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bulletin

SPACE FOR EUROPE

European Space Agency
Agence spatiale européenne

european space agency

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(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.

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agence spatiale européenne

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

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(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.

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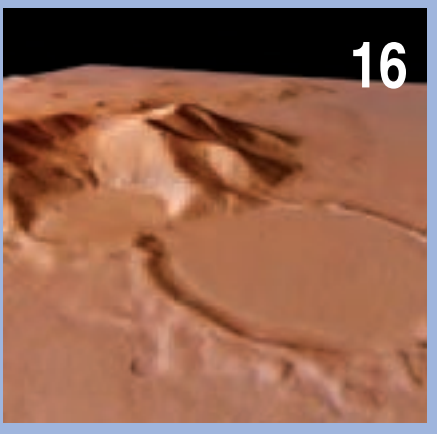
Cover: The highest resolution composite image of the entire Crab Nebula ever produced, thanks to the Hubble Space Telescope; see page 80 of this issue.
(Credit: NASA, ESA, J. Hester & A. Loll (Arizona State Univ.))

Twenty Years after Giotto
– ESA's pioneering mission to Comet Halley



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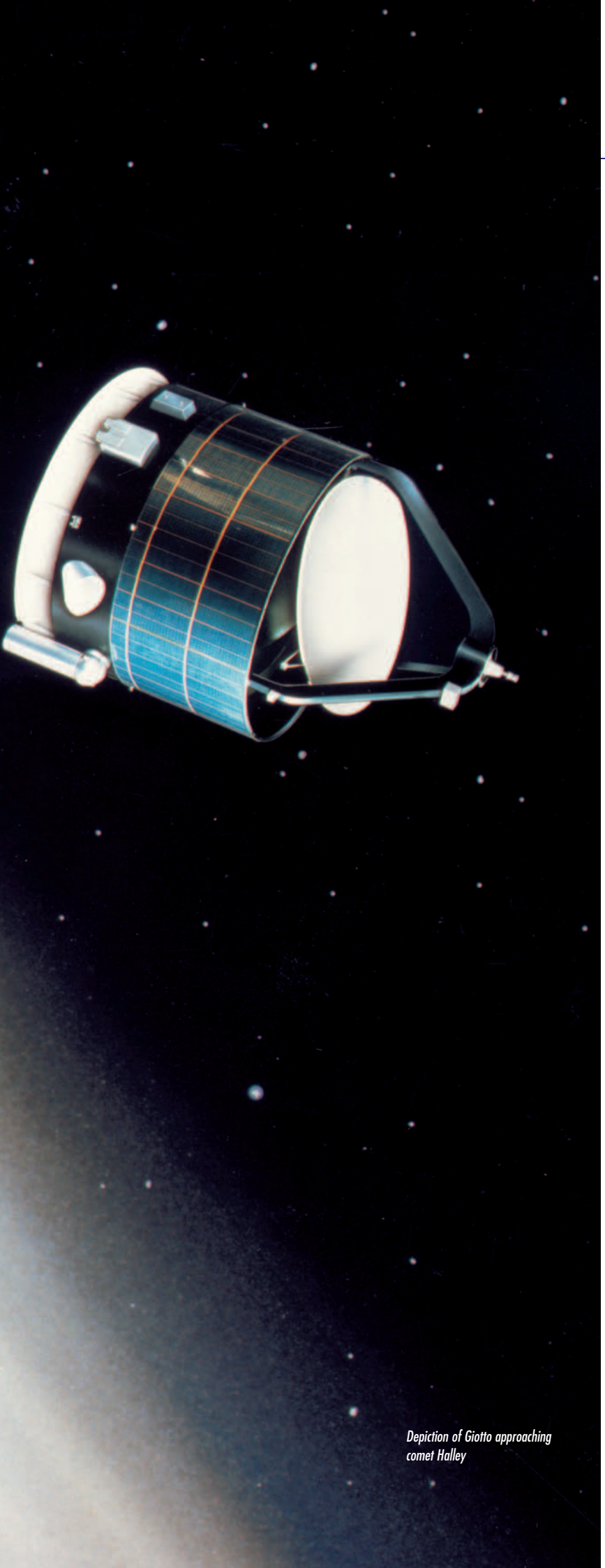


Depiction of Giotto approaching comet Halley

Almost exactly twenty years ago, on 14 March 1986, ESA's Giotto spacecraft made its historic fly-by of comet Halley at a distance of about 596 km. This close encounter represented a major milestone for planetary science in general, but also gave an important boost to the European planetary-science community that is still having an impact today. Besides its scientific importance, it was also the first big mission-related media event for ESA. The 'Night of the Comet' at ESOC in Darmstadt (D) was relayed by Eurovision, with 56 TV stations from 37 countries reporting the encounter live, attracting a television audience of more than 1.5 billion. The images sent back by Giotto's Halley Multicolour Camera radically transformed everyone's ideas about what the nucleus of a comet really looked like.

After the successful tours of NASA's Pioneer and Voyager spacecraft through our Solar System with their close fly-bys of the outer planets, an encounter with a comet was perhaps the last but one truly exploratory mission left in terms of Solar System studies. The last one, the New Horizons mission to study Pluto from close quarters, has only just been launched on 20 January this year. Interestingly enough, like Giotto, it is again exploring an 'icy body' and thereby probing the early stages of the evolution of our planetary system.

Before the Giotto mission, very little was known about the most active and most primitive members of our Solar System; for example, we could only speculate about the existence and size of the cometary nucleus, which becomes active when it approaches the Sun. Heated by insolation, the nucleus releases large amounts of gas and dust during the comet's passage through the inner Solar System. The gas streaming away from the nucleus carries with it large quantities of fine dust, which is responsible for much of the comet's visual brightness. The gas and dust form the coma and the characteristic gas and curved dust tails of the comet.

Although we had large sets of ground-based observations of comets gathered over many centuries at our disposal, our real knowledge before the Halley encounters was still very limited and only in-situ measurements, even with a simple fly-by mission, could provide answers to a number of fundamental questions, such as:

– Is there a nucleus at the centre of the comet?
– What are the size, shape, albedo, composition, surface temperature, rotation rate and rotational axis of the nucleus?
– Are there active regions on the nucleus?
– What are the parent molecules?
– Which chemical processes occur in the cometary coma?
– What are the dust and gas production rates?
– What is the dust size distribution?
– How big are the smallest dust particles?
– What is the composition of the dust particles?
– What are the abundances of the different molecules and ions making up the cometary atmosphere?

These and many other such fundamental questions drove the rationale for Giotto's in-situ exploration of comet Halley.

Still, twenty years later, one can claim that Giotto carried the most comprehensive and sophisticated payload to date with which to study a comet nucleus at close quarters. Only ESA's Rosetta mission, with its Philae Lander, will address a wider range of science when it reaches comet 67P/Churyumov-Gerasimenko in 2014, circles it and then follows it for a considerable fraction of its orbit – in another ten years from now!

Giotto Science Instruments
Halley Multicolour Camera (HMC)
CCD camera with f/7.68 Ritchey-Chretien telescope, 22 m resolution from 1000 km.13.5 kg, 11.5 W. PI: H.U. Keller, MPI für Aeronomie (D)
Neutral Mass Spectrometer (NMS)
Energy/mass of neutral atomic particles: 1-36 amu, 20-2110 eV. 12.7 kg, 11.3 W. PI: D. Krankowsky, MPI für Kernphysik (D)
Ion Mass Spectrometer (IMS)
Energy/mass of ions. 9.0 kg, 6.3 W. PI: H. Balsiger, Univ. of Bern (CH)
Dust Mass Spectrometer (PIA)
Mass (3×10^{-16}-5×10^{-10} g) and composition (1-110 amu) of dust particles. 9.9 kg, 9.1 W. PI: J. Kissel, MPI für Kernphysik (D)
Dust Impact Detector (DID)
Mass spectrum of dust particles: 10^{-17}-10^{-3} g. 2.3 kg, 1.9 W. PI: J.A.M. McDonnell, Univ of Kent (UK)
Johnstone Plasma Analyser (JPA)
Solar wind and cometary ions 10 eV-20 keV, cometary ions 100 eV-70 keV/1-40 amu. 4.7 kg, 4.4 W. PI: A. Johnstone, Mullard Space Science Laboratory (UK)
Rème Plasma Analyser (RPA)
Solar wind and cometary ions 10 eV-30 keV, cometary ions 1-200 amu. 3.2 kg, 3.4 W. PI: H. Rème, Centre d'Etude Spatiale des Rayonnements (F)
Energetic Particles Analyser (EPA)
3-D measurements of protons (15 keV-20 MeV), electrons (15-140 keV), α-particles (140 keV-12.5 MeV). 1.0 kg, 0.7 W. PI: S. McKenna-Lawlor, St Patrick's College (IRL)
Magnetometer (MAG)
0.004-65 536 nT. 1.4 kg, 0.8 W. PI: F.M. Neubauer, Institut für Geophysik und Meteorolgie (D)
Optical Probe Experiment (OPE)
Coma brightness in dust and gas bands. PI: A.C. Levasseur-Regourd, Service d'Aeronomie du CNRS (F)
Radio Science (GRE)
Cometary electron content and mass fluence. PI: P. Edenhofer, Institut für Hoch- und Höchstfrequenztechnik (D)

Giotto's scientific payload consisted of 10 experiments weighing a total of approximately 60 kg: a camera for imaging the comet nucleus, three mass-spectrometers for analysing the elemental and isotopic composition of the cometary dust and gas, various dust-impact detectors, a photo-polarimeter for measuring the coma's brightness, and a suite of plasma instruments for studying the solar-wind/comet interaction.

Why Halley?

The most active and therefore the brightest comets are the so-called 'new' ones, which are entering the inner Solar System for the first time. Ideally then, one would like to organise an encounter with one of these comets, but with present-day technology this is impossible. To be able to plan a successful mission to a comet, its orbit must be well-known, which means that the comet must have 'returned' several times. This rules out new comets and leaves only the short-periodic and a few intermediate-period comets as potential candidates for investigation.

The preference for also visiting a well-known and very active comet left very little choice, and Halley, with its 30 recorded previous apparitions, proved to be the most logical target. It is the only one of more than 1000 catalogued comets that has a well-known orbit and a high gas and dust production rate. Comet Halley is also the most famous of all the comets. Although its fame was not the main factor in its selection, the prime reason for its choice, namely its brightness and its well-known orbit, are the very reasons for its fame. It is so bright in the sky and it reappears so regularly that it has been observed during each of its 30 apparitions since 240 BC. It was this comet that led Edmond Halley to his most important discovery of the periodicity of some comets.

The Encounter

The Giotto spacecraft was launched on 2 July 1985 by an Ariane-1 vehicle from Kourou in French Guiana. The ESA ground station at Carnarvon in Australia

The Giotto spacecraft installed on its Ariane-1 launcher in Kourou, French Guiana

was used for the spacecraft's operation, and CSIRO's 64 m radio-astronomy dish at Parkes (Australia) for the high-rate transmission back to Earth of its scientific data. During the encounter itself, NASA's 64 m Deep-Space Network station in Canberra (Aus.) was in 'hot standby'.

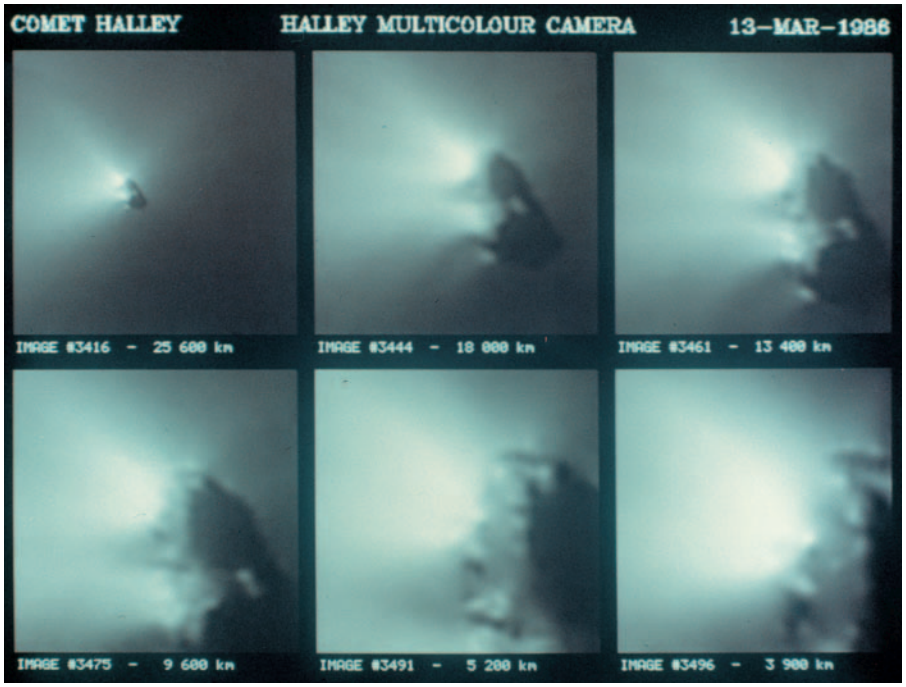
A few days before the encounter, the decision had to be taken regarding the spacecraft's closest approach distance to the nucleus. 500 ± 40 km was chosen as the best compromise between the requirements from the payload Principal Investigators for the camera, the instruments that wanted to pass as close as possible, but with a high chance of survival, and those who wanted to go as close as possible even if the spacecraft wouldn't survive the resulting dust impacts. All went well until about 14 seconds before closest approach, when a hit from a 'large', i.e. 0.1 - 0.2 gram, dust grain caused a nutation of the spacecraft. For about 32 minutes, the telecommunications link to Earth could not be maintained continuously and scientific data were received only intermittently. Thereafter, the spacecraft returned to its nominal operating mode and science data-taking was continued for another couple of days. It very soon became clear, however, that a few of the instruments had been severely damaged, namely the HMC, NMS, IMS-HERS, JPA-FIS and RPA (see table).

Nevertheless, for the Giotto spacecraft the journey wasn't over. On 2 April, it was put into a hibernation (safe) mode, and essentially powered down. Then, after nearly four years in this state of hibernation, the spacecraft was reactivated on 24 February 1990, retargeted to make an Earth fly-by on 2 July 1990 at a distance of 22 720 km (the first-ever gravity assist at Earth for a spacecraft coming from deep space) and, after a second hibernation period, reactivated again on 8 May 1992 to encounter its second comet, Grigg-Skjellerup, on 10 July 1992.

The Halley Armada

ESA wasn't the only space agency to send a spacecraft to Halley in 1986: the Soviet Vega-1 and Vega-2 spacecraft were launched on 15 and 21 December 1984, respectively; Japan's Sakigake was launched on 8 January 1985, and the second Japanese spacecraft, Suisei, was launched on 19 August 1985. Although these launch dates were spread over a period of eight months, all of the encounters with Halley occurred within a week of each other in March 1986: 6 March for Vega-1 at 8890 km from the comet, 8 March for Suisei at 151 000 km, 9 March for Vega-2 at 8030 km, and 11 March for Sakigake at 7 million km, 14 March for Giotto, and 25 March for NASA's ICE at 28 million km.

The space agencies involved had realised several years earlier that many aspects of mission planning, spacecraft and experiment design, and data evaluation were common to all missions, and that the overall scientific return could be increased through cooperation. They therefore agreed in 1981 to form the Inter-Agency Consultative Group for Space Science (IACG), which had the task of informally coordinating all matters related to their missions to comet Halley and the observations of it from space. Perhaps the most visible achievement of the IACG was the improvement of Giotto's targeting accuracy through the Pathfinder Concept. Giotto was last to make its fly-by and could use information about the position of the nucleus obtained by the cameras onboard the Vega-1 and Vega-2 spacecraft to improve its targeting accuracy. NASA supported this effort by reducing the Vega

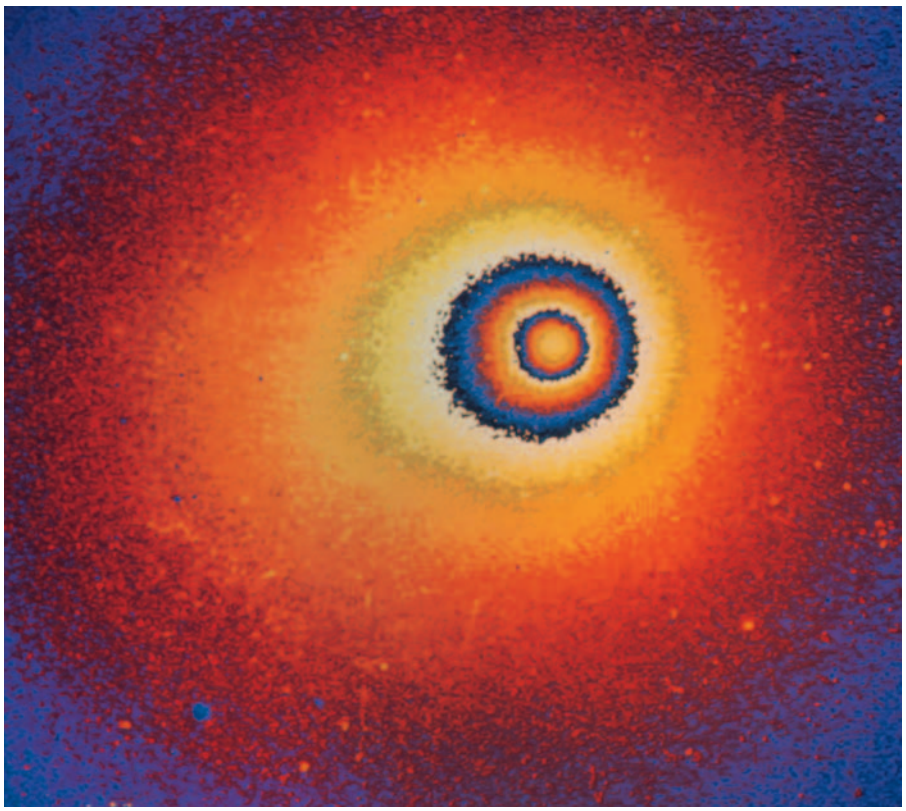


Giotto returned more than 2000 images during its fly-by of comet Halley. The six shown here range from 375 seconds (#3416) to 55 seconds (#3496) before closest approach (Courtesy of H.U. Keller, MPS)

positioning uncertainty to about 40 km using Very Long Baseline Interferometry techniques with the widely separated tracking stations of its Deep Space Network.

The other big international effort was the IHW (International Halley Watch), which complemented the in-situ observations made by the various experiments carried by the six fly-by spacecraft with remote observations from the ground and from space. It was a huge international network that brought together both professional and amateur astronomers around the World to monitor the target comet in all of its different aspects, including the development of the dust and gas coma, the plasma tail dynamics and, especially for Giotto, astrometric observations to improve the knowledge of the ephemeris. The wealth of data collected through the efforts of the IHW helped to put the spacecraft in-situ observations into the proper scientific context.

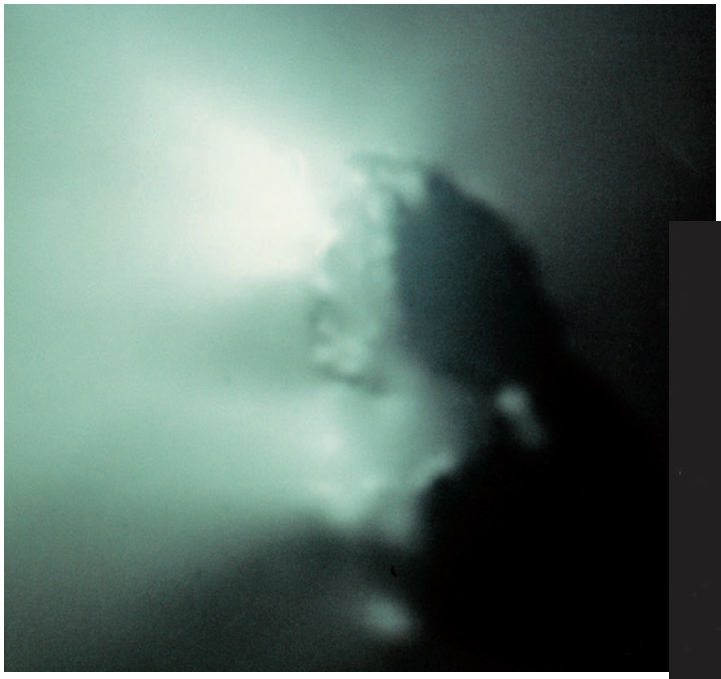
The IHW later became the role model for all future campaigns mounted to provide support for flight projects to comets. The Rosetta mission has been building up a network of ground-based observatories to monitor its target comet since the mission was first approved ten years ago, and our US colleagues have been following this example for the Deep Space 1 and Stardust missions. On 4 July 2005, ground-based telescopes around the World, the NASA/ESA Hubble Space Telescope, and ESA's Rosetta mission all monitored the impact on comet Tempel 1 of NASA's Deep Impact spacecraft.

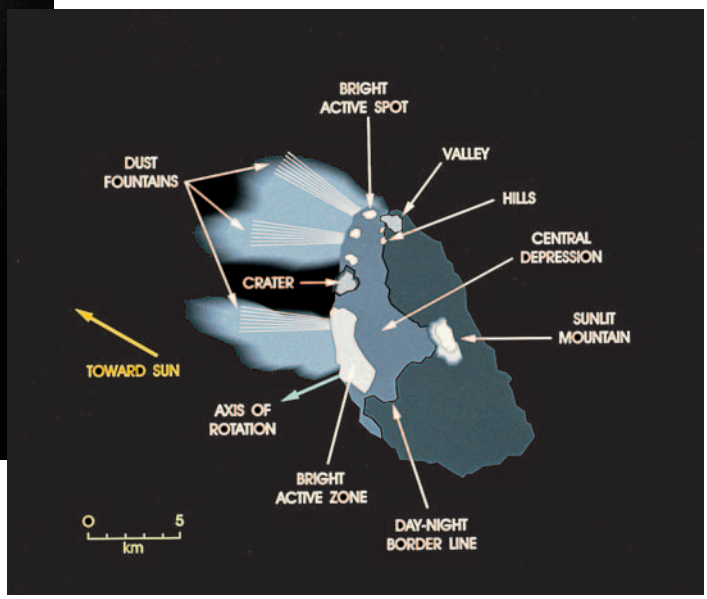


Far-ultraviolet image of comet Halley taken from a sounding rocket at an altitude of 194 miles on 13 March 1986, just 13 hours before Giotto's closest approach to the comet. It highlights in false colours the hydrogen cloud surrounding the nucleus. (Courtesy of NRL, Washington DC)

The Halley Results in a Nutshell

The first results from the encounters with Halley were published in a joint publication in *Nature*, coordinated by the IACG. The most striking results were the images from the Halley Multicolour Camera on Giotto, which revealed that the comet had a single nucleus with an elongated, potato-like shape, being about 15 km long and 9 km across, and was thereby larger than previously anticipated. The fact that we could determine the body's albedo directly for the first time led to the discovery that only 2-4% of the





Left: Composite of seven Halley imges, highlighting details on the nucleus and the dust jets emanating from the sunlit side (Courtesy of H.U. Keller, MPS)
Right: Principal features identified in Giotto's images of comet Halley

incident light was reflected, which means that comets are among the darkest objects in the Solar System. Two major bright jets emanated from the sunward side of the nucleus and it appeared – and this was one of the big surprises – that only a relatively small fraction of the nucleus was active. Combined with other observations, it was possible to establish that the nucleus had a fairly low density, at < 0.6 g/cm^3.

Giotto's Neutral and Ion Mass Spectrometer provided a wealth of data on the composition of the comet's molecular structure, including detailed information about the abundances of the various species as a function of distance from the nucleus. From the analysis of the dust spectra, we learned that most of the dust particles were rich in hydrogen, carbon, nitrogen and oxygen, with minerals and most probably organic components present, which is characteristic overall of a very complex chemistry.

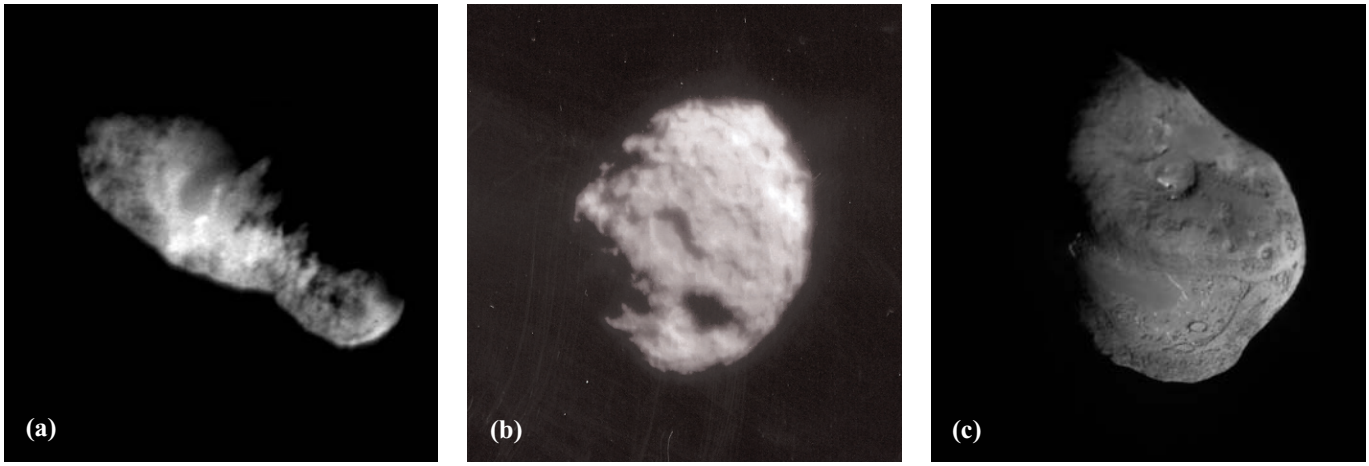
The first dust-particle impact on the Giotto spacecraft was recorded by the Dust Impact Dectection System when still 290 000 km from the comet's nucleus, which was much further away than predicted by the dust models. More than 12 000 dust-particle impacts were recorded during the fly-by, with particle masses ranging from 10^{-17} to 4 x 10^{-2} g. From these measurements, a dust production rate of approximately 3 x 10^6 g/s was derived.

The interaction between the solar wind and the comet's ionosphere can be characterised by two distinct boundaries, the bow shock and the contact surface, and several additional sharp transition regions, which indicate a multi-layered interaction region. The Giotto data are textbook examples for these interaction regions. The spacecraft crossed the bow-shock region when 1.15 million km from the nucleus, and crossed the contact surface when 4700 km away. Inside this region, the magnetic field dropped essentially to zero, as had been theoretically predicted and had been expected by analogy with Venus and the 'artificial' comet of the AMPTE mission.

The Post-Halley Era

Giotto's visit to comet Halley certainly taught us a great deal, but as always with such exploratory missions it also raised new questions, whetting the scientific community's appetite for learning even more about these fascinating primordial space objects and prompting calls for more cometary missions. A few weeks before the launch of Giotto, a number of planetary scientists had met in Zurich (CH) to prepare an input for the Agency's long-term scientific programme known as 'Horizon 2000', which contained a so-called 'Planetary Cornerstone' mission. They already wanted it to become a Comet-Nucleus Sample Return (CNSR) mission in collaboration with NASA, which would represent a logical next step after Giotto. In the mid-nineties, when it turned out that NASA would no longer participate, it became an ESA-led mission and was redefined as a cometary orbiter with a lander. This Rosetta mission was launched on 2 March 2004 and is currently on its way to comet 67P/Churyumov-Gerasimenko, which it will reach in mid-2014. *"When we can't bring back a sample to the laboratory, we have to bring the laboratory to the comet"* was the motto under which Rosetta's state-of-the-art payload has been developed.

The US colleagues who had originally

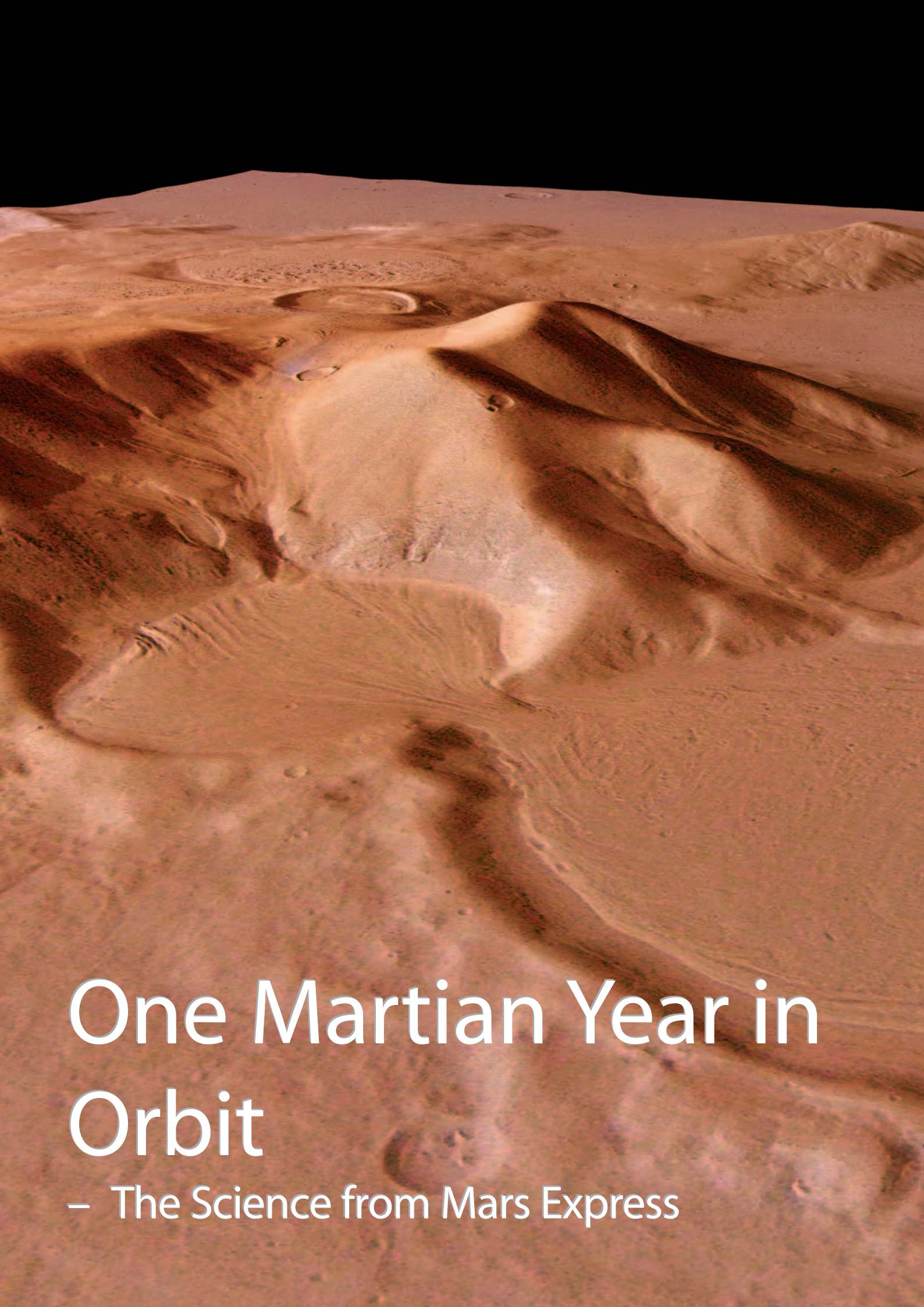


The different faces of comets: (a) Comet Borelly (resolution ± 60 metres); (b) Comet Wild 2 (composite image, resolution ±20 metres); (c) Comet Tempel 1 (composite image, scaled to 5 metre resolution) (Images courtesy of NASA)

criticised flyby missions to comets even in the exploratory phase as not providing a good scientific return were eventually won over by the tremendous success of Giotto and the wealth of data that it and the Vega1 and 2 spacecraft provided. Consequently, NASA's Deep Space 1 mission, launched on 24 October 1998 with the prime objective of the in-flight testing of new technologies, and solar electric propulsion in particular, went on during its extended mission to fly-by comet Borelly in September 2001.

Three cometary missions then followed as part of NASA's Discovery programme. Stardust, launched on 7 February 1999, passed comet Wild 2 on 2 January 2004 at 240 km and collected comet grains that were returned to Earth on 15 January 2006. It was followed by Contour, a mission to study the diversity of comets by making close fly-bys of at least two of them, in a similar manner to Giotto. Launched on 3 July 2002, that spacecraft was unfortunately lost during the main-engine burn that should have injected it into its interplanetary trajectory. The third spacecraft Deep Impact, launched on 12 January 2005, fired a projectile into comet Tempel 1 on 4 July 2005, an event that was monitored by observatories around the World.

Giotto was therefore instrumental in improving our fundamental knowledge about comets. Based on its results and the follow-on missions that it spawned, we have gradually learned more and more about these mysterious bodies over the past decades. Our ground-based observing techniques have also improved tremendously, and we have now a couple of very large telescopes at our disposal, something that we could have only dreamed of in 1986. But when we compare the images of the various comets, we realise that they all look quite different. Why, we don't really understand yet! A lot of questions have been answered, but the more we have discovered, the more we want to know in order to really understand comets, their origin, their physics and their chemistry. ESA's Rosetta will be the next spacecraft to visit a comet, in 2014, this time to make detailed, longer-term studies. Based on what we have learned so far from these 'frozen snowballs of mud and ice' that periodically crisscross the firmament, it will certainly be worth the wait! esa



One Martian Year in Orbit

– The Science from Mars Express

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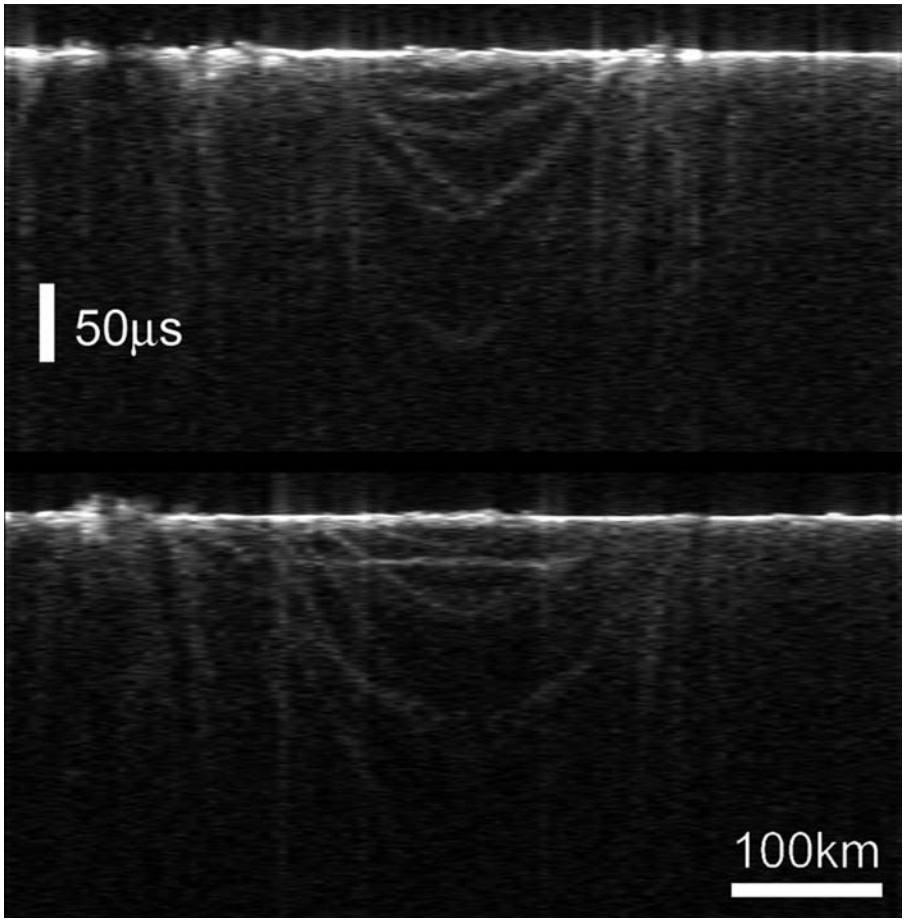
Mars Express, launched in June 2003 and in orbit around Mars since December that year, has been continuing its investigations, painting a new picture of the 'Red Planet'. This includes the first-ever probing below the surface of Mars, new geological clues with implications for the climate, newly-discovered surface and atmospheric features and, above all, the presence of abundant water ice on this world.

In November 2005 it was announced that information about the deep subsurface of Mars had, for the first time in the history of planetary exploration, been provided by the MARSIS radar. The subsurface of Mars had been so far unexplored territory.

First results revealed an almost circular structure, about 250 km in diameter, shallowly buried under the surface of the northern lowlands of the Chryse Planitia region in the mid-latitudes on Mars. Scientists have interpreted it as a buried basin of impact origin, possibly containing a thick layer of water-ice-rich material.

To date, the MARSIS team has not observed any convincing evidence for liquid water in the subsurface, but the search has only just begun. However, substantial quantities of liquid water must have been stably present in the early history of Mars, as OMEGA, the visible and infrared mapping spectrometer, is finding in many places, including abundant water ice in the polar caps.

A perspective view from Mars Express's HRSC of an unusual 'rock glacier'. Ice-rich material seems to have flowed from a small, 9 km wide crater into a larger, 16 km wide crater below. The ice may have precipitated from the atmosphere only a few million years ago (ESA/DLR/FU Berlin/G. Neukum)



Two MARSIS 'radargrams', spaced about 50 km apart, show echoes from a 250 km diameter circular structure in the subsurface of Mars, interpreted to be a buried impact basin. In the lower image, a linear reflector is seen parallel to the surface, which may come from the floor of the basin (ESA/NASA/ASI/G. Picardi)

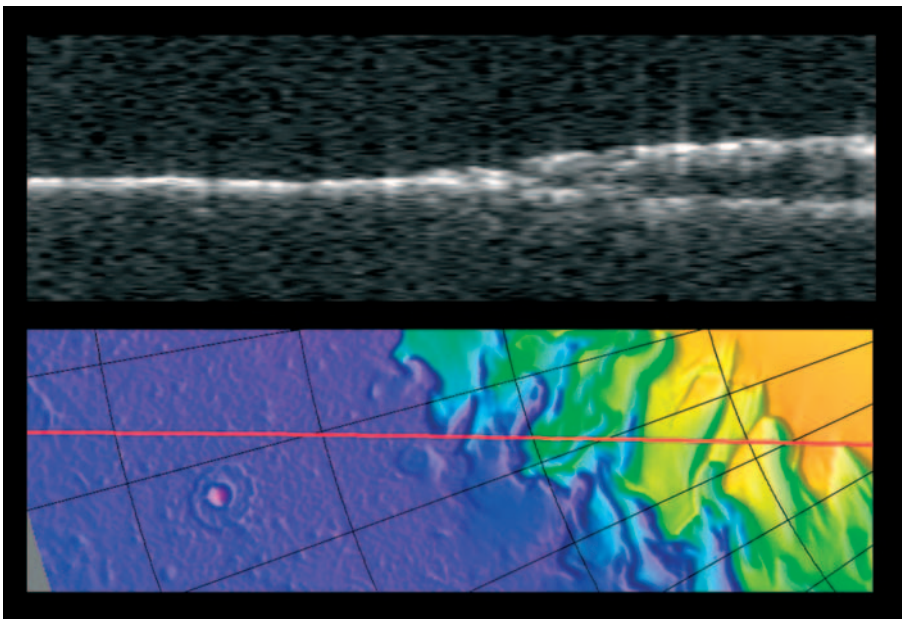
A MARSIS radargram (top) of layered deposits at the Martian north pole. The lower image shows the groundtrack on a MOLA topographic map, covering an area 458 km wide and with 2 km elevation between the lowest surface (magenta) and the highest (orange).

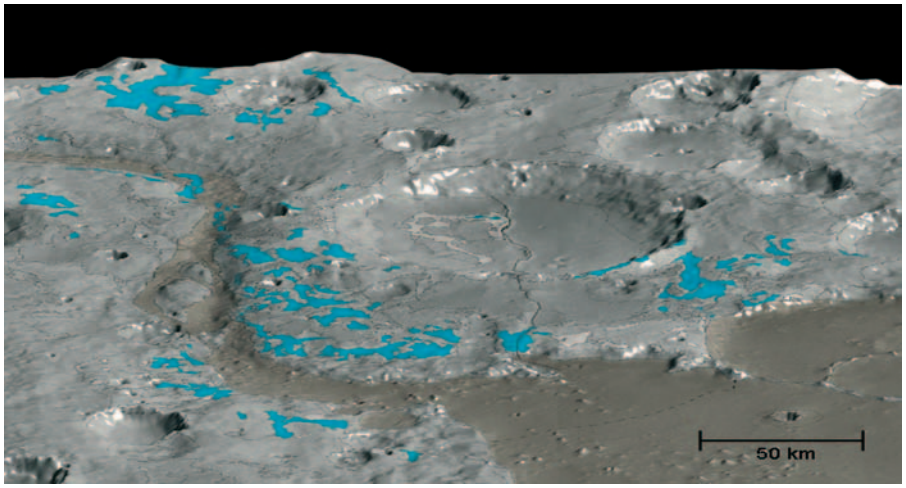
The echo splits into two where the track crosses from the smooth plains onto the elevated layered deposits. The upper trace is the echo from the surface of the deposits. The lower trace is the boundary between the lower surface of the deposits and the underlying material. The material in between is thought to be nearly pure water ice, about 1.8 km thick (ESA/NASA/ASI/G. Picardi)

Data collected by OMEGA unambiguously reveals the presence of specific surface minerals that imply the long-term presence of large amounts of liquid water on the planet. This instrument has provided unprecedented maps of water and carbon dioxide ice in the polar regions, and determined that the minerals, alteration products such as phyllosilicates, correspond to abundant water in the early history of Mars, while other minerals, called post-Noachian products (sulphates), suggest a colder drier planet with only episodic water on the surface.

MARSIS has also performed its first sounding of the Martian ionosphere – the upper part of the atmosphere – and found a number of unexpected features. MARSIS scientists have discovered a number of oblique echoes, different from the vertical echoes normally expected from the upper interface of the ionosphere.

By comparing the MARSIS data with maps of the Martian crustal magnetic fields, scientists noted that the areas of ionosphere producing these echoes correspond to areas of strong magnetic fields in the crust of the planet.





Over this HRSC perspective view of Marwth Vallis, OMEGA has mapped the water-rich minerals (blue). Ancient hydrated clay-rich minerals have been exposed by erosion, tracing an early era when water was present (ESA/OMEGA/HRSC/J.P. Bibring/G. Neukum)

Other unexpected echoes have also been recorded by MARSIS. For example, unusual reflections recorded in the night-side of Mars that would be impossible in a horizontally stratified atmosphere, may indicate the presence of low density 'holes' in the ionosphere, like those observed in the night-side of Venus.

Also in the ionosphere, the MaRS radio-science experiment has discovered a previously unseen third ionospheric layer. This layer, whose existence was predicted but not detected before, is non-continuous and sporadic. Scientists believe its origin may be due to the interaction of the ionosphere with incoming meteorites.

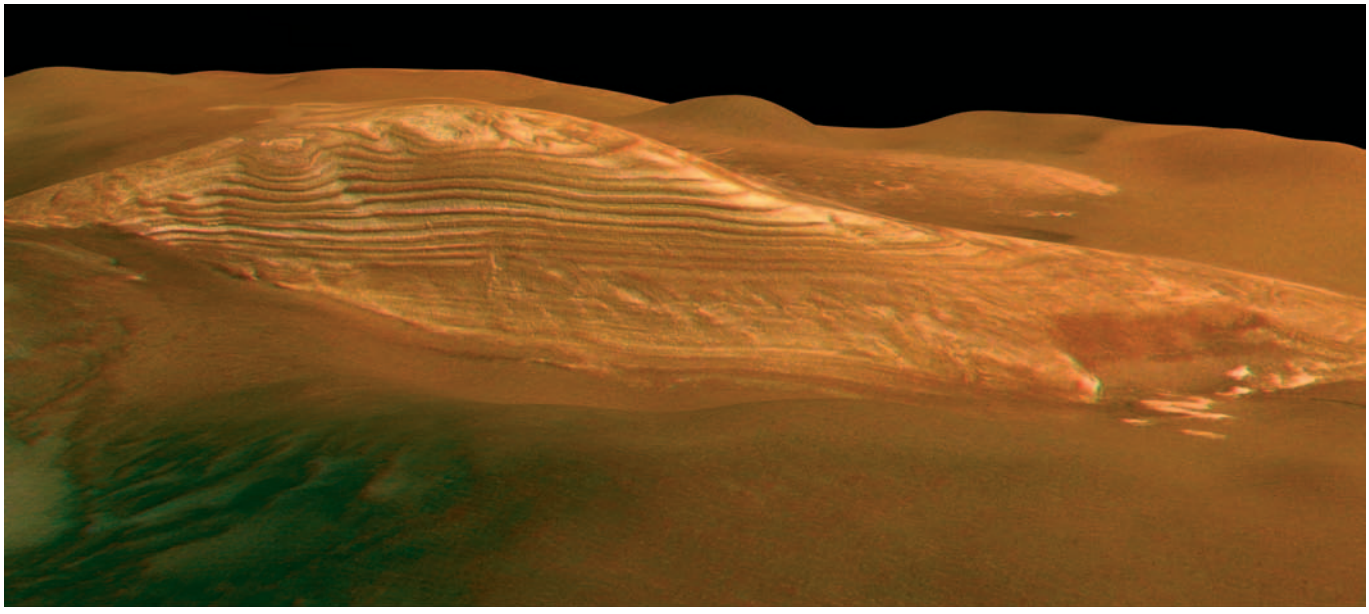
The HRSC has so far covered 25% of the Martian surface at a resolution of better than 20 metres per pixel, and over 50% at better than 50 metres per pixel, all in colour and stereo images. These spectacular images are shedding light on Martian climate history, for example, how the glacier remnants we see today were formed, and about the conditions on the planet when this happened.

SPICAM has provided the first complete vertical profile of carbon dioxide density and temperature and discovered the existence of 'nightglow' as well aurorae not just over the polar regions but also regions with paleomagnetic signatures.

The ASPERA instrument has identified solar wind scavenging of the upper atmosphere down to about 270 kilometres altitude as one of the main culprits of atmospheric degassing.

The PFS is now back in operation after a malfunction, reported a few months ago. The PFS was unable to produce scientific data from July to September 2005. A recovery was made possible by using internal instrument redundancy, and PFS started to take new measurements routinely in early November 2005.

The instrument had been successfully investigating the chemical composition of the Martian atmosphere since the beginning of 2004, when Mars Express began orbiting the Red Planet. It was the first instrument ever to make direct 'in situ' measurements of methane in the atmosphere of Mars, and provided first indications of traces of formaldehyde, both candidate ingredients for life. esa



Close-up HRSC perspective view of a 'sulphate' mountain in Juventae Chasma (ESA/DLR/FU Berlin/G. Neukum)

Biomimetics

– A new approach for space system design

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Biological systems represent millions of years of trial-and-error learning through natural selection according to the most stringent of metrics: survival. 'Biomimetics' may be defined as the practice of 'reverse engineering' ideas and concepts from nature and implementing them in a field of technology. This reverse engineering has recently attracted significant research due to an increasing realisation that many of the problems faced by engineers are similar to those already solved by nature.

ESA's Advanced Concepts Team views biomimetics as a means of finding new and realistic technologies for application in future space missions. The research is not concerned with mere imitation of biological systems, but rather focuses on understanding the fundamental processes and mechanisms used in nature, in order to discover promising concepts valuable to space engineering. Benefits are expected in areas as diverse as sensors, actuators, smart materials, locomotion, and autonomous operations.

Biomimetics

The success of biological organisms in solving problems encountered in their environments is attributed to the process of natural selection, whose primary metric is survival – failure implies extinction! Such biological solutions offer insights into alternative strategies for designing engineering systems. Biological systems represent millions of years (billions of years in the case of microbes) of trial-and-error learning through natural selection. Nature has implemented 550 million years of multi-cellular evolution, generating some 5-10 million species, of which only some 1.7 million have so far been catalogued. This represents a huge database of biologically-inspired solutions to problems. There is thus much that engineers can learn from biology and emulate in their design of engineering systems – this discipline is called 'biomimetics'.

Biomimetics involves 'reverse engineering' the principles of evolutionary design of biological organisms in order to implement biological solutions to general engineering problems. The problems encountered by biological systems are similar in many respects to those encountered in engineered systems. It seems appropriate therefore to examine biological solutions in order to analyse engineering issues. Research efforts in this direction have recently become significant in interdisciplinary-engineering topics.

Biomimetics Technology Tree

Structures and Materials	Structures	*Novel Structures* *Dynamic/adaptive Structures* *Deployment, Folding and Packing*
	Materials	*Composites* *Bio-Incorporated Composites* *Smart Materials*
Mechanisms and Processes	Mechanisms	*Muscles and Actuators* *Locomotion*
	Processes	*Novel Processes* *Thermal Management* *Fabrication* *Power Generation and Storage*
Behaviour and Control	Behaviour	*Classical Artificial Intelligence* *Behavioural Artificial Intelligence* *Learning Mechanisms* *Swarm Intelligence (DAI)*
	Control	*Reflexive Control* *Rhythmic Control*
Sensors and Communication	Sensors	*Vision* *Hearing* *Touch* *Taste and Smell*
	Communication	*Passive Group Communication*
Generational Biomimicry	Generational	*Ecological Mechanisms* *Genetic Mechanisms* *Cultural Mechanisms* *Geneering/Human Alteration*

Biomimetics Applied to Space Engineering

A spacecraft is designed to cope with a hostile and highly variable physical environment. Although it may not seem totally appropriate to examine biological organisms that have evolved in the terrestrial environment in order to seek novel solutions to problems encountered in space engineering, we seek not to replicate biological organisms *in toto*, but rather to abstract the biological principles by which organisms function and survive. The appropriate level of abstraction of such bio-inspiration is not a trivial issue. A successful example of already developed bio-inspired engineered solutions is represented by artificial neural networks used for control systems, which are highly simplified and re-structured abstractions of biological neural architectures.

Satisfying solutions

Engineers often seek optimal solutions in spacecraft and payload design. The process, which is generally very costly/time consuming, could benefit if 'satisfying solutions' are already known. Satisfying solutions represent the approach in biology whereby the historical constraints of available genetic resources lead to the evolution of organisms compliant with the prevailing environment.

Robustness and adaptability

Robustness and adaptability are particularly critical issues in space, as the environments to be explored are typically unknown and vary with unpredictable dynamics. The most sophisticated engineered systems are often lacking in robustness and adaptability, while simple natural organisms excel in terms of adaptability to their environment, actuation flexibility and sensory robustness. Ideas inspired by nature could therefore represent valuable solutions with regard to these issues.

Autonomy

Another critical issue for space systems is that of autonomy – the distances involved, particularly once spacecraft venture beyond Earth orbit, preclude real-time control, thus necessitating high degrees of onboard autonomy. Although autonomy is typically associated with exploration spacecraft, the issue of autonomy is also relevant to Earth-orbiting platforms, as ground-station-based control is the dominant factor in operational costs.

Biological organisms evolve, adapt and learn in highly variable environments whilst maintaining their functionality. They exhibit autonomy *par excellence*, and could therefore inspire new solutions for highly autonomous engineered systems.

Miniaturisation

Volume, mass and power are important and often critical parameters for spacecraft and their payloads. Their reduction implies several benefits, including significant cost savings.

Biomimetics applied to space engineering promises the prospect of greater miniaturisation, integration and packaging efficiency, which biological systems exhibit. This has natural synergies with micro-systems technology, which integrates electronics, mechanics and optics on a highly reduced scale to achieve high performance and high complexity within a very small volume (e.g. a few mm^3). An important consideration for such miniaturised systems is that their surface-area/volume ratio increases, and this has two important consequences: their power dissipation increases, requiring greater power volume density, and their structural strength increases, allowing greater loadings.

System design

A characteristic of natural systems is their holistic design. A more systematic adoption of biomimetics in space systems design could involve a new approach that treats a functional unit in a concurrent and multidisciplinary way. The payload of the spacecraft is thereby not treated separately, but as an integrated, indeed primary output of the space mission – its behaviour. The environment also acts as a feedback mechanism to the spacecraft. This provides the basis for the modular and hierarchical division of the spacecraft.

Implementing Concepts from Nature in Technological Fields

Reverse engineering of ideas and concepts from nature and implementing them in a particular technological field is not a straightforward process. There are a number of major differences between engineered products and biological systems when designing a bio-inspired system:*

1. Most organisms are characterised by cylindrical shapes and curved surfaces, while engineered structures generally have straight edges and sharp corners.
2. Engineered products are generally constructed from homogeneous materials, while biological materials are composites to a variety of degrees.
3. Engineered structures are designed for stiffness (and so tend to be brittle), while organisms favour strength over stiffness for toughness.
4. Biological features often have multi-functional roles.

When reverse-engineering concepts from nature and adopting biomimetic solutions, the following general caveats are proposed in order to obtain applicable engineering solutions:**

(i) Biomimetics may be a good starting point.
(ii) Pure biomimetic approaches can yield non-optimal performance solutions.
(iii) Sometimes optimal solutions result from traditional technology.
(iv) Biology relies heavily on good integration through the use of multifunctional structures.

A wide number of engineering disciplines could be analysed taking into account existing solutions adopted by nature, some of which are shown in the 'Biomimetics Technology Tree' on the facing page. Although this tree could be greatly

* From P. Husbands et al. (1998), *Connection Science*, pp. 185-210.

** From R. Michelson & M. Navqi (2003), Von Karman Institute for Fluid Dynamics Lecture Series.

expanded and extended, it can be used as a starting point for future studies and analyses.

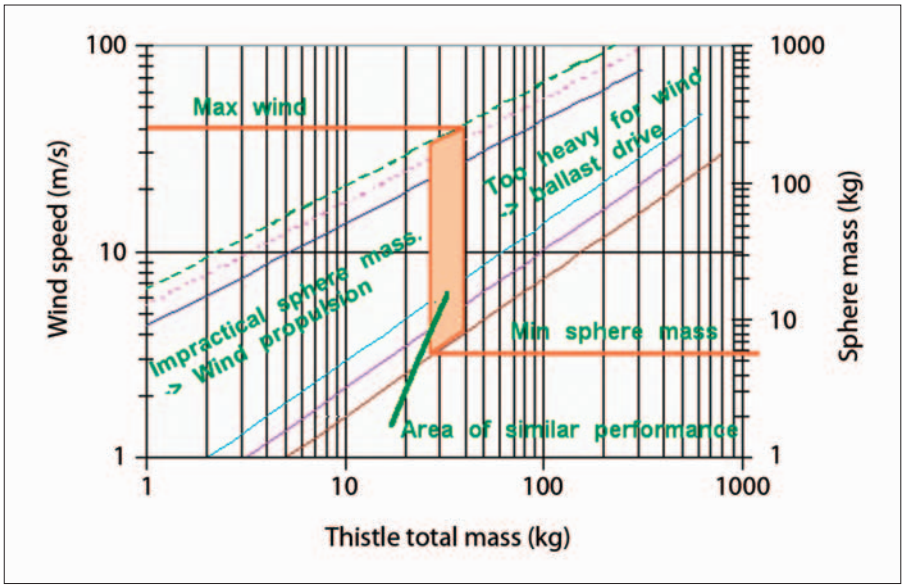
Research on Biomimetics

Considering the advantages of reverse-engineering concepts from nature and taking into account the major differences between engineered products and biological systems, ESA's Advanced Concepts Team has already analysed some bio-inspired systems for space applications.

Biologically inspired solutions for mobility

Mobility is one of the most interesting fields for bio-inspired space solutions. In nature, there exist several types of systems used for mobility in the air, on the ground, and in liquids. Dandelion seeds, maple seeds (see lead photo) and hoppers are just a few examples that have been considered for bio-inspired space system design.

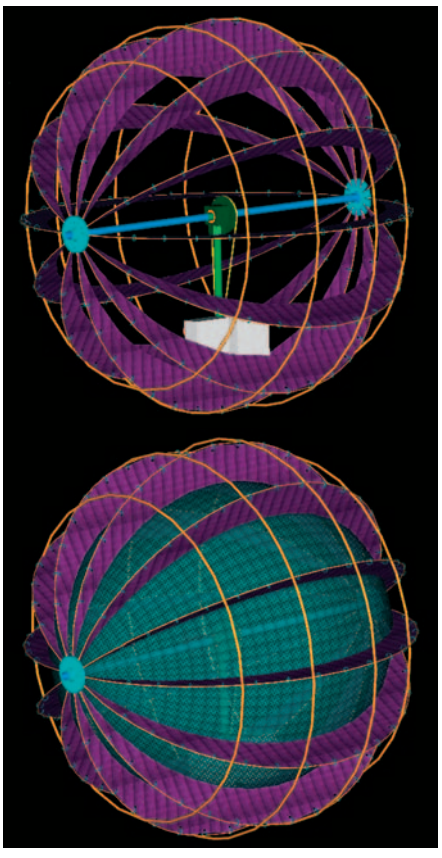
One design concept based on the Russian thistle was produced by the Helsinki University of Technology in collaboration with ESA's Advanced Concepts Team. While rolling in the wind, this thistle disperses its seeds (typically 250 000 per plant) over a wide area. Both passive wind propulsion and ballast-drive mechanisms were compared and interesting results were obtained, as shown in the accompanying figure.



Overlap in terms of similar performances for wind-propulsion and ballast-drive mechanisms

Maple seeds

Russian thistle caught on a barbed-wire fence. Image courtesy of DesertUSA.Com



A bio-inspired thistle-based design concept

Considering the Mars surface environment as one potential application, particular attention was paid to ways in which natural energy sources could be harnessed (solar, wind, thermal, gravitational potential energy, etc.). In the bio-inspired thistle-based design concept shown here, the system, which has turbine blades and an external skeleton, may have an open (top figure) or a pressurised closed section (bottom figure). An optimal wind-turbine configuration would increase the efficiency of the system and perhaps include a ballast-drive mechanism for steering, overcoming obstacles, and actively moving the system to locations of scientific interest.

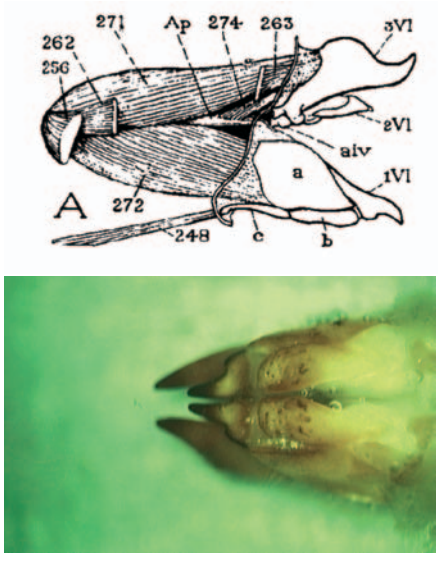
Digging mechanisms

Natural digging mechanisms used by insects have also been investigated to identify techniques that space engineers could replicate to produce better surface diggers. Among the wide variety of such mechanisms in nature, two specific 'biological drills' have been studied in more detail.

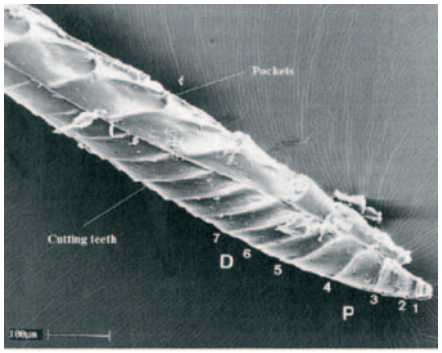
The first are the ovipositor 'valves' of the female locust (analysed together with D'Appolonia, Italy, and the University of Bath, UK). Snodgrass presented his

studies of the morphology of ovipositor valves in 1935. The upper sketch in the accompanying figure represents the digging mechanism of a typical grasshopper, while the lower image is a photograph of an ovipositor. The ovipositor valves open and close cyclically while the system moves up and down using different sets of muscles. The upper valve is used for excavation, whereas the lower one pulls the locust's abdomen down the hole. When the two valves are in their closed position, they are inclined by about 20 degrees with respect to the direction of the apodeme. This natural mechanism has been used as the basis for a digging mechanism design that was dynamically simulated as a concept for a miniaturised space drill.

The second digging mechanism was inspired by Sirex Noctilio, a type of wood wasp (analysed together with the Universities of Surrey and Bath, and EADS Astrium Ltd., UK), which uses a reciprocating motion to drill holes in trees into which it deposits its eggs. With this mechanism, it is able to drill at a rate of about 1-1.5 mm/min. The two valves, which slide longitudinally against each other, have backward-pointing teeth that allow the driller to move forward into the hole. In contrast to a conventional rotating



Above: morphology of the ovipositor valves and muscles of typical grasshoppers (from Snodgrass (1935), Smithsonian Institution). Below: photograph of an ovipositor



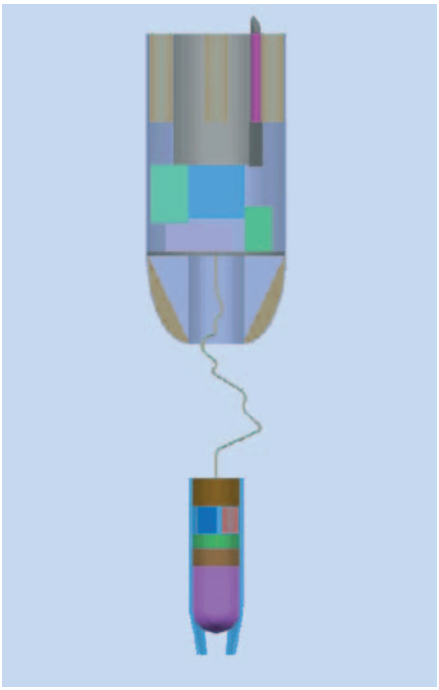
Sirex ovipositor digging mechanism (From J.F.V. Vincent & M.J. King (1995), Biomimetics, pp. 187-201; reproduced with the kind permission of Springer Science and Business Media)

drill, this system requires no external reaction force during drilling as the linear reaction forces required are generated within the pair of valves. A conceptual design for such a bio-inspired digger has been constructed to evaluate its feasibility for space applications. In particular an asteroid subsurface-sampling mission profile was considered, but the solution inspired by the Sirex Noctilio can potentially be employed in a wide variety of mission scenarios. Based on the asteroid micro-penetrator shown in the accompanying figure, the study confirmed the feasibility of applying the wasp-inspired concept to design a digging mechanism.

While both of these systems show promise in terms of being novel digging designs, their potential benefits are still to be fully assessed through further investigations.

Artificial muscles

The development of electrically deforming materials, in particular Electro-Active Polymers (EAPs), has led to improvements in the performance of actuators designed to serve as 'artificial muscles'. Compared with conventional systems, these bio-inspired actuators are of interest for use in space systems because of their inherent compactness, lightness and ability to perform large displacements when an electric field is applied. In addition, these materials, when combined with unconventional biomimetic designs, could provide compelling solutions for complex problem areas.



Schematic of an asteroid micro-penetrator

Joint research work has been carried out by ESA's Advanced Concepts Team and other European research centres (Inter-departmental Research Centre 'E. Piaggio', University of Rome, Kayser Italia, and University of Reading, UK) to assess the potential of EAPs for space systems. A thorough investigation of the physical and chemical properties of the different classes of EAP showed that sensor/actuators based on dielectric effects are of particular interest for space applications. Dielectric EAPs can exert large forces and produce considerable displacements, making it possible to design high-performance actuators. A prototype linear electromechanical actuator made of a dielectric EAP developed by the 'E. Piaggio' Centre is shown in the accompanying figure.

Development of EAPs in fibre form is currently at an early stage, but is of particular interest because of the extra flexibility that they could bring to actuator design. Promising work is also being carried out on the use of dielectric EAPs in elastic energy-storage devices (e.g. as elastic springs). This combination could increase the maximum power delivery of these devices, allowing higher-velocity

displacements. The performances of the EAPs themselves may also be improved through the use of anisotropic dielectric polymer-fibre systems, allowing greater strains for a given input.

Compared to the other classes of EAPs, however, dielectric electro-active polymers require high voltages, with the associated risk of electrical breakdown. This will have to be carefully considered for practical implementations, and especially in space applications where spacecraft safety is of primary importance.

Energy-storage structures

Although plants are not renowned for their mobility, some species are capable of rapid movements, especially when such essential functions as defence, nutrition and seed dispersal are involved. The leaf of the Venus flytrap plant is particularly interesting due to its ability to close up in a fraction of second. In the initial phase, whilst the leaf is still convex, its movement is quite slow. In a second phase, the leaf changes its curvature to become concave and performs about 60% of the displacement needed for closure in roughly 0.1 seconds. In the final closing phase, the leaf again moves slowly.

The behaviour of the Venus flytrap during its opening phase suggests that the system undergoes a redistribution of stresses, probably caused by changes in cell-wall stiffness and modifications to the turgor pressure. The leaf's motion during the opening phase also suggests that its elastic instability boundary is not crossed. Once the leaf opens again, it returns to the initial pre-strained state, accumulating the necessary elastic strain energy for another cycle.

Prototype of a linear Electro-Active Polymer (EAP) actuator

The Venus flytrap's behaviour has been analysed in the context of new space mechanisms and structures (with D'Appolonia, Italy and University of Bath, UK). A proposed engineering solution involves the use of shape-memory-alloy, hybridised fibre-thermoplastic laminates to obtain bi-stable tubular extendable systems. The structural, modal and stability analyses performed suggest that they could be used, for example, in jointless deployable mechanisms.

Hibernation and a possible human hypo-metabolic state

Human hibernation is one of the fascinating concepts that could enable astronauts to reach the farthest planets and moons of the Solar System and beyond, by reducing their life-support-system requirements during long-duration space flights. Given the compelling nature of this concept, ESA's Advanced Concepts Team has studied the technical feasibility of, and possible performance gains from this technology, with the help of biomedical scientists. There are many mammals, of at least six mammalian orders, which exhibit torpor. This torpor, which can be seasonal or non-seasonal, is characterised by a drastic reduction in body temperature. Also, when an animal is entering torpor, its heart and respiratory rates decrease, accompanied by a reduction in oxygen consumption. Physiological functions are kept to a minimum during torpor and the body is maintained at near-ambient temperature.

Several mechanisms could induce such a hypo-metabolic state in humans. The first involves a lowering of body temperature that could be achieved by changing its 'set-point' or lowering it directly, for example by inhibiting the shivering mechanism. Other mechanisms might effect a variation in the human metabolism or the modulation of cell-nucleus activity. One example of the latter involves the use of DADLE, an opiate derivative, which inhibits the activity of living cells. When injected into a rodent, the animal is considerably less active and its body temperature drops notably. Hydrogen sulphide has also been tested on house mice (non-hibernating species), inducing a harmless and reversible suspended-animation-like state. These successful experimental results suggest the possibility of medical applications. Regulation of gene expression is another mechanism that could potentially provide a means of inducing human hibernation, as evidenced by the ability of some seasonal animal hibernators to enter torpor in the absence of any environmental changes.

The induction of a hypo-metabolic state in humans would require the careful monitoring of such parameters as blood pressure, body temperature, respiratory rate and tremor, as well as electro-cardiograms, electro-encephalograms and electro-myograms. Special equipment would also be needed to induce, maintain, monitor and arouse the subject from a hypo-metabolic state. Nevertheless, the 'technology' remains potentially interesting for long-duration human space flight due to the possibility of significantly reducing the overall mass of the life-support systems needed.

While the studies that have been carried out so far show that we are far from being able to induce hypo-metabolic states in humans, and that even the processes involved are not well-understood, the relevant subject areas will continue to be monitored to constantly review the approach's feasibility in the light of scientific developments.

Future work and studies

To facilitate the transfer of biomimetic ideas from nature to space technology, a special database (www.bionics2space.org) is under construction. The aim is to link researchers in the biological and space-related fields by providing a resource that makes it easier for them to find and communicate bio-inspired solutions.

Current research is focusing on mechanical joints inspired by nature. New biomimetic designs have been produced that promise performance gains due to space and mass savings compared with conventional systems.

Behaviour and control is another area that can benefit from biomimetic studies

(see table). Some bio-inspired algorithms have in fact already been developed by looking at natural mechanisms and processes. These studies, which are currently being carried out within the Advanced Concepts Team, will be further pursued in the near future with the help of experts in the field.

As biological micro-sensors and actuators (biologically sensitive mechano-receptors, campaniform sensilla, cilia, etc.) have the potential to be small, light and embedded in an ordinary structure, just as they are embedded in the bodies of insects, they will also be the subject of future research. This research could eventually lead to the design of new bio-inspired force sensors, strain sensors and distributed actuators for particle or fluid motion.

Conclusions

There are numerous instances of technology and mission requirements across most technical and service domains that could benefit from the application of biomimetics. They range in the technology domain from the potential application of bio-inspired artificial intelligence to onboard data-management systems, formation-flying control, deep-space navigation, rendezvous and docking. Biomimetic proprioceptors, biosensors and technologies such as electro-active polymers could also be considered for autonomous orbital systems, in support of life-sciences research. Biomimetics also has potential applications across several service domains, ranging from the use of biomimetic automation and data-fusion algorithms in Earth-observation systems, to biomimetic-based environmental control and life-support subsystems. As reported here, the first short studies aimed at assessing new bio-inspired concepts for European space systems have already been performed through joint collaborations between ESA's Advanced Concepts Team and European research centres. This fascinating domain of interdisciplinary research is already producing innovative ideas and conceptual solutions for the long-term development of space systems and subsystems.

Acknowledgements

The authors would like to thank their colleagues in the Advanced Concepts Team, and in particular Nicholas Lan, Cristina de Negueruela, Leopold Summerer and Andrés Gálvez, for their valuable suggestions and inputs.

For more information about the work of the Advanced Concepts Team, visit:

www.esa.int/act

Earth Observation Market Development

Benefits to Industry

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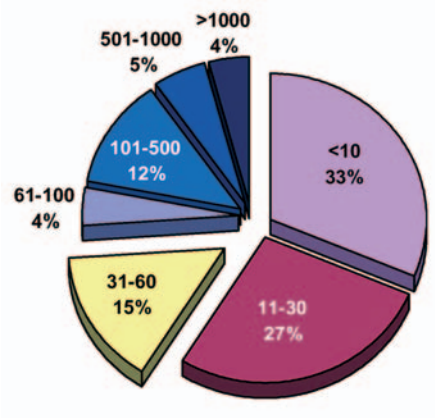
Established in 2000, ESA's Earth Observation Market Development (EOMD) activity is designed to foster the use of Earth Observation (EO) based geo-information services within various market sectors. Working in close cooperation with European and Canadian EO service companies, EOMD supports these firms in growing business by attracting new clients and encouraging the building of partnerships. The activities over the past five years have resulted in a better understanding of the EO service industry, as well as the involvement of over 120 new users and the generation of additional business revenues of some 6 million Euro. In addition to exploring new innovative prospects for EO services, future activities will address several identified challenges facing the industry as a whole.

Introduction

The potential value of EO products and services has long been well-recognised. However, despite significant progress in the techniques over the years, many actual and potential users find that these products and services still fall short of expectations, or present limitations in terms of their effective use. As a result, the market for such products and services has remained small when compared with the cost of developing space assets. Furthermore, a large portion of the demand is coming from the public sector, and some segments of the market are also faced with strong competition from terrestrial technology.



Size of EO Value-Adding Companies in terms of staff numbers

In contrast to the United States, where government military contracts (e.g. ClearView, NextView) are guaranteeing substantial revenues to private EO companies, European and Canadian EO companies do not have any such 'anchor-tenant' customers, and are therefore fully exposed to the risks involved in developing their businesses. Although the potential of the commercial market is still considered to be large, it has also become clear that the optimistic forecasts of the early 1990s regarding growth in the commercial exploitation of EO missions have not been realised. Nowadays, it is well recognised that the market is a difficult one to exploit without appropriate accompanying measures being taken.

It was in this context that the Earth Observation Market Development (EOMD) initiative was launched in 2000 as an activity within the ESA Earth Observation Envelope Programme. EOMD provides the first opportunity for specific programmatic support within ESA for activities related to the market-development and commercialisation phase in the overall evolution of satellite-based products and services. The main objective is to foster the emergence of a European downstream industry offering EO-based services, with the prospect of their becoming sustainable in the global marketplace.

To this end, EOMD has been focusing its support on small and medium-sized Value-Adding Companies (VACs) that are specialised in working with raw satellite data to turn it into the types of information services that bring major benefit to customers. The basic approach has been to engage larger non-EO companies from a range of industrial sectors (e.g. oil & gas, civil engineering, renewable energy, mining, reinsurance) to evaluate whether the types of EO services provided are of practical value in the context of their business and/or operational needs.

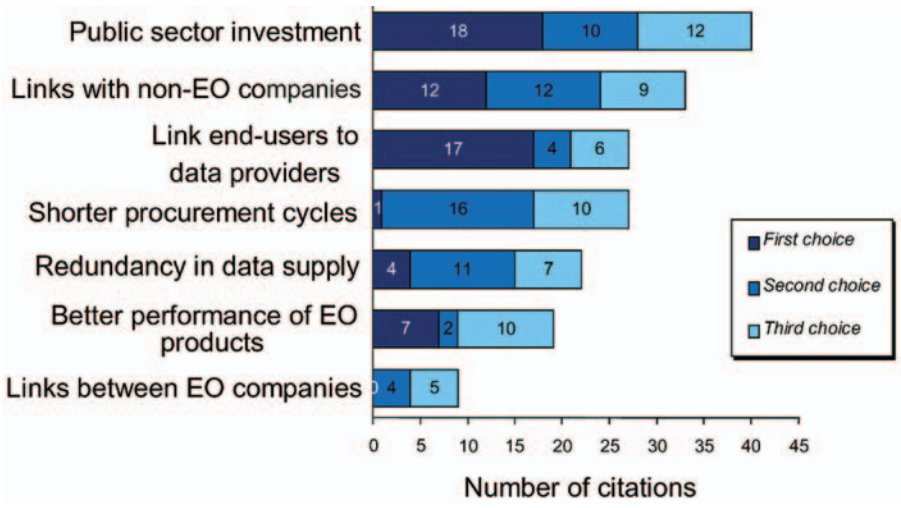
The Industry Sector

The EO service industry in Europe and Canada has typically been described as fragmented and consisting of diverse players, including many privately owned VACs, small units within the few main aerospace companies, and some larger government-financed agencies. In order to better characterise the EO services available today, as well as to better understand the working practices and financial health of the industry as a whole, a detailed industry survey was conducted for ESA by Vega Group plc and Booz Allen Hamilton in 2003/4.

This survey, which was the first extensive bottom-up study of the VAC industry, identified more than 160 companies showing evidence of EO value-adding, 45% of which subsequently participated in the study. Geographically, they are present in the majority of ESA Member States, but their main centres of operation are in Germany and France. Forty-two of them reported their actual revenues, totalling 139 million Euro. From this figure, the total annual revenue across the industry was estimated to be about 285 million Euro in 2002, which compares well with previous top-down estimates. With an estimated 2900 employees involved, the EO-specific revenue per employee is about 107 000 Euro. This figure is in the lower range for technical, labour-intensive industries (i.e. engineering services and IT are typically in the 100 000-150 000 Euro range), and below the typical returns for capital-intensive industries (e.g. fixed telecommunications and pharmaceuticals with revenues of up to 200 000 Euro per employee). As shown in the accompanying figure, the majority of companies are small, with 60% of them employing fewer than 30 people.

The products and services cover both Land (cartography, geohazards/land motion, land use/cover, natural-resource monitoring, multi-thematic services) and Ocean (met-ocean, marine surveillance, coastal charting and monitoring, multi-thematic services). Most of the products use data from more than one satellite sensor (2.7 satellite sensors per product, on average), include data from either ground- or aircraft-based sensors, and often apply further assimilation and modelling in their product generation.

Looking at the factors that influence product prices, they are mainly driven by the costs of labour and data in the production process. This is consistent with



Priority improvement goals of Value-Adding Companies

the fact that data and highly skilled staff are the main elements in the value-adding process. It was also noted that prices are under pressure from buyers, implying that the VACs have difficulty in demonstrating the value of their proposition and instead are challenged to reduce prices. The dominant customers are governments and other public bodies, which account for 78% of the products marketed. 53% of sales are national, 32% are within Europe, and only 15% are outside Europe, showing that the EO companies generally maintain a high reliance on local/national markets.

The industry's performance and practices show a high degree of competition. 75% of EO products entering the market must compete either partially or fully with non-EO products that may have been established for many years and have achieved widespread customer acceptance. Another factor constraining the industry's performance and growth is the general difficulty of meeting delivery promises. According to the VACs, these delivery problems are mainly caused by external influences, such as data-supply problems. Furthermore, the majority of the companies are very small and do not have the critical mass to absorb fluctuations in demand or to overcome unforeseen difficulties.

Several challenges have been identified which have to be addressed in order to secure the future of the EO service industry. Possible solutions are increased collaboration between VACs, to strengthen individual EO offerings, as well as more partnerships with non-EO service providers, to deliver more complete solutions. Also, customer confidence could be increased by establishing standards and methods to certify EO services, only 12% of which currently carry any form of certification. In addition, the industry needs a stronger and more coherent marketing and lobbying voice. The accompanying figure shows the major improvement goals for the industry reported by the VACs in the survey.

The Services on Offer

As noted earlier, the basic approach has been to 'plug in' EO-based information into conventional information services to improve or enhance what is already on offer. This has been done by building partnerships between VACs and larger companies currently selling information services to the market (the 'downstream' services sector). In the end, customers need to be convinced of the added benefits that EO can bring, and this means working closely with them to set up and run service trials tailored to their specific needs.

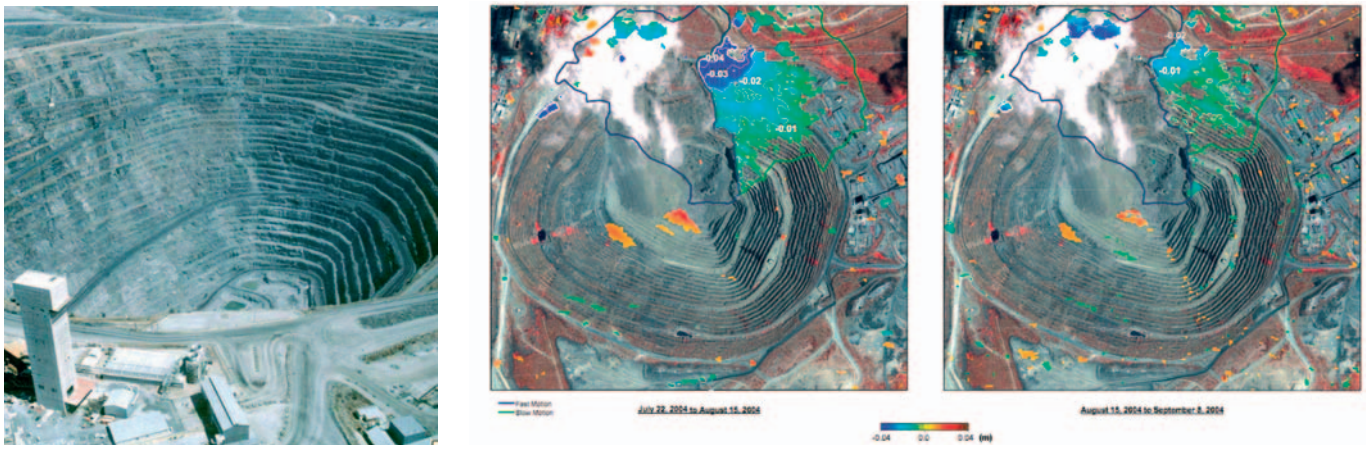
Over the last 5 years, a total of 75 service trials have been conducted, involving more than 60 VACs and 130 end-users and focusing on 20 service portfolios. For these trials, a variety of EO-based information services have been developed, including monitoring of the ocean, atmosphere, land conditions and motion. These services have been evaluated within the business operations of large companies (e.g. Shell, BP, Suez) spanning various industrial sectors, including oil & gas, renewable energy, geotechnical engineering, mining and tourism.

Three examples of EO-based information services developed within EOMD to assist mining activities, oil extraction and solar-energy-plant planning are presented in detail in the following paragraphs.

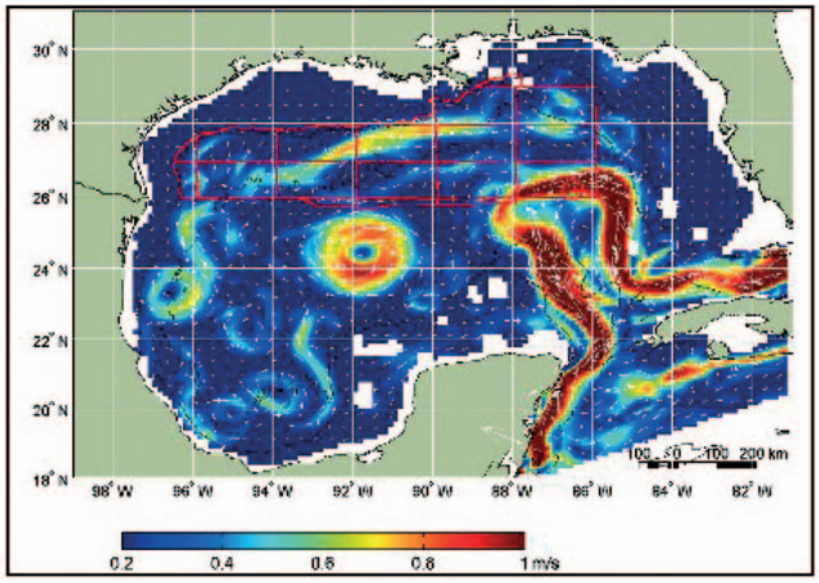
Monitoring land motion to support mining activities

Mining activities can lead to severe surface-subsidence problems. One such example is the Palabora copper mine near Pretoria, the largest 'man-made hole' in Africa, operated by the Rio Tinto company. It uses uses a highly-efficient mining method called 'block caving', which is based on extracting thin blocks of rock to induce large-scale cave-ins in the overhanging ore. Even though the excavation is being carried out more than a kilometre underground, last year surface instabilities caused more than 60 million tonnes of material to collapse into the pit from its north wall. Rio Tinto was concerned that future subsidence might threaten the installations on the pit's eastern rim.

The international geotechnical engineering company AMEC, assisted by Vexcel Canada and Infoterra UK, is evaluating the commercial possibilities of



Monitoring land motion from space. Left: The Palabora mine in South Africa; Right: Subsidence results from InSAR for two subsequent data periods, overlaid on very-high resolution imagery of the area (with cloud cover at top left). Courtesy of Vexcel Canada; Infoterra Ltd./Eurimage (Quickbird image)



Ocean eddies. Right: forecast of surface current velocities from the Ocean FOCUS service during the formation of the 'Sargussum Eddy'. Courtesy of Ocean Numerics Ltd.

a technique known as Interferometry of Synthetic Aperture Radar (InSAR) images, with which they are able to measure slow movements of the Earth's surface from space with millimetre accuracy. The InSAR technique has been used at the Palabora mine to monitor deformation around the excavations and it shows that subsidence on the northern side of the pit has tapered off and that there is zero subsidence near the smelter, refinery and other buildings on the east rim (see figure). In addition to its test-monitoring of the Palabora mine, AMEC is conducting 10 more field trials for other mining companies, for railway operators in Germany and the UK, and for a pipeline route in Western Canada.

Mapping ocean eddies to protect deep-water drilling operations

Oil & gas exploitation in the Gulf of Mexico has an enormous potential, but deep-water drilling operations there are plagued by the presence of eddies, spinning off from a large oceanic current called the 'loop'. The latter is formed when warm water from the Caribbean enters the Gulf of Mexico through the Yucatan Straits and flows clockwise through the basin before exiting through the Florida Straits to merge with the Gulf Stream. When approaching the Florida Straits, the loop current bends strongly, becomes unstable, and thereby releases energetic warm core eddies (with a typical diameter of 100 km) into the northern waters of the Gulf of Mexico, which is heavily populated with production platforms and drilling rigs.

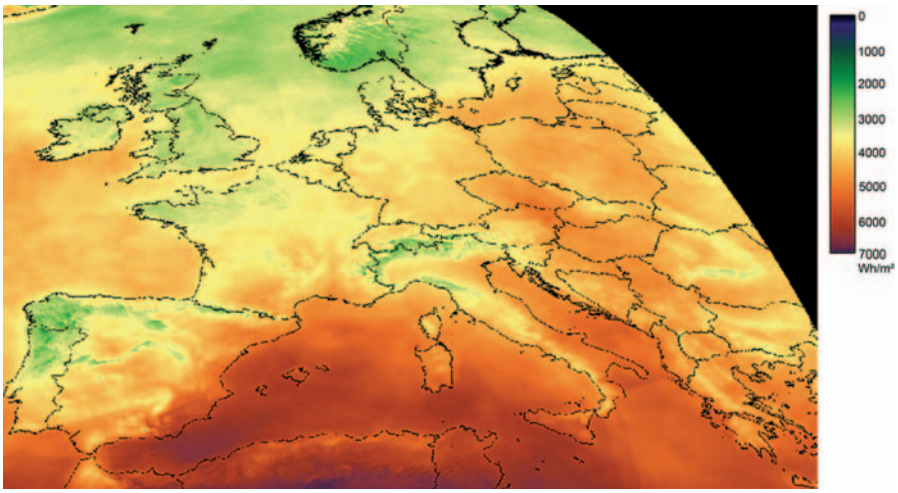
Eddies generally have strong associated currents, which can significantly disrupt offshore exploration, construction and production operations. In 2003, the so-called 'Sargassum Eddy' (see figure) crossed a heavily exploited sector and caused production losses valued at several million dollars. More recently, hurricane Katrina has highlighted the strategic importance of oil and gas production in the Gulf of Mexico for the World's economy.

Monitoring of eddies in the Gulf of Mexico is therefore of vital importance to ensure safe, cost-effective and environmentally-responsible decision-making for offshore operations. Until now, the oil & gas industry has relied heavily on the deployment of surface drifters (tracked by satellites) to monitor the behaviour of the loop current and its associated eddies in relation to the locations of offshore installations. However, this approach remains costly and can only provide an incomplete picture.

Within the EMOFOR (Envisat Monitoring and Forecasting Services for the Offshore Industry) project, Ocean Numerics – a joint venture between the Nansen Environmental and Remote Sensing Centre (NERSC), Collecte Localisation Satellites (CLS) and FugroGEOS – has developed a new eddy-forecasting system. Previous attempts to use EO data were based on Sea-Surface Temperature (SST) measurements only. However, temperature measurements in the Gulf of Mexico are limited during the summer, due to the uniform warmth of the surface layer. The new service uses an innovative approach to observe and forecast eddies, by combining satellite measurements of SST, altimeter measurements of sea-surface height (SSH), and ocean-colour measurements with in-situ data and employing a state-of-the art numerical model. In this way, it is possible to create detailed synoptic maps of sea-surface height, which show eddies detaching from the main current in near-real time (see figure).

Optimising siting and operations of solar-energy plants

The market in solar photovoltaics, i.e. the direct conversion of sunlight to electricity, has an annual turnover of 1.5 billion Euro in Germany and 5.8 billion Euro worldwide (in 2004). There are two kinds of solar-energy establishments: solar thermal plants that concentrate heat from



Monthly mean irradiance map for Europe derived from Meteosat-7 for April 2000 (irradiance measured in Wh/m^2). Courtesy of Univ. Oldenburg, Germany

the Sun, and photovoltaic plants that convert sunlight into electricity. In both cases precise, long-term solar irradiance data are needed for choosing plant locations and estimating likely energy yields for prospective investors. Then, once a plant is built, the managers need near-real-time data to check that the facility is working optimally, and that the energy output is consistent with the available sunshine.

EO-based information services for solar-resource monitoring have been developed by a pan-European consortium led by Germany's DLR. The service helps solar-energy managers to automatically assess the performances of photovoltaic plants (i.e. by comparing the actual daily or monthly solar-energy yield with the average value expected from satellite data) and rapidly detect faults, and thereby reduce costs.

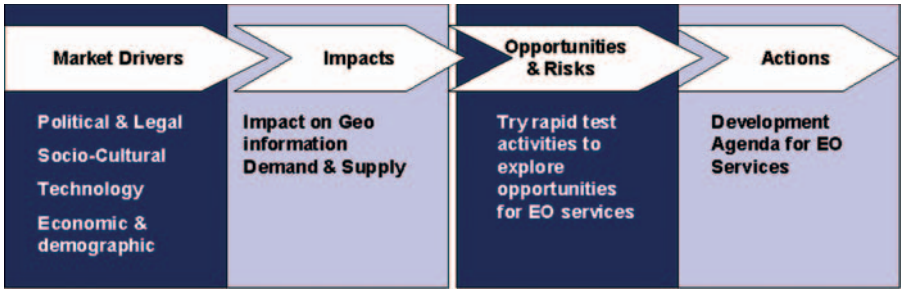
Geostationary meteorological satellites can provide global irradiance maps with high temporal resolution. Over Europe and Africa, the first-generation Meteosat satellites have an imaging repeat time of 30 minutes; the SEVIRI imager onboard the Meteosat Second Generation (MSG) satellites now provides a new image every 15 minutes. By combining the irradiance maps derived from Meteosat (see figure) with other EO products, such as digital-elevation-model and cloud-cover maps, it is possible to estimate the optimal sites for photovoltaic plants. The possibility to go back in time via the Meteosat data archive – the first-generation Meteosats have been operating continuously since the early 1980s – provides the long-term direct/diffused solar-illumination statistics necessary to quantify solar resources.

Market Intelligence

In order to gain a better understanding of the prospects for EO in emerging market sectors, a series of market-driver studies was conducted between 2002 and 2005. Led by players in the downstream service industry, these studies were designed to give VACs a broader and more complete view of upcoming business opportunities. As outlined in the accompanying figure, the overall approach was to determine the impact of the main factors or 'drivers' affecting the demand and supply of geo-information for 12 distinct market sectors. The goal was to identify opportunities and threats to EO services, and to elaborate appropriate responses by the EO industry for the short to medium term (3 to 5 years). The 12 market sectors addressed were:

- Forestry
- Coastal-zone management
- Urban mining and subsidence
- Tailings dams and mine waste monitoring
- Pipeline management
- Offshore winds
- Insurance
- Tourism
- Aquaculture
- Ports and harbours
- Location-based systems, and
- Geo-marketing.

For each of these market sectors, a separate dossier of results was compiled. Their analysis identified a set of over 200 drivers affecting the demand and supply of geo-information in these markets. Despite this complexity, some common factors affecting nearly all of the sectors emerged. An increasingly legislative environment, together with greater emphasis on



Market drivers

What the Customers Say

"While traditional survey techniques and geotechnical instrumentation can provide detailed information at specific points of interest, InSAR provides continuous data coverage over large areas to sub-centimetre accuracy within a particular timeframe of interest. These data are often available back to the early 1990s for many locations".

Tim Conley, AMEC

"Recent advances in numerical modelling, and satellite data processing techniques are resulting in the ability to locate eddies accurately, and to predit in advance their separation from the loop current and propagation towards areas of intense deep water O&G activity."

Robin Stephens, FugroGEOS/Ocean Numerics Ltd.

"We cannot set satellite-derived data aside when building and operating systems, especially with regard to the future markets like Spain, where we need solid information for investment decisions. The resolution of ground-based data is too coarse (for example in Spain there are only 30 sites available at the moment) and satellite data can therefore help a lot".

Uwe Ilgeman, S.A.G. Solarstrom AG

sustainable development, environmental reporting and security, is driving the demand for geo-information from both Industry and Government users, particularly in Europe. Globalisation is affecting industries such as forestry, mining, pipelines and shipping (ports) through issues such as public accountability, industry consolidation, and accession of countries to global markets. Economic drivers relating to the need for greater operational efficiencies, cost savings, availability of funding and willingness on the part of customers to spend are also of primary importance. The main obstacles to EO uptake are low awareness among user communities, lack of recognised suppliers, and issues concerning the reliability, accuracy, cost and usability of EO products.

Possible responses by the EO industry are specific to each market sector, but common recommendations include the development of more complete information products, which fit seamlessly into industry working practices, improved standardisation and quality control to increase product reliability, the need for lobbying, and a strong need to increase product awareness in downstream industries.

Conclusions

Over the past 5 years, ESA's Earth Observation Market Development activities have built understanding, participation and momentum in the EO service industry. They have also supported the industry in engaging with new private-sector customers and better addressing new market opportunities.

Looking at the individual projects, a total of 6 million Euro of additional business has been generated to date as a direct consequence of the EOMD activities. Most of the new business is coming from 11 service actions conducted over three years whereby EO-based VACs work with downstream industry players and their clients. An important element of these activities were service trials whereby satellite-based services have been integrated into the operations of non-EO-based geo-information companies. Such service trials give industry customers the confidence to make the first purchase, thereby opening the door for future follow-on business. So far, the services with most follow-on business have been land motion, geological mapping and maritime surveillance, with an even split between private and governmental customers.

Another way of assessing the usefulness of the EO-based services is through the collection of 'value statements' from key customers. Over the last years, a total of 28 value statements have been collected, yielding 19 positive, 7 neutral and just 2 negative responses. The accompanying panel (left) presents customer feedback associated with the service examples described earlier in the article.

The industry survey and the market intelligence studies have helped everyone involved to achieve a better understanding of the EO service industry and have highlighted commercial opportunities as well as the challenges related to its structure, offerings and presence. Realising the full potential of EO for the industry will require increased collaboration and partnerships, standards and certification, together with a stronger industry marketing and lobbying voice. Another important factor will be the long-term continuity of EO data, as customers will be wary of adopting new services for which the future supply of the raw data is not secure.

Outlook

Recent studies (e.g. OECD report 'Space 2030, Tackling Society's Challenges') confirm that the future demand for space applications is likely to be substantial, with information-intensive applications such as telecommunications, navigation and EO

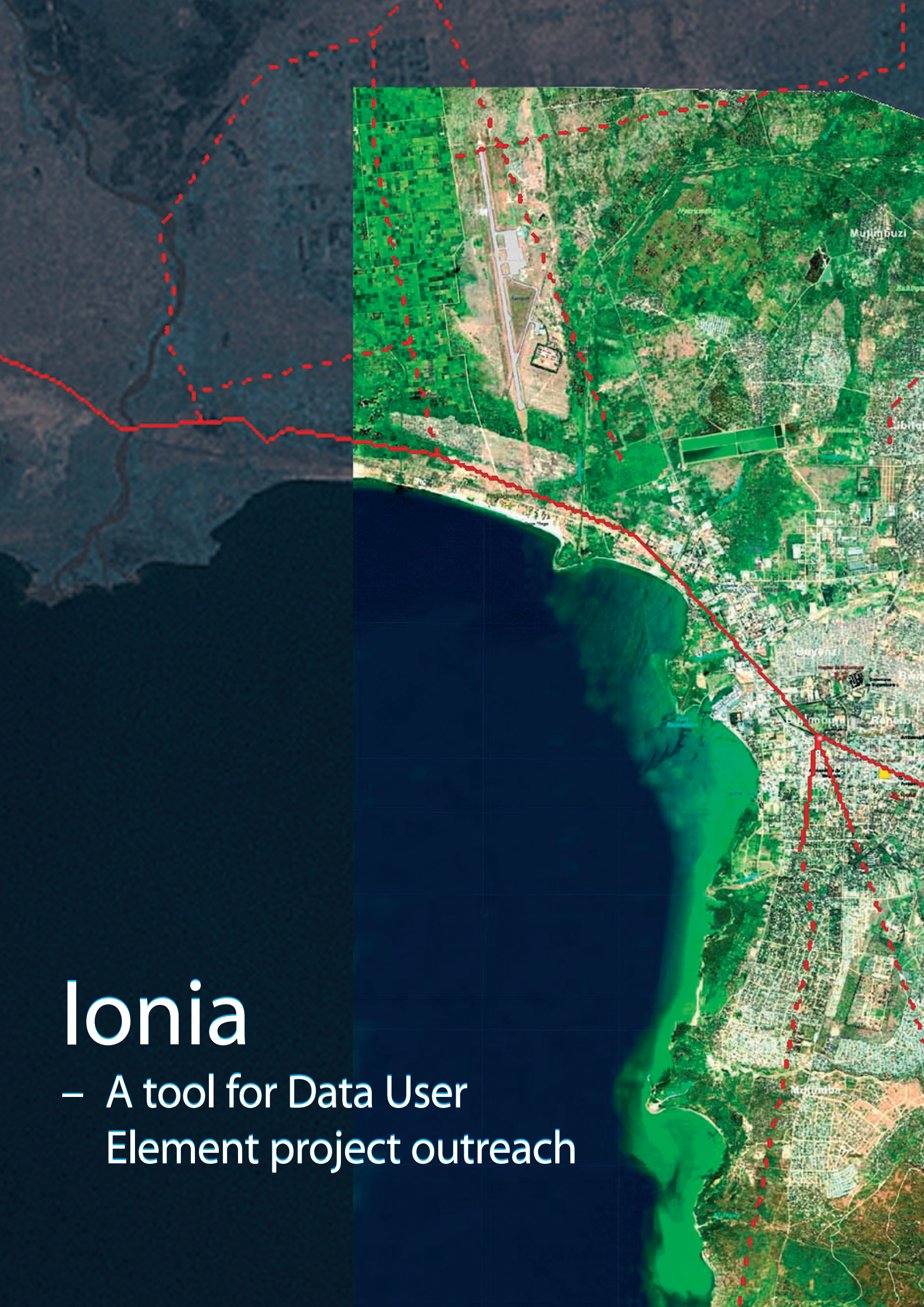
offering the best prospects. Furthermore, with the European Commission (EC) placing renewed emphasis on the Lisbon Agenda for Europe to advance towards the most competitive and dynamic knowledge-driven economy by 2010, and also the new joint EC-ESA initiative for Global Monitoring for Environment and Security (GMES), the timing is right for the EO service industry to take advantage of these opportunities for growth. GMES is a major step forward in structuring public-sector demand within Europe. It offers a chance for industry to come forward with an effective framework for large-scale service provision.

In this context, future ESA activities with the value-adding industry will focus on developing the private sector's engagement with EO in three major directions. The first direction will further build and expand European EO service capabilities. In the short-term, several 'innovative contracts' have been started in 2004 and 2005 to cover new thematic areas, e.g. national-park management, tourism and public health. In the medium and longer term, it includes the integration of new EO data from ESA, Eumetsat, national and third-party missions to further strengthen EO services. The second direction will focus on establishing a strong European EO service industry in global markets, by seeking progress in the areas of industry standards, service certification and effective industry representation, as well as including initial actions to analyse and eventually access markets outside Europe. Finally, the third direction will further develop the need to integrate EO into downstream industrial operations and practices. This will involve taking EO to new industrial sectors and combining EO with other non-EO information services. As a first step, several initiatives have recently been started with large companies to assess how EO can be of help in the context of their 'corporate sustainable development'.

In summary, ESA's EOMD activities have already contributed substantially to a shift from a rather technology-pushed approach within the EO service industry, to a more market-pulled, user-oriented approach. They have provided a solid basis for a future programme of work to further strengthen and develop the functioning, credibility and acceptance of the EO Service Industry sector and help it to profit from upcoming opportunities and address the main challenges that it will face in achieving sustained growth.

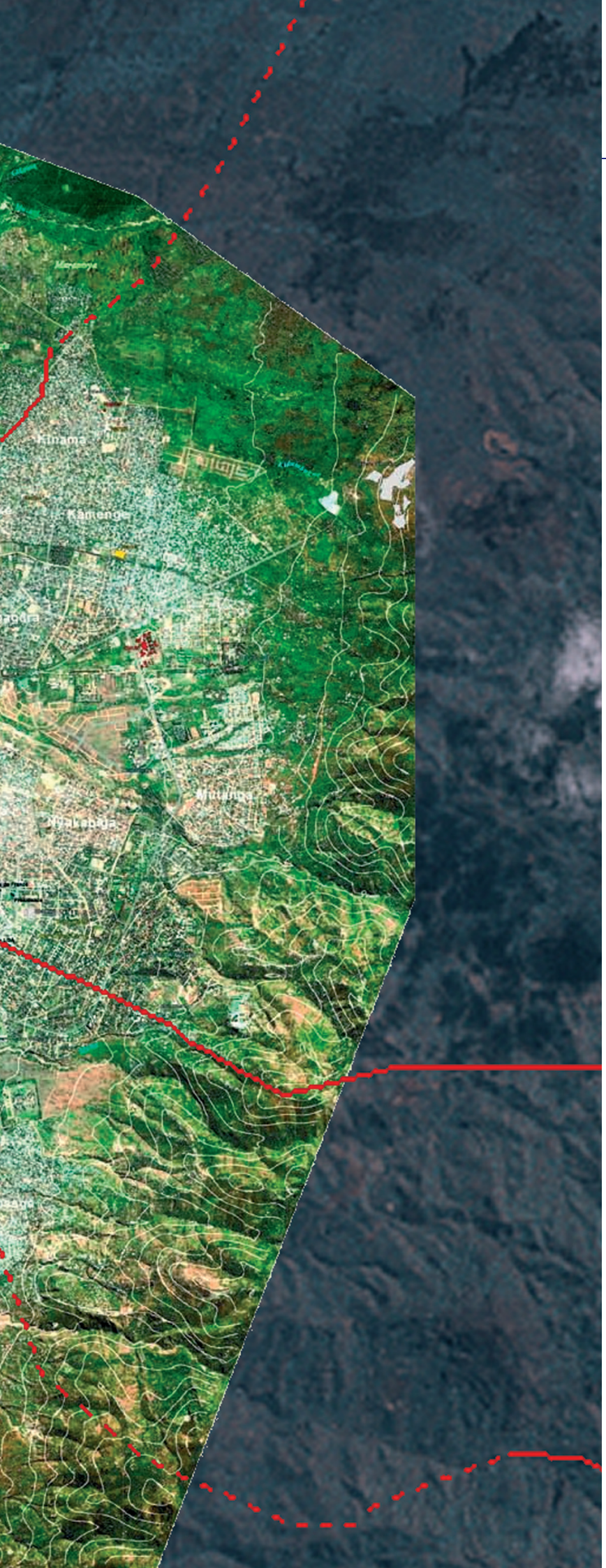
More information about ESA's EOMD activities can be found at:

http://www.esa.int/eomd.



Ionia

– A tool for Data User Element project outreach



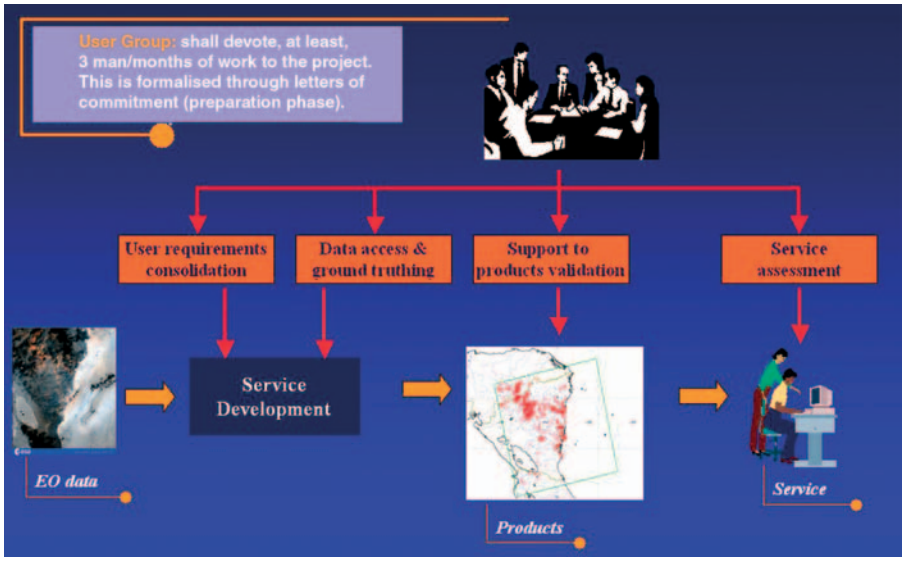
Marc Paganini, Muriel Simon, Roger Nay & Olivier Arino
ESA Directorate of Earth Observation Programmes, ESRIN, Frascati, Italy

Achieving the maximum outreach from ESA pilot projects funded through the Data User Element (DUE) of the Earth Observation Envelope Programme (EOEP) is one of the duties of those responsible for the programme's execution. The projects section of the Earth Observation Science and Applications Department at ESRIN is using numerous communication channels and opportunities for effective project dissemination prior to, during and after contract execution. Internet technologies are seen as the widest-reaching and most cost-effective means of showcasing the results of the DUE pilot projects for all interested communities; hence the Agency's decision to develop the Ionia website (http://www.esa.int/due/ionia) as an Internet gateway for fast and easy access to demonstration products developed within the DUE pilot projects.

Introduction

The EOEP Data User Element

The Data User Element (DUE) is a programmatic component of the Earth Observation Envelope Programme (EOEP), an ESA Optional Programme currently subscribed to by 14 ESA Member States. Its function is to increase and strengthen user communities involved in Earth Observation (EO) applications by carrying out projects that develop and demonstrate user-driven EO-based services. The DUE largely follows the objectives of its predecessor, the Data User Programme (DUP), which ran from 1996 to 2003 and was subscribed to by just four Member States (B, NL, CH and I), with a total of 50 projects funded and an overall budget of 14 MEuro. As of December 2005, there are 27 on-going DUE projects, with a total value of 13.5 MEuro.



Conditions for user participation in DUP/DUE pilot projects

The three main DUE programme objectives are to:
- create an environment allowing for the development of user communities for both institutional and commercial applications;
- support European industry in the development and demonstration of information products, principally derived from current and future ESA missions;
- support European industry in establishing useful and cost-effective services.

User-driven, a key feature of the EOEP Data User Element

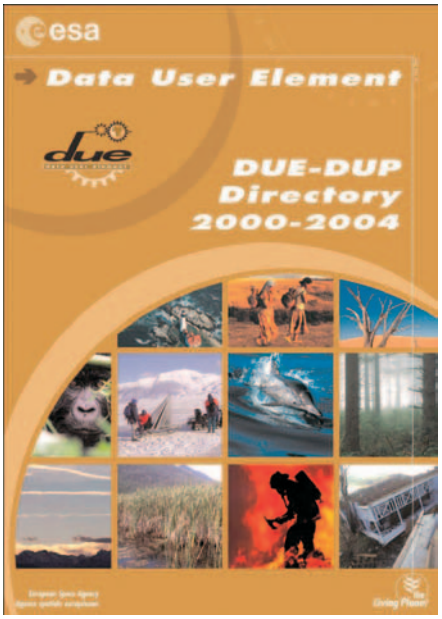
Top priority for the DUE is on the user side. To attract the interest of end-user organisations from widespread and fragmented user communities, the Agency is working in close partnership with overarching user organisations that have a strong influence on their communities. The definition, implementation, integration, validation and qualification of the products and services developed under the DUP/DUE are carried out in close collaboration with these user organisations, and in agreement with their standards and practices. Such a user partnership is perceived by the Agency as the best manner in which to reach out to the large community of user organisations that are directly concerned by the systems and products developed and demonstrated under the DUP/DUE projects.

By the end of 2005, more than 150 user organisations had participated in DUP/DUE demonstration projects, conducted in more than 50 countries worldwide.

Exploiting all communication channels

Since the birth of the Data User Programme in early 1996, ESA has continuously explored all communication mechanisms and has put in place an effective framework within which all opportunities for project outreach are fully exploited. The overall objective of these communication activities is to increase public awareness of the benefits of Earth Observation from Space, in the broadest sense possible. The audiences are primarily the end-user communities (i.e. policy and decision makers, as well as technical staff), but also include other beneficiaries and sponsors of EO technology. This includes: the EO value-adding industry as it tries to gain a lasting foothold in the highly competitive market for remote-sensing products; research laboratories and universities; the downstream industrial sector (i.e. those service companies currently offering similar types of services with traditional technologies); and last but not least the governments of the ESA Member States.

During the preparation and execution of the DUP/DUE pilot projects, but also following contract completion, the Agency is very active in exploiting all communication channels for effective project dissemination. This includes organising workshops in collaboration with participating user organisations as a first step; organising regular meetings with overarching user organisations; publication of papers in scientific and user journals; participation in scientific and user symposia; distribution of brochures, handbooks, flyers, posters, publicity CD-ROMs and DVDs; distribution of project newsletters; publishing of a DUP/DUE Directory; organisation of user workshops; organisation of side events at international conferences; publication of web stories on the ESA Portal (more than 30 news stories have been published so far on DUP/DUE projects); publication of articles in newspapers and magazines; and maintenance of a dedicated Web Portal. All of these communications channels are necessary elements in establishing strong user communities around EO satellite applications.



The DUE-DUP 2000-2004 directory, an exhaustive report on five years of ESA working with user communities

The DUE website, an indispensable tool for project outreach

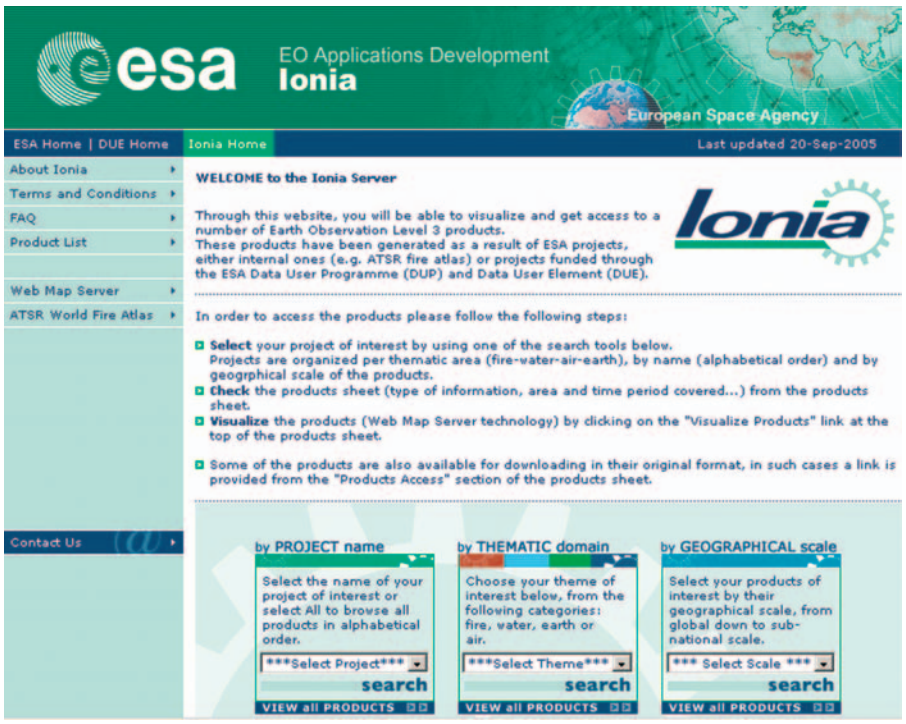
Developing an outreach mechanism centred on Internet services

The DUE *web portal* (http://www.esa.int/due), which has been active for more than three years, is a fundamental communications asset for DUE project outreach, and in particular for enhancing user and industry awareness of the programme's achievements.

The website provides inventories and descriptions of all pilot projects financed by the DUP/DUE programme (with final reports available online), as well as of all participating companies and user organisations (with contact details). It is an essential gateway for project outreach, but more can be done using state-of-the-art Internet applications. An extension of the DUE Web Portal, called the *Ionia website,* was therefore recently implemented, allowing online browsing of the demonstration products and providing access to the most-representative results.

Ionia as a Gateway to EO-based Geospatial Products

The Ionia website is named after the ancient Greek school of philosophy that explained all natural phenomena as the outcome of four basic elements: fire, water, air and earth. These four elements, which are now observed from spaceborne instruments and constitute the main fields of interest for Earth Observation, have been used as a classification system for the Ionia products, which can also be searched alphabetically and geographically. The website provides online access to a growing number of EO-based products generated under ESA DUP/DUE-funded projects, using sensors from a variety of satellites, including third-party missions. In addition, some products are generated through ESA internal projects. This is the case in particular for the World Fire Atlas (WFA) products, which consist of monthly global inventories of 'hot spots' produced using the ATSR instrument series onboard



Ionia homepage, a gateway to EO demonstration products

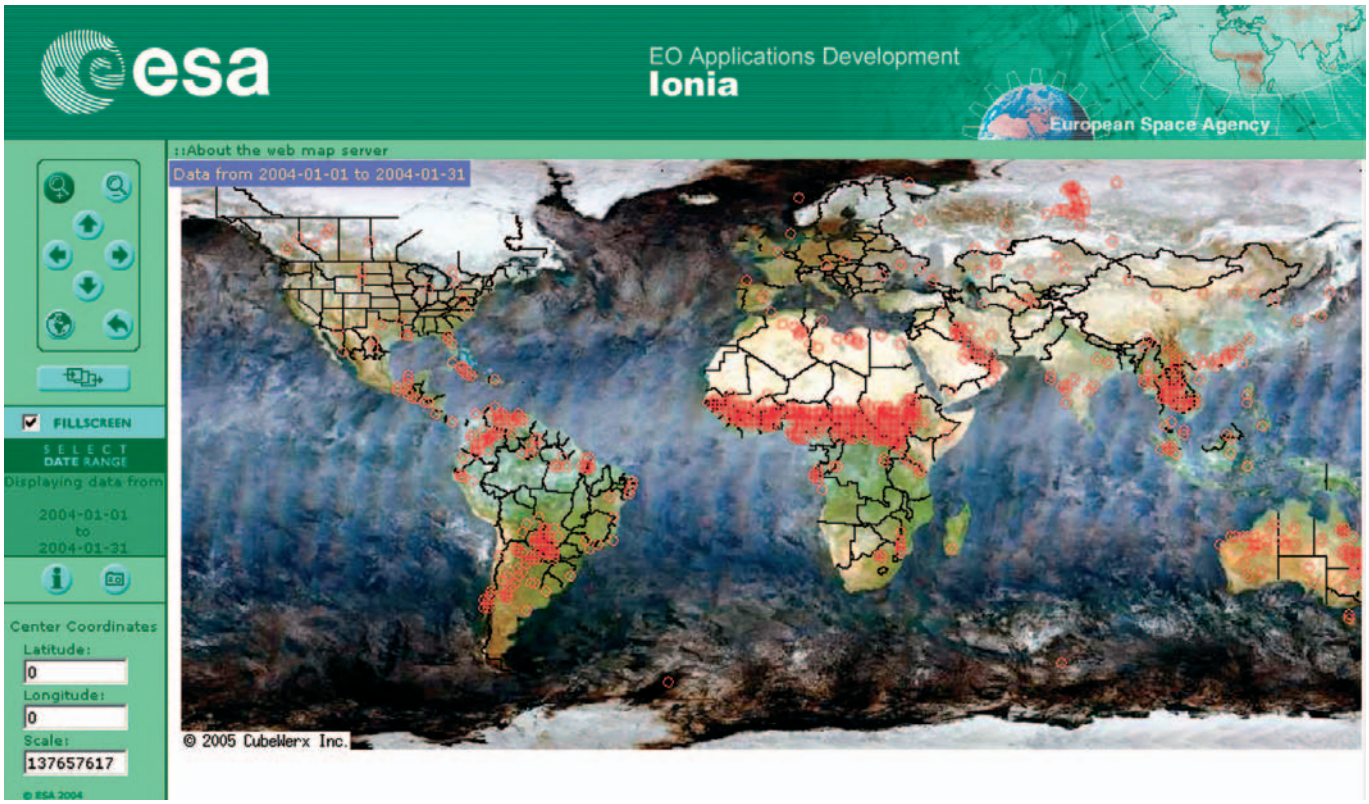
ITALSCAR products: annual burn scars on Sicily as displayed via the Ionia Web Map Server. Each colour corresponds to a single year: yellow - 1997, blue - 1998, green - 1999, red - 2000

ESA's ERS-2 and Envisat satellites. 14 pilot projects were listed on Ionia as of November 2005.

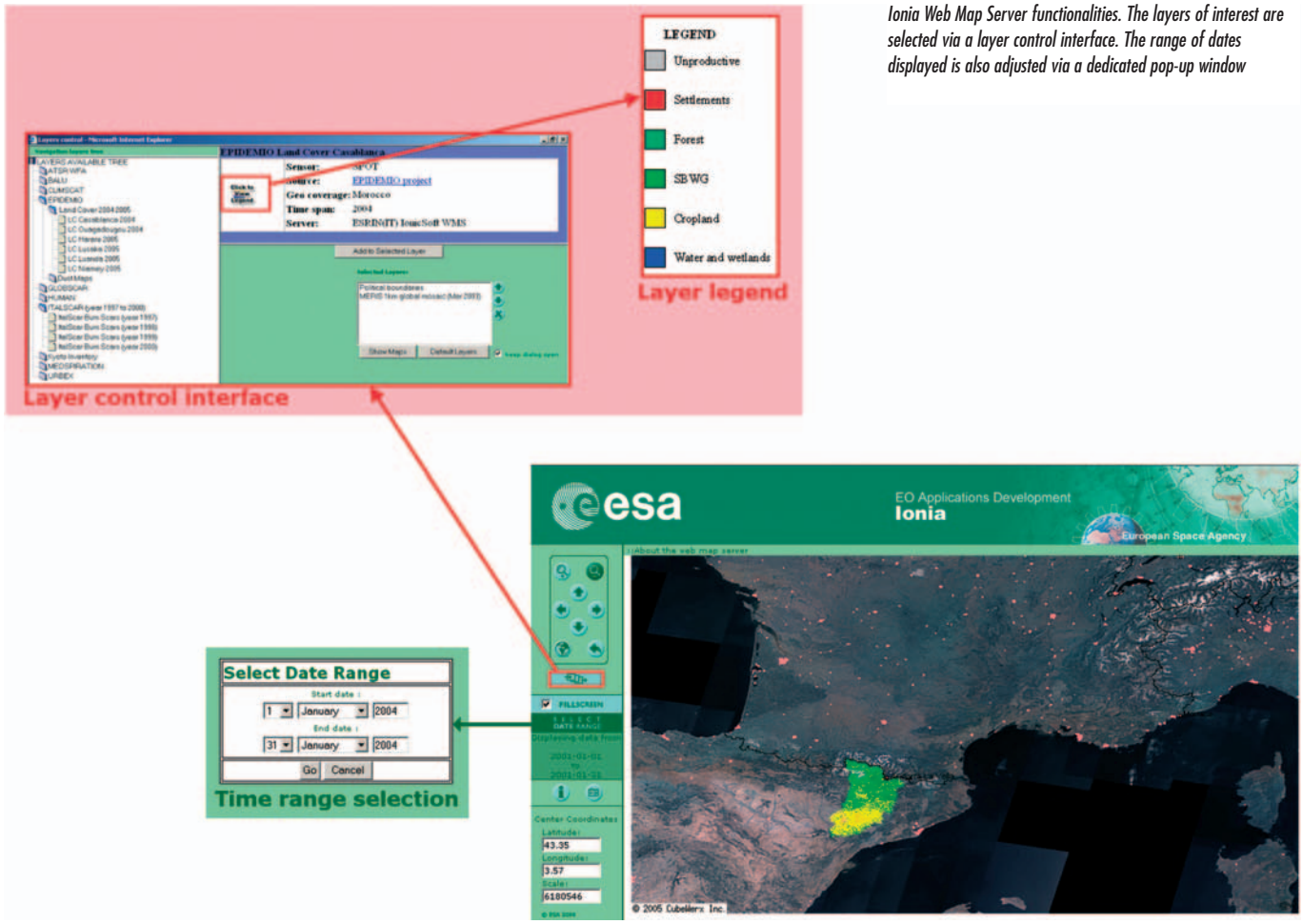
The Ionia website has existed since 1995, but was initially mainly a repository for internal ESA products. It is only since 2004 that the number of products listed has increased dramatically, with the inclusion of the products generated within the DUP and DUE projects. The products listed can either be browsed using a dedicated Internet application (Web Map Server technology), or downloaded directly. Associated documentation and links to scientific papers that have employed the products are also available for consultation.

Ionia: a varied selection of demonstration products

The products available on Ionia cover a large variety of thematic applications and have very different geographical and temporal scales. Some of the projects regularly generate large-scale products over a long time period, such as the CLIMSCAT soil-moisture monitoring project, which generates soil water index measurements across the globe on a monthly basis for 10 years. The CLIMSCAT products can be visualised via the Ionia Web Map Server, and tailored data products can be directly requested from IPF Vienna, one of the project partners, which hosts the entire product database (http://www.ipf.tuwien.ac.at/radar/ers-scat). The MEDSPIRATION sea-surface-temperature monitoring project is another good example, generating high-



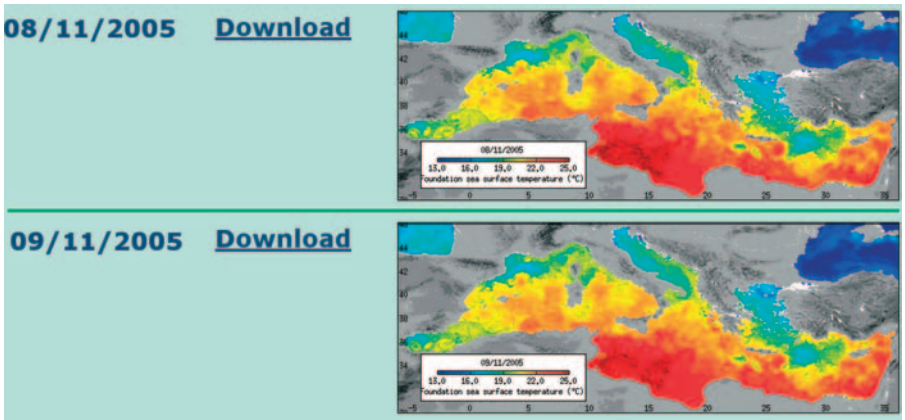
WMS client application developed for Ionia. Layers selected here include political borders from the Cubewerx server, a MERIS global mosaic in the background, and the ATSR hot spots recorded during the month of January 2004 (ATSR World Fire Atlas)



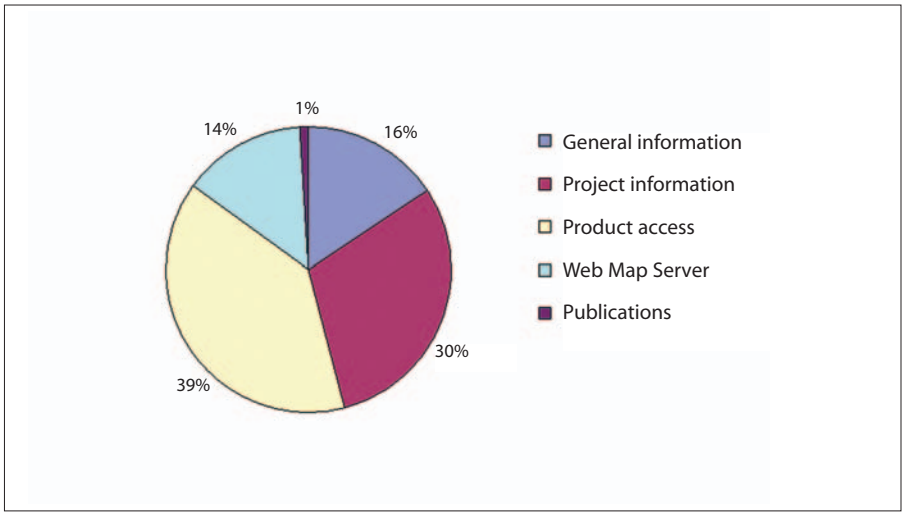
Ionia Web Map Server functionalities. The layers of interest are selected via a layer control interface. The range of dates displayed is also adjusted via a dedicated pop-up window

resolution sea-surface-temperature maps of the Mediterranean with 2 km resolution, on a daily basis for the period 2005-2007. MEDSPIRATION products are available via FTP from the project website (http://www.medspiration.org) and from the Ionia website, an average of 24 hours after acquisition. Visualisation via the Ionia Web Map Server Client is also available in near-real-time. The outputs for these types of projects are generated using a set of satellite data combined both in time and space in order to cover the area and period of interest.

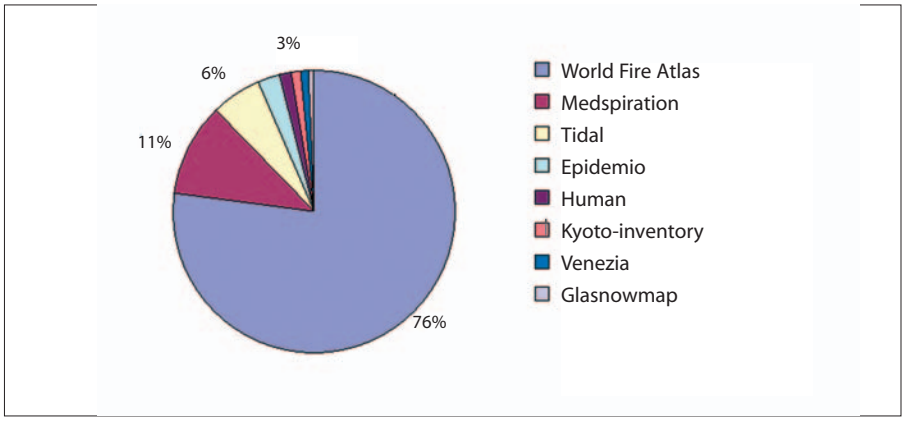
By contrast, other projects produce unique outputs over more limited geographical areas, at national or sub-national scale. This is the case for the URBEX products (urban-expansion monitoring) for instance, which consist of urbanization maps of Italy from 1995 to



Near-real-time access from Ionia to the daily sea-surface-temperature products of the ESA DUE MEDSPIRATION project. In addition to the technical data files (netcdf format), quick-looks are also available for downloading



Types of requests (total 40 044) made to the Ionia server. General information includes Frequently Asked Questions, Terms and Conditions, etc.



Requests (total 15 755) made to the Ionia Server for access to products in the period August-November 2005, classified by pilot project

2000, plus one evolution map between 1995 and 2000. Another such project is ITALSCAR (burn-scar mapping), which produced annual inventory maps of burned areas of Italy at 1 ha resolution for four consecutive years (1997 to 2000). The products were generated from 136 Landsat image pairs covering Italian territory at the beginning and the end of each summer season.

Going further down in geographic scale, some projects concern local areas within one or more countries, as in the case of the HUMAN service (high-resolution customised local maps for humanitarian-aid agencies, involving 11 different countries) or the EPIDEMIO project (EO-based environmental information to support epidemiologists in several African countries). The output products for those projects are typically the size of one satellite image over each of the areas of interest.

Ionia: a user-friendly tool for visualising DUP/DUE products

The Ionia website uses the Web Map Server (WMS) and Web Feature Server (WFS) technologies. WMS is an Internet application used to visualise and generate maps drawn in a standard image format (PNG, JPEG, etc), based on a standard set of input parameters. It allows one to explore geographical data from many sources, including geo-spatial data derived from EO satellites. A number of geographic data sources can be displayed and arranged in layers. Using WMS and WFS technologies extends the distribution of spatial data and analysis to a wider audience, since it becomes unnecessary for users to purchase GIS software to manipulate the data and perform analyses – all of which is accomplished via an Internet browser interface.

In Ionia's case, a dedicated WMS configuration has been developed for each pilot project (thematic layers of interest, pertinent geographical scale and time span). The Web Map Server follows the recommendations of the internationally recognised Open Geospatial Consortium (OGC), a voluntary organisation encouraging the development and implementation of standards for geospatial content and services, GIS data processing and exchange. In practice, this means that layers from other servers can be overlaid easily with the Ionia products. Conversely, external users can link from their own WMS system into the Ionia product layers.

In a similar way, products from different DUP/DUE pilot projects can also be visualised simultaneously on the WMS client. This facilitates in particular inter-comparison and correlation analysis of the results whenever appropriate.

Ionia: a fast and easy way to access DUP/DUE products

Demonstration products from several projects are available for downloading via the Ionia website. In most cases, access is provided directly from the website, as with the EPIDEMIO project. Access can also be provided through the website of the contractor responsible for the project's execution, when online product delivery forms part of the contractor's duties. This is the case, for example, for the GLOBSCAR products (Global Burned Forest Mapping), which are available at: http://www.geosuccess.net.

In the case of the TIDAL service (tidal information on water levels and currents for offshore users), only one set of demonstration products is available on Ionia, together with a link to the online subscription service hosted by ARGOSS, the company in charge of the project (http://www.tidal-info.com). Similarly, in

the case of the HUMAN project (Humanitarian Disaster Mapping Service), demonstration products are available for downloading on Ionia, while the overall mapping service developed within the HUMAN project is available online to subscribing customers at:
http://human.keyobs.be/human.

Ionia access statistics

Since August 2005, there has been a monitoring system in place to generate a number of indicators concerning how the Ionia website is being used. According to the figures provided by this first analysis, more than 50% of the requests concern product visualisation and downloading, reflecting a strong interest in Ionia website assets.

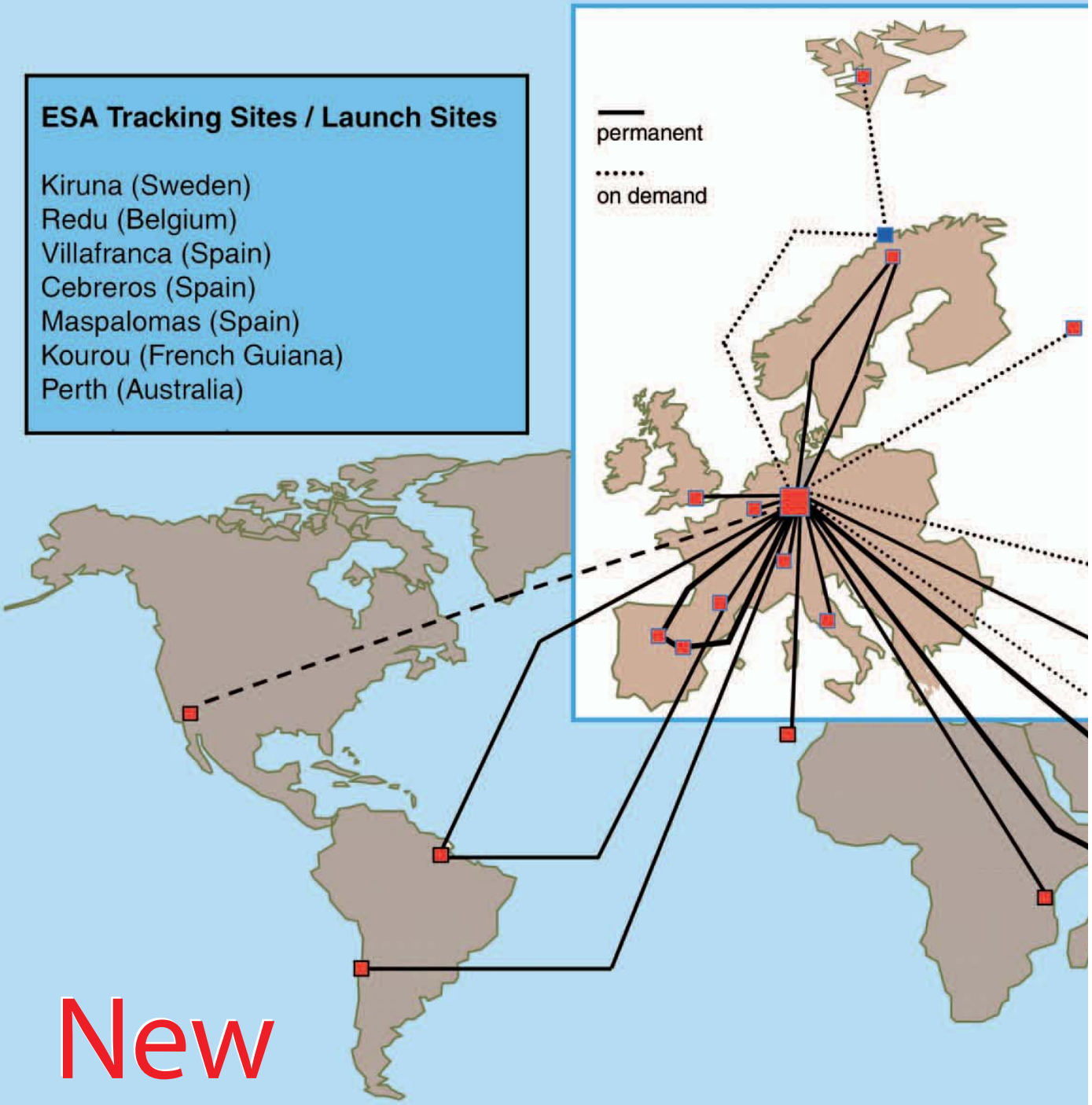
A significant portion of the requests for Ionia products concern 'World Fire Atlas' files, which have been available online for several years now (but via a different environment) and have an established user community. It is estimated that, on average, 500 Fire Atlas products are retrieved each month from the Ionia website. Another indicator of the high interest in the Atlas is that four of the five top search keywords used to access the website are associated with those products: ATSR, world, fire and atlas. However, more recent products have also stimulated strong interest among the visitors: the MEDSPIRATION sea-surface-temperature files for example, which have been available in near-real-time (1 day) on Ionia since mid-September 2005, have already attracted more than 300 requests for products.

Looking at the geographical distribution of the visitors to the website, as of November 2005 requests for access had been made from more than 55 different countries, the core of the identifiable requests being from Europe, followed by North America and Asia. The visualisation of the products generated by DUP/DUE projects is therefore already recognised as a significant asset of the Ionia website. The ultimate objective is to load it with demonstration products from all DUP/DUE pilot projects with visualisation and download access. Future improvements will be to explore new means of geospatial data visualisation, in particular the Google Earth visualisation and navigation tool, or NASA's World Wind, the most recent web-based applications that enable the viewing of geographic information over 3-D models of the Earth.

Acknowledgements

We would like to thank the staff of the Projects Section within the Earth-Observation Science and Applications Department, the SERCO support team, and the staff of the Earth-Observation Ground Segment Department responsible for the development and operation of the ESIN Web Map Servers, for their contributions to the Ionia website:

http://www.esa.int/due/ionia



New Communications Solutions for ESA Ground Stations

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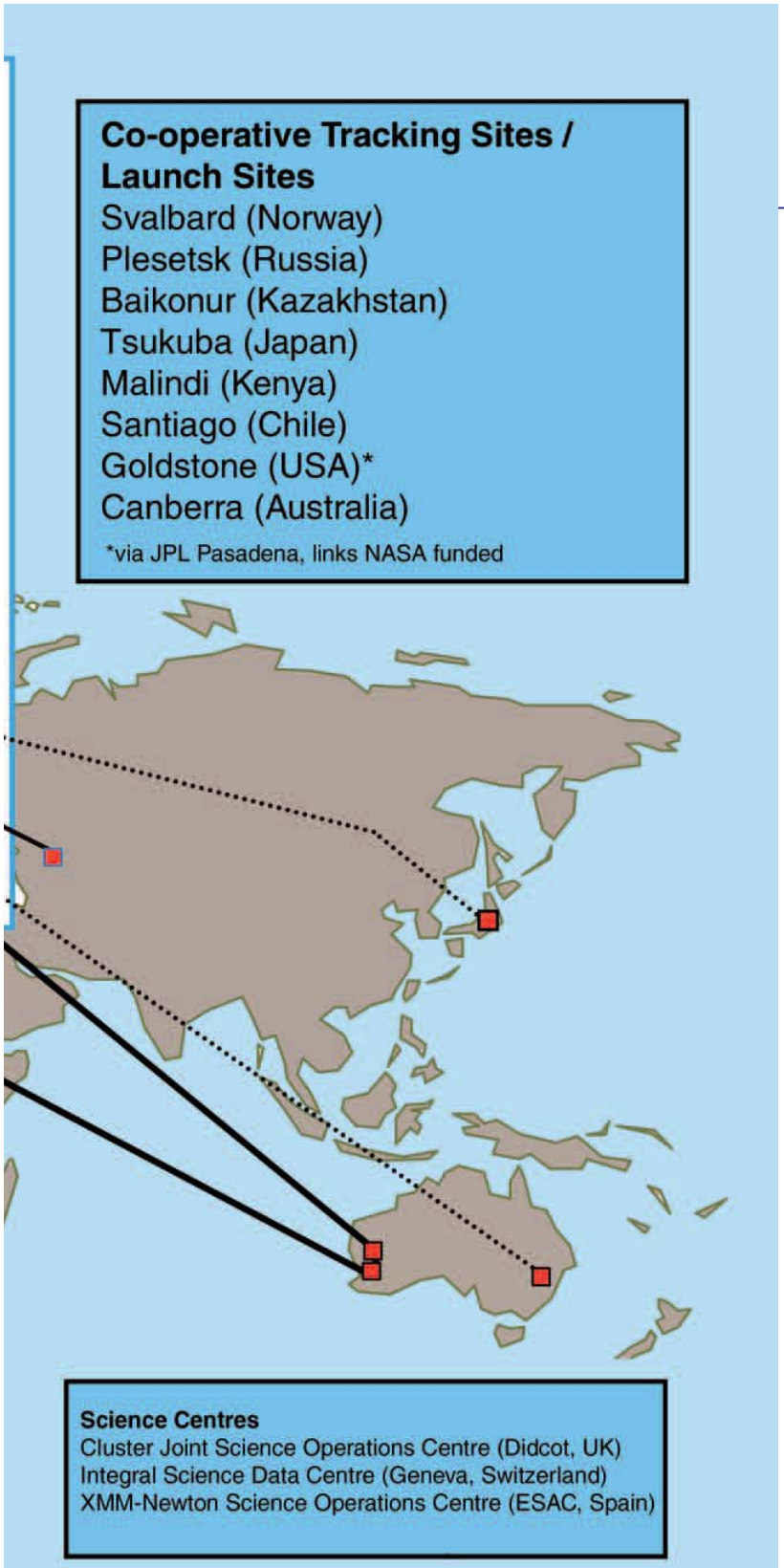
ESOC, Darmstadt, Germany



ESA operates a global system of ground stations known as ESTRACK, the ESA Tracking Network. Communications services for all ESTRACK stations are provided by a network known as OPSNET. Dedicated to space mission operations, OPSNET is built as a closed private network ensuring effectively non-stop availability of control-centre facilities and ground-station services to ESA's, and also third-party, space missions. The OPSNET modernisation programme has involved all control-centre interfaces to ESTRACK and, one by one, all ESA ground stations. The hand-over of the second ESA Deep-Space Station, at Cebreros in Spain (see ESA Bulletin No. 124), for routine operations in time for the Venus Express mission marked the completion of this modernisation effort.

Introduction

The de-facto global standard for data communications nowadays is the Internet Protocol (IP). IP had been the standard in OPSNET Local Area Networks (LANs) for several years, whereas the OPSNET Wide Area Network (WAN) was traditionally a network to which subscribers connected over the X.25 protocol, an error-correcting protocol designed to work well even over poor-quality telecommunications lines. With the ever-improving quality of international links, and the rapid growth of the Internet,

The Communications Services of the ESA OPSNET

- **Voice** – Permanent voice conferencing ('Intercom') for human coordination of OCC and ESTRACK operations
- **TT&C** – Telemetry, Tracking and Commanding data transmissions in support of spacecraft operations; real-time, near real-time, off-line
- **Payload Data** – Science data from stations to control centre; real-time, near real-time, off-line
- **M&C, Network & Service management** – Monitoring and Control data for Ground Stations systems and subsystems, in support of remote operations of Ground Stations and OPSNET
- **Special customer services** – e.g. Navigation, Delta-DOR
- **Auxiliary customer services** – e.g. building management, remote diagnostics

however, it could be predicted that the sourcing of X.25 products and support would become increasingly difficult and cost-ineffective. Since the end of the 1990s, the Internet Protocol has therefore been the de-facto data-transmission protocol for new ESA space missions. A corresponding rationale to drive towards a consolidated IP network was its ability to support international space collaboration by applying Space Link Extension (SLE) standards via IP-based interfaces with partner networks and increasingly within ESTRACK.

The Directorate of Operations and Infrastructure therefore launched a migration from X.25 to IP for the entire complex of mission operations (facilities and applications software), ground stations, and communications. The objective for OPSNET was to evolve towards IP as the single protocol, run on a globally uniform infrastructure that uses products and services sourced from a mature and highly competitive marketplace, thereby ensuring reliability and longevity.

The Framework

Just as the mission-control systems and ESTRACK stations play a key role in the operation of space missions, OPSNET plays a critical role as an underlying enabling infrastructure. Communications must be available effectively non-stop. A reliable, high-quality service is essential to be able to serve concurrently the 12 ESA spacecraft that are presently in their routine operational phases. Under-performances and service flaws must be avoided, particularly during the Launch and Early-Orbit Phases (LEOPs) of space missions. Despite this rigorous need for stability, it must still be possible to reconfigure systems at almost zero notice to handle contingency situations occurring on the ground and in space, for both ESA spacecraft and those of ESA's partners and customers. It must also be possible to react flexibly to the re-planning of project schedules, and OPSNET must continually adapt – without impacting on ongoing services – to changing technical needs, be it to serve evolutions of its user systems or ground-segment implementations for new missions.

Those demands have to be met not only by the OPSNET design and technology itself, but equally through the approach to the sourcing and change management of OPSNET facilities and services. ESA has therefore chosen to retain a maximum degree of ownership, control and agility. OPSNET equipment is fully owned by ESA (except the wide-area links, which by their very nature have to be rented from telecommunications carriers). First- and second-line maintenance and operations support (M&O) is provided by industry on site, 24 hours a day seven days a week. The lion's share of renewals and changes are engineered by industry also on site. In each service area, there is also a close co-operation with and service management by ESA experts. Such a concept of 'customer proximity' – both industry to ESA communications support and ESA communications support to the mission customers – ensures smooth integration into mission operations and a highly synergetic and effective workflow cycle from demand to introduction into service. This concept is reflected also in the modernisation of OPSNET.

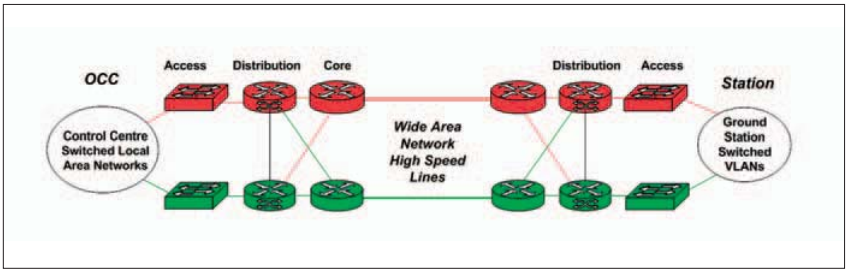
A few decisions of principle that were very instrumental for the efficiency of the project as such, and for minimising service and cost impacts on the missions supported, were taken very early in the modernisation effort:

- The governance for the entire design and equipment configurations would be with ESA.
- The station communications upgrades were to be aligned with a global project for the modernisation of tracking, telemetry and telecommand (TT&C) and ranging systems in the ground stations, including their monitoring and control elements.
- The communications modernisations were always the first to be deployed at a station.
- The work was to be contracted to the same systems integration contractor, to ensure synergy and coherence of standards and documentation.
- The same active equipment was standardised upon that had been selected and deployed only some 3 years before to modernise the Local Area Networks in the Operations Control Centre (OCC) at ESOC. This minimised the need for costly and time-consuming inter-operability-validation campaigns and 'learning curves'.
- The design in principle is uniform for the OCC and each of the ground stations, with only the scale of the individual building blocks varying.
- The OCC, the stations and OPSNET were made dual-protocol-capable, but mission operations were not forced to go to IP immediately. This left it to customer missions to find reasonable and cost-effective windows of opportunity for their own migrations.
- The old packet network was 'frozen' as of 2001. Remaining expenditure was essentially limited to a portion of a maintenance and operations service contract and to access to the manufacturer's software support.

The New Communications Solutions

The top-level requirements placed on OPSNET can be summarised simply as two goals:

- a high-performance capability with low procurement and running costs
- high flexibility and adaptability with low maintenance and change-management costs.



Key features for achieving those goals are:

- An availability figure of not less than 99.95%, on average, per month.
- Redundancy for critical devices, with highly automated fail-overs.
- Powerful Quality of Service (QoS) and prioritisation features:
  - critical data get guaranteed capacity even under adverse conditions
  - non-critical data get capacity on best effort basis.
- Scalability/flexibility of network architecture and of station installations.
- Dedicated logical LAN segments per function/purpose (such as telemetry/telecommand, monitoring and control, intercom, office automation, telephony, video/audio conferencing, Internet access)*.
- Centralised network management (round the clock) in the control centre, local systems management in stations available if needed in contingency scenarios.
- Longevity of installations and equipment.
- Co-existence with the X.25 network, with X.25-based mission operations.
- Low procurement cost, low running cost (devices, telecom services, maintenance & operations, and sustaining engineering services).

The modernised physical infrastructure in the ground stations is based on standards and best practices for structured hierarchical building cabling systems. One physical access point is capable of supporting all applications. The cabling towards end-user systems is Gigabit-capable and hence suitable for the foreseeable future. The LAN backbones are based on fibre optics with gigabit Ethernet interfaces. For critical services, two independent sets of devices are deployed end-to-end for redundancy (referred to as independent 'chains').

The overall network architecture is a classical hierarchical three-layer model, with:

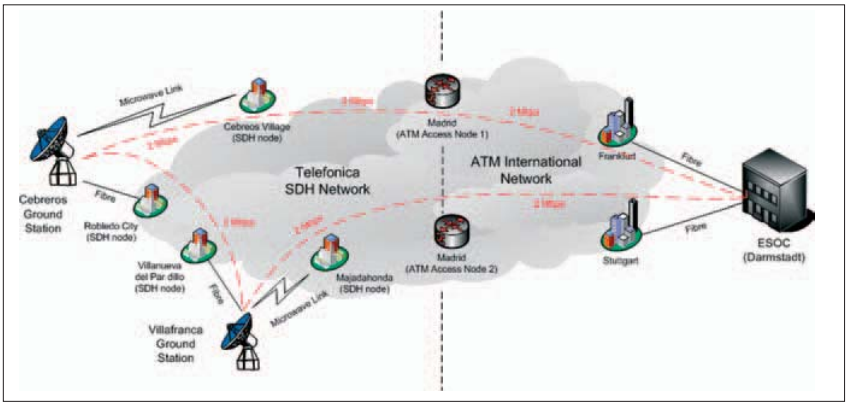
- a core layer
- a distribution layer, and
- an access layer.

It is this architecture, and its implementation using modular equipment, that makes the network highly flexible in terms of adding sites and/or user systems.

The *access* layer provides the first point of access from a connected system to the network. The *distribution* layer handles the switching of the data streams, security, and grouping of user systems into different logical entities (the VLANs). The distribution layer also aggregates links based on the same groups, and implements the routing and security within the campus. The *core* layer of the network is designed to handle the routing between the distant sites, including re-routing in case of outages of WAN links. The core functionality resides mainly inside the core routers at the control centre, but a few tasks are shared with the routers at the ground stations.

The accompanying figure illustrates the principle, shown here for a link between the Operations Control Centre (OCC) and one ground station. Red and green colours denote the redundancy concept of the two 'chains'. As can be seen, there always remains at least one path between user systems in the OCC and those in the station, even if a leased line or an in-between item of communications equipment would fail.

The illustration of the 'layers' and 'chains' functionality per site by one device each just shows the principle. At the Cebreros ground station, for example, a total of 18 switch/router devices are deployed, offering about 1000 ports in the access layer. With this capacity, Cebreros has the largest information and communications technology (ICT) infrastructure of any ESA ground station. The high number of ports reflects the fact that, in addition to the 'traditional' ESTRACK data and voice services, as supported in all other ground



* *Several such 'logical' LAN segments can be configured within the same Local Area Network hardware. The technique is known as Virtual LAN (VLAN) technology.*

Snapshot of Cebreros Active and Passive Communications Installations

- 18 LAN switches/routers yielding ca. 1000 connections
- 4 full IP address ranges (254 user system addresses each)
- 35.7 km of optical fibre lengths for data, voice, video distribution and station base- band specific links
- 2 telecom provider and 7 ESA communications equipment cabinets installed in 3 different buildings
- 6.4 km of fixed copper cabling inside and between installation cabinets
- 682 cable runs validated via ca. 1400 logical/functional tests
- 2053 patchable cables for communications and connected equipment

stations, the Cebreros ICT infrastructure supports much more. All antenna front- and back-end equipment monitoring and control, previously still based on dedicated bus structures, is now supported over IP. Furthermore, IP telephony is deployed; LAN ports provide both the channel and the electrical power for the IP phones. Audio- and video-conferencing and video-distribution are also served, and so too are building-facility-management functions. With this thorough LAN technology concept, the only links that are needed between different buildings are optical fibres. This has big benefits for electrical grounding conditions and lightning protection.

Cebreros Active and Passive Communications Installations

The building of ESA's two deep-space ground stations near Perth and at Cebreros has been complemented by the enhancement of the OPSNET WAN topology in both Australia and Spain. Traditionally, OPSNET was a star network with ESOC as the hub, whereby each outstation was connected to the control centre via two diversely routed international leased lines (redundant pair). With the advent of the deep-space stations, this dual-link topology could be replaced by a ring topology, for ESOC-Villafranca-Cebreros. The ESOC-Perth-New Norcia ring is similar. The physical infrastructure conditions end-to-end must of course ensure that none of these links has a potential failure element in common with another link. The three links then form a ring in which any one site can still communicate with any other even if one link fails. The economic benefits are substantial. Instead of four international lines into the same foreign country, two can fulfil the needs. The capacity per line in the ring has to be larger than per line in a star configuration, but this is no disadvantage, as the ratio of price increase per capacity increase is strongly regressive. This redesign in fact paved the way for using 2 Mbit/s lines as standard building blocks for the rings. In recent years, this type of link has in fact become the market offering with the best price/capacity ratio for the type of trunks required for the ESA OPSNET, and is also deployed elsewhere.

The Benefits

The performance benefits of the modernised network are illustrated by the fact that excellent service-availability figures have been achieved both for X.25-based and IP-based missions, and that the design has been stable since the initial deployment in 2001 for New Norcia, with no need for subsequent adjustments. Key contributing factors are:

- high availability and redundancy
- enhanced IP QoS and prioritisation scheme
- capacity-management flexibility due to modularity of design and equipment
- unified physical infrastructure, with media commonality for all LAN-based station services
- uniform single-manufacturer installed base, facilitating efficient maintenance and operations support.

Economic benefits are already inherent in most of those factors. A particular example for flexibility is the support to 'Delta Differential One-way Ranging' (Delta-DOR) on the shared capacity available on the 2 Mbit/s rings. For Delta-DOR, the signal from an interplanetary spacecraft is recorded simultaneously at two deep-space stations, preceded and followed by calibrations using an extra-galactic radio source with a well-known position. The data volume of one Delta-DOR measurement is more than 10 Gbyte, and so if transmitted at normal telemetry transfer rates it would load the link for several days, but the Delta-DOR result must be available in far less than 24 hours. It is therefore quite a challenge to avoid the blocking of normal operations or the procurement of extra capacity at extra cost. However, in combination with a load-sharing file-transfer management scheme, the new 2 Mbit/s rings are able to support Delta-DOR transactions within a few hours with no interference with routine mission support.

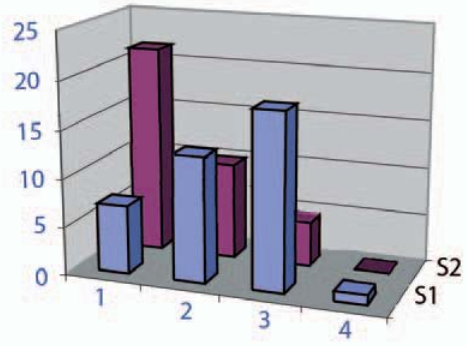
OPSNET-link rationalisations have also been made for other remote sites, increasing overall capacity and driving down absolute costs (see accompanying key indicators for 2004/2005).

Conclusion and Outlook

The commencement of routine operations at ESA's second deep-space ground station rounded off years of effort to modernise and future-proof all of the ESA tracking stations and their backbone communi-cations. The result is a LAN-LAN interconnecting system capable of connecting all space mission-support systems, from control centres to stations based on IP as the single data-transmission protocol.

The modernised infrastructure uses standard commercial equipment available from many vendors. This concept has brought, and will continue to bring, cost benefits in procurements, sparing, sustaining activities and in engineering, operations and maintenance services. The modularity of the implemented design gives ESA the freedom to use devices from another manufacturer should this become necessary or desirable.

	2Q 2004	4Q 2005
Total Leased Capacity, Mbit/s	7.1	21.6
Total Monthly Cost, 10 kEuro	12.99	9.98
Average kEuro per Mbit/s per month	18.30	4.62
Normalised Unit Cost	1.00	0.25



OPSNET cost/performance indicators: Capacity, Total Monthly Cost, Unit Cost and Normalised Unit Cost

The unified network architecture that has been deployed provides a high degree of flexibility and scalability, fostering cost-effectiveness in capacity and service management. It also includes IP connections for systems traditionally based on other technologies. Such high exploitation of state-of-the-art LAN technology has allowed considerable economies of scale. Where possible, due to the proximity of ground stations, i.e. in Australia and Spain, the topology of the WAN has been optimised. The change from a star to a ring topology with single high-speed lines has yielded economies of several hundred thousand Euros per year.

The ESTRACK-wide and flexible IP networking, in combination with its own firewall-based security perimeter, will yield further benefits for ESA, such as inter-Agency collaboration based on Space Link Extension protocol over IP, or support to remote maintenance from industry with reduced reaction times and travel costs.

For the time after the demise of X.25, there is the potential to change the telecommunications service types and their sourcing. This will require a solid cost/benefit analysis, including also the suitability of change-management processes for the operations concept of space missions and of ESTRACK. Given a positive assessment, a future OPSNET Wide Area Network could be sourced as a managed private network. The provider could be the same as for ESA's corporate network ESACOM, or a global competitor, depending on whether an exclusive or an alternate provider sourcing strategy is adopted at Agency level.

Acknowledgements

The modernisation of ESTRACK communications, closely interleaved with the construction of two new deep-space ground stations and the modernisation of other ESA ground stations, has been a long and intense collaborative effort involving many entities. The authors gratefully acknowledge the team spirit, support and contributions of colleagues in the ESOC Ground Station Systems Division, the Ground Facilities Operations Division, of NDSatCom, the Vega IT GmbH communications engineering team, the Serco GmbH operational communications facilities support, the maintenance and operations teams at each ground station, and trainees from the University of Catania. ESA is also indebted to XANTIC Australia, Telefonica Spain and T-Systems International Germany for the dedicated and coordinated support in the end-to-end optimisation of the OPSNET routings.

Resolutions Adopted at the ESA Council Meeting at Ministerial Level

First row, left to right: José Montilla Aguilera, Minister for Industry, Tourism and Trade (E), Laurens Jan Brinkhorst, Minister for Economic Affairs (NL), Jean-Jacques Dordain, Director General of the European Space Agency, Michael Glos, Federal Minister for Economics and Technologies (D), Maria J. A. van der Hoeven, Minister for Education, Culture and Science (NL), José Mariano Gago, Minister for Science, Technology and Higher Education (PT), Lord Sainsbury of Turville, Parliamentary Under Secretary of State for Science and Innovation (UK), François Biltgen, Minister for Culture, Higher Education and Research (LUX), Guido Possa, Vice Minister for Teaching, Universities and Research (I), Sigmar Wittig, Chairman of ESA Council

Second row, left to right: Tony Killeen, Minister of State, Department of Enterprise, Trade and Employment (IRL), Virendra Jha, Acting President of the Canadian Space Agency (CDN), Kari Tilli, Director of the National Agency for Technology (SF), Charles Kleiber, Secretary of State for Education and Research (CH), Marc Verwilghen, Minister for Economy, Foreign Trade and Science Policy (B), Helge Sander, Minister for Science, Technology and Innovation (DK), François Goulard, Minister for Higher Education and Research (F)

Third row, left to right: Ioannis Tsoukalas, Secretary General for Research and Technology, Ministry of Development (GR), Thomas Östros, Minister for Industry and Trade (S), Georg Wilhelm Adamowitsch, Secretary of State, Bundesministerium für Wirtschaft und Technologie (D), Eduard Mainoni, State Secretary, Federal Ministry for Transport, Innovation & Technology (A), Frode Berge, State Secretary, Ministry of Trade and Industry (N)

As reported in the November issue of ESA Bulletin, at their meeting in Berlin on 5 and 6 December the Ministers responsible for space activities in the Agency's 17 Member States and Canada endorsed the continuation of a set of ongoing ESA programmes and agreed to undertake major new initiatives designed to give Europe a clear vision and tangible means to further strengthen its space exploration and exploitation activities. The Ministers also reaffirmed the strategic importance of Europe continuously improving its scientific, technological and industrial capabilities in the space field, to enable it to better respond to the expectations of its citizens concerning the environment, quality of life and security. A major political step was achieved with the approval of an overall European launcher policy ensuring coherence between the launcher and satellite fields.

On the programmatic side, the Ministers took decisions concerning the Agency's mandatory activities (scientific and basic) and optional programmes (Earth observation, telecommunications, satellite navigation, human spaceflight, microgravity, exploration, launchers).

The six Resolutions adopted by the Ministers were as follows:
– Resolution on the Agency's Long-Term Plan for Discovery and Competitiveness (ESA/C-M/CLXXXV/Res. 1 (Final))
– Resolution on the Level of Resources for the Agency's Mandatory Activities 2006-2010 (ESA/C-M/CLXXXV/Res. 2 (Final))
– Resolution on the Evolution of the European Launcher Sector (ESA/C-M/CLXXXV/Res. 3 (Final))
– Resolution on the CSG - Extension until end-2008 (ESA/C-M/CLXXXV/Res. 4 (Final))
– Resolution on the Evolution of the Agency (ESA/C-M/CLXXXV/Res. 5 (Final)), and
– Resolution on the International Space Station Programme (ESA/C-M/CLXXXV/Res. 6 (Final)).

RESOLUTION ON THE AGENCY'S LONG-TERM PLAN FOR DISCOVERY AND COMPETITIVENESS

(adopted on 6 December 2005)

Council, meeting at Ministerial Level,

RECALLING the purpose of the Agency as outlined in Article II of the Convention,

HAVING REGARD to the Resolution on directions for the Agency's evolution and policy: "Space Serving European Citizens" (ESA/C-M/CLIV/Res. 1 (Final)) adopted at Ministerial Level in Edinburgh on 15 November 2001,

HAVING REGARD to the Framework Agreement between the European Space Agency and the European Community, which came into force on 28 May 2004,

HAVING REGARD to the Orientations endorsed by the Councils at Ministerial Level on the occasion of the Space Councils held on 26 November 2004 (ESA/C-M(2004)1, rev.1), 7 June 2005 (ESA/C-M(2005)1) and 28 November 2005 (ESA/C-M(2005)22),

HAVING REGARD to the Resolution on the evolution of the Agency's financial, budgetary and industrial policies (ESA/C/CLXXI/Res. 2 (Final)), adopted by Council on 17 June 2004, and the Resolution on the Financial Regulations (ESA/C/CLXXIX/Res. 7 (Final)), adopted on 21 June 2005,

HAVING REGARD to the Director General's proposal for the 2005 Council Meeting at Ministerial Level (ESA/C-M(2005)6),

CHAPTER I
EUROPEAN VISION FOR SPACE EXPLORATION AND EXPLOITATION

1. WELCOMES the progress made in recent years to ensure that space activities are addressed at the highest political level in Europe, in response to the requirement already expressed during the Agency's Ministerial Meeting of Council held in Edinburgh in 2001 and still confirmed, in the international context, by the increasing attention and resources dedicated to space activities both in the established, such as the United States and Russia, and in the new space powers, such as China and India;

2. WELCOMES the steps made to heighten European citizens' awareness of space activities and their benefits; in particular, the success of the recent European scientific missions, such as Envisat, Huygens and Mars Express, which has confirmed, that combined European skills and efforts allow Europe to succeed in the most challenging enterprises and to reach a level of excellence for discovery and innovation in the global context;

3. WELCOMES Greece and Luxembourg as new Member States acceding to the ESA Convention, thus enhancing the resources and capabilities of the European space sector for the benefit of European citizens;

4. WELCOMES the improvements made in fostering the European dimension of space related activities in Europe in particular through the cooperation between the Agency and the European Community established by the Framework Agreement referred to in the preamble;

5. RECOGNISES the steps made towards the development of an overall European Space Policy as reflected in the orientations elaborated by the Space Councils, as mentioned in the preamble, which provide the guidelines for Europe's strategy and priorities in space and outline the roles and responsibilities of the European Union, the Agency and their Member States and Co-operating States, and INVITES the Director General and the Member States to pursue their efforts to elaborate such an overall European Space Policy;

6. WELCOMES the progress made in the implementation of the GNSS initiative, including the EGNOS and Galileo programmes and RECOGNISES that this initiative represents the largest recent European effort in the space field, combining the interests of the different actors in the public sector together with those in the manufacturing and operating industries; and EMPHASISES that the Galileo initiative is a further opportunity for Europe to affirm its prominence in space activities in the international context;

7. WELCOMES the second generation of operational meteorological satellites developed by the Agency for Eumetsat, NOTES the increased use of space infrastructures, to mitigate disasters also in the frame of the cooperation established via the International Charter on Space and Major Disasters and WELCOMES the substantial progress achieved by the EU and the Agency in developing forerunner services for the GMES initiative, which provides the ground for a key European contribution to the ten year plans set within the Global Earth Observation System of Systems initiative;

8. NOTES, with appreciation, the concrete implementation of the Plans for European Cooperating States (PECS) and the increase in the volume and quality of the relationships between the Agency and international partners, the enhanced cooperation with the Russian Federation, in particular in the launchers field, with the People's Republic of China and with India within the scientific programme and EMPHASISES that the Agency has extended the technological cooperation with third countries while preserving the strategic nature of its programmes and the role of the European industry;

9. TAKES NOTE of the progress achieved in the Agency's managerial and technical capabilities and of the efforts made in improving its capacity to respond to the broader role requested in the frame of the above-mentioned overall European Space Policy and international cooperation; and therefore INVITES the Director General to pursue such efforts;

10. NOTES the steps made in combining space-related capabilities and skills within the space sector in Europe for the implementation of ESA and national programmes; ACKNOWLEDGES the need to pursue the related efforts, also through the systematic research of the optimal utilization of the Agency's and Member States' capabilities, thus avoiding useless duplications of effort, and RECALLS the role of the Agency as technological and scientific pole for those States relying primarily on its expertise;

11. RECOGNISES that the global scenario in the space field is rapidly evolving, with the increase of resources dedicated to homeland security and defence and of the number of major actors, which are mastering major space technologies for civil and dual-use applications at competitive conditions;

12. NOTES with concern the difficulties encountered in the recent years by the European industries, resulting from a significant downturn in the commercial market on which they are dependent as well as from the competition with industries working at lower production costs, while the industries of the some other space-faring nations benefit from a strong institutional captive market; TAKES NOTE of the measures taken by the European industry to improve its position, through difficult reorganisation and concentration processes which have led to a reduction of the volume and of the distribution of European capabilities;

13. NOTES that the urgency to face the above difficulties has made necessary the increase of efforts for production activities, thus reducing the availability of the resources for the funding of research and development activities which are one of the key factors for acquiring new technologies and maintaining a competitive stance; NOTES the expectations, as expressed in the Space Councils' orientations mentioned above, that the European Union will use its full potential to lead in identifying and bringing together user needs and will identify and allocate resources for ensuring the availability and continuity of space-based operational services supporting its policies, in particular for the joint ESA-EU initiatives GNSS and GMES;

14 REAFFIRMS the strategic importance for Europe of continuously improving its scientific, technological and industrial capabilities in the space field, in order to increase Europe's capability to respond to the expectations of its citizens in the fields of environment, quality of life and security, supported by a European scientific community being at the leading edge of the progress of knowledge and a European industrial sector being successful on the commercial market, thus contributing to growth and employment and UNDERLINES that the current context requires urgent actions to improve the scientific and technological capabilities of Europe in order to consolidate its excellence and reinforce its ability to reap the benefits of the commercial market;

15. CONSIDERS that the above urgent actions require the continuous fostering of European cooperation in the space field, including all space value chain segments, by the further development of an overall European Space Policy encompassing ESA, EU, national and industrial programmes and by the allocation of the available resources and capabilities to common European initiatives, so as to reach the critical mass to face the worldwide competition and DECIDES, by taking account of the orientations of the Space

Councils on the respective roles and responsibilities of the Agency and the European Union, that the Agency's Long-Term Plan be focused on discovery and competitiveness;

16. CONSIDERS, taking into account the extent of the resources expected for the financing of ESA programmes and activities, that it is necessary to streamline the allocation of such resources by directing the investments to fields in which:
    a. within the overall European Space Policy, the Agency will play a leading role;
    b. Europe has demonstrated its ability to excel;
    c. significant user demand can be consolidated;
    d. the technological value is high;

    and thereby allowing unrestricted availability to Europe of critical technologies;

17. EMPHASISES therefore that priority in the short term must be given to the Agency's programmes providing the necessary scientific progress and technological steps to enhance the European competitiveness, and better serving the citizens;

18. ACKNOWLEDGES that given the present uncertainties related to:
    – the assembly and exploitation of the International Space Station;
    – the level and timing of the EU funding for the EU led programmes, in particular GMES;
    – the evolution of the institutional and commercial launch services demand;

    part of the ESA activities relevant to the above context should be implemented within a stepped approach, and AGREES upon the Director General's proposal to plan for them a second decision step at a next Council at Ministerial Level to be organized in early 2008, as outlined in Chapter IV below;

19. WELCOMES the Director General's proposal referred to in the preamble, which provides the basis for the decisions taken on this day for implementing the first step of the Long-Term Plan provided for in Chapter II below;

CHAPTER II
THE AGENCY'S LONG-TERM PLAN 2006-2015

20. WELCOMES the Director General's proposal of a Long-Term Plan 2006-2015 consistent with the orientations provided by the Space Councils and providing a strategic framework for implementing Member States' priorities, objectives and correlated financial resources for a period of ten years, thereby favouring coordination with EU and national initiatives and providing the financial frames per programme domain for approved and not yet approved programmes and initiatives; RECALLS that the Long-Term Plan does not imply by itself any financial commitment by the Member States;

21. AGREES that such a Long-Term Plan 2006-2015 is being developed along the following strategic guidelines and be subject to regular revisions and assessments to take into account the factors which may have an impact on its evolution:

    – Focus on science and discovery, foster innovation and transfer the relevant progress and knowledge to enhance existing and open new operational applications;

    – Consolidate European competitiveness and technological excellence in co-operation with industry and operators;

    – Promote and extend the utilisation of space-based infrastructures and services in current and new application domains;

    – Ensure the availability and maintenance of European sources and in particular the unrestricted availability to Europe of critical capabilities, components and technologies;

    – Enhance coherence in the development and growth of all European space capacities;

    – Maintain a balance in international relations, where Member States derive benefits from their investments, be it through cooperation or competition;

22. INVITES the Director General to implement the above mentioned guidelines through the inclusion in the Long Term Plan of consistent overall and sectorial long-term roadmaps illustrating:
   – the link among demand requirements, the space solution offered through ESA programmes and missions, the expected benefit for Member States and citizens,
   – the link between research and technology developments and their planned utilisation in ESA programmes and missions,
   – the overall coherence in the optimal utilisation in ESA programmes and missions of all ESA developed products, so implementing in particular the relevant principles included in the Resolution on Launchers (ESA/C-M/CLXXXV/Res. 3 (Final)) adopted today,

   and outlining how ESA programmes and missions can on the one hand enhance European competitiveness, and on the other hand lead to the availability, reliability and upgrading of space-based services and applications required to achieve Europe's overall objectives, be they strategic, economic, social, cultural, scientific, or technological, and improve the daily life of European citizens;

23. AGREES that for the implementation of such a Long-Term Plan, the Agency shall provide the necessary technical and managerial skills, both through its own resources and expertise and by availing itself of the competences and expertise existing in Europe, both in the public and in the private sector;

24. INVITES the Director General to further elaborate, on the basis of the above strategic guidelines, such a Long-Term Plan 2006-2015, to issue a report to Council by March 2006 giving his evaluation on the progress achieved and submit the Long-Term Plan to Council for endorsement on a yearly basis starting from 2006, in accordance with the Financial Regulations. Thereafter, a report will be issued by the Director General on an annual basis giving the progress of the implementation of the endorsed Long-Term Plan;

CHAPTER III
DECISIONS ON PROGRAMMES AND ACTIVITIES

25. WELCOMES the decisions taken this day in respect of the Agency's mandatory activities and optional programmes, implementing the first step of the 2006-2015 Long-Term Plan and pursuing its strategic guidelines, as follows:

   a) the decisions including:
      – the Resolution on the Level of Resources for the Agency Mandatory activities 2006-2010 adopted by Council on the same date hereof;
      – the subscription to the European Space Exploration Programme Aurora, comprising its first Exploration mission ExoMars and a Core Programme to prepare for future exploration missions;
      – the subscription to the Earth Observation Envelope Programme;
      – the subscription to the ELIPS Programme - Period 2;

      which confirm the engagement by ESA Member States to boost the progress in science, and to be at the leading edge of discovery, thus supporting the development of competitive services and future applications for European citizens;

   b) the decisions including:
      – the subscription to the ARTES Programme, focused on the telecommunication technologies, applications and mission demonstrations, including in particular the preparation of the AlphaSat Programme;
      – the subscription to the GSTP Programme, aimed at developing and demonstrating in-orbit advanced technologies as well as stimulating new services, and in particular at preparing and demonstrating new concepts such as formation flying satellites which may achieve breakthroughs in future space systems and enable missions of strategic and economic value for space science, Earth observation and new domains, in particular related to security;

   which both contribute to consolidate European competitiveness and technological excellence in cooperation with industry and operators;

   c) the decisions including:
      – the subscription to the GMES Space Component Programme, representing also a key European contribution to the GEOSS initiative;

– the subscription to the GSTP Programme for the preparation of a new dedicated technology programme, focused on the development of technologies in particular for non-dependence and security;

which, together with those relevant to the development and exploitation of the European launchers, are focused on the non-dependence and availability of European sources;

d) the decision regarding the subscription to the programme conducted in the frame of international cooperation, i.e. the International Space Station Exploitation Programme Period 2;

which, together with science and the other exploration programmes mentioned in point a) above, consolidate the cooperation with space faring countries, while the programmes related to competitiveness, non-dependence and availability of European sources mentioned in points b) and c) above provide the necessary balance in the domain of relations with international actors;

26. WELCOMES, for the implementation of the above activities and programmes, the entry into force on this day of the Declarations, amended Declarations, and amended additional Declarations or their subscriptions by the Participating States concerned, the corresponding financial envelopes being indicated at 2006 economic conditions, or at other economic conditions when specified;

27. INVITES the Director General to elaborate, in close coordination with the European Community, an organisational scheme and implementation plan for the GMES initiative to ensure its long-term operational sustainability and enable timely responses to policy and user requirements and to propose relevant decisions to Council for approval;

28. WELCOMES the Enabling Resolution on the European GNSS Evolution Programme adopted by the Council on 3 November 2005 (ESA/C/CLXXXI/Res. 1 (Final)) and invites Member States to finalize the relevant Declaration and subscriptions so as to allow the start of the programme activities during 2006;

CHAPTER IV
DECISIONS TO BE PREPARED FOR THE COUNCIL AT MINISTERIAL LEVEL PLANNED FOR 2008

29. INVITES the Director General to prepare, in close coordination with Member States, and based on the decisions taken on the same date hereof, the elements contributing to the progressive development of an overall European Space Policy and Programme to be endorsed by the Space Councils before 2008, following consultations with the high-level representatives of the Member States of the Agency and of the European Community as foreseen in art. 8.4 of the Framework Agreement mentioned in the preamble;

30. INVITES the Director General to enhance cooperation with the EU, including in the frame of the cooperation established with the European Community under the Framework Agreement mentioned in the preamble, for developing multipurpose and security related technologies, in addition to those in support of already identified EU policies;

31. INVITES the Director General to prepare decisions to be proposed at the next Ministerial Council planned for early 2008, concerning among others:
- the launchers sector, consistent with the Resolution on the evolution of the European Launcher Sector (ESA/C-M/CLXXXV/Res. 3 (Final)) adopted on the same date hereof;
- the ISS programmes, consistent with the Resolution on the International Space Station (ESA/C-M/CLXXXV/Res. 6 (Final)) adopted on the same date hereof;
- the further Agency contribution to the GMES initiative, on the basis of the arrangements to be concluded with the European Community;
- the development of further meteorology programmes responding to Eumetsat requirements;
- the development and in-orbit demonstration of a system of satellites flying in formation, on the basis of preparatory activities decided today;
- the next steps for exploration, on the basis of preparatory activities decided today for the Core programme and of discussions with international partners engaged in exploration activities;
- the start of a dedicated technology programme for the development of critical technologies for European non-dependence, of enabling technologies for civil security applications and of applications of multipurpose technologies to the space sector.

RESOLUTION ON THE LEVEL OF RESOURCES FOR THE AGENCY'S MANDATORY ACTIVITIES 2006-2010

(adopted on 6 December 2005)

Council, meeting at Ministerial Level,

HAVING REGARD to Articles V.1 (a) and XI.5 (a) (ii) and (iii) of the Convention,

HAVING REGARD to the Director General's proposal for the Level of Resources for the Agency's mandatory activities 2006-2010 (ESA/C-M(2005)21),

1. DECIDES by a unanimous vote of all Member States to determine the level of resources to be made available to the Agency for the period 2006-2010, which is broken down as follows:

   (a) for the Scientific Programme, an amount of 2080.0 MEuro,

2006	2007	2008	2009	2010	TOTAL
395.7	405.6	415.8	426.1	436.8	2080.0

   (b) for the Agency's basic activities, an amount of 998.0 MEuro,

2006	2007	2008	2009	2010	TOTAL
199.6	199.6	199.6	199.6	199.6	998.0

   to be financed by:
   – 188.6 MEuro of contributions by Member States and Canada per year, amounting to 943.0 MEuro;
   – 11.0 MEuro of other income per year, amounting to 55.0 MEuro.

   The amounts mentioned in sections (a) and (b) are in MEuro at current economic conditions and are not subject to any form of adjustment for price variations.

2. STRESSES its wish to ensure the implementation of planned missions and preparations for the follow-on Cosmic Vision 2015-2025 Programme based on a detailed analysis of risk and cost for each mission approved by the Science Programme Committee of the Agency.

3. UNDERLINES the excellence of the Scientific Programme, its worldwide reputation resulting from its successful scientific missions, its broad international cooperation and its contribution to the development and qualification of advanced technologies, supporting the general expertise of the Agency, its Member States and industry; and INVITES the Director General to continue to develop international cooperation on scientific projects.

4. INVITES the Director General to take the necessary steps to enhance the synergies of the Scientific Programme with:

   (a) the other programmes of the Agency in the fields of space exploration, Earth observation and ISS utilization; and
   (b) the Member States' programmes, other European programmes and international cooperative ventures.

5. UNDERLINES the importance of the basic activities as an essential element for the Agency's technological and managerial capabilities; EXPRESSES its support to the Director General in his efforts to optimise the use of the resources of the General Budget, with emphasis on providing, within the Technology Research Programme (TRP), qualified technologies, and on supporting, within the General Studies Programme (GSP), the preparation of future activities, with the overall objective of reducing the risks for new space missions; EXPRESSES its support to the objectives and the continuation of the Earthnet Programme; and EXPRESSES further its support to the activities undertaken in the Technology Transfer and Education Programmes.

6. NOTES that Greece and Luxembourg are participating for the first time in the formal decision on the Agency's Level of Resources and INVITES the Director General to continue the Agency's dedicated exercise of involving industrial and scientific organisations of these Member States in activities financed through the budgets for the mandatory activities, with a view to achieving the appropriate level of participation of the interested entities at the earliest opportunity.

RESOLUTION ON THE EVOLUTION OF THE EUROPEAN LAUNCHER SECTOR

(adopted on 6 December 2005)

Council, meeting at Ministerial Level,

HAVING REGARD to the Resolution on the restructuring of the Ariane launcher sector (ESA/C-M/CLXV/Res. 1 (Final)) and to the Resolution on 2010 perspectives for the European launcher sector (ESA/C-M/CLXV/Res. 4 (Final)), both adopted at Ministerial Level on 27 May 2003,

HAVING REGARD to the Resolution on directions for the Agency's evolution and policy: "Space Serving European Citizens" (ESA/C-M/CLIV/Res. 1 (Final)), adopted at Ministerial Level on 15 November 2001, and in particular Chapter VI thereof on the evolution of the European launcher sector,

HAVING REGARD to the Declaration by certain European Governments on the Ariane launcher production phase, which entered into force on 20 December 2001 and is applicable until the end of 2006 (the "Ariane Production Declaration"),

HAVING REGARD to the Resolution on the Agency's mandate for the current Ariane launcher production phase and the evolution towards an overall coherent strategy in the European launcher sector (ESA/C/CLXIX/Res. 4 (Final)) adopted on 4 February 2004,

HAVING REGARD to the Resolution on the renewal of the Ariane launcher production phase (ESA/C/CLII/Res. 1 (Final)), adopted on 11 October 2001, by which Council has accepted that the Agency should fulfil the mandate entrusted to it by the Governments party to the Ariane Production Declaration,

HAVING REGARD to the Convention between the Agency and Arianespace on the Ariane launcher production phase, signed on 3 April 2004 ("The 2004 ESA/Arianespace Convention") and its Riders, and in particular its Rider 5.3 on the exploitation of the Soyuz launcher from the CSG (ESA/C(2005)18),

HAVING REGARD to the general principles of the bilateral framework agreements on the use of the Ariane launcher to be concluded between the Agency and European user institutions (ESA/C(2004)37), approved on 4 February 2004,

HAVING REGARD to the Agreement between the European Space Agency and the Government of the French Republic on the Agency's launch sites and associated facilities at the CSG (hereinafter referred to as "The ELA Agreement") signed on 11 April 2002,

HAVING REGARD to the Declaration on the Small Launcher Development Programme (ESA/PB-ARIANE/CLXXI/Dec. 2, rev. 10 (Final)), drawn up on 24 June 1998,

HAVING REGARD to the Additional Declaration to the Small Launcher Development Programme on the P80 solid-propulsion stage demonstrator drawn up on 15 December 2000 (ESA/PB-ARIANE/CLXXXIII/Dec. 1, (Final), rev. 1),

HAVING REGARD to the Resolution concerning cooperation between ESA and Russia in the field of launchers (ESA/C/CLIX/Res.3 (Final)), adopted by Council in Montreal (Canada) on 13 June 2002,

HAVING REGARD to the Declaration on the Soyuz at the CSG Programme (ESA/PB-ARIANE/CCVI/Dec. 2, rev. 2 (Final)) drawn up on 4 February 2004,

HAVING REGARD to the Agreement between the European Space Agency and the Russian Federal Space Agency on long-term cooperation and partnership in the field of the development, implementation and use of launchers (hereinafter referred to as "The ESA/FSA Launcher Agreement"), signed in Moscow on 19 January 2005,

HAVING REGARD to the Agreement between the European Space Agency and the Government of the French Republic concerning the Soyuz Launch Site (ELS) at the Guiana Space Centre (hereinafter referred to as "The ELS Agreement"), signed on 21 March 2005,

HAVING REGARD to the Resolution on the Agency's legal liability adopted by Council on 13 December 1977 (ESA/C/XXII/Res.3) (hereinafter referred to as "The 1977 Resolution"),

CONSIDERING the provisions of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies, of 27 January 1967, the provisions of the Convention on International Liability for Damage Caused by Space Objects of 1 September 1972 and of other multilateral treaties and agreements on the exploration and peaceful uses of outer space, to which the Member States of the Agency are parties, and which the Agency has accepted,

HAVING REGARD to the document entitled "Reference Framework for a coherent implementation, as from 2007, of decisions related to the restructuring of the European launcher sector" (ESA/PB-ARIANE (2005)3, rev 3),

HAVING REGARD to the document entitled "Implementation modalities of the ESA Convention (Article VIII) for launchers" (ESA/C/R(2005)3, rev. 1),

HAVING REGARD to the principles of the Intergovernmental Agreement providing a new framework for the launchers exploitation phase beyond 2008, as included in ESA/GOV. REP. ARIANE DEC.(2005)4,

HAVING REGARD to the Convention of the European Space Agency and in particular Articles II, V and VIII, thereof,

I SECURING GUARANTEED ACCESS TO SPACE FOR EUROPE

1. UNDERLINES that the guarantee of an available, reliable, and independent access to space at affordable conditions has been and will remain an essential goal for Europe, enabling the implementation of a European Space Policy.

2. ACKNOWLEDGES that operational launch systems together with the European relevant industrial capabilities for research and technology, development and subsequent exploitation, an operational launch range and a launch-service provider constitute the main elements of such a guarantee for all European customers, in particular for European institutional missions.

3. RECALLS that taking into account the limited size of the European institutional market and the lack of a launch-service procurement policy for European institutional missions, capturing a significant share of the worldwide commercial market has been an important factor in achieving and maintaining such a guaranteed access to space.

4. RECOGNISES that such a guarantee requires striking a proper balance between public and private sector commitments in order to support the competitiveness of the European launcher sector.

5. NOTES that, following the Council Meeting held at Ministerial Level in 2001, a sharp downturn in the commercial market, not compensated by institutional procurements, and the entry of aggressive new competitors leading to a drastic drop in market prices, endangered the existence of the European launcher sector. These factors, aggravated by the consequences of the failure of the first launch of the Ariane-5 ECA, led in 2003 to the decision to set up the following specific measures in order to secure access to space for Europe in the short term:

   – the Ariane-5 Recovery Plan for a timely return to flight;
   – the European Guaranteed Access to Space (EGAS) Ariane Programme;
   – the Soyuz at the CSG Programme to enhance the flexibility of launch services offered by Arianespace;
   – the Future Launchers Preparatory Programme (FLPP) to prepare the technologies necessary for new launcher developments.

6. ACKNOWLEDGES the progress achieved through such measures and through the ongoing industrial restructuring which has led to the successful return to flight of Ariane-5 ECA, and to positive Arianespace financial results.

7. ACKNOWLEDGES the progress achieved in the implementation of the small launcher and P80 development programmes referred to in the preamble, and RECOGNISES the need to prepare the Vega exploitation phase in accordance with the principles referred to in Chapter III and taking into account the industrial commitments referred to in the preamble.

8. ACKNOWLEDGES the progress achieved in the implementation of the Soyuz at CSG programme referred to in the preamble, and RECALLS that the exploitation of the Soyuz launcher by Arianespace from the CSG is expected to provide significant support to the exploitation of the Ariane launcher.

9. RECOGNISES the need to further consolidate the European launcher sector and WELCOMES the confirmation and renewal of Member States' interest in supporting such consolidation through the launcher development programmes subscribed on this same day, as follows:
   – the Ariane-5 ARTA Programme (ESA/PB-ARIANE/CLIV/Dec.3, rev. 12 (Final)), covering all activities during the period 2007-2010;
   – the Ariane-5 ACEP Programme (ESA/PB-ARIANE/CCXX/Dec.2 (Final)) for activities to be undertaken in the period 2006-2010;
   – the Vega Research and Technology Accompaniment (VERTA) Programme (ESA/PB-ARIANE/CCXXII/Dec. 1 (Final)), for activities to be undertaken in the period 2006-2010;
   – the Future Launchers Preparatory Programme (ESA/PB-ARIANE/CCI/Dec.1, rev. 3 (Final)) for activities to be undertaken in Period 2 Step 1 (2006-2009).

10. RECOGNISES that beyond the consolidation referred to in paragraph 9, decisions must be taken in 2008, in order to secure the guaranteed access to space for Europe, in accordance with the principles concerning the launchers exploitation phase beyond 2008, including the CSG launch range, referred to in Chapters III and V below, and on the basis of the following criteria:

   – sustainability of the European industrial launcher sector;
   – adaptation to the core European institutional needs;
   – innovative technological and industrial capabilities providing quick reactivity to respond to the evolving launch-service demand;
   – relevance of the launchers development to user requirements.

II THE ARIANE LAUNCHER EXPLOITATION UP TO END-2008

11 WELCOMES the extension of the Ariane Production Declaration up to end-2008 and ACCEPTS that the Agency fulfils the mandate entrusted to it by the Governments party to the Ariane Production Declaration, from the date of its entry into force.

12. INVITES the Director General to negotiate the extension of the 2004 ESA/Arianespace Convention referred to in the preamble, which should remain in force for the same duration as the Ariane Production Declaration, hereafter referred to as "The ESA/Arianespace Convention".

13. ACCEPTS, subject to the terms of the ESA/Arianespace Convention, to make available to Arianespace or, with the latter's agreement, to its suppliers, the production master files and facilities owned by the Agency, funded by the Ariane development programmes, necessary for the manufacture, marketing and launch of the operational Ariane launcher, together with its intellectual property rights deriving from the Ariane development programmes.

14. ACCEPTS that the Ariane Launcher Programme Board is entrusted with the role set out in Section II.9 of the Ariane Production Declaration.

15. ACCEPTS that the Director General shall exercise the duties of depository of the Ariane Production Declaration and also those set out in Section IV.2 thereof.

III PREPARATION OF A NEW FRAMEWORK FOR THE LAUNCHERS EXPLOITATION PHASE BEYOND 2008

16. CONSIDERING the importance of the guarantee of access to space for Europe as referred to in paragraph 1, RECOGNISES the need to prepare a common framework for the launchers exploitation phase beyond 2008 implementing a coherent European launcher strategy and succeeding to the scheme of the Ariane Production Declaration, based on the following principles:

a) Such guaranteed access to space shall be assured by (i) launchers developed and produced by European industry, primarily designed to respond to European institutional mission needs, (ii) an operational European launch base, and (iii) European industrial capabilities.

b) The European launch base shall be maintained in operational condition so as to allow ready access to space for all Member States.

c) ESA launcher programmes shall be primarily focused on research, technology and development activities, thus contributing, together with national space programmes, to reinforcing European industrial capabilities.

d) When launchers are developed within the framework of the Agency's programmes ("ESA-developed launchers"), a launch-service provider, reflecting the interests of the European launcher industry, shall be entrusted with the execution of the exploitation phase of such launchers in compliance with the roles and responsibilities defined in ESA/PB-ARIANE(2005)3, rev. 3, referred to in the preamble.

e) Following an ESA Council decision, non-ESA developed launchers may be operated by the launch service provider from the CSG in compliance with the relevant Agreements to be concluded between ESA and France, and under the condition that their exploitation:

– is defined in specific arrangements to be concluded between the launch-service provider and ESA;
– is in support to the exploitation of ESA-developed launchers in accordance with the payload allocation policy referred to in paragraph 20 below;
– does not induce any additional costs for Member States.

f) The utilisation of ESA-developed launchers for appropriate payloads of European institutional missions shall be in line with the following principles:

(i) The launch-service procurement for ESA missions shall comply with the provisions of Chapter IV.

(ii) Member States are invited to take the ESA-developed launchers and the Soyuz launcher operated from the CSG into account, on the basis of the principles contained in Chapter IV, when defining and executing their national programmes as well as the European and other international programmes in which they are involved, except where such use compared to the use of other launchers or space transport means available at the envisaged time presents an unreasonable disadvantage with regard to cost, reliability or mission suitability.

17. INVITES the Director General, in close consultation with Member States, to pursue discussions with the European Community so as to assess the conditions for setting up a regulatory framework governing: (i) the procurement of launch services for programmes of the European Community and for other European institutional programmes, (ii) competition so as to ensure a level playing field for Europe in the worldwide market for launch services.

18. NOTES that Member States shall conclude as soon as possible and by end-2006 at the latest, on the basis of the relevant provisions of Chapter III, an Intergovernmental Agreement with a view to its entry into force on 1 January 2009, and NOTES the principles of the Intergovernmental Agreement referred to in the preamble.

19. NOTES that Member States participating in the relevant Agency launcher development programmes shall conclude, within the frame of the Agency, as soon as possible and in time for the entry into force of the above Intergovernmental Agreement, the relevant exploitation agreement(s) for Ariane and Vega, setting the specific principles for the exploitation phase of each launcher concerned, in compliance with the provisions of the Agreement referred to in paragraph 16.

20. INVITES the Director General to conclude with the launch-service provider specific arrangements in order to implement the principles contained in such exploitation agreements. Such arrangements shall in particular contain the commitment of the launch-service provider to:
– implement a payload allocation policy with the objective to secure, for each launcher, the minimum launch rate contributing to maintain the European industrial capabilities necessary to secure the guarantee of access to space for Europe and taking into account the range of their respective performances;

– a business plan, defined on the basis of committing objectives agreed with the Agency such as cost, reliability, launch rate capability, and schedule and jointly agreed, with respect to ESA developed launchers, with the relevant launcher-system prime contractor;

– provide full visibility to ESA Member States.

21. NOTES that, for ESA-developed launchers other than Ariane, the regime defined by the 1977 Resolution needs to be adapted according to the following principles:

– This liability shall be shared between France and ESA, in their capacity as launching States; France shall bear one-third of such liability and ESA two-thirds. ESA's liability shall be shared, according to a scale to be agreed, among Member States which are both participating in the relevant launcher development programme(s) and having an industrial return in their exploitation.

– Other States may, if appropriate, share such liability, it being understood that, unless otherwise agreed among the parties concerned, the liability share of ESA in its capacity as launching State will be reduced accordingly.

– The launch-service provider shall be required to reimburse the parties mentioned above, according to their above-mentioned liability shares, the amount they may be liable to pay for any damage caused by the relevant launches, within a ceiling of 60 MEuro per launch.

22. INVITES the Director General to take all necessary actions in order for such principles concerning international liability for the Vega launches to be effective as from 1 January 2009, it being understood that the international liability schemes currently applicable to the Ariane and Soyuz launches and defined in the relevant agreements referred to in the preamble, shall remain unchanged.

IV. LAUNCH-SERVICE PROCUREMENT POLICY FOR ESA MISSIONS

23. CONSIDERING the importance of ensuring coherence among the different Agency programmes and TAKING ACCOUNT of the requirements of the programmes for which launch services are to be provided, the Director General shall comply with the following principles when implementing Article VIII of the ESA Convention:

a) any new satellite platform, satellite or mission to be developed by the Agency, shall be conceived so as to be compatible with the use of at least one of the ESA-developed launchers or with the Soyuz launcher operated from the CSG, within the range of their respective performances, unless this is not feasible in respect of reliability and mission suitability;

b) any new mission to be developed by the Agency shall plan for a launch-service back-up solution and the conditions for its use shall be defined at the time of the selection of the launcher envisaged for that mission;

c) preference shall be granted to launchers, referred to in Article VIII.1 of the ESA Convention, in the following order of priority:

– ESA-developed launchers,

– the Soyuz launcher operated from the CSG, when comparing the options to launch ESA missions by non-ESA-developed launchers,

– other launchers,

provided that such preference does not present an unreasonable disadvantage in respect of cost, in accordance with paragraph 24, reliability and mission suitability.

24. ENDORSES the implementation modalities of the ESA Convention (Article VIII) for launchers, as included in ESA/C/R(2005)3, rev.1 and AGREES that the launch-service costs provided for therein do not constitute, for future ESA missions, an unreasonable disadvantage within the meaning of Article VIII of the ESA Convention. Consequently, subject to the provisions of paragraph 27,

the Director General shall assess the cost of ESA missions in the relevant programme proposals on the basis of ESA/C/R(2005)3, rev.1. As a result the Scientific Programme and the Programme Declarations requiring the use of launch services shall include, in compliance with such launch-service costs, the relevant financial provisions.

25. ACKNOWLEDGES that Member States which fulfil at least one of the following two conditions: (i) no participation in the relevant ESA launcher development programmes, (ii) no industrial return in the relevant launchers' exploitation, have no undertaking to ensure that the launch services making use of ESA-developed launchers stay within the costs referred to in paragraphs 24 and 27.

26. TAKES NOTE that the VERTA Programme referred to in the preamble provides for the necessary means to ensure that no additional costs with respect to those currently referred to in Programme Declarations in force on the day of the approval of the present Resolution, will be borne by States participating in programmes requiring the use of the Vega launch services covered by the VERTA Programme, and TAKES NOTE that in case of delays in the Vega qualification which would introduce unreasonable delays for a planned ESA mission on a VERTA flight, Rockot will provide the related launch service unless this is not feasible with respect to cost, reliability and mission suitability.

27. INVITES the Director General to submit every two years to Council a status report on the evolution of the respective launch services for Ariane, Vega and Soyuz, and further INVITES the Director General to perform periodic reviews of launch services for ESA missions, starting with the following reviews:
    (i) for Ariane, in time for a decision in 2009 and consistent with the decision taken under the EGAS Ariane Programme;
    (ii) for Soyuz, in 2010, consistent with Rider 5-3 to the ESA/Arianespace Convention referred to in the preamble;
    (iii) for Vega before the start of the production of Vega launchers following the ten initial launchers after qualification.

    The Director General shall provide Council with full transparency on the result of such reviews including a market assessment and any variation of the launch service costs, in particular taking into account the learning process during the launcher production phase. The Director General shall conclude the relevant arrangements with the launch-service provider so as to enable the Agency, or independent entities mandated by the Agency, to perform the necessary verifications and audits throughout the contractual chain.

    On that basis, the Director General shall propose to Council for decision to be taken by a two-thirds majority of all Member States, the new launch-service costs for ESA missions.

V. CSG LAUNCH-RANGE FUNDING

28. STRESSES that the adoption on this day of the Resolution on the CSG - Extension until end-2008 (ESA/C-M/CLXXXII/Res.4 (Final)) is an essential element of the guarantee of access to space.

29. INVITES the Director General, together with CNES, the launch-service provider and industry, to complete the reorganisation of the industrial activities at the CSG, in order to further decrease the costs of the CSG launch range, taking into account its specificities.

30. INVITES the Director General to propose a new funding scheme, applicable as from 2009, to be included in a Resolution to be adopted by Council by a unanimous agreement of all Member States, based on the principles below:

    i) The scheme adopted on this same day for the funding of the CSG Launch Range fixed costs related to Ariane exploitation (2006-2008) shall be extended to cover the total fixed costs related to the exploitation of Ariane, Vega, and Soyuz as follows:
    – 1/3 funded by France;
    – 2/3 funded by ESA Member States and the launch-service provider on the basis of a nominal mission model to be agreed. The ESA Member States' contribution will be calculated according to a scale to be agreed among ESA Member States, reflecting a balance between solidarity and industrial return in exploitation. The costs corresponding to the exploitation of Ariane and Vega shall be borne by ESA Member States, while the costs corresponding to the exploitation of Soyuz shall be borne by the launch-service provider. It is understood that the exploitation of Vega will not introduce additional costs for the States which fulfil at least one of the two following conditions: (i) no participation in the Vega small-launcher development programmes, and (ii) no benefit from the industrial activities associated with the exploitation of the Vega launcher.

ii) All CSG Launch Range variable costs actually incurred shall be borne by the launch-service provider.

The above-mentioned scheme shall be applied as appropriate to any new launcher operated from the CSG.

31. NOTES that the industrial return related to the exploitation phase of Ariane, Vega, and Soyuz shall be calculated in compliance with applicable ESA rules, procedures and practices.

VI. NEXT STEPS TO PREPARE DECISIONS TO BE TAKEN IN 2008

32. ACKNOWLEDGES the ESA Launchers Strategic Plan 2006-2015 proposed by the Director General in ESA/PB-ARIANE(2005)22, rev. 4, as an important step for preparing the relevant decisions to be taken in 2008.

33. NOTES that the strategy for guaranteeing access to space for Europe may need adaptations to take into account factors such as the evolution of institutional needs, of the commercial market, and of the competition, impacting in particular the sustainability of the European industrial launcher sector, and UNDERLINES the importance of the ongoing mitigation measures, such as the additional efforts on industrial restructuring, and of the Future Launchers Preparatory Programme activities.

34. INVITES the Director General, in consultation with the launch-service provider and industry, to continuously assess the ability of the European industrial launcher sector to guarantee access to space for Europe and to develop, with the support of Member States, possible scenarios for the evolution of the European launcher sector so as to respond in the short/medium term to the launcher-sector needs preparing for decisions in 2008.

RESOLUTION ON THE CSG - EXTENSION UNTIL END-2008

(adopted on 6 December 2005)

Council, meeting at Ministerial Level,

HAVING REGARD to the Resolution on the CSG (2002-2006) (ESA/C-M/CLIV/Res. 3, rev.1 (Final)) adopted at Ministerial Level on 15 November 2001, as amended by Resolution ESA/C/CLXIX/Res. 5 (Final) adopted on 4 February 2004, hereinafter called "The CSG Resolution",

RECALLING the Resolution on the industrial-policy provisions applicable to EOEP, ELIPS, FLPP, ISS Exploitation and CSG (ESA/C/CLXXIX/Res. 5 (Final)) adopted on 22 June 2005,

HAVING REGARD to the Resolution on the evolution of the launcher sector (ESA/C-M/CLXXXV/Res. 3 (Final)), adopted at Ministerial Level on this day, and in particular Chapter V,

HAVING REGARD to the Declaration by certain European governments on the Ariane launcher production phase, hereinafter called "The 2001 Production Declaration", drawn up on 7 June 2001, and its extension until end-2008,

HAVING REGARD to the Resolution on the renewal of the Ariane launcher production phase (ESA/C/CLII/Res. 1 (Final)), adopted on 11 October 2001, by which Council has accepted that the Agency should fulfil the mandate entrusted to it by the Governments party to the Ariane Production Declaration,

HAVING REGARD to the Convention on the Ariane launcher production phase concluded between the Agency and Arianespace on 3 April 2004, which upon signature shall remain in force for as long as the above-mentioned Production Declaration remains in force,

HAVING REGARD to the Agreement between the French Government and the Agency on the Guiana Space Centre (CSG) (2002-2006) signed on 11 April 2002,

HAVING REGARD to the Agreement between the European Space Agency and Government of the French Republic on the Agency's launch sites and associated facilities at the CSG (hereinafter referred to as "The ELA Agreement"), signed on 11 April 2002,

HAVING REGARD to the Agreement between the European Space Agency and the Government of the French Republic concerning the Soyuz Launch Site (ELS) at the Guiana Space Centre (hereinafter referred to as "The ELS Agreement"), signed on 21 March 2005,

HAVING REGARD to the addendum to the Director General's technical and financial proposal on the CSG funding, covering the period 2006-2008 (ESA/PB-ARIANE(2005)72, rev. 2),

HAVING REGARD to the document entitled "Reference Framework for a coherent implementation, as from 2007, of decisions related to the restructuring of the European launcher sector" (ESA/PB-ARIANE(2005)3, rev. 3),

1. DECIDES to extend the CSG Resolution for the period 2006-2008, using for this purpose the provisions contained in the corresponding Resolution adopted on 15 November 2001 and amended on 4 February 2004, also taking into account Resolution ESA/C/CLXXIX/Res.5 (Final)) referred to in the preamble, as such provisions are modified as follows:

   1.1 by replacing the title with the following: "Resolution on the CSG (2002-2008)";

   1.2 by adding in the preamble the following:

   "HAVING REGARD to the Resolution on the CSG – Extension until end-2008 ESA/C-M/CLXXXV/Res. 4 (Final),

   HAVING REGARD to the addendum to the Director General's technical and financial proposal on the CSG funding, covering the period 2006-2008 (ESA/PB-ARIANE(2005)72, rev. 2),"

1.3 by replacing Section II thereof with the following:

"II. AGREES on the following funding arrangements:

II.1 The amount of funding to be contributed by the Agency in respect of the fixed costs incurred by CNES at the CSG to meet the requirements of the Ariane programmes (including the production phase thereof entrusted to Arianespace) shall be set for the period 2006-2008; this amount shall be fixed, subject to updating according to the Agency's rules and procedures. This amount shall also cover the industrial costs included in the CSG contract referred to in Section VII.1 (b) in compliance with the provisions of Section II.2.

It should be noted that, in accordance with the provisions of paragraph V.1, the contributions of the Member States to the above-mentioned fixed costs of the CSG shall be alleviated according to the system involving Arianespace defined in the Convention between ESA and Arianespace referred to in the preamble.

II.2 For the period 2006-2008, the total amount of CNES/CSG fixed costs taken into account in this Resolution is estimated at 366.3 MEuro*; the funding for CNES/CSG fixed costs (excluding the Agency's internal costs) to be contributed by the Agency for the period 2006-2008 shall be a fixed amount of 244.2 MEuro. The Agency's internal costs during this period 2006-2008 are estimated at 6.9 MEuro. In addition an amount of 20 MEuro shall be set up to cover industrial costs included in the CSG contract referred to in Section VII.1 (b) which are due in the event no decision on the Agency funding of CNES/CSG fixed costs for the new period beyond 2008 is taken within the time limit mentioned below. The total amount of funding to be contributed by the Agency shall thereby amount to 271.1 MEuro.

The additional amount of 20 MEuro shall, if no decision on the Agency funding of CNES/CSG fixed costs for the new period beyond 2008 is taken by 30 June 2008 pursuant to Section XI, be automatically incorporated into the 2009 budget for the CSG to be adopted according to the Agency's rules and procedures. The Director General shall report to the Ariane Launcher Programme Board and to the Administrative and Finance Committee on the disbursement of this above-mentioned amount.

If the decision on the Agency funding of CNES/CSG fixed costs for the new period beyond 2008 referred to Section XI is taken after the above-mentioned date and before the end of the year 2008, a revised 2009 annual budget for the CSG will be submitted to Member States for approval, on the basis of the new legal instrument covering such continuation.

II.3 The fixed amount of Agency funding for the CNES/CSG costs including the additional amount quoted in Section II.2 above may not be varied other than in the event of a substantial change in the activities to be provided by CNES at the CSG, which shall be taken into account by a procedure agreed between CNES and the Agency; any substantial change shall be referred to the Ariane Launcher Programme Board for examination and recommendation to Council for approval.

II.4 On the basis of estimates supplied by CNES of total CNES/CSG costs, which shall be examined and negotiated between the Agency and CNES, and on the basis of a review concerning the relative weight of GNP and the production return in the scale of contributions, the Director General shall submit to Council a proposal on Agency funding of CNES/CSG for a period beyond the year 2008. Council shall before 30 June 2008 decide the amount of funding to be contributed to CNES/CSG by the Agency for this new period and the applicable scale of contributions".

1.4 by replacing Section III thereof with the following:

"III.1 AGREES that the Member States' contributions shall be established in accordance with a composite scale half of which shall be calculated on the basis of the scale applicable to Member States for the Agency's mandatory activities and half on that of the estimated Ariane production geographical distribution scale; this composite scale shall be adjusted each time the above scale applicable to Member States for the Agency's mandatory activities is changed in accordance with Agency rules; the composite scale applicable during the period 2006-2008 is given in Annex I hereto;

** All the amounts in MEuro quoted in this Resolution are expressed at 2006 economic conditions, except when stated otherwise.*

III.2 At the end of the period 2006-2008, the initial composite scale shall be retroactively adjusted by taking into account the actual Ariane production geographical distribution scale calculated on the basis of the actual number of Ariane-5 launches carried out in that period."

1.5 by adding the following at the end of Section IV.1 thereof:

"For the period 2006-2008, the financing of CNES/CSG activities under the Agency Vega Programme will be funded by the participants in the programme slices concerned; and ACKNOWLEDGES that Arianespace has undertaken to cover the fixed and variable costs associated with the use of the CNES establishment in French Guiana (CNES/CSG) for the purpose of the exploitation of the Soyuz-ST launchers from CSG."

1.6 by replacing Section VII.1 thereof with the following:

"VII.1 INVITES the Director General to conclude on the basis of this Resolution:

(a) an extension until end-2008 of the CSG Agreement with the French Government referred to in the preamble;

(b) a new contract with CNES, to take effect as from 1 January 2006, covering the years 2006 to 2011, it being understood that the previous contract with CNES referred to above shall be terminated at the end of the year 2005. This new contract shall lay down the arrangements for applying the above-mentioned Agreement and specifying the services to be provided by CNES and the arrangements for funding and control by the Agency, and its association to the strategic decision making process referred to in Section VII.2 of the present Resolution. On the basis of the provisions in Section II above, the contract shall be divided into two periods:

- A first period covering the years 2006, 2007 and 2008, for which the amount of funding to be contributed by the Agency, including the additional amount referred to in paragraph II.2, is fixed.
- A second period covering the years 2009, 2010 and 2011, for which the amount of funding mentioned in ESA/PB-ARIANE(2005)72, rev. 2 referred to in the preamble, is a ceiling price. This ceiling price shall be converted into a fixed price and will, subject to the decision to be taken pursuant to Section XI, be incorporated in the follow-on contract covering the period beyond 2008."

1.7 by replacing Section VIII.5 thereof with the following:

"VIII.5 STRESSES the need to foster the participation of European industry in the investment and exploitation activities, on the basis of the following measures:

(a) by implementing a procurement policy aiming at drawing the maximum benefits, in terms of cost reduction and enhancement of opportunities for industry, from the synergies between all investment and exploitation activities performed on the site, including the activities concerning CNES/CSG and the Ariane launch site (ELA);

(b) by implementing a system of active monitoring of the evolution of the industrial return allowing to dynamically adapt the targets applied to the procurement actions to the actual return situation, with a view to reach a return objective of 1 for each Member State;

(c) by introducing a guarantee for each Member State of a minimum return coefficient of 0.84 at the end of 2008;

(d) by performing, in mid-2006, an intermediate review of the achieved industrial return over the period 2002-2006 and of the forecasts at the end of 2008. On the basis of this review, should any deficit be forecasted, corrective actions shall be taken, including, in decreasing order of priority:

- industrial activities to be committed for CNES/CSG over the period 2007-2008;
- other industrial activities on the CSG site in the period 2007-2008.

These corrective actions shall be defined for each Member State concerned by taking into account potential surplus industrial activities originated in other Agency programmes concerning the CSG site:

(e) by performing, at the end of 2008, a formal review of the achieved industrial return over the period 2002-2008. The remaining deficits with regard to the minimum return coefficient of 0.84 shall be balanced in 2009 under a scheme to be agreed between the States concerned;

(f) by duly documenting in the Agency's statistics the actions referred to in sub-sections VIII.5(d) and VIII.5(e) above."

1.8 by replacing Section XI with the following:

XI. AGREES to review all the arrangements contained in this Resolution in due time with a view to establishing at the latest by 30 June 2008, the arrangements for Agency funding of CNES/CSG beyond the year 2008, and to that end INVITES the Director General of the Agency, in consultation with the Director General of CNES, to submit to the Member States, in due time and no later than end-December 2007, a proposal on Agency funding of CNES/CSG beyond the year 2008, including the legal arrangements required to cover that continuation."

1.9 by replacing Section 1 of the Annex thereto with the following:

"1. Scale of contributions by Member States to the funding of CNES/CSG

(a) The composite scale applicable for the period 2006-2008 is as follows:

Country	**Contribution scale as %**
Austria	1.47
Belgium	4.36
Denmark	0.88
Finland	0.70
France	35.75
Germany	19.34
Greece	0.79
Ireland	0.63
Italy	10.98
Luxembourg	0.11
Netherlands	3.12
Norway	1.36
Portugal	0.61
Spain	5.07
Sweden	1.95
Switzerland	3.50
United Kingdom	9.42
Total	*100*

The composite scale shown above has been worked out on the basis of the scale applicable to Member States for the Agency's mandatory activities and the Ariane production geographical distribution scale (defined in ESA/PB-ARIANE(2005)72, rev. 2)".

1.10 by replacing Section 2 of the Annex thereto with the following:

"2. Indicative schedule expenditure

The indicative schedule of expenditure (in MEuro at 2006 economic conditions) is as follows:

	2006	2007	2008	2009*	TOTAL
Estimate of total CNES/CGS fixed costs	125.9	121.2	119.2	20	386.3
ESA funding for CNES/CSG	83.9	80.8	79.5	20	264.2
Internal costs	2.3	2.3	2.3	–	6.9
Total ESA funding	86.2	83.1	81.8	20	271.1

** Year corresponding to the possible call up of the additional amount pursuant to Section II.2 of the present Resolution*

2. CONFIRMS, notwithstanding Sections II.5 and II.6 of the CSG Resolution of 11 November 2001, as amended, that the budgets adopted on the basis of the CSG Resolution for the year 2005 will not be adjusted retroactively and will therefore remain operative as executed.

3. SPECIFIES that the renewed CSG Resolution provided for in Section 1 above will come into force on 1 January 2006, with non-retroactive effect.

4. NOTES with appreciation that relevant savings have been achieved in the CSG fixed costs during the period 2003-2005, consistent with the amendments made to the CSG Resolution on 4 February 2004, and NOTES further that these savings were achieved by reductions in costs brought about by the CSG reorganisation and in expenditure pursuant to the CSG capital investment plan.

RESOLUTION ON THE EVOLUTION OF THE AGENCY

(adopted on 6 December 2005)

Council, meeting at Ministerial Level,

HAVING REGARD to the Resolution on directions for the Agency's evolution and policy: "Space Serving European Citizens" (ESA/C-M/CLIV/Res. 1 (Final)), adopted at Ministerial Level in Edinburgh on 15 November 2001,

HAVING REGARD to the accession of Greece and Luxembourg to the Agency's Convention in the first half of 2005,

HAVING REGARD to the Framework Agreement between the European Space Agency and the European Community, which came into force on 28 May 2004,

HAVING REGARD to the Orientations endorsed by the Councils at Ministerial Level on the occasion of the Space Councils held on 26 November 2004 (ESA/C-M(2004)1, rev.1), 7 June 2005 (ESA/C-M(2005)1), and 28 November 2005 (ESA/C-M(2005)22),

HAVING REGARD to the Resolution on the evolution of the Agency's financial, budgetary and industrial policies (ESA/C/CLXXI/Res.2 (Final)), adopted on 17 June 2004, and to the Resolution on the hierarchy of industrial-policy rules on return coefficients (ESA/C/CLXXIX/Res.4 (Final)), and the Resolution on the Financial Regulations (ESA/C/CLXXIX/Res.7 (Final)), adopted on 22 June and 21 June 2005 respectively,

HAVING REGARD to the Resolution on the Agency's Long-Term Plan for Discovery and Competitiveness (ESA/C-M/CLXXXV/Res.1 (Final)), adopted on this day at Ministerial Level,

HAVING REGARD to the Director General's proposal for the 2005 Council Meeting at Ministerial Level (ESA/C-M(2005)6),

CHAPTER I
THE AGENCY IN AN EVOLVING ENVIRONMENT

1. SHARES the Director General's view on the main features of the evolving environment in which the Agency is called to carry out its mission, and EMPHASISES in particular the following factors:

   (a) an increase in the number and scope of space programmes and activities, with significant involvement of the European Community;
   (b) the recent enlargement of the European Union and the prospects for further enlargement involving other European States in the short and medium term;
   (c) the concrete implementation of activities in the framework offered by the Programme for the European Cooperating States (ECS) by industrial and research entities in a number of European States;
   (d) the far-reaching restructuring of the European space industry and the measures taken to develop a capacity to procure from European sources all critical components and technologies required for the development of space systems and related equipment, as well as the measures taken for enabling competition at system-integrator level, in particular for small and medium-sized missions;
   (e) a noticeable increase in industrial competition in the space sector with the arrival of new players such as China and India offering quality goods and services at lower costs; and
   (f) the need for broader involvement of the private sector in the financing of space-related activities in association with the public sector.

2. ACKNOWLEDGES the measures already taken towards adapting applicable Agency policies, procedures and systems to the above changes, and INVITES the Director General to further implement those measures and propose subsequent adaptations based on an assessment of the progress made in implementing the said measures and reflecting the evolving environment, in particular in the following domains:

(a) industrial and procurement policy in order to reinforce the global competitiveness of the European space industry in the delivery of goods and services;

(b) internal operations, in particular its rules and procedures, with a view to offering to other publicly-funded organisations in Europe a transparent and predictable Agency system for the implementation of their space activities; and

(c) the Agency's institutional framework for associating all interested European States in its space programmes with a view to reinforcing trans-European cohesion.

3. INVITES the Director General to report to the next Council Meeting at Ministerial Level on results achieved.

CHAPTER II
INDUSTRIAL AND PROCUREMENT POLICY

4. WELCOMES the outcome of the formal review of the geographical distribution of contracts and return coefficients achieved for the period 2000 to 2004 (ESA/IPC(2005)30) and LOOKS FORWARD to the results of the on-going implementation of the measures decided for correcting return imbalances identified at that review, and RECALLS the Resolution on the hierarchy of industrial-policy rules on return coefficients referred to in the preamble which enables the Agency to increase flexibility in the application of its industrial-return rules, thus encouraging competition.

5. UNDERLINES that, in order to enhance the global competitiveness of the industrial sector, a strong technology portfolio is required together with the harmonisation of technology and procurement policies extending beyond the Agency's framework and applied on a voluntary basis, thereby favouring a more open European market promoting innovation and a specialisation-oriented approach, and also facilitating the selection of competitive European equipment in the frame of governmental space procurements in Europe.

6. INVITES the Director General to ensure that, in the application of the Agency's procurement policy, due consideration is given to a proper risk-sharing between the Agency and industry, and also between the prime contractors and their respective sub-contractors.

7. STRESSES that all categories of firms shall have fair access to the Agency's activities.

8. INVITES the Director General to take appropriate measures in order to help consolidate the industrial fabric of the European space sector, taking account of the contributions of all industrial players in order to enrich the European space sector capabilities and competitiveness.

9. INVITES the Director General to propose a comprehensive roadmap and associated action plan to Council within six months.

CHAPTER III
INTERNAL OPERATIONS

10. EMPHASISES the need to further strengthen the management of the Agency with a view to continuous optimisation in using its available resources and attracting additional ones, and UNDERLINES the necessity to proceed with the evolution of the financial management system and of the corporate governance system of the Agency so as to continuously increase productivity within the programme running costs and within corporate and administrative activities, and to respond to strategic needs and to new requirements such as the development of the internal security system of the Agency.

11. CONVEYS its appreciation to the members of the Audit Commission for having provided their expert opinion on different aspects of the Agency's financial management.

12. RECALLS the Resolution on the Financial Regulations, referred to in the preamble, which constitutes a significant improvement of the Agency's financial system, bringing it into line with current best practices.

13. INVITES the Director General to implement the actions remaining under the roadmap on reforming the financial management of the Agency (ESAC(2005)78), in line with the recommendations made by the Audit Commission, in close consultation and cooperation with Council and the Agency delegate bodies, with a view to completing the financial reform by end-2008, RECALLS that a report is due in 2008 on the results brought by the implementation of the in-year flexibility and the budgetary planning process, and INVITES the Director General to report annually on the Agency's year-end performance, starting from 2006, on the basis of an agreed list of indicators and taking into account the corresponding objectives to be outlined in the Agency's Long-Term Plan.

14. SUPPORTS the Director General in his continuous effort to enhance further the Agency's management methods and tools with a view to increasing accountability and reducing programmatic risks, through the introduction of efficient project planning and corporate control, and consequently pursue the continuous optimisation of the use of the Agency's resources.

15. UNDERLINES the importance of having motivated and qualified staff, and ENCOURAGES the Director General to take further measures with a view to developing career planning, strengthening technical and managerial expertise, and supporting staff mobility and the equal-opportunity policy.

CHAPTER IV
APPROACH TO SPACE GOVERNANCE IN EUROPE AND THE POLICY ON ENLARGEMENT OF THE AGENCY

16. RECALLS the recommendation made by the Space Council to identify possible cost-efficient scenarios for optimising the organisation of space activities in the future in Europe and to initiate a wide-ranging appraisal of these scenarios in comparison to present processes, and INVITES the Director General to assess the potential consequences of these scenarios on the Agency's role and operations and to inform Council of the outcome of this assessment.

17. NOTES the growing interest of several new Member States of the European Union in participating progressively in the Agency's programmes and to foster public interest in space exploration, and RECALLS the joint initiatives between ESA and the European Community such as Galileo and GMES which involve all of these new Member States.

18. WELCOMES the implementation of the programme for the European Cooperating States through which the signatory States are given access to the Agency's programmes and INVITES the Director General to:

    (a) pursue a detailed examination of the existing cooperation framework, and in particular the ECS, with the objective of offering the largest number of European States the possibility to participate in the execution of the Agency's programmes; and

    (b) assess the impact that the association or accession to the Convention of new Member States may have on the European space sector, the Agency's policies and activities and the Agency's decision-making processes, and report to Council on the outcome of this assessment within six months.

19. NOTES the setting-up of the European GNSS Supervisory Authority by the Council of the European Union to manage the public interest relating to the European GNSS and to be its regulatory authority and the provisions, contained in the regulation establishing the Authority, that ESA shall be requested to provide the Authority with its technical and scientific capabilities, and INVITES the Director General:

    (a) to define and agree, as soon as possible, with the European GNSS Supervisory Authority, the arrangements for the Agency's involvement in the deployment and operational phases of the GNSS programmes, including on the corresponding funding, and

    (b) to initiate discussions with the European Commission with a view to defining a policy for ESA's involvement in operational phases of joint initiatives, taking into account the relevant orientations endorsed by the Space Council.

RESOLUTION ON THE INTERNATIONAL SPACE STATION PROGRAMME

(adopted on 6 December 2005)

Council, meeting at Ministerial Level,

HAVING REGARD to the Resolution on the Agency's Long-Term Plan for Discovery and Competitiveness (ESA/C-M/CLXXXV/Res. 1(Final)), adopted at Ministerial Level on this day,

HAVING REGARD to the Declaration on the European participation in the International Space Station Development Programme (ESA/PB-MS/XI/Dec.1 (Final), rev.3),

HAVING REGARD to the Declaration on the European participation in the International Space Station Exploitation Programme (ESA/PB-MS/XXIX/Dec.1, rev.3 (Final)) amended on this day,

HAVING REGARD to the Declaration on the European Programme for Life and Physical Sciences and Applications in Space - ELIPS (ESA/PB-MG/LXX/Dec.1, rev.5 (Final)) amended on this day,

HAVING REGARD to the Agreement among the Government of Canada, Governments of Member States of the European Space Agency*, the Government of Japan, the Government of the Russian Federation and the Government of the United States of America (hereinafter referred to as "The Partners") concerning cooperation on the civil International Space Station (hereinafter referred to as the "IGA"), signed on 29 January 1998 and entered into force for the European Partner on 28 June 2005,

HAVING REGARD to the Memorandum of Understanding between the European Space Agency (ESA) and the National Aeronautics and Space Administration of the United States of America (NASA) concerning cooperation on the civil International Space Station (hereinafter referred to as the "Space Station MOU"), signed on 29 January 1998,

1. REAFFIRMS that the International Space Station (ISS) Programme is essential for the Agency to consolidate cooperation with other space-faring organisations and to contribute to new discoveries through the realisation of scientific experiments and for the preparation of the exploration of space.

2 . CONCERNED with the delays experienced in the ISS assembly, which have resulted in adverse consequences on the ISS Programme as a whole, STRESSES that complete stability must be restored at the earliest opportunity in that programme to ensure that the Partner States and their Cooperating Agencies exercise the rights and discharge the obligations to which they have agreed, respectively, in the IGA and ISS MOUs.

3. RECALLS that:

   – the European Partner States, signatory of the IGA, have invested significant resources through the Agency's dedicated programmes for developing ISS elements and equipment, and
   – the European scientific communities have also contributed considerable efforts and means in the preparation of ISS utilisation,

   with the expectation to reap the benefits of these investments after the launch and in-orbit verification of the Columbus laboratory, through an extensive exploitation of the laboratory and the use of the Automated Transfer Vehicle (ATV) for ISS logistics and re-boost.

4. NOTES with appreciation that:

   – NASA has taken significant steps for returning its Space Shuttle to flight, with a view to providing the means for completing

Collectively called the European Partner within the meaning of the IGA, whose rights and obligations are exercised and discharged through the European Space Agency.

the assembly of the ISS in a configuration that meets the resources and utilisation requirements of all the Partners, a matter which falls primarily under NASA's responsibility as defined in the ISS Agreements;

– the Russian Space Agency has worked closely with NASA, in particular over the last three years since the Space Shuttle Columbia accident, to ensure the continued sustainability and permanent manning of the ISS, resulting in valuable utilisation opportunities being offered to the other Partners, including through the provision of flights using the Soyuz and Progress vehicles; and

– the US and Russian Partners have taken steps to initiate the development of new crew transportation systems which are intended to be available for servicing the ISS, thereby enhancing its robustness after the retirement of the Space Shuttle system.

5. MINDFUL of the uncertainties currently confronting the ISS partnership, EMPHASISES the necessity for the Columbus laboratory to be launched in the timeframe end 2007/early 2008, on the condition that the Director General receives assurances that an adequate level of utilisation resources for the exploitation of the laboratory will be provided, including after the retirement of the Space Shuttle system, consistent with the relevant provisions of the ISS Agreements.

6. CALLS for the US Partner to take all necessary measures to restore its portion of the International Space Station Programme to full stability and to ensure that the objectives of the ISS partnership, as agreed by the Parties to the IGA and to the corresponding MOUs among the Cooperating Agencies, are maintained in their entirety.

7. ENCOURAGES the Director General to work expeditiously with the other ISS Partners, in particular NASA, to arrange for the launch of the Columbus laboratory in the timeframe indicated above and to establish a robust ISS operations and transport scenario that takes into account the planned retirement of the Space Shuttle in 2010 and the need to enable a permanent crew of six astronauts to work onboard the ISS before such retirement, and INVITES the Director General to continue to involve the Participating States concerned in that process.

8. NOTES with satisfaction the completion of European hardware developed for the ISS (Columbus and its payloads, Node-2, Cupola, European Robotic Arm (ERA)), the progress made in the development of the remaining elements (Automated Transfer Vehicle (ATV), Node-3, European Ground Segment) and the implementation of a broad interim ISS utilisation programme in key scientific disciplines, by making use of US and Russian modules.

9. BEARING IN MIND that the above-mentioned uncertainties may not be entirely cleared before end-2007, EMPHASISES the need to manage the activities within the ISS Exploitation Programme in a manner that will ensure both that the European Partner maintains in full its capability to reap the benefits entailed by its participation in the ISS partnership and that no resource is spent unnecessarily.

10. WELCOMES the amendments made on this day to the respective Declarations, and the additional subscription made by Participating States to the related financial envelopes, governing the following Agency programmes:

    (a) the European participation in the International Space Station Exploitation Programme (ESA/PB-MS/XXIX/Dec.1, rev. 3 (Final));

    (b) the European Programme for Life and Physical Sciences and Applications in Space – ELIPS (ESA/PB-MG/LXX/Dec. 1, rev.5 (Final)).

11. NOTES the decisions of the States participating in the ISS Exploitation Programme, which take into account the uncertainties in the assembly and operations of the ISS:

    (a) to limit their financial commitment in Period 2 to four years (2005-2008), of which the first three years represent a firm commitment and the last year represents a provisional commitment, bearing in mind that a decision on Period 3 will be taken in 2008; and

    (b) to establish an appropriate mechanism, as detailed in the Annex to this Resolution, by which dedicated decisions by them

based on the achievement of specific programme milestones will permit implementation of the programme of activities for 2007 and 2008.

12. INVITES the Director General to make arrangements for securing additional flight opportunities for European astronauts, further enhancing the public visibility of the European participation in the ISS Programme and the related scientific and application results, and drawing attention on the educative dimension of that programme.

13. INVITES the Director General to report regularly on the progress made in the overall ISS Programme, specifically where it affects the European participation, and in particular for what concerns the achievement of the programme milestones referred to in the Annex.

14. EXPRESSES its conviction that the continued international cooperation to build, operate and utilise the ISS marks a major advance in the peaceful collaboration among space-faring nations, and that all Partners must abide by the obligations they have assumed under the IGA and ISS MOUs.

ANNEX

Special Provisions Applicable to the Implementation of the ISS Exploitation Programme Period 2 (2005-2008)

1. Within the subscribed financial envelope for Period 2 of 649.7 MEuro at 2006 e.c., an amount of 349.3 MEuro, composed of 169.4 MEuro within the firm financial sub-envelope (2005-2007) and 179.9 MEuro corresponding to the provisional sub-envelope (2008), is blocked.

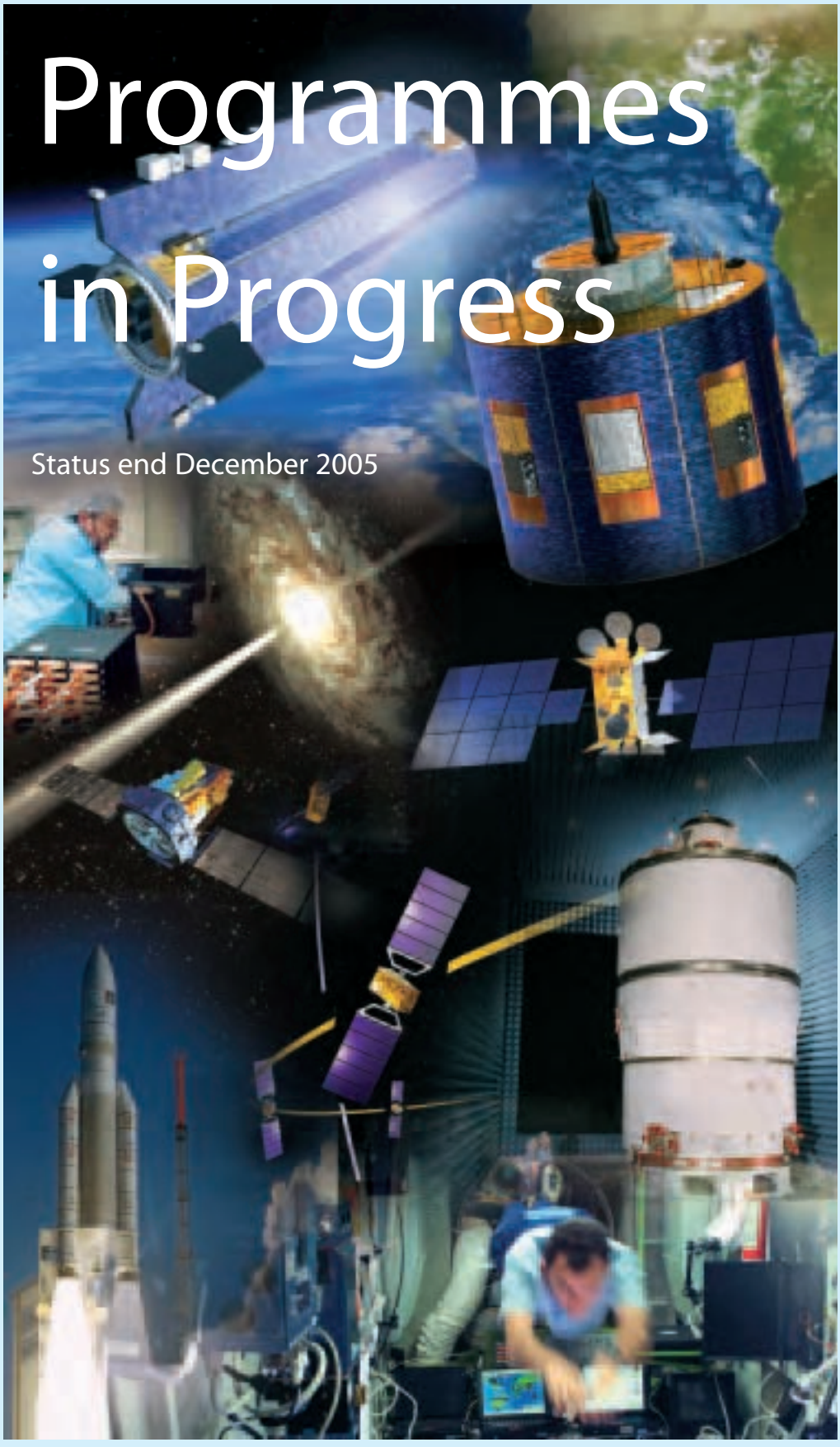
2. The unblocking of specified amounts will be done through dedicated decisions of the participating States concerned, taken in the relevant Programme Board or at Council following achievement of the milestones referred to below and on the basis of a report drawn up by the Director General, on the understanding that such decisions shall require a two-thirds majority vote representing at least two-thirds of the contributions in the programme. Specifically, the decision to unblock:

   – the above-mentioned amount of 169.4 MEuro, in principle by October 2006, is related to (i) the successful second return-to-flight mission of the Space Shuttle, and (ii) the confirmation that the launch of the Columbus laboratory shall occur prior to the end of 2008 (expected at a meeting of the Heads of the ISS Cooperating Agencies in 2006); and

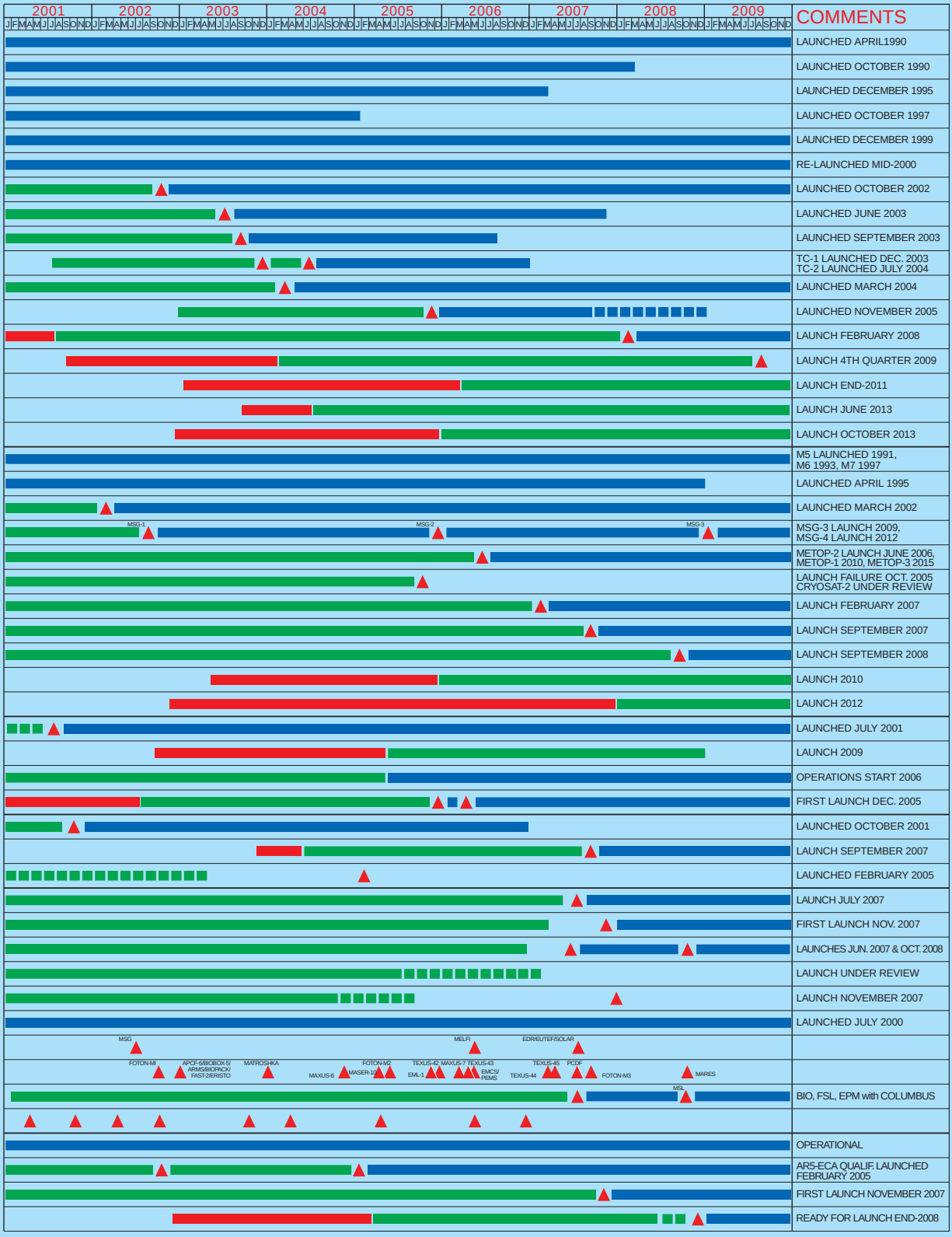
   – the above-mentioned amount of 179.9 MEuro, in principle by October 2007, is related to: (i) the successful docking of the first ATV (Jules Verne), currently planned for May 2007, and (ii) the re-confirmation of the launch of the Columbus laboratory prior to the end of 2008; successful docking of the first ATV shall also authorise the Agency to initiate the integration of ATV-2 and the procurement of ATV-3.

Programmes in Progress

Status end December 2005



	PROJECT
SCIENTIFIC PROGRAMME	SPACE TELESCOPE
	ULYSSES
	SOHO
	HUYGENS
	XMM-NEWTON
	CLUSTER
	INTEGRAL
	MARS EXPRESS
	SMART-1
	DOUBLE STAR
	ROSETTA
	VENUS EXPRESS
	HERSCHEL/PLANCK
	LISA PATHFINDER
	GAIA
	JWST
	BEPICOLOMBO
EARTH OBSERVATION PROGRAMME	METEOSAT-5/6/7
	ERS-2
	ENVISAT
	MSG
	METOP
	CRYOSAT
	GOCE
	SMOS
	ADM-AEOLUS
	SWARM
	EARTHCARE
COMMS./NAV. PROGRAMME	ARTEMIS
	ALPHABUS
	GNSS-1/EGNOS
	GALILEOSAT
TECHNOL. PROG.	PROBA-1
	PROBA-2
	SLOSHSAT
HUMAN SPACEFLIGHT, MICROGRAVITY & EXPLORATION PROGRAMME	COLUMBUS
	ATV
	NODE-2 & -3
	CUPOLA
	ERA
	DMS (R)
	ISS SUPPORT & UTIL.
	EMIR/ELIPS
	MFC
	ASTRONAUT FLT.
LAUNCHER PROG.	ARIANE-5 DEVELOP.
	ARIANE-5 PLUS
	VEGA
	SOYUZ AT CSG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J F M A M J J A S O N D
COMMENTS
LAUNCHED APRIL1990
LAUNCHED OCTOBER 1990
LAUNCHED DECEMBER 1995
LAUNCHED OCTOBER 1997
LAUNCHED DECEMBER 1999
RE-LAUNCHED MID-2000
LAUNCHED OCTOBER 2002
LAUNCHED JUNE 2003
LAUNCHED SEPTEMBER 2003
TC-1 LAUNCHED DEC. 2003
TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004
LAUNCHED NOVEMBER 2005
LAUNCH FEBRUARY 2008
LAUNCH 4TH QUARTER 2009
LAUNCH END-2011
LAUNCH JUNE 2013
LAUNCH OCTOBER 2013
M5 LAUNCHED 1991,
M6 1993, M7 1997
LAUNCHED APRIL 1995
LAUNCHED MARCH 2002
MSG-1
MSG-2
MSG-3
MSG-3 LAUNCH 2009,
MSG-4 LAUNCH 2012
METOP-2 LAUNCH JUNE 2006,
METOP-1 2010, METOP-3 2015
LAUNCH FAILURE OCT. 2005
CRYOSAT-2 UNDER REVIEW
LAUNCH FEBRUARY 2007
LAUNCH SEPTEMBER 2007
LAUNCH SEPTEMBER 2008
LAUNCH 2010
LAUNCH 2012
LAUNCHED JULY 2001
LAUNCH 2009
OPERATIONS START 2006
FIRST LAUNCH DEC. 2005
LAUNCHED OCTOBER 2001
LAUNCH SEPTEMBER 2007
LAUNCHED FEBRUARY 2005
LAUNCH JULY 2007
FIRST LAUNCH NOV. 2007
LAUNCHES JUN. 2007 & OCT. 2008
LAUNCH UNDER REVIEW
LAUNCH NOVEMBER 2007
LAUNCHED JULY 2000
MSG
MELFI
EDR/EUTEF/SOLAR
FOTON-MII
APCF-6/BIOBOX-5/
ARMS/BIOPACK/
FAST-2/ERISTO
MATROSHKA
FOTON-M2
MASER-12
MAXUS-6
TEXUS-42
EML-1
MAXUS-7
TEXUS-43
EMCS/
PEMS
TEXUS-45
TEXUS-44
PCDF
FOTON-M3
MARES
MSL
BIO, FSL, EPM with COLUMBUS
OPERATIONAL
AR5-ECA QUALIF. LAUNCHED
FEBRUARY 2005
FIRST LAUNCH NOVEMBER 2007
READY FOR LAUNCH END-2008
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
STORAGE
LAUNCH/READY FOR LAUNCH
OPERATIONS
ADDITIONAL LIFE POSSIBLE

Hubble Space Telescope (HST)

The Hubble Space Telescope continues to provide excellent data that not only enable advances in science, but also excite and engage the public. Two recently released examples include an image of the star cluster NGC 346 and its surrounding star-formation region, and an image of the Crab Nebula. The NGC 346 image was obtained by an ESA astronomer on assignment to the Space Telescope Science Institute in Baltimore, Maryland, using the HST Advanced Camera for Surveys. Located 210 000 light-years away in the Small Magellanic Cloud, a satellite galaxy of our own galaxy, the cluster is one of the most dynamic and intricately detailed star-forming regions in space. A dramatic structure of arched, ragged filaments with a distinct ridge encircles the cluster. The Crab Nebula is a six-light-year-wide, expanding remnant of a star's supernova explosion. Japanese and Chinese astronomers recorded this violent event nearly 1000 years ago in 1054, as did, almost certainly, Native Americans. This composite image was assembled from 24 individual exposures taken with Hubble's Wide Field and Planetary Camera 2. It is one of the largest images taken by HST and is the highest resolution image ever made of the entire Crab Nebula (see front cover of this Bulletin).

To extend the lifetime of HST, preparations were made over the last year to switch off one of the gyroscopes and operate in a two-gyro configuration. Since the switch to two-gyro mode in late August 2005, operations have continued successfully and without any problems. 'Operational trending' began immediately to evaluate the new mode and identify potential areas for improvement. A meeting in October identified several opportunities for efficiency improvements, which were quickly implemented. With the two-gyro mode operating well, work shifted to evaluating the potential for a one-gyro operating mode. An initial study by pointing-control engineers confirmed the feasibility of the mode, and work began in earnest to define the operational concept and requirements. Following a successful preliminary design review took place in November and the various teams began moving forward on detailed design activities for implementing this contingency one-gyro mode.

Plans for a servicing mission to Hubble using the Space Shuttle continue, but the final decision on whether to actually fly the mission will only be made after a successful second flight of the Shuttle after the 'Columbia' accident, now expected in early spring 2006. The manifest for this Servicing Mission 4, planned for late 2007, now includes two new instruments, the Wide-Field Camera 3 (WFC3) and the Cosmic Origins Spectrograph (COS), as well as many life-extending items such as gyroscopes and batteries. Repair of the Space Telescope Imaging Spectrograph (STIS) – the instrument that failed in August 2004 – may also be attempted by the astronauts. A de-orbit module and the Aft-Shroud Cooling System are no longer part of the plans for this servicing mission, due to a general consensus that they are either not needed at all (cooling system), or at least not until 2020 (de-orbit module).

From the operational point of view, the Hubble spacecraft is operating nominally. All of the scientific instruments – with the exception of STIS – are delivering data that will continue to advance our knowledge of the Universe.

Star cluster NGC 346 and its surrounding star-forming region as seen by HST's Advanced Camera for Surveys (Courtesy of NASA, ESA & A. Nota)

Ulysses

Ulysses was one of the missions reviewed by NASA's Sun-Solar System Connections Senior Review Panel at its meeting on 14 and 15 November. The purpose of the Review, which focused on the period 2007/8, was to rank the expected scientific return from the various

projects on a 'science per dollar' basis. A positive outcome for Ulysses is needed to safeguard NASA's participation up to the end of the mission, presently foreseen for 31 March 2008. (The corresponding decision on ESA's part was taken by the Science Programme Committee in 2004). Presentations were given by the NASA Project Scientist and the ESA Mission Manager, and focused on recent science highlights not included in the formal proposal and the status of the Ulysses project in ESA. These presentations were well received, and the formal recommendations from the Review are expected to be made known early in the New Year.

All spacecraft subsystems are operating nominally. On 1 February 2006, Ulysses will be at a radial distance of 4.35 AU from the Sun and a heliographic latitude 40 deg south of its equator.

Like water droplets from a rotating garden sprinkler, the magnetic field carried away from the rotating Sun by the radially out-flowing solar wind is on average wound into a spiral pattern (an Archimedean spiral) in the heliosphere. A recurring theme in many of the results obtained by Ulysses, however, is the unexpectedly large degree to which the instantaneous heliospheric magnetic-field direction measured at the spacecraft deviates from this pattern. Theories exist to explain such systematic deviations, but these require radial distances of several astronomical units (AU) for a deviation of order 1 AU to develop. However, observations of 'jets' of energetic electrons from Jupiter's magnetosphere, acquired by Ulysses during its distant encounter with the planet in 2003/4, show that such deviations are common within a radial interval of as little as 0.1 AU. Electron jets were discovered during Ulysses's first Jupiter flyby in 1992, and were identified as brief (lasting minutes to hours), highly focused bursts of MeV electrons flowing away from Jupiter along the heliospheric magnetic field. Jets were observed up to distances of an AU from Jupiter and were interpreted as evidence for direct magnetic connection to Jupiter's magnetosphere. In the recent cases, the position of Ulysses relative to Jupiter was such that magnetic connection along the average spiral field could not have occurred, implying large deviations. If such large deviations are indeed common, they may play a significant role in the distribution of charged particles throughout the heliosphere. It is not yet clear how or why such large-scale deviations develop, whether they are consistently present throughout the solar cycle, or how to incorporate them into current theories of particle propagation.

XMM-Newton

XMM-Newton operations are continuing smoothly, with the spacecraft, instruments and ground segment all performing according to plan. The launch of MSG-2 had an impact on XMM-Newton operations with the loss of six science orbits, because the XMM-Newton ground stations were required to support the meteorological satellite's launch and early-orbit phase.

The completion status of the observing programme is currently as follows:
- AO-3 programme: 99.7%
- AO-4 programme: 73.5%.

Completion of both programmes is expected by April 2006, in line with the planned start of AO-5 observations.

The Fifth Announcement of Opportunity (AO-5) closed on 14 October. A total of 632 valid proposals were submitted, requesting 106 737 kiloseconds of science time, implying that 7.4 times more observing time was requested than is available. The meeting of the chairpersons of the Observing Time Allocation Committee took place on 13-14 December at ESAC (E) in order to select the AO-5 observing programme.

A total of 996 papers based either completely or partially on XMM-Newton observations had been published in the refereed literature by 30 December, 276 of them in 2005.

Cluster

The four spacecraft and their instruments are operating nominally. Phasing manoeuvres were executed in November 2005 to change the spacecraft multi-scale configuration (C1, C2 and C3 spacecraft separated by 10 000 km and C3 and C4 separated by 1000 km) to a perfect tetrahedron of side 10 000 km in order to observe the polar cusp in February/March 2006. The solid-state recorder capacity was increased from 5 to 7.5 Gbit by switching on the third memory module. This will allow greater flexibility in the data dumping that will be required for the switch from Villafranca (Spain) to the Perth (Aus.) ground station in January 2006.

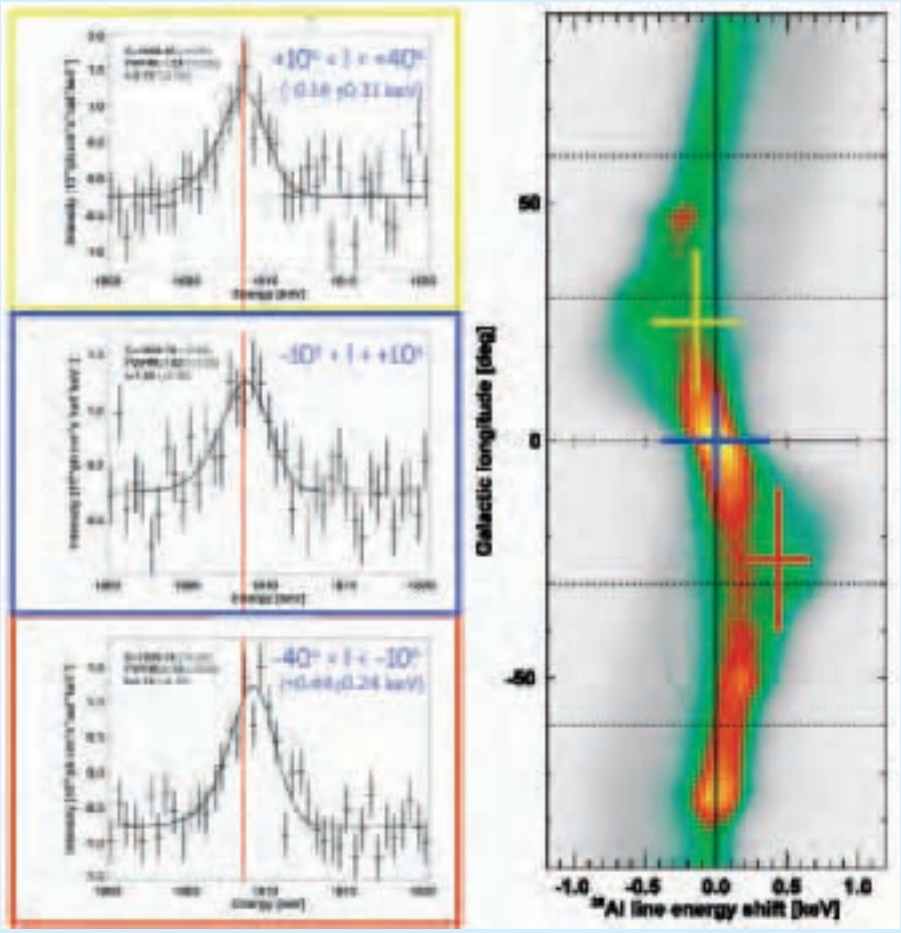
JSOC and ESOC operations are continuing according to plan. Work is progressing for the switch to the Perth ground station starting early in 2006. The data return from September to mid-November 2005 averaged 99.8%.

The Cluster Active Archive (CAA) has been in a beta-testing phase since 26 September. Up to now, 63 software problems have been reported, of which 19 are still open but none of them are critical (mostly related to the ingestion processes). The CAA will be officially opened on 1 February 2006. A new activity on cross-calibration between different instruments has been started; the first meeting was held in September and the next one will be in February 2006.

A new multi-spacecraft method to estimate the magnetic reconnection rate has been developed and applied to the Cluster data. This requires at least two spacecraft to be in the reconnection layer at the same time. The results from one magnetopause crossing by Cluster showed that the reconnection rate is significantly lower than that obtained from previous observations. This finding could stem from the fact that a particular type of reconnection called 'component reconnection' was occurring at that time.

Integral

The results of detailed studies using the Integral Spectrometer (SPI) of the diffuse galactic line emission from the radioactive decay of ^{26}Al (1.81 MeV) have been reported in the journal *Nature* by Roland Diehl (MPE)



The left panels show the line profiles obtained by the Integral Spectrometer at different locations. A clear shift in the line positions in the top and bottom panels compared to the centre panel (l = 0) is visible. Detailed modelling shows that this shift is fully consistent with the Doppler shift expected from galactic rotation. The map on the right shows this expectation based on modelling of the galactic rotation curve and a three-dimensional distribution of ^{26}Al sources, together with the measured values (crosses)

and collaborators. This emission is a key tracer of recent star formation, as ^{26}Al is produced during core collapse supernovae and in the preceding intense stellar winds. The emission rapidly decays within about a million years as the radioactive ^{26}Al is converted to magnesium, and so traces the very recent star formation history of our Galaxy. The line has been observed by Integral at high significance in the inner Galaxy and, for the first time, small energy shifts (of the order of one tenth of a keV) due to galactic rotation have been measured. This supports a Galaxy-wide origin for the ^{26}Al emission and allows an independent estimate of the galactic core collapse supernova rate of 1.9 ± 1.1 per century. This rate corresponds to a star-formation rate of ~4 solar masses per year, or ~7.5 stars per year, and is typical of spiral galaxies similar to our own.

Mars Express

Final commissioning operations for the MARSIS instrument – primarily the commissioning and calibration of the monopole antenna – have been planned and will start in February 2006, after which the MARSIS radar will be fully operational.

At the end of November, a successful orbit-correction manoeuvre was performed in order to return from the current free-drift orbit to a frozen orbit. Operations generally are proceeding well. During some so-called 'SPICAM Sun' pointings in November 2005, a worse than expected reduction in solar-array power was observed. Analysis has shown this to be due to an unforeseen shading of part of the solar array by one of the MARSIS antenna booms when in a specific attitude.

The Planetary Fourier Spectrometer (PFS) is back in operation after a malfunction was encountered a few months ago. The recovery was made possible by exploiting internal instrument redundancy. After switching to the instrument back-up motor (more powerful than the primary motor), the instrument is able to produce science data as before. Following this recovery action, PFS began to routinely acquire new measurements in early November.

Science operations are proceeding well and planning of future observations is progressing smoothly. Further instrument data deliveries were recently made to the mission's data archive, and a new map-based interface was added to the search capabilities of the Planetary Science Archive.

A paper on the ionospheric structure of Mars by the Radio Science team has recently been published in Science. A very successful Press Conference, highlighting the acceptance of one OMEGA instrument article by *Nature* and two MARSIS articles by *Science*, was held at ESA Headquarters in Paris on 30 November.

Double Star

The two spacecraft and their instruments are operating nominally. The drift of their spin axes is continuing as predicted, with the spin axis of TC-1 about 3.5 degrees from the ecliptic pole and that of TC-2 around 16 degrees. This should not cause problems before July 2006 for TC-2 and December 2006 for TC-1. TC-1 has entered the eclipse season, which will last 7 months, and payload operations will be reduced during those eclipses lasting longer than one hour.

The European Payload Operation System (EPOS) co-ordinates operations for the seven European instruments on TC-1 and TC-2 and this is running smoothly. The new contract for the extension of EPOS, starting on 1 January 2006, is in place with RAL. ESOC has acquired an average of about 3 hours of data

per day using the Vilspa-2 ground station and has covered around 80% of the passes. The rest of the passes were acquired by the Chinese stations in Shanghai and Beijing.

Twenty-four Double Star based papers have been published in the special November 2005 issue of Annales Geophysicae, including mission and instrument descriptions and the first results.

On 27 December 2004, radiation from the biggest starquake on a neutron star ever recorded reached Earth. Unique data obtained by Double Star TC-2 and Cluster satellites have shown the first observational evidence of cracks in the neutron star crust, during the initial phase of the starquake. The intensity of this major peak was hundreds of times stronger than any other observed so far (only two other giant flares have been recorded in the past 35 years). For the first 200 ms, it saturated almost all instruments on satellites equipped to observe gamma-rays. Although designed to study the Earth's magnetosphere, the PEACE instruments onboard the Double Star TC-2 and Cluster satellites performed unsaturated observations of this initial flare growth and decay. This result, published in the Astrophysical Journal, will help to discriminate between current theories regarding the physical origin of such massive starquakes.

Venus Express

Venus Express was successfully launched from Baikonur on 9 November aboard a Soyuz rocket. The launch phase was concluded with a nominal separation and injection of the spacecraft onto an interplanetary trajectory to Venus by the Fregat upper stage. The ESOC Flight Control Team then proceeded with the activation of the spacecraft, which went extremely smoothly and was concluded on 11 November.

The next phase of the mission was dedicated to near-Earth commissioning. Each subsystem of the spacecraft was checked out to verify its in-flight performance, with positive results in all cases. On 22 November, the imaging payloads took images of the Moon and the Earth, demonstrating the spacecraft's ability to point to a given target, perform observations, store the data, and transmit it back later to Earth. The remaining payload instruments were then also successfully activated, except for the Planetary Fourier Spectrometer (PFS), a mechanism of which appeared to have stuck due to the very low temperature environment. Near-Earth commissioning activities were concluded on 14 December when, aside from the PFS issue under investigation, the spacecraft's behaviour was declared to be nominal.

The various teams in industry and ESA will now focus on the preparations for testing the main engine in February, and on the spacecraft's insertion into a Venus orbit, planned for 11 April 2006.

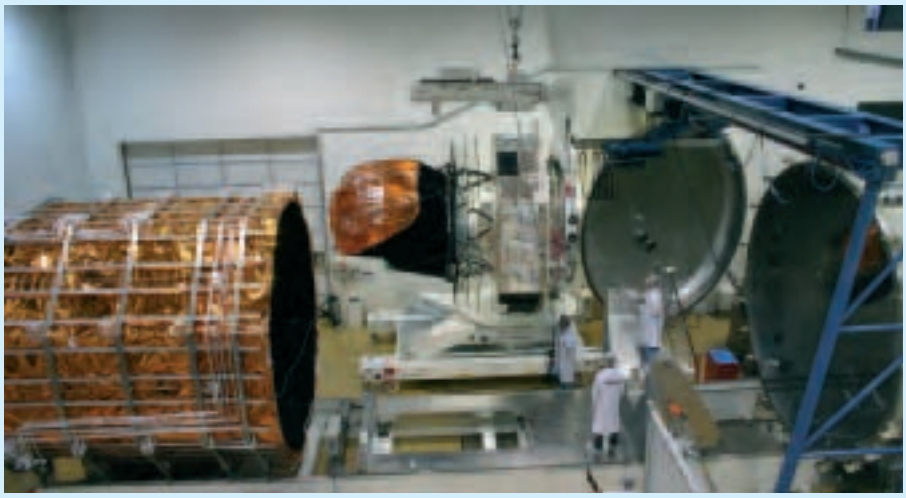
Herschel/Planck

The development efforts in industry for both the Herschel and Planck spacecraft are progressing at a good pace. The flight-model integration of the Planck spacecraft has continued at Alcatel Alenia Space in Cannes (F), and it is now well on the way to the first thermal vacuum test on the flight satellite. During this test, one of the two flight models of the NASA-supplied hydrogen sorption coolers will also undergo flight acceptance tests (both coolers having already been delivered).

On the Herschel spacecraft, after completion of the cryo thermal testing of the protoflight model of the Payload Module, it was mated with the structural model of the Herschel Service Module and is presently being prepared for system mechanical testing in early 2006. The flight model of the Herschel Service Module has been integrated during this period at Alcatel Alenia Space in Turin (I) and its functional testing has also started. The functional, performance and electromagnetic compatibility testing of the Herschel instrument qualification models in the modified ISO cryostat has also been completed.

The development of the flight-model instruments has experienced some delays, but a close monitoring has been put in place. The Planck instruments are now progressing towards delivery in mid-2006, and the

The Herschel spacecraft in the Large Space Simulation (LSS) facility at ESTEC (NL) for the cryogenic lifetime test



The Planck Cryogenic Qualification Model at the CSL facilities in Liege (B)

Herschel instruments towards delivery before end-2006.

The hardware activities on the Herschel telescope were completed during the last quarter of 2005 and the telescope is now fully assembled and aligned. All environmental testing has been successfully completed, with the cryogenic optical testing remaining to be completed in early 2006. For the Planck telescope, the flight-model reflectors have completed all testing and will soon be integrated onto the telescope structure for the final cryogenic optical testing of the telescope assembly.

In mid-December, ESA and Arianespace signed the contract for the provision of the Ariane-5 ECA launcher that will lift the Herschel and Planck spacecraft to their intended orbits around the second Lagrangian point (L2). Taking into account the accumulated delays and the recovery actions in place, the launch is presently foreseen for February 2008.

LISA Pathfinder

The SMART-2/LISA Pathfinder Implementation Phase work is well underway at Astrium Ltd., with all activities proceeding according to schedule. The main activity by the spacecraft engineering team in the reporting period has been the implementation of the actions derived from the System Preliminary Design Review (PDR) and the preparation of the Mission PDR. Work has also progressed on the LISA Technology Package (LTP), on the NASA's Disturbance Reduction System (DRS) interface definition, and on the procurement of the various subsystems and equipment. At the time of writing, fifteen Invitations to Tender (ITTs) have already been issued. Nine subsystem/equipment items have been kicked-off, while the others are at various stages in the selection process. The few remaining ITTs are in a late stage of preparation and will be issued during the first quarter of 2006.

Organisation of the LTP procurement according to the Multilateral Agreement between ESA and the participating Member States (D, I, UK, E, CH, F and NL) is now fully in place, with all contracts between the funding agencies and the relevant contractors negotiated and signed. After the programme re-shaping, performed in the last months in cooperation with the industrial contractors and the national partners involved in the LTP, a series of subsystem reviews is taking place to assess technical and programmatic consistency. These reviews are still ongoing and will be completed in February 2006. Good progress has been made in many areas, but it is evident that the activities leading to a timely delivery of the LTP remain very challenging and will require the full commitment of all parties involved.

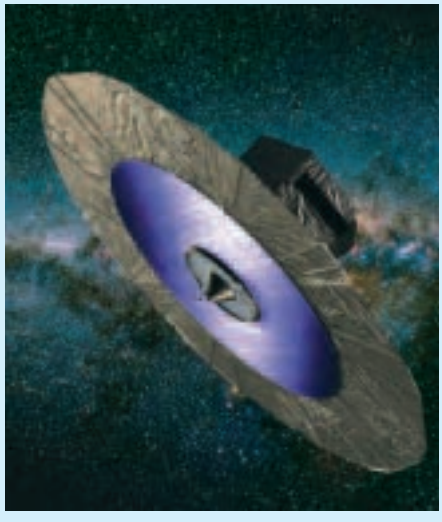
Following a series of reviews at JPL and NASA Headquarters, the American contribution to the LISA Pathfinder mission, the DRS, has been descoped by NASA. It now consists of only the colloidal micropropulsion subsystem and the computer with the drag-free software. In this new configuration, the DRS will make use of the European gravitational sensor, embedded within the LTP, for its operation.

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

Gaia

Two industrial consortia submitted proposals in response to the Invitation to Tender (ITT) for the implementation and early operational phase of the spacecraft. The proposals were received on 4 October and a detailed assessment by a team of more than 70 ESA experts followed. The Tender Evaluation Board formulated its recommendations on 12 December and these are now being submitted to ESA's advisory structure for formal approval.

The ongoing technology-development efforts on a cold-gas micro-propulsion system are progressing smoothly and giving good confidence regarding the feasibility of such a novel system. The technology activity related to the grinding and polishing of the big, rectangular-shaped SiC primary mirror is nearing completion.



Artist's impression of Gaia

James Webb Space Telescope

JWST continues to be the highest-priority NASA astronomy mission. However, due to the increased cost to completion and the NASA budgetary situation, the launch date has been delayed to June 2013. The JWST System Definition Review was, however, successfully completed in January. All of the critical developments are well advanced in terms of design and verification approach.

NIRSpec

The procurement process for the instrument critical elements has been completed. Manufacturing readiness reviews for the first SiC ceramics qualification and flight parts were held in late December, marking a major milestone in the NIRSpec project.

NASA, which is responsible for developing the Micro Shutter Assembly (MSA) for the NIRSpec instrument, has made significant progress in the development of a full-sized MSA. Problems with shutter stiction remain to be solved.

MIRI

The MIRI Structural Thermal Model test programme has been completed. A thermal leak anomaly during the 7 K thermal balance test is under investigation. Intense preparation for the unit-level Critical Design Reviews (CDRs), leading up to the optical system CDR in summer 2006, is underway. The manufacture of parts for the verification model is in progress.

Launcher

NASA has confirmed its decision to use an Ariane-5 ECA, provisioned by ESA, for the JWST launch. The corresponding Memorandum of Understanding (MOU) between ESA and NASA is being finalised.

LISA

Phase-2 of the Mission Formulation study led by Astrium GmbH is in progress. The next milestone will be the Mid-Term Review in April 2006. The interface with NASA is very effective, with technical matters presented and discussed regularly at Technical Interchange Meetings and via weekly teleconferences, leading to the finalisation of the project baseline architecture. The top-level risk list is being compiled and a joint ESA-NASA Technology Plan has been prepared.

Microscope

The Phase-B of the Microscope project at CNES, kicked-off in October 2004, is devoted to the completion of the technical requirements, and the specification of the internal and external interfaces. The Preliminary Design Review (PDR) that will close Phase-B is planned for January/February 2006. Prior to the spacecraft PDR, the main milestones related to the development of the critical technologies were the Electric Propulsion System (EPS) Delta-PDR held in July 2005, and the ONERA Inertial Sensor PDR in November/December 2005. The launch is presently scheduled for March 2009.

The EPS, to be provided by ESA, is now in Phase-C, after successful completion of the Delta-PDR. The next milestone is the validation key-point, related to the successful completion of the engineering-model tests, including a partial-life demonstration of 2000 hours. The engineering-model test programme, started in September, includes functional and performance testing at thruster and at subsystem level, environmental, direct thrust measurement, and lifetime testing. All of the contracts for the EPS flight-hardware critical procurement activities are ongoing.

GOCE

Following the recommendations of the July meeting of the System-Level Critical Design Review (CDR) Board, a close-out report on the system's development status was presented to the Board on 8 December. This report included a revised schedule that seeks to mitigate as much as possible the consequences of the delay incurred in the production of the Accelerometer Sensor Head (ASH) flight models (FMs). The Board acknowledged that satisfactory progress had been made on all the issues identified at the July meeting and confirmed the closure of the GOCE System CDR. The Board also noted the significant progress achieved in the development of the various elements of the ground segment and in launcher procurement.

Concerning the long-standing accelerometer anomalous-stiffness problem, following the positive results on ASH FM3 reported in the previous ESA Bulletin ASH FM4 was

The MIRI Structural Thermal Model before starting a cryogenic test at RAL (UK)

successfully integrated and tested, showing nominal stiffness both before and after environmental testing. Additionally, ASH FM1, which had previously revealed a non-compliant stiffness, was reassembled and tested before environmental vibration, again exhibiting nominal stiffness behaviour. The significant conclusion from this is that, with the adoption of special cleanliness precautions, fully compliant ASHs can be manufactured and/or integrated. Unfortunately, technical problems in the subsequent functional and performance testing of ASHs both individually and at pair level have led to a further delay in the acceptance testing of the flight models. It is estimated that about six months of work is still required to complete the acceptance of the full set of six ASH FMs. In view of this, the Board made recommendations on possible improvements in the manufacturing process, such as increasing the number of available spare parts and undertaking parallel testing activities. On the positive side, the first part of the flight-model electronics functional testing involving the Gradiometer Accelerometer Interface Electronics Unit, one FEEU and the Gradiometer Thermal Control Unit has been successfully completed.

On the platform side, the first series of closed-loop functional tests of the Drag-Free Attitude Control System on the Platform Engineering Model (EM) Test Bench (TbH) was performed. In parallel, the debugging of the platform EM TbH to payload EM (i.e. the SSTI Engineering Qualification Model (EQM) and the Gradiometer EM) interfaces is progressing at a good pace. Moreover, the platform flight-model integration activities have progressed according to plan, with the integration of all FM units (except that of the Ion Propulsion Assembly) completed and functional testing of the data handling underway. Testing of the Ion Propulsion Assembly (IPA) EM has successfully verified its overall performance and, in particular, the compatibility between the EQMs of the Ion Thruster, the Ion Propulsion Control Unit and the Xenon Feed System. Concerning the solar array, the four FM body-mounted panels and the two FM wing panels have been acceptance tested after the installation of the solar cells. All panels successfully passed these tests, with the exception of one wing panel whose substrate had already shown a weakness in a specific porous area that had been previously reinforced. Unfortunately, the injection of additional glue into the weak area proved to be inadequate and a small delamination has occurred in the affected area. Investigations are being carried out to establish a suitable repair method and, in parallel, a backup solution of having a new wing panel manufactured is also being assessed.

SMOS

The payload Critical Design Review/ Qualification Results Review has been successfully completed and flight-unit production is in full swing. As one of the first activities, a deployable arm of three segments from the STM has been equipped with flight receivers to undergo very accurate measurement of the 'on farm' antenna pattern.

After the Calypso launch (another CNES Proteus-based project) was delayed to at least February 2006, the Ground Support Equipment was returned to Alcatel so that the SMOS platform assembly work can start in January. Major mechanical interfaces have been agreed with the selected launch-service provider, Eurockot. The CryoSat launch failure is assumed to have no impact on the general viability of the launcher.

All technical and contractual issues have been agreed with Indra (E), the prime contractor for the ESA part of the ground segment, and contract signature is imminent. An overall ground-segment Preliminary Design Review, including the adaptation of the Proteus-generic satellite-control elements, is scheduled for Spring 2006.

ADM-Aeolus

The flight-model structure of the spacecraft has been delivered to Astrium in Stevenage (UK). The first stage of integration of the flight platform, namely that of the Reaction Control Subsystem, has begun.

The flight-model structure of the payload instrument has also been delivered to Astrium in Toulouse (F). The first flight models of the instrument's electrical equipment are also arriving.

The polishing of the silicon-carbide primary mirror has been completed at Opteon in Finland, and the mirror is now being coated

The laser qualification model is being readied for testing, including the first two weeks of vacuum operation, which will take place shortly. Resistance to laser-induced damage has been demonstrated for the majority of components and coatings for flight, but some questions still remain with respect to the frequency-tripling crystal. Alternatives are on order as a backup.

The Aladin Airborne Demonstrator, a version of the instrument compatible with airborne and ground operation, was flown for the first time aboard DLR's Falcon aircraft. The instrument produced the first Mie and Rayleigh returns from the atmosphere below the aircraft. It will now be used for the first ground campaign in April of this year.

Launch of the satellite remains scheduled for September 2008.

The Aladin Airborne Demonstrator aboard the DLR Falcon aircraft

Swarm

Swarm is the fifth ESA Earth Explorer Mission. The mission concept involves placing a constellation of three satellites in three different near-polar orbits at altitudes of 450 to 530 km, which will provide high-precision and high-resolution measurements of the strength and direction of the Earth's magnetic field.

The Phase-B satellite activities have been kicked off with the prime contractor EADS Astrium GmbH at the end of November. The Absolute Scalar Magnetometer (ASM) Phase-B was begun by CNES in mid-October.

The risk-reduction activities funded by the Canadian Space Agency (CSA) for the Canadian Electrical Field Instrument (C-EFI) are ongoing. A design that increases the lifetime of the phosphor screen has been successfully tested, while work on the shutter design needed to limit the ion flux under extreme conditions and preserve the lifetime of the micro-channel plates is still in progress. The Phase-B1 is ongoing with ComDev (Cnd) as the instrument prime contractor, together with the University of Calgary for the sensor head's definition and the University of Uppsala (S) for the Langmuir probe.

The direct-injection capability of the Vega launcher for the three Swarm satellites is under investigation with the Arianespace team.

The Preliminary Design Review is planned for January 2007.

MetOp

ESA and Eumetsat have continued to monitor closely the status of preparations for the launch of the first MetOp satellite, and have concluded that a 30 June 2006 launch is still a feasible baseline. Reviews held in the last months included that of the Satellite In-Orbit Verification (SIOV) programme, and the provisional acceptance review for the core Ground Segment.

Lift-off on 21 December of the Ariane-5G vehicle carrying MSG-2 and Insat-4A

The next milestones to be achieved before giving the satellite formal consent-to-ship to Baikonur include:

- a successful outcome to the (Eumetsat) Launch and Operations Readiness Review to be held mid-February 2006
- a successful outcome to the (first) satellite system verification test in March
- the completion of the launch vehicle's qualification
- satisfactory resolution of the thruster flow-control-valve anomaly.

It is now confirmed that the required retrofits affecting the AMSU-A1 and A2 instruments will be performed at EADS Astrium in Toulouse (F) at the end of January/early February 2006, together with the re-integration of the re-calibrated SEM sensors.

The qualification process for the new elements of the Soyuz ST/Fregat launch vehicle continues, with mechanical testing of the Fregat, launcher intermediate bay and the fairing underway. A pre-shipment review for the thee-stage Soyuz ST, including the fairing, was held at TsSKB (Samara) in late December. The launcher has been shipped to Baikonur for the 'dry run' activities needed to validate the modified launcher infrastructure at the cosmodrome.

Activities in the systems and operations area are intensifying, focusing on the performance of a number of final system tests to guarantee safe spacecraft in-orbit operability and the ability to generate flawless level-0 data. The review by industry and the Eumetsat Partners of all critical LEOP, SIOV and routine procedures has been initiated. These procedures are all being validated on a satellite simulator that has recently been upgraded to better model appendage deployment during LEOP.

Meteosat Second Generation (MSG)

MSG-1

Meteosat-8 (formerly MSG-1) operations have been nominal over the last quarter. Instrument performance remains excellent.

MSG-2

After a difficult period of permanent standby and an interrupted launch campaign, MSG-2 was successfully launched on 21 December at 7:33 p.m. Kourou time (22:33 GMT) by a standard Ariane-5G launcher. The latter put the satellite into a near-perfect transfer orbit. After launch, ESOC assumed control of the satellite for the Launch and Early Operations Phase activities and ensured its safe arrival at 6.5°W longitude in geostationary orbit.

Eumetsat subsequently took control of the satellite on 2 January to start the commissioning activities. Activation of the SEVIRI and GERB instruments and verification of the Mission Communication Package's performance are now in progress.

The first MSG-2 signal was received by the Eumetsat commissioning team on 28 December from the MSG ground station in Usingen. During the commissioning period, which will last until Summer 2006, the satellite and ground systems will be carefully tested and tuned in preparation for routine operations. The first image from MSG-2 is expected to be transmitted at the end of January 2006, and the dissemination of imagery to the meteorological user

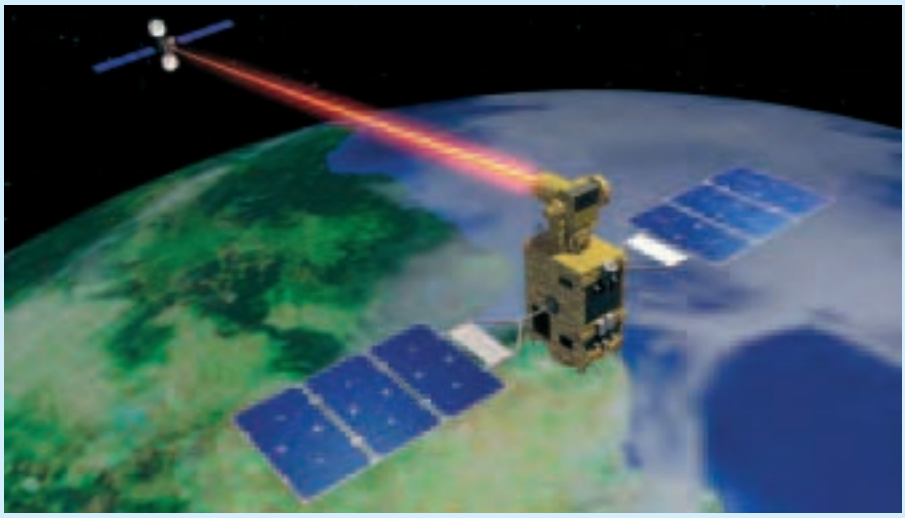
communities for evaluation purposes is expected to start in the Spring.

MSG-3

MSG-3 has remained in short-term storage in the Alcatel clean room. Open work will be completed after the team's return from the MSG-2 launch campaign, after which MSG-3 will be put into long-term storage while awaiting its own launch, which is currently foreseen for 2009.

MSG-4

The MSG-4 assembly, integration and test activities are proceeding according to plan.



The OICETS/Artemis optical link

Artemis

Artemis has now been operating for almost three years since its final arrival in geo-stationary orbit. Services to the main data-relay, land-mobile and navigation users have been consolidated and preparations for new users are now underway. All current users have expressed their satisfaction with the reliability and quality of service.

Envisat has relied heavily upon Artemis since June 2004 for the acquisition of both real-time and recorded data, and two-thirds of the science data is now downloaded via Artemis. Envisat has now accumulated more than 10 000 radio-frequency (RF) links, or a total of 5000 hours. This heavy-duty scenario has proved the value of in-orbit data relay for the fast delivery of high volumes of Earth-observation data. Many of the scenes taken over areas beyond Europe are now acquired directly via Artemis at the Envisat data-processing centre at ESRIN in Frascati (I).

Spot-4 is still making relatively modest but steady use of Artemis with two optical data links per day, recently reaching a total of 1200 links, or 230 hours. Many additional optical and RF links have been made via Artemis for the evaluation of system performance and the testing of interfaces with future users. Both service availability and success rate are now consistently above that required for reliable data acquisition.

The L-band land-mobile capacity of Artemis is leased to Telespazio and Eutelsat. These operators are continuing the European Mobile System (EMS) and related services started by ESA some years ago. There has been a steady growth in new users and the full capacity of the L-band payload is now being exploited. In addition to the integrated voice and data services initially foreseen, new services emerging include voice conferencing, mobile broadband Internet.

The Artemis navigation payload is now being used continuously by EGNOS for its Initial Operations Service. The navigation payload has been fully available for EGNOS transmissions from its NLES earth terminals at Scanzano and Torrejon, and the EGNOS operator reports that good results are being obtained from the payload.

Recently, a significant effort has been devoted to the preparation of the operations interfaces for the new ATV, USV, LOLA and OICETS users:

– The Automated Transfer Vehicle (ATV) will make extensive use of the Artemis S-band service during the free-flight, rendezvous-and-docking and attached phases of the Jules Verne mission. S-band links have been established between the ATV flight model and Artemis and linked via the Artemis earth terminal at Redu in Belgium to the ATV Control Centre in Toulouse (F).
– Artemis will also provide an S-band link for telecommand and flight-data reception during the balloon ascent phase and the drop and free-flight phase of the Italian USV (Unmanned Space Vehicle) mission developed by the CIRA aerodynamic research institute. The USV is an aerodynamic test vehicle for the evaluation of re-entry conditions. USV data will be transmitted and received by the Artemis earth terminal at Redu (B), and transferred to the CIRA control centre and launch base in Italy.
– EADS-Astrium, prime contractor for the SILEX development, is building an improved optical terminal to be flown on an aircraft for the transmission of image data via Artemis. This project (Liaison Optique Laser Aeroporté, or LOLA) will demonstrate optical communication between an unmanned reconnaissance vehicle (UAV) and Artemis under particular conditions of aircraft dynamics and atmospheric propagation. The project is well advanced and the first flights will take place in 2006.
– One of the highlights of recent months has been the success of the OICETS optical-link experiment with Artemis. It represents the culmination of several years of cooperation between ESA and JAXA in the area of data relay and free-space optical communication. Following the launch of OICETS in August, and its subsequent commissioning, the first optical links were established at the end of December. All links up to now have been successful, with very short acquisition times and excellent

tracking performance. This is the second optical user for Artemis and the first demonstration of an optical inter-operability between agencies. The in-orbit experiment will run until late 2006 for the detailed qualification of the OICETS technology.

The Artemis satellite has continued to perform nominally since its commissioning in 2003, and its lifetime expectation is ten years. New funding arrangements have been agreed for the cost of operations in 2006 and beyond for the continuation of its demonstration and operational mission objectives.

Human Spaceflight, Research and Applications

Highlights

In a Multilateral Coordination Board (MCB) teleconference on 25 October, NASA's Associate Administrator for Space Operations confirmed that 18 Shuttle flights to the International Space Station (ISS) is the NASA baseline. Subsequently, multilateral technical meetings have taken place to evaluate the ISS final configuration and assembly sequence, aiming at establishing the feasibility of advancing the launch of Columbus and its payloads (as well as the Japanese JEM and the Canadian SPDM, 'Dextre' and the six-person crew equipment). This evaluation has shown that an advancement of three flights of Columbus in the sequence is barely feasible technically, but a two-flight advancement – leading to Columbus being the six flight – is feasible.

2 November 2005 marked the fifth anniversary of continuous human presence aboard the International Space Station.

The flight of the Texus-42 sounding rocket, on 1 December, carrying an experimental payload, the Electromagnetic Levitator (EML), marked a major step forward in zero-g experimentation for the Intermetallic Materials Processing in Relation to Earth and Space Solidification project (IMPRESS). IMPRESS is a multi-million euro materials-science project co-funded by ESA and the European Commission, involving 150 materials scientists from across Europe and Russia.

The Russian Progress Cargo spacecraft (20P) docked with the ISS on 21 December, carrying supplies for the crew.

Space infrastructure development

The Columbus Preliminary Acceptance Review (PAR), covering the module without payloads, has been completed successfully. Preparation of the Final Acceptance Review 1 (FAR1), covering the module outfitted with its payload complement, is progressing well. The module has been weighed (and is some 350 kg below specification mass), the payload rack facilities have been re-integrated, and the final system test campaign has been successfully completed. The external payload complements have been integrated physically and functionally with the module and interface tests successfully performed. They were subsequently returned to their developers for final integration testing. The integrated Columbus module is due to arrive at Kennedy Space Center on 1 June 2006.

The retrofitted latch valves on the ATV 'Jules Verne' are being re-integrated. Qualification and functional tests, and de-bugging on the Functional Simulation Facility (FSF), are ongoing. A simulation of the ATV approach and docking with the ISS has been successfully performed on the software verification facility, this being the first significant operational 'end-to-end' functional simulation to have been performed with the flight software.

Closeout activities for Node 2 are ongoing at Kennedy Space Center (KSC). Mechanical integration of all of the major internal subsystems of Node 3 has been completed and electrical testing has started.

On 27 October, a contract was signed for the launch preparations and first operations of the European Robotic Arm (ERA) on the ISS. The Mission Preparation and Test Equipment (MPTE) sets for Russia are ready for shipment following inspection by RSC-Energia experts.

The second three-week training course for Russian instructors was completed in December.

Operations and related ground segments

The in-orbit commissioning of the ESA Pulmonary Function System (PFS) payload was successfully performed on 18 October in the US laboratory by the NASA astronaut W. McArthur. Three ESA experiments (MOP, SAMPLE and MUSCLE) were successfully conducted by G. Olsen – Soyuz 11S Spaceflight Participant – in October. Two ESA experiments NOA and CARDIOCOG 2 have been started by the Russian cosmonaut V. Tokarev, who is part of the Increment 12 Russian Expedition Crew. A third experiment IMMUNO will be performed later in the increment.

The passive Matroshka (human phantom) radiation dosimeters were returned to Earth with the Expedition 11 crew, who landed safely on 10 October; new detectors were uploaded in December with the Progress 20P flight.

ATV Control Centre qualification has almost been completed and interface testing with Houston, Moscow, the Columbus Control Centre, and Kourou is nearly finished.

The Columbus Control Centre (COL-CC) Qualification Review Part 1 (QR-1) was successfully completed; QR-2 is now planned for mid-2006. A major system validation between the Columbus flight segment and the COL-CC has been conducted. The docking of the 19P Progress and 11S Soyuz missions was successfully supported from the COL-CC using the ESA ground segment for the routing of live video. This service will be provided for all future Soyuz, Progress and ATV missions.

The procurement of ATV-2 equipment is practically complete. Some ATV-3 equipment has also been procured. The ATV production contract is being renegotiated to reflect the reduction from six to four ATVs, the different launch dates, and to provide bridging of the production teams until production can be restarted.

A contract for all industrial operations services

up to end-2007, including launch and commissioning of Columbus and the Columbus payloads, has been placed with the industrial operator as an end-to-end service.

Utilisation planning, payload developments and preparatory missions
The second stage of the Women's International Space Simulation for Exploration (WISE) Bed Rest Study has been completed.

Following the European Commission's selection of ESA's proposal to use the ISS as a research infrastructure (SURE project), negotiations with the EC have been completed and the Announcement of Opportunity (AO) has been released. Contacts with 12 EU countries are ongoing and visits to selected countries are foreseen for January/February 2006.

The 41st ESA Parabolic Flight Campaign took place between 3 and14 October and all 12 experiments were conducted successfully. The 42nd and 43rd campaigns are currently under preparation and both are now planned for March 2006.

The drop-tower campaign plan for 2005 has been completed as scheduled; three campaigns are currently scheduled for 2006.

The launch of the Texus 43 sounding rocket is planned for May and preparations for the launch of Maxus-7, which is scheduled for April/May, are progressing.

New payload developments and refurbishment activities for Foton-M3 are in progress; the launch is planned for September 2007.

The -80°C Freezer (MELFI) and the European Modular Cultivation System (EMCS) are being re-integrated into the Multi-Purpose Logistics Module (MPLM) prior to launch on ULF-1.1 (after final refurbishment).

The flight models of the European Physiology Module (EPM), Biolab, Fluid-Science Laboratory (FSL) and the European Drawer Rack (EDR), including the Protein Crystallisation Diagnostic Facility (PCDF), have been delivered to Bremen (D) where they have been integrated into Columbus and have successfully completed interface testing.

A request has been sent to NASA to launch the Portable Glove Box, which is needed for experiments in Autumn 2006, on a Shuttle flight; launch on a Russian Progress in mid-2006 is also under investigation as an alternative.

The flight models of the two Columbus External Payloads, SOLAR and EuTEF, have been successfully integrated and interface tested on Columbus, and subsequently returned to their developers.

A detailed study of the Atomic Clock Ensemble in Space (ACES) payload's accommodation on Columbus has started.

ISS education
The new European Master Course in Aeronautics and Space Technology (EuMAS), an initiative of the European Commission through the Erasmus Mundus programme, started on 3 October. ESA, largely through the ISS Education Fund, is the main non-academic contributor and sponsor.

The SUCCESS competition university student visit to ESTEC took place 9-12 October; experiments have been selected and endorsed by the Life and Physical Sciences Advisory Committee (LPSAC).

ARISS Radio contact was made with ISS and six schools from Norway, Italy, Belgium, Portugal and Greece on 22 November.
The preparation of selected future student experiments for the Long Duration Mission and ATV-1 is in progress.

Commercial activities
The ISS Business Club General Meeting and workshop took place in November. The presence of Dr. G. Olsen, the latest spaceflight participant on the ISS, drew a lot of participants, including selected press representatives. The event also marked the official entry into the Club of three new members. A nutritional company has expressed interest in testing a new product with a bed-rest and on the ISS.

The commercial proposal concerning the utilisation of ESA assets for training and corporate events to be held at the European Astronaut Centre (EAC) and at the Erasmus User Centre (ESTEC) has been negotiated.

Astronaut activities
The trilateral protocol between ESA, NASA and Roskosmos on the implementation of the ISS Increment mission by an ESA astronaut (T. Reiter) foresees launch to the ISS on the next Shuttle flight (STS 121), with a Shuttle or Soyuz return flight, and that the ESA astronaut will perform an EVA in an Extravehicular Mobility Unit (US EVA suit). Training for this EVA will be provided by NASA.

T. Reiter and L. Eyharts have continued with their Astrolab training, and A. Kuipers and F. de Winne received ISS and robotics training at Johnson Space Center (JSC).

The first Columbus simulation in the Integrated Simulation Set-Up was performed in October. The simulation was run on the Columbus Trainer at EAC, with the Flight Control Team in the Columbus Control Centre commanding the module.

Columbus Payload Advanced Training was provided at EAC from 24 to 28 October for 12 ground-support personnel and training engineers. A first NASA-ESA EVA training workshop was also held at EAC from 5 to 9 December, resulting in significant progress in the development of an ESA EVA pre-familiarisation training course.

Vega

The first firing test of Vega's Zefiro-9 third-stage solid-rocket motor was successfully performed on 19 December. This test was particularly important because the data collected will allow verification of:

- the ballistic performances (pressure and thrust curves)
- the internal thermal-protection efficiency
- the performance of the thrust-vector control system
- the induced thermal and dynamic environment.

A first assessment of the data shows that the test ran according to plan and all expected data have been recorded.

Analysis of the data from the AVUM engine firing test in October has confirmed performances in line with expectations. An anomaly caused by the test facility itself is under investigation.

Several other milestones have also been achieved in recent months:

- The P80 nozzle flex-seal models and thrust-vector control units and actuators have been manufactured.
- The compression test on the Z23 development model has been successfully completed.
- The Z23 development-model winding has been completed.
- The interstage 2/3 vibration tests have been successfully conducted.
- The Review Board for the half-fairing stiffness test met on 1 December and confirmed its complete success.
- The AVUM structure and 3/4 inter-stage have been manufactured.
- The interface database for the ground segment has been delivered. The consolidated analyses of the environment at lift-off and related dimensioning cases for the ground segment design have been completed.
- The new mobile-platform design has been accepted and the mobile gantry design has been revised to be compatible with the existing foundations and maximum loads.

The P80 winding test should start by mid-January 2006, after validation of the modifications to the winding machine. The Vega Industrial Day took place on 4 November in Colleferro (I), together with a visit to the facilities there. The first Vega Customer Day took place on 4 November in Rome.

At the ESA Ministerial Council in December, the Vega follow-up programme Verta was approved, which includes five launches between 2008 and 2010 and a number of activities to improve customer service and to keep launcher design and quality under close scrutiny, based on similar criteria to those established for Ariane.

Soyuz at CSG

Austria joined the Programme in October as a Participating State.

As far as technical achievements are concerned, the earthworks at the future Soyuz Launch Site (ELS) have advanced at a rapid pace, thanks to a very favourable dry season in French Guiana. Completion of the ground works is now expected more than six months ahead of schedule. The construction site was officially 'opened' on 16 November and work on the excavation of the exhaust ducts began immediately.

Following the complementary Preliminary Design Review at the end of June 2005, the main open issue remains the safety review by CSG. A detailed analysis of the safety environment during launch operations has been carried out and several meetings have taken place in cooperation with the Russian partners. The final results are expected in February 2006.

On the contractual side, CNES has now secured the so-called 'European activities' concerning the ground-segment infrastructure: a major contract was signed on 9 December with a consortium of companies representing all of the Participating States. As a consequence, and in order to facilitate the interaction of all companies involved as well as CNES staff, a project group (Plateau Project) is being assembled in Toulouse (F) to improve the coordination of the construction work between all partners, including the Russians.

The contract for the manufacture and assembly of the mobile gantry has been awarded. Insurance cover for the construction phase has finally been negotiated, so that all companies and organisations working on the site are now fully covered.

FLPP

The Future Launchers Preparatory Programme (FLPP) agreed in 2004 has the objective of performing preparatory activities for the development of the Next Generation Launcher (NGL), to be operational from 2020 onwards. Activities in 2005 focused on the finalisation of the FLPP Period-1 contracts for system-level activities, technology development (rocket propulsion, materials and structures, aerothermodynamics), as well as efforts related to the preparation of Ariane-5's evolution. Within this framework, an arrangement between ESA and the Russian Space Agency regarding cooperation on research and technology for future launchers was signed on 19 May.

During the ESA Ministerial Council in December, Member States subscribed to Step-1 of Period-2 of FLPP. This additional FLPP slice, which received a substantial financial allocation, focuses on preparing the ground for a decision to be taken in 2008 regarding the future evolution of the European launcher sector and the development of the Next Generation Launcher (NGL). esa

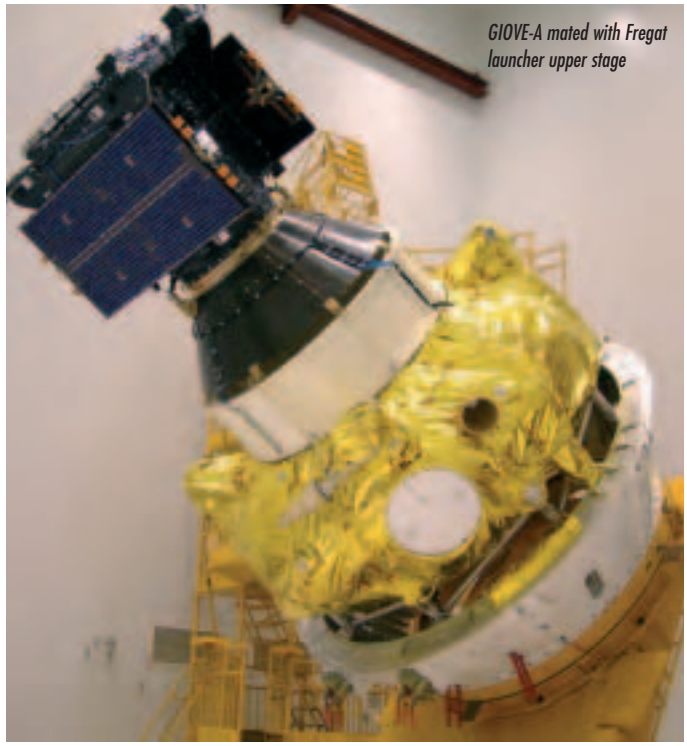
The earthworks at the future Soyuz Launch Site (ELS)

In Brief

GIOVE-A Transmits the First Galileo Signals

The GIOVE-A satellite is in good health and started transmitting the first Galileo signals on 12 January.

GIOVE-A (Galileo In-Orbit Validation Element) was placed in orbit by a Soyuz-Fregat rocket on 28 December from the Baikonur cosmodrome. Following a textbook lift-off at 05:19 UTC, the Fregat upper stage performed a series of manoeuvres to reach a circular orbit at an altitude of 23 258 km, inclined at 56 degrees to the equator, before safely deploying the satellite. The prime contractor, Surrey Satellite Technology Ltd. (UK), then opened the 7-metre solar array panels, commissioned the satellite platform and prepared the payload for tests from its Mission Control Centre.



GIOVE-A mated with Fregat launcher upper stage

On 12 January, the first Galileo navigation signals were transmitted by GIOVE-A. These were received and analysed by the Galileo receivers using the 25-metre diameter dish of the Chilbolton Observatory Facilities for Atmospheric and Radio Research (UK) and the ESA Station in Redu (B). The various Galileo signal modes will now be generated sequentially using the various GIOVE-A payload chains. Payload commissioning activities are planned to be completed by mid-February. Additional measurement campaigns will then be carried out to assess the medium-Earth-orbit radiation environment, characterise the performance of the onboard clocks and perform signal-in-space experimentation.

GIOVE-A is the first element of the Galileo In-Orbit Validation phase. This pilot satellite marks the very first step towards Europe's new global navigation satellite system, a partnership project involving the European Space Agency and the European Commission.

GIOVE-A's mission is to secure use of the frequencies allocated by the International Telecommunications Union (ITU) for the Galileo system, demonstrate critical technologies for the navigation payloads of future operational Galileo satellites, characterise the radiation environment of the orbits planned for the Galileo constellation and test the receivers on the ground. Galileo will be Europe's very own global navigation satellite system, providing a highly accurate and guaranteed positioning service under civilian control. It will be inter-operable with the two other systems: the US Global Positioning System (GPS) and Russia's Global Navigation Satellite System (Glonass). Galileo will deliver real-time positioning services with unrivalled accuracy and integrity.

A second satellite, Giove-B, built by the European consortium Galileo Industries, is currently in preparation. It will demonstrate the Passive Hydrogen Maser (PHM), which with a stability of better than 1 nano-second per day will be the most accurate atomic clock ever launched into orbit. Two PHMs will be used as primary clocks onboard the operational Galileo satellites, with two rubidium clocks serving as backups.

Subsequently, four operational satellites will be launched to validate the basic Galileo space and related ground segments. The contract for this key phase was signed on 19 January in Berlin with Galileo Industries. Once this In-Orbit Validation (IOV) phase is completed, the remaining satellites will be launched to achieve the Full Operational Capability (FOC).

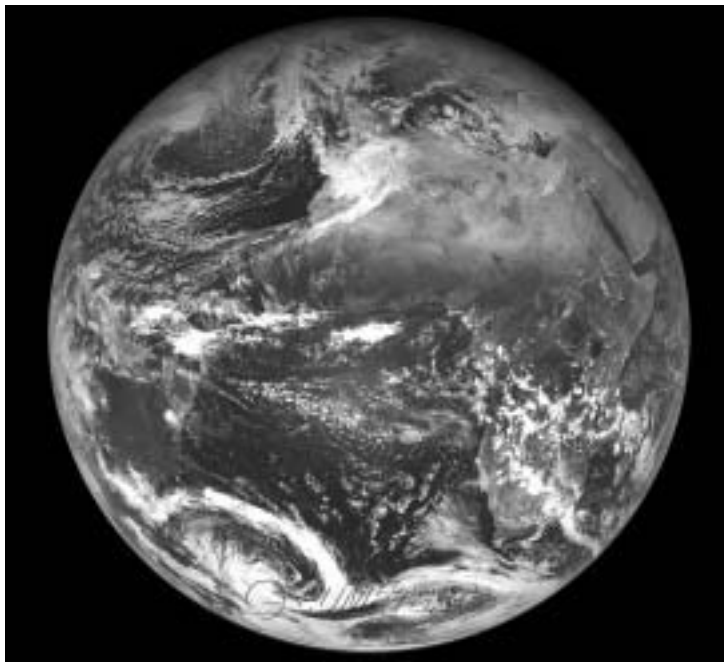
esa

The Soyuz carrying GIOVE-A lifted off on 28 December

Witnessing Global Climate Change: MSG-2 Successfully Launched

The second member of Europe's new generation of weather satellites has been successfully lifted into orbit by an Ariane-5 launcher. This ninth Meteosat satellite has been developed by ESA on behalf of Eumetsat, the European meteorological satellite organisation.

MSG-2 (the second flight model of Meteosat Second Generation) was one of the two payloads of Ariane-5's latest launch on 21 December. The European launch vehicle lifted off from the Guiana Space Centre, Europe's spaceport, in Kourou, French Guiana, at 19:33 local time and safely delivered its two passenger payloads into a geostationary transfer orbit (GTO). Under the control of ESA's European Space Operations Centre (ESOC) in Darmstadt (D), MSG-2 successfully performed a series of orbital manoeuvres using its onboard propulsion system in order to circularise its orbit at geostationary altitude. It will now undergo several months of in-orbit commissioning before being declared operational in summer 2006 and entering operational service over the Gulf of Guinea.



The first image recorded by MSG-2/Meteosat-9 in visible light at 13:00 UT on 24 January 2006

The launch of MSG-2 from the European spaceport in Kourou, French Guiana, at 19:33 local time (23:33 CET) on 21 December

MSG-2 is the first of three satellites based on the same concept, designed to improve the provision of essential data and information for operational weather forecasting and sustainable development. The new Meteosats are configured to observe the Earth in twelve spectral bands and to deliver visible, infrared and water-vapour spectral-wavelength images, with a ground resolution of 1 km.

Once operational, therefore, and renamed Meteosat-9, MSG-2 will replace Meteosat-8 as the primary satellite for monitoring the Earth's atmosphere and climate. Meteosat-8 will then be moved to 3.4°W as a back-up satellite to ensure continuity of service under unforeseen circumstances. In addition, Eumetsat is still operating the first-generation Meteosat-5, 6 and 7 satellites provided by ESA. With two more satellites currently ordered, the MSG series should provide coverage until at least 2018. The data that the Meteosats are providing are a unique record in terms of the evolution of our planet's climate over nearly three decades and its consequences for our weather.

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Science, Sun and New Friends: The ESA Space Camp

The annual Space Camp for around 130-150 children of ESA staff aged from 8 to17 has always been a very successful and increasingly popular inter-Establishment activity. The Space Camp is an exceptional forum for ESA children to bring families of different Establishments together, learn about space in general and ESA's activities in particular, including why ESA families sometimes need to move from one Establishment to another. ESA has centres in a number of European countries. The ESA space camp children are young Europeans with intercultural experiences and knowledge who are keen on space.

Models made by students exhibited during the Space Nights

Every summer the Space Camp takes place in a different ESA Member State. It culminates in the ESA Astronaut Day event, to which local media are also invited. For several years, ESRIN's Public and Institutional Relations Office has been providing material and support for the Space Camp's organisation.

The major nationalities and group languages of the 2005 Space Camp in Portugal were French, Italian and German. As usual, nearly all of the children were bilingual, and many were even trilingual. The children who came from other Member States such as the Netherlands, Spain or the United Kingdom could always find a way to communicate within their group and with their group leaders. English was the common language for many who have lived in more than one European country.

The Activities

The Camp's activities were based on local culture, history and science education. Overall there was an excellent mix of fun and education, leisure and learning, challenge, adventure and holiday. In particular, the children enjoyed:

- Lectures on the history of great Portuguese nautical explorers who discovered other continents, e.g. Dom Henrique, Fernando Magalhães, Vasco da Gama, Pedro Alvares Cabral.
- The Tavira Camera Obscura, a magical 360 degree voyage through Tavira and its surroundings hosed in a former water tower.
- A Galileo and EGNOS related activity about time and a GPS-receiver-based scavenger hunt.
- A fun and challenging treasure hunt.
- A mobile planetarium with an astro-navigation presentation.
- The Science and Space Fair, which offered the children the possibility to conduct scientific experiments.
- The Ciência Viva science centre in Tavira.
- The sports area where the children practised their sailing, canoeing, aqua-gym, basketball, volleyball, and climbing skills.

"What a wonderful camp!!!! "I will miss you all so much!!! SPACE CAMP is so cool!!!" "J'suis trop triste de vous Ki-T." "T.V.B. (ti voglio bene) ... e ho detto tutto..." "Le Space Camp au Portugal c'était SUPER, le meilleur de TOUS! Le seul truc énervant c'est qu'on peut pas rester PLUS LONGTEMPS ."
..... just some of the comments of the multilingual 'ESA campers' on the last day of the 'Navigation from Sea to Space' adventure camp, held in Tavira, Algarve, Portugal from 23 July to 3 August 2005.

Another highlight of the Space Camp were the 'Science Nights', a two-day event that takes place every year in Portugal, which promotes science during the summer holidays. This year's event was organised by Ciência Viva, the Portuguese National Programme for Science, in collaboration with the Town Council of Tavira and ESA. During both nights Michel Tognini, Head of the ESA Astronaut Centre in Cologne (D), R. Lucas Rodriguez, working in ESA's Navigation Department at ESTEC (NL) and C. Moura Cruz from the ESA Country Desk for Portugal at ESRIN (I) presented ESA's activities, focussing in particular on the Human Spaceflight, EGNOS and Galileo Programmes. The Portuguese Minister for Science, Technology and Higher Education Jose Mariano Gago, and the Head of Ciência Viva Rosália Vargas, attended the event and visited the Science Fair that was organised to let participants try several scientific experiments themselves.

The ESA Communications Country Desk for Portugal set up a stand in the old market place in Tavira for the local community and visiting tourists. The Space Camp participants also acted as ambassadors for ESA and the European youth of today by showing and explaining the experiments they had constructed in the Ciência Viva Centre.

Looking to the Future

The ESA Space Camp is an ideal way to bring together truly 'European' youngsters and to experiment with new didactic material in various European languages. It combines raising awareness of space issues with a multilingual holiday education experience, and it can also spin-off fascinating space-education projects for other national organisations.

Science on holiday can be an enjoyable experience

Preparations are already underway for the next Space Camp, which will take place in Greece from 18 to 31 July 2006, with the theme 'From Argonauts to Astronauts', highlighting man's spirit of exploration through the centuries. Further information can be found at: ccc@esa.int.

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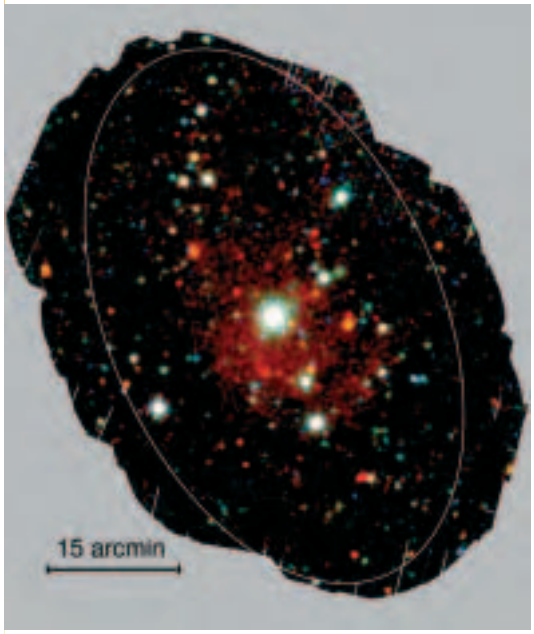
Susanna Attolico, Simonetta Cheli & Clara Moura Cruz, ESA/ESRIN

1000th XMM-Newton Scientific Paper Published



This X-ray image, showing a mosaic of the spiral galaxy M33, was taken by the X-ray imaging cameras on board ESA's XMM-Newton in August 2000. The ellipse delimits the area of the optical view of this galaxy. Credit: W. Pietsch, MPE (D) and ESA

XMM-Newton, ESA's scientific X-ray observatory mission, continues its quest to unravel the unknowns in our Universe. In January, after just five years of operations, the mission saw the publication of the 1000th scientific paper based on XMM-Newton data in top-class scientific journals.

There are several ways to measure the scientific success of a mission. One is certainly to look at the use the scientific community makes of the data obtained by a particular spacecraft, and at the number, novelty and significance of the results so produced.

From the very beginning of its operation in early 2000, hundreds of scientists all around the World have been eagerly 'booking' observing time with XMM-Newton, gathering data and searching for new clues about the hidden and powerful phenomena taking place in the Universe, not least about black holes, the births and deaths of stars, and active galactic nuclei. As a result, scientific findings based on XMM-Newton observations are now being published at a steady rate of almost 300 papers per year, which is comparable with the scientific output of the famous Hubble Space Telescope.

XMM-Newton was launched on 10 December 1999. In November 2005, the mission was extended until 31 March 2010. A further review of the mission's scientific performance and operational status will take place around autumn 2007. esa

Herschel and Planck to be Launched by Ariane

During a ceremony at ESA Headquarters in Paris on 13 December, the Agency signed a contract with Arianespace for the provision of an Ariane-5 ECA launcher for the Herschel and Planck scientific spacecraft. Herschel will study the birth of galaxies and stars and Planck the very early history of the Universe. The Ariane-5 ECA is an upgraded version of the previous Ariane-5 G ('generic') launcher. Herschel and Planck will be launched by the so-called 'long-fairing' version of Ariane-5 ECA in order to accommodate the two spacecraft, which are 7.5 metres and 4.2 metres high, respectively, and will have a total launch mass of 5.3 tons.

The launcher will deliver both spacecraft into a transfer orbit on route to their final observation site – an orbit around the second Lagrangian point (L2) situated 1.5 million kilometres from Earth away from the Sun. The launch is currently scheduled for late 2007/early 2008. esa

ESA Director General Jean-Jacques Dordain and Jean-Yves Le Gall of Arianespace signing the launch contract for Herschel and Planck

Publications

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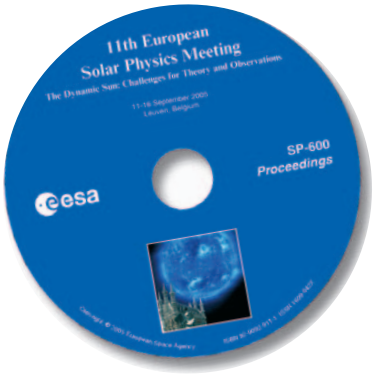

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