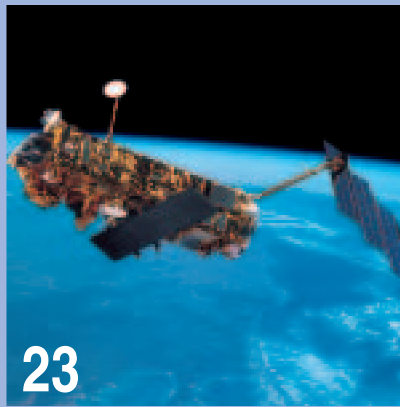


Cover: *Saturn's moon Titan as seen by Cassini-Huygens on 26 October 2004. See article on page 11.*

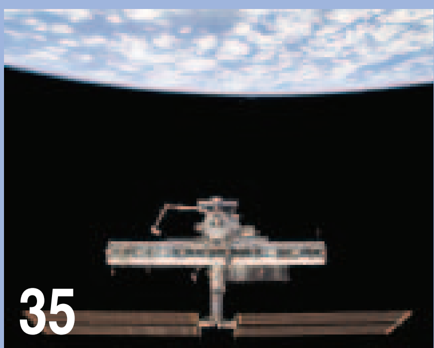


High Ambitions for an Outstanding Planetary Mission: Cassini-Huygens

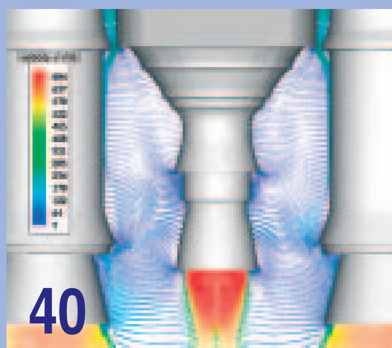


Mapping Forest-Fire Damage with Envisat

Following the Tour de France with EGNOS



Sharing ESA's Knowledge and Experience



Modelling Launcher Aerothermodynamics

Enlarging ESA?

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Jean-Jacques Dordain

ESA's Recent Achievements

A great deal has been happening in the space world, particularly in the European context, since I last addressed the Bulletin's readers. The last year has been a very busy and important one for ESA missions, especially within the Scientific Programme. We have launched SMART-1, which went into orbit around the Moon on 15 November, we are already orbiting Mars with Mars Express, we have launched Rosetta towards the comet, and the Huygens Probe will be landing on Saturn's largest moon, Titan, in mid-January. We have sent two European astronauts for stays onboard the International Space Station (ISS) during the year. We have also been preparing the Ariane-5 ECA launcher for a new qualification flight in January 2005.

We also continue to work hard on exploiting the vast amounts of data that our satellites are providing. We have 17 scientific satellites currently operating. On the applications side, ERS-2 and Envisat continue to provide crucial and timely Earth-observation and environmental data in this era of serious concern about global warming. In early September, ESA hosted the 2004 Envisat and ERS Symposium and there were more than one thousand scientists in attendance from 53 countries, showing that the data from our satellites are being used by scientists not only from Europe, but from all over the World.

The political perception of space has improved a great deal in the last year, thanks in large part to the benefits that these data from our satellites are seen to be providing.

The New Member States

A concrete example of the changing political perception is the fact that ESA has recently acquired two new Member States, with Luxembourg having signed an accession Agreement in June, and Greece in July. They will become full working members of the Agency next year and we very much look forward to their active participation. The implications of their joining and of further possible future enlargement of the Agency's membership are addressed in detail in one of the articles in this issue of the Bulletin.

ESA and the European Union

ESA's institutional relationship with the European Union has also progressed substantially in 2004, with the Framework Agreement signed in November having been in force since May this year. This Agreement provides the foundation on which to build joint activities with the EC. Moreover, the new EU Treaty includes space among the Union's competences, which is major step forward in that space is now regarded as a serious issue for Europe's citizens and no longer just the playground of a few inquisitive scientists and wily engineers. ESA is mentioned in the new Treaty and this is highly important, because it represents the first step towards what in Agenda 2007 I have called 'legitimacy among the European Union institutions'. It is a small step for now, but a 'giant leap' for the future. In fact, the Commission's White Paper on Space has taken some of its inspiration from Agenda 2007.

The latest step towards a closer working relationship between ESA and the EC is the setting up of a joint Secretariat, which is already busy preparing for the first meeting of the joint Space Council, scheduled for 25 November this year. This will be a very important event, because it will be the first time that the EC and ESA Councils meet together to discuss space policy and the future of space in Europe.

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Progress in Implementing Agenda 2007

Apart from the highly successful missions and the closer relationship with the EU already mentioned, we have also made good progress towards achieving the other objectives that I set for the strategic reform of the Agency in Agenda 2007, published in October last year (ESA BR-213).

In addition to maintaining the momentum of its ongoing scientific and applications programmes, the Agency has to be open to change if it is to remain an optimised organisation in an environment that increasingly needs its services, skills and knowhow. As a leading-edge R&D organisation, it needs to adapt continuously to respond to the emergence of new user communities, the introduction of new commercial and public services, the arrival of new operators, and the growing dependence of Europe's citizens on space-enabled systems and services.

In this context, solid progress has been made through the launching of several new initiatives. I was concerned by the fact that the majority of ESA's activities were becoming too much driven by decisions taken some years ago and I have therefore tried to open new doors by setting three priorities for the future.

The first one is in telecommunications. Telecommunications is a very important field for us because it is one of increasing demand, not only from the public sector, but also for telemedicine and safety and security related applications. Increased demand for commercial broadband telecommunications services is also driving an acceleration of the space telecommunications initiative, and here satellites can make a significant contribution. Telecommunications is also a domain in which European industry has already had a lot of success, not only via the space manufacturing industry, but also the telecommunications operators, two of the largest of which are SES Global, based in Luxembourg, and Eutelsat, which has its headquarters in Paris.

The second priority is Global Monitoring for Environment and Security, or GMES. The environment and security are two of the biggest concerns of Europe's citizens, and ESA has been working with the European Commission during the last three years to build an implementation plan. The time has now come to implement that plan, based on the concrete results that we have already achieved in Earth Observation, especially with ERS and Envisat.

Together, the GMES and Telecommunications initiatives provide the foundation upon which further developments responding to the demands of the European security and defence policy can be built.

The third priority on the list is Exploration. It is a very important priority for our future for many reasons, providing the basis for enhanced scientific benefits as well as for robust European participation in future large international cooperative space programmes beyond the lifetime of the ISS. Europe has always been highly successful in this domain, as our scientific missions have proved time and time again, and it is one that has a new momentum, created in part by the latest initiative of President Bush. Europe is going to the Moon, we are orbiting Mars, we are orbiting Saturn, and we are about to land on Titan. So we are not building our future on dreams, we are building it on results.

The GMES preparatory activities were approved at the last meeting of the Agency's Earth Observation Programme Board, and on the Exploration side the Declaration for the Aurora Programme has been opened for subscription and we are making progress in attracting more contributions. We are also currently busy securing agreement from the Member States for the planned preparatory activities in Telecommunications.

The three new initiatives have not been defined in isolation and they correspond to the priorities defined in the European Commission's White Paper on Space issued last November. The various preparatory activities have been also been proposed after active consultation with the EC and Member States in June this year. All of this means that we are much better placed today than one year ago in terms of preparing Europe's future in space.

In terms of ESA's internal operations also, we have made significant progress since the unanimous support in the December Council for my new organisational structure. In June, the Council also endorsed the Resolution on the next step in the reform of ESA's financial system, which will provide us with much greater budgetary flexibility year on year, not least in the way the geographical-return rules are applied. The many benefits that this will provide for the Agency's Industrial and Procurement Policy are described in more detail in one of the article's in this Bulletin.

New Directorate Structure and Directors

Europe's enlargement and the expansion of its areas of competence make it incumbent on ESA to meet ambitious, challenging objectives over the next four years. For ESA to succeed in meeting those objectives and the mission entrusted to it by its Member States, it was essential for me, in the context of Agenda 2007, to establish a new organisational structure.

The three main features of the new organisational structure are as follows:

– A collegial management with a strong Committee of Directors driving the organisation towards one ESA.
– A stronger relationship with the EU institutions through the creation of a Programme Directorate dedicated to EU

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and Industrial Programmes, in addition to the Earth Observation Programme Directorate in charge of GMES, and a Director General's Cabinet in Brussels.
– A streamlined relationship between the Programme Directorates and the Support Directorates, based on Project Plans constituting the basis for human, technical and financial resource planning.

Having fully supported this proposed new structure last December, in March the Council appointed the corresponding team of Directors:

– Volker Liebig : Earth Observation Programme (D/EOP)
– Giuseppe Viriglio : EU and Industrial Programmes (D/EUI)
– Jean-Pol Poncelet : External Relations (D/EXR)
– Daniel Sacotte : Human Spaceflight, Microgravity and Exploration Programmes (D/HME)
– Antonio Fabrizi : Launcher Programme (D/LAU)
– Gaele Winters : Operations and Infrastructure (D/OPS)
– Hans Kappler : Resources Management (D/RES)
– David Southwood : Science Programme (D/SCI)
– Michel Courtois : Technical and Quality Management (D/TEC).

We are already working very hard together to achieve the ambitious goals laid down in Agenda 2007!

What are the priorities for end-2004/ early 2005?

In the light of the programmatic and financial developments in 2004, the objectives for 2007 are still the same, but I have found it necessary to change some of the priorities associated with Agenda 2007 for the short term in what are deemed key areas for ESA's future. These revised priorities are as follows:

Priority 1: Further reinforce control over the ongoing large programmes, namely Ariane, the ISS and Galileo, in order to manage the associated risks, not all under the control of ESA, and not jeopardise the future because of the current risks.

Priority 2: Implement preparatory activities for the three priority initiatives for the future, namely GMES, Telecommunications and Exploration, and formulate the necessary high-quality programme proposals in order to convince all Member States of their value and maturity for decisions to be taken at the end of next year.

Priority 3: Renew ESA's ambitions in terms of the development of new technologies, as an innovation factor, as a competitiveness factor, and as a key to the consolidation of Europe's industrial capabilities, without which there would be no space activities. Agenda 2007 puts a lot of reliance on technology programmes, and there is no time to lose in putting in place a new way of defining and implementing those technology programmes.

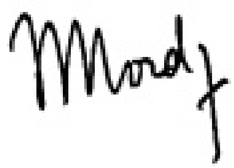
Priority 4: Develop a Long-Term Plan both as a strategic tool and an instrument for dialogue with Delegations. It must give clear priorities for the future, while taking into account the resources required for completing already approved programmes, including margins to cover a risk-management approach

Priority 5: Pursue the internal reform of ESA by prioritising objectives and by modifying reflection processes, in order to limit staff time and energy dedicated to this reform, yet still put in place corporate-level tools that are reliable enough to make sure that we can drive the overall organisation forward effectively and efficiently.

Major Events in the Coming Months

We have a lot of missions in the ESA calendar for next year, which will keep us extremely busy. After the imminent launch of Ariane-5 ECA, we have the descent and landing of Huygens on Titan in January. Then we have the launch of Cryosat in March, which is the first in the series of five Earth Explorer missions. ESA astronaut Roberto Vittori will visit the ISS in April, and the second of the Meteosat Second Generation spacecraft will be launched in June. Just a few months later, there will be the first launch of the ATV to the ISS in October, the launch of Venus Express also in October, and the MetOp-2 launch before the end of the year.

There are currently a number of niggling concerns within the Agency, especially surrounding the three major programmes, but I believe that with the progress that we have made in recent months we shall soon be able to put the present difficulties firmly behind us. The present may be a difficult time in space, but when you look to the menu of launches and missions that we have in store for 2005, as well as the prospects offered by our closer relationship with the EU, it is hard to see anything other than a bright future.



Jean-Jacques Dordain
Director General

ESA's remarkable record places it in the front rank of space organisations, generating enormous benefits for its Member States and their citizens. The Agency has been responsible for developing systems that are now accepted as everyday – and profitable – parts of our lives. In the decades ahead, ESA will be presented with even more challenges and opportunities to enhance the lives of millions of citizens through the transformation of Europe's economic, scientific and technological capabilities.

This ESA brochure highlights the broad sweep of the Agency's current and future missions up to the end of 2007.

THE SPACE DIMENSION – ESA BR-190
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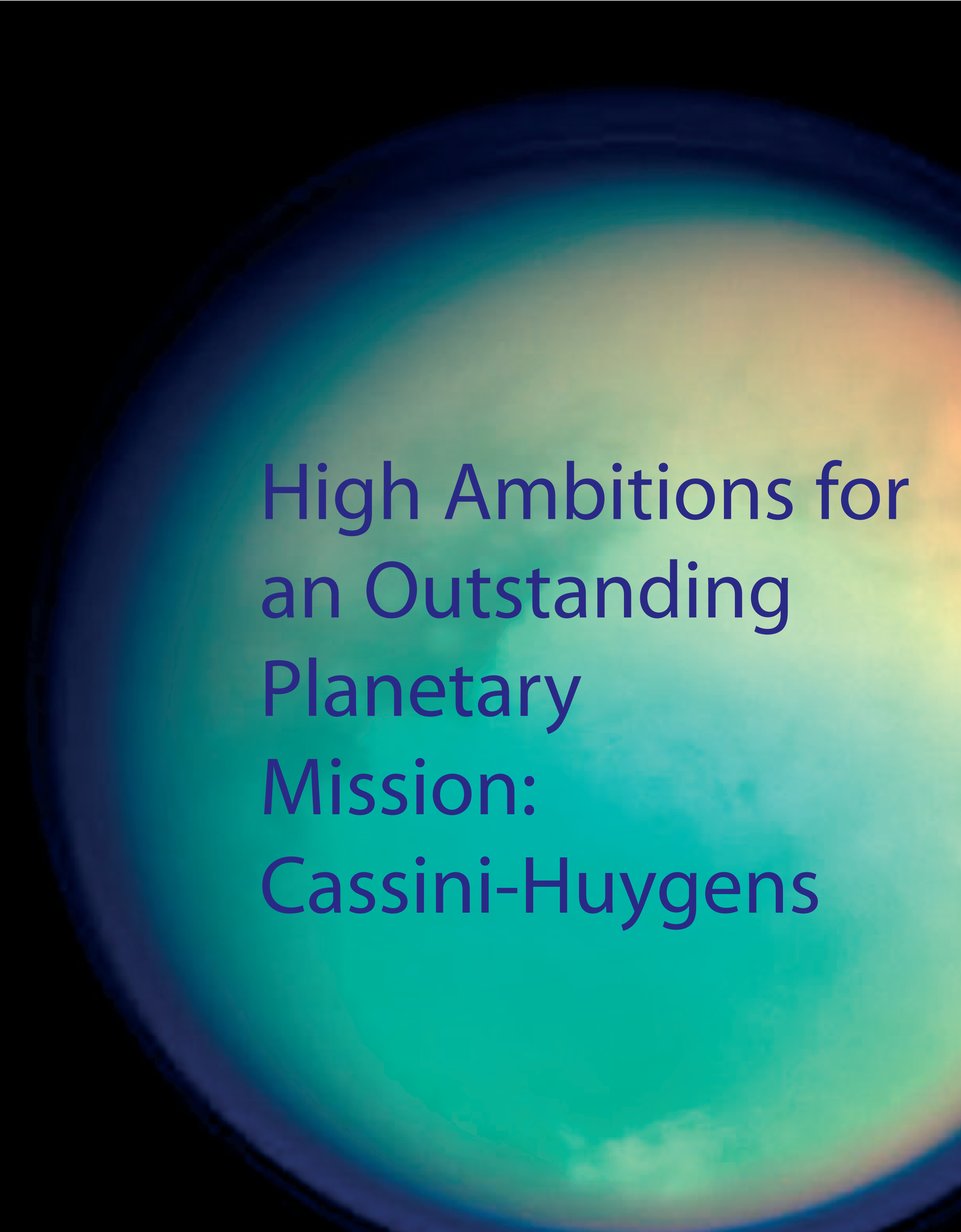
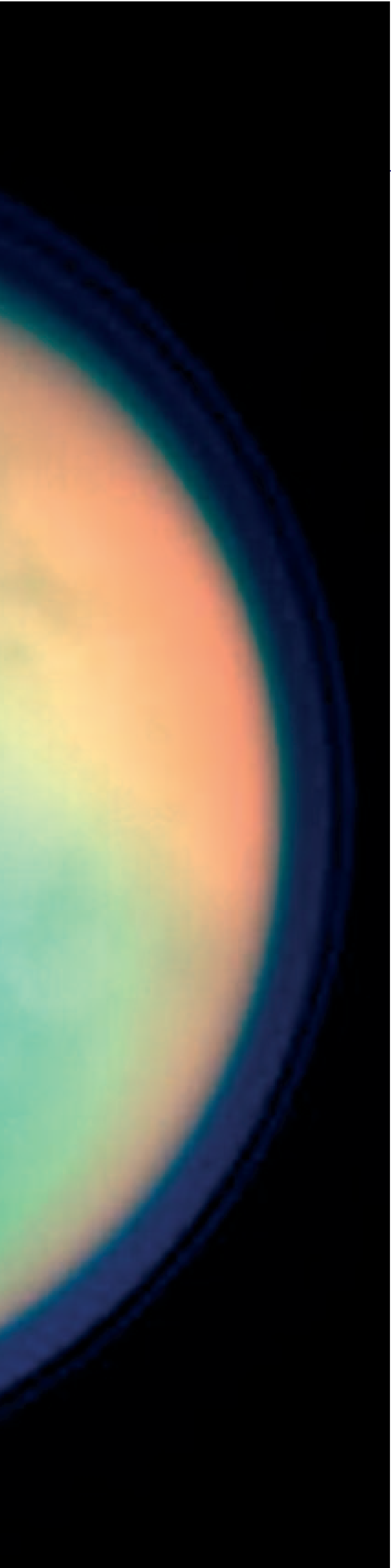
High Ambitions for an Outstanding Planetary Mission: Cassini-Huygens



Composite image of Titan in ultraviolet and infrared wavelengths taken by Cassini's imaging science subsystem on 26 October. Red and green colours show areas where atmospheric methane absorbs light and reveal a brighter (redder) northern hemisphere. Blue colours show the high atmosphere and detached hazes (Courtesy of JPL /Univ. of Arizona)



Jean-Pierre Lebreton[1], Claudio Sollazzo[2], Thierry Blancquaert[1,3], Olivier Witasse[1] and the Huygens Mission Team
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Cassini-Huygens, named after the two celebrated scientists, is the joint NASA/ESA/ASI mission to Saturn and its giant moon Titan. It is designed to shed light on many of the unsolved mysteries arising from previous observations and to pursue the detailed exploration of the gas giants after Galileo's successful mission at Jupiter. The exploration of the Saturnian planetary system, the most complex in our Solar System, will help us to make significant progress in our understanding of planetary system formation and evolution, which is also a key step in our search for extra-solar planets.

Questions to be Answered by Cassini-Huygens

- What is the source of heat inside Saturn that produces almost twice the amount of energy that the planet absorbs from sunlight?
- What is the origin of Saturn's rings?
- Where do the subtle colours in the rings come from?
- How many more moons are there?
- Why does the moon Enceladus have such an abnormally smooth surface? (Has recent melting erased craters?)
- What is the origin of the dark organic material covering one side of the moon Iapetus?
- Which chemical reactions are occurring in Titan's atmosphere?
- What is the source of the methane, a compound associated with biological activity on Earth, which is so abundant in Titan's atmosphere?
- Are there any hydrocarbon oceans on Titan?
- Do more complex organic compounds and 'pre-biotic' molecules exist on Titan?

Introduction

In many respects, a journey to Saturn is a journey back to the origins of the Solar System. Saturn's rings and moons are a model of the archetypal Solar System, when fragments of rock and ice collided with each other and melted on a grand scale. Titan, Saturn's most interesting moon, is thought to bear similarities to the primaeval Earth in its frozen state. A complex organic chemistry is at work in Titan's atmosphere and on its surface. Perhaps the building blocks of life have been preserved there, but did not evolve in Titan's cold and hostile environment? This environment is certainly an intriguing place, where time appears to have stood still for billions of years.

Cassini-Huygens is the most ambitious effort in planetary space exploration ever mounted. The mission calls for a sophisticated robotic spacecraft to orbit the ringed planet over a four-year period and a scientific Probe called 'Huygens' to be released from the main spacecraft, parachuting through Titan's atmosphere and eventually touching down on its surface.

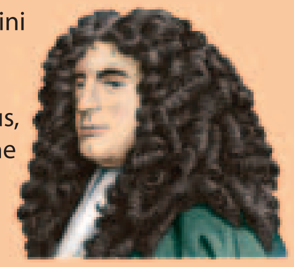
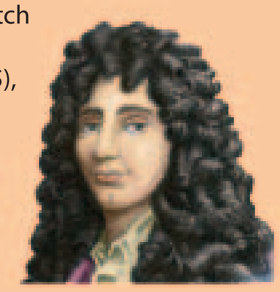
Cassini-Huygens is a masterpiece of collaboration that, from the initial vision in the early 1980s to the completion of the nominal mission in July 2008, will span nearly 30 years. It is a joint endeavour by the US National Aeronautics and Space Administration (NASA), providing the Cassini Orbiter, the European Space Agency (ESA), providing the Huygens Probe, and the Agenzia Spazio Italiana (ASI) which, through a bilateral agreement with NASA, is providing hardware systems, such as the High-Gain Antenna, for the Cassini Orbiter and instruments.

The twelve scientific instruments on the Orbiter will conduct in-depth studies of the planet, its rings, atmosphere, magnetic environment and a large number of its moons. The six instruments on the Probe will provide our first direct and detailed sampling of Titan's atmospheric chemistry and the first detailed photographs of its hidden surface.

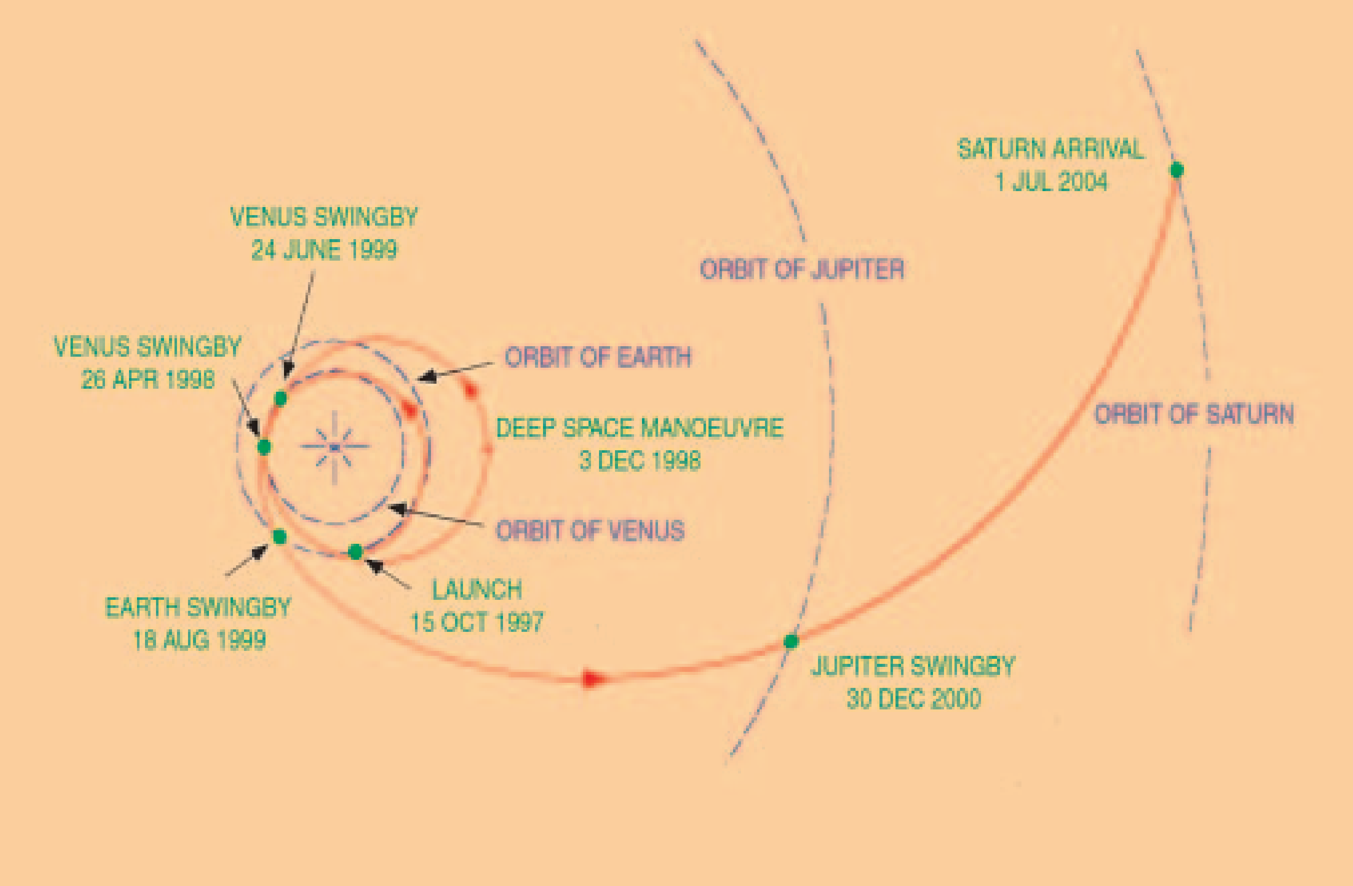
The Scenic Route to Saturn via Venus (twice), Earth and Jupiter

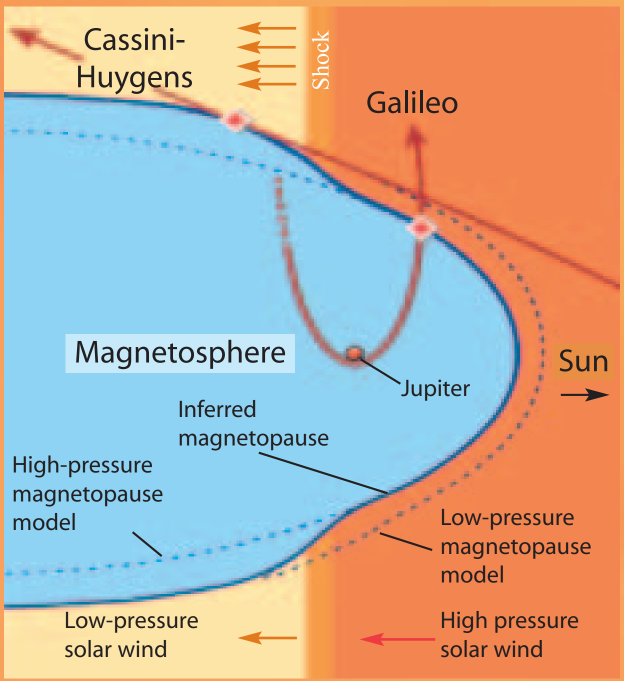
Cassini-Huygens has flown-by three planets – Venus, Earth and Jupiter – to acquire sufficient energy to reach Saturn. In addition to boosting the spacecraft's velocity, those planetary flybys have provided a wealth of unique observations thanks to the Cassini Orbiter's highly sophisticated instrument payload with its outstanding capabilities. In tandem with Galileo, Cassini performed

The Mission at a Glance

	Cassini Orbiter	**Huygens Probe**
Mission name	Named after the French-Italian astronomer Jean-Dominique Cassini (1625-1712), who discovered the four major moons – Iapetus, Rhea, Tethys and Dione – and the 'Cassini Division' 	Named after the Dutch scientist Christiaan Huygens (1629-1695), who discovered Saturn's rings and Titan 
Destination	Saturn and its moons	Titan
Objectives	In-depth studies of Saturn, its atmosphere, rings, magnetic environment and moons, especially Titan	First direct sampling of Titan's atmospheric chemistry and first photographs of the surface
Experiments	12 instruments, led by the USA, Germany and United Kingdom	6 instruments, led by France, Italy, Germany, the United Kingdom and the USA
Launch date	15 October 1997, from Cape Canaveral (USA)	
Launcher	Titan-IVB/Centaur	
Expected operational lifetime	Four years, from 1 July 2004 (Saturn Orbit Insertion) to 1 July 2008	22 days, including up to 2.5 hours of descent through Titan's atmosphere and a few hours on its surface
Ground operations	NASA/JPL, using stations of NASA's Deep Space Network in California, Spain and Australia.	ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany

The Cassini-Huygens mission's interplanetary trajectory





Cassini-Huygens explored the dynamics of the Jovian magnetosphere, which was 'caught in the act of compression.'

what NASA calls a 'discovery-class mission' at Jupiter. The planetary flyby opportunities were also used by the Science Teams to 'calibrate' the instruments and to 'train' for the arrival at Saturn.

Getting Closer to Saturn: Phoebe

The encounter with Phoebe, Saturn's distant moon, was the first and only targeted flyby of a Saturnian object planned for Cassini-Huygens before Saturn Orbit Insertion (SOI). Phoebe was discovered by William Henry Pickering in 1898 and has a rotation period of about 9.4 hours, an orbital period of 550 days, and a diameter of about 220 km. Its inclined, retrograde and chaotic orbit is strong evidence that the moon is a captured object. The Phoebe encounter occurred 19 days prior to the SOI burn. The trajectory to and arrival date at Saturn were specifically selected to accommodate this flyby as it was the only opportunity during the mission to study Phoebe at close quarters. Phoebe's orbit is simply too far from Saturn – at almost 13 million kilometres, nearly four times as far as the planet's next closest major satellite Iapetus – to make a later encounter feasible. At closest approach, Cassini passed within a mere 2000 km of Phoebe's surface, allowing imaging with a resolution of up to 15 metres per pixel. At this distance, it also allowed gravity measurements to be made through precise spacecraft tracking.

The Phoebe flyby provided far more information about the moon than the distant observations made by Voyager, whose images were only a few pixels across. Cassini returned truly spectacular images and composition colour maps of what is most likely a captured Kuiper Belt object. The Phoebe data will help to determine the moon's surface properties, geological history, surface age, body shape, local topography, and the distribution of its surface materials. These latest spectacular observations have demonstrated the ability of the many instruments in the payload to work together efficiently to study targets in the best possible manner. They also brilliantly demonstrated that the spacecraft and the mission teams were ready for the task at Saturn.

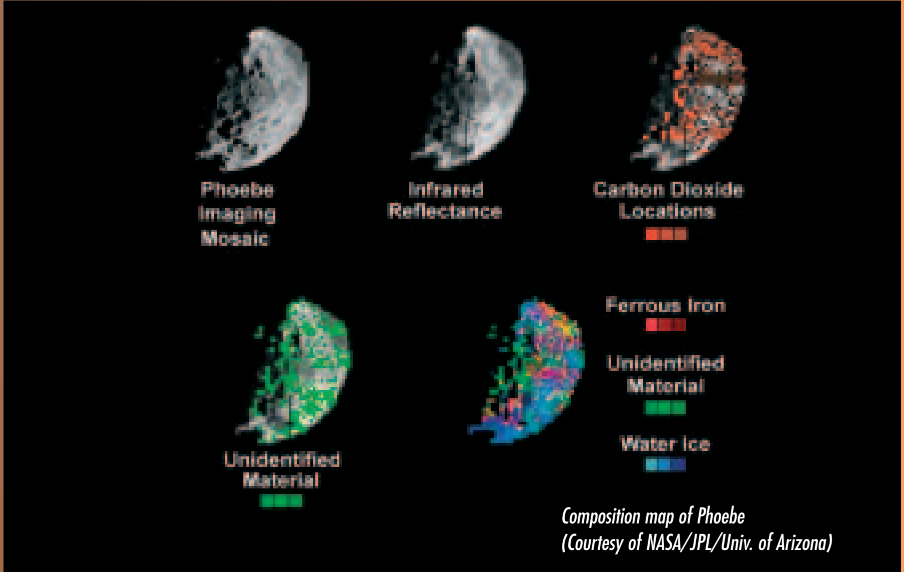
Saturn Orbit Insertion

Saturn Orbit Insertion for Cassini-Huygens took place on 1 July 2004. The SOI sequence included science observations, as the insertion geometry offered a unique opportunity to probe Saturn's higher magnetic field moments and its nearby environment, and to observe its rings. The spacecraft passed twice through the planet's rings, the first time prior to the 96-minute main-engine burn, and again later after the burn had been completed, allowing some unique scientific observations.

One hour and 25 minutes before the burn, the spacecraft turned to orient its high-gain antenna (HGA) in the direction of the incoming dust. Cassini-Huygens crossed through Saturn's ring plane at a radius of 158 500 km – between the F and G rings (both before and after the burn). This location was considered safe, but to protect the spacecraft as much as possible it was felt prudent to use the HGA as an 'umbrella' to shield it from any dust that might be present. The main engine's cover was opened before the ascending ring-plane crossing. After the crossing, the spacecraft was turned to the burn attitude, and the orbit-insertion burn initiated.

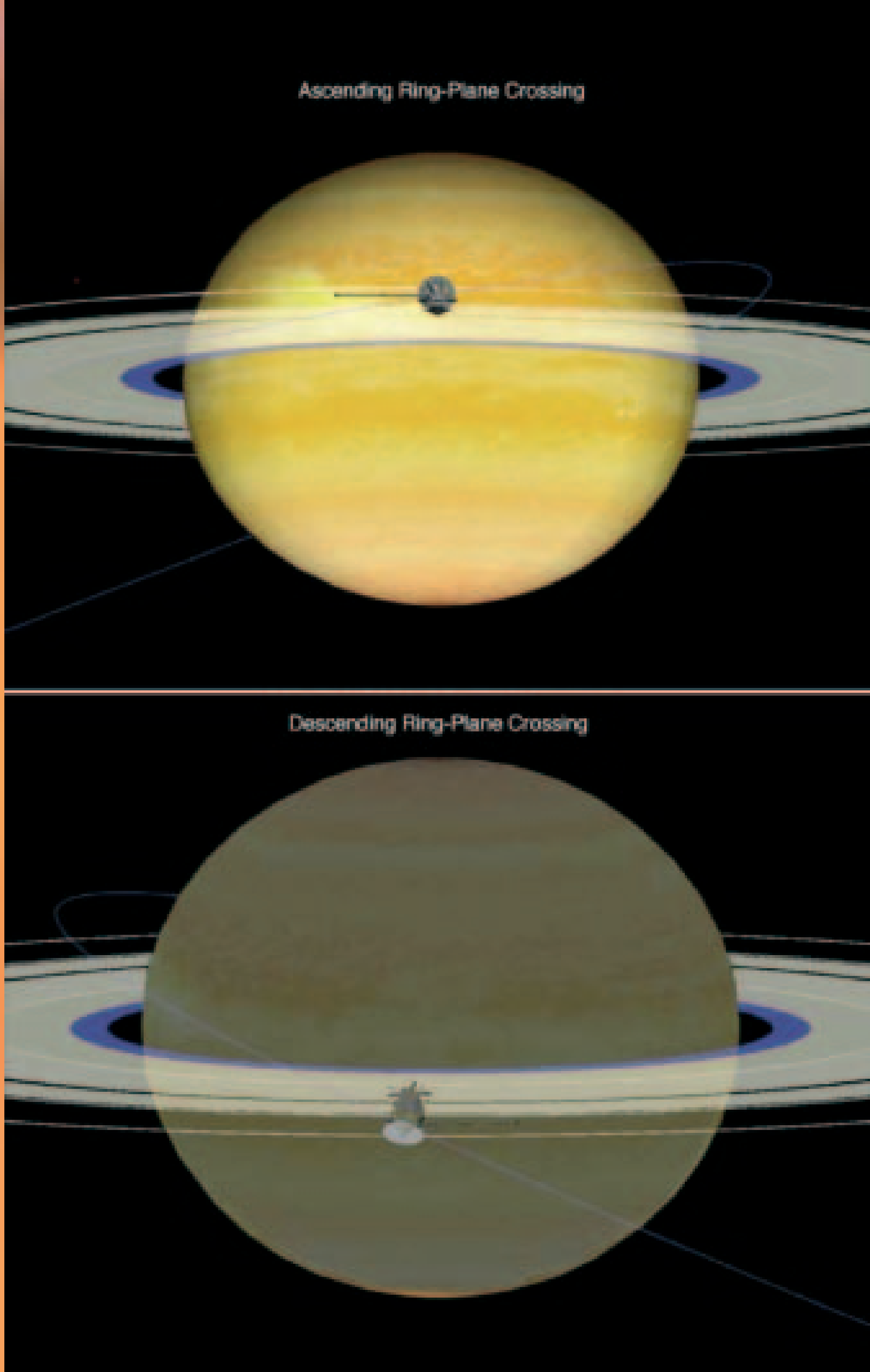
The SOI manoeuvre consisted of a 96.4-minute main-engine burn, delivering a total velocity increment (ΔV) of 626 m/s. Cassini was captured into an orbit around

High-resolution image of Phoebe taken by Cassini's camera near closest approach (Courtesy of NASA/JPL/Space Science Institute)



Composition map of Phoebe (Courtesy of NASA/JPL/Univ. of Arizona)

Trajectory of Cassini-Huygens for the two ring crossings



Saturn after 78 minutes of main-engine firing, and the remaining time was used to reduce the period of the initial orbit, which had a periapsis radius of 1.3 R_s, an apoapsis radius of 150.5 R_s (where R_s is the radius of Saturn), a period of 117 days, and an inclination of 16.8 degrees.

After the burn was completed, the spacecraft reconfigured itself for normal operations. It turned back towards the Earth, gave a call home, and then went on with the planned post-burn science observations. After about an hour of such observations, the spacecraft again oriented the HGA towards the incoming dust direction for the descending ring-plane crossing. About 45 minutes of further science was collected, and then the spacecraft turned back to Earth again to play back both the engineering data collected during the SOI period and the science data, which had been recorded onboard.

Breathtaking images of the rings were sent back. Some showed 'textbook' features within the rings (density waves across the rings, scallop-shaped edges, etc). Besides the camera, the spectrometers also obtained data that were converted into 'false-colour' images showing the subtle compositional variations across the rings in unprecedented detail (see accompanying images).

The field and particle instruments also acquired their fair share of excellent data, starting with an earlier-than-anticipated crossing of the bow shock, the region in which the solar wind piles up against the planet's magnetic field that the magnetosphere. The bow-shock crossing occurred about 3 million kilometres in front of Saturn, about 50% further away from the planet than was expected based on the Pioneer-11 and Voyager-1 and -2 observations made in 1979, 1980 and 1981.

In fact, the bow shock varied significantly during Cassini's approach, in response to large variations in the solar wind, which allowed the spacecraft to cross the shock several times (more correctly, the bow shock swept in and out of Cassini's path during its approach to the planet).

Thanks to a new kind of camera, which allows one to observe source regions of energetic neutral atoms which can be 'imaged', Cassini discovered a new inner radiation belt inside the innermost ring of Saturn.

Mysterious Titan

Titan, Saturn's largest moon, is a truly fascinating world. It is freezing cold, with temperatures reaching minus 180°C, and has a very thick atmosphere whose origin is still unknown, consisting mainly of nitrogen, just like Earth's, but also very rich in organic compounds, which are

Science experiments on Huygens

Instrument	Purpose
Gas Chromatograph and Mass-Spectrometer – GCMS (USA, A, F, D)	Measures the chemical composition of gas in the atmosphere
Aerosol Collector and Pyrolyser – ACP (F, A, USA)	Measures the chemical composition of aerosols (dust)
Descent Imager (panoramic camera) and Spectral Radiometer – DISR (USA, D, F, CH)	Takes images to study the distribution of aerosols (dust) and cloud droplets and to determine the nature of the surface. Makes spectral measurements to record the thermal properties of the atmosphere and measure its composition
Huygens Atmosphere Structure Instrument – HASI (F, I, A, D, E, N, FIN, USA, UK, ESA, IS, P)	Measures the temperature, density and electrical properties of the atmosphere during the entry, descent and after landing. Research into lightning on Titan
Doppler Wind Experiment – DWE (D, I, USA)	Measures the vertical wind profile and the horizontal winds via the propagation of radio signals through the atmosphere
Surface Science Package – SSP (UK, F, PL, USA, ESA)	Studies the state (physical properties and composition) of the surface at the impact site

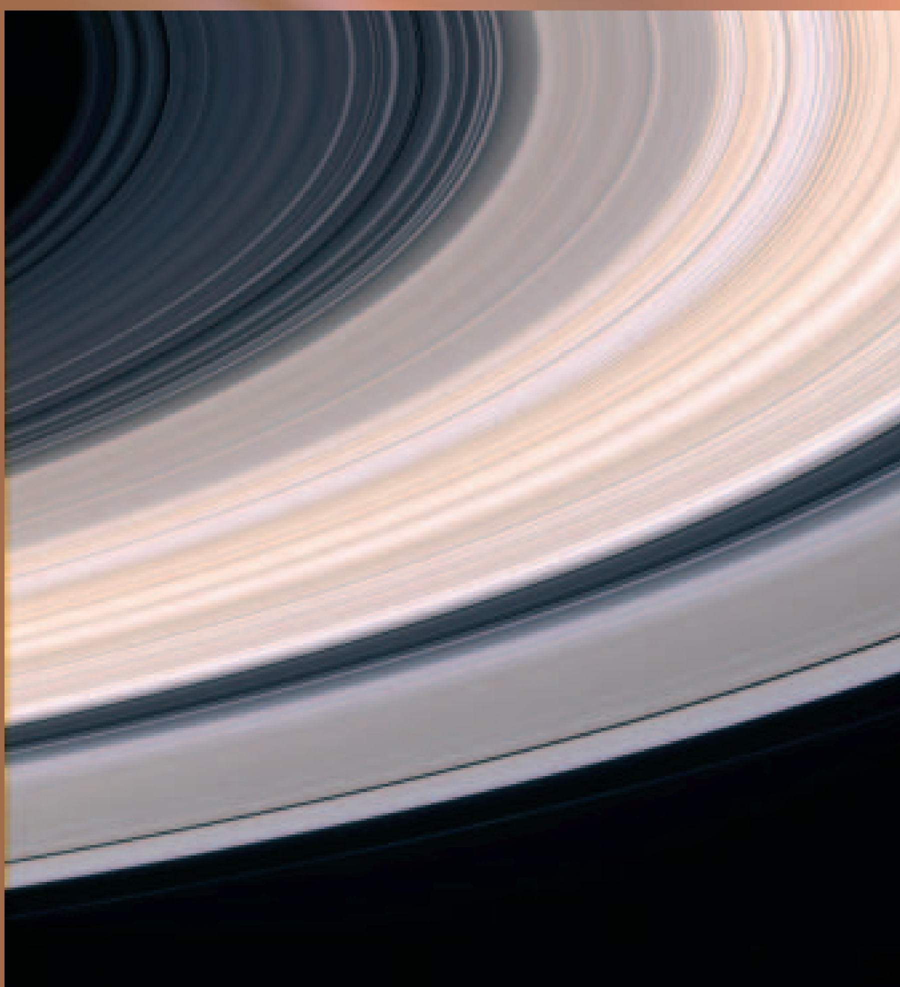


Image of Saturn's rings taken by the Cassini camera (Courtesy of CICLOPS/Space Science Institute)

constantly reacting. In particular, a few percent of methane is continuously re-supplied in Titan's atmosphere by a mechanism that is still a complete mystery.

Orange-coloured clouds and mists due to the organic haze are so opaque that the surface can only be seen when looking through infrared 'atmospheric windows'. The haze is created by sunlight and cosmic rays breaking down the methane in the moon's atmosphere, and producing a range of complicated organic compounds that float down to the surface and accumulate over time.

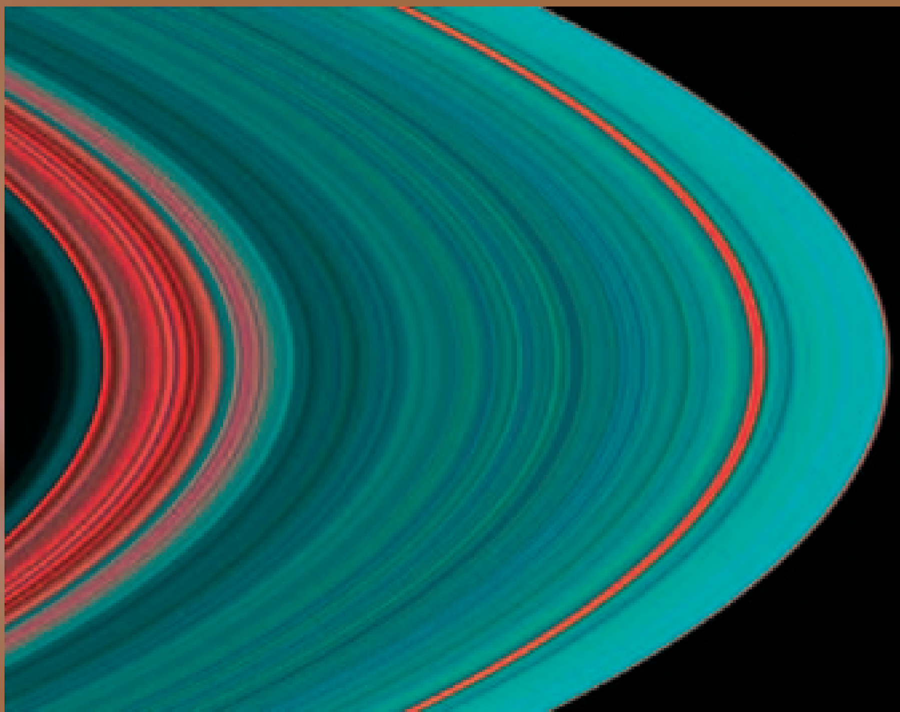
Titan also has a 'greenhouse-warmed' climate, like the Earth, but sustained by different gases. Volcanoes and impacts shape the surface and maybe provide energy to make even more complex organic molecules. Water cannot exist in liquid form because the surface is far too cold, unless it exists for relatively short periods because of the heat generated by volcanism or asteroid impacts. Very little is known about the moon's surface and scientists speculate that Huygens may find lakes or even oceans composed of a mixture of liquid ethane, methane and nitrogen, and possibly underground reservoirs. The pressure and temperature on Titan's surface are sufficient to liquify these natural gases.

The Main Characteristics of Titan

Distance from centre of Saturn	1 221 870 km (= 20.3 Saturn radii)
Orbital period (Titanic day)	About 16 Earth days
Diameter	5150 km (larger than Mercury - 4878 km, and slightly smaller than Jupiter's Ganymede – 5262 km; Earth's Moon is only 3476 km in diameter)
Atmospheric thickness	More than 1000 km
Mass	1/45 of Earth's mass (more massive than Pluto)
Expected surface temperature	About -180°C
Surface pressure	About 1.5 times higher than on Earth
Average density	About 1.9 times the density of water

Science Experiments on the Orbiter

Instrument	**Purpose**
Imaging Science Subsystem – ISS (USA, F, D, UK)	Takes pictures in visible, near-ultraviolet and near-infrared light
Cassini radar – RADAR (USA, F, I, UK)	Maps surface of Titan using radar imager to pierce veil of haze. Also used to measure heights of surface features
Radio Science Subsystem – RSS (USA, I)	Searches for gravitational waves in the Universe; studies the atmosphere, rings and gravity fields of Saturn and its moons by measuring telltale changes in radio waves sent from the spacecraft
Ion and Neutral Mass-Spectrometer –INMS (USA, D)	Examines neutral and charged particles near Titan, Saturn and its other moons to learn more about their extended atmospheres and ionospheres
Visible and Infrared Mapping Spectrometer – VIMS (USA, F, D, I)	Identifies the chemical compositions of the surfaces, atmospheres and rings of Saturn and its moons by measuring colours of visible light and infrared energy emitted or reflected
Composite Infrared Spectrometer – CIRS (USA, F, D, I, UK)	Measures infrared energy from the surfaces, atmospheres and rings of Saturn and its moons to study their temperature and compositions
Cosmic Dust Analyser – CDA (D, CZ, F, UK, USA, ESA)	Studies ice and dust grains in and near the Saturnian system
Radio and Plasma-Wave Spectrometer – RPWS (USA, A, F, S, UK, N)	Investigates plasma waves (generated by ionised gases flowing out from the Sun or orbiting Saturn), natural emissions of radio energy and dust
Cassini Plasma Spectrometer – CAPS (USA, F, FIN, HU, N, UK)	Explores plasma (highly ionised gas) within and near Saturn's magnetic field
Ultraviolet Imaging Spectrograph – UVIS (USA, F, D)	Measures ultraviolet energy from atmospheres and rings to study their structure, chemistry and composition
Magnetospheric Imaging Instrument – MIMI (USA, F, D)	Images Saturn's magnetosphere and measures interactions between the magnetosphere and the solar wind, a flow of ionised gases streaming out from the Sun
Dual-technique Magnetometer – MAG (UK, D, USA, HU)	Studies Saturn's magnetic field and its interactions with the solar wind, the rings and the moons



False-colour image of Saturn's rings obtained using Cassini's UV Imaging Spectrograph (Courtesy of Univ. of Colorado)

Both Cassini and Huygens will look at Titan, and their combined data will greatly improve our understanding of this mysterious moon. They will study its atmospheric chemistry and investigate the energy source that makes it so active. They will also look into Titan's 'weather', measuring winds and temperatures, monitoring cloud physics and circulation, lightning and seasonal changes, as well as possible climate changes.

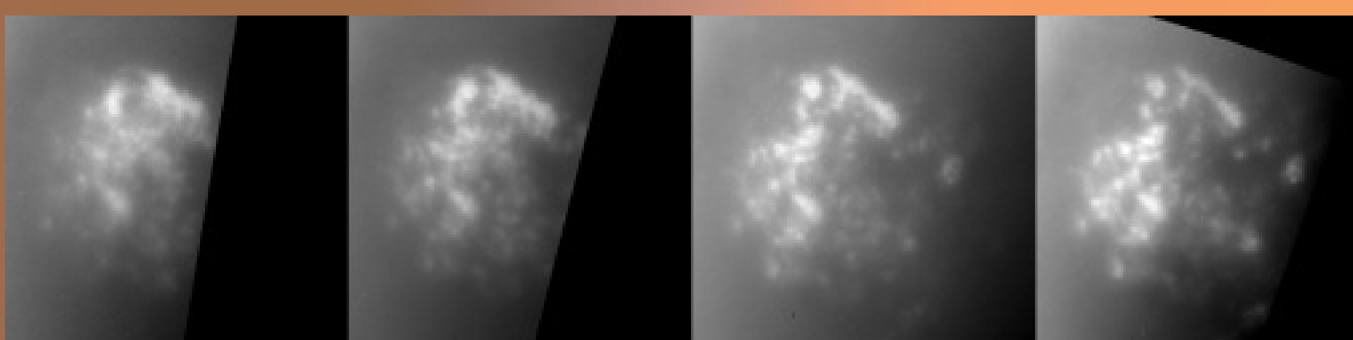
The physics, topography and composition of the surface will all be investigated. A radar will map the surface of Titan. Both Cassini and Huygens will provide clues about the moon's inner structure. Cassini will also see how Titan's upper atmosphere interacts with the magnetosphere of Saturn and if it has a significant magnetic field of its own. The combined observations of Cassini and Huygens will help constrain the possible scientific scenarios for the formation and evolution of Titan and its unique atmosphere.

Cassini's First Look at Titan

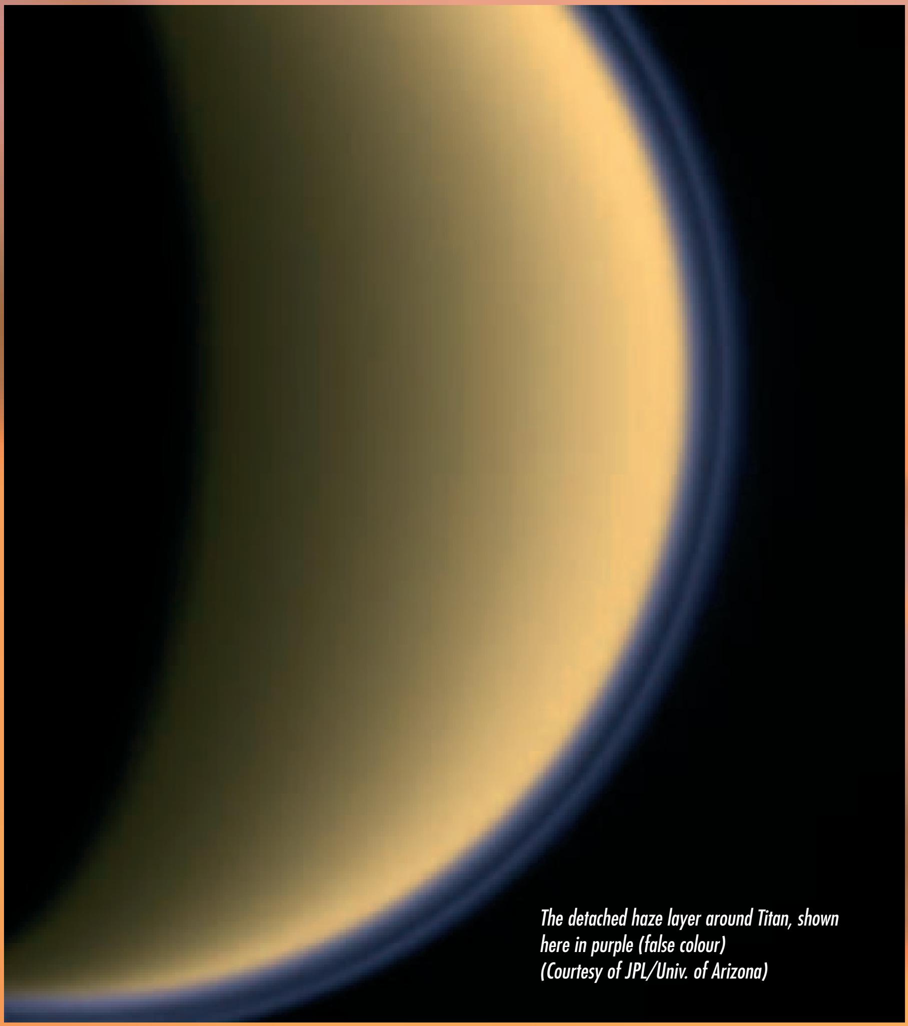
The Cassini camera has already observed Titan over a period of several months while approaching Saturn. It obtained a composite image of its surface that confirmed the main features seen in the Hubble Space Telescope observations in 1994 and later in ground-based adaptive-optics infrared images.

An early opportunity to observe Titan occurred on the day after SOI. In addition to the Phoebe flyby, the 1 July arrival date also provided an opportunity for a non-targeted flyby of Titan about 31 hours after SOI at a distance of less than 340 000 km. This so-called 'Titan-0 opportunity' (revolution 0 is defined as the orbit segment from SOI until the initial apoapsis) was exploited to acquire a unique data set for Titan using the four optical remote-sensing instruments aboard Cassini, namely ISS, VIMS, CIRS and UVIS. Highlights included some observations of the methane polar cloud, which seemed to vary over a matter of just a few hours, and a composite map of Titan's surface with approximately 150 km resolution by VIMS.

One of the main goals of the Titan-0 observations was to obtain a data set that would allow validation of the model of Titan's atmosphere that has been used to design the Huygens Probe's entry and descent, especially in the stratosphere, in the altitude range between 150 and 400 km, where the Probe first brakes and then its parachutes are deployed. The data set, which was of excellent quality, was analysed in combination with recent ground-based observations. It confirmed that the state of the atmosphere at the time of the Titan-0 flyby was well within the envelope of the model used for Huygens (Yelle model), and in fact only slightly warmer and denser than the recommended profile.



Four views of the Titan south polar cloud taken by Cassini-Huygens over a period of almost five hours (Courtesy of NASA/JPL/Space Science Institute)



The detached haze layer around Titan, shown here in purple (false colour)
(Courtesy of JPL/Univ. of Arizona)

Two low-altitude flybys of Titan at a height of 1200 km take place, on 26 October and on 13 December, before Huygens's descent begins on 14 January 2005. They will provide additional data that will be used to further validate the moon's atmospheric model for Huygens and to validate the estimated density at 950 km altitude, which Cassini is intended to reach during the 5th Titan flyby.

A Drop into the Unknown

The whole of the Huygens scientific mission is to be carried out during just 2.5 hours of exciting descent through Titan's atmosphere and possibly up to a few hours on its surface. Despite such a short mission duration, however, scientists will be able to gather such a huge amount of data that it will make their enormous efforts over many years worthwhile. The Probe is not designed to survive long after the touchdown and so even if it does not survive the impact, the mission will still be considered a tremendous success.

Is there a primaeval Earth around the corner?

One of the main reasons for sending Huygens to Titan is because in some ways it is the closest analogue to Earth before life began. Its atmosphere and surface may contain many chemicals of the kind that existed on the young Earth, and stocked the primaeval soup in which the first living organisms appeared. It is known that complicated carbon molecules are present in cosmic space, but ultraviolet light from the Sun, cosmic rays and lightning strokes could also manufacture carbon compounds on planets like Earth.

Huygens will investigate this 'home cooking' on Titan. It will identify the complex molecules by their masses, and by their speeds of transit through various filters. It will collect particles from the atmosphere and use an oven to vaporise them for identification. Even today, we still do not know how the self-sustaining assemblies of nucleic acids, proteins and fats at the basis of life came into existence. By identifying the likely chemical precursors that filled the primaeval soup, Huygens will give a fresh impetus to the theories regarding the origin of life on the Earth.

Weather and chemistry in the haze

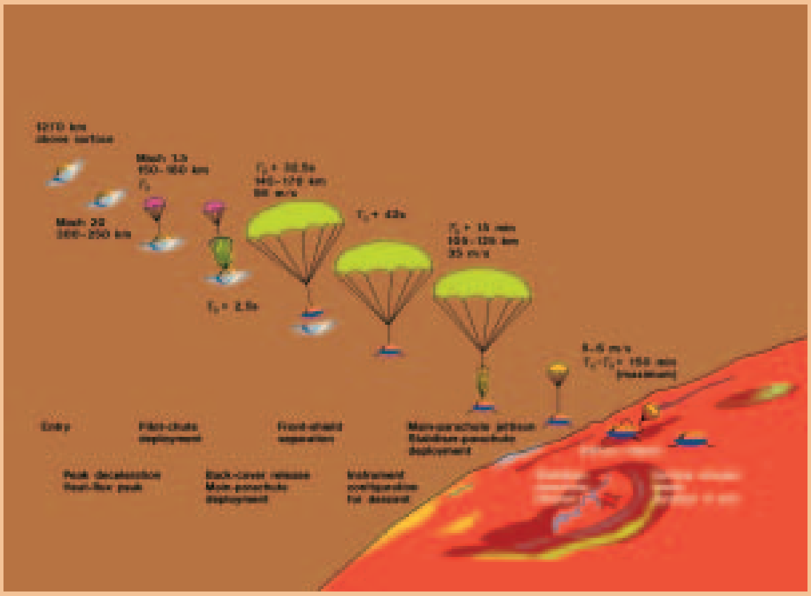
Meteorologists will be fascinated by the parallels and contrasts with the weather on Earth, in a world where clouds and raindrops are made of methane and nitrogen. Winds of 500 km/h, which are expected to diminish during the descent, will propel Huygens sideways when the main parachute opens. The Probe will be able to deduce the prevailing wind speeds and provide detailed weather information, such as temperature and pressure. It will also be able to measure the electrical properties of the atmosphere and register radio pulses from lightning strokes, if they occur. A microphone will listen for any noise from Titan.

The Huygens Probe's Arrival

Huygens is attached to the Cassini Orbiter by a separation mechanism, which will push it off towards Titan at the right moment. The mechanism will also start the Probe rotating, to make sure that it is stabilised and enters the moon's atmosphere front-shield-first. Huygens is built like a shellfish, with a hard shell (carbon-fibre honeycomb covered by silica-fibre tiles) to protect its delicate interior from extreme temperatures (as high as 8000°C in the heated gas in front of the Probe) during the entry into Titan's atmosphere. The Probe itself consists of two parts: the Entry Assembly Module and the Descent Module. The Entry Assembly Module carries the equipment to control Huygens after its separation from Cassini, and has a front shield that will act both as a brake and as thermal protection. The

Huygens Descent Profile

Huygens' entry into Titan's atmosphere is currently planned for 14 January 2005 at 9:07 UTC.



With Huygens' instruments awoken and the radio link activated, the Orbiter can listen to the Probe for 4.5 hours (after that Cassini will disappear behind Titan's horizon).

During the first three minutes inside Titan's atmosphere, Huygens will decelerate from 18 000 to 1400 km/h. The temperature of the gas heated by friction with the Probe's heat shield may reach 8000°C.

When Mach 1.5 (400 m/s) is reached, a pilot parachute is automatically deployed to pull out the main parachute at a speed of about 1500 km/h. The Probe's speed is then reduced to less than 300 km/h within a minute.

The shell of the descent module falls away and exposes the scientific instruments to Titan's atmosphere at a height of about 160 km. The atmospheric temperature may then be about -120°C.

15 minutes later at about 120 km altitude, the main parachute will be cut away and replaced by a smaller one, designed to allow a steady descent at about 20 km/h to touch-down.

At about 45 km altitude, the Probe will go through the coldest layer of the atmosphere, with about –200°C at the tropopause.

A radar altimeter will measure the Probe's altitude during the last 30 km. During its descent, the Probe's camera will capture images of Titan's cloud deck and surface. Data from Huygens will be relayed to Cassini as it passes overhead for later playback to Earth.

Descent Module contains the six scientific instruments. The Probe will use three different parachutes in sequence during its descent.

Huygens remains dormant until just before its separation from Cassini. Contacts with Huygens during the cruise phase were only possible via an umbilical link with Cassini. This link has been used to subject the Probe to periodic checkouts during the long journey for health-monitoring and instrument-calibration purposes. The setting of the timers that will wake up Huygens about four hours before it reaches Titan's atmosphere will be the last commands sent to the Probe from the ground. After its separation, Huygens will have to work autonomously.

Huygens will rotate as it drops, and its cameras will scan the surrounding scene over a full 360 degrees, imaging the cloud layers. The view will be very fuzzy, with the Sun plainly visible, but its halo will allow the Probe to measure the size and abundance of the haze particles, while the spectrometers will measure the heat flows inwards from the Sun and outwards from Titan into space. These instruments will tell us about the kinds and numbers of molecules in the atmosphere, and will analyse aerosol (dust) particles distributed in two layers of Titan's atmosphere (between 150 and 40 km altitude, and at around 20 km altitude).

As the Probe breaks through the haze layers, its camera will take up to 1100 pictures of the panorama and observe surface properties. Perhaps 50 km above the surface, the haze may clear and give Huygens its first glimpse of the surface between fluffy cloud-tops. A radar altimeter, whose main function is to measure the Probe's altitude, will also help to determine Titan's surface characteristics by listening for echoes.

A special lamp, turned on for the final stage of the descent, will allow accurate measurement of the colours of the surface to help the Probe's spectrographs analyse its composition.

Will Huygens splash down in an ocean of methane and ethane, with coloured organic icebergs, or will it touch down on a solid surface with geysers spouting methane from underground reservoirs? Will it see volcanoes erupting with ammonia and water? If the Probe survives the touch-down, the Surface Science Package will come into its own for the last phase of the mission with a sonar and an array of 'simple' sensors for measuring the physical properties of the surface material. It will be able to tell whether the surface is in a liquid, and if so the chemical composition of that liquid. It may even detect waves and measure the depth. It will be able to deduce the ratio of methane to ethane in the liquid, which will give an indication of how long Titan has spent converting the one into the other. Scientists should then be able to judge whether the ocean is as old as Titan, or a later addition. On a dry surface, Huygens will be able to measure its hardness and whether the surface is level.

Cassini's Exploration of Saturn Continues

After the Huygens portion of the mission, Cassini will continue to focus on making measurements with the Orbiter's 12 instruments and returning the information to Earth. It will study Saturn's polar regions in addition to the planet's equatorial zone. Observations of seven selected icy moons will be made, plus at least two dozen more-distant fly-bys of other moons, and there will be more than 44 encounters with Titan (also used for gravity-assist orbit changes that shape the Cassini orbital tour):

- 15 February 2005: 4th Titan low-altitude fly-by.
- 17 February 2005: 1st Enceladus fly-by at about 2900 km altitude. This smooth moon is ten times as bright and reflective as the Earth's moon. Its orbit is embedded in the thickest part of Saturn's E-ring.
- 9 March 2005: 2nd Enceladus fly-by at about 750 km altitude.
- 2005-2008: Cassini continues Saturn observations and Titan fly-bys.
- 1 July 2008: Nominal end of the Cassini Huygens mission.

An International Endeavour

Hundreds of scientists and engineers from 18 nations, including 17 European countries and the USA, make up the team responsible for designing, building, flying the Cassini-Huygens spacecraft and collecting their scientific data. Of these 18 countries, 17 have been active participants since the mission started.

The mission is managed by NASA/JPL, where the Orbiter was designed and assembled. Development of the Huygens Probe was managed by ESA. The Prime Contractor for the Probe is Alcatel (F). Equipment and instruments for the mission have been supplied from many European countries and the USA.

Cassini flight operations are being conducted from NASA/JPL in Pasadena, California, using Deep Space Network (DSN) stations in California, Spain and Australia. The Huygens flight operations are being conducted from ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany. All of the Probe's commands are prepared at ESOC and sent to JPL for merging into the strings of commands sent via the DSN to Cassini, which stores them onboard for release to Huygens at a pre-determined time. Huygens data are received back via the reverse path, and distributed to the Scientific Teams by ESOC.

Acknowledgements

The Cassini-Huygens mission is great example of international collaboration in space exploration. We acknowledge all the teams who have made such an exciting mission possible. Special thanks go to the Orbiter instrument teams and to the ground-based observers who are kindly sharing their early observations of Titan's atmosphere prior to formal publication. The validation/updating of the model of Titan's atmosphere is being done within the Titan Atmosphere Model Working Group (TAMWG) under the leadership of R. Yelle.

Mapping Forest-Fire Damage with Envisat

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Wildfires are a major environmental problem in many parts of the World, including some European countries around the Mediterranean where large forest fires have often spread uncontrollably at frightening rates in recent years. Such fires play a critical role in many aspects of ecosystem functioning, such as biodiversity and hydrology. They can destroy large tracts of the landscape, as well as triggering the release of considerable amounts of the main greenhouse gas carbon dioxide, thereby affecting the global atmospheric chemistry of our planet.

Background

Global studies (e.g. GLOBSCAR) have produced widely differing figures for biomass burning varying, according to the literature, from 200 to 1000 million hectares per year, with Africa the largest contributor. Of the different vegetation types under threat, savannas are by far the most affected. In the European Union region, according to the European Commission, the five Mediterranean States – France, Greece, Italy, Portugal and Spain – suffer burnt areas of between 200 000 and 600 000 hectares per year as a result of the 20 000 to 60 000 forest fires that have occurred annually in the period 1980 to 2003.

Since forest fires are a major source of concern both for environmental and safety reasons, information about them must be available in a timely and harmonized way. Remote sensing from space is especially suitable for forest-fire-related studies, including those focusing on estimating the degree of damage caused by wildfires as well as mapping the affected areas.

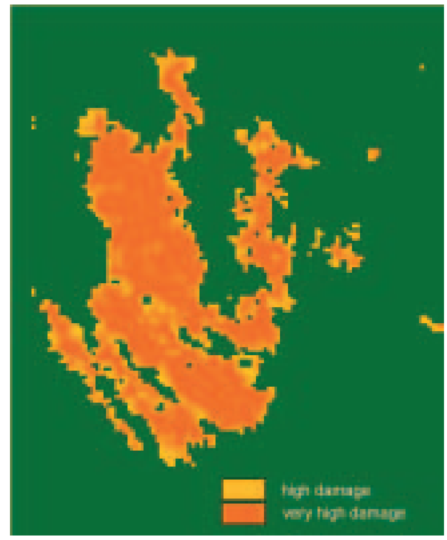
ESA's Envisat environmental satellite, launched in March 2002, is a powerful tool for monitoring the state of our planet and the impact that human activities are having on it. For doing so, it carries ten highly sophisticated instruments, one of which is the Medium Resolution Imaging Spectrometer, better known as 'MERIS', which is providing unique fire-damage information.

Mapping the Level of Damage

The MERIS instrument has shown itself to be an accurate eye in space for estimating the degree of damage caused by forest fires, thanks to its multi-spectral imaging capabilities in the visible and near-infrared regions of the spectrum and its narrow spectral bands. MERIS's imagery has also been used very successfully for estimating the areas affected by particular fires, thanks largely to its improved spatial resolution (300 metres in Full Resolution Mode) compared with other satellite sensors, such as the AVHRR instrument on the NOAA satellite series.

Level-of-damage estimation on the basis of remote sensing from space can also be of considerable help in terms of catastrophe management because it is both time-saving and cost-effective. It can be used for subsidy assignment and for better planning of post-fire restoration actions, allowing more investment to be targeted at the areas that are most badly affected.

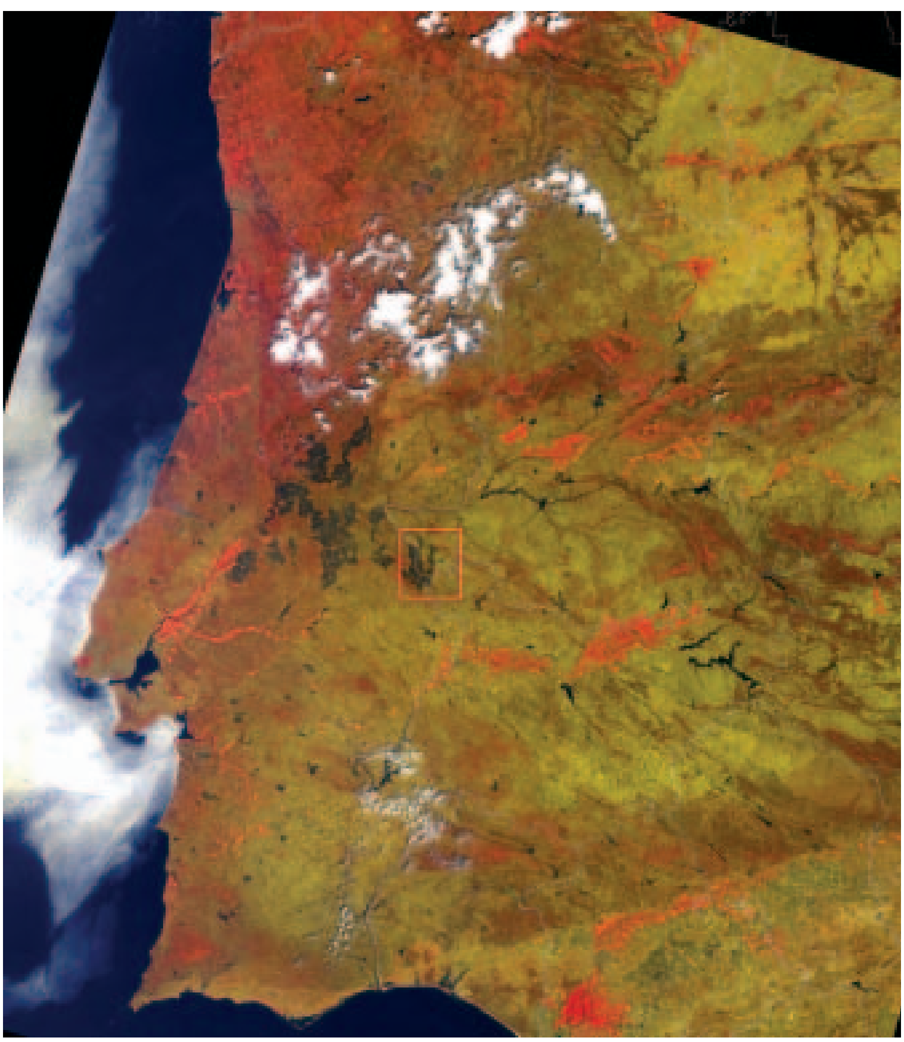
Information about forest fires is also of strategic value for protocol implementation and treaty verification. The Kyoto Protocol strives to reduce carbon-dioxide and other greenhouse-gas emissions by an average of 5% of 1990 levels, and wilderness fires are an important contributor of carbon dioxide to the atmosphere. On a global scale, land-use changes are considered one of the main sources of this gas, deliberate burning being one of the most common means of transforming forest into agricultural land, especially in the tropics.



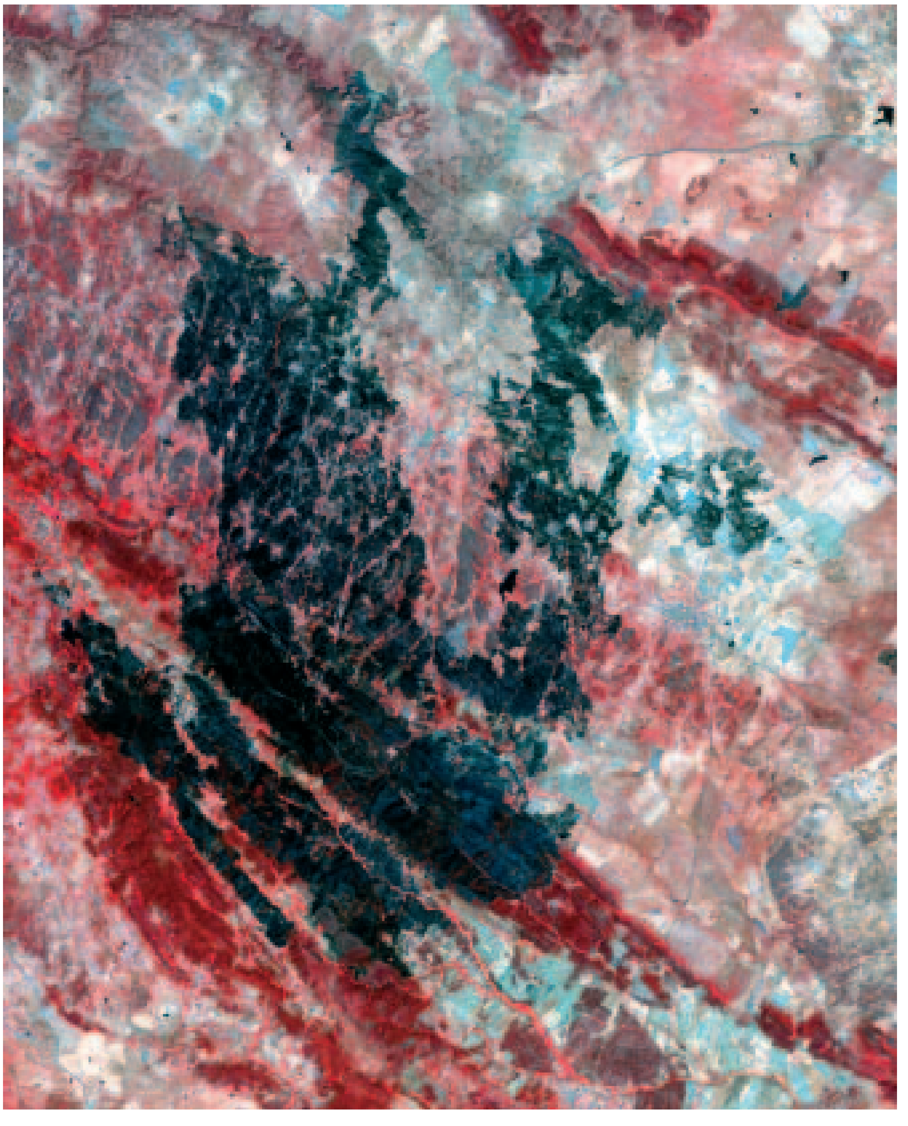
Level-of-damage estimates obtained by MERIS image processing

The preliminary results of space-based level-of-damage and burnt-area-assessment studies for the fires that occurred at the border between Portugal and Spain during the first days of August 2003 are already very interesting. It was a particularly dramatic summer in terms of forest fires for much of Southern Europe, and especially Portugal where almost 8% of the wooded area was mapped as burnt at the end of the dry season. In Spain and Portugal alone, the total area razed during 2003 was more than 450 000 hectares.

The study area known as Valencia de Alcántara, delineated on the accompanying MERIS image, is where all of the analyses were carried out. Some image-processing analysis based on linear unmixing algorithms was performed on a



The fire-scarred landscape of Central Portugal and Spain, as seen by Envisat on 8 August 2003, with the Valencia de Alcántara fire outlined in red (MERIS instrument RGB image: 12,9,1 composite)



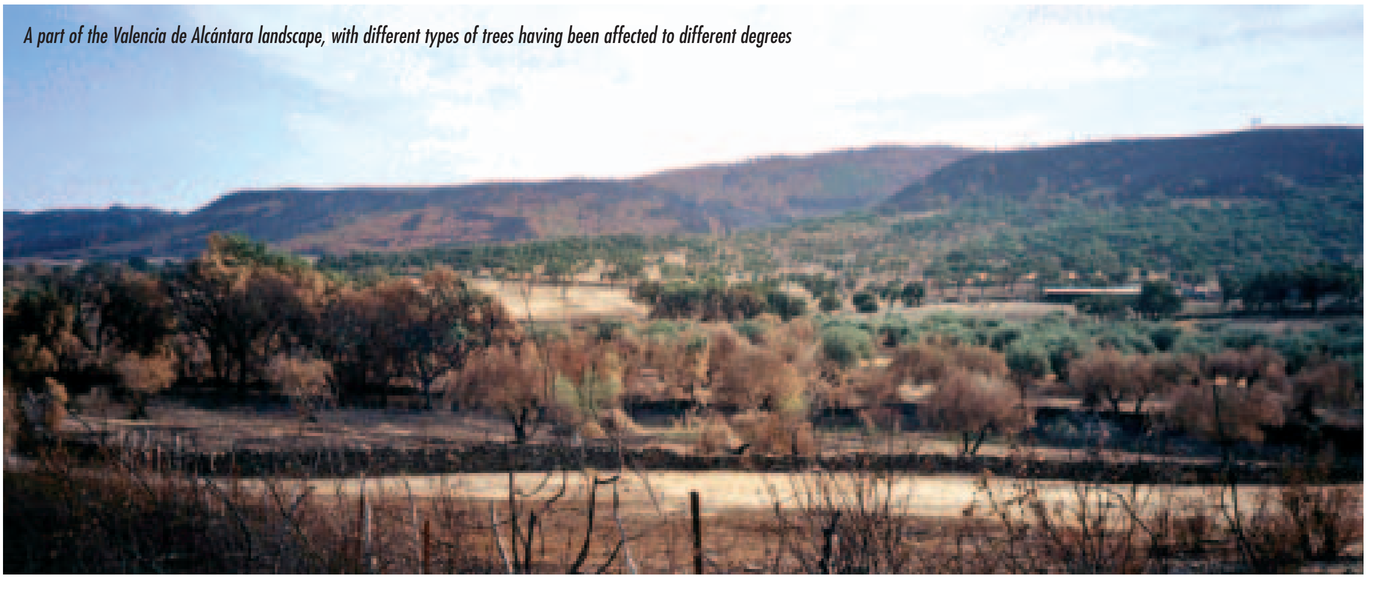
The scars from the Valencia de Alcántara fire as recorded by SPOT-5's HRG1 instrument on 21 August 2003

post-fire sub-scene of the MERIS image and on a post-fire SPOT-5 image (dated 21 August 2003). The latter is a four-band image with a 10 metre spatial resolution. Two of the spectral bands are located in the visible, the third in the near-infrared and the fourth in the shortwave-infrared region.

The algorithms applied resulted in a fire level-of-damage estimate that was reclassified into two degrees of damage ('high' and 'very high') in order to achieve a better understanding of the problem and for further statistical analysis. Because of its higher spatial resolution and particular spectral capabilities, the SPOT-5 image could be used as the 'ground truth' for evaluating the MERIS-derived estimates of the two parameters of interest, namely level of damage and area affected. The affected area was evaluated with the MERIS data to have 4350 hectares in the 'high damage' category, and 19 050 hectares in the 'very high damage' category.

The information provided by satellite was completed with data from two field trips. The first was made just a few weeks after the fire had been extinguished (September 2003), and the second during the next growing season (June 2004).

A part of the Valencia de Alcántara landscape, with different types of trees having been affected to different degrees



Ground data from the September field trip confirmed the high degree of devastation caused by fire. During the June 2004 trip, clearing-up work could be seen in the ravaged areas, as well as evident signs of the vegetation recovering in various places. Photographs of several locations were linked to GPS points, and subsequently to MERIS and SPOT-5 images, which confirmed a high degree of correlation between the level of damage as evaluated from satellite sensors and what was seen on the ground.

MERIS-derived level-of-damage information was also compared with information on forested land-cover classes as derived from the Spanish National Forest Map (cartography scale 1:50.000). The objective here was to check to what extent the degree of damage was related to a particular type of forest or tree species. The first analysis revealed that there was indeed a link between the forest type and the degree to which the land cover was affected, with most types of trees seemingly affected by wildfire in a characteristic manner. This tendency might be peculiar to this site and might be different in other areas. In particular, our detailed statistical analysis showed that forests dominated by holm oak *(Quercus ilex)* were the most fire-resistant, while those dominated by sessile oak *(Quercus pyrenaica)*, pine *(Pinus pinaster)* and chestnut *(Castanea sativa)* trees were the least resistant. The areas where the cork tree *(Quercus suber)* was the dominant species tended to show an intermediate level of damage.

Conclusion

The results achieved so far show that MERIS-based estimates of wildfire damage over forested areas can be extremely useful not only in establishing the scale of the damage, but also for the subsequent forest renewal projects and for subsidy management. MERIS data can also be used to good effect for future forestry planning activities, since more fire-resistant types of trees - as established by this or similar studies - should be proposed for new plantations in vulnerable areas.

Acknowledgements

The work reported here was made possible by ESA support for a so-called 'Category-1 project for the use of Envisat data', entitled *'An Assessment of the Potential of Spanish Forests as Carbon Sinks using Remote-Sensing Techniques',* and an agreement between the Spanish Ministry for the Environment and the INIA – Ministry of Education and Science.

Following the Tour de France with EGNOS

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Thanks to the new European EGNOS satellite-positioning system, it was possible to accurately track the positions and speeds of riders in this year's Tour de France cycle race in real time! A first trial was conducted over the race's famous and tortuous Alpe d'Huez stage on 21 July.

Background

The tracking of individual sports competitors by satellite is just one of a whole host of applications that have been made possible by the high positioning accuracy and integrity provided by EGNOS, the European Geostationary Navigation Overlay Service, which is now being implemented across Europe. Currently in an experimental phase, this particular application was demonstrated for the first time during the Tour de France time trial between Bourg d'Oisans and Alpe d'Huez, when 10 riders were tracked.

By installing an EGNOS receiver in the Team Director's vehicle accompanying each rider, it was possible to monitor the precise gaps between riders and even to model their ascents over the entire 15 kilometres of this legendary stage. It was even possible to 'visualise' the efforts of Lance Armstrong as he negotiated the 21 bends leading to the top of l'Alpe d'Huez and to compare his ascent with those of other riders, such as Richard Virenque.

The EGNOS receivers that were installed in the Team Directors' cars

Working on the EGNOS data from the riders

Putting EGNOS Technology to Work

The technology concept adopted for the Alpe d'Huez trial was as follows. GPS receivers were installed in the boots of ten of the Team Directors' vehicles, which shadowed their riders very closely. These receivers transmitted their data via a GPRS modem link to the mobile operator. A message server collected this information and forwarded it to the Control Centre located at the summit of Alpe d'Huez. There, the receiver-computed position and raw pseudo-ranges were stored on a server. At the same time, an EGNOS receiver, also installed at the Control Centre, received the EGNOS/ESTB messages, which were used to compute a correction to the GPS pseudo-ranges.

The computed locations were then sent to another server for 'visualisation', showing the positions of the riders in 3D using a Trimaran graphics system. The various servers were linked by a standard local area network (LAN), connected to the Internet via a router, as shown in the accompanying diagram.

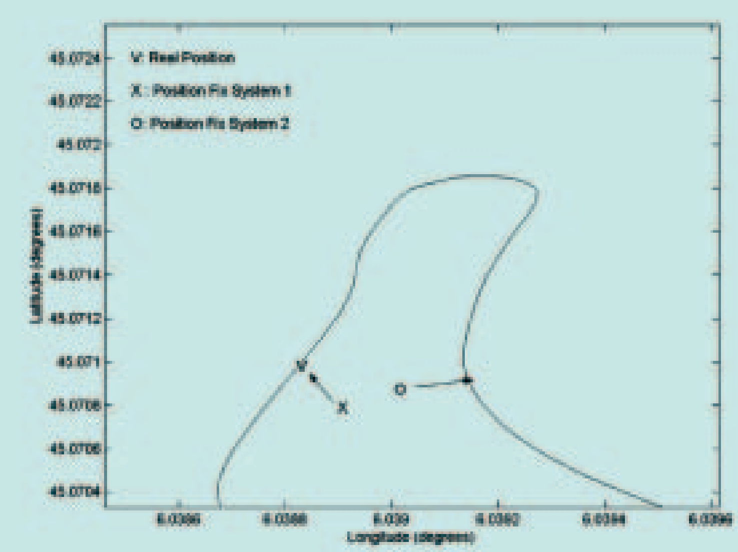
The reason for computing the EGNOS position at the Control Centre was that during such a mountain stage, geostationary satellite visibility is greatly reduced because they are located over the equator and their elevation in the sky for users in Europe is therefore rather low. Consequently, the statistical probability of having a geostationary satellite in view decreases considerably in the mountains.

The EGNOS technology provides a number of benefits to users compared with 'standard' GPS. For the Tour de France application, two of those benefits were of major importance: namely the improved accuracy and the improved reliability of map matching. As a result of the improved accuracy offered by EGNOS, it is even possible to locate the position of a particular cyclist relative to the others in a peloton. This requires a relative positioning accuracy of approximately 1 metre, which stand-alone GPS is unable to provide. Map matching is a technique that is commonly used in navigation to improve accuracy and most of today's in-car navigation systems rely on it.

EGNOS (the European Geostationary Navigation Overlay Service) is a joint project of the European Union, ESA and Eurocontrol. The network is made up of satellites and ground stations that correct and augment data provided by the US Global Positioning System (GPS). In its current form, the GPS system is neither accurate nor reliable enough for applications of the sort described here, while EGNOS, operational as of this summer, provides the accuracy and continuity required to follow the riders' positions minute by minute. This already high level of performance will be given a further boost with the deployment of Galileo, the first civil global satellite navigation system for Europe, funded by ESA and the European Commission.

The EGNOS Control Centre near the finishing line at Alpe d'Huez

When a vehicle is driving along a road and position fixes are made using GPS, the fixes will not be located on the road itself due to measurement errors. With map matching, the section of the road closest to a position fix is searched for in a database of road coordinates. Although the accuracy of the position fixes is thereby generally significantly improved, there is a small risk of matching the position fix to the wrong road segment, as shown in the accompanying figure. Here a vehicle is travelling on a mountain road and two navigation systems are being used, one with map matching (System 1) and one without (System 2). In this example, the position fix of System 1 is located on the correct segment of road due to the improved accuracy when using map matching, but the position fix from System 2 is on the wrong part of the road due to its larger measurement error.

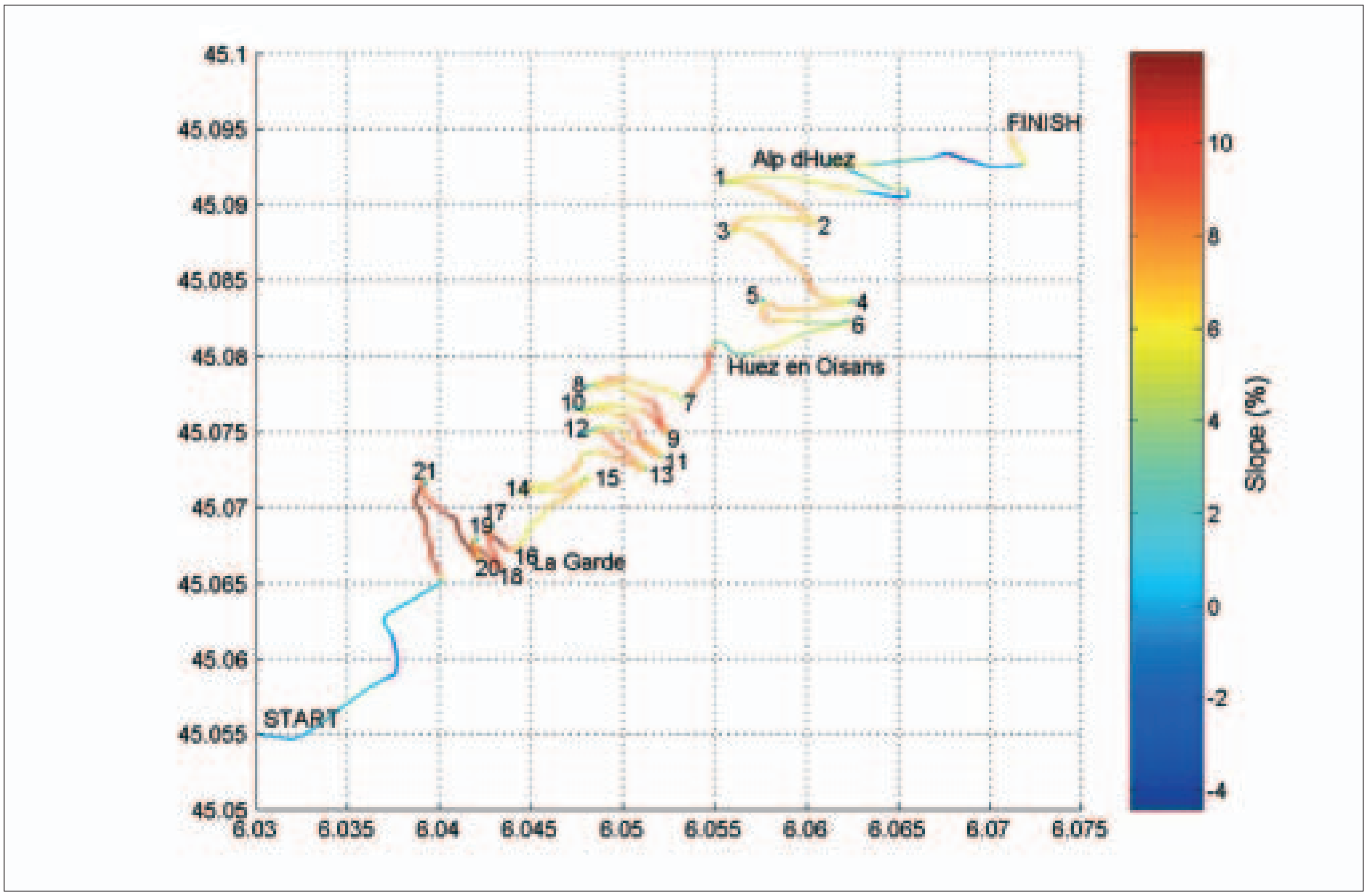


EGNOS's greater positioning accuracy provides for more reliable map matching (see text)

An alternative possibility for real-time precise tracking is a technique known as 'Real-Time Kinematic Phase Processing' (RTK), which was used to produce the reference track for the Alp d'Huez time trial. However, due to the trees next to the road and blocking due to the mountains, the RTK carrier positioning experiences large data outages, which means it cannot be used for tracking the cyclists themselves. This phenomenon is not experienced with the EGNOS solution, where more reliable code observations are used. Even to produce the reference track using RTK, ascending and descending passes had to be recorded several times, pausing at important locations. The final reference track is shown in the accompanying figure, with colour coding of the mountain slope and showing the turn numbers counting down until the village of Alpe d'Huez, indicating to the cyclists how far they still had to pedal!

How Well Did EGNOS Do ?

The final results of the EGNOS trial are

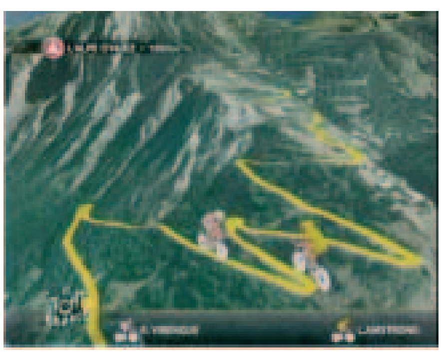


The reference track for the Alpe d'Huez time-trial stage

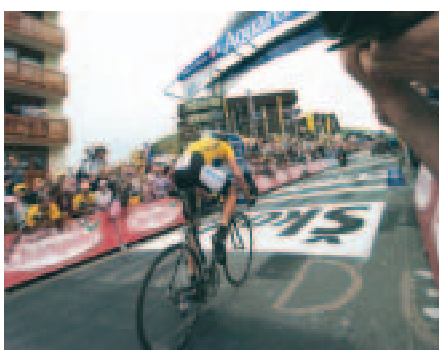
illustrated in the accompanying graph, showing jut how well the receiver calculated Lance Armstrong's position. The purple line is the pre-computed reference track. The red line indicates the unfiltered GPS-only solution, turning into black when filtering was applied. The blue line is the EGNOS filtered solution, which is always within less than 1 metre of the real track.

A major conclusion from this test is that having the Galileo system operational would really make a difference for this application. Since the average number of satellites in view was particularly low in the area where the trial was conducted, due to the blocking effect of the mountains – generally about 6, and sometimes fewer than 4 – more satellites would be of great help. This is illustrated in the next figure, where the number of satellites tracked by Lance Armstrong's receiver are shown by the black line, and the interval in seconds between successive samples is shown by the red one.

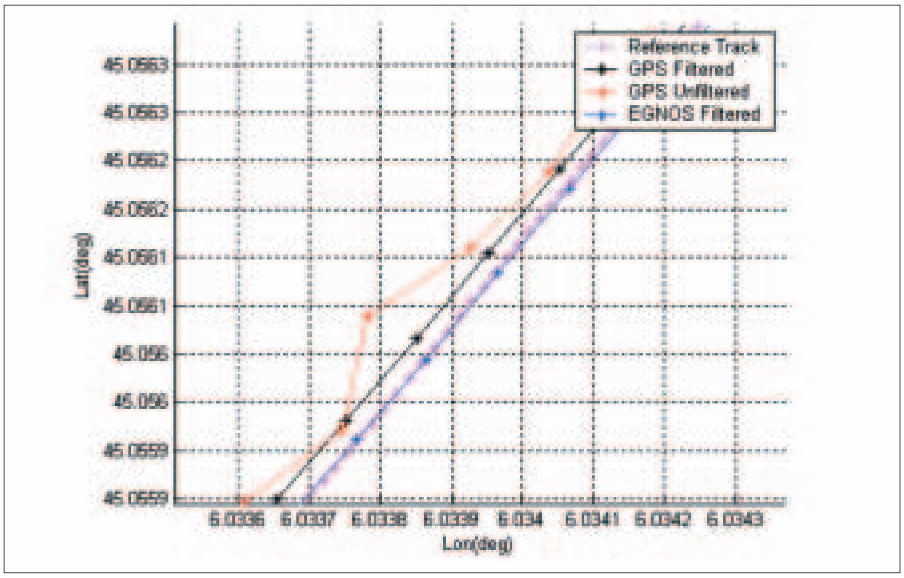
This EGNOS trial has demonstrated a whole new way of following not only the Tour de France, but any race, thanks to the evolution of satellite navigation. With the help of satellites, it will be possible at any given time to know where each rider is and how he is doing in the race, whether he is in the peloton or has broken away and is out in front. This is useful information not only for Tour fans who want to know how their favourite rider is placed, but also for the Team Directors who want constant updates on their star performers and their opponents, or to analyse the race afterwards together with the riders. The information is also of great value to the race organisers, not least for safety



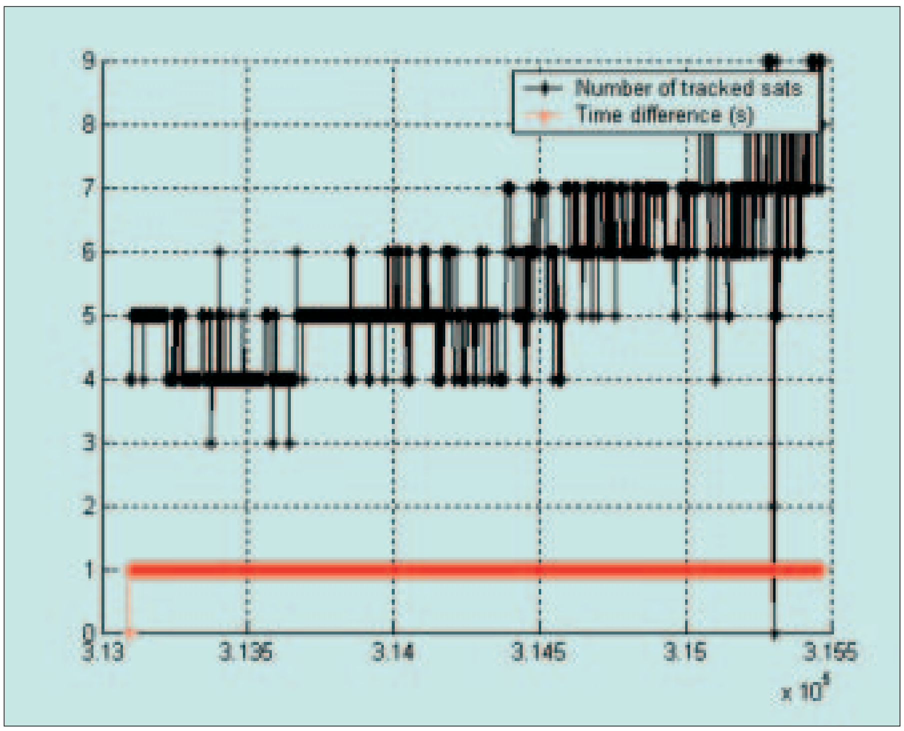
A virtual reconstruction of the race between Armstrong and Viranque over the Alpe d'Huez stage



Lance Armstrong's arrival at the Alpe d'Huez finish



Graphical representation of the EGNOS receiver's superior tracking capabilities



The number of satellites visible to Lance Armstrong's EGNOS receiver at different times during the stage

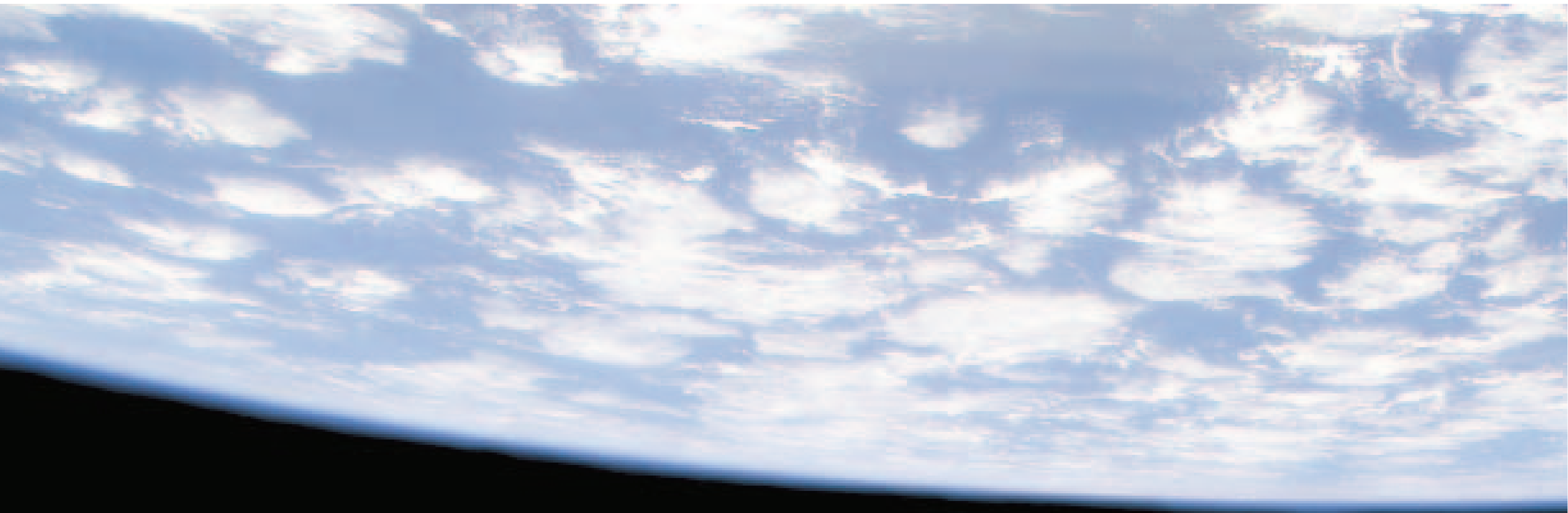
purposes, giving them an overall perspective of how the stages are unfolding, complete with the exact positions of all competitors at any given moment. This data can be made available on the Internet, on the Tour de France channel or can be broadcast by other television channels even when they have no presence on the ground.

And Next Year?

A further aim of the project is to use the EGNOS data to construct a virtual image of each rider's progress. The accuracy of EGNOS is such that the position of any moving object equipped with a receiver can be pinpointed to within 1 metre. It will therefore be possible to watch the progress of each rider through all the stages of the Tour against the backdrop of a 3-D visualisation of the surrounding countryside. The combination of precise topographical data and data on the position of each rider will provide a 3-D real-time picture of the competition. This will be an invaluable addition to television broadcasts, which are currently unable to show all of the riders. With this kind of system, each broadcaster will, for example, be able to have a dedicated channel on which viewers can choose which rider they want to follow without needing to have a camera trained on each cyclist. This value-added service is currently under development within the framework of a partnership between the European Space Agency, Tour de France organiser ASO, and the computer graphics firm Trimaran.

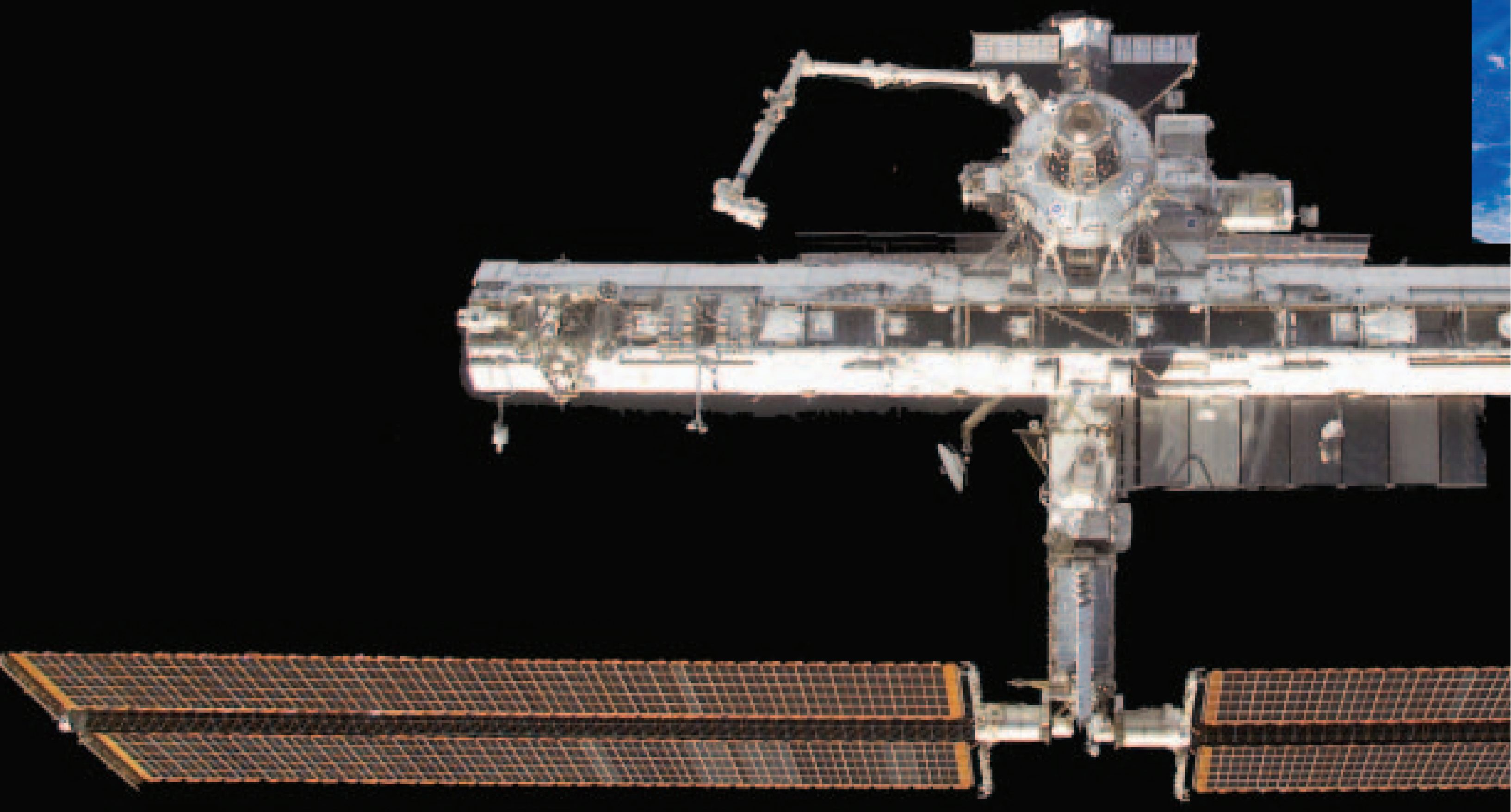
Conclusion

This demonstration project with the Tour de France served to underline the wide diversity of the applications that are now becoming possible thanks to satellite navigation. From blind people to sport, from air traffic to road tolling, every sector of our society could soon be heavily influenced or even transformed by precise tracking and positioning. Many see this as a 'revolution' in our daily lives, comparable to the invention of the wristwatch – not only do we now need to know the time, but also exactly where we are at any given moment! How true this will turn out to be remains to be seen, but we can certainly be sure that EGNOS represents just the beginning of these new services, which Galileo will go on to enhance and expand. r



Sharing ESA's Knowledge and Experience

– The Erasmus Experiment Archive



Dieter Isakeit, Massimo Sabbatini & William Carey
ESA Directorate of Human Spaceflight, Microgravity and Exploration, ESTEC, Noordwijk, The Netherlands

The aim of the Erasmus Experiment Archive is to make available to scientists, engineers, decision makers, students and future generations of researchers the results of low-gravity experimentation carried out under the responsibility of with the support of the Directorate of Human Spaceflight over the last 30 years, and to keep track of new experiments. The archive groups into a single repository as much information as possible regarding research carried out under these special conditions, in an effort to inspire new research and share with the science and industrial space community at large the body of knowledge acquired so far. As is well-known, the time lapse between consecutive space missions is often a major problem in retaining expertise in the scientific and industrial teams. The Erasmus Archive is another way to achieve that goal of passing knowledge across the generations.

Introduction

The Erasmus Experiment Archive is an electronic database, accessible via the Internet, that collects in a single reference repository information regarding all experiments performed to date in the facilities that fall under the responsibility of the ESA Directorate of Human Spaceflight, Microgravity and Exploration. The archive was developed and is maintained and kept up-to-date by the Erasmus User Centre, which forms part of the Directorate and is located at ESTEC in

Noordwijk (NL). Abstracts from the experiment proposals, scientific results and a list of relevant references and publications are some of the features that can be found for each experiment record.

The Erasmus Experiment Archive cooperates in this effort with the experiment archives of the partner space agencies NASA and JAXA (Japan). By means of the International Distributed Experiment Archive (IDEA), a mutually agreed standard for experiment records, the experiments contained in the databases of the three partners are shared so that users around the World can browse all experiment records through the Internet, regardless of whether they start their search via the ESA, NASA or JAXA database Internet site.

The archive was established by ESA to facilitate access to the results of experiments performed under microgravity conditions with the objectives of providing experienced and potential European scientists, via a user-friendly reference tool, with:

- An overview of European experiments carried out on space platforms and ground-based facilities.
- Coverage of the ESA Research Cornerstones.
- The scientific results of the experiments, wherever possible.
- References for further details and results.
- As much multi-media material relating to the experiments as possible, including images, videos, audio, graphs, tables, animations, etc.

With the growing use of the Internet and the progress in Internet technology, particularly in the field of database-driven web applications, and with the advent of streaming video broadcast techniques, it was decided to substantially re-engineer and upgrade the existing Microgravity Database to form the 'Erasmus Experiment Archive'.

The technology of streaming video recordings stored on an Internet server which has been incorporated into the new Erasmus Experiment Archive lets the scientists behind each of the experiments explain the rationale of their experiment and the results to be expected, in small video clips that can be accessed over the Internet. Video recordings and other photographs and illustrations of the experiment's execution can be archived and made available online using the same techniques.

Experiment Facilities Covered by the Archive

The ESA Directorate of Human Spaceflight, Microgravity and Exploration facilitates and coordinates the access of European users to a number of experiment facilities that provide a very particular physical and operational environment that other facilities cannot offer. They include the International Space Station, recoverable Foton satellites, Maser and Maxus sounding rockets, the Airbus A3000 Zero-G aircraft for parabolic flights, as well as various ground facilities in Europe.

Most, but not all, of these facilities are characterised by a 'weightlessness environment', which is why they are commonly called 'facilities for microgravity research'. This term is a little misleading, however, in that microgravity is a tool, not a scientific discipline as such. In fact, these 'microgravity facilities' are not used by 'microgravity scientists', but by researchers from scientific disciplines as diverse as biology, human physiology, physics, material science, fluid science, combustion science, as well as more application-oriented engineering sciences, and for the evaluation and demonstration of innovative techniques and industrial processes and of new commercial services.

The use of these facilities is intended to increase our collective knowledge in the scientific and technical arena. It has in fact already led to many new discoveries, new insights into physical processes and phenomena, and increased confidence in new manufacturing processes.

The Beginning

In the early 1990s, ESA set up a catalogue of the experiments performed in the various facilities for research under microgravity conditions. This catalogue started as a collection of printed fact sheets, developed into a computer-based database that was distributed on floppy disc and later CD, and finally evolved into an online database that could be accessed through the Internet. This became known as the 'Microgravity Database'.

The Target Groups

The Erasmus Experiment Archive primarily addresses the following large and diverse audience:

- Scientists interested in utilising experiment facilities for their own research activities.
- Project engineers and managers involved in developing, building or operating similar facilities.
- Scientists and engineers at the European User Support and Operations Centres (USOCs), who support users in the preparation and utilisation of their experiments.
- Political decision makers and project managers from governmental services who decide on the funding and orientation of research programmes.
- University students in search of reference material for their studies or for information that can guide them in their study, and later professional career, choices.
- Public and private education and information-dissemination institutions and centres that focus on the popularisation of science and technology activities in space.
- Media representatives and other lay people with an interest in space research and technology.

The major vehicles for the dissemination of scientific findings are publications in scientific journals and presentations at scientific symposia. The only problem is that both are usually very focused on a given discipline, whereas the utilisation potential of the research facilities with which the ESA Directorate of Human Spaceflight, Microgravity and Exploration is dealing is of a very multidisciplinary nature.

This scientific diversity means that a special effort is necessary to ensure that the results of the work performed in the said facilities and their scientific returns not only benefit the specific community of the scientists directly involved in an

The Archive's Content

The information contained within the archive is collated in individual experiment records. Their structure has been carefully chosen to capture and retain the most important knowledge concerning any one experiment, without overwhelming the user querying the system with excessive information. Each record has a primary and secondary field set: the primary set assists in the definition and recovery of the specific record, while the secondary set covers the core knowledge associated with the experiment.

The primary field set consists of experiment name, research team members and their affiliations, particular mission associated (e.g. 35th ESA Parabolic Flight Campaign, Delta Soyuz Mission and Maxus 5 Sounding Rocket), and the date on which the experiment was conducted. Two other very important fields, research cornerstone and research area, complete the primary set. Two fields related to the discipline area addressed by the experiment are required as the research-cornerstone definition has only been in existence since 2001, when the following 14 Cornerstones, or 'areas of European excellence', were defined in the six major research areas:

– ***Fundamental Physics:***
  Complex Plasmas and Dust Particles Physics
  Cold Atoms and Quantum Fluids
– ***Fluid and Combustion Physics:***
  Structure and Dynamics of Fluids and Multi-Phase Systems Combustion
– ***Material Sciences:***
  Thermophysical Properties
  New Materials and Processes
– ***Biology:***
  Biotechnology
  Plant Physiology
  Cell and Developmental Biology
– ***Physiology:***
  Integrated Physiology
  Muscle and Bone Physiology
  Neuroscience
– ***Astro/exobiology and Planetary Exploration:***
  Origin, Evolution and Distribution of Life
  Preparation for Human Planetary Exploration.

http://spaceflight.esa.int/eea

The secondary field set consists of references, processing facility, experiment objectives, experiment procedure, experiment results, attachments and validation point. The attachments associated with each record may include images, PDF files, videos or sound files that help to explain the scientific objectives, particular procedures or protocols followed, and experimental results.

The validation point field contains the name and address of the person at ESA who is responsible for validating the record entry, and who may be contacted for further information regarding the experiment. It is the key field associated with the entry of records into the archive. In the past, the lead scientist for each experiment was responsible for entering the record into the archive, and this record was subsequently validated by the respective Life- or Physical-Sciences Coordinator at ESA. This process proved to be extremely time-consuming and inefficient and led to significant disparities between individual records in terms of content and style. This initial step is now carried-out by the Erasmus User Centre, which produces the initial content based on inputs provided by the scientists. A final validation by the respective science coordinator is performed prior to publishing the record. This approach results in a more timely insertion of the record, and indeed in a more homogeneous and consistent set of records, as well as in reducing the administrative task for both the research team leader and science coordinator.

experiment, but that they are also made known to scientists from other disciplines. In this way, the effects of synergy and cross-fertilisation of ideas can be promoted and exploited.

A further consideration in the design of the Erasmus Experiment Archive was the fact that the 'customers' for these facilities fall into two categories: one 'half-customer' uses the facilities and gets the benefit of their use, but does not pay for their use. This is usually a scientist from a publicly funded research institute. In addition, there is a second 'half-customer' who does not use the facilities and does not necessarily get direct scientific benefit from their use, but who pays for the use of the facilities by the researchers. This is normally a representative from a national ministry or other governmental service which is funding research projects. This 'sponsor' in turn has to explain and justify the funding of research projects to the media and the tax-paying public. Their life can certainly be made easier if they have direct access to the results and benefits of the experiments, especially if this information is presented in a form in which it can be re-used for informing other decision makers, the media and the interested public.

Retrieving the Information

The Erasmus Experiment Archive is accessible online through the Internet via a very simple web-based graphical user interface, without need for a specific user identification or password.

The main area of the opening page of the archive allows the user to make either a full text search or an advanced search. There are also links to a description of the archive, to international-partner archives and to a list of contact persons. A powerful feature is that each time the archive's Home Page is opened in the user's web browser, it automatically performs an indexing of the complete database at that instant. This means that the user will always see the most up-to-date content, even if a new record was entered only seconds before. This instant indexing is repeated each time a new search is initiated.

Full Text Searching – The archive does not use the concept of 'keywords', which are subjective and very time-dependent and may use terminology that is fashionable at the time, but soon loses its meaning. It means that records that should be found are 'lost'. A full-text search is extremely powerful in that it ensures any occurrence of the text-string within a record is not accidentally overlooked. It is similar to going into a shop where there is an assistant to help you find what you are looking for! This method is also useful when the user has limited information on which to base a search, such as an author's surname, the mission or even just the year in which the experiment took place. Although a large number of records may initially be returned, the search can be repeated and the desired information retrieved through a gradual refinement of the search criteria.

Advanced Searching – The advanced search is intended for users who have a greater knowledge of what they are looking for, and is therefore more of a self-service 'hypermarket approach', where each aisle is clearly marked and you can readily find what you are looking for.

To assist the user in searching the archive, the records have been collated into a number of groups reflecting the microgravity platforms on which the experiments have been performed, i.e. space stations, retrievable capsules, sounding rockets, parabolic flights, Space Shuttle and ground facilities. By clicking on the icon associated with a platform, the complete list of relevant missions or campaigns is listed. In addition, three 'pre-programmed' searches may be performed to show a list of records involving team members from a particular country, the number of experiments performed in any given year between 1971 and the present, and a complete list of all experiment records in the archive.

The archive can also help users who wish to find partners with whom to team up. Searches may be performed to find a partner in a specific country or in a specific scientific discipline, or where, for example, a complementary scientific capability is required in order to complete a team.

The advanced search is particularly useful for a user to see what capabilities are offered by a particular platform or facility.

Cooperation with International Partners

One of the major features of the Erasmus Archive is its participation in the International Distributed Experiment Archive – IDEA for short. Through this partnership with the National Aeronautics and Space Administration (NASA) and the Japanese Aerospace Exploration Agency

The IDEA search page

(JAXA), users have access to all three databases using a single search.

The problem of sharing or operating databases together is currently a very active area of discussion within the European Union, particularly with respect to cooperative policing and security, where combining Member State databases is proving problematical due to their different structures and contents, and in some instances because not all records can be disclosed to all partners. ESA, NASA and JAXA have achieved such interoperability, making records mutually accessible by means of sharing record indexes in a commonly agreed format – the IDEA concept – while retaining their own database structure.

An IDEA search will retrieve records from all three ESA, NASA and JAXA microgravity databases in the common format and the joint approach avoids overlapping information and inconsistencies between the distributed archives, and provides the user with access to a much greater bank of information.

Where Do We Stand Today?

At the time of writing, the Erasmus Archive contains approximately 1200 individual records corresponding to European experiments carried out since 1971, up to the present day. Records for around 90% of all experiments conducted have been inserted to date, and the primary emphasis of present activities is on completeness of the database in terms of record content, completing the entries in reverse chronological order. A recent decision to also include experiments performed during the ESA student parabolic-flight campaigns means another 200 records need to be added to the archive to cover the 7 student campaigns flown to date.

What Does The Future Hold?

The Erasmus Experiment Archive represents one of the cornerstones of the informatics infrastructure of the Human Spaceflight, Microgravity and Exploration Directorate, and more specifically also of the Virtual Campus information framework provided to the users of the International Space Station (ISS) by the Erasmus User Centre. One major enhancement to be provided in the immediate future is improved integration of the archive with the Virtual Campus's other tools and databases, such as: the User Documentation Access System (UDAS), a system covering the utilisation and the development of scientific payloads, which narrows down the range of required documents and collects them into a single document; the MSM Photo-Video Archive; the remote collaboration tool iLinc; and the ESA Spaceflight Internet site.

Another important addition to the archive would be that of a 'lessons learned' section to each record. It is a fact that scientific journals tend to focus primarily on the scientific outcome of research, while not necessarily addressing to the same extent the technical and operational aspects of conducting the experiments themselves. Thus, it would be beneficial if a record is kept of the lessons learned with given experimental set-ups, and of the little 'tricks of the trade' that could facilitate the work of future researchers. This would allow, in particular, the introduction of young scientists more easily to the subject and would avoid each new generation re-inventing the wheel.

On the technical side, one foreseen improvement is to add the capability to conduct 'a search within a search', which is a rapid way of refining a search that has returned a high number of records.

It is hoped that within the not-too-distant future, ESA's other ISS Partners, Russia and Canada, will also make their experiment databases accessible via the IDEA system.

The Technologies Utilised

The Erasmus Experiment Archive is a Macromedia ColdFusion application running on a Solaris platform, one of the Directorate's servers outside the ESA firewall. The web server is an Oracle Application server and the data are shared in an Oracle database. The application can be maintained remotely, and a ColdFusion Administrator module allows the Erasmus User Centre team to modify the content from anywhere over the Internet. The IDEA approach described in the main text provides a full-text search on experiment data that are stored in HTML files, and these HTML files are refreshed automatically once a week by the ColdFusion Administrator module.

Most records are provided with multimedia attachments that increase the usability of the archive by enlarging the range of audience that can have access to it. In particular, most new records are provided with video attachments ranging from selected scenes from the experiment itself to interviews with the team coordinator, explaining in his/her own words the scientific objectives of the experiment. Published papers, pictures, data visualisation techniques and animations are also widely used. The video products are standardised by the Erasmus User Centre team that produces them during the various launch events and makes them available a few days after in streaming-video format.


A Schlieren photograph of the Ariane-5 launcher in the wind tunnel at FOI in Sweden (speed Mach 0.85)

Modelling Launcher Aerothermo-dynamics

– A Vital Capability for Space Transportation

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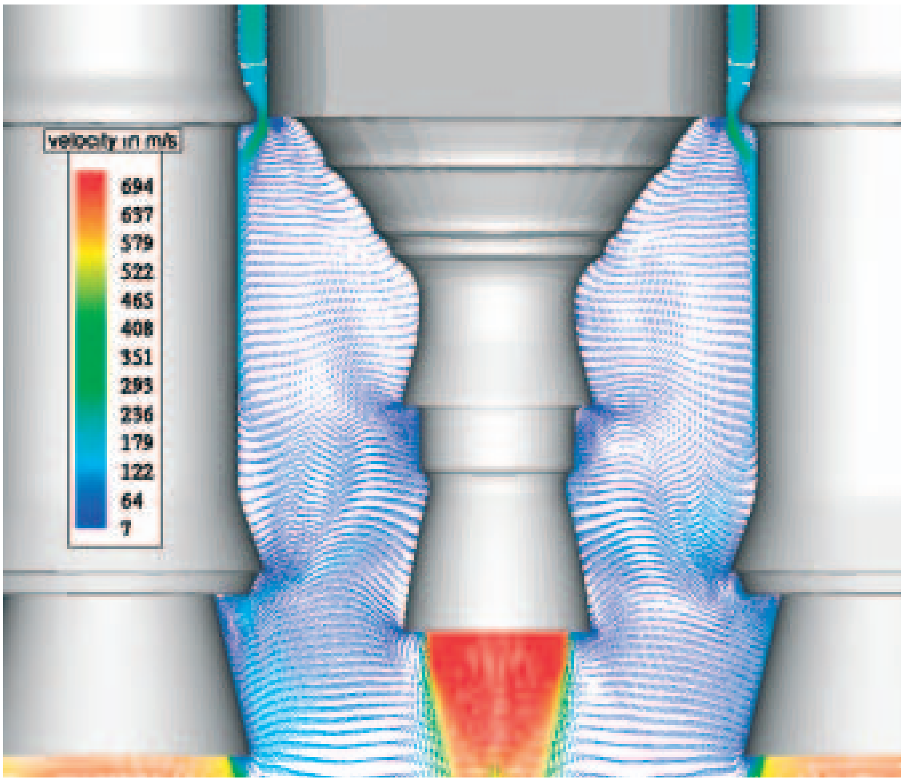
Europe's access to space today relies primarily on the Ariane family of heavy-lift launchers and the future Vega launcher for smaller payloads. The successful development of such launchers critically depends on finding reliable solutions in the challenging areas of propulsion and aerothermodynamics, which are the key elements of any launch vehicle. The processes involved are highly complex because these disciplines strongly interact with the other build elements such as structures, thermal protection, acoustics, and guidance, navigation and control. To illustrate the aerothermodynamic challenges, we need only look at the various phases in the flight of a generic vehicle containing technology elements from both Ariane-5 and Vega.

Introduction
In the past, the aerodynamic and aerothermodynamic development work on vehicles such as the Space Shuttle or Ariane-4 has been based almost exclusively on engineering and empirical methods and experiments. In the last two decades, however, Computational Fluid Dynamics (CFD) has matured to a point where it can make meaningful contributions when fast analytical modelling requires that the physical problem be strongly simplified, and testing is either extremely expensive or cannot recreate the real problem. Increasingly, CFD-based methods offer the only feasible solution for accelerating and refining the space-transportation design process whilst still maintaining sufficient confidence in the results for safe design decisions to be made.



Snapshot of an unsteady flow field at the Ariane-5 launcher's base

The Launch Sequence

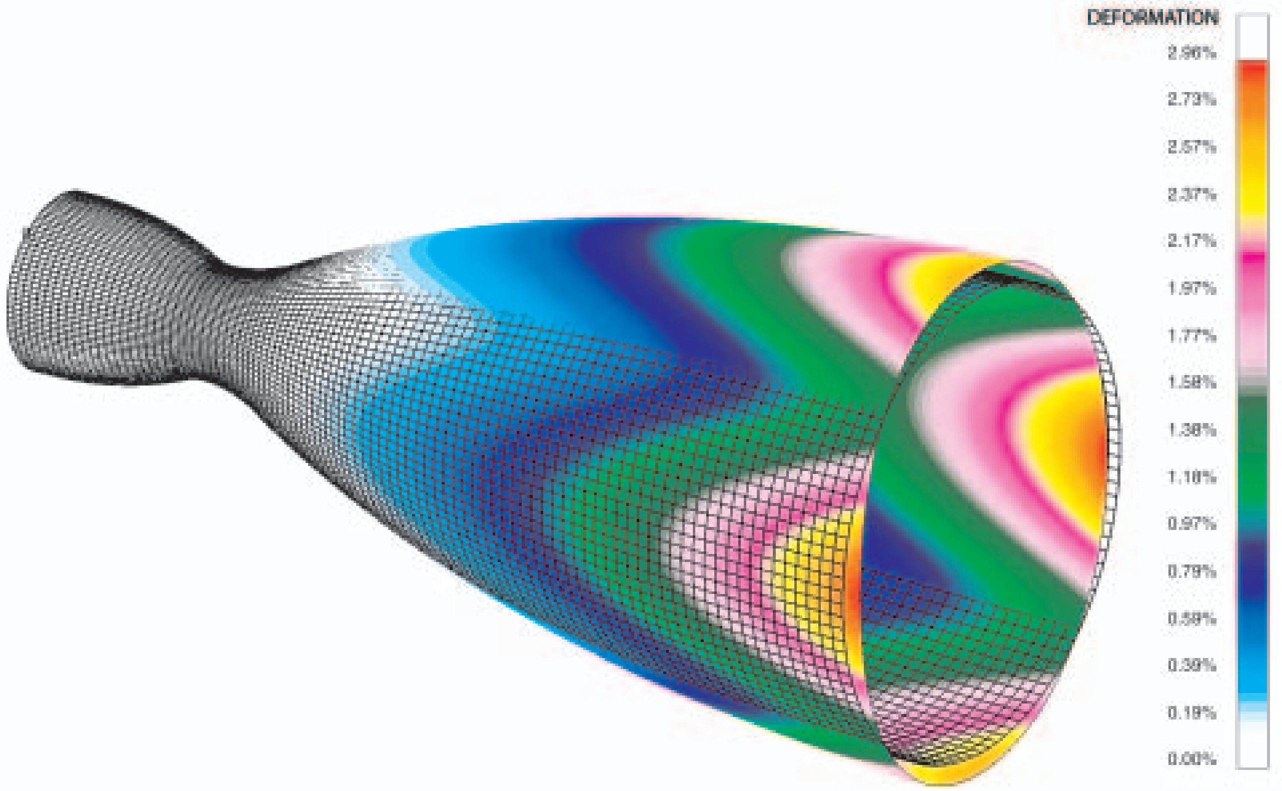
T_0 – 12 hours: Launcher Roll-out
The launcher is transported from the controlled environment of the integration hall to the launch pad, and into what may possibly be a 'hostile' environment due to rain or gusty winds. Aerodynamically, this may already be a problem because if a cylindrically shaped object, such as a tall building or launch vehicle, is exposed to sufficiently strong cross-winds, vortices formed in the wake of the structure cause pressure fluctuations, resulting in a fluctuating force on the object.

CFD methods and simplifying analytical modeling are therefore used to determine critical wind velocities for the launcher structure on the launch pad, through the simulation of vortex shedding effects coupled with structural dynamics. This is a substantial help in determining critical roll-out and launcher installation conditions.

T_0 – 7 seconds: Main-Engine Ignition
After main-engine ignition, the development of the engines' exhaust plumes and the blast wave characteristics determine the acoustic environment before lift-off, which has a direct impact on the acoustic vibration levels acting on the payload. As more and more stringent acoustic requirements are imposed on the launchers, aerodynamic optimisation of the launch-pad area by diverting the high noise level of the engine plume away from the launch vehicle becomes more important. CFD methods are currently used, together with subscale testing and empirical modelling, to predict the effect of the complex flow in the ducts that divert the exhaust plumes on the launch pad.

Ignition of the main engine also involves high structural loads on the expansion nozzle due to a transient asymmetric flow field within the nozzle. Detailed knowledge of the physics of such unsteady flows allows one to arrive at a nozzle design that combines high efficiency with low operational risk. Due to the expense of conducting full-scale tests, such understanding is usually derived from a combination of subscale testing, empirical methods and sophisticated CFD methods.

T_0 + 0-10 seconds: Solid Booster Ignition and Lift-off
Lift-off takes place immediately after the ignition of the solid-rocket boosters. During the very first flight phase, especially if an early pitch-over manoeuvre is necessary to reach a planned trajectory, interactions between the hot main-engine and booster plumes and the ground facilities, e.g. launch tower and mobile gantry, have to be taken into account. A combination of empirical, analytical and numerical methods is used to assess critical parameters in this area.



CFD modelling of the deformation, or so-called 'ovalization' of a Vulcain-2 engine nozzle due to asymmetric internal pressure loads

Flow/structure coupling makes an important contribution to the structural noise level that is transmitted to the payload. Computational tools are used to describe the interaction of launcher oscillations with the flow for the most important structural modes.

During the first flight phase, high heat loads are observed in the nozzle near the exit due to incipient separation of the flow in performance-optimised nozzles. Control of such heat loads again requires detailed knowledge of the nozzle flow, since a large separation could cause post combustion and overheating close to the nozzle's exit. Experimental and numerical methods are used to determine the extent and severity of flow separation for this first highly over-expanded flow phase.

T_0 + 30-50 seconds: Launcher in the Transonic Flight Regime

The point where the launcher goes supersonic represents another critical phase. The local flow-field around the launcher becomes highly complex, including localised regions of supersonic flow terminated by strong shock waves with associated high pressure variations (see Schlieren photograph of Ariane-5 on title page).

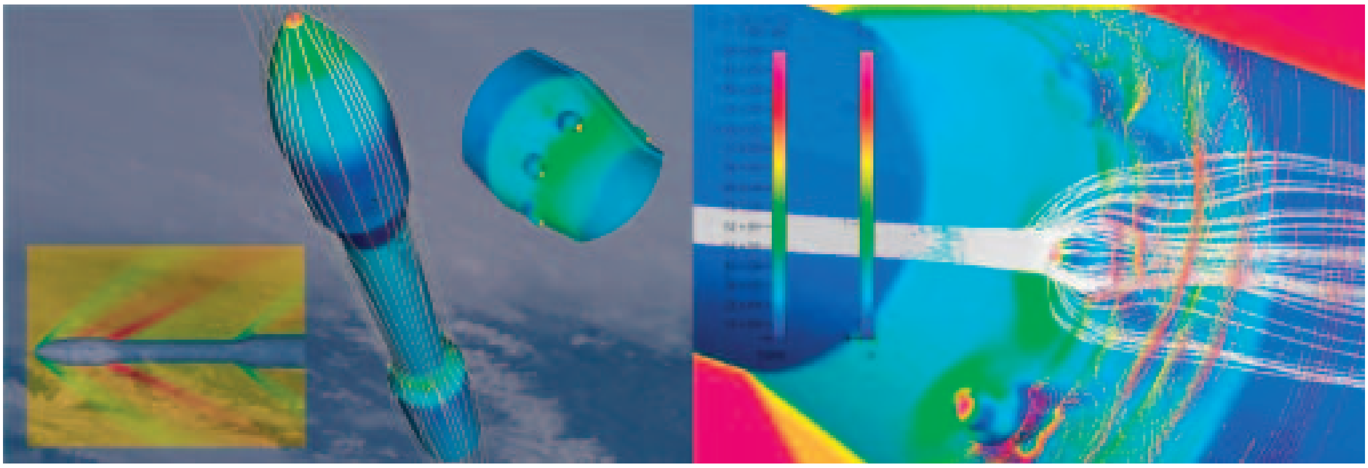
The flow-field is then highly sensitive to small changes in flight direction (pitch and yaw) and significant asymmetric loads may result from such motions. Moreover, the shock waves around the vehicle exhibit oscillations, and the resulting typical high frequency shock motion is another source of severe acoustic noise, against which measures must be taken, either by changing the shape or by protecting instruments or mechanisms located near the disturbances.

Experience has shown that in this flight phase, the simulation and control of the interaction of the main engine plume and the ambient flow field requires the greatest attention because of the generation of side loads and large local heat loads. Uncontrolled side loads can also lead to malfunctioning of the gimbal system. However, since the complex aero-thermodynamics of separating flow in expansion nozzles and the coupling to the ambient flow field are not yet entirely understood, nozzles have to be designed with large margins and therefore cannot be fully optimised for both sea-level and rarefied atmospheric conditions.

More sophisticated three-dimensional computational results, e.g. wall stream-lines and velocity vector plots near the nozzle exit (see accompanying figure), as well as experimental data obtained both on the ground and in flight, are essential for an in-depth understanding of the flow physics and ultimately for shape improvements that reduce the loads to an acceptable level. Such results will be employed in future work on buffeting reduction through launcher shape optimisation.

T_0 + 30 - 120 seconds: Ovalization of Launcher Nozzles

Currently, analytical models are generally used in nozzle design to, for example, evaluate structural fatigue and nozzle



Pressure distribution and Mach-number contours in plane of symmetry and streamlines past retro-covers for Vega

deformation known as 'ovalization'. However, due to the necessary simplifications for the complex coupled flow field, such models require the application of large safety factors, leading to non-optimal performance. Benefiting from today's greatly improved computer performances with cost-efficient high-performance parallel-processing systems, the enhanced validation levels of CFD methods are becoming more and more important. For engine components, such as nozzles, recent coupling of flow with heat transfer as well as structural dynamics is leading to better understanding of the limiting structural loads, and hence to reduced design margins.

Analytical models can only predict nozzle stability limits for separated flows. Very recent computational analysis has provided the first evidence that fully attached flow can also excite nozzle ovalization. The accompanying illustration shows the CFD-predicted structural deformation response of a thin-walled nozzle under an internal pressure load.

An exact quantitative analysis is currently being pursued, but already at this stage the conclusion that safety factors cannot replace a thorough understanding of the aerothermodynamic flow properties seems justified.

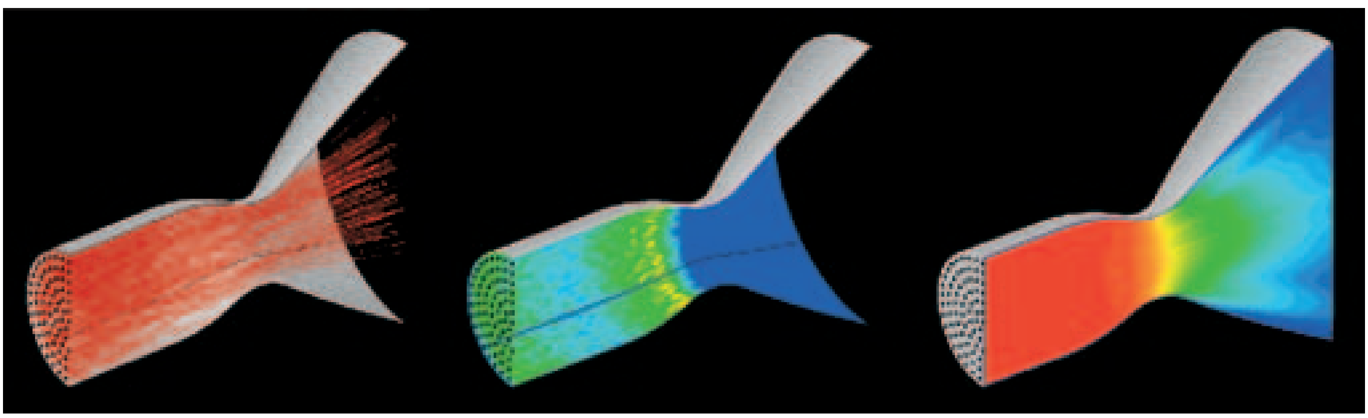
T_0 +120 seconds: Flight at Maximum Dynamic Pressure

Due to its increasing velocity and the decreasing ambient pressure, the launcher reaches a point on its trajectory where the ambient flow results in the highest dynamic loads on the launcher's structure. It typically occurs at roughly twice the speed of sound, and not only the main structure of the launcher, but also protuberances such as wiring tunnels, fuel pipes and retro-rocket covers have to withstand such loads. Such local flow effects are strongly viscous-dominated and cannot be accurately modelled in sub-scale wind-tunnel experiments. CFD modelling of the flow has become an indispensable tool for the extrapolation of wind-tunnel results to actual flight conditions.

The above figure shows CFD modelling results for a Vega-shaped vehicle travelling at Mach 2 at an altitude of approximately 14 000 metres (angle of attack 3 deg and roll angle 45 deg).

T_0 + 240-244 seconds: Ignition of Upper Stage Engine

Typically 4 minutes into the flight, at hypersonic speeds and in rarefied atmospheric conditions, the first stage



Low-pressure oxidiser pre-flow in the combustion chamber and nozzle of the Aestus engine reaches the end of its lifetime and is pyrotechnically separated from the upper-stage. Following a possible ballistic flight phase, the upper-stage engine is ignited in vacuum, involving the injection of pressurised liquid propellants into the combustion chamber, contact ignition, and an increase of pressure resulting in steady reacting flow.

Upper-stage engines as Aestus have been designed by means of experiments including the simulation of ambient vacuum conditions for the cold pre-flow and extensive use of system-level simulation tools. To ensure a stable transition to nominal engine operation for a wide variety of initial conditions, customised 3D-CFD methods are used to analyse the dynamics of the initial low-pressure flow processes in the engine's feed system, combustion chamber and nozzle. Experience has shown that the transient priming of the fuel dome and the oxidiser pre-flow in the combustion chamber of the engine require special consideration to guarantee smooth and reliable operation.

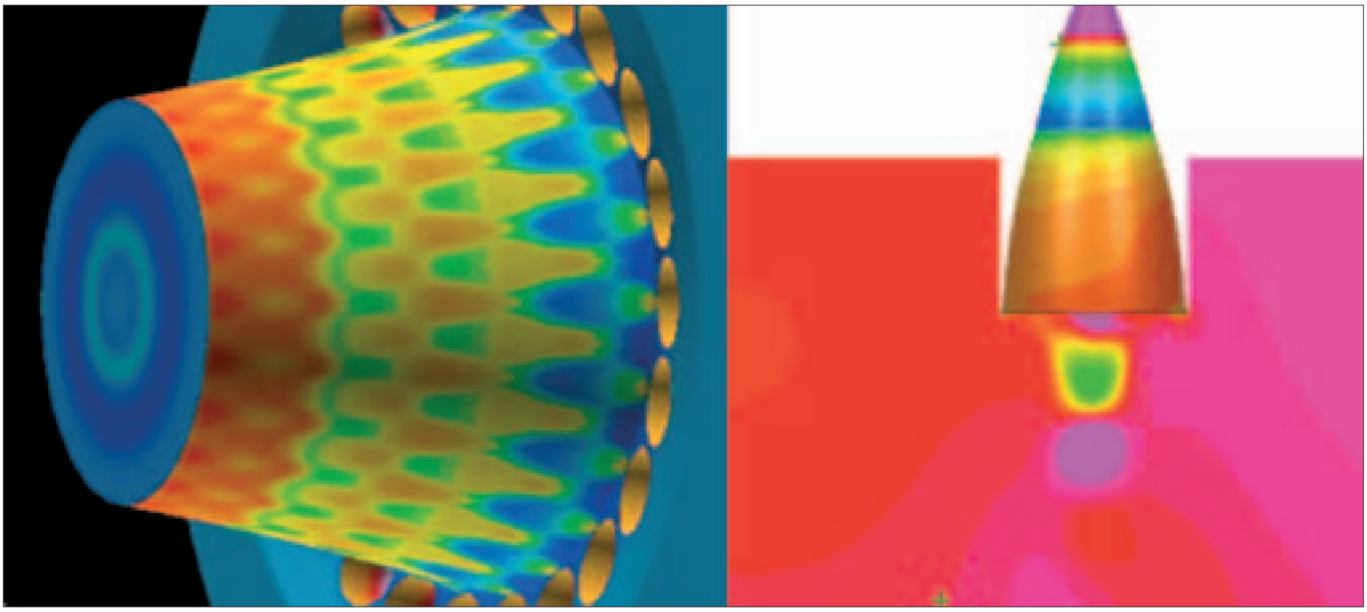
The start-up sequence also involves an oxidiser pre-flow phase to ensure well-defined flow conditions in the combustion chamber prior to fuel injection and contact ignition. This non-reacting low-pressure flow expands into vacuum and is characterised by a severe drop of oxidiser temperature and complex two-phase flow phenomena. Propellant and engine temperatures have a key influence on the pre-flow; however, these parameters can vary significantly, depending on the mission profile. Due to the complexity of experimental testing at vacuum conditions, 3D-CFD analysis has recently been employed to assess this parametric influence in a cost- and time-efficient way and identify critical limits, such as icing of oxidiser, local accumulation on chamber walls, or backflow into the fuel dome.

The figure on the previous page shows the flash-evaporating oxidiser spray (left), with the vapour flow field ranging from low subsonic conditions in the combustion chamber to supersonic conditions at the nozzle exit (middle), and the deposition of liquid oxidiser on the chamber walls (right). The second phase of this analysis addressed the dynamic evolution of the oxidiser spray during pre-flow, providing essential

The Sequence of Aerodynamic Events during a launch

Time	LV Condition	Flow Problem	Tool*	Expected or Achieved Benefit
T_0-12 hours	LV rolled out	LV exposed to environment	CFD, AM	Launch cost reduction, risk mitigation
T_0-7 sec	EPC ignition	Blast wave EPC start up loads	CFD, EXP	Improved payload environment, risk mitigation
T_0	Lift-off	Plume / ground interaction V2 with incipient separation	CFD, EXP AM	Cost reduction for ground facilities, risk mitigation
T_0 + 30-120 sec	Transonic flow regime Base buffeting impact on EPC	Side loads on EPC nozzle	EXP, CFD, AM	Permit LV performance optimisation
T_0 + 120 sec	Max. dynamic pressure	Loads on structure and protuberances	CFD, EXP	Structural design optimisation
T_0 + 240-244 sec	Stage separation and ignition of upper stage	Ignition of upper stage engine	CFD, EXP	Risk mitigation
T_0 + 244-251 sec	Transients in HM7B start up	Impact of HM7B plume on EPC	CFD	Risk mitigation

* EXP: Experimental Methods CFD: Computational Fluid Dynamics AM: Analytical Modelling



CFD predictions for advanced nozzle concepts: left, pressure contours for a clustered aero-spike nozzle; right, wall-pressure contours for a dual-bell nozzle

information for accurate system-level simulation of the engine start-up phase.

T_0 + 244-250 seconds: Upper Stage Engine Plume Impact on the Main Stage

The interaction of the plume from the starting of the upper-stage engine (e.g. HM7B) with the separated first stage (EPC) needs to be thoroughly investigated to avoid damage by high heat fluxes that could cause residual fuel in the tanks of the first stage to explode and thereby endanger the upper stage. Forces and moments on the first stage also have to be controlled to avoid stage collision due, for example, to interaction with the plume of a gimballed upper-stage engine nozzle.

A computational study was performed to arrive at an improved estimate for the heat fluxes on the EPC dome for steady nozzle operation, assuming a constant position of the two stages relative to each other for the start-up process. The main conclusion of that investigation is that the heat-flux on the first stage fluctuates strongly, and the peaks by far exceed the time-averaged values. Hence, the usually applied steady-state flow simulations substantially under-predict the transient loads encountered. This could have been expected for the time-dependent engine start-up, but is in fact also true for steady HM7B operation. These results highlight the need for careful resolution of time-dependent flow phenomena for design purposes also.

Advanced Nozzle Design

The research activities mentioned so far in the context of the various stages in a launch scenario are mainly concerned with clarifying the aero/aerothermodynamic challenges faced with today's launchers on the ground and in flight. Another essential task is to support the development of new launcher technologies aimed at overcoming existing limitations, for example in propulsion.

Conventional nozzles for main-stage application typically expand the combustion products to pressure levels well below sea-level conditions in trying to optimise the overall nozzle performance for the entire flight envelope. Unfortunately, the higher ambient pressure at sea level results in a recompression of the plume and in potentially unstable flow separation within the nozzle. A direct consequence of such behaviour is the increased and unacceptable level of side-loads exerted on the nozzle structure. This limits the performance that may be derived from conventional nozzle designs by limiting the maximum area ratio that can be safely employed.

Efforts thus concentrate on new nozzle concepts to meet the ambitious cost-reduction goals to maintain and increase the competitiveness of Europe's launchers. This implies the need to consider also thrust-chamber design options that offer a substantial cost reduction, meeting overall performance requirements possibly at the expense of maximum specific impulse. Losses due to low-cost approaches for engine components and architectures may be compensated for by advanced nozzle designs allowing for altitude adaptation of the nozzle area ratio.

Europe has already been successful in expanding the knowledge base relating to advanced nozzle concepts. The figure above shows two such concepts that have been, or are currently being investigated with ESA's industrial partners. They are primarily designed to overcome the previously described separation problem by adapting the plume boundary pressure to that of the ambient environment.

The application of advanced nozzle technology to upper-stage propulsion is also under active consideration due to the reduced packaging volumes inherent in several of the concepts.

Today, European LO_X/LH_2 engine nozzles rely on welded tubular wall structures for actively cooled configurations, such as the HM7B and Vulcain nozzles. This is a simple but not very cost-effective solution due to the special rectangular tubes needed and the extensive welding procedures employed. Alternative design options offer reductions in recurring costs by using a laser-welded sandwich design for actively cooled parts. Further advantages include: a high stiffness and strength/mass ratio; greater flexibility in cooling-channel design to tailor cooling characteristics; more efficient use of the engine's coolant pressure budget for nozzle cooling; and improved modelling accuracy, both from a mechanical and an aerodynamic point of view.

A number of European research programmes are being initiated to look at the effects of both hot-gas and coolant flows on nozzle-wall heat transfer for such novel concepts. One such programme, under the management of the French Space Agency CNES, is focusing on Flow Separation Control Devices (FSCDs), with working-group members drawn both from industry (SNECMA, Volvo Aero Corp., EADS-ST) and research organisations (DLR, ONERA, LEA Poitiers and ESA/ESTEC). A cornerstone of the group's work is the development of a scaling logic from subscale cold testing, via subscale hot testing, to flight configurations. At the subscale level, cold and hot techniques are both deemed vital and neither are sufficient in isolation. Used in conjunction, however, they become a powerful propulsion-system design tool.

While cold-flow experiments are ideal for several of the tasks in hand, for the design of a new rocket engine's thrust chambers and expansion nozzles, accurate prediction models and tools are needed for studying wall pressure, heat transfer and side-loadings. Such models are incomplete without the inclusion of hot test data and so a 'Calorimeter Nozzle Programme' (CALO) was initiated by EADS in 2001 with support from SNECMA and VAC. Three different thrust-chamber configurations, including actively cooled and film-cooled nozzle extensions, were built and equipped with the latest measurement diagnostics.

The work of the FSCD group showed clearly that high-area-ratio conventional nozzles were an undesirable choice if separation was present in the nozzle extension. Consequently, a detailed study of alternative advanced nozzle concepts was made and, based on various trade-offs, the dual-bell nozzle was finally selected as the most promising candidate for future high-performance engine concepts. Further experimental and numerical testing is being performed with respect to this configuration based on previously applied numerical techniques and the further utilisation of the HYP500 wind-tunnel facility at FOI in Sweden. The potential of extending dual-bell testing to hot configurations, in a programme similar to the CALO campaign of EADS and SNECMA, is also being considered.

Conclusion

This article has given a brief overview of the key role that aerodynamics and aerothermodynamic design factors play in determining the efficiency and reliability of operation of any launch vehicle. In summary:

- Aero/aerothermo-dynamics is a discipline that is strongly coupled to most of the other technologies that are needed for launcher design and optimisation.

- The rapid development of experimental and numerical techniques for enhanced understanding of, in particular, three dimensional, time-dependent flow fields, which were not available until just a few years ago, will support rapid improvements not only in the aerodynamic characteristics of launch vehicles, but also in their performance, reliability and cost-efficiency.

Much work remains to be done to further improve physical modelling, for example for turbulent flows, to arrive at efficient 3D time-accurate computational simulations, particularly for flows with large separations, as well as experimental techniques for complex time-dependent flows. Consequently, the mastery of aerothermodynamics problems is considered one of the fundamental factors governing Europe's competitiveness in terms of launcher-technology development.

Enlarging ESA?
– After the Accession of Luxembourg and Greece

Greece as seen by ESA's Envisat environmental satellite (MERIS image)

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The European Space Agency's Council recently approved the accession of Luxembourg and Greece to the Agency's Convention, making them ESA Member States. The arrival of two new members demonstrates growing interest in the Agency's activities. Apart from opening up new development opportunities for the Agency, these accessions represent new challenges for it, particularly regarding the implementation of its industrial policy. More generally, they raise the question of the future evolution of ESA's membership and operations in light of the enlargement of the European Union.

Europe as a political entity came into being historically out of the determination of six States to work more closely together by setting up the European Community over 40 years ago. It was gradually enlarged through the admission of nine further countries to become the European Union. It has very recently been enlarged again, with the addition of 10 new members: on 1 May 2004, several former Soviet bloc countries also joined the Union's institutions. Their representatives now sit in the European Parliament, and each of them has nominated one of the members of the European Commission. This is a very

Mrs Erna Hennicot-Schoepges, Minister for Culture, Higher Education and Research of the Grand Duchy of Luxembourg, and Mr Jean-Jacques Dordain, Director General of ESA, sign the Agreement on Luxembourg's accession to the ESA Convention, in Paris on 6 May 2004 (copyright ESA/S. Corvaja)

Mr Dimitris Sioufas (right), Greece's Minister for Development, and Mr Jean-Jacques Dordain, ESA's Director General, having signed the Agreement on Greece's accession to the ESA Convention, in Paris on 19 July 2004 (copyright ESA/S. Corvaja)

significant event and illustrates the reconciliation of Europe, which was divided up at the end of the Second World War by the Yalta Conference. Above all, it marks the end of the Cold War and the confrontation, fortunately mainly virtual, which mobilised the two blocs one against the another for half a century.

ESA did not follow the same original political integration path that the EU embodies. It was formed later, on an intergovernmental basis. It has thus played its part in the scientific and technological cooperation of a number of the same States for 30 years in the key area of space. Its achievements and successes have endowed this other Europe with both strategic autonomy and an advanced industrial sector. The question therefore very naturally arises of whether the Agency should take the same direction as the EU. Should ESA likewise expand to the East?

As a contribution to this debate, this article examines one by one the provisions made by the founders of the Agency to enable it to cooperate with potential partners, as well as the arrangements for taking in new members. It also gives a brief historical overview of the various stages that have brought the European Space Agency to its present configuration. In particular, this article examines the way in which, during each part of the process, the objectives of the Agency's characteristic industrial policy have been preserved. Lastly, it looks at the specific situation of the EU's 10 new Member States in the light of these developments.

The Agency's Convention

The ESA Convention, the outcome of a Ministerial Conference held in Brussels in 1975, entered into force on 30 October 1980. From the start, its visionary founders paid careful attention to the aspect of international cooperation.

Thus, Article XIV of the Convention lays down the principle of the Agency's *cooperation* with other organisations and institutions, whether international or belonging to non-member States. Such cooperation may take the form of specific agreements. It may take the form of participation in one or more Agency programmes. It may also translate into granting Associate Membership to a non-member State, which would then undertake to contribute at least to the studies of future projects included in the Agency's basic mandatory activities.

Moreover, Article XXII lays down the arrangements for *accession* to the Agency's Convention. As this involves acceding to a Treaty, obviously only a government can take such an initiative. A request for accession by a State is submitted to Council, which will of course decide by unanimity of its members.

Cooperation and Accession

Since the Convention entered into force, a large number of cooperation agreements have been concluded by the Agency, in the spirit of the provisions of Article XIV, with the organisations of non-European States and/or international organisations. The most recent of these, and one of the most important in terms of the prospects it opens up, is the cooperation and partnership agreement negotiated with the Russian Federation, which was the first agreement of its kind.

In parallel, certain non-member European States expressed interest in establishing a cooperative relationship with the Agency in order to participate in European space activities while developing their national industry. Thus, *Austria* and *Norway,* which began by taking part in certain optional Agency programmes, obtained in 1979 and 1981, respectively, Associate Membership, in line with Article XIV of the Convention. The cooperation agreement concluded to that end offered them the possibility, after three years, of ending it or renewing it or else changing its nature and considering an application to accede to the Agency's Convention. Once the cooperation agreement had been renewed, each country confirmed its wish to accede to the Convention. The ensuing negotiations having reached a positive conclusion, the ESA Council, in accordance with Article XXII, approved the accession of Austria and Norway as from 1 January 1987.

On that same date, Council also conferred Associate Membership on Finland, which had in previous years already taken part in activities relating to the Meteosat programme and Earth observation. That cooperation agreement was renewed in 1991 and 1993, after which Finland too confirmed its wish to accede to the Agency's Convention. Following negotiations to that end and with Council's approval, Finland became ESA's 14th Member State, as from 1 January 1995.

New Members

Because of the way in which they occurred, this trio of accessions to the Agency's Convention established a kind of de facto precedent according to which obtaining Associate Membership is a prerequisite to accession. In fact, this transition is not provided for in the ESA Convention which, and justifiably so, deals with cooperation and accession in separate articles. This situation was confirmed in 1999 when *Portugal*, which had previously taken part in certain activities under the ARTES telecommunications programme, but did not have Associate Membership, expressed the wish to accede to the Agency's Convention in turn.

For the first time, a non-member State, which had no links with ESA via a Cooperation Agreement and was thus less familiar with Agency procedures and programmes, was making a ‘direct’ request to accede to the Agency – in full compliance, it must be said, with the terms of the ESA Convention. This was bound to raise particular problems, especially regarding the inclusion of Portuguese firms in activities developed by the Agency and the application of industrial policy. These particular issues are given more general consideration below. Eventually, after the customary negotiations, in which these concerns were taken into account, the ESA Council approved, in November 2000, the accession of Portugal, which thereby became the 15th State to be party to the Convention.

Lately, a fairly similar scenario occurred in the case of *Luxembourg*, followed by *Greece*.

Greece had signed a cooperation agreement with ESA in January 2001, which enabled it to participate in activities under the ARTES, GMES and GSTP programmes, and also familiarise itself with the Agency's operational procedures. In July 2003, Greece placed its first telecommunications satellite (HellasSat 1) in orbit, confirming the priority it would be attaching to space technology. In September of the same year, the Greek government officially applied for accession. On the basis of an expert report and the outcome of the negotiations, the ESA Council approved Greece's accession, in March 2004.

As to Luxembourg, it had signed a Cooperation Agreement with ESA in September 2000, enabling it to join the ARTES programme activities. In December 2003, Luxembourg's government officially applied to accede to the Agency's Convention. After negotiations, this was also approved by the ESA Council in March 2004. According to the sequence of the official signing ceremonies, Luxembourg became the 16th and Greece the 17th ESA Member State. In both these countries, accession to the Convention has still to be ratified by the respective Parliamentary Assemblies.

Historically, the Agency's composition has thus followed an evolutionary pattern, the cooperation established by Article XIV constituting a kind of springboard for subsequent accession pursuant to Article XXII. All the latest States that are parties to the Convention are also members of the EU. At present, following these latest accessions, the European Space Agency shares with the European Union a common base of 15 ‘historical’ members. This is sure to have implications for the future relationship between the two institutions, as will be explained below.

Industrial Policy

Formulating and implementing industrial policy constitutes one of the Agency's four basic objectives, as set out in Article II of the Convention. The industrial policy in question is described further in Article VII, which makes particular reference to the necessary competitiveness of European industry and to the advantages of free competitive bidding. That same article also lays down the principle that all Member States should participate equitably in the implementation of programmes according to the financial contribution of each country. This constitutes the principle of ‘industrial return’ on a geographical basis, a provision subject to rules that are adapted at various intervals and approved by Council by a two-thirds majority. It is of interest to examine how this essential feature of the system introduced by the Agency, and which most distinguishes it from other organisations, has been maintained throughout its successive enlargements.

A Transition Period

It quickly became apparent, from the moment Austria and Norway acceded to the Agency's Convention, that it would not be possible for the ‘fair return’ explicitly provided for in the Agency's industrial policy to be made immediately available to the new members. The general consensus

Luxembourg, to the bottom right in this image of the Benelux countries, as seen by ESA's Envisat environmental satellite

was that such an objective could only be reached after several years. To take up the challenge of including their national firms in the activities of ESA's mandatory programmes, *special measures* were adopted by Council to help them, admittedly not without provoking criticism on the part of certain other Members, who considered their own returns insufficient.

Having learned lessons from that experience, it was agreed, when subsequently negotiating Finland's accession, that instead of special measures, a transition period would be created between the date on which its accession came into force and the date on which a full guaranteed return for Finland was to apply. For the first time, a clause departing from the general regime would form an integral part of the accession agreement. Certain specific measures applicable for the benefit of Finnish firms only would, for instance, enable industrial contracts to be awarded in the framework of the Agency's basic activities and science programme following direct negotiations. Implementing this derogation arrangement turned out to be problematical at times, although it had by the end of 1999 successfully contributed to attaining the objective set for Finland.

Portugal, on the other hand, had not yet established any particular relationship with the European space industry at the time of its accession. Swift integration of Portuguese firms was precisely one of the objectives fixed by its authorities. A six-year transition period, set up on a basis similar to that for Finland, was proposed. During that period, a portion of Portugal's contribution to ESA's mandatory activities, and thus part of its guaranteed return, would be kept separate in a special account. It would be used subsequently only to support initiatives aimed at helping Portuguese firms adapt to the Agency's activities and requirements. At the end of this transition period, the return system would be fully applied, without however making provision for any compensation for the previous period, whether it had been balanced or not.

A similar set of accompanying measures, applicable to the Agency's basic activities and science programme, was eventually agreed with Greece and Luxembourg and incorporated in the accession agreement itself. It provides, over a period of six years, for specific support for their national firms prior to full application of the return rules to which all Member States are subject.

A Joint Task Force

Essentially, the transitional arrangements, as they apply to the latest Member States, provide for a portion of a country's contribution to mandatory activities to be used directly for funding those activities intended to help national firms adapt to the Agency's requirements.

Thereafter, the difference between the ideal theoretical return that would result from a contribution to mandatory activities and the amount thus set aside will serve to cover contracts in the area of mandatory activities.

It has been agreed that no industrial-return guarantees will be given in relation to mandatory activities, and no provision made for any compensation at the end of the transition period. Any statistical records for that period will be discarded and subsequent industrial-return evaluations will follow the method applied to all the Member States.

A Joint Task Force, composed of representatives of a Member State and the Agency, will make recommendations to the ESA Director General on the implementation of these transitional provisions, the progress of which it will monitor on a regular basis. It will have responsibility for evaluating proposals for activities, selecting those with the most potential, ensuring the necessary resources are made available to enable national industry to take part in normal Agency procurement procedures, and encouraging the development of long-term relationships with European industrial partners.

Funding earmarked for these activities could, for example, cover contracts with industrial firms and research and training institutes, as well as the organisation of workshops. These contracts will follow the Agency's rules and procedures.

As can be seen from the above, the Agency has so far succeeded, on the accession of several new members, in keeping intact the essential principles of its Convention, in particular the industrial-return arrangements, which the firms of each Member State benefit from in proportion to the size of individual national contributions to the Agency's budget. However, there is a considerable risk that any new increase in the number of partners could get in the way of the various decision-making mechanisms that exist at present, or even cause them to grind to a halt. For instance, the intergovernmental system calls for unanimity. The Agency has generally been able to get round that, thanks to the mechanism applicable to optional programmes, which, once they are decided in principle, bring together only those countries wishing to participate in them. Would such a Europe '*à la carte*' still be possible after an institutional *rapprochement* between the Agency and an EU itself already enlarged to 25 members?

One Europe, Several Models

The EU reflects a completely original model of political integration. It is a supra-national body, and this entails a partial loss of sovereignty on the part of its Member States. For example, the governments of the countries that have opted for the euro have, possibly to the surprise of some, relinquished for the sake of the community institutions, their sovereign right to mint their own currencies. These institutions will gradually be taking more and more majority decisions.

As this article has shown, ESA embodies the European space sector on an intergovernmental basis, and does so with evident success. Its members take sovereign decisions on what they agree they will do together, on a case-by-case basis. This of course implies unanimity and the difficulties inherent in consensus-seeking. In particular, in the case of ESA, the cooperation involves a very high technological and industrial content, which tends to encourage countries to push their national interests and hence slow down decision-making procedures.

The recent *rapprochement* between the EU and the Agency, formalised by a Framework Agreement, translates the concern of each party to enjoy the assets of the other: political clout on the one side, technological and scientific know-how on the other. The 'cohabitation' of the two models is not something new. It is in fact inherent to the construction of Europe, as illustrated by the Schengen Accords or the single currency, which do not yet involve all EU Member States. It is intended, in the draft Treaty establishing a Constitution for Europe, to place closer or structured cooperation on a more formal footing, in line with the intergovernmental method, between only the countries that so wish.

A Common Basis

Historically, the membership of the Agency has, as described above, been built up as part of a gradual process, which has only recently led to the EU and the Agency having a common base of 15 'historical' members.

In view of the interest that some of the new EU members have shown in space, the Agency wished to respond as early as 2001 to their concern with establishing closer ties. It proposed a 'Plan for European Cooperating States (PECS)', which provides for a special status for these potential candidates for future accession. Notwithstanding their lack of industrial backing, they can take part in certain Agency projects by making a limited contribution, and thus become better acquainted with ESA. Hungary and the Czech Republic have already become involved in this process; Poland and Romania may follow.

Moreover, the EU - with at the time 15 members - and the Agency have formalised their cooperation with the Galileo satellite navigation and positioning programme, which they are funding in equal share. The 10 enlargement States, now in the EU, were also invited to join the Agency's GalileoSat programme in order to take part in the development and validation of the in-orbit phase and ground segment associated with the future constellation. The state of their industrial structures and lack of financial resources could, however, be an obstacle in terms of their concern with obtaining a fair share of the work, a basic assertion of entitlement under the Agency system.

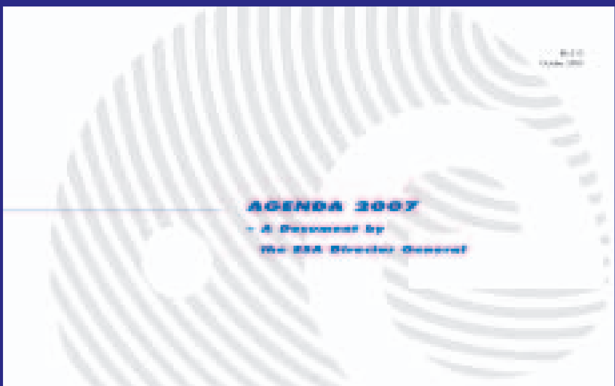
Convergence ?

There is a risk that the difficulties now being faced in the framework of Galileo - the first programme to embody a new sharing of roles between the EU and the Agency - could mount up with subsequent joint programmes, such as the GMES initiative (Global Monitoring for Environment and Security) or the action being taken to bridge, by means of satellites, what is generally referred to as the 'digital divide', i.e. unequal access to broadband services. In each case, the enlargement countries will be full partners in the EU's decision-making mechanisms. Can the Agency, for its part, continue ignoring them in the long term?

As can be seen, a specific mechanism might be needed to enable ESA to meet more satisfactorily requests for greater cooperation on the part of the so-called 'enlargement countries'. The PECS arrangements, set up before the accession of those countries to the EU, might quickly prove to be inadequate; some countries are already finding them too complex, and for others the cooperation they offer is too restrictive.

An eminently political question arises out of these mainly technical considera-tions: if, as set out in its Convention, the Agency and its constituent countries aim to build together a European space science and technology sector, can they do so without ensuring a certain harmony with the efforts being made by the same partners to obtain, through the EU, broadly integrated political structures? In other words, can the potentially many and varied forms of European construction avoid converging in the long term? A political question begs a political answer: it will be for the Member States, the essential stakeholders in this dual-edged strategy, to decide. How can ESA reap the political advantages of taking in the enlargement countries, in line with arrangements to be agreed, without creating unrealistic expectations? How can it avoid the pitfalls of blocked decision-making processes and paralysis of a system as many as 25-strong? This is a tough challenge for ESA and for governments always highly preoccupied with national interests…… r

ESA's Industrial Policy after the FINPOL Initiative



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The medium-term strategy for the Agency, formulated in September 2003 by the Director General in his Agenda 2007 document, focuses on a series of fundamental changes in ESA's every day life that will strongly influence the Agency's future.

The political and industrial landscape in which the Agency is operating is continuously in motion. The European Union is undergoing profound institutional changes, with enlargement to 25 Member States with new borders, new responsibilities, and new needs (narrowing the digital divide, increasing security, sustaining development, etc.), calling for a redistribution of resources. The recently finalised European Constitution foresees shared competencies in space matters, and a European security and defence policy. Additional sources of funding for the development of space systems are being identified, associated with specific sectorial policy demands and complementing the traditional sources of funding for ESA activities based on technological and industrial interests.

As far as European industry is concerned, in the medium term institutional programmes will rely on large and small system integrators. The restructuring process involving large system integrators will have come to an end, probably resulting in one (or a maximum of two) large telecommunications satellite manufacturer(s) in Europe and one large launcher prime contractor. The equipment-supplier industry will have gone through a restructuring exercise leading to more specialised suppliers serving European and non-European primes. Alliances with non-European partners will also be in place.

The expected recovery in the commercial market in the next few years will be very low, and the levels of activity generated by this market in European industry will produce a workload only representing close to half the industrial production capabilities currently available in Europe. This trend, combined with the increasing importance over the years to come of the public space sector, linked mainly to the implementation of ESA and EU policies, will constitute a substantial challenge.

With an imminent future so different from the reality we know today, ESA had no choice but to adapt in anticipation of these events. The first step of the reforms referred to in Agenda 2007, including financial, budgetary, and industrial policy issues, was then proposed. Following the Council's decision of 18 December 2003, a Council Working Group known as FINPOL was set up, charged with studying the possible evolution of these issues. The Group's work was speedily completed, so that a final report could be presented to Council in June this year, accompanied by a Resolution (ESA/C/CLXXI/Res. 2 (Final)), which was approved unanimously.

The new Resolution covers three domains:

– Co-ordination of the European programme with national programmes.
– Planning and budgetary policies.
– Industrial and procurement policies.

An overview of the conclusions is presented below, focussing particularly on the industrial and procurement issues.

Co-ordination of the European Programme with National Programmes

This topic is mentioned in the ESA Convention, but is only partially implemented as of today.

Starting from an analysis of the effects of the existing *Technology Harmonisation Programme* (a process aimed at rationalising the various technology efforts in Europe, but mandatory neither for Member States nor for ESA programmes), it becomes evident that the future of this process calls for the enforcement by the Director General of the recommendations of the process itself within ESA programmes, where he has direct powers, and for greater promotion of the conclusions of the said process within Member States and industry for their programmes, where that process can only be implemented on a voluntary basis. A first proposal for a modified process will be presented at the November 2004 meeting of the Agency's Industrial Policy Committee (IPC).

Total agreement was reached on the need for developing a *Strategic European Procurement Policy,* in order to ensure that such strategic areas as technologies, components and equipment remain under the control/leadership of European industry. As this falls within the mandate of the Director General, he can set up the necessary internal rules and responsibilities.

Concerning the proposal to *'foster the participation of European industry in national programmes'* (where participation of non-national European industry is rare, and the ESA and national programmes can become a source of duplication and inefficiency), the principle was supported by a large majority of States, with the understanding that it can only be implemented with the express agreement of those Member States involved, since it impinges on national prerogatives, and on a basis of reciprocity. Detailed rules will have to be worked out by the IPC, based on such industrial-policy criteria as non-distortion of competition, improvement of industrial specialisations, and the opening of new markets for competitive equipment suppliers, as well as on technology- and innovation-related criteria.

Planning and Budgetary Policies

Council has also approved the introduction of a new *Long-Term Plan (LTP) concept,* which will be useful not only as a management tool for the Executive, but also for the Member States, as it contains the best estimate of budgetary requirements for the implementation of the decisions already taken on approved programmes, as well as forecasts for the budgetary requirements for future programmes. It also includes the best estimate of the forthcoming contributions from Member States. The Agency's Administrative and Finance Committee (AFC) began studying the details of the new approach in September.

The introduction of *flexibility for in-year budget execution,* in the frame of the new Long-Term Plan, is probably one of the most radical reforms, and one on which the AFC will be working intensively in the coming months.

Industrial and Procurement Policies

Another profound change approved by Council is that relating to the *hierarchy of return rules*. The return constraints per State have been rendering ESA programmes almost unmanageable in recent years because of the multiple constraints that co-exist in terms of: overall return obligations (for a five-year period, counting all ESA programmes and activities together), return obligations per programme (on programme completion), return obligations for the mandatory programmes and activities (every five-year period), and return obligations per sub-envelope of a certain programme. The new approach foresees a pyramid-like hierarchical arrangement, in which greater flexibility is allowed for the return rules of individual programmes, a lesser degree of flexibility is set for the overall return (which supersedes any other return obligation), whilst the need to target the ideal return coefficient of one* is maintained. Member States will have to decide on the minimum overall return coefficient (for the period 2000-2004 it was 0.90), and on the minimum return coefficient for programmes (on completion for optional programmes, and every five years for mandatory ones). For the latter, the Executive has proposed a value of 0.8. This major change will go hand in hand with the approval of new programmes in 2005.

The need for *mastering risks* for programmatic and procurement purposes has been recognised: some examples in the recent life of the Agency (Space Station and Launchers, for instance) demonstrate that this is a fundamental issue in a domain which, by definition, includes risky activities. It has been stressed that adequate funding has to be assured by Member States within the programme envelopes for preparatory activities and the early phases of programmes, before embarking on the main development phase. In the procurement approach, it will be necessary to prepare a development dossier (in practical terms, a detailed risk analysis of what can happen during the development phase of a programme, and the means, technical and financial, to counteract those risks), before starting procurement for the development phase. The development-dossier concept will be analysed by the IPC in January 2005. An incremental approach to procurement when risks are deemed very high (e.g. in the case of interfaces not under the Agency's direct control) is also foreseen: this consists of procuring, within a given overall ceiling, only a share of the total development programme, in line with a practice in use in, for instance, the defence and nuclear fields.

The *Code of Best Practices,* which dictates the rules to be followed by the Prime Contractor in a competitive environment vis-à-vis its subcontractors, will be revised and presented to the IPC for approval in early 2005. It will be complemented by the *'Make or Buy' Plan*, which on the one side establishes the boundaries of the activities of the Prime Contractor and of its subcontractors, whilst on the other maximising the opportunities for competition. Furthermore, the *return requirements approach* (based on return figures per State imposed on the Prime as a performance requirement, like the mass or the power for a satellite) will become the basis for the achievement of competitive offers within a given return constraint.

The set of detailed rules will be put before the IPC in January 2005.

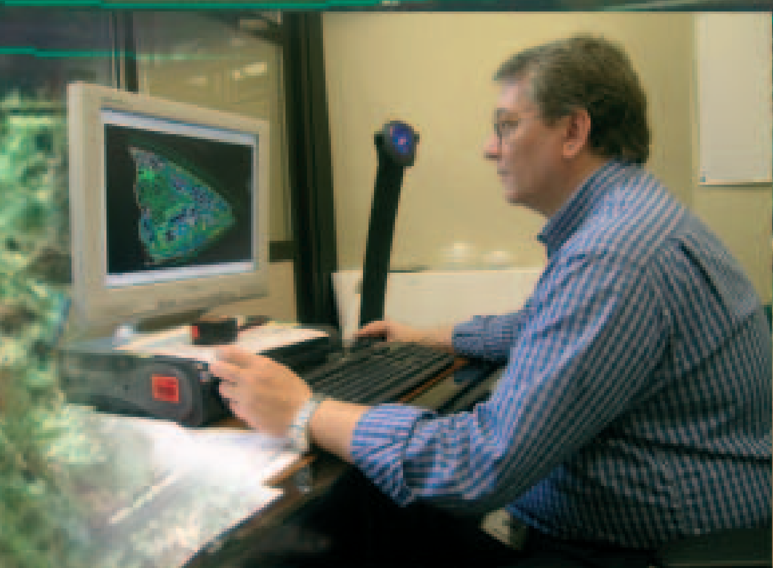
Conclusion

With the FINPOL-based decisions, and the subsequent detailed rules and procedures that will be in force towards the middle of 2005, the Agency will change its way of operating in the world of finance and procurement, resulting in improved flexibility at all levels. r

** The 'return coefficient' is the ratio between the sum of actual contractual commitments awarded to industry in a Member State for a particular programme, and the sum of ideal contractual commitments corresponding to that State's nominal contribution to the programme. If, for example, a State participates at a level of 10% in a given programme, its ideal return in terms of contractual commitments is 10% of the total overall commitments awarded to industry for that programme.*

ESA's New Approach to Facility Management

Satellite image of ESRIN merged with an AutoCAD drawing from CIFM



Angelo Bodini, Francois Giraud
ESA Directorate of Operations and Infrastructure, ESRIN, Frascati, Italy

Pierre Jeanne, Laurent Jauniaux
Directorate of Operations and Infrastructure, ESA, Paris

Jean-Michel Kluft
DBAssociates, Brussels, Belgium

The Computer Integrated Facility Management (CIFM) system that is now operational across ESA's main sites is a major achievement in terms of the rationalization and streamlining of management procedures, as foreseen in the Director General's Agenda 2007 reform plan for the Agency. The main challenges lay in the harmonisation of existing management practices that were already well established at all sites, and the alignment of legacy data and their conversion/migration from the former systems. The results achieved go well beyond initial expectations and now, after integration with the other corporate data systems in the Agency, real-time visibility is provided across sites on people movement as well as on all aspects of site maintenance. The comprehensive central reporting provides management with invaluable decision-making support.

Introduction

Being in charge of buildings, logistics, staff accommodation and movements, the Site Management Services of the four main ESA establishments had, in the past, adopted a number of different automation tools to support them in that function. In recent years, however, with the creation of the ESA Site Management Department it was more and more perceived as a priority to approach the problem of process automation in a more systematic way across the Agency, on the basis of a professional software solution based on today's industry standards, yet flexible enough to cope with local exigencies. The project was tackled in conjunction with the ESA Information System Department.

The General Concepts of Facility Management

The ultimate purpose of Facility Management is to support and even to leverage the core business of an organization by providing its employees with the best possible working environment, through smooth integration of the infrastructure, management processes, technologies and services. In recent years, Facility Management has progressed from being a reactive support function to a pro-active infrastructure and service organizer and provider, which is constantly challenged to provide:

- Visibility: of current and future resources (space, services, fixed assets, energy, …) requirements and allocations.
- Flexibility: to adapt the work environment as swiftly as market conditions and corporate strategies are evolving.
- Cost Control and Performance Monitoring: to constantly get from internal and external contractors the required added value and quality for the right price.
- Comfort at Work: to provide the whole organization with an efficient and pleasant working environment.

The combination of re-engineered processes with a state-of-the-art information system is the best way to meet the challenge, especially when the organization is as geographically dispersed as ESA.

A preliminary market survey that identified the key players in the Facility Management (FM) domain was followed by a consultancy effort aimed at selecting the off-the-shelf commercial software product best suited to meeting ESA's needs. The product eventually chosen was ARCHIBUS/FM and a subsequent integration contract, awarded after an open tender to DBAssociates, covered its adaptation to the Agency's data types and business processes.

ESA's Requirements

The Site Management Department is responsible for providing the necessary safety and security, infrastructure and support services at the Agency's four largest sites – Head Office in Paris, ESTEC in Noordwijk (NL), ESOC in Darmstadt (D) and ESRIN in Frascati (I) – plus (as of 1 September 2004) ESAC in Villafranca (E) and the Redu station in Belgium (B).

Site Services were traditionally organized on a local basis. In 1999 it was decided to create a single centralised structure, reporting to the Agency's Director of Administration. In a recent reorganization (April 2004), the reporting line was changed to the Director of Operations and Infrastructure, located at ESOC.

In the past, the four ESA sites were using different practices and standards. Users had to enter the same data into different systems and timely corporate reporting was difficult to achieve. There was therefore a need to unify the Department's standards and processes, improve overall information quality and availability, and allow reporting to be consolidated at ESA level by putting in place a market-proven overall facility-management tool. It would need to have a central database, accessible to a large user community spread across Agency sites, an open configuration, providing scalability and potential for evolution, with efficient and autonomous reporting tools, suitable for managers at all levels. Last but not least, it had to improve the Department's overall effectiveness in serving the staff, and thereby contribute to the Agency's overall efficiency.

The project, begun in 2000, was therefore divided into two phases, the first being an in-depth analysis of ESA business scenarios. The second focused on the implementation of the main processes identified, namely:

- Management of accommodation-related information for the main ESA sites (buildings, floors, rooms), including complete drawings.
- Administration of employee-related information (staff and contractors).
- Employee moves management.
- User calls management (helpdesk tool), with provision of web access for the whole ESA community.
- Preventive-maintenance scheduling.
- Equipment management.
- Project management.
- Local and central reporting.

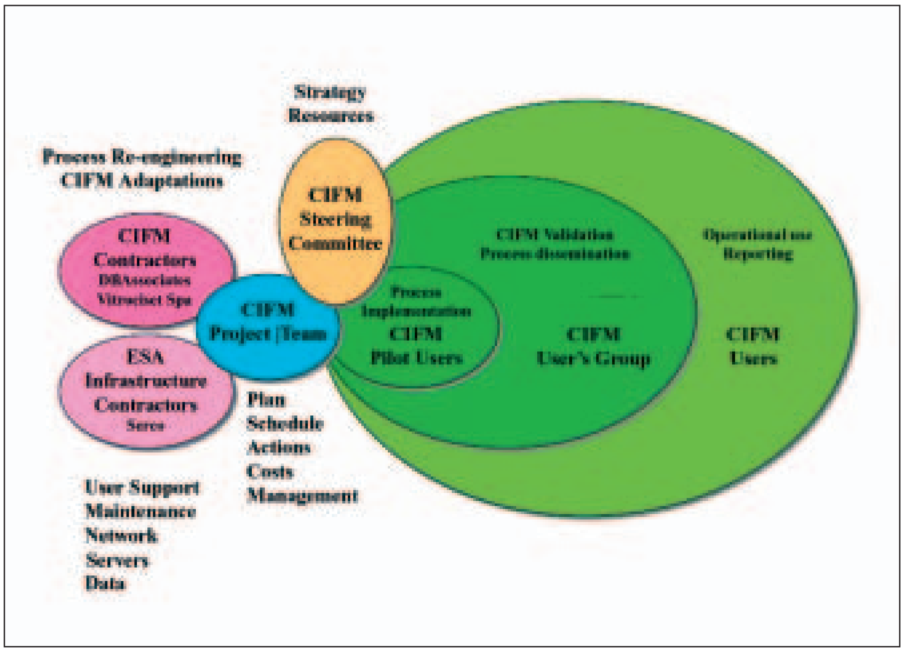
Organizing the Project

Given the cross-site nature of the project, it was difficult to imagine a traditional project team structure: on the one hand the foreseen CIFM users wanted to be involved from the outset in all aspects of the project's life cycle, while on the other a structure ensuring quick decisions and guaranteed delivery dates was crucial for success. A dynamic multi-layered structure was therefore set up. The project's core team was composed of five engineers, responsible for managing the project's schedule, activities and costs. The second layer consisted of pilot users representing the four ESA sites, plus the reporting level. These experts were selected for their sound experience with existing practices and data at each site, as well as having a clear understanding of the future processes to be implemented. The third layer gathered a wider user community across sites and processes. They received advanced training in the product and were thereby able to gradually validate the new CIFM functionality.

Above this operational structure, a Steering Committee, composed of Site-Management and Information-System Department managers, met every month to monitor the project's overall progress and sanction additional support and resources when needed.

Solution Features

CIFM consists of an integrated system, composed of several different modules, each addressing a specific facility-management area. Data entered into one of



The CIFM project organisation

these modules is automatically reflected in other relevant areas, ensuring accurate, up-to-date information throughout the whole system. In addition, AutoCAD architectural drawings, such as the floor and office plans for ESA's buildings, are automatically linked to employee names, room and telephone numbers, etc., ensuring that there is always accurate and consistent information in the database.

The current release of CIFM contains six modules:

Space Management is used for managing accommodation (type and number of rooms, security access level, etc.) and for allocating rooms to employees and/or organizational units. It allows the Site Management Department to perform an accurate and efficient inventory of the space available, with continuous control of its usage and the possibility to deal with questions like:

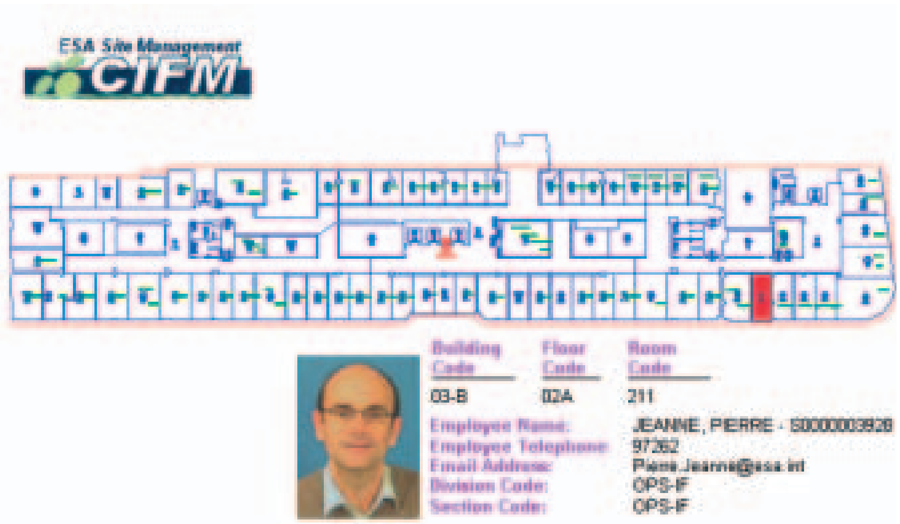
– What is the current occupancy level of a given site/building?
– What is the space allocation for a particular organizational unit?
– What is the Agency's overall use of space (occupiable and non-occupiable rooms, laboratories, communal areas, etc)?

Drawing Management links the AutoCAD architectural plans with the CIFM database (employee, room, building and floor data). It increases information accuracy by simultaneous updating the AutoCAD and CIFM database environments. An enriched AutoCAD menu allows the Site Management Department to modify the plan of a building and update the CIFM database content (occupant name, phone, etc.) in the same on-screen window. CIFM, which is aligned with the DIN 277 standard, also allows benchmarking against the facility-management databases of other organizations using the same norm.

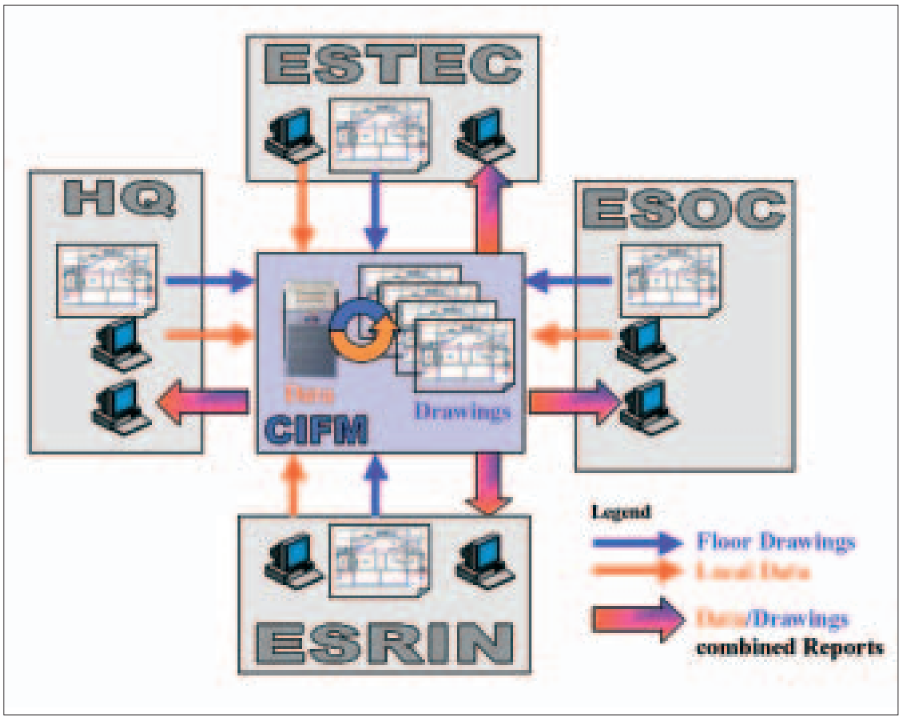
Employee Administration allows CIFM to be used as the primary entry system for registering on-site contractors (personal data, company, organizational unit assignment) and for allocating/recording the facilities required by each employee, whether an ESA staff member or on-site contractor, for their daily work, such as phone, fax, room, furniture/equipment, badge information, ID card information, etc. This module therefore allows the Site Management Department to immediately provide accurate answers to such questions as:

– Where is this employee located and how large is his/her office?
– Who are the emergency contacts in a given building, and what are their phone numbers?
– Which contractor staff are active on a given site and when does their ESA accreditation expire?

Move Management is used to plan employee moves (arrivals, departures, changes of duty station, internal moves) and to schedule move requests received from managers. It handles the work orders necessary to implement those moves and allows the required tasks to be performed



Employees and their locations at ESA Headquarters in Paris



CIFM is deployed on the four main ESA sites

in the correct sequence. For example, the facilities and furniture in each office are tracked and requirements anticipated before the people are in place.

Site Helpdesk Service is used to track and manage maintenance requests received by the Site Service helpdesk. This module provides efficient supervision of correct execution of the work while controlling the related costs. Immediate answers can be provided to such questions as:

– How many work requests have been issued in that building, and what are their nature, status and cost?
– What kind of problems have been signalled for a particular type of equipment given over a period of time?

Preventive Maintenance covers the management of all ESA equipment associated with preventive maintenance and provides for an accurate inventory. The Site Management Department can thereby forecast, plan and manage the preventive maintenance needed to maintain the Agency's buildings and offices in the best working condition, with the system automatically issuing and dispatching all necessary work-requests and work-orders.

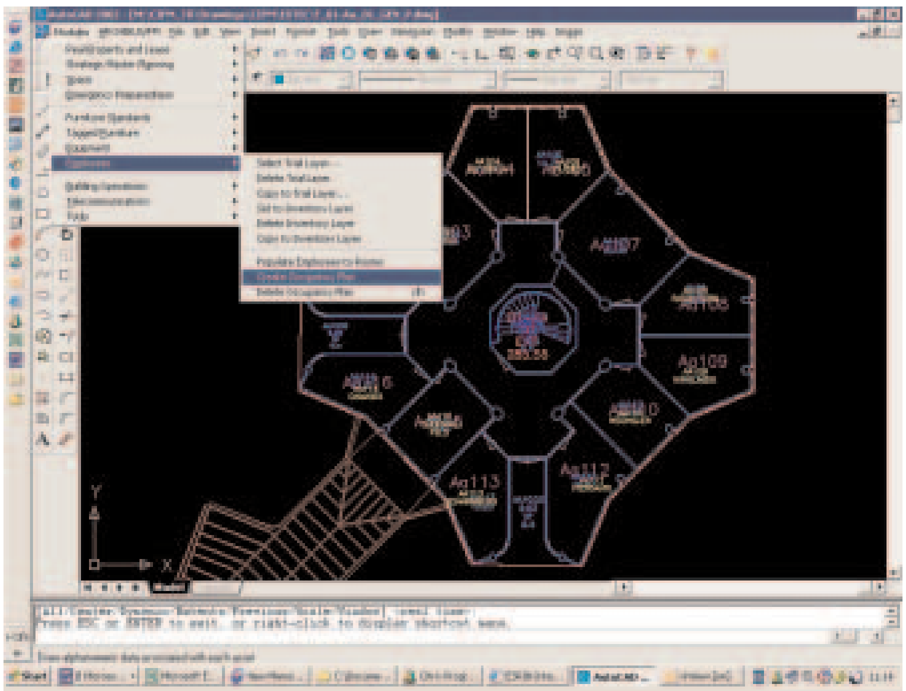
An impression of the data volumes and valid as of 31 August 2004:

– 4065 employees, including ESA staff and contractors, managed
– 232 000 square metres of building fully represented and managed
– 329 AutoCAD drawings created and maintained, covering all ESA buildings
– 3112 offices, meeting, conference and training rooms, and libraries managed, involving a total area of 56 000 square metres
– 317 laboratories, computer rooms and test areas controlled, involving a total area of 24 500 square metres
– 14 000 work-requests for corrective maintenance issued and closed
– 3700 work-requests for preventive maintenance issued automatically and closed
– 1900 moves, including new arrivals, departures, changes of site, and internal movements.

Integration with Other Corporate Systems

During the first half of 2003, all Information System Department teams dealing with directory-type data made a major effort to harmonise the formats of their data. When all teams were ready in August 2003, the Steering Committee authorised the activation of a first series of interfaces involving the interconnection of five systems:

– the Human Resource Management System (HRMS) in SAP



CIFM combines data and drawings, generating management reports

– the ESA Operational Data Store (ODS), in Oracle
– the ESA Directory, in Lotus Domino
– the Name and Address Book (N&AB), in Lotus Domino
– the new ESA Facility Management System (CIFM), in Archibus/FM.

As a result, twice a day CIFM receives the updated organizational structure and staff list from HRMS and returns the actual accommodation data (telephone numbers, office indication, etc). Similarly all data regarding contractors working on ESA premises are collected in CIFM and propagated to the other directories.

In July 2004 at ESTEC, another interface was opened with an information system owned and operated by the external contractor responsible for maintenance on the site, with updated status reports being regularly fed back to CIFM. This is a first example of closer interaction with contractor systems, which will become more common in the framework of advanced outsourcing.

Looking to the Future

Due to ARCHIBUS/FM's modularity, scalability and inherent growth potential, there are several areas where future expansion can be envisaged. Firstly, interesting new functions can be activated within the modules presently in use, such as greater interaction with contractor company information systems.

The definition of a 'facility' can also be expanded to include areas not falling under the authority of Site Management Services, but requiring substantially similar functionality in terms of management, maintenance, utilization schedules and so on. Facilities ranging from technical laboratories and antenna installations to technical equipment could find CIFM a natural interpreter of their management needs.

One direction of future evolution is certainly that of stronger integration with ESA's other corporate information systems, where CIFM could be enhanced in scope by including other data sectors presently not managed in an integrated way, and in performance by replacing present batch-based data-exchange methods with more advanced real-time paradigms. Other ESA sites, including remote offices and ground stations, could also be made part of the same facility-management system in order to benefit from the centralised management and reporting capabilities.

The power and the flexibility of the Agency's new CIFM system certainly provides a solid basis not only for managing the present processes, but also for meeting the Agency's evolving and ever more demanding site-management needs in the years to come. r

The 35th COSPAR Assembly

– A Record-Breaking Success

*Jean-Paul Paillé**
Directorate of External Relations, ESA, Paris

Coordinating and promoting space research at worldwide level and regularly providing open forums for all space scientists are the ambitious objectives of the Committee on Space Research (COSPAR). Created in 1958, COSPAR holds its general Scientific Assembly every two years. After Houston in 2002 and prior to Beijing in 2006, Paris was the chosen location for the 2004 session.

* *ESA Representative on the Local Organising Committee*

The Opening Ceremony. From left to right: R-M. Bonnet, Y. D'Escatha, F. D'Aubert, J.-J. Dordain, J. Audouze and M. Abadie

Tackling the Task

When this decision was taken in 2000 to hold the 35th COSPAR Scientific Assembly in Paris, from 18 to 25 July 2004, both the President of CNES and the Director General of ESA agreed to give their full support to its organisation. A Local Organising Committee was subsequently set up, under the chairmanship of Prof. Jean Audouze, and charged with the task of organising this prestigious event in the best possible way, but within a reasonable financial envelope … a real challenge indeed!

As the Assembly was expected to attract more than 1500 participants, an experienced company, Colloquium, was selected to handle all logistics and organisational matters on behalf of and in close collaboration with the Local Organising Committee. After detailed investigation, the Palais des Congrès was chosen as the only suitable venue in Paris able to cope with the large number of participants and to offer the necessary technical facilities.

ESA Director General Jean-Jacques Dordain's address during the Opening Ceremony

Finding the Support

In order to respect budgetary limits, much hard work was required on the part of ESA and CNES representatives to keep the logistics costs as low as possible and to find external partners. The first obvious potential partner was the French Research Ministry, which indeed gave significant financial support. The Minister, Mr François d'Aubert, also very kindly accepted to chair the Opening Ceremony. The Région Ile de France, which is developing a strong innovation and research policy, also made an important contribution. In addition to several French scientific institutions, such as the National Scientific Research Centre (CNRS), international organisations like EUMETSAT also gave their support.

Despite of the current difficult financial climate, Industry also participated, with the main contribution coming from GIFAS, the French Association of Aeronautical Industries. Arianespace was also present in the exhibition area, which was set up to allow some of our partners to present their activities to the participants. ESA and CNES, for example, had a joint stand highlighting their involvement in COSPAR 2004 and presenting their programmes and activities.

A Welcome for Everyone

Not only the world's top scientists took part, but also many students and members of the general public also participated. Under a grant system set up by COSPAR and ESA, students from many different countries were able to present papers and meet experienced scientists during the various conference sessions and workshops. The public was also welcome to attend the morning and evening lectures and panels, such as those given by the 2002 Physics Nobel Prize winner Prof. Riccardo Giacconi, and the 1995 Chemistry prizewinner Prof. Paul Crutzen.

The media, of course, were also not forgotten. A special room was made available for them, and the press could attend not only the regular sessions, but also a number of events organised particularly for them.

The joint ESA/CNES stand

The Arianespace stand and SERCO's 'Cyber Space'

A PERSONAL ASSESSMENT

The record participation in this 35th Scientific Assembly indicates the continuing importance of a forum in which scientists and engineers working in closely related fields can meet colleagues with whom they might not come in contact at events addressing a more limited range of topics. Indeed, the range of science on offer in Paris was impressive, with 94 scientific 'events' making up the core of the programme. These events were loosely grouped according to the topics covered by COSPAR Scientific Commissions and Panels, but many were organised jointly between these bodies to increase the interdisciplinarity. The Programme Committee chaired by Dr Marie-Lise Chanin has received unanimous praise from the COSPAR Council for the excellent job it did.

The topics covered at this year's Assembly included: the Earth's surface, meteorology and climate, the Earth-Moon system, planets and small bodies of the Solar System, atmospheres of the Earth and planets, including reference atmospheres, space plasmas in the Solar System, including planetary magnetospheres, astrophysics, life and material sciences, fundamental physics, satellite dynamics, scientific ballooning, space debris, space weather, planetary protection, research in developing countries, and capacity building. The climax of the meeting was certainly the presentation of the latest results of the NASA and ESA Mars missions and of Cassini-Huygens, which include many exciting discoveries. Of great interest also, with meeting rooms filled to capacity, were the astronomy sessions in which the results of XMM-Newton, Chandra and Integral were reviewed, as well as the presentation on the Gravity probe-B, the first mission fully dedicated to fundamental physics. The Mars presentations offered a unique opportunity to demonstrate the originality and uniqueness of ESA's Mars Express mission, displaying for the first time, and with unprecedented spatial resolution, a global three-dimensional map of the surface and of the chemical composition of the red planet.

In addition to the core scientific programme, two series of general lectures were organised: one each morning on an interdisciplinary topic, and one each afternoon taking the form of a panel discussion in which high-level participants addressed the conditions and policy affecting the carrying out of space research. In spite of their timing early and late in the day, these special sessions attracted a substantial number of attendees, including both COSPAR scientists and the general public.

An early assessment of the papers presented and the ensuing discussions indicates that participants generally found the level of science high and the Assembly extremely interesting and useful.

The COSPAR Scientific Assembly is also a unique forum in which to discuss matters requiring international cooperation, such as the establishment of international guidelines for planetary protection, reference atmospheres and standards of interest to space agencies - and ESA in particular - and the ISO organisation, space debris, etc.

At the initiative of the European Science Foundation's Space Committee, a meeting was organised to initiate contacts between the US National Academy of Sciences represented by Prof. Len Fisk, Chairman of the Space Studies Board, and his Chinese, Japanese and Russian counterparts, with a view to strengthening and developing international cooperation. The roles of the Inter-Agency Consultative Group (IACG) and of the joint ESA-China Double Star Programme were seen as perfect examples of successful ventures in international cooperation. This meeting was very successful and all parties agreed to re-enforce international cooperation, possibly through a new type of IACG.

From a personal point of view, the Paris meeting was my first Assembly since being elected President of COSPAR in October 2002 in Houston. Being French, I felt a special responsibility for ensuring that the Paris meeting would be a success. I was therefore particularly pleased that the Local Organising Committee, composed of ESA and CNES representatives and chaired by Prof. Jean Audouze, worked in such a highly cooperative and efficient way. The number of sessions and meetings was so large and of such great interest that it was frustrating for me not to be able to attend all of them and I would have loved to have been present at more of the presentations.

I was naturally concerned that the inauguration ceremony should go well, especially with a new Minister in charge in France. I was extremely worried when I saw that the large auditorium in the Palais des Congrès still nearly empty just five minutes before the Minister's official entrance! Actually, Mr François d'Aubert was very understanding and agreed to wait fifteen minutes, using the time for informal discussions with ESA's Director General and the President of CNES, until the auditorium was full. In the end, the ceremony went off perfectly and drew many compliments.

In conclusion, organising COSPAR is to me (nearly) as challenging as directing a space science programme. In both cases, when everything is launched and working well, it is so nice to be able to say: "mission accomplie"!

Roger-Maurice Bonnet
President of COSPAR

One of the ninety-four scientific sessions in progress

All our best wishes for Beijing 2006!

Everything possible had been done to ensure that this, the 35th COSPAR Scientific Assembly, would take place under the best possible conditions. The only unforeseeable - even if pleasant! - surprise was the record attendance of the event: instead of the expected 1500 participants, more than 2800 scientists and engineers in fact registered. Counting accompanying persons, the total number of attendees was more than 3100, which is by far the highest participation in the history of COSPAR.

Conclusion

The success of the 35th Assembly can be attributed to several factors, the first of which was the high number and quality of recent space-science-related events, such as the American and European missions to Mars and Saturn, which provided the opportunity for numerous, highly interesting presentations. Secondly, the unquestionable attraction of Paris in summertime played its part. Finally, the strong cooperation between ESA and CNES in the organisation of the event was also certainly a positive factor.

This 35th COSPAR Scientific Asssembly was indeed a unique opportunity for the European scientific community to promote its programmes and successes and for Europe, through ESA, and for France, through CNES, to demonstrate the importance of their role in the world of space science.

Looking to the future, I wish our Chinese friends, who were present in Paris, every success for the 2006 Scientific Assembly in Beijing!

Acknowledgement

In underlining the crucial role played by the cooperative partnership between all of the entities involved in the organisation of this year's Assembly, I would like to acknowledge also the substantial support received from the ESA Directors involved, namely: Jean-Pol Poncelet, Director of External Relations, David Southwood, Director of Scientific Programmes, José Achache, Director of Earth Observation Programmes and Jörg Feustel-Büechl, Director of Human Spaceflight.

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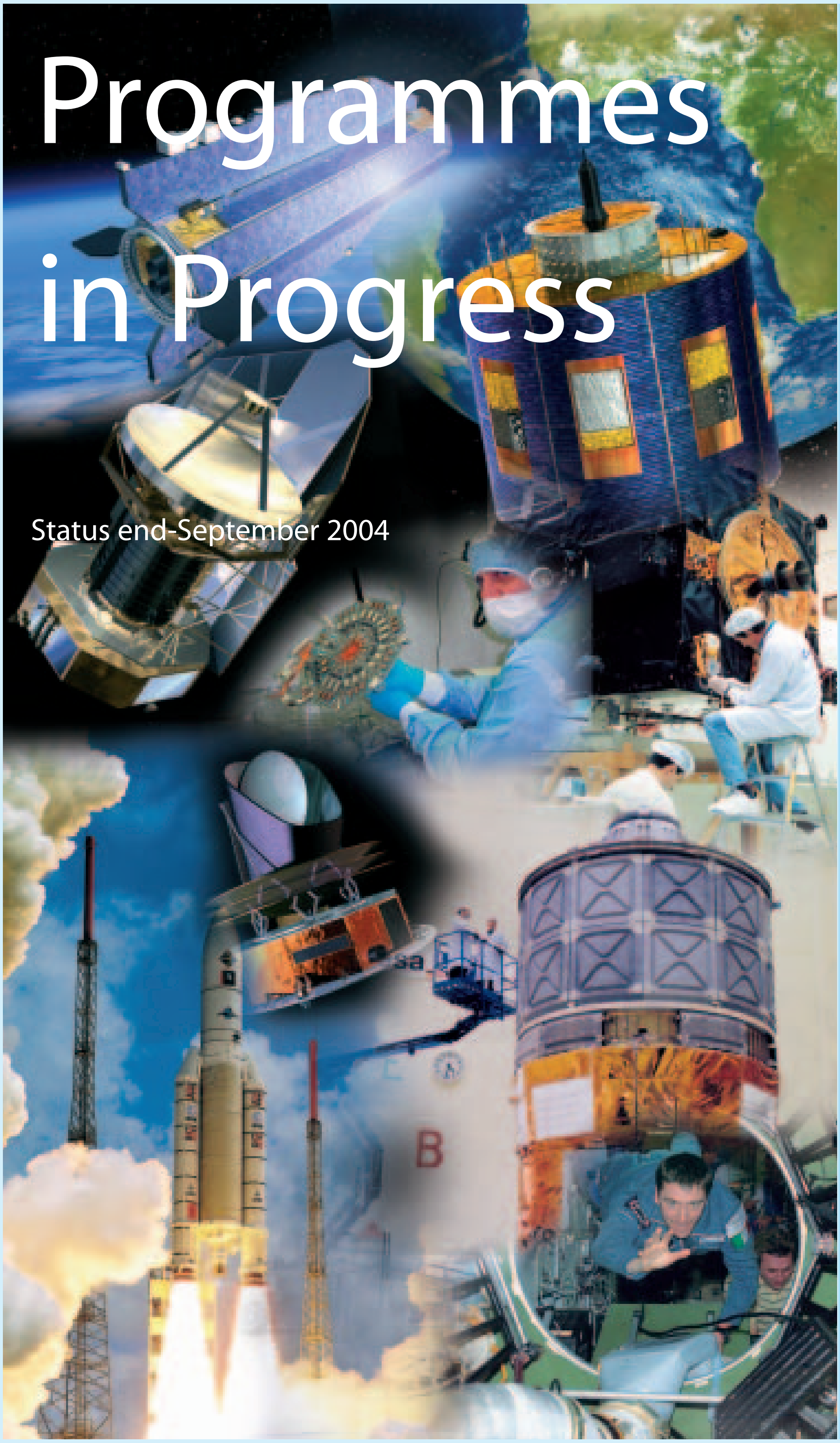
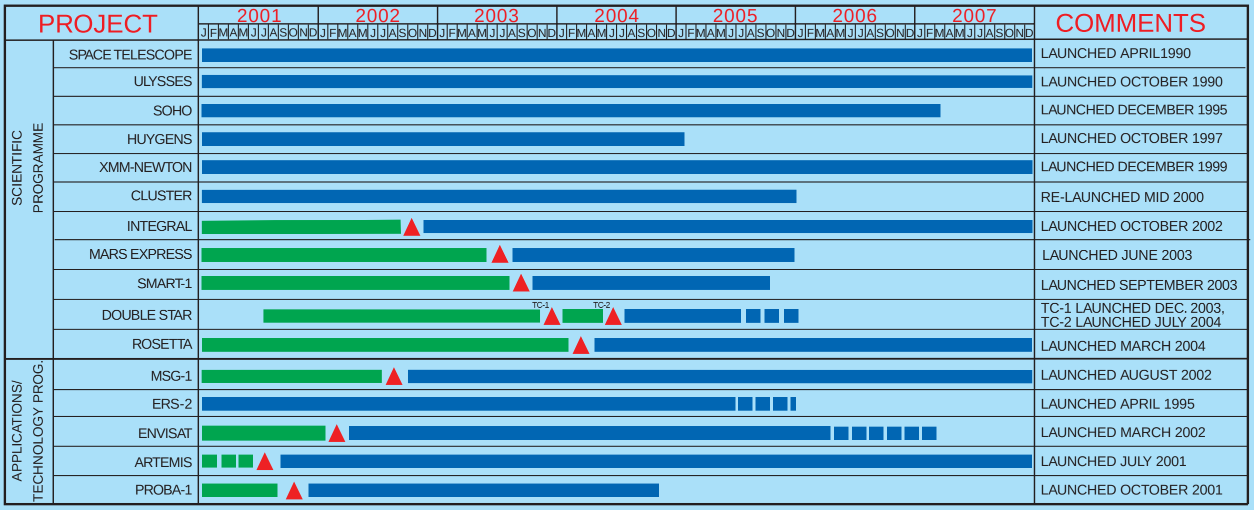
Programmes in Progress

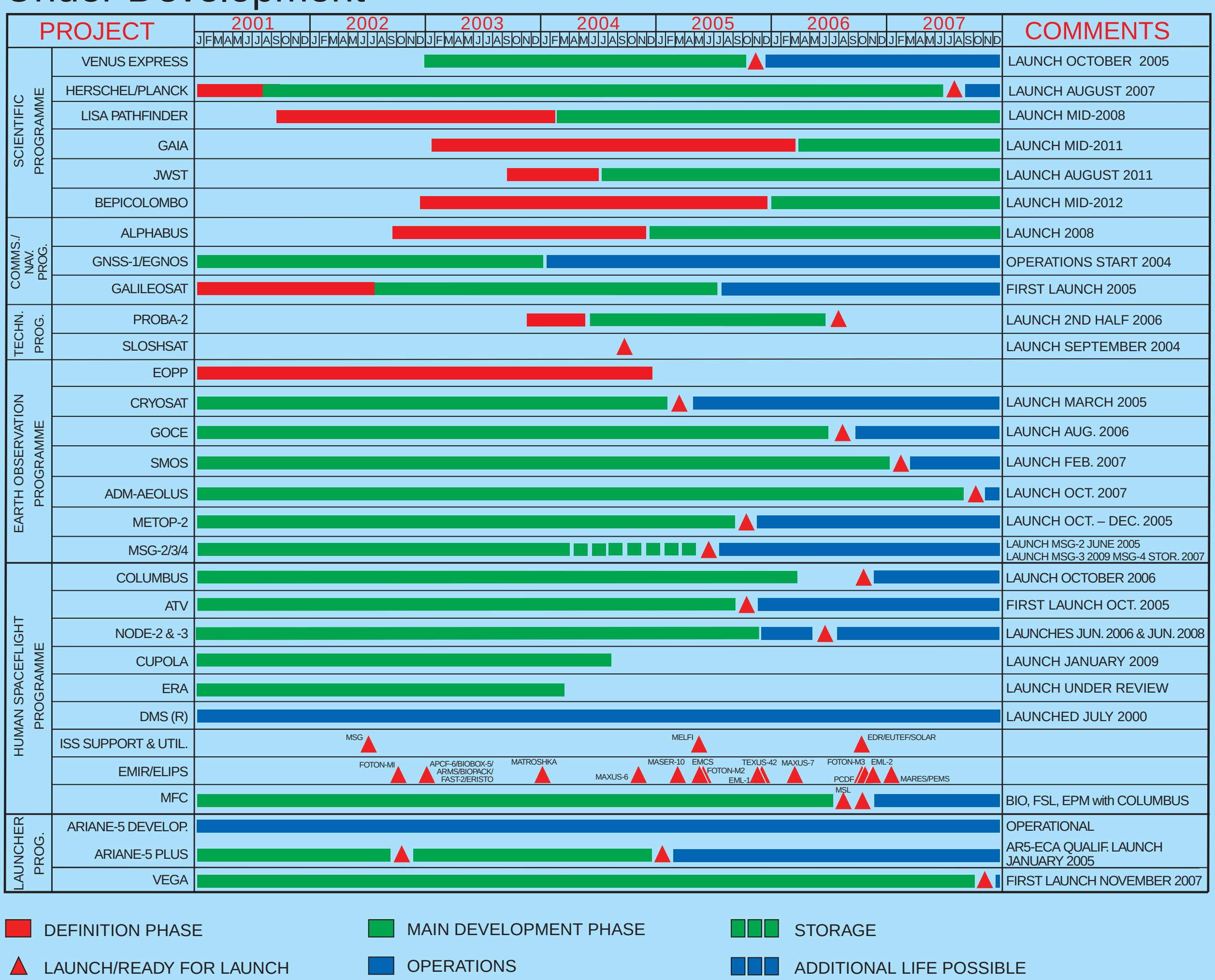
Status end-September 2004



In Orbit

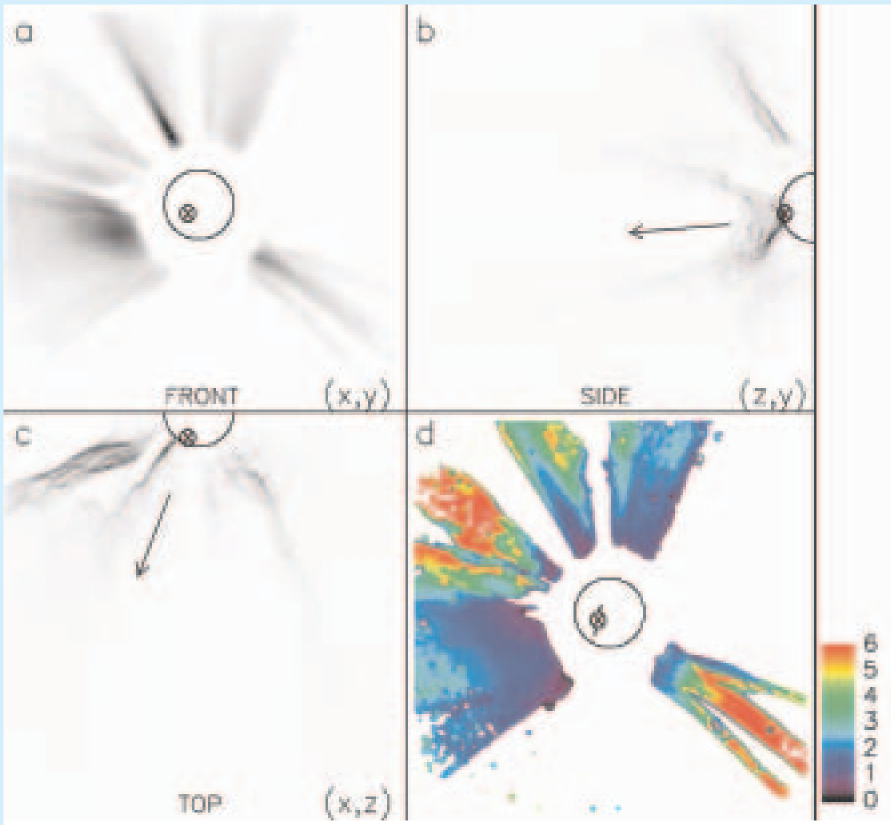


Under Development



ISO

The ISO Data Archive has been enhanced in content with a new set of Highly Processed Data Products, on SWS observations of asteroids and planetary satellites. The first nine years of ISO Science results are being compiled in a special issue of the *Space Science Reviews* journal. ISO continues to have a significant presence in the refereed literature, with 1160 papers published to date, embracing all areas of astronomy. Two large catalogues have recently been published, from the European Large Area ISO Survey (ELAIS), listing 3762 sources, stars and galaxies, observed by ISO in various infrared bands and from the ground over an area of 12 square degrees on the sky, and from the ISOPHOT 170 micron Serendipity Survey, listing more than 1900 galaxies observed serendipitously while the spacecraft was moving from one object to the other in the observing programme. In addition, a major review paper on 'ISO Spectroscopy of Gas and Dust: from Molecular Clouds to Protoplanetary Disks' has just been published. This showcases the breadth and depth of observations made by the ISO spectrometers in the 2.4–200 micron range of interstellar gas-phase and solid-state species.



A Coronal Mass Ejection (CME) heading almost directly towards Earth, observed by SOHO's LASCO C2 instrument. The size of the Sun is indicated by a circle, and the x-marked circle on the Sun shows the origin of the CME. Panel a shows the total intensity (darker means more intensity) as imaged directly by LASCO. Panel d is a topographic map of the material shown in panel a. The distance from the plane of the Sun to the material is colour-coded - the scale in units of solar radii is shown on the side. Panels b and c show the intensity as it would have appeared to an observer positioned to the side of the Sun or directly above it, respectively

SOHO

Using data from the LASCO coronagraph onboard SOHO, scientists have produced the first three-dimensional views of Coronal Mass Ejections (CMEs). This new result is critical for a complete understanding of these dramatic phenomena.

CMEs are the most powerful eruptions in the Solar System, blasting thousands of millions of tonnes of electrified gas into space from the Sun's atmosphere at millions of kilometres per hour. Researchers believe that CMEs are triggered when solar magnetic fields become strained and suddenly 'snap' to a new configuration, like a rubber band that has been twisted to breaking point. To fully understand the origin of these powerful blasts and the process that launches them from the Sun, scientists need to see the structure of CMEs in three dimensions.

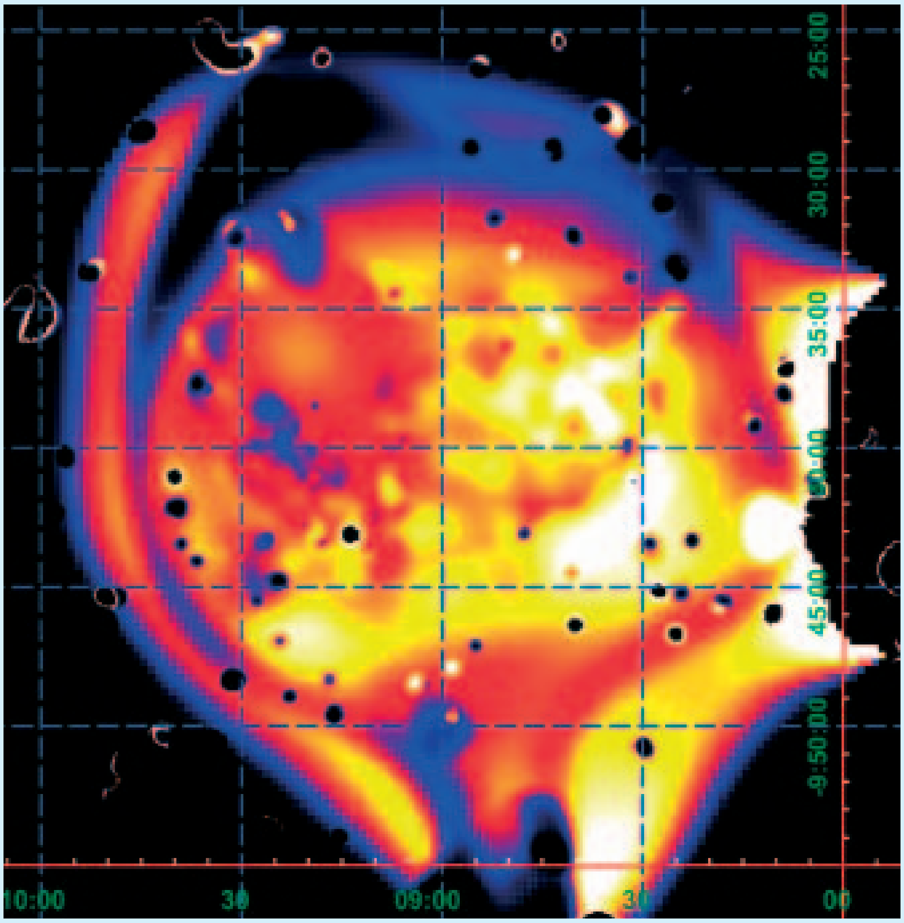
The new analysis technique determines the three-dimensional structure of a CME by taking a sequence of two-dimensional LASCO images with various polariser settings. Whilst the light emitted by the Sun is not polarised, once it is scattered off electrons in the CME plasma it takes on some polarisation. Light from CME structures closer to the plane of the Sun (as seen on the LASCO images) is more polarised than light from structures farther from that plane. Thus, by computing the ratio of polarised to unpolarised light for each CME structure, one can measure its distance from the plane. This provides the missing third dimension to the LASCO images.

This new method will complement data from the upcoming STEREO mission, scheduled for launch in February 2006. A NASA mission with significant European contributions, it will use two widely separated spacecraft to construct 3D views of CMEs by combining images from the different vantage points of the twin spacecraft.

XMM-Newton

Operations continue to run smoothly and the autumn 2004 eclipse season passed without problems. The upgrading of the overall ground segment from SCOS-1b to SCOS-2000 is progressing, albeit with some delays, but it is believed that the overall schedule (final switchover on 1 April 2005) can be maintained.

The status of the Announcement of Opportunity (AO) observing programmes is as follows:



This image shows the temperature of gas in and around the two merging galaxy clusters in A754, based directly on X-ray data. The galaxies themselves are difficult to identify; the image highlights the hot 'invisible' gas between the clusters heated by shock waves. The white colour corresponds to regions of the highest temperature - millions of degrees, hotter than the surface of the Sun - followed by red, orange, yellow and blue

– AO-2 programme: 99.7% complete
– AO-3 programme: 70.9% complete.

Full completion of the above programmes is expected by March 2005, which is in line with the planned start of AO-4 observations. Currently, over 3514 observation sequences have been executed and the data for 3398 of these have been shipped. The fourth AO was released on 30 August and closed on 8 October. Once again, the response was overwhelming, with seven-times more observing time requested than is actually available.

Version 6.0 of the XMM-Newton Science Analysis System (SAS) had been downloaded 780 times by end-September. Based on replies to a questionnaire, about 1650 scientists have access to this version and 250 people were downloading the SAS for the first time.

The XMM-Newton Science Archive (XSA) has some 1700 registered users, as of end-September. Monthly usage is characterised by the numbers for August, during which 130 scientists used the XSA and about 1400 separate data sets were downloaded.

A paper by J.P. Henry et al. about a mosaic of XMM-Newton observations of the nearby major merger cluster A754 has been accepted by the *Astrophysical Journal*. The authors construct maps of X-ray surface brightness and temperature integrated along the line of sight, and they show a basic pattern similar to numerical hydrodynamic simulations of cluster mergers. A new feature revealed by these observations is a plume-like structure that appears to emerge from the bar heading northwest. Another new feature is a rim of hot gas to the east, south and west. The authors interpret the bar as the core gas from the original main cluster, flattened and displaced from the dark-matter potential minimum by the merger. The hot rim is the outgoing forward shock from the merger. These observations lend support to the merger hypothesis for A754, but some of the parameters of existing models need modification.

Some 634 papers either directly or indirectly based on XMM-Newton observations have been published in the refereed literature.

Integral

An Integral-discovered gamma-ray burst called GRB 031202 has turned out to be the closest and faintest GRB observed so far. Two papers in the August issue of *Nature* address the nature of this intrinsically sub-energetic event. Its luminosity is similar to only one other event (GRB 980425) out of the 40 or so GRBs with measured luminosities. It is possible that these two anomalous bursts represent an as yet unknown GRB population of very faint events. These could have a different origin than the collapse of a rapidly spinning massive star leading to the formation of a black hole thought to be responsible for the majority of GRBs.

The fourth spectrometer (SPI) annealing was successfully completed with a full recovery of the pre-launch energy resolution. However, SPI detector #17 failed on 17 July (2 out of 19 detectors are now unusable) and attempts to recover it have been unsuccessful. These failures reduce the SPI efficiency by ~10%. It is still unclear whether they are linked to the annealing which preceded the failures in both cases.

The fourth version of the Integral Science Data Centre (ISDC) public Off-line Scientific Analysis (OSA) software was released in July. This release includes a number of improved data-analysis tools that allow better modeling of off-axis sources, as well as improved spectral-response matrices. The ISDC continues to routinely dispatch data products to observers within 6-8 weeks of their observation. The first Integral observations have already entered the public domain and are being made available to the scientific community via the on-line ISDC archive. Currently, observations from approximately the first eight months of observations are publicly available. The ISDC has also put a bright-source catalogue online at: http://isdc.unige.ch/index.cgi?Data+sources. This contains science products from the Imager and SPI for the ~70 brightest Integral sources. It is regularly updated as more data are added to the public archive.

Mars Express

Following a successful period of science data taking in July and early August, the end of August and most of September were dominated by a solar conjunction. In such a situation, Mars is located diagonally across from the Sun, as seen from Earth. Such a constellation blocks efficient radio communications and the spacecraft was prepared to survive extended periods of no contact. Almost no science data could be taken during this period. On the egress from conjunction, all spacecraft systems were nominal.

Studies on the safe deployment of the radar antenna for the MARSIS experiment are approaching completion, and are expected to lead to clear conclusions during the last quarter of the year. In parallel, it has been decided that the earliest deployment window, based on both technical and scientific grounds, starts around mid-March 2005.

Operations planning is progressing steadily. With the Mars – Earth distance still being high, and consequently a low-bit rate on the telecommunications link, only a limited amount of data can be downlinked. Together with the other mission constraints, this sometimes leads to difficult trade-offs in the distribution of observations over the instruments.

A dedicated Mars Express Science Conference will take place at ESTEC in the week of 21-25 February 2005. A very successful international Mars Conference was held in Ischia, Italy from 19 to 23 September. A significant number of recent results from Mars-Express were presented, an example of which is given below.

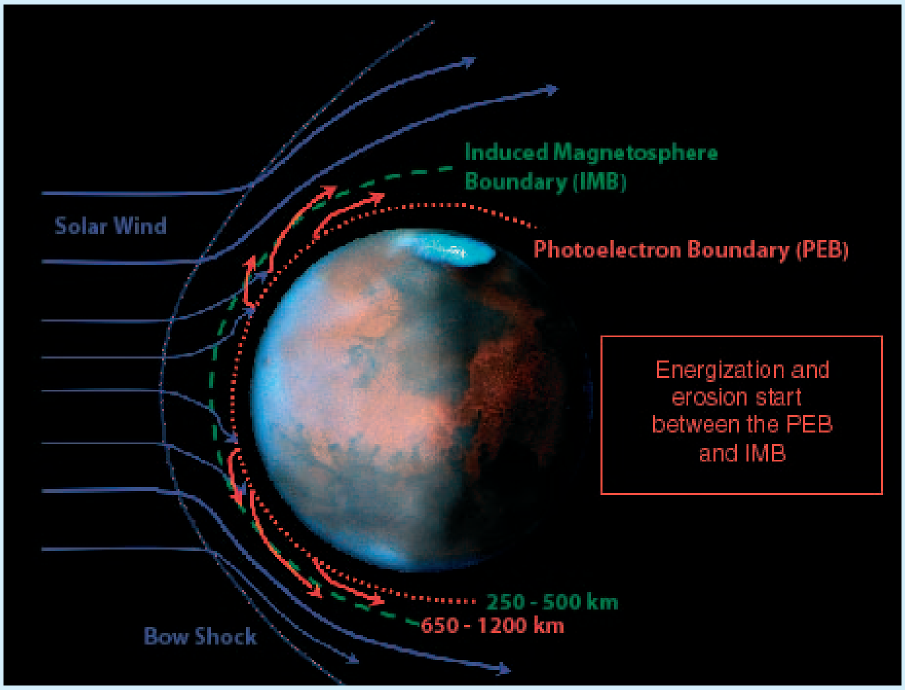


Diagram illustrating the ASPERA-3 instrument's findings regarding solar-wind-induced planetary ion erosion from the dayside ionosphere of Mars, showing how planetary ions pick up speed at altitudes located between the photoelectron boundary (PEB) and the induced magnetospheric boundary (IMB)

It is generally believed, and indicated by results from the High-Resolution Stereo Camera (HRSC), that there were once abundant fluvial activities on Mars. However, even though recent OMEGA observations confirm that today water still exists as vast fields of perennial water ice stretching out from the South Pole, an efficient mechanism for removing water from the planet must have been at work. Recent results from the ASPERA instrument confirm that such a process is indeed active in the Martian atmosphere, explaining the loss of water over time. It is believed that the solar wind erodes the atmosphere and has stripped away large amounts of water that were present on the planet about 3.8 billion years ago. ASPERA has measured a process called 'solar-wind scavenging', or the slow 'invisible' escape of volatile gases and liquid compounds which make up the atmosphere and hydrosphere of a planet. These measurements have established that the solar wind penetrates the ionosphere and very deeply into the Martian atmosphere down to an altitude of 270 km. This seems to be the reason for the acceleration processes that could explain the loss of atmosphere on Mars.

SMART-1

SMART-1 has continued to fly on its transfer trajectory, gradually bringing the spacecraft closer and closer to the Moon. So-called 'lunar resonant approaches' took place on 19 August, 15 September and 12 October, when the gravitational pull of the Moon was used to raise the perigee and change the inclination of SMART-1's orbit. These encounters take place every lunar month after many revolutions of the spacecraft around the Earth in the intervening period; hence the term 'resonances'.

The spacecraft's Electric Propulsion (EP) system has been working well during the transfer phase, as have the other spacecraft subsystems also. By mid-November, the engine had logged about 3500 hours of operation, producing a cumulative velocity

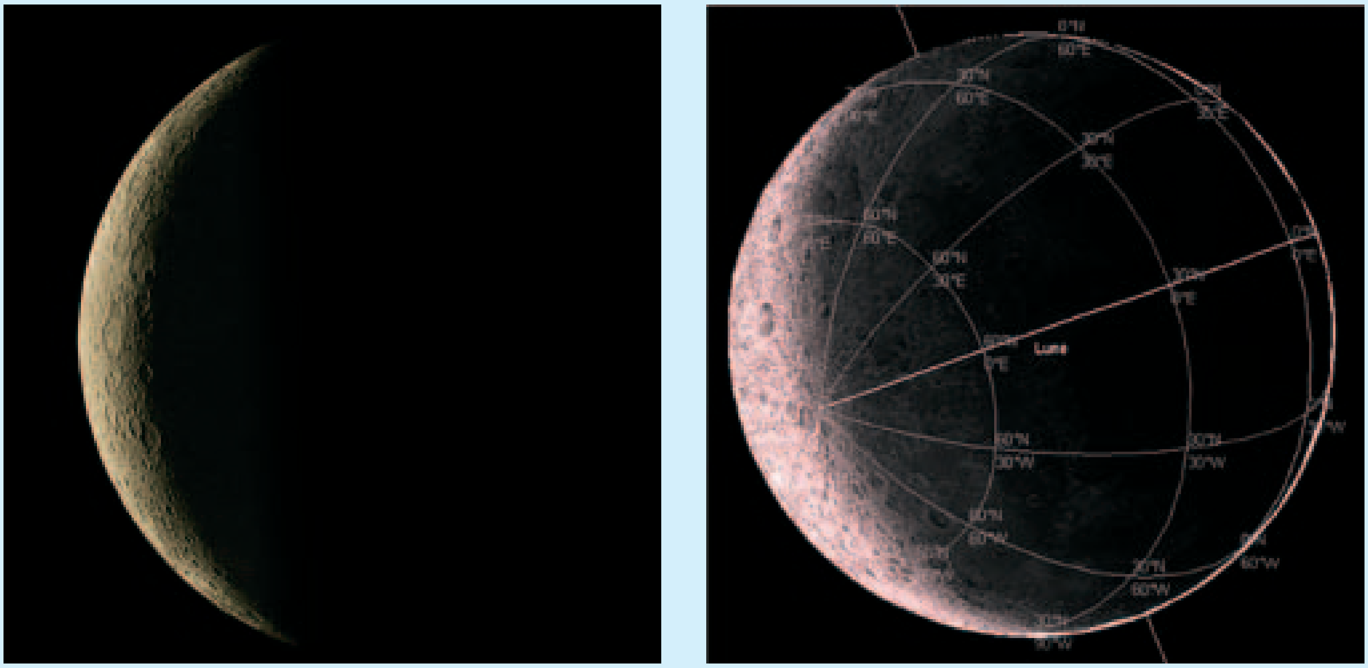


Image (left) of the Moon's north pole taken by SMART-1's AMIE camera on 12 November during the Moon capture phase, when at a distance of 60 000 km from the lunar surface. The right-hand image has been compiled from existing maps of the lunar surface

increment of more than 2.6 km/s. The last burn before lunar capture was successfully performed on 14 October. The spacecraft then flew for one month without any orbital correction. The relative position of the Moon and the Earth allowed the latter's gravitational field to 'hand-over' the probe to the Moon's gravitational pull without further intervention from the ground. The ESOC Flight Control team carefully monitored the spacecraft's trajectory throughout.

Shortly before the first lunar perilune on 15 November, the Electric Propulsion system was turned on again to lower the spacecraft into the required operational polar lunar orbit of 300 x 3000 km altitude.

All of the payload instruments have been commissioned and the cruise-science phase is nearly complete. The main lunar science phase will begin in January 2005.

Double Star

Following the launch of the second Double Star spacecraft, TC-2, on 25 July, the commissioning of both the space and ground segments lasted until the end of September. The Commissioning Review was held at Mullard Space Science Laboratory (UK) on 6/7 October 2004. The Review Board, consisting of members from the Chinese National Space Agency (CNSA) and ESA, examined the performances of the spacecraft, instruments and ground segment and declared TC-2 ready for its nominal operational phase.

With both rigid booms on the spacecraft correctly deployed shortly after launch and no magnetic interference from the solar arrays on TC-2, it was confirmed that the problems encountered with TC-1 had been solved. A few unexpected problems have, however, occurred since, during the early stages of the mission. Soon after TC-2's launch, the near-Earth space environment became filled with very high fluxes of relativistic (>2 MeV) electrons for a period of almost two weeks; the peak electron fluxes were estimated to be the highest for 20 years. Such electrons can produce high charging levels inside the spacecraft, causing discharge events that can trigger a variety of problems within the payload and the satellite subsystems. Both Double Star satellites cross the radiation belts twice per

Chinese and European participants in the double Star TC-2 Commissioning Review at MSSL (UK) on 6/7 October orbit, which is approximately twice a day for TC-1 and four times a day for TC-2. Several instruments on TC-2, as well as some on TC-1, experienced multiple resets; fortunately, all instruments survived and few data were lost. However, both the main and redundant computers in TC-2's attitude-control system failed within two weeks of the launch. The cause is still under investigation, but the severe space-weather conditions are believed to have played a role. The spacecraft's attitude can still be determined, however, using a technique based on the magnetic field measured around perigee by the European instrument onboard. The drift of the spin axis is observed to be as predicted, but unfortunately due to the attitude-control-system failures can no longer be changed. Otherwise, the spacecraft is in good health and these failures are not expected to have a major impact on the nominal duration (12 months) of the mission.

The ground segment, which includes Chinese stations in Beijing and Shanghai and the ESA ground station at Villafranca in Spain, has been tested and is working as designed. Unfortunately, the Beijing station suffered a lightning strike and has been out of operation since August, but could be replaced by the other two stations. The three operation centres - the European Payload Operation System at RAL (UK), the Chinese Double Star Science Operation Centre and the Double Star Operation and Management Centre - are now routinely operating both the European and Chinese instruments. The European Data Disposition System at IWF (Austria) forwards the raw data to European users, and the Austrian, Chinese, French and United-Kingdom data centres have successfully exchanged and distributed preliminary science data.

TC-1 operations were essentially routine during the reporting period, and a recent Cluster Workshop in New Hampshire (USA) underlined the strong interest in and very good prospects for combined Cluster and Double Star scientific operations. The next science event will be the 2nd Double Star-Cluster Workshop, to be held in Beijing on 6-8 November, where the latest Double Star observations will be compared with Cluster data, particularly during conjunctions when the satellites are on the same magnetic field lines but at different distances from the Earth.

Rosetta

Owing to the sharing of the New Norcia ground station with the Mars Express mission, the main payload commissioning for Rosetta took place in two parts, the first part up until June and the second part in September/October. So far all instruments are performing nominally, and pointing and interference campaigns have been conducted. During the commissioning phase, various instruments have made scientific measurements, including taking images of comet Linear and coordinated magnetometer measurements near the tail of comet 21P/Giacobini-Zinner.

All of the Rosetta spacecraft functions have also been fully characterised, including the performance of its high- gain antenna and its thermal behaviour. A major software update loaded to the spacecraft during the summer is working well. A Mission Commissioning Results Review will now take place, in November/December, to assess the performance of all payload and spacecraft elements.

During the first seven months of the mission, the ground segment, including the new New Norcia station, has performed according to plan. Having made its first deep-space manoeuvre at the end of May, the spacecraft is now on course to return to Earth for its first gravity-assist in March 2005. This will complete the first part of the grand tour, designed to allow Rosetta to rendezvous with comet Churyumov-Gerasimenko in 2014.

Venus Express

The project continues to progress according to plan, with the spacecraft Assembly, Integration and Testing (AIT) activities having been completed at Alenia Spazio's integration facilities in Turin (I). All flight-model

The Venus Express spacecraft packed and ready for transport from Alenia Spazio in Turin (I) to Interspace in Toulouse (F)

experiments have been delivered and integrated into the flight spacecraft, except for an add-on module to the SPICAV instrument (called 'SOIR'). The spacecraft has recently been moved to Intespace in Toulouse (F) in preparation for a 7-month environmental test campaign.

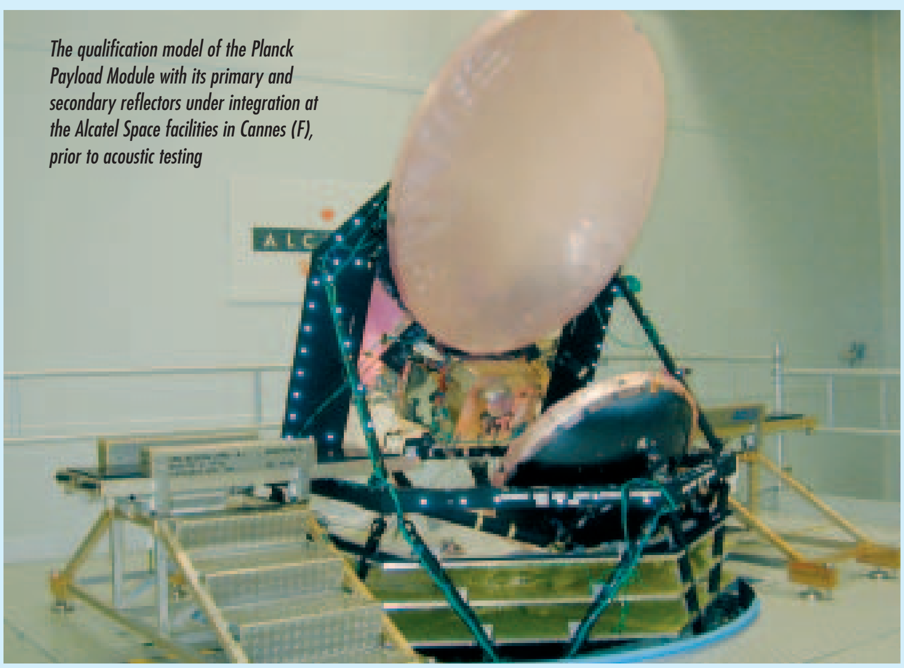
The Venus Express Ground Station Implementation Review (GSIR) was successfully completed in September and overall progress on the ground segment is good. Work on the new ESA station at Cebreros in Spain, which will be used for Venus Express operations, is progressing well.

Venus Express is now scheduled to be launched on 26 October 2005 from the Baikonur Cosmodrome in Kazakhstan. The agreed launch mass for the combined spacecraft and adaptor is 1270 kg.

Herschel/Planck

Integration of the avionics model of the Planck Service Module has started with the availability of the first two units, the data

management unit and the power distribution unit. The qualification model of the Planck Payload Module has been integrated, together with the structural models of the two Planck focal-plane instrument units and the qualification models of the Planck reflectors.



The qualification model of the Planck Payload Module with its primary and secondary reflectors under integration at the Alcatel Space facilities in Cannes (F), prior to acoustic testing

The Payload Module has achieved mechanical qualification with an acoustic-noise test.

For Herschel, the manufacture of the structural/thermal and qualification-model cryostat hardware is nearly complete, with most units having already been delivered.

Integration of the flight model of the Herschel cryostat with its two helium tanks and the vacuum vessel is in progress. The cryogenic components for helium management have been integrated with the tanks and installation of the multi-layer insulation is in progress. The Critical Design Review for the system and for the Service Module has been completed. Due to the late availability of some units for integration, the launch date has had to be delayed from February to August 2007.

The qualification models of the scientific instruments are in the final stages of their functional and performance testing and are on schedule for delivery to industry by mid-November. The Herschel telescope primary mirror is at Opteon in Finland undergoing final surface polishing. The evaluation of the cryogenic optical testing of the Planck telescope secondary reflector qualification model has been completed. The flight models of the reflectors are now being assembled and will be completed before the end of the year.

SMART-2/LISA Pathfinder

The main activity in the last quarter has been close-out of the actions assigned by the ESA System Requirements Review (SRR) team, relating to the mass-margin requirements, the incorporation of the scientific requirements into the system specifications, and the mission-performance budgets. The Review will be finalised with a presentation to the Board in early November. The status of the LISA Technology Package (LTP) system requirements, produced by the LTP industrial architect Astrium GmbH on the basis of the scientific requirements set by the Principal Investigators and ESA, is also being reviewed. A third element under review is the American equivalent of the LTP, known as the Disturbance Reduction System (DRS), which is also accommodated on LISA Pathfinder.

The development of the LTP engineering model, the main experiment and core of the mission, being conducted under Technology Research Programme (TRP) and Core Technology Programme (CTP) contracts, is encountering technical problems and further delays. This is also affecting the development of the flight model, which is to be procured by a European consortium of industries and institutes funded by ESA and some of its Member States (D, I, UK, E, CH and NL) under a Multilateral Agreement. The starting of the various contracts is governed by national procedures and the process is taking longer than anticipated, and hence some delays in LTP deliveries are expected.

Gaia

The definition studies being performed by the two independent teams - Alenia/Alcatel and Astrium - have reached a major milestone, with mid-term presentations. Both consortia presented the status of their spacecraft designs, critical areas and problems to the ESA Project Team and the Gaia Science Team members.

On 4-7 October, a major Symposium dedicated to the scientific aspects of the Gaia mission was held at the Observatoire de Paris in Meudon (F). The four-day meeting, attended by 240 delegates, was an opportunity to present the current status of the mission to the scientific community, as well as the results of investigations carried out in the various mission-related areas over the last four years. The Proceedings of the Symposium will be published shortly by ESA Publications Division as ESA SP-576.

James Webb Space Telescope (JWST)

The overall industrial set-up for the JWST mission has been completed with the selection of the prime contractor for the Mid-Infrared Instrument (MIRI) cryostat, the Fine Guidance Sensor and the Near-Infrared Spectrograph (NIRSpec). Several key system trade-off studies have also been concluded, resulting in a consolidated Payload Module design with significant mass savings and an improved thermal architecture accommodating the instrument electronics in the vicinity of the optical packages.

NIRSpec

Selection of the NIRSpec Instrument Science Team has been completed. All of the technology studies have been completed, including the extension of the Mechanical Slit Mask (MSM) study. The MSM is a backup to the NASA provided Micro Shutter Array (MSA). EADS Astrium GmbH was selected as the NIRSpec prime contractor and the contract was kicked-off on 2 July.

MIRI

The multilateral agreement has been signed by all of the participating funding agencies. The preliminary design phase for the Optical Bench Assembly (OBA) has been completed. Preliminary Design Reviews are planned in October-November. The contract between Jet Propulsion Laboratory (JPL) and Lockheed-Martin for the cryostat has been signed off. The OBA structural-model programme is well underway with all of the components having been manufactured. Testing is planned to start in November.

AlphaBus

Following the release of the common (ESA and CNES) Request for Quotation for the AlphaBus main development phase (Phase-C/D), EADS Astrium (F) and Alcatel Space (F) will submit their joint proposal by the end of October 2004.

The AlphaBus proposal submission is closely linked to the equipment selection process, taking place during the preparatory Phase-B to complete the industrial consortium for Phase-C/D.

The Preliminary Design Review (PDR) starting in October will conclude the preparatory Phase-B and will confirm the technical baseline for the AlphaBus.

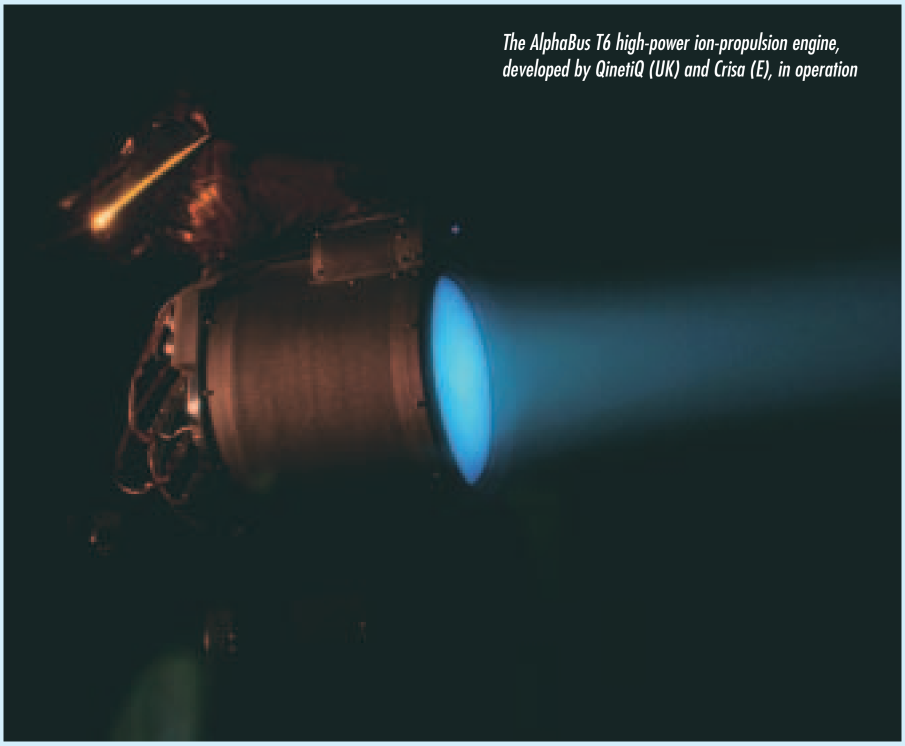
Both the PDR and the Phase-C/D Proposal require extensive team efforts in Industry and on the side of the cooperating Agencies ESA and CNES. As a result, AlphaBus will be on track to commence the main development phase towards the end of this year.

CryoSat

A major milestone has been achieved in the development of the CryoSat satellite with the completion of the integration activities in Friedrichshafen (D) at the end of July. The Prime Contractor, EADS Astrium GmbH (D), shipped the spacecraft in early August to IABG (Ottobrunn) for the environmental tests and some complementary activities.

Prior to the start of the mechanical testing sequence, a ‘flasher test’ was performed on the solar array manufactured by EMCORE (USA). It confirmed that the power requirements are met with some margin.

To verify compatibility with the Rockot launcher, the adapter manufactured by Khrunichev (Russia) has been interfaced with the spacecraft, and a separation test, using a pyrotechnic device, successfully performed. The first part of the mechanical test campaign



The AlphaBus T6 high-power ion-propulsion engine, developed by QinetiQ (UK) and Crisa (E), in operation

The CryoSat satellite ready to undergo the first vibration testing at IABG's facility in Ottobrunn (D)

included a set of vibration tests, which were also performed in a timely manner.

On the payload side, the flight model of the SIRAL altimeter successfully passed the final performance and environmental tests in Toulouse. At the end of September, Alcatel (F) was able to ship the instrument to IABG, where the pre-integration activities on the spacecraft are now in progress.

The activities related to the CryoSat Ground Segment are progressing according to plan. The first part of the second Satellite Validation Test (SVT 1-a) was successfully performed by ESOC in mid-July. In Kiruna (S), the Payload Data Segment facility (which includes the Instrument Processing Facility for Level-1b and Level-2 products) has been upgraded, and the Ground-Segment Validation Campaign is progressing well.

In order to prepare the validation activities for the CryoSat Level-2 products, a scientific campaign involving the airborne altimeter ASIRAS and simultaneous ground-truth measurements was performed in early September in the Artic and Greenland areas.

Overall, significant progress has been made in the CryoSat mission's development in the past months. Unfortunately a few repair activities, due mainly to quality problems lately reported on some electronic parts, are hampering progress. The launch, which should take place from the Plesetsk cosmodrome, has now been re-scheduled for late-March 2005.

GOCE

Good progress continues to be made with the space-segment development activities, and the sequence of equipment-level Critical Design Reviews (CDRs) for platform and payload units is steadily nearing completion. After the successful completion of the satellite mechanical qualification test programme in July, the satellite structural-model primary structure was transported from ESTEC (NL) to CASA (E) at the beginning of July, where it is now being refurbished for the flight-model programme.

Alcatel Space has completed the first phase of the Gradiometer engineering model's electrical integration and testing. Their activities are presently focusing on the thermal-balance testing of the radiometer structural-thermal model. Meanwhile, ONERA (B) has started the integration tests between the Accelerometer Sensor Head (ASH) development model and the Front-End Electronic Unit (FEEU) engineering model. Levitation of the ASH proof mass has been successfully achieved and its positioning has been controlled using an FEEU. Being the first demonstration of the performance of the digital control loops of the accelerometers, this represents a key milestone in the instrument's development. Production of the ASH flight models is also progressing. To date, ONERA has integrated three of the six ASH flight models needed for the Gradiometer instrument.

Concerning the satellite-to-satellite tracking instrument development, the qualification test programme for the GPS antenna was completed in September. The receiver software validation has also been completed in the same time frame. These tests will immediately be followed by the qualification testing of the combined GPS receiver and antenna assembly at Alenia-Laben (I).

In the platform area, Astrium GmbH (D) has progressed with the integration of the engineering-model Test Bench. Mechanical and electrical integration of equipment units is continuing, and will be followed by an exhaustive test programme that will focus on verifying the functioning and performance of the platform, including real-time closed-loop testing of the satellite's drag-free control mode.

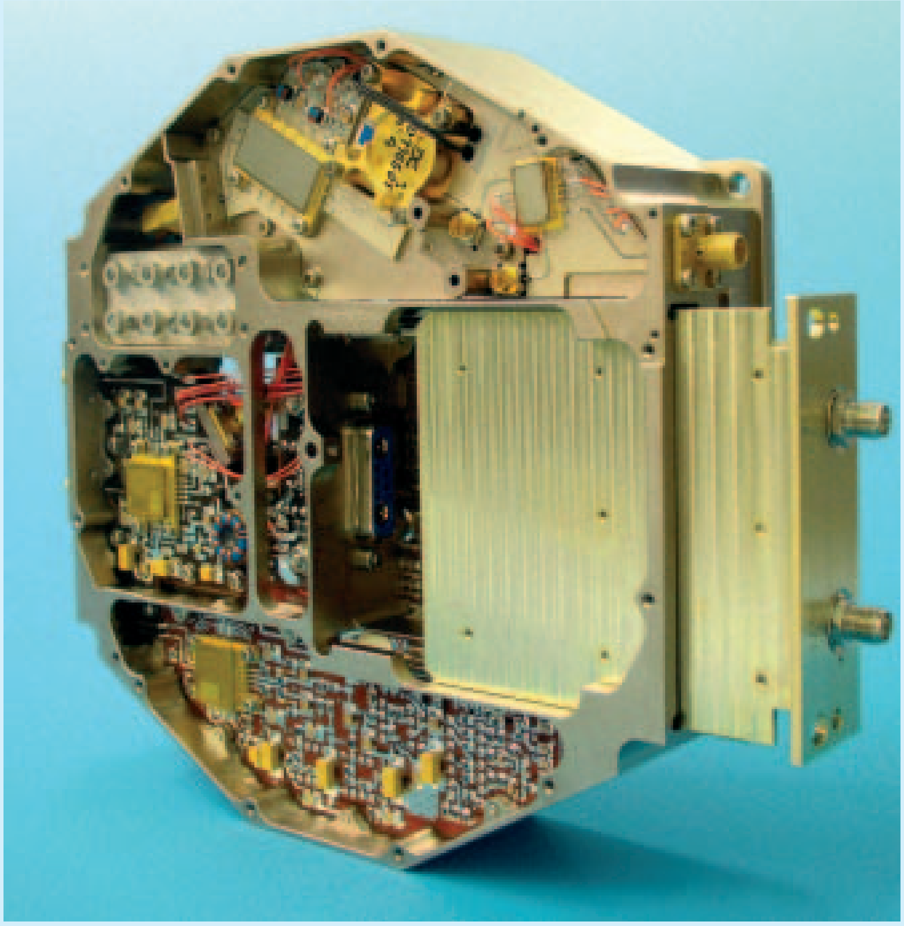
On the Ground Segment side, the tender evaluation for the procurement of the Calibration and Monitoring Facility (CMF) and the Reference and Planning Facility (RPF) has been completed. The European GOCE Gravity Consortium for the Level-1 to Level-2 data processing successfully completed the System Requirements Review (SRR) at the beginning of July. Following the SRR, the Consortium has worked on the definition of the High-Level Processing Facility architecture and on the consolidation of its interfaces. Presently, the Consortium's output is being reviewed in the framework of the Architectural Design and Interface Review.

SMOS

The production of subsystem engineering models for the payload is in full swing. Problems encountered in the environmental testing of some of the units are under resolution, but in most cases should have no impact on the further conduct of the overall engineering-model programme. Production of the structural/thermal model has started, despite problems encount-ered with the availability of raw material for the carbon-fibre elements.

An abbreviated Phase-B for the satellite (including the recurrent Proteus platform) has been kicked off with Alcatel in Cannes (F), in order to prepare for the satellite Preliminary Design Review in early 2005. Release of Phase-C/D is expected to follow immediately thereafter.

The Ground Segment, particularly that for the scientific data processing, is making progress.



The LICEF receiver engineering model (without antenna). SMOS carries 72 of these receivers, 6 of which are combined in 3 noise-injection radiometers (photo courtesy of MIER Communications SA)

Selection of the subcontractor for the 'core' elements of the Payload Data Processing Centre is scheduled to take place in November. These elements are supposed to be largely derived (recurrent) from other programmes, in order to reduce the risks. Other elements are under detailed definition. A Ground Segment Requirements Review is being prepared for the end of 2004.

ADM-Aeolus

The structure for the spacecraft platform, which will be part of both the structural- and flight-model spacecraft, has been delivered along with Mechanical Ground-Support Equipment. Dummy payload units are currently being integrated.

The 1.5 m structural-model mirror has been successfully tested, including the stability of focus under the launch environment. The structural model of the tripod for supporting the secondary mirror has also been successfully tested. Delivery of the rest of the instrument structure is expected in November 2005.

The flight primary mirror is being polished at Opteon in Finland.

An engineering model of the critical laser-pump chamber has been successfully integrated and subjected to mechanical testing, functioning correctly in vacuum.

The first testing for laser-induced damage to the optical coatings of the transmit-receive optics has been successfully carried out both in air and in vacuum. No damage was detected at power densities of up to 400 MW/cm^2.

There have, unfortunately, been further problems with the supply of flight-model pump diode stacks. The problem appears again to be with the basic semi-conductor wafer material. The suppliers cannot provide a firm delivery schedule until the problem is fully understood. The possibility of back-up European pump diode supplies is being investigated.

Good progress is being made with the Model-based Development and Verification Environment (MDVE), which fulfils many of the functions of a classical engineering model. The EGSE is working successfully with the bread-board CDMU and the first delivery of the flight software.

The satellite Critical Design Review is now planned for September 2005. Launch remains scheduled for October 2007.

MetOp

The MetOp-2 Payload and Service Modules were finalised in July, allowing the satellite integration campaign to start. This is progressing well, with the recent completion of the radiated auto-compatibility test in the anechoic chamber at Intespace (F). Preparations are now in hand for the mechanical test campaign (vibration, acoustic and shock) to be also conducted in the Intespace facilities.

The third Satellite System Verification Test has also been successfully conducted, with the satellite being controlled by ESOC for the first time in preparation for their conducting the Launch and Early Orbit Phase (LEOP) operations.

The leakage problem on the MetOp-2 Service Module has been localised, thanks to the help of a specially designed cold plate, to a thruster flow-control valve. This thruster will be replaced with a spare prior to the mechanical testing.

The Eumetsat Polar System (EPS) site for MetOp in Norway

Work is progressing on the preparations for the satellite in-orbit verification, during which the correct functioning of the satellite and its instruments will be checked prior to the start of the commissioning-phase proper.

Provision of the AVHRR and AMSU-A instruments for MetOp-3 has recently been formally confirmed by NOAA. However, as these instruments are either refurbished from NOAA-N' (AMSU-A) or need to be newly built (AVHRR), their availability is delayed to 2006-2008. This makes the current integration planning for MetOp-3 obsolete and discussions are underway with industry to defer this until the 2008 time frame.

A change proposal for the further re-baselining of the AIV programme subsequent to customer-furnished instrument delivery evolution is in negotiation with industry, and a further change proposal for the 'variable baseline tasks' (launch campaign, in-orbit support, storage and destorage) is in preparation.

The MetOp programme remains on track for launch readiness in the third quarter of 2005. Eumetsat, following consultation with ESA, will announce the launch month in December this year.

Progress is also being made on the Eumetsat Ground Segment, which is now entering the system integration and verification phase.

Meteosat Second Generation (MSG)

MSG-1

A longitude control manoeuvre was successfully executed in September. During the reporting period, an anomaly was experienced on the spacecraft, which was caused by the PCU (Power Control Unit). However, full nominal operations could be restored soon afterwards.

The performances of the spacecraft's instruments - Spinning Enhanced Visible and Infrared Imager (SEVIRI), the Geostationary Earth Radiation Budget (GERB) monitor and the Search & Rescue (S&R) payload - remain excellent.

MSG-2

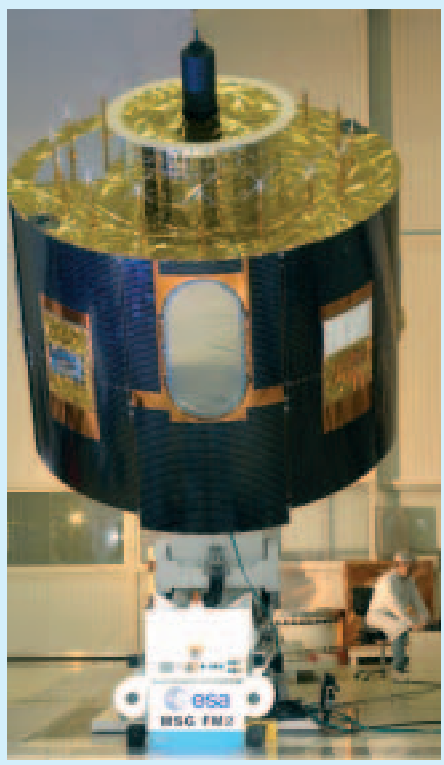
MSG-2 de-storage activities and finalisation of the open work should be completed by the end of October. A successful outcome to the MSG-2 Readiness for Shipment Review (RSR), followed by Eumetsat's System Readiness Review (SRR), will allow the spacecraft to be shipped to the Ariane-5 launch site in Kourou, Fr. Guiana. The MSG-2 launch notification provided by Arianespace indicates a launch in June 2005, but the launcher type (GS or ECA) and the co-passenger are still to be decided.

MSG-3

The MSG-3 Pre-Storage Review (PSR) was successfully completed in July. The spacecraft will remain in short-term storage in the Alcatel clean room until after the MSG-2 launch campaign, when it will be put into long-term storage awaiting its own launch, which is currently foreseen in 2009.

MSG-4

Progress on the MSG-4 assembly, integration and test activities is according to plan. The propellant tanks are mounted on the central cone, the antenna platform is undergoing pre-integration, and the SEVIRI instrument is in the final stages of integration.



MSG-2 during MCI testing at Alcatel Space in Cannes (F) (photo courtesy of Alcatel Space)

Human Spaceflight, Research and Applications

Highlights
In preparation for the arrival at the International Space Station (ISS) next year of the first Automated Transfer Vehicle (ATV), the Expedition 9 Crew performed a 4 1/2-hour Extra Vehicular Activity (EVA) on 3 August, and another 5 1/2-hour sortie on 3 September, to install the complete videometer target assembly and five of the nine antennas required by the ATV. The Space Shuttle Return to Flight date has slipped to no earlier than 14 May 2005, due to delays caused by three hurricanes that hit Florida in September. The Progress flight 15P to the ISS was successfully launched on 11 August 2004, and was the 42nd flight to the ISS. The International Agreement between ESA, NASA and CNES on Long-Term Bed-Rest Studies on females was signed at the end of July.

All parties (ESA, World Health Organization, International Telecommunication Union and the European Commission (EC) Directorate of Information Society Technologies Programme) signed the contract for the TM Alliance Telemedicine project, which officially started on 1 August. Agreement was reached to start the 41 million Euro IMPRESS Integrated Project, which will investigate the materials processing, structure and properties of new higher-performance inter-metallic alloys for industrial applications, on 1 November. The contract signature with the EC is planned for 10 November 2004.

Space infrastructure development
All four active Columbus payload-facility racks – Biolab, European Physiology Modules-EPM, Fluid Science Laboratory-FSL and European Drawer Rack-EDR – have been integrated into the Columbus flight model (FM), which has successfully completed both the individual payload Integrated Functional Testing and the Integrated System Test. The payloads are now being returned to developers for further flight-readiness completion work until Autumn 2005. The Columbus Qualification Review 2 has started and the Board Meeting is planned for early-November.

ATV-1 *Jules Verne* was delivered to ESTEC in Noordwijk (NL) in mid-July for extensive environmental testing prior to shipment to Europe's Spaceport in French Guiana. In the meantime, system functional tests have been carried out on the spacecraft and the Russian electronic and Kurs equipment (Russian transponder, which is part of an independent system for monitoring the ATV's approach to the ISS) have been delivered, installed and checked-out successfully. System integration and testing is progressing on schedule.

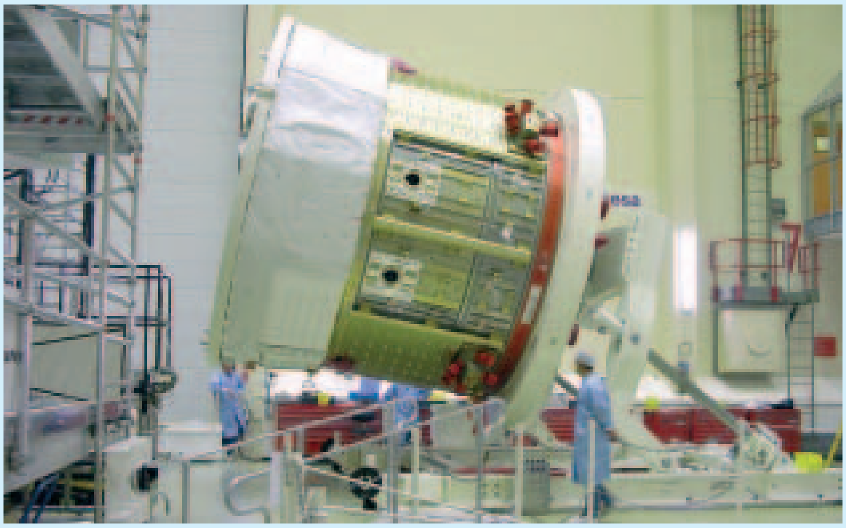
ESA and NASA have established an updated formal technical baseline for Node 3, an updated schedule forseeing delivery in late-2006, and a joint management approach for the future implementation of the remainder of the project.

Programmatic discussions about NASA requirements for the Cryogenic Freezer (CryoSystem) have been concluded and configuration-modification activities are in progress as part of Phase-B completion.

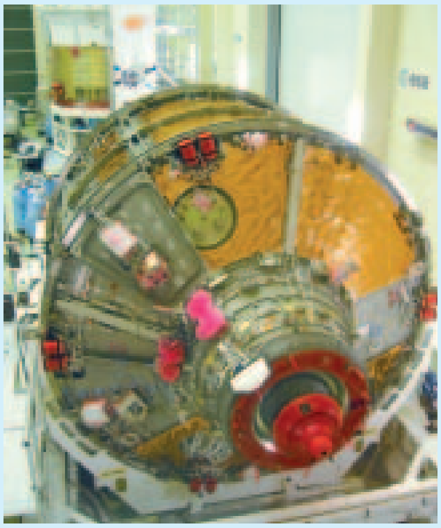
The Qualification and Acceptance Reviews Part 1 for the Cupola have been successfully completed and the flight unit delivered to Kennedy Space Center (KSC).

The European Robotic Arm (ERA) Acceptance Review closeout meeting was held in early July. The new design for the Russian Segment of the ISS now features a Multipurpose Laboratory Module, which should be used to launch ERA (in 2007) and act as its 'home base'.

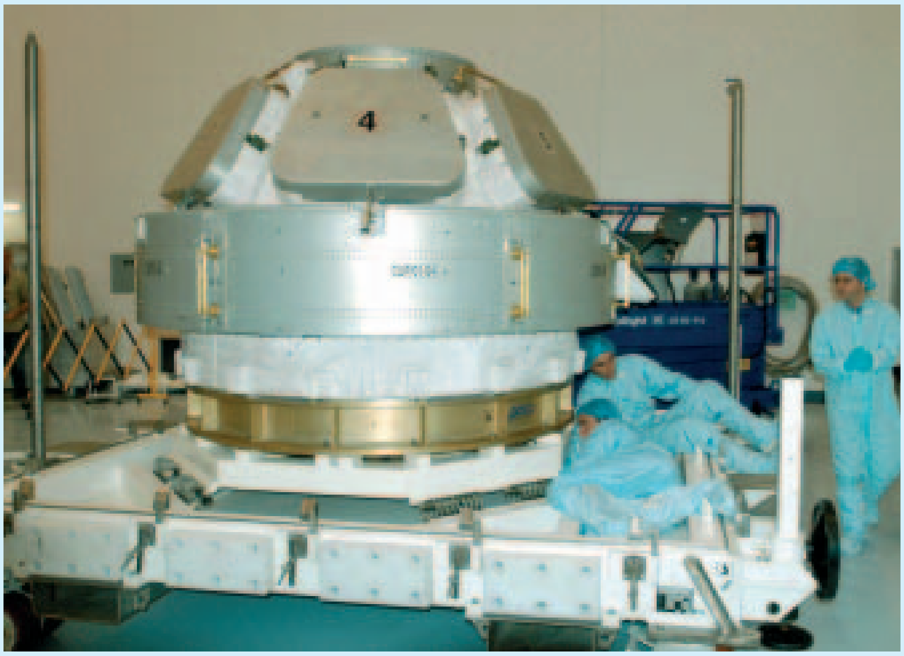
Operations and related ground segments
Negotiations on the ISS Initial Exploitation contract have been completed, and its signature, which covers a total amount of 1.046 billion Euro, and includes the production of six ATVs, logistics and sustaining engineering, ATV crew training and Operations Preparation activities, took place on 13 July.



The Jules Verne spacecraft at ESTEC in Noordwijk (NL) ready for mating with the Cargo Carrier



The Integrated Cargo Carrier of Jules Verne at ESTEC



The Cupola arrived at the Kennedy Space Center on 8 October (photo NASA)

Initial end-to-end system-validation tests, involving the ATV Flight and Ground Segments and using the Data Relay Satellite System (TDRSS), have been successfully completed. Qualification and acceptance testing of the ATV Control Centre (ATV-CC) systems is ongoing and system-level integration has started. The ATV Flight Operations Readiness Review was successfully held in September 2004.

The first end-to-end tests, System Validation Test-1 (SVT-1), involving the Columbus Control Centre (COL-CC) and the Columbus engineering model, and the SVT-2 involving the Columbus flight model, Payload Racks, COL-CC, relevant User Support and Operations Centres (USOCs) and the Interconnected Ground Subnet (IGS) ground communications network, have been successfully performed. The COL-CC Mission Control Rooms are now outfitted and being used by the operations teams.

The Data Management System (DMS-R) on-board the ISS is continuing to perform flawlessly.

The human upper-body radiation phantom, Matroshka, is currently running in minimum science operation mode and, since its operation is not flawless, a recovery action is being worked on.

Utilisation planning, payload development and preparatory missions

A new general Announcement of Opportunities for Life and Physical Sciences, including a part for new Microgravity Application Promotion proposals, was issued in July.

International Peer Boards have reviewed the proposals received following the International Life Sciences Research Announcement (ILSRA 2004). 19 of the ESA proposals received high marks. The International Space Life Sciences Working Group Steering Committee will decide on the final list of experiments.

Following signature in July of the International Agreement, the first 60-day campaign of Long-Term Bed-Rest Studies on females will start on 22 February 2005.

Integration of the SOLAR Coarse Pointing Device mechanical-assembly engineering qualification model has been completed and random vibration tests have been performed. Flight-model instrument acceptance is progressing with Columbus Rack-Level Test Facility (RLTF) testing scheduled for November.

The EuTEF Level-II Integration Readiness Review has been completed and preparations for the Preliminary Acceptance Review-1 and testing on the RLTF are ongoing. The first three experiments have been integrated onto the EuTEF flight model.

Within the Interim Utilisation Activities, the development phases for the various physical-science experiments in the Microgravity Science Glovebox, planned to be executed in 2006, have started, and preparation of the human-physiology experiments for the ISS (Respiratory, Cardio/Neuro, Flywheel) is continuing with new items planned for 2005/6.

The Acceptance Review for the European Transport Carrier has been completed and analytical payload stowage integration for the Columbus 1E flight is ongoing.

Testing of the flight model of the Protein Crystallisation Diagnostics Facility is approaching finalisation, while the Acceptance Review for the engineering model started in mid-September.

The Muscle Atrophy Research and Exercise System has completed the Critical Design Review and the full functionality of its interface with the Percutaneous Electrical Muscle Stimulator was verified in July.

The flight model of the Pulmonary Function System (PFS) is being prepared for shipment to KSC for launch-preparation activities. The PFS will be made suitable for periodic astronaut-fitness evaluations.

The first flight unit (FU1) of MELFI is being prepared for installation in the Multi-Purpose Logistics Module (MPLM) for launch in May 2005. FU2 was delivered to KSC for MPLM testing at NASA, and the FU3 Test Readiness Review took place at the end of September.

The European Modular Cultivation System Flight Acceptance Review was successfully completed in September and delivery of the flight model to KSC for integration into an EXPRESS Transportation Rack ready for launch in May 2005 is in progress.

The German Space Days in September 2004 attracted thousands of visitors to ESA/EAC in Cologne (D)

The 7th ESA Student Parabolic Flight Campaign, involving 30 experiments, was successfully completed in July, and the 38th Campaign, involving 13 experiments, in October.

Development of the Maxus-6 sounding-rocket payload complement due for launch in November is progressing according to schedule.

The 400 kg payload for FOTON-M2, comprising 38 experiments in the fields of physics, biology, technology and education, is approaching completion and the System Design Review has been successfully completed in Russia.

The proposed FOTON-M3 payload complement (a more than 300 kg payload package for all scientific disciplines) has been presented to the Russian parties for accommodation assessment. The final payload will be defined in November.

ISS education

The first DVD, titled 'Newton in Space', is being distributed to schools throughout Europe.

The EC project 'Life in Space' 2004 was concluded with a two-week workshop in Banyuls (F), with the participation of students from five European universities and ESA astronaut André Kuipers.

Commercial activities

The contract appointing the Commercial Agent to market and sell the use of the European facilities and resources onboard the ISS to the biotechnology, health, food and nutrition market sectors throughout Europe, was signed on 21 September. The 'ESA Space Training' contract has also been signed.

Astronaut activities

During the reporting period, ESA astronaut Roberto Vittori has received Soyuz training in Russia, while ESA astronaut Christer Fuglesang continued training for the STS-116 mission in the United States. Preparation for the Italian Soyuz Mission is also in progress.

A class of six ISS astronauts – five from ESA and one Canadian – received Columbus Science Payload and ATV Advanced Training at the European Astronaut Centre (EAC) during September.

Three biomedical engineers completed their Columbus system training and internal training on ISS countermeasure devices.

The Final Acceptance of the EDR Training Model took place on 27 July.

The German Space Days, held during the weekend of 18-19 September and supported by EAC and most ESA astronauts, attracted some 100 000 visitors. The opening Gala, the 'Nacht der Astronauten', on 17 September in the Cologne Arena was attended by about 5000 people (see 'In Brief' in this issue).

The Technological Model of the Vega first stage's P80 motor during manufacture at the Colleferro factory (photo courtesy of Avio)

Vega

The main event in recent months has been the completion of the System Design Review Board. The actions resulting from the June meeting of ESA's Industrial Policy Committee (IPC) were followed up during the rest of June and July and presented to a final meeting of the Board on 30 July. Action-blocking items were closed-out and a detailed plan for the closure of the other actions in the autumn time frame was presented to and agreed by the Board. ELV, the Vega prime contractor, presented a new organisational scheme whereby the Integrated Project Team's (IPT) system analysis and synthesis abilities are improved by the recruitment of senior managers and by a rearrangement of the internal ELV organisation. A new schedule agreed between the IPT and ELV which leads to a qualification-flight launch in November 2007 was also presented.

The inert propellant casting for the Zefiro-9 motor has successfully taken place, concluding activities for this first development model of the third stage. The manufacture of the P80 Technological Model (shorter cylindrical section) was completed in August, marking an important milestone in the development of Vega's first stage. The P80 BEAP modifications have also been completed and the results of acceptance tests are expected shortly.

The Ground Segment development effort started in earnest after the IPC's endorsement in June of the Executive's proposal for an industrial structure with Vitrociset (I) as Prime Contractor. A Preliminary Authorisation to Proceed was discussed with Vitrociset and issued at the end of July, in order to start detailed design activities taking into account modifications incurred since the issue of the Invitations to Tender (ITTs) and to safeguard the schedule. Kick-off meetings with Vitrociset subcontractors took place in late August and early September. A Change Request reflecting the modifications of the roles and responsibilities of the IPT and the CNES/DLA Ground Segment Sub-Directorate was also issued in early August to begin the process of modifying the engineering and test-management contract between CNES and ESA. r

In Brief

Europe reaches the Moon – SMART-1 enters lunar orbit

During the night of 15 to 16 November, ESA's SMART-1 spacecraft made the first of its closest approaches to the Moon after its 13-month journey from Earth. The spacecraft, the first of Europe's Small Missions for Advanced Research in Technology, then began adjusting its orbit around the Moon in preparation for a comprehensive scientific investigation of the lunar surface, which will start in January.

During the long cruise phase, consisting of a spiralling orbit around the Earth that brought the spacecraft close to the lunar capture point, SMART-1 achieved all of the technology-demonstration goals that it had been assigned for this first part of the mission. They included a complex package of tests on new technologies that will pave the way for future planetary missions.

In particular, SMART-1's novel solar-electric propulsion system was tested over the long spiralling trip to the Moon that covered more than 84 million km, which is a distance comparable to an interplanetary cruise. For the first time ever, gravity-assist manoeuvres using the gravitational pull of the approaching Moon were performed by an electrically propelled spacecraft. The success of this test was important for the viability of future interplanetary missions using ion engines.

SMART-1 has also demonstrated new techniques for eventually achieving autonomous spacecraft navigation. The OBAN experiment tested navigation software on ground computers to determine the exact position and velocity of the spacecraft using images of celestial objects taken by SMART's AMIE camera as a reference. It demonstrated how OBAN will allow future spacecraft to know not only where they are in space, but also how fast they are moving, limiting the need for intervention by ground control teams.

The view from SMART-1 as it neared the Moon

SMART-1 also carried out deep-space communication tests with its KaTE and RSIS experiments, consisting of testing radio transmissions at very high frequencies compared to traditional radio frequencies. Such transmissions will allow the transfer of the ever-increasing volumes of scientific data back to Earth from future spacecraft.

With its Laser Link experiment, it tested the feasibility of pointing a laser beam from Earth at a spacecraft moving at deep-space distances for future communication purposes.

During the cruise, to prepare for the lunar-science phase, SMART-1 conducted preliminary tests on four miniaturised instruments, which are being used for the first time in space: the AMIE camera, which has already imaged Earth, the Moon and two total lunar eclipses from space, the D-CIXS and XSM X-ray instruments, and the SIR infrared spectrometer.

In all, SMART-1 clocked up 332 orbits around Earth before reaching lunar orbit. It fired its ion engine 289 times during the cruise phase, operating for a total of about 3700 h. Only 59 of the 82 kg of xenon propellant available were used and overall the engine performed extremely well, enabling the spacecraft to reach the Moon two months earlier than planned. The extra fuel thereby available has allowed the mission designers to significantly reduce the altitude of SMART's final orbit around the Moon. This closer proximity to the surface will be even more favourable for the unique science observations that will start in January. r

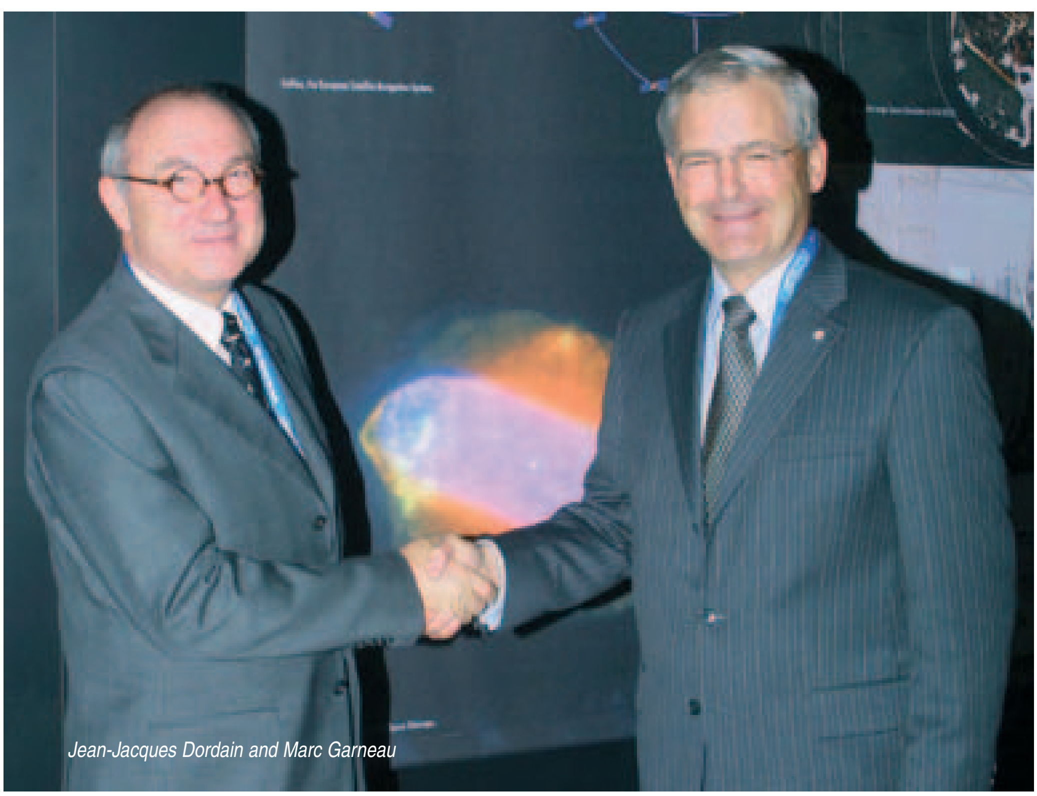
Canada and Europe celebrate 25 years of space excellence together

Vancouver played host from 4 to 8 October to the 55th International Astronautical Congress (IAC), organised by the International Astronautical Federation (IAF) together with the International Academy of Astronautics (IAA) and the International Institute of Space law (IISL). With the theme 'Infinite Possibilities/Global Realities', it brought together World experts in a broad range of space disciplines, from space agencies, research institutes, universities and industry, sharing and debating results, studies, projects and visions for the future in space. ESA's Director General Jean-Jacques Dordain headed an ESA delegation comprised of specialists in disciplines ranging from space sciences to future space exploration and space law.

This year's Congress also coincided with the Anniversary of 25 years of cooperation between ESA and Canada, and on 5 October Jean-Jacques Dordain and Canadian Space Agency President Marc Garneau held a joint Press Conference to mark this significant milestone.

"Europe and Canada have built a space bridge across the Atlantic through cooperation in space", said Jean-Jacques Dordain. *"ESA and the Canadian Space Agency (CSA) are already strong partners in key technologies for Telecommunications and Earth Observation, besides being partners in the International Space Station, and I am confident they are committed to continue pursuing this fruitful cooperation in new international endeavours such as the future Space Exploration programme",* he added.

More than a hundred European university students, and a number of students from developing countries which cooperate with ESA, were able to attend this year's Congress thanks to ESA's support, as part of the process of 'handing down' space expertise to the next generation of space scientists and engineers. r



Jean-Jacques Dordain and Marc Garneau

Three years of Proba in orbit

ESA's first ever microsatellite has completed three years of successful operations. The size of a large television set, Proba was launched to demonstrate new technologies for future European spacecraft, but continues to provide images of Earth.

"It is amazing what we have got out of Proba," says Frederic Teston, ESA's Proba Project Manager. ***"The mission has lived up to its full name of 'Project for On-Board Autonomy' – for every day of the last three years the spacecraft steered, navigated, estimated target fly-bys and took images. These are all functions that have to be handled from the ground for larger spacecraft."***

The thinking underpinning Proba is that tightly focused missions can be delivered in a short time frame useful to scientists if the time taken from the original concept to launch and operation can be greatly reduced. To simplify its construction and reduce costs Proba was constructed as much as possible with existing off-the-shelf components, rather than customised space-hardened parts typical for satellites. The good news is that these systems have continued to work well throughout Proba's 1096 days in space.

In polar orbit 600 kilometres above the Earth, Proba acquires around 300 images of about 60 separate sites per month. To date the spacecraft has provided more than 10 000 images from its two onboard imaging instruments: the Compact High Resolution Imaging Spectrometer (CHRIS) and the black and white High Resolution Camera (HRC). r

New Delhi in October 2004 – imaged by Proba's High Resolution Camera

Student satellite coming to life

SSETI student Jörg Schaefer shows the student satellite's propulsion management system in the clean room

Scattered in universities across Europe, a team of 250 students have never collectively met in person, but between them they have built a satellite. SSETI Express is currently being integrated in an ESA clean room for a planned launch in May next year.

The pan-European network of students, universities and experts involved in the Student Space Education and Technology Initiative (SSETI) communicated mainly via the internet. The completed subsystems have been delivered to ESA's European Space Technology Centre (ESTEC) in the Netherlands.

Jörg Schaefer of Stuttgart University in Germany has taken time out from studying for a PhD in Satellite Systems Design to take part in the integration work at ESTEC: **"***We are assembling the final spacecraft flight model. After all the planning and preparation for the mission it is exciting to see it finally take shape, with new parts being delivered almost every day."*

SSETI Express will carry inside it three smaller 'cubesats' – 10-centimetre cube technology testers built by universities in Germany, Japan and Norway – for deployment in orbit. The main SSETI Express satellite will test a propulsion system, return images of the Earth and serve as a transponder for amateur-radio users. SSETI Express measures just 60 by 60 by 70 cm, small enough to piggyback its way to orbit on next year's commercial Cosmos DMC-3 launch from Plesetsk in Russia. *"With SSETI Express, we've come from design to integration in a year, which is a very rapid schedule for a spacecraft,"* explains Neil Melville, initially an ESA Young Graduate Trainee and now the SSETI Express Project Manager and also satellite system engineer. *"We hope to have the flight model completed by the end of November, in time to undergo checks. The key deadline we face is to transport the spacecraft to Russia by the end of February next year for a launch in mid May."*

SSETI Express is a test-bed and technology demonstrator for another larger scale mission, the European Student Earth Orbiter (ESEO), due to hitch a ride on an Ariane-5. *"ESEO is a complex 100 kg plus microsatellite with multiple instruments, due to launch into geostationary transfer orbit in 2007,"* explains Philippe Willekens of the ESA Education Department. *"Express serves as a motivational aid, a technological test-bed, a logistical precursor, and, most importantly, a demonstration of capability to the SSETI and educational communities, our support network at ESA, and the space community in general. Participants are getting educated in all facets of mission preparation, from design to launch and operations, including legal and risk management aspects."*

Coordination between groups is carried out using a dedicated news server and weekly Internet Relay Chats (IRCs) as well as the SSETI website. Face-to-face meetings are the exception rather than the rule, with group representatives meeting every six months for a workshop at ESTEC.

A student holds one of the smaller cubesats

Global pollution map from space: Earth's dark matter

Based on 18 months of Envisat observations, this high-resolution global atmospheric map of nitrogen dioxide pollution makes clear how human activities impact air quality.

ESA's ten-instrument Envisat, the world's largest satellite for environmental monitoring, was launched in February 2002. Its onboard Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) instrument records the spectrum of sunlight shining through the atmosphere. These results are then finely sifted to find spectral absorption 'fingerprints' of trace gases in the air.

Nitrogen dioxide (NO_2) is a mainly man-made gas that can cause lung damage and respiratory problems. It also plays an important role in atmospheric chemistry, because it leads to the production of ozone in the troposphere, the lowest part of the atmosphere.

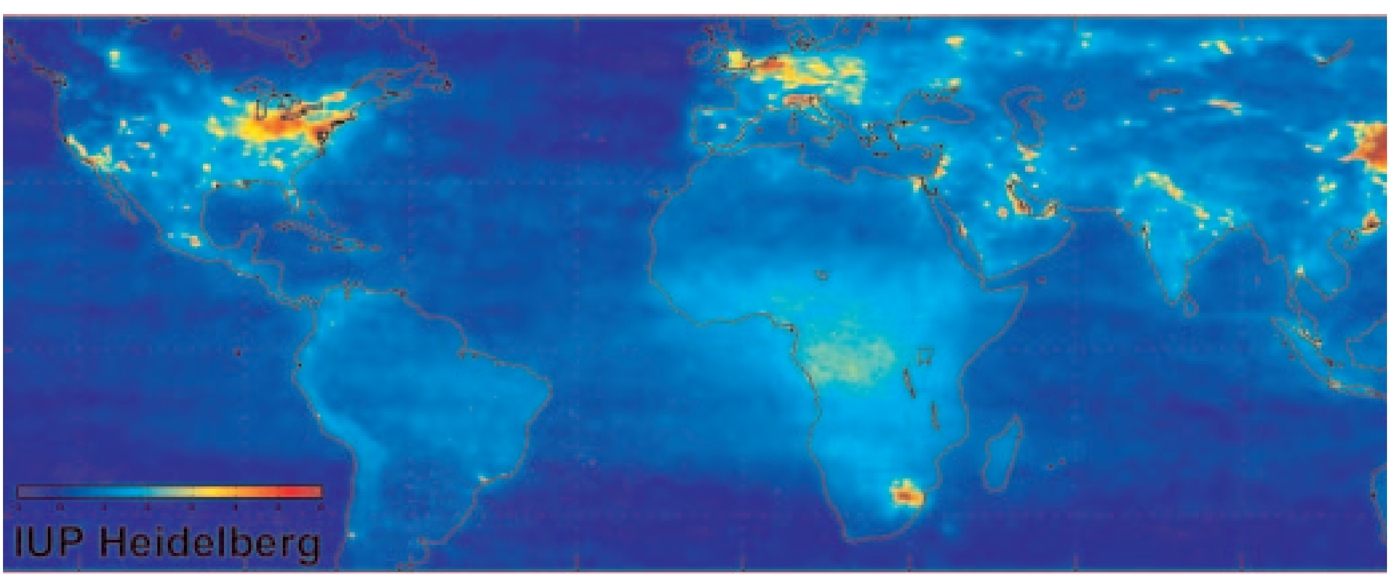
Nitrogen oxides are produced by emissions from power plants, heavy industry and road transport, along with biomass burning. Lightning in the air and microbial activity in the soil can also create nitrogen oxides naturally.

Teams from the Universities of Bremen and Heidelberg in Germany, the Belgian Institute for Space Aeronomy (BIRA-IASB) and the Royal Netherlands Meteorological Institute (KNMI) have successfully processed SCIAMACHY data to generate the sharpest maps yet made of the vertical columns of tropospheric nitrogen dioxide.

"The higher spatial resolution delivered by SCIAMACHY means we see a lot of detail in these global images," says Steffen Beirle of the University of Heidelberg's Institute for Environmental Physics. *"High vertical column distributions of nitrogen dioxide are associated with major cities. Across South East Asia and much of Africa we can see seen nitrogen dioxide produced by biomass burning. Tracks of ships that send a large amount of NO_2 into the troposphere are also visible."*

This map is averaged out across all available data, spanning 18 months. Researchers use a method called Differential Optical Absorption Spectroscopy (DOAS), a complex filtering process also used with ground-based air-sampling instruments. DOAS removes the predominant spectral 'noise' from air particles and the absorption patterns from the oxygen, nitrogen and water molecules that make up most of the atmosphere. Left behind after these subtractions is the desired 'signal' of narrower trace gas spectral absorption patterns, to be identified against sample cross sections.

"Results from this and other similar sensors could be used for chemical weather and air quality prediction in future," Beirle added. *"For now we are focused on using the SCIAMACHY results to quantify the contributions of the different sources of nitrogen oxides – such as fossil fuel combustion, biomass burning, lightning – especially as the value of the latter is still highly uncertain."*



The image shows the global mean tropospheric nitrogen dioxide (NO_2) vertical column density between January 2003 and June 2004, measured by SCIAMACHY. The scale is in 10^{15} molecules/cm^2. Image produced by S. Beirle, U. Platt and T. Wagner of the University of Heidelberg's Institute for Environmental Physics.

Dish of the day

Brett Schipp explains the control room

The group of Probus pensioners in New Norcia

These pictures of ESA's New Norcia tracking station were taken in September during a visit by a group of Probus members. Probus is an Australasia-wide organisation promoting the association of retired PROfessional and BUSiness leaders and trips such as the ESA visit are part of a busy programme of enriching experiences.

Brett Schipp gave a tour of the facility and, as maintenance work was going on, he was able to demonstrate practically how communication between the European Space Operations Centre ESOC in Darmstadt and the New Norcia station works.

Colombus Control Centre inaugurated in Oberpfaffenhofen

On 19 October, ESA and DLR officially inaugurated the Columbus Control Centre. The Centre has been set up under ESA contract in Oberpfaffenhofen at the premises of DLR, near Munich, Germany. The Columbus Control Centre is now ready to take up operations of the European elements of the International Space Station (ISS).

For the coming months ESA, DLR and industrial teams will establish operational procedures, train the flight control teams, connect to all other centres of the ISS operations network and test the communication lines.

The Columbus Control Centre will see its first real-time operations in April next year, when the Italian ESA astronaut Roberto Vittori will visit the ISS for 10 days. An ESA/DLR team will control and command the scientific programme of the European experiments on board the ISS using the Columbus Control Centre for the first time.

Later in 2005 the Control Centre will provide communications support for the launch and in-orbit operations of ESA's Automated Transfer Vehicle (ATV). In 2006 it will control the operations of ESA's Columbus laboratory once it is connected to the ISS.

The new Colombus Control Centre in Germany (photo DLR)

Space-tech goes for gold in paralympics

On the final day of the Paralympics German athlete Wojtek Czyz surpassed his wildest dreams by breaking the world record for the long jump, earning him his third gold medal. Competing with a space-tech enhanced prosthetic leg, he got the gold in all three of his events, 100 m sprint, 200 m sprint and long jump.

Having lost part of his left leg three years ago in a sports accident, he uses a prosthesis, parts of which are made from high-performance materials designed for space systems. Space expertise made it both stronger and lighter.

In March 2004 the European Space Agency's Technology Transfer and Promotion Office and its German partner MST Aerospace started working with a specialist in high-performance materials for space systems, the German company ISATEC, to strengthen parts of Czyz's prosthesis that had a tendency to break. Two versions were designed and developed in record time, both taking advantage of special materials developed for space programmes. The first, optimised for the long jump, uses carbon-fibre-reinforced plastics to strengthen the weak part in the prosthesis; the second, for running, uses ultra-light, high-strength aluminium.

For his training at the German Sports University in Cologne, ESA's Human Spaceflight Directorate let Czyz use the Percutaneous Electrical Muscle Stimulator (PEMS) II developed by the Swiss company Syderal. PEMS II, created for use on the International Space Station, prevents the side effects of microgravity on astronauts, particularly muscle atrophy and accompanying effects like bone mineralisation and cardiovascular de-conditioning. r

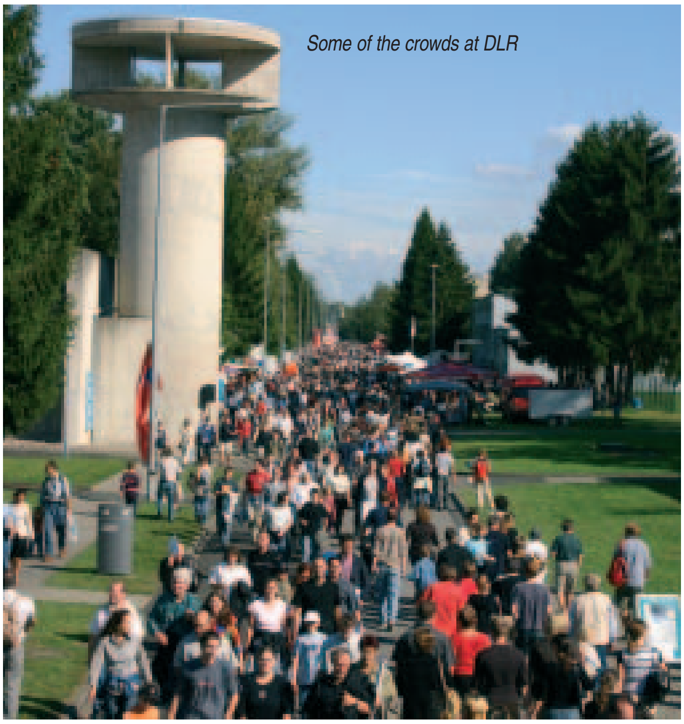
Fascination space: Visitor records at Germany's Long Night of the Stars and Space Day

"Greetings to all the people of Europe and especially tonight at the Night of the Stars at the European Space Operations Centre," boomed International Space Station crewman Mike Fincke's voice over the public address system as a listening crowd burst into applause. This live, public radio chat with orbiting astronauts was just one part of an unforgettable evening at ESA's mission control centre.

As the astronauts spoke, visitors to the European Space Operations Centre (ESOC) glimpsed their home in space, the International Space Station (ISS), which was flying at an altitude of 360 kilometres over Darmstadt, Germany, at 20:54 local time on Saturday, 18 September 2004.

The visitors had registered to attend ESOC's open house, part of the Long Night of the Stars ("Lange Nacht der Sterne") event involving 170 planetaria, observatories, astronomical organisations, museums, companies and scientific institutes in Germany, Switzerland and Austria.

The public radio discussion with the ISS astronauts, which lasted about five minutes as the station sped overhead, was just one highlight of the evening, which saw over 3000 people welcomed to ESOC.



Some of the crowds at DLR

Young rocket launchers at ESOC

Star-gazing during the Long Night of the Stars

Minister Bulmahn takes off at the German space day

An initiative of Germany's Stern magazine, the Long Night of the Stars aimed to boost public support for and understanding of space science, astronomy, and space-related research, education and industry. It was supported by the European Space Agency, Germany's Ministry of Education and Research, automaker Mercedes Benz, the German Space Agency (DLR), the European Southern Observatory (ESO) and the Association of Friends of the Stars.

Together, the Long Night of the Stars and the German Space Day, held the same weekend, attracted more than 200 000 visitors from all over Germany. Observatories, planetaria, universities and space-related institutes opened their doors. More than 100 000 people made their way to the main DLR site in Cologne to visit its gigantic wind tunnel, ESA's astronaut training centre (EAC) or the A300 Zero-G, the Airbus aircraft used for parabolic flights. Germany's Minister for Education and Research Edelgard Bulmahn even donned a blue flight suit and spent a few minutes in weightlessness during a flight aboard the A300.

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