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bulletin

SPACE FOR EUROPE

Searching for Life on Mars

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 coordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
(d) by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

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The ESA HEADQUARTERS are in Paris.

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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;
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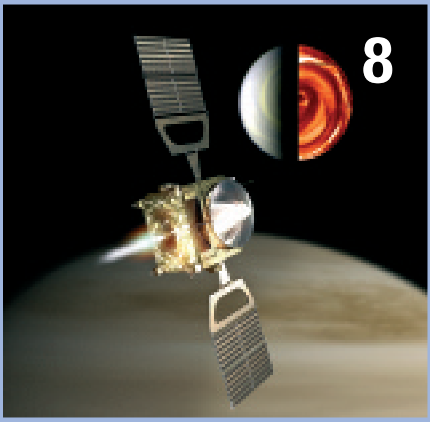
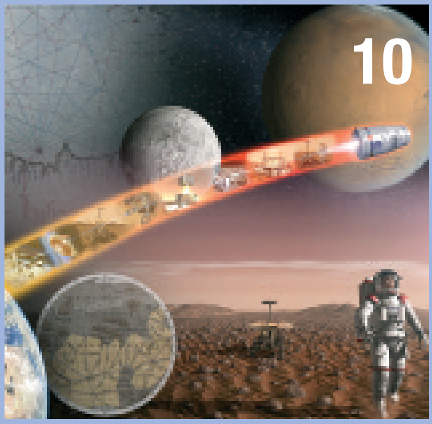
ESA plans to launch the ExoMars mission in 2011 to investigate if life ever existed on the Red Planet or is perhaps still active. See page 16 of this issue.

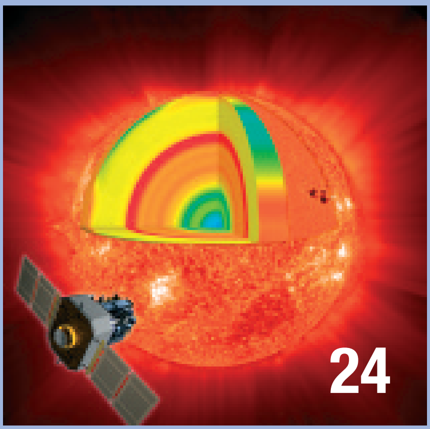


ESA at Venus!



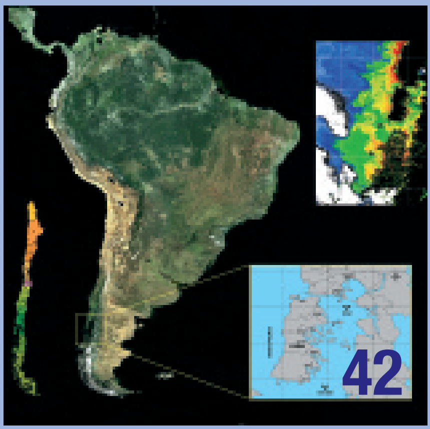
The Aurora Programme
Europe's Framework for Space Exploration

ExoMars
Searching for Life on the Red Planet



10 Years of Soho

The International Space University



Monitoring Marine Life from Space
Envisat Experience in Chile

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ESA at Venus!

At 07:17 UT (09:17 CEST) on 11 April 2006, the Venus Express spacecraft fired its main engine to enter orbit around Earth's sister planet, making ESA the first space agency to have vehicles orbiting the Moon, Mars and Venus at the same time.

With this latest success, the Agency has added another celestial body to its range of targets in the Solar System. ESA is operating Mars Express around Mars and SMART-1 around the Moon, and is a partner on the Cassini orbiter circling Saturn. ESA also has the Rosetta spacecraft en route to Comet 67P/Churyumov-Gerasimenko.

"With the arrival of Venus Express, ESA is the only space agency to have science operations under way around three planets and a moon," said David Southwood, Director of ESA Science. *"We are really proud to deliver such a capability to the international science community."*

Venus Express was launched on 9 November 2005, and its 50-minute main engine burn ended the 153-day and 400-million kilometre cruise through the inner Solar System. The spacecraft reduced its relative velocity towards the planet from 29 000 km/h to about 25 000 km/h and was captured by the planet's gravity field.

After arrival in its initial capture orbit, engineers lost no time in switching on several of the instruments. The southern hemisphere of Venus was observed for the first time in space history, by the Venus Monitoring Camera (VMC) and Visible & Infrared Thermal Imaging Spectrometer (VIRTIS) as the spacecraft arced below the planet.

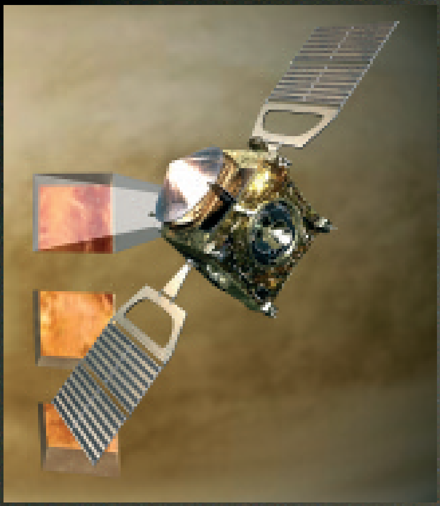
Scientists were especially intrigued by the dark vortex shown almost directly over the south pole, a previously suspected but until now unconfirmed structure that corresponds to a similar cloud structure over the north pole. *"Just one day after arrival, we are already experiencing the hot, dynamic environment of Venus,"* said Dr Hakan Svedhem, Venus Express Project Scientist. *"We will see much more detail at an unprecedented level because we will have over 100 times better resolution as we get closer to Venus, and we expect to see these spiral structures evolve very quickly."*

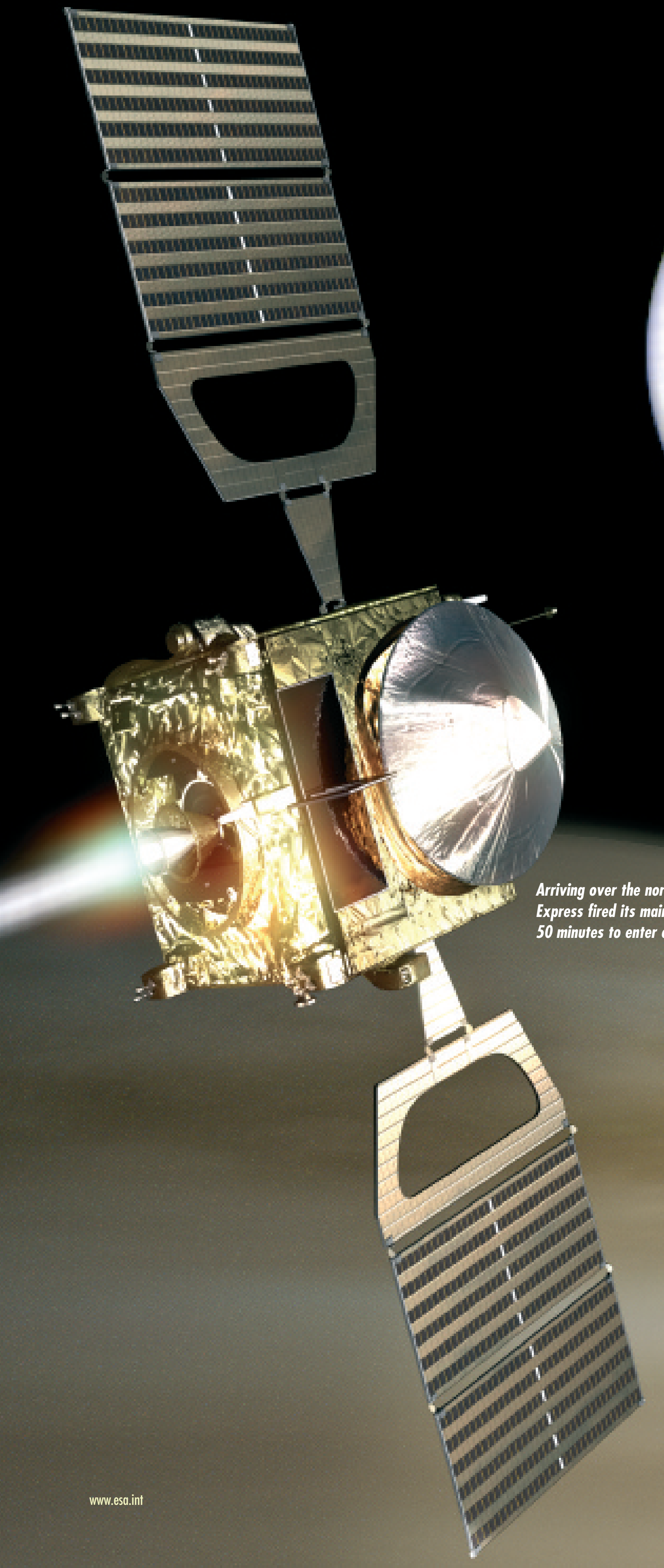
The initial, low-resolution images were taken from a distance of 206 452 km from the planet, and yet still caught the scientists' attention, particularly with the surprisingly clear structures and unexpected detail shown in the VIRTIS spectrometer images.

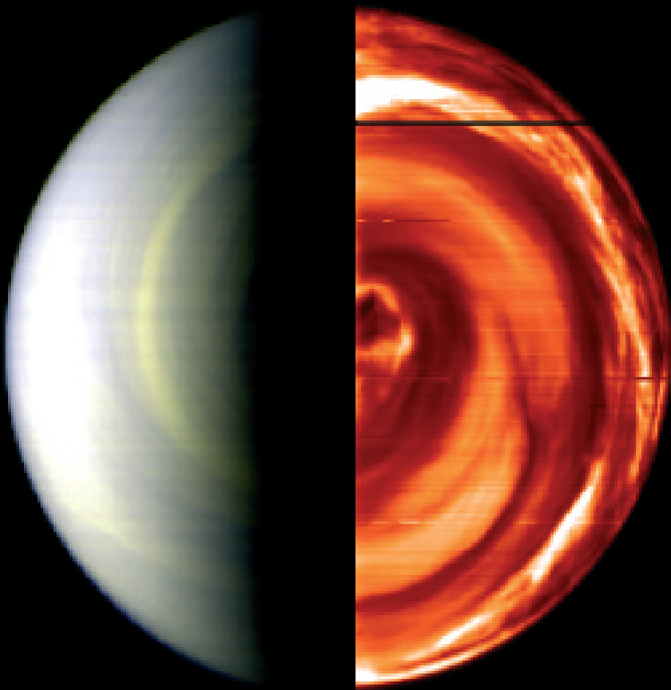
During the following four weeks, Venus Express made a series of manoeuvres to reach the scheduled orbit for its scientific mission. A highly elongated first nine-day capture orbit took it to an apocentre (maximum height) of 330 000 km below the south pole.

In the first capture orbit, Venus Express had five additional opportunities for gathering data before reaching pericentre. These observations were a great opportunity because, at apocentre, the whole disc of Venus was fully visible to the instruments. Such opportunities will not occur again during the nominal mission, starting on 4 June 2006, because the range of distances to the planet will be much smaller.

A series of further engine and thruster burns gradually reduced the apocentre during the following 16 orbital loops, bringing Venus Express to its operational 24-hour polar orbit at an altitude of 66 000 km. From this vantage point, the spacecraft will conduct in-depth observations of the structure, chemistry and dynamics of the atmosphere for at least two Venusian days (486 Earth days).







ESA's Venus Express has returned the first-ever images of the planet's south pole. The images were taken on 12 April 2006 during the spacecraft's initial capture orbit after successful arrival on 11 April. The false-colour VIRTIS composite image shows the day side (left) and night side (right), with a resolution of 50 km per pixel. (ESA/INAF-IASF, Rome, and Observatoire de Paris)

Arriving over the north pole, Venus Express fired its main engine for 50 minutes to enter orbit

The Aurora Programme

Europe's Framework for Space Exploration

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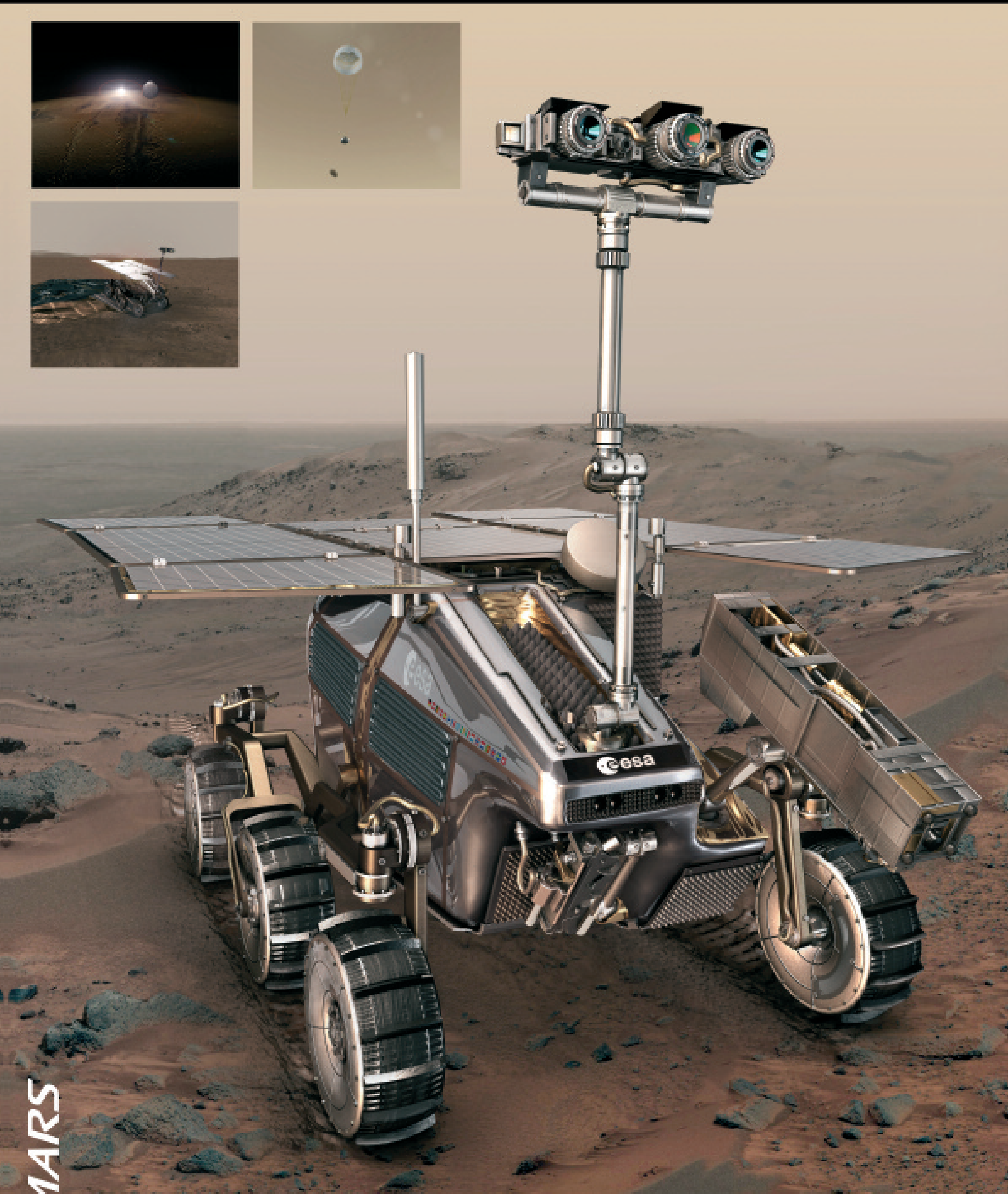
By 2001, ESA had identified robotic and human exploration of the Solar System as one of the major undertakings for Europe and its international partners in the 21st century. Spacefaring nations, with Europe at the forefront, have successfully explored other planets through unmanned missions, and the International Space Station is a permanent presence in low Earth orbit. Creating the framework that brings together the robotic and human elements of space activities for further exploration of the Solar System is the next logical step.

The Aurora Programme Preparatory Phase

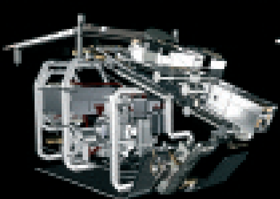
The scientific, academic and industrial communities were polled on the preferred destinations and objectives of a potential long-term exploration programme. Mars scored first, followed by other destinations that included the Moon. The advice from the different communities was an important element in proposing a new European programme – the Aurora Space Exploration Programme – as a building block in a broader international effort for the robotic and human exploration of Mars, with the Moon as an important stepping stone.

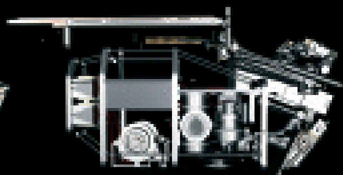
EUROPEAN SPACE EXPLORATION PROGRAMME

AURORA



EXOMARS





- Search for traces of past and present life
- Characterise geochemistry and water distribution
- Improve environment and geophysics knowledge
- Identify biological hazards to future missions

The Preparatory Phase lasted from the beginning of 2002 to December 2005, with the number of participating countries growing along with the funding. From the initial €14 million, the envelope reached more than €48 million from 12 States (Austria, Belgium, Canada, France, Germany, Italy, The Netherlands, Portugal, Spain, Sweden, Switzerland and the UK). Italy was the main contributor.

In January 2004, the US President announced a new space policy directing NASA to implement the *Vision for Space Exploration*. This was a turning point in global space policy, creating a renewed interest in space exploration among spacefaring nations. An assessment on how far this new policy would affect Europe's exploration programme was conducted in cooperation with European space agencies, industry and other stakeholders gathered in the Space Exploration Policy Assessment Group. At the same time, a thorough revision of the ExoMars mission and its scientific objectives was performed with the scientific community and the national delegations.

The long-term and visionary nature of space exploration requires well-rooted support by society at large. This is why a dialogue with stakeholders and with sectors not usually involved in space was conducted throughout 2005. The aim was to identify the main elements that should drive Europe's sustained involvement in space exploration with its international partners. At the end of the consultations, four main drivers were identified:

Europeans in space: allowing Europe to be a significant partner in exploration by assuring access to enabling technologies, the presence of European culture in future space endeavours, the enhancement of European integration, and the creation of European pride around an inspiring and ambitious cooperative project;

Habitability and life beyond Earth: increasing our knowledge of life, its evolution and its environment;

Sustainable human life in space: the development of enabling technologies to support life and protect health, to access energy, manage environmental risks and exploit local resources;

Sharing the space adventure and benefits: communicating the excitement of human spaceflight and exploration, and sharing the benefits with the general public.

On the basis of all the above, together with indications of support from Member States, an ambitious yet realistic proposal was prepared for the Aurora Space Exploration Programme and submitted to the ESA Council Meeting at Ministerial Level in Berlin (D) on 5–6 December 2005.

The Approved Aurora Programme

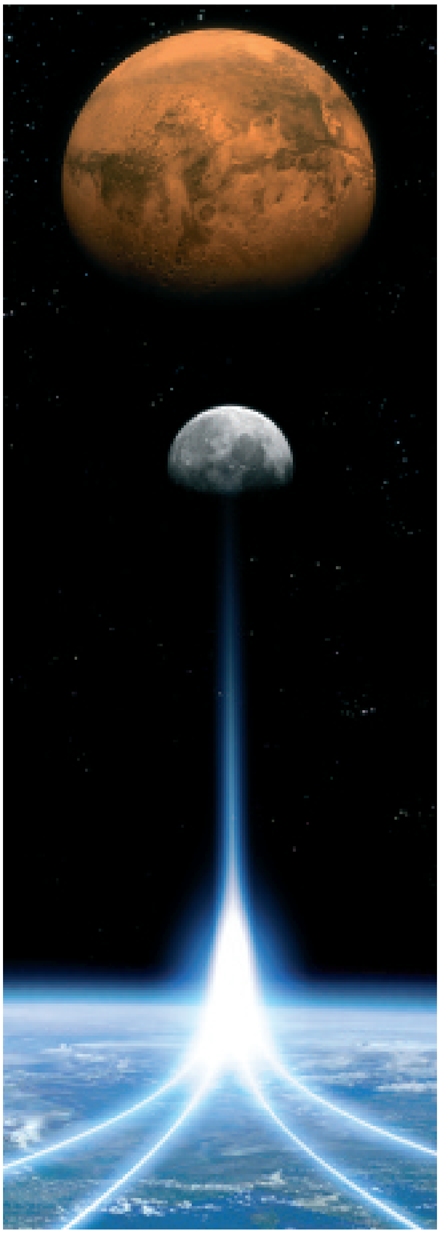
European Ministers confirmed, at the highest political level, the willingness of Europe to play a significant role in exploring and understanding the Solar System, in particular Mars and the Moon.

The approved Aurora Space Exploration Programme consists of two main elements: the Core Programme and Robotic Missions. The first is defining architectures and scenarios, and preparing for missions and their enabling technologies; the other is developing actual missions.

Core Programme

The Core Programme aims to allow Europe to participate meaningfully in the future exploration endeavours, although further decisions at later Ministerial Councils will be required. Based on a building-block approach, the activities will ensure the robustness of Europe's contribution, and include:

- exploration roadmaps, scenarios and architecture studies. Updating the scenarios and roadmaps elaborated during the previous Preparatory Phase, based on continuous consultations with the stakeholders and leading to system studies and mission architectures for human and robotic missions to the Moon and Mars. These activities will enable Europe to determine its objectives, interests and priorities by identifying further missions and elements for realisation;
- development of enabling technologies for Mars Sample Return (MSR). The goal of bringing back the first sample of Martian soil is a major technological challenge – and a great opportunity for the scientific world. It has important implications for understanding the planets, studying the origin of the Solar System, and



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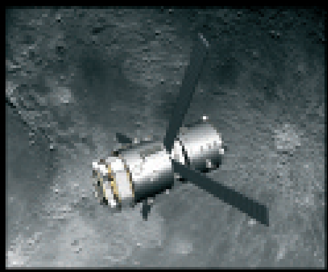
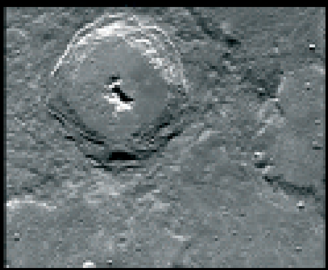
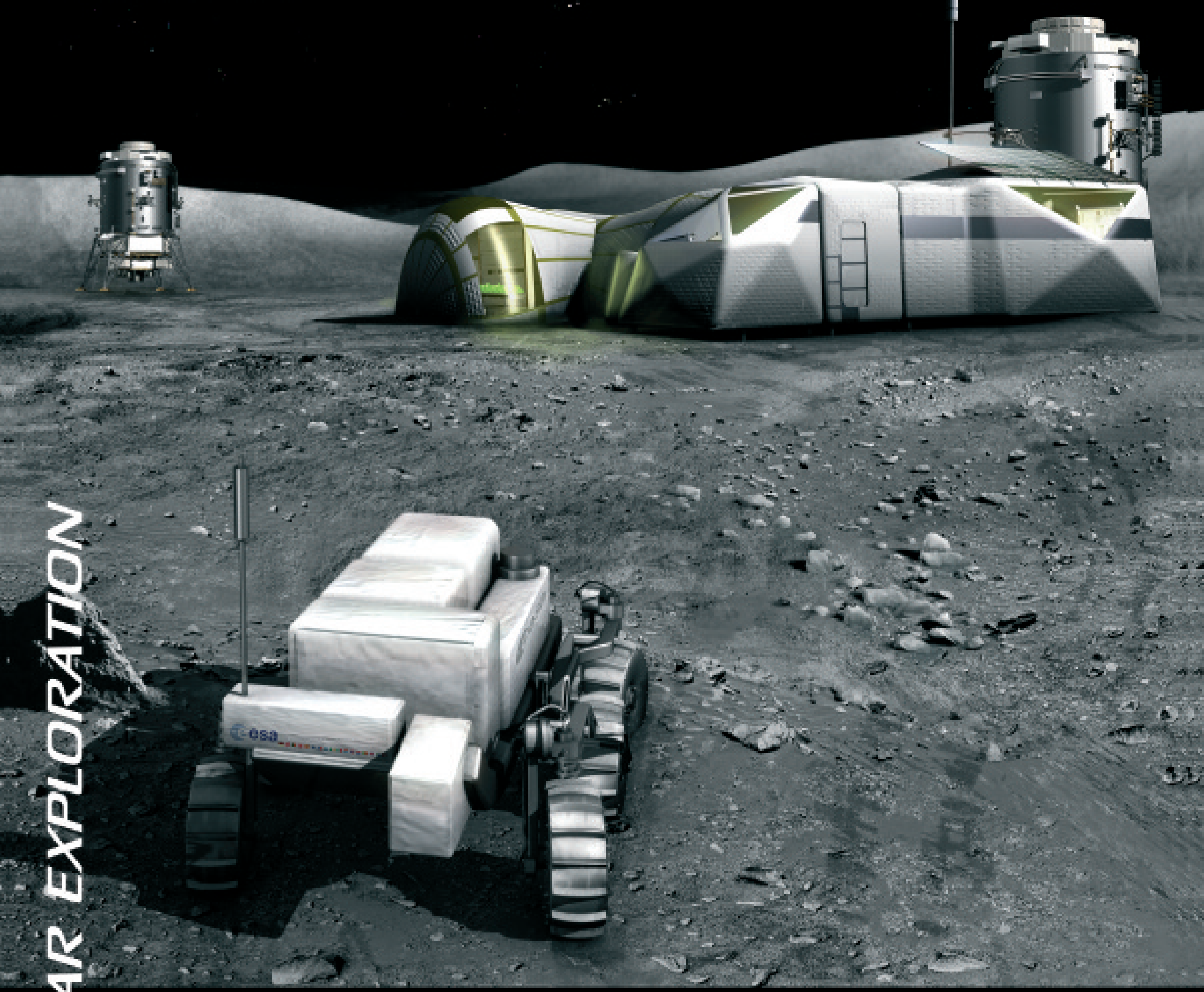
EUROPEAN SPACE EXPLORATION PROGRAMME

AURORA

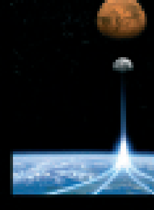






LUNAR EXPLORATION

- General human and robotic exploration technology
- Habitat and Inflatable Module Technologies
- Robotic Crew Aids/Surface Robots
- Life Support, Food Production,Waste Management



searching for life on Mars. MSR is also a major milestone for exploration because its mission profile is suitable for a subsequent human visit to Mars;

- development of general enabling technologies for exploration, flight demonstrations of selected enabling capabilities, and the preparation of potential European contributions to lunar exploration;
- awareness activities, in association with the European Union, to engage European citizens in space exploration and to inspire new generations through, among others, the involvement of universities in the elaboration of future exploration missions.

Robotic Missions

This component covers the development, launch and operation of selected exploration missions. The first proposed European mission is ExoMars – the first exobiology mission to the planet. Slated for launch in 2011, it will provide valuable experience in the design and operation of new enabling technologies and capabilities: the entry, descent and landing system, and the rover, drill and sample-acquisition systems. It will thus open the way to future scientific and exploration missions. At the same time, ExoMars will return excellent scientific information by searching for traces of past and present life, characterising the planet's biological environment, improving our knowledge of the Martian environment and geophysics, and identifying hazards before landing other spacecraft. ExoMars will qualify Europe to undertake future Mars exploration. The mission is described in greater detail in the following article.

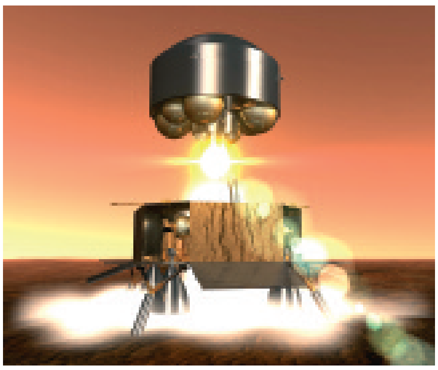
At the Ministerial meeting in December 2005, Member States could subscribe to either or both elements: 14 of the 17 countries chose both. In particular, ExoMars received overwhelming support, especially by Italy. Subscriptions of more than €650 million exceeded the financial envelope required for the proposed baseline configuration. The Core Programme attracted some €73 million for 2006–2009, with Belgium and Italy being the main contributors, followed by the UK and Switzerland.

Status and Next Steps

Phase-B1 of ExoMars is due to be completed by the end of 2006. Under the prime contractorship of Alcatel Alenia Space Italy (AAS-I), the phase has accommodated the outcome of the Ministerial Council. The baseline mission, launched by a Soyuz from Kourou in 2011, includes a carrier, a descent module, a rover and the scientific payloads: the exobiology 'Pasteur' on the rover and a geophysical package on the lander. Communications and data-relay will be provided by NASA's Mars Reconnaissance Orbiter, which arrived at the planet last March.

In order to increase mission robustness and capabilities – in anticipation of interest by Member States – two additional options are being studied in parallel by industry. An orbiter could be launched on a second Soyuz, or an Ariane-5 would allow the baseline's carrier to be replaced by an orbiter. Participating States will be called on to decide early next year at the Implementation Review. That meeting will also take into account the maturity of the mission concept.

A series of activities is being launched within the Core Programme, with special attention to architecture and system studies, a Mars Sample Return Phase-A2 study, and key technology developments for the next mission to Mars. In particular, the MSR mission is considered by the scientific community worldwide as a logical step in the exploration of Mars. From a scientific point of view, it will provide samples of Martian soil to study in our laboratories, where instruments are far more powerful than could ever be carried by spacecraft or rovers. From a technology standpoint, the MSR mission would be the first attempt at a return trip to the Red Planet, with all its operational implications.



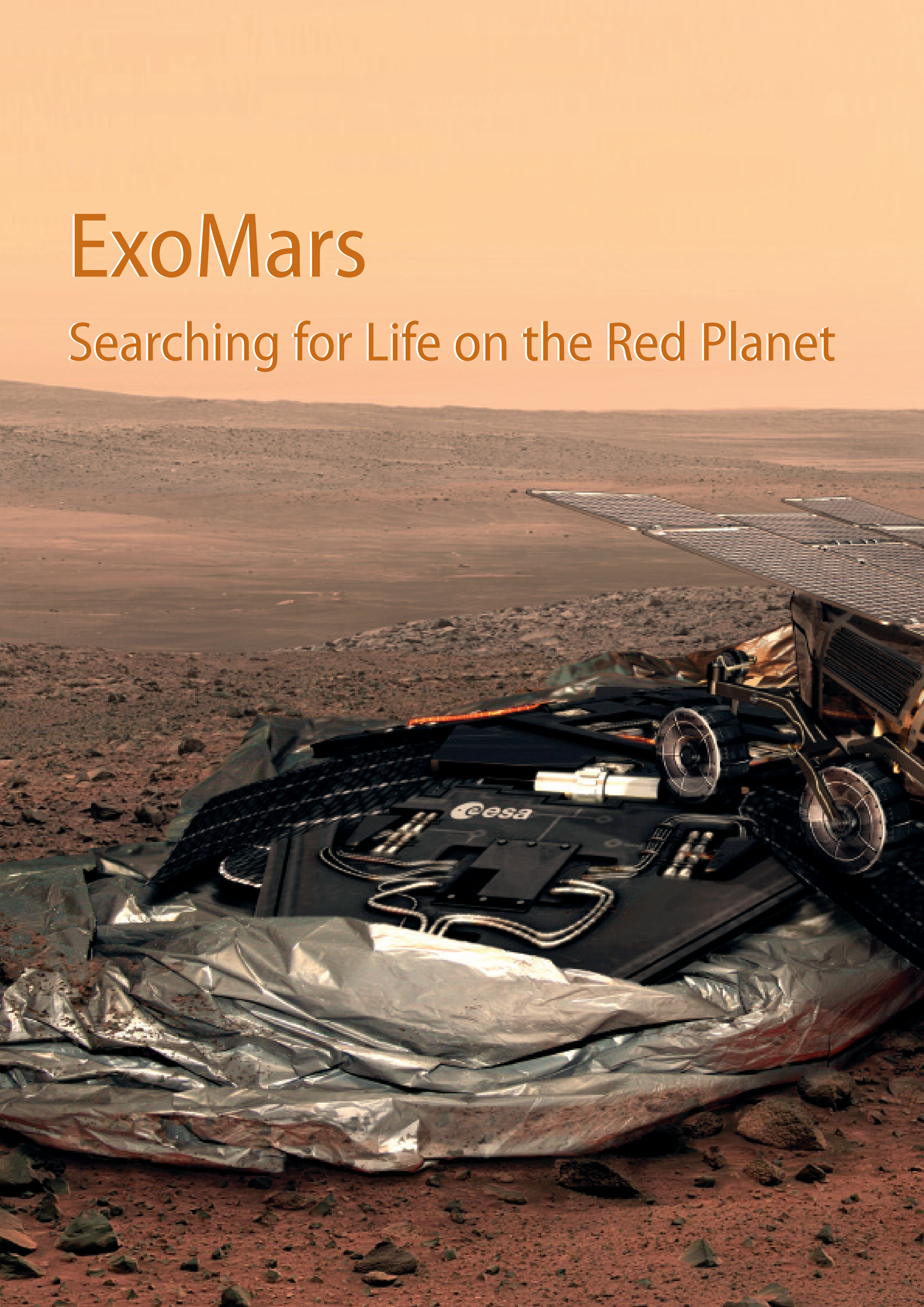
Conclusions

Aurora is Europe's framework, through ESA, for defining and developing the European contribution, be it capabilities, building blocks or autonomous missions, to the global endeavour of the robotic and human exploration of the Moon and Mars. Europe's ambition is to work out a comprehensive, long-term exploration strategy, building in a degree of independence alongside significant commonality with NASA's and other partners' plans. Europe is seeking to be a key partner, building on its achievements and experience in robotic, scientific and planetary missions, infrastructure development and human spaceflight. ESA's planned robotic missions are fully in line with the internationally agreed strategy for the scientific exploration of Mars. They fit nicely in terms of timing and scientific goals with other missions to Mars. In an evolving international context, it is important that the European contribution is robust and sustainable and, to the maximum extent possible, does not critically depend on a single partner's capabilities. Since Aurora's inception, international cooperation has always been identified as a key enabling element to achieve the long-term goals. Sound, yet flexible, international cooperation is therefore an important element for sustainability and robustness in the worldwide endeavour in which Europe and ESA intend to play a significant role. esa

Further information on Aurora can be found at www.esa.int/aurora

ExoMars

Searching for Life on the Red Planet



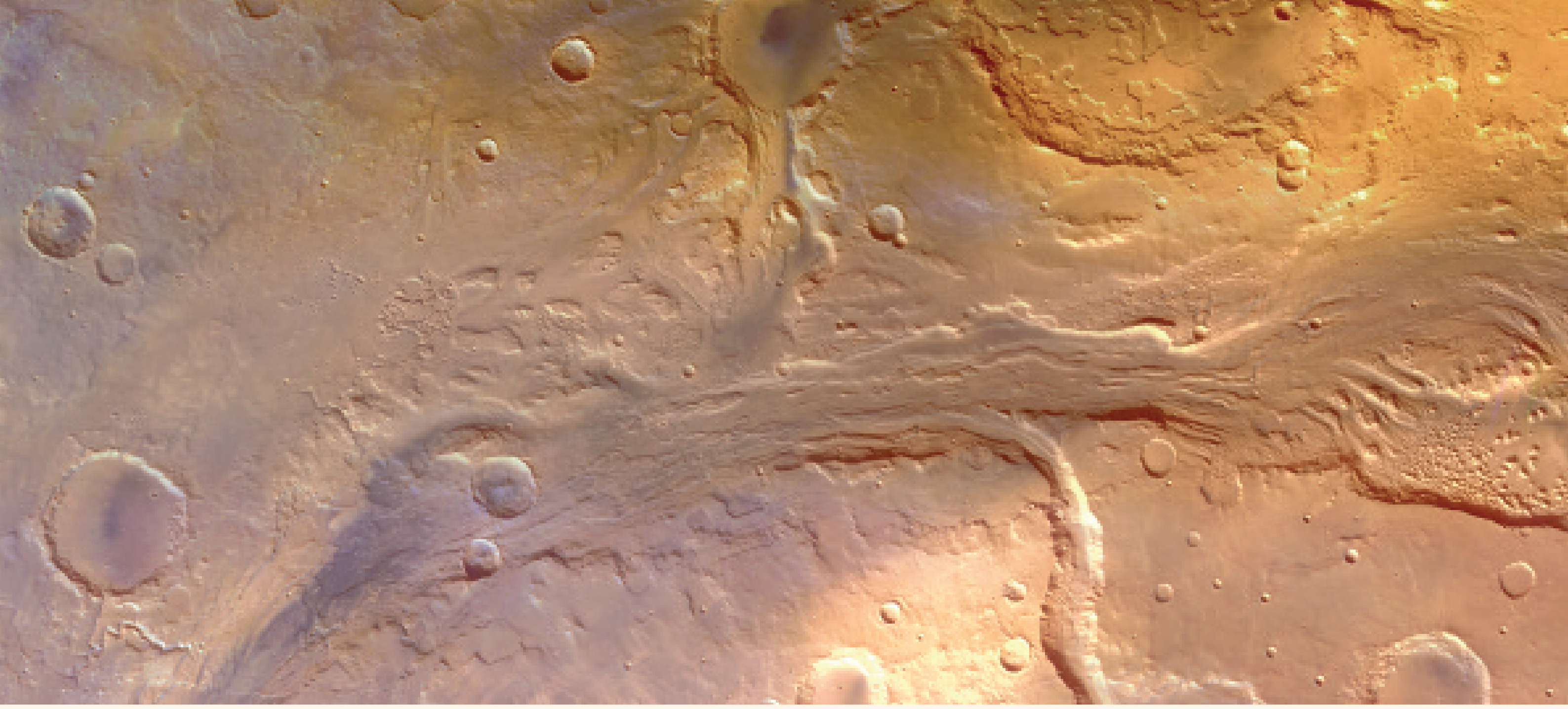
Jorge Vago, Bruno Gardini, Gerhard Kminek, Pietro Baglioni, Giacinto Gianfiglio, Andrea Santovincenzo, Silvia Bayón & Michel van Winnendael
Directorate for Human Spaceflight, Microgravity and Exploration Programmes, ESTEC, Noordwijk, The Netherlands

Establishing whether life ever existed on Mars, or is still active today, is an outstanding question of our time. It is also a prerequisite to prepare for future human exploration. To address this important objective, ESA plans to launch the ExoMars mission in 2011. ExoMars will also develop and demonstrate key technologies needed to extend Europe's capabilities for planetary exploration.

Mission Objectives

ExoMars will deploy two science elements on the Martian surface: a rover and a small, fixed package. The Rover will search for signs of past and present life on Mars, and characterise the water and geochemical environment with depth by collecting and analysing subsurface samples. The fixed package, the Geophysics/Environment Package (GEP), will measure planetary geophysics parameters important for understanding Mars's evolution and habitability, identify possible surface hazards to future human missions, and study the environment.

The Rover will carry a comprehensive suite of instruments dedicated to exobiology and geology: the Pasteur payload. It will travel several kilometres searching for traces of life, collecting and analysing samples from inside surface rocks and by drilling down to 2 m. The very powerful combination of mobility and accessing locations where organic molecules may be well-preserved is unique to this mission.



ExoMars will also pursue important technology objectives aimed at extending Europe's capabilities in planetary exploration. It will demonstrate the descent and landing of a large payload on Mars; the navigation and operation of a mobile scientific platform; a novel drill to obtain subsurface samples; and meet challenging planetary protection and cleanliness levels necessary to achieve the mission's ambitious scientific goals.

The Search for Life

Exobiology, in its broadest terms, denotes the study of the origin, evolution and distribution of life in the Universe. It is well established that life arose very early on the young Earth. Fossil records show that life had already attained a large degree of biological sophistication 3500 million years ago. Since then, it has proved extremely adaptable, colonising even the most disparate ecological habitats, from the very cold to the very hot, and spanning a wide range of pressure and chemical conditions. For organisms to have emerged and evolved, water must have been readily available on our planet. Life as we know it relies, above all else, upon liquid water. Without it, the metabolic activities of living cells are not possible. In the absence of water, life either ceases or slips into quiescence.

Mars today is cold, desolate and dry. Its surface is highly oxidised and exposed to sterilising and degrading ultraviolet (UV) radiation. Low temperature and pressure preclude the existence of liquid water; except, perhaps, in localised environments, and then only episodically. Nevertheless, numerous features such as large channels, dendritic valley networks, gullies and sedimentary rock formations suggest the past action of surface liquid water on Mars – and lots of it. In fact, the sizes of outflow channels imply immense discharges, exceeding any floods known on Earth.

Mars's observable geological record spans some 4500 million years. From the number of superposed craters, the oldest terrain is believed to be about 4000 million years old, and the youngest possibly less than 100 million years. Most valley networks are ancient (3500–4000 million years), but as many as 25–35% may be more recent. Today, water on Mars is only stable as ice at the poles, as permafrost in widespread underground deposits, and in trace amounts in the atmosphere. From a biological perspective, past liquid water itself motivates the question of life on Mars. If Mars' surface was warmer and wetter for the first 500 million years of its history, perhaps life arose independently there at more or less the same time as it did on Earth.

An alternative pathway may have been the transport of terrestrial organisms embedded in meteoroids, delivered from Earth. Yet another hypothesis is that life may have developed within a warm, wet subterranean environment. In fact, given the discovery of a flourishing biosphere a kilometre below Earth's surface, a similar vast microbial community may be active on Mars, forced into that ecological niche by the disappearance of a more benign surface environment. The possibility that life may have evolved on Mars during an earlier period surface water, and that organisms may still exist underground, marks the planet as a prime candidate in the search for life beyond Earth.

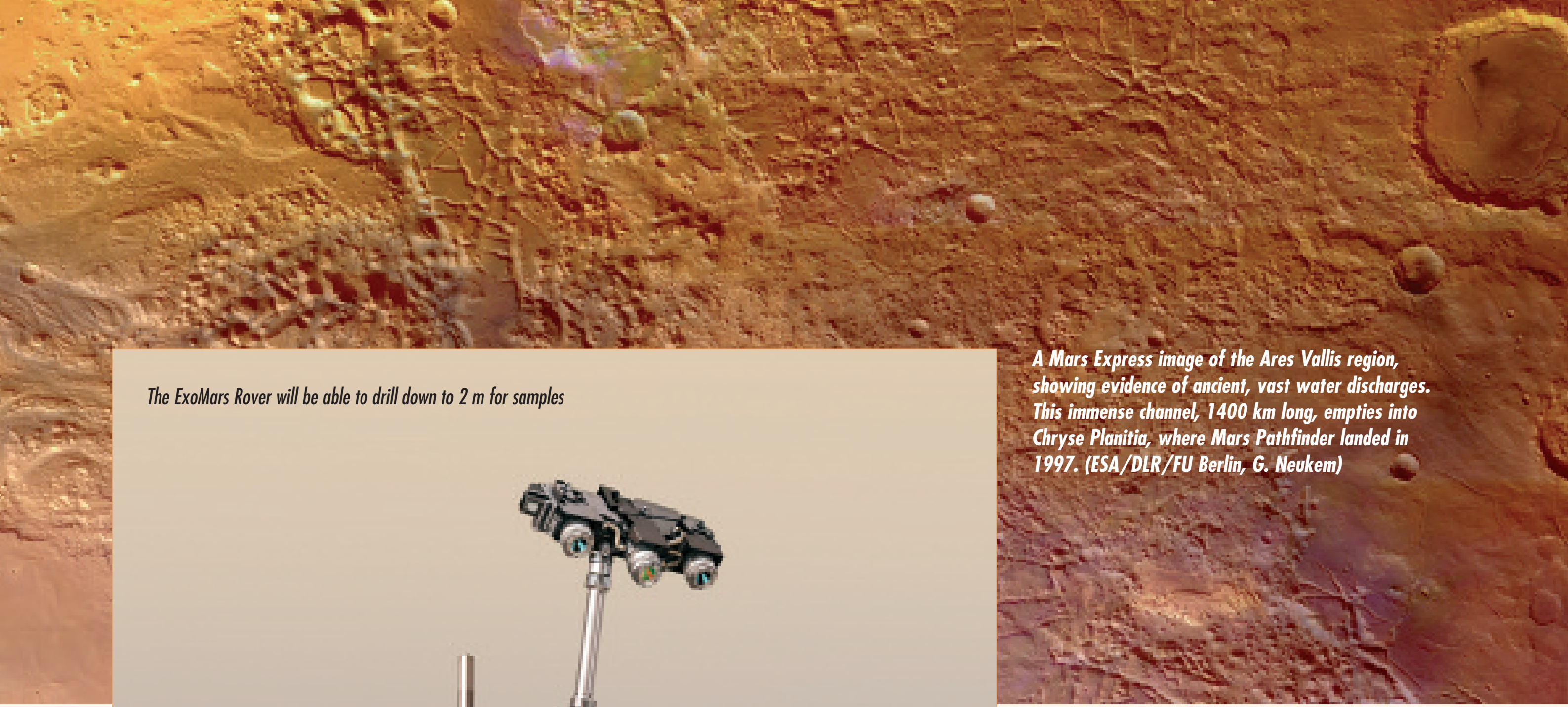
Hazards for Manned Operations on Mars

Before we can contemplate sending astronauts to Mars, we must understand and control any risks that may pose a threat to a mission's success. We can begin to assess some of these risks with ExoMars.

Ionising radiation is probably the single most important limiting factor for human interplanetary flight. To evaluate its danger and to define efficient mitigation strategies, it is desirable to incorporate radiation-monitoring capabilities during cruise, orbit and surface operations on precursor robotic missions to Mars.

Another physical hazard may result from the basic mechanical properties of the Martian soil. Dust particles will invade the interior of a spacecraft during surface operations, as shown during Apollo's operations on the Moon. Dust inhalation can pose a threat to astronauts on Mars, and even more so under microgravity during the return flight to Earth. Characteristics of the soil, including the sizes, shapes and compositions of individual particles, can be studied with dedicated *in situ* instrumentation. However, a more in-depth assessment, including a toxicity analysis, requires the return of a suitable Martian sample.

Reactive inorganic substances could present chemical hazards on the surface. Free radicals, salts and oxidants are very aggressive in humid conditions such as the lungs and eyes. Toxic metals, organics and pathogens are also potential hazards. As with dust, chemical hazards in the soil will contaminate the interior of a spacecraft during surface operations. They could damage the health of astronauts and the



A Mars Express image of the Ares Vallis region, showing evidence of ancient, vast water discharges. This immense channel, 1400 km long, empties into Chryse Planitia, where Mars Pathfinder landed in 1997. (ESA/DLR/FU Berlin, G. Neukem)

The ExoMars Rover will be able to drill down to 2 m for samples

operation of equipment. Many potential inorganic and organic chemical hazards may be identified with the ExoMars search-for-life instruments.

Geophysics Measurements

The processes that have determined the long-term 'habitability' of Mars depend on the geodynamics of the planet, and on its geological evolution and activity. Important issues still need to be resolved. What is Mars' internal structure? Is there any volcanic activity on Mars? The answers may allow us to extrapolate into the past, to estimate when and how Mars lost its magnetic field, and the importance of volcanic outgassing for the early atmosphere.

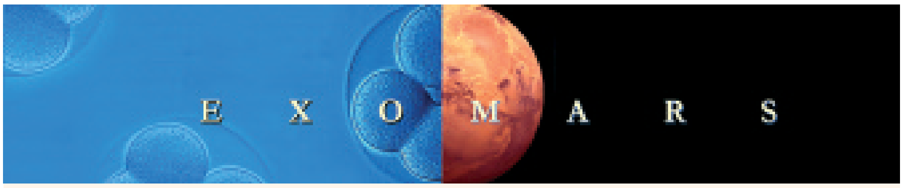
ExoMars will also carry the Geophysics/ Environment Package, accommodated on the Descent Module and powered by a small radioisotope thermal generator.

Searching for Signs of Life

If life ever arose on the Red Planet, it probably did so when Mars was warmer and wetter, during its initial 500–1000 million years. Conditions then were similar to those on early Earth: active volcanism and outgassing, meteoritic impacts, large bodies of liquid water, and a mildly reducing atmosphere. We may reasonably expect that microbes quickly became global. Nevertheless, there is inevitably a large measure of chance involved in finding convincing evidence of ancient, microscopic life forms.

On Earth's surface, the permanent presence of running water, solar-UV radiation, atmospheric oxygen and life itself quickly erases all traces of any exposed, dead organisms. The only opportunity to detect them is to find their biosignatures encased in a protective environment, as in suitable rocks. However, since high-temperature metamorphic processes and plate tectonics have reformed most ancient terrains, it is very difficult to find rocks on Earth older than 3000 million years in good condition. Mars, on the other hand, has not suffered such widespread tectonic activity. This means there may be rock formations from the earliest period of Martian history that have not been exposed to high-temperature recycling. Consequently, well-preserved ancient biomarkers may still be accessible for analysis.

Even on Earth, a major difficulty in searching for primitive life is that, in essence, we are looking for the remnants of minuscule beings whose fossilised forms can be simple enough to be confused with tiny mineral precipitates. This issue lies at the heart of a heated debate among



Mission strategy to achieve ExoMars's scientific objectives:

1. To land on, or be able to reach, a location with high exobiology interest for past and/or present life signatures, i.e. access to the appropriate geological environment.
2. To collect scientific samples from different sites, using a Rover carrying a drill capable of reaching well into the soil and surface rocks. This requires mobility and access to the subsurface.
3. At each site, to conduct an integral set of measurements at multiple scales: beginning with a panoramic assessment of the geological environment, progressing to smaller-scale investigations on interesting surface rocks using a suite of contact instruments, and culminating with the collection of well-selected samples to be studied by the Rover's analytical laboratory.
4. To characterise geophysics and environment parameters relevant to planetary evolution, life and hazards to humans.

To arrive at a clear and unambiguous conclusion on the existence of past or present life at the Rover sites, it is essential that the instrumentation can provide mutually reinforcing lines of evidence, while minimising the opportunities for alternative interpretations.

It is also imperative that all instruments be carefully designed so that none is a weak link in the chain of observations; performance limitations in an instrument intended to confirm the results obtained by another should not generate confusion and discredit the whole measurement.

The science strategy for the Pasteur payload is therefore to provide a self-consistent set of instruments to obtain reliable evidence, for or against, the existence of a range of biosignatures at each search location.

Spacecraft:	Carrier plus Descent Module (including Rover and GEP) Data-relay provided by NASA
Launch:	May–June 2011, from Kourou on Soyuz-2b (backup 2013)
Arrival:	June 2013 (backup 2015)
Landing:	Direct entry, from hyperbolic trajectory, after the dust storm season. Latitudes 15°S–45°N, all longitudes, altitude: <0 m, relative to the MGS/MOLA* zero level
Science:	Rover with Pasteur payload: mass 120–180 kg, includes: Drill System/SPDS and instruments (8 kg); lifetime 180 sols Geophysics Environment Package (GEP): mass <20 kg; includes: instruments (~4 kg); lifetime 6 years
Ground Segment:	Mission control and mission operations: ESOC Rover operation on Mars surface: Rover Operations Centre GEP operations: to be decided

**MGS/MOLA: Mars Global Surveyor/Mars Orbiter Laser Altimeter*

palaeobiologists. It is therefore doubtful that any one signature suggestive of life – whether it is an image implying a biostructure, an interesting organic compound or a fractionated isotopic ratio – may reliably demonstrate a biogenic origin. Several independent lines of evidence are required to construct a compelling case. ExoMars must therefore pursue a holistic search strategy, attacking the problem from multiple angles, including geological and environmental investigations (to characterise potential habitats), visible examination of samples (morphology) and spectrochemical composition analyses.

In 1976, the twin Viking landers conducted the first *in situ* measurements focusing on the detection of organic compounds and life on Mars. Their biology package contained three experiments, all looking for signs of metabolism in soil samples. One, the labelled-release experiment, produced provocative results. If other information had not been also available, these data could have been interpreted as proof of biological activity. However, theoretical modelling of the atmosphere and regolith chemistry hinted at powerful oxidants that could more-or-less account for the results of the three experiments. The biggest blow was the failure of the Viking gas chromatograph mass spectrometer (GCMS) to find evidence of organic molecules at the parts-per-billion level.

With few exceptions, the majority of the scientific community has concluded that the Viking results do not demonstrate the presence of life. Numerous attempts have been made in the laboratory to simulate the Viking reactions. While some have reproduced certain aspects, none has succeeded entirely. Incredibly, 30 years after Viking, the crucial chemical oxidant hypothesis remains untested. ExoMars will include a powerful instrument to study oxidants and their relation to organics distribution on Mars.

Undoubtedly, the present environment on Mars is exceedingly harsh for the widespread proliferation of surface life: it is simply too cold and dry, not to mention the large doses of UV. Notwithstanding

Recommended Pasteur Exobiology Instruments[1]

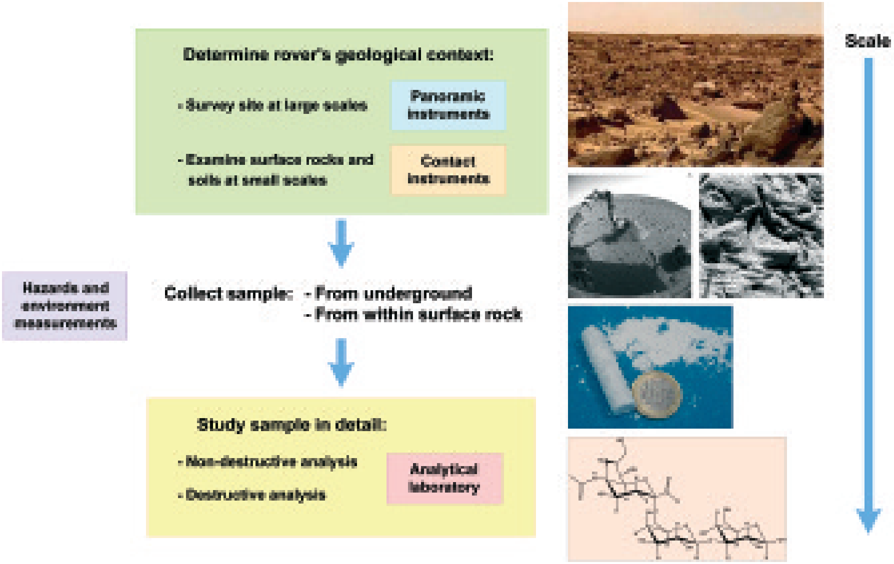
Panoramic Instruments	To characterise the Rover's geological context (surface and subsurface). Typical scales span from panoramic to 10 m, with a resolution of the order of 1 cm for close targets.
Panoramic Camera System	2 wide-angle stereo cameras and 1 high-resolution camera; to characterise the Rover's environment and its geology. Also very important for target selection.
Infrared (IR) Spectrometer	For the remote identification of water-related minerals, and for target selection.
Ground Penetrating) Radar (GPR)	To establish the subsurface soil stratigraphy down to 3 m depth, and to help plan the drilling strategy.
Contact Instruments	To investigate exposed bedrock, surface rocks and soils. Among the scientific interests at this scale are: macroscopic textures, structures and layering; and bulk mineralogical and elemental characterisation. This information will be fundamental to collect samples for more detailed analysis. The preferred solution is to deploy the contact instruments using an arm-and-paw arrangement, as in Beagle-2. Alternatively, in case of mass limitations, they could be accommodated at the base of the subsurface drill.
Close-Up Imager	To study rock targets visually at close range (cm) with sub-mm resolution.
Mössbauer Spectrometer	To study the mineralogy of Fe-bearing rocks and soils.
Raman-LIBS[2] external heads	To determine the geochemistry/organic content and atomic composition of observed minerals. These optical are external heads connected to the instruments inside the analytical laboratory.
Support Instruments	These instruments are devoted to the acquisition and preparation of samples for detailed investigations in the analytical laboratory. They must follow specific acquisition and preparation protocols to guarantee the optimal survival of any organic molecules in the samples. The mission's ability to break new scientific ground, particularly for signs-of-life investigations, depends on these two instruments.
Subsurface Drill	Capable of obtaining samples from 0 m to 2 m depths, where organic molecules might be well-preserved. It also integrates temperature sensors and an IR spectrometer for borehole mineralogy studies.
Sample Preparation and Distribution System (SPDS)	Receives a sample from the drill system, prepares it for scientific analysis, and presents it to all analytical laboratory instruments. A very important function is to produce particulate material while preserving the organic and water content.
Analytical Laboratory	To conduct a detailed analysis of each sample. The first step is a visual and spectroscopic inspection. If the sample is deemed interesting, it is ground up and the resulting particulate material is used to search for organic molecules and to perform more accurate mineralogical investigations.
Microscope IR	To examine the collected samples to characterise their structure and composition at grain-size level. These measurements will also be used to select sample locations for further detailed analyses by the Raman-LIBS spectrometers.
Raman-LIBS	To determine the geochemistry/organic content and elemental composition of minerals in the collected samples.
X-ray Diffractometer (XRD)	To determine the true mineralogical composition of a sample's crystalline phases.
Urey (Mars Organics and Oxidants Detector)	Mars Organics Detector (MOD): extremely high-sensitivity detector (ppt) to search for amino acids, nucleotide bases and PAHs in the collected samples. Can also function as front-end to the GCMS. Mars Oxidants Instrument (MOI): determines the chemical reactivity of oxidants and free radicals in the soil and atmosphere.
GCMS	Gas chromatograph mass spectrometer to conduct a broad-range, very-high sensitivity search for organic molecules in the collected samples; also for atmospheric analyses.
Life-Marker Chip	Antibody-based instrument with very high specificity to detect present life reliably.

[1]Mass (without drill and SPDS): 12.5 kg. [2]LIBS: Laser-Induced Breakdown Spectroscopy.

Recommended Pasteur Environment Instruments[3]

Environment Instruments	To characterise possible hazards to future human missions and to increase our knowledge of the Martian environment.
Dust Suite	Determines the dust grain size distribution and deposition rate. It also measures water vapour with high precision.
UV Spectrometer	Measures the UV radiation spectrum.
Ionising Radiation	Measures the ionising radiation dose reaching the surface from cosmic rays and solar particle events.
Meteorological Package	Measures pressure, temperature, wind speed and direction, and sound.

[3]Mass: 1.9 kg. The Pasteur environment instruments are presently planned to be accommodated in the GEP.



The ExoMars surface science exploration scenario. The Rover will conduct measurements of multiple scales, starting with a panoramic assessment of the geological environment, progressing to more detailed investigations on surface rocks using a suite of contact instruments, and culminating with the collection of well-selected samples to be analysed in its laboratory

these hazards, basic organisms could still flourish in protected places: deep underground, at shallow depths in especially benign environments, or within rock cracks and inclusions.

The strategy to find traces of past biological activity rests on the assumption that any surviving signatures of interest will be preserved in the geological record, in the form of buried/encased remains, organic material and microfossils. Similarly, because current surface conditions are hostile to most known organisms, as when looking for signs of extant life, the search methodology should focus on investigations in protected niches: underground, in permafrost or within surface rocks. This means that there is a good possibility that the same sampling device and instrumentation may adequately serve both types of studies. The biggest difference is due to location requirements. In one case, the interest lies in areas occupied by ancient bodies of water over many thousands of years. In the other, the emphasis is on water-rich environments close to the surface and accessible to our sensors today. For the latter, the presence of permafrost alone may not be enough. Permafrost in combination with a sustained heat source, probably of volcanic or hydrothermal origin, may be necessary. Such warm oases can only be identified by an orbital survey of the planet. In the next few years, a number of remote-sensing satellites, like ESA's Mars Express and NASA's Mars Reconnaissance Orbiter (MRO), will determine the water/ice boundary across Mars and may help to discover such warm spots. If they do exist, they would be prime targets for missions like ExoMars.

On Earth, microbial life quickly became a global phenomenon. If the same explosive process occurred on the young Mars, the chances of finding evidence of it are good. Even more interesting would be the discovery and study of life forms that have successfully adapted to the modern Mars. However, this presupposes the prior identification of geologically suitable, life-friendly locations where it can be demonstrated that liquid water still exists, at least episodically throughout the year. For these reasons, the 'Red Book' science team advised ESA to focus on the detection of extinct life, but to build enough flexibility into the mission to be able to target sites with the potential for present life.

Mission Description

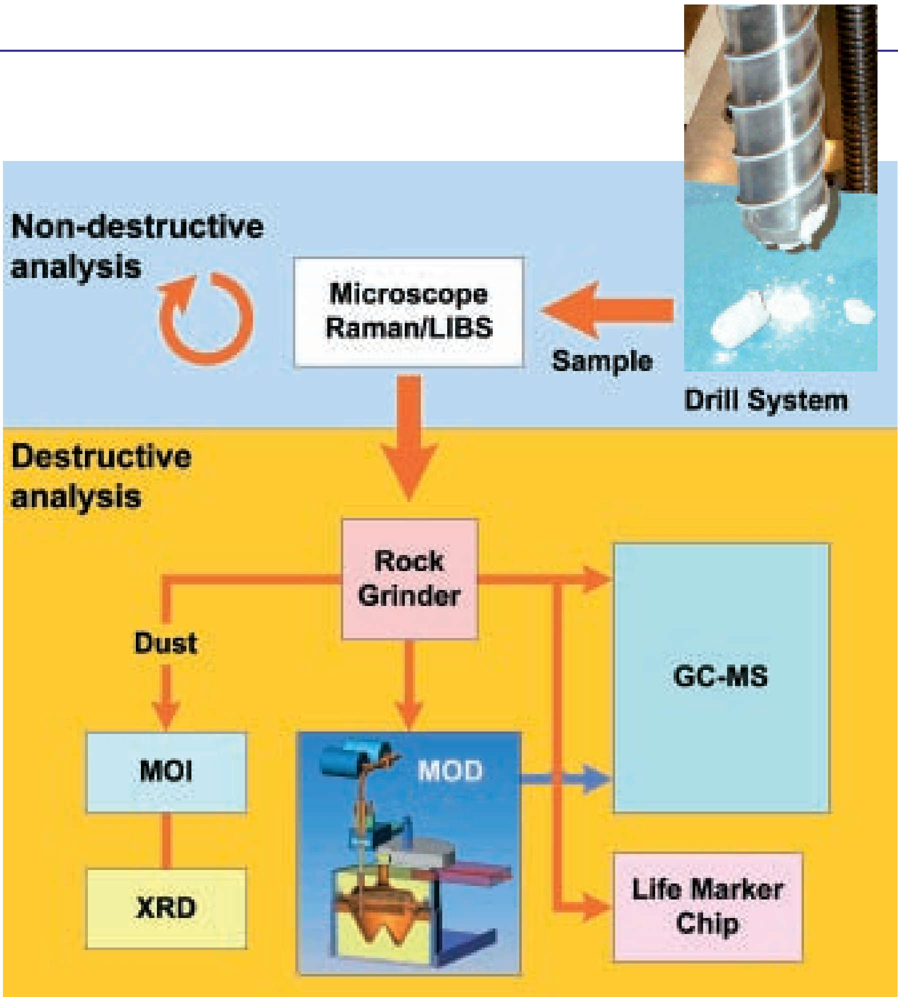
The baseline mission scenario consists of a spacecraft composite with a Carrier and a Descent Module, launched by a Soyuz-2b from Kourou. It will follow a 2-year 'delayed trajectory' in order to reach Mars after the dust-storm season. The Descent Module will be released from the hyperbolic arrival path, and land using either bouncing (non-vented, as in NASA's rovers) or non-bouncing (vented) airbags, and deploy the Rover and GEP. In the baseline mission, data-relay for the Rover will be provided by a NASA orbiter.

An alternative configuration, based on an Ariane-5 ECA launcher, may be implemented depending on programme, technical and financial considerations. In this option, the Carrier is replaced with an Orbiter that provides end-to-end data relay for the surface elements. The Orbiter will also carry a science payload to complement the results from the Rover and GEP, and provide continuity to the great scientific discoveries flowing from Mars Express.

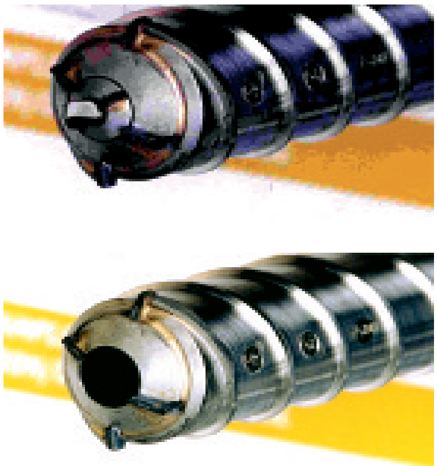
ExoMars is a search-for-life mission targeting regions with high life potential. It has therefore been classified as Planetary Protection category IVc. This, coupled with the mission's ambitious scientific goals, imposes challenging sterilisation and organic cleanliness requirements.

The ExoMars Rover

The Rover will have a nominal lifetime of 180 sols (about 6 months). This period provides a regional mobility of several kilometres, relying on solar array electrical power. The Pasteur model payload includes panoramic instruments (cameras, ground-penetrating radar and IR spectrometer; contact instruments for studying surface rocks (close-up imager and Mössbauer spectrometer), a subsurface drill to reach depths of 2 m and to collect specimens from exposed bedrock, a sample preparation and distribution unit, and the analytical laboratory. The latter includes a microscope, an oxidation sensor and a variety of



The analysis sequence within Pasteur's analytical laboratory



The Pasteur payload's drill-bit design concept. The drill's full 2 m extension is achieved by assembling four sections (one drill tool rod, with an internal shutter and sample-collection capability, plus three extension rods). The drill will also be equipped with an IR spectrometer for mineralogy studies inside the borehole. (Galileo Avionica)

instruments for characterising the organic substances and geochemistry in the collected samples.

A key element is the drill. The reason for the 2 m requirement is the need to obtain pristine sample material for analysis. Whereas the estimated extinction horizon for oxidants in the subsurface is several centimetres, damaging ionising radiation can penetrate to depths of around 1 m. Additionally, it is unlikely that loose dust may hold interesting biosignatures, because it has been moved around by wind and processed by UV radiation. In the end, organic substances may best be preserved within low-porosity material. Hence, the ExoMars drill must be able to penetrate and obtain samples from well-consolidated (hard) formations, such as sedimentary rocks and evaporitic deposits. Additionally, it must monitor and control torque, thrust, penetration depth and temperature at the drill bit. Grain-to-grain friction in a rotary drill can generate a heat wave in the sample, destroying the organic molecules that ExoMars seeks to detect. The drill must therefore have a variable cutting protocol, to dissipate heat in a science-safe manner. Finally, the drill's IR spectrometer will conduct mineralogy studies inside the borehole.

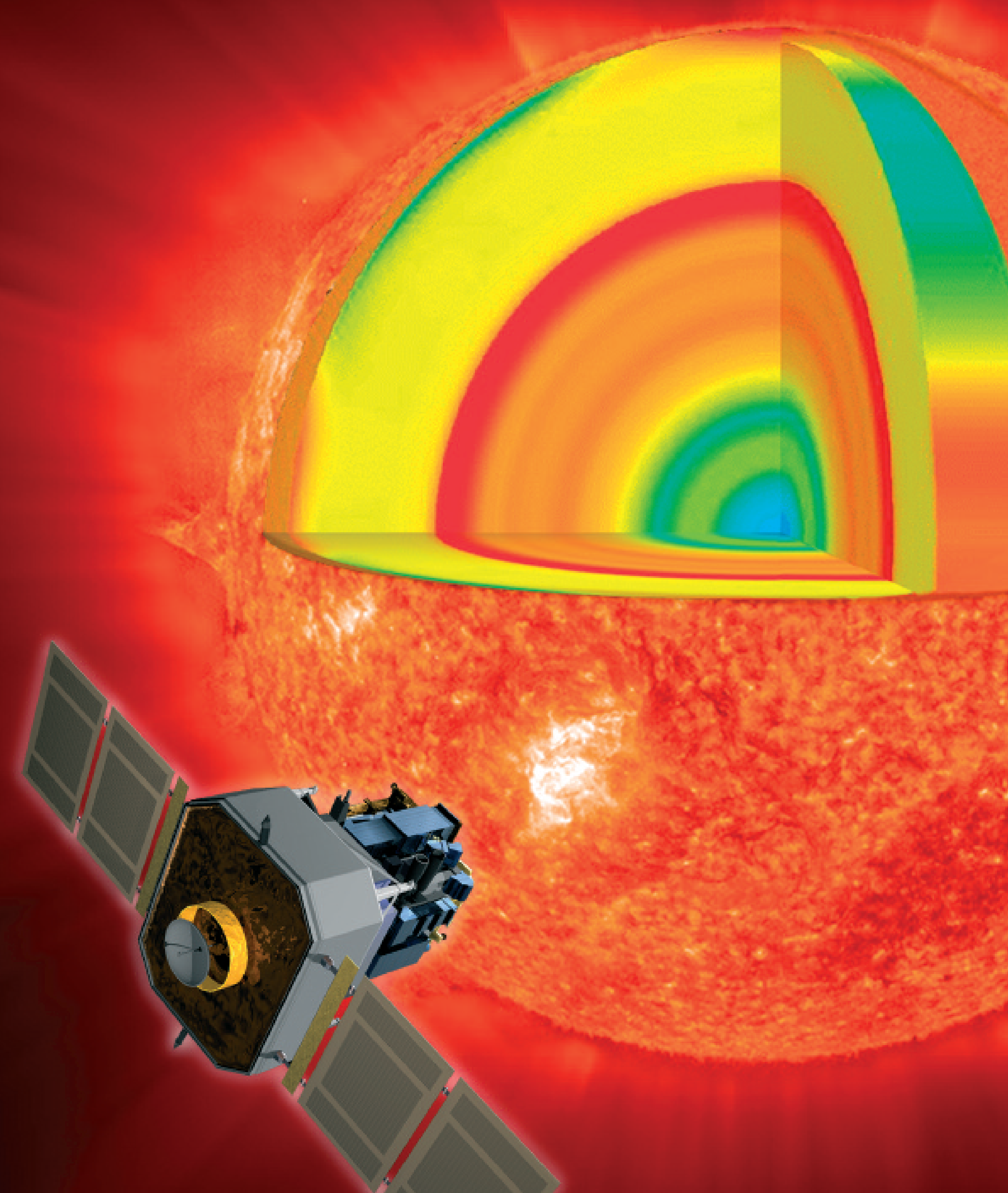
Conclusion

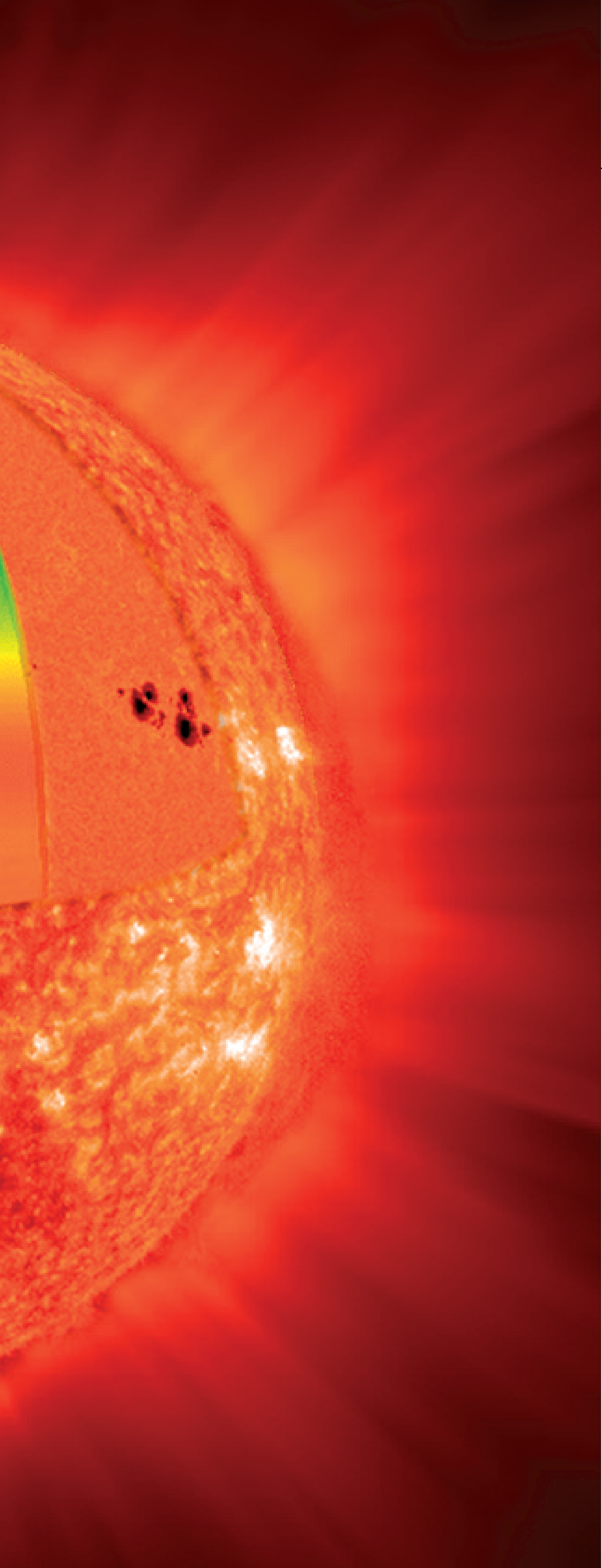
NASA's highly successful 2004 rovers were conceived as robotic geologists. They have demonstrated the past existence of long-lasting, wet environments on Mars. Their results have persuaded the scientific community that mobility is a must-have requirement for all future surface missions. Recent results from Mars Express have revealed multiple, ancient deposits containing clay minerals that form only in the presence of liquid water. This reinforces the hypothesis that ancient Mars may have been wetter, and possibly warmer, than it is today. NASA's 2009 Mars Science Laboratory will study surface geology and organics, with the goal of identifying habitable environments. ExoMars is the next logical step. It will have instruments to investigate whether life ever arose on the Red Planet. It will also be the first mission with the mobility to access locations where organic molecules may be well-preserved, thus allowing, for the first time, investigation of Mars' third dimension: depth. This alone is a guarantee that the mission will break new scientific ground. Finally, the many technologies developed for this project will allow ESA to prepare for international collaboration on future missions, such as Mars Sample Return.

Following the recent accomplishments of Huygens and Mars Express, ExoMars provides Europe with a new challenge, and a new opportunity to demonstrate its capacity to perform world-class planetary science.

ExoMars is now in Phase-B1 and is expected to begin Phase-B2 in mid-2007 and Phase-C/D in early 2008. esa

10 Years of SOHO





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Since its launch on 2 December 1995, SOHO has revolutionised our understanding of the Sun. It has provided the first images of structures and flows below the Sun's surface and of activity on the far side. SOHO has revealed the Sun's extremely dynamic atmosphere, provided evidence for the transfer of magnetic energy from the surface to the outer solar atmosphere, the corona, through a 'magnetic carpet', and identified the source regions of the fast solar wind. It has revolutionised our understanding of solar-terrestrial relations and dramatically improved our space weather-forecasting by its continuous stream of images covering the atmosphere, extended corona and far side. The findings are documented in an impressive number of scientific publications: over 2500 papers in refereed journals since launch, representing the work of over 2300 individual scientists. At the same time, SOHO's easily accessible, spectacular data and fundamental scientific results have captured the imagination of the space science community and the general public alike. As a byproduct of the efforts to provide real-time data to the public, amateurs now dominate SOHO's discovery of over 1100 Sun-grazing comets.

Introduction

We all live in the extended atmosphere of a magnetically active star. While sunlight sustains life, the Sun's variability produces streams of high-energy particles and radiation that can affect life. Understanding the changing Sun and its effects on the Solar System has become one of the main goals of the SOHO mission, which was launched to address three fundamental science questions: what is the structure and dynamics of the solar interior, how is the corona heated, and how is the solar wind accelerated?

A consortium of European space companies led by prime contractor Matra Marconi Space (now EADS Astrium) built SOHO under overall management by ESA, and international consortia developed its suite of 12 instruments. NASA launched SOHO on 2 December 1995, inserting it into a halo orbit around the L1 Lagrangian point in February 1996.

The SOHO Experiment Operations Facility (EOF), at NASA's Goddard Space Flight Center, serves as the focal point for mission science planning and instrument operations. Half of the 12 SOHO Principal Investigator Teams have resident representatives at the EOF, where they receive telemetry and send commands directly from their workstations through the ground system to their instruments.

An overview article cannot do justice to the 2500-plus articles published in the refereed literature and an even greater number in conference proceedings and other publications. Here, we touch upon a few selected results. Highlights from the first 4 years of SOHO were described in *Bulletin* 102 (May 2000).

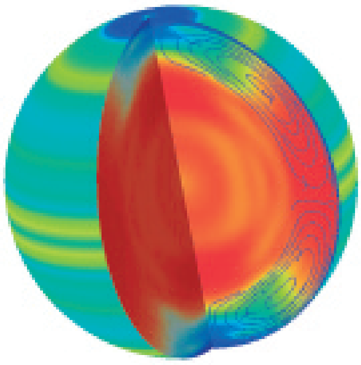
Making the Sun Transparent

Just as seismology reveals the Earth's interior by studying earthquake waves, solar physicists probe the Sun's interior via 'helioseismology'. The oscillations detectable at the visible surface are due to sound waves reverberating through the Sun's inner layers. By precisely measuring the frequencies, we can infer the Sun's temperature, density, atomic abundances, interior structure and the age of the Solar System, and even pursue such esoteric matters as testing the constancy of the gravitational constant.

One of the most productive instruments, the Michelson Doppler Imager (MDI), shows oscillations of the whole Sun. It has revealed strong variations in the velocity of the plasma in the solar interior, and found an 'adjustment' layer at the base of the convection zone. This layer, about 220 000 km beneath the visible surface (about a third of the way down to the Sun's centre), connects the more orderly interior of the Sun (the radiative zone) with the more turbulent outer region (the convection zone). It is of particular interest because this is where the solar dynamo that creates the Sun's magnetic field is believed to operate. In this region, the speed of the gas changes abruptly. Near the equator, the outer layers rotate faster than the inner layers. At mid-latitudes and near the poles, the situation is reversed.

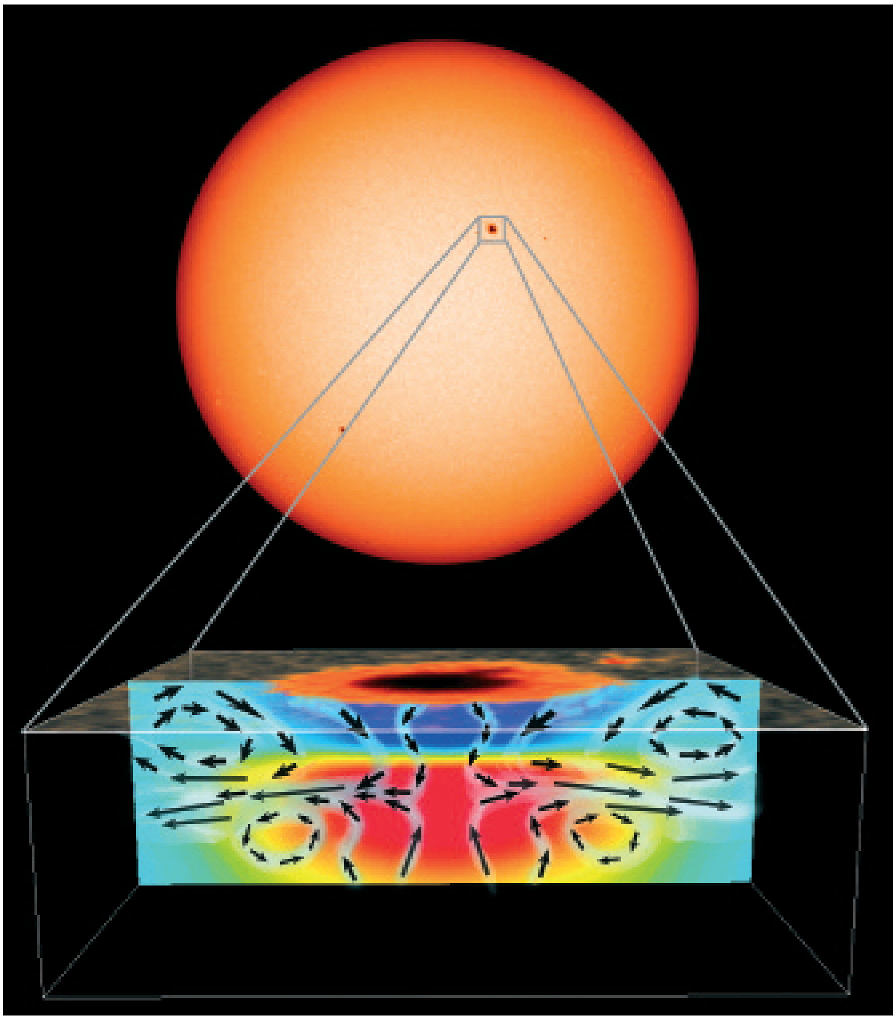
MDI data have revealed a fascinating picture of the large-scale, subsurface dynamics of the Sun, with dramatic changes with the solar cycle. We all know of the crucial importance of large-scale streams in our atmosphere (e.g. jet stream) and in the oceans (e.g. gulf stream) for Earth's climate. MDI has for the first time enabled us to observe such large-scale streams inside the Sun. Researchers discovered transient storms, high- and low-pressure zones, and swirling wind flows near active regions that vary from day to day like weather patterns on Earth's surface.

Ever since MDI began to deliver helioseismic information at finer spatial scales than previously available, the new field of 'local-area helioseismology' has developed rapidly. New methods allowed construction of the first true 3-D images and flow maps of the interior of a star, and even the first images of the far side of our Sun. Applying the novel 'acoustic tomography' method to MDI data, scientists could for the first time study the structure of sunspots below the Sun's surface. They were thus able to solve two long-standing puzzles about these blemishes on the Sun, which have been a source of wonder ever since they were described (and drawn in painstaking detail) by Galileo Galilei: how deep do the spots extend below the surface, and how can sunspots last for several weeks without breaking up? The MDI team found the answers: strong, converging downflows stabilise the structure of the sunspots, and sunspots are relatively shallow.



Solar rotation and polar flows of the Sun deduced from MDI measurements. The left side shows the difference in rotation speed between various areas. Red-yellow is faster than average, while blue is slower than average. The light orange bands are zones that move slightly faster than their surroundings. The cutaway reveals rotation speed inside the Sun. The large dark red band beneath the solar equator is a massive fast flow of hot, electrically-charged gas: plasma. The blue lines at right show the surface flow from the equator to the poles. The return flow indicated at the bottom of the convection zone has not yet been observed

'Solar Subsurface Weather' map, showing magnetic field (black/red) and average 'wind' flow (blue arrows) under the solar surface



Using advanced analysis techniques, SOHO/MDI can reveal the temperature and flow structure beneath sunspots

Just a little over 4 years after the launch of SOHO, scientists published an astonishing result: the first successful holographic reconstruction of features on the far side of the Sun. An active region on the far side reveals itself because its strong magnetic fields speed up the sound waves. The difference becomes evident when sound waves shuttling back and forth fall out of step with one another. In the meantime, the astonishing has become routine, and MDI offers daily far-side images online, at *http://soi.stanford.edu/data/full_farside/*.

Violent solar activity occasionally disrupts satellites, radio communications and power systems. Advance warning of magnetic storms brewing on the far side that could rotate with the Sun and threaten Earth is therefore of vital importance for space weather forecasting.

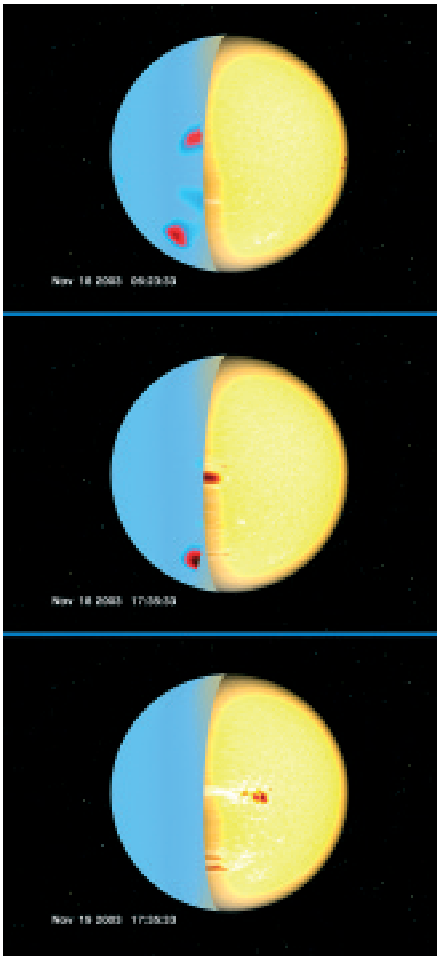
The Sun's Dynamic Corona

The outer atmosphere of the Sun, the corona, has a typical temperature of about 1 million K and emits light mainly in the ultraviolet (UV) part of the spectrum. It is this radiation from the Sun's hot corona that controls the composition and dynamics of Earth's upper atmosphere. Water vapour and ozone are especially sensitive to changes in the Sun's UV output. Fortunately, Earth's atmosphere protects us from this harmful radiation. This also means that we have to leave Earth's atmosphere behind and observe the Sun from space.

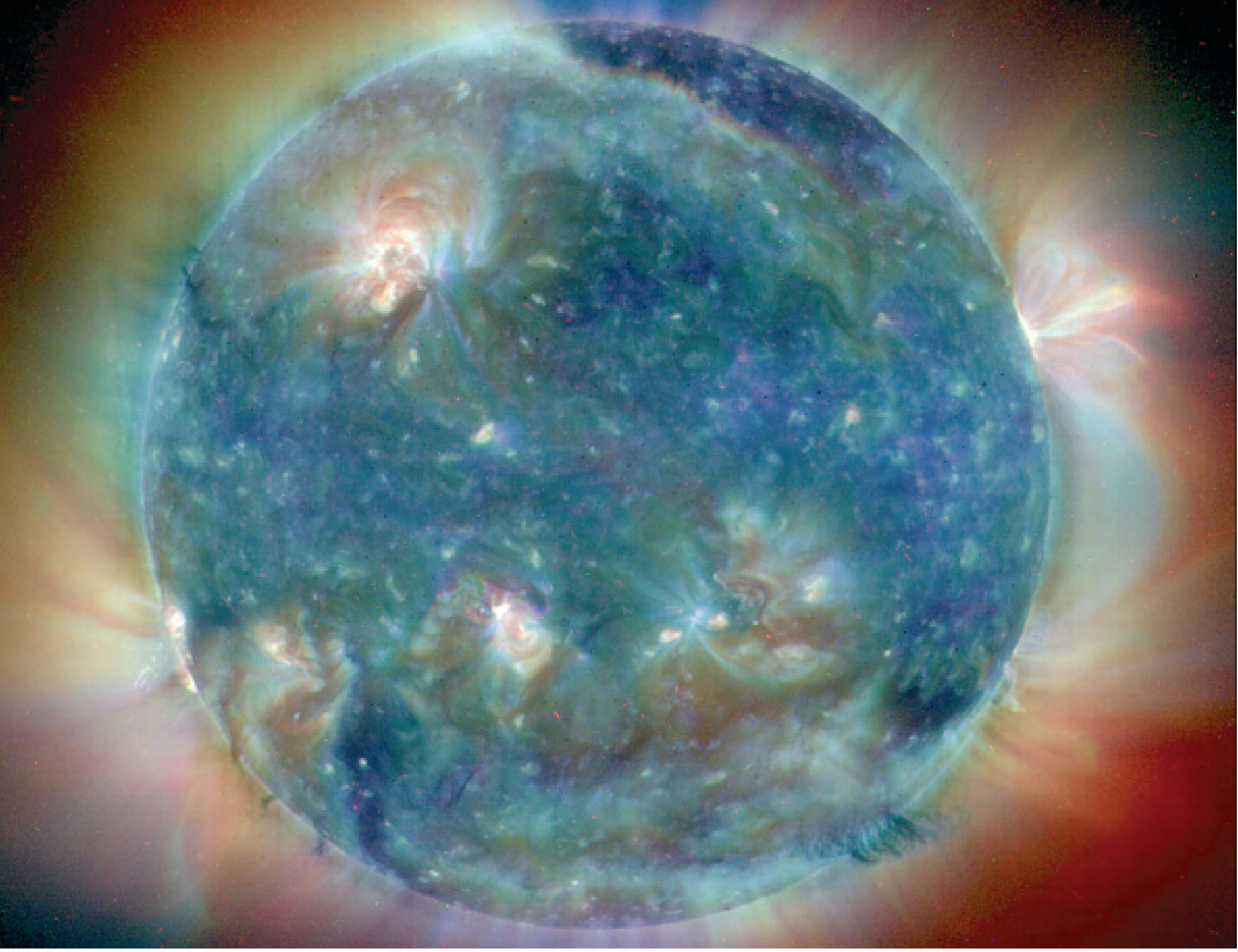
SOHO's Extreme ultraviolet Imaging Telescope (EIT) provides us with stunning images of the Sun's corona, showing delicate coronal loops, bright flares and intriguing coronal holes. EIT and the UV spectrometers SUMER and CDS show us that the outer solar atmosphere is extremely dynamic and changing, and that plasma flows play an extremely important role.

Gone With the Solar Wind

The solar wind is a stream of mainly electrons and protons flowing from the



Holographically reconstructed side view of the Sun showing the two large active regions 10486 and 10488 as they rotate from the far side (left) to the hemisphere visible from Earth (right). During the previous rotation, these two active regions were the source of the powerful 'Halloween' storms in 2003, which included the largest ever recorded X-ray flare

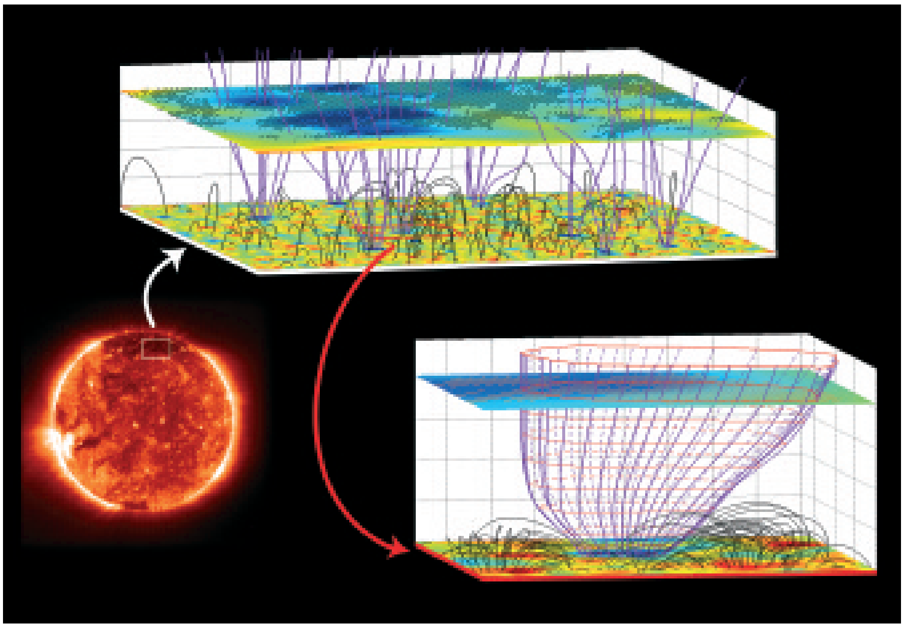


Composite image of the solar corona with three wavelengths (171 Å as blue, 195 Å as yellow and 284 Å as red) combined to show features unique to each wavelength. The 171 Å filter captures emission at about 1 million K, 195 Å at about 1.5 million K, and 284 Å at about 2.5 million K

Sun faster than 3 million km/h. It is essentially the hot solar corona expanding into interplanetary and interstellar space. It deforms Earth's magnetosphere and ionises atoms in our upper atmosphere, causing beautiful aurorae.

Interpreting data from the Ultraviolet Coronagraph Spectrometer (UVCS), scientists found evidence that the solar wind streams out of the Sun by 'surfing' on waves produced by vibrating magnetic field lines, just like an ocean wave carrying a surfer.

Using SUMER, scientists have mapped the outflow of plasma from coronal holes, and found a clear connection between the flow speed and the network structure of the chromosphere, a lower layer of the atmosphere. This is the first spectroscopic discovery of the source of the fast solar wind. In a later study, a Chinese-German team has used SUMER and MDI data to show that the solar wind

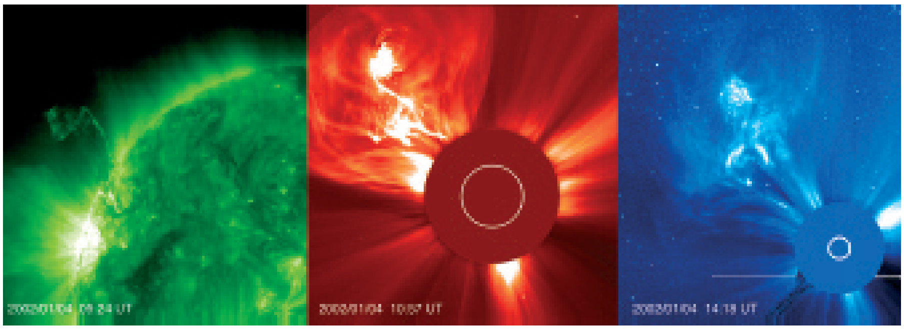


The solar wind emerges from coronal funnels. The magenta curves are open magnetic field lines, dark grey arches show closed ones. The lower plane shows the magnetic vertical component measured by MDI (blue to red). The upper plane shows Ne VIII Doppler shifts from SUMER (hatched regions have large outflows), together with the inclination of the magnetic field (blue to red), as extrapolated from the MDI measurements escapes from the Sun in funnels of open magnetic fields.

SOHO, the Space Weather Watchdog

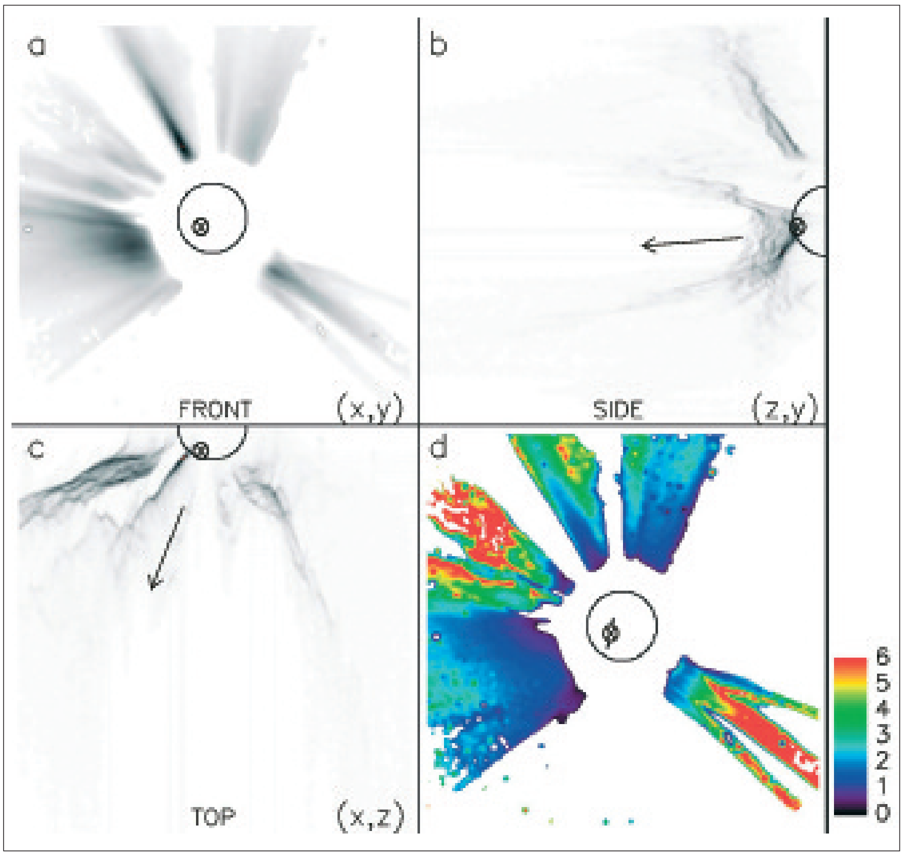
While the Sun's total radiative output is reassuringly constant, it is at the same time a dynamic and violent star. Besides emitting a continuous stream of plasma in the solar wind, the Sun periodically releases huge amounts of matter in coronal mass ejections (CMEs). These are the most powerful eruptions in the Solar System, with billions of tonnes of electrified gas propelled from the Sun's atmosphere into space at millions of km/h. If they hit Earth, these immense clouds can cause large magnetic storms in our magnetosphere and upper atmosphere. Researchers believe they are launched when solar magnetic fields become strained and suddenly snap into a new arrangement, like a rubber band twisted to breaking point.

Apart from causing beautiful aurorae, CME disturbances can damage satellites, disrupt telecommunications, endanger astronauts, lead to corrosion in oil pipe lines and cause current surges in power lines. As our society becomes increasingly dependent on space-based technologies, our vulnerability to 'space weather' becomes more obvious, and the need to understand it and mitigate its effects becomes more urgent. In recent years, forecasting the conditions in the near-Earth environment and the 'geo-effectiveness' of CMEs and solar flares has become one of the key research areas in solar and solar-terrestrial physics; SOHO is playing a pioneering role in this new discipline. While satellites that make *in situ* measurements in near-Earth orbits can give only about a 2-hour alert of solar storms, SOHO's coronagraphs and EUV imager observe the source of CMEs and flares and thus provide up to 3 days' warning, sufficient to save costly equipment. SOHO's LASCO and EIT are the primary source of operational information on the location, speed and orientation of CMEs from the Earth-facing hemisphere of the Sun. These remote-sensing observations are complemented by the CELIAS, COSTEP and ERNE *in situ* measurements of the arrival of the CME and energetic particles at the L1 Lagrangian point.

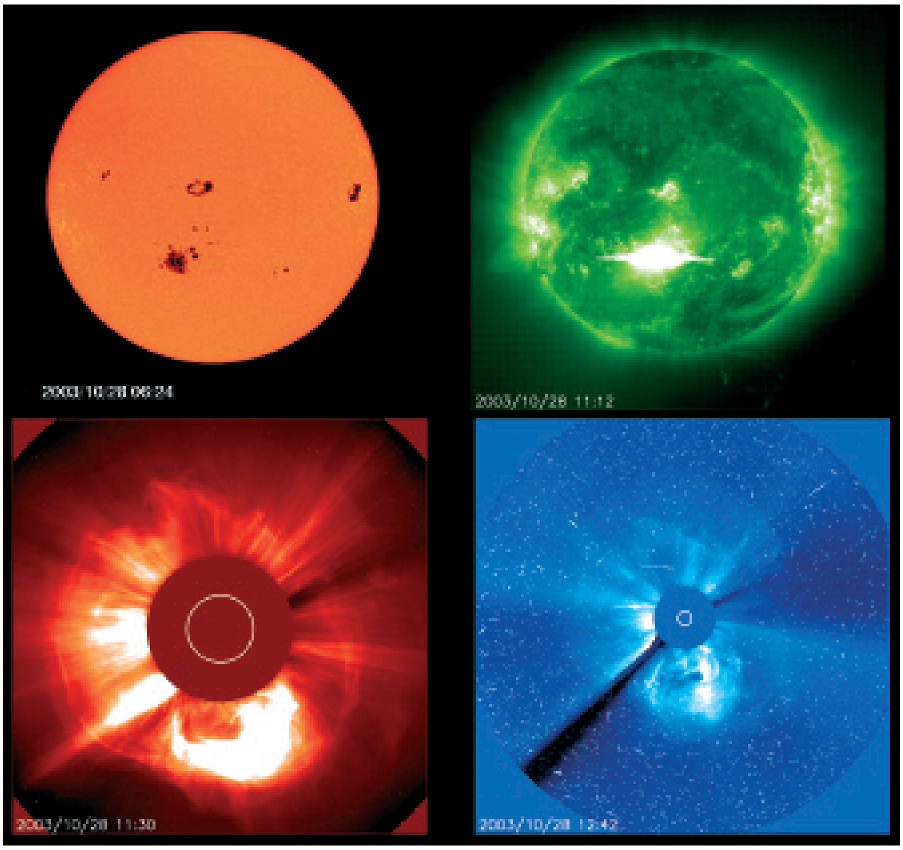


This fiery coronal mass ejection shows stunning details in the ejected material, revealed by SOHO's LASCO coronagraph. The direct sunlight is blocked (red disc), exposing the surrounding faint corona. The white circle represents the approximate size of the Sun

The LASCO team has compiled an extensive catalogue that summarises the mass, speed, acceleration, angular width, position and so on of the more than 10 000 CMEs observed since launch. This catalogue has been used in numerous studies, including how the number of CMEs varies with the solar cycle: the rate increases from 0.5 per day during solar minimum to over 6 per day during solar maximum. Using LASCO data, scientist can also for the first time reconstruct 3-D images of CME structures. Combined



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



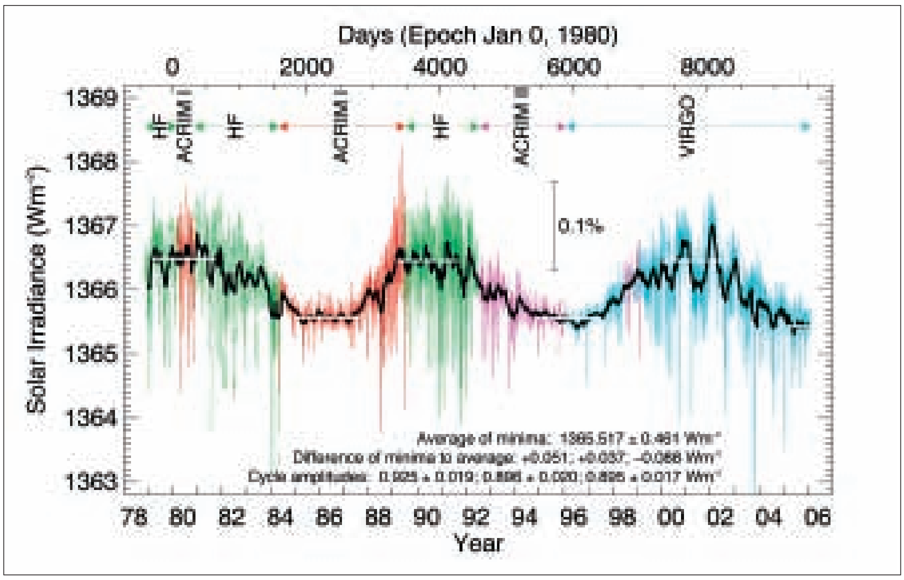
Active Region 10486 unleashed a spectacular show on 28 October 2003: an X 17.2 flare, a fast-moving coronal mass ejection and a strong solar energetic particle event. From top left: giant sunspot groups seen by MDI in white light; the flare as seen by EIT at 195 Å; the fast-moving CME in the LASCO C2 coronagraph, then in the LASCO C3 coronagraph, with the particle shower becoming visible as 'snow' in the image. The cloud struck Earth's magnetosphere only19 hours later, almost a record speed

with other views from the coronagraphs on the STEREO satellite to be launched later this year, this technique should significantly reduce ambiguities in the reconstruction of interplanetary CME morphology.

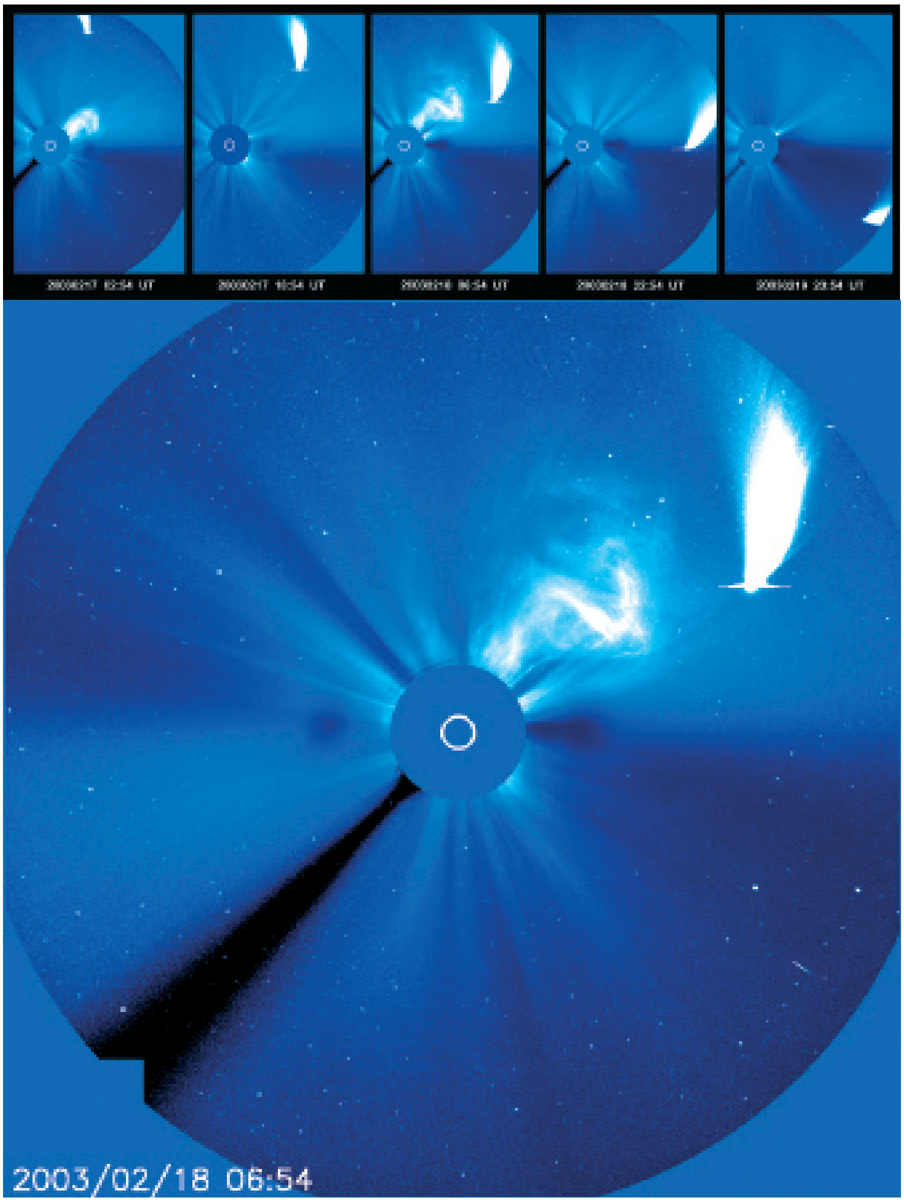
During 2 weeks in October/November 2003, the Sun featured three unusually large sunspot groups, which gave rise to 11 X-class flares (including the strongest ever recorded), numerous CMEs and two large proton storms. Satellites, power grids, radio communications and navigation systems were significantly affected. The events, among the best-observed ever, will be analysed for years to come. The events triggerred unprecedented attention from the media and public. SOHO images appeared in nearly every major news outlet. Furthermore, the great public interest wiped out all existing SOHO web traffic records, with the web server serving over 31 million page requests and 4.3 Terabyte of data in just one month.

Measuring the Total Solar Irradiance

A crucial question is whether the Sun's total irradiance is changing on longer time scales. Indications of such a change would have a broad social and political impact as governments would have to devise strategies in response to global warming. SOHO's VIRGO instrument is monitoring the total solar irradiance (TSI), also known as the 'solar constant'. The VIRGO team has constructed composites of TSI measurements from SOHO and other spacecraft over the last 26 years. From this composite record, it now appears that there is no evidence for a significant long-term trend in the TSI: the total radiation from the Sun does not show any systematic brightness increase or decrease on observed time scales. However, while the total solar irradiance varies by less than 0.1% over the 11-year solar cycle, the irradiance in the extreme-UV (EUV) part of the spectrum changes by as much as 30% within weeks and by a factor of



The composite total solar irradiance (TSI) over two solar cycles, combining data from multiple spacecraft instruments, does not show a long-term change. Different colours indicate different data sources; the blue data are from SOHO's VIRGO



Perihelion passage of comet NEAT (C/2002 V1) in February 2003, as imaged by LASCO C3

2–100 (depending on wavelength) over the solar cycle. Detailed knowledge of the solar spectral irradiance is crucial for understanding climate variability, and to disentangle natural variations from anthropogenic climate changes.

SOHO, the Comet Finder

SOHO is providing new measurements not only about the Sun. On 5 August 2005, Toni Scarmato, a high school teacher from Calabria, Italy, discovered SOHO's 999th and 1000th comets. As of February 2006, LASCO had detected over 1100 comets, most of them 'Sun-grazers'. These comets pass very close to the Sun and grow prominent tails as their icy cores are heated. Nearly half of all comets for which orbital elements have been determined (since 1761) were discovered by SOHO, and over two-thirds of those by amateurs accessing LASCO data via the Web. This is a field where amateurs can actively contribute to scientific research; each day, numerous people from all over the world download the near-realtime data to search for new comets.

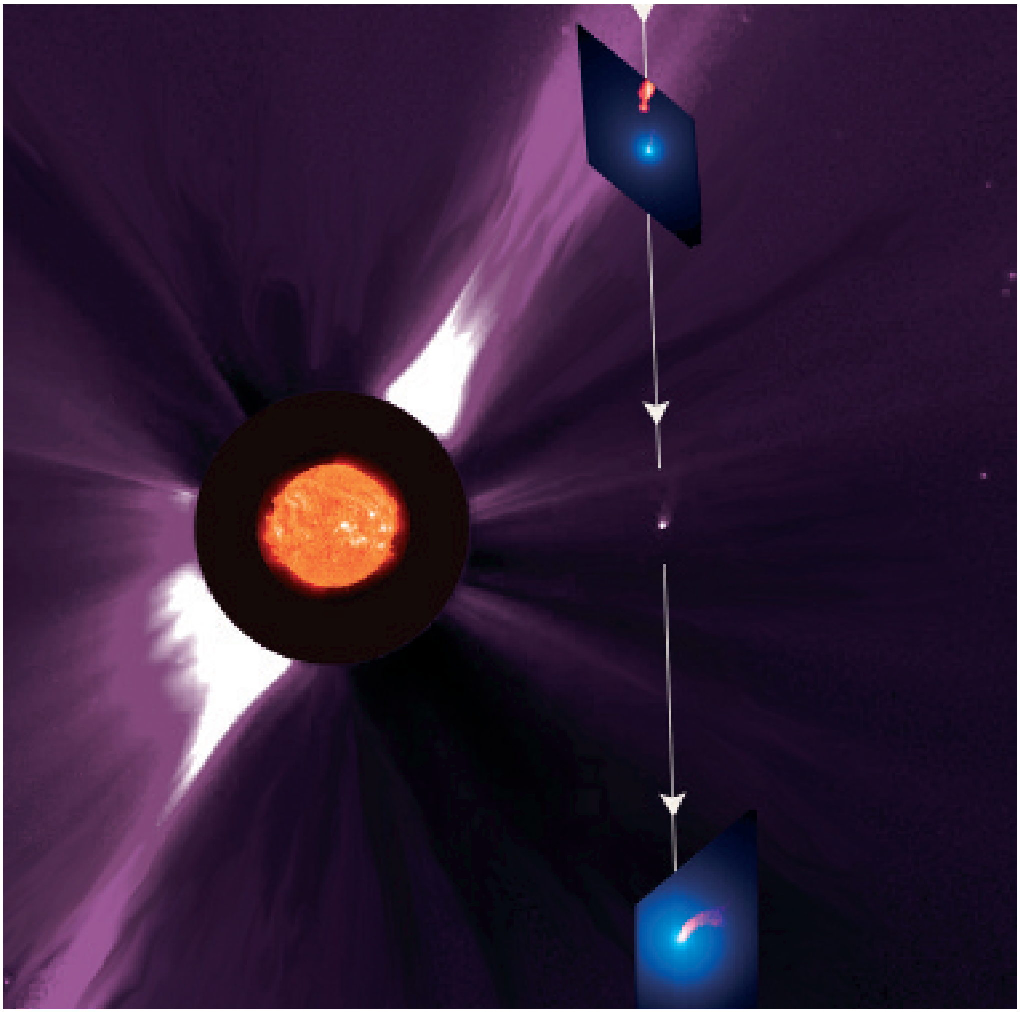
As the brightest, most spectacular comet ever observed by SOHO, comet NEAT (C/2002 V1) provided some enticing data for further study, thanks to a grazing encounter with a coronal mass ejection. The LASCO C3 observations during 16–20 February 2003 suggest interaction between the comet's ion tail and other magnetic fields in the outer corona at the time of the oblique impact with the CME. This is the first time that such an event has been imaged, and no comet has ever been observed closer to the Sun.

The analysis of high-resolution spectroscopic observations of comet C/2002 X5 (Kudo-Fujikawa) from UVCS has revealed a near-spherical cloud of neutral hydrogen and a variable tail of ionised carbon (C^+ and C_2^+) that disconnected from the comet and was subsequently regenerated.

SOHO's SWAN instrument monitored the break-up of comet LINEAR C/1999 S4. The total amount of water vapour observed by SWAN from 25 May to 12 August 2000 was estimated at 3.3 million tonnes. Only about 1% of this was left on 6 August, when observations by the Hubble Space Telescope of the dying comet's fragments gave an estimate of the total volume. Combining the numbers gives a remarkably low value for the density: about 15 kg/m^3, compared with 917 kg/m^3 for familiar non-porous ice. Even allowing for an equal amount of dust grains, 30 kg/m^3 is far less than the 500 kg/m^3 often assumed by comet scientists.

Conclusions and SOHO's Future

The journey has not always been easy. For example, an unexpected loss of contact occurred on 25 June 1998. Fortunately, the mission was completely recovered in one of the most dramatic rescue efforts in space, and normal operations could be resumed in mid-November 1998 after the successful recommissioning of the spacecraft and all 12 instruments. Despite the subsequent failures of all three gyroscopes (the last in December 1998), new gyroless control software installed by February 1999 allowed SOHO to return to normal scientific operations, providing an



Composite image of comet C/2002 X5 (Kudo-Fujikawa) as it passed within 0.2 AU of the Sun in late January 2003. The path of the comet is in white, with arrows indicating the direction of travel. The solar disc is shown as an EIT 304 Å image. The background is a combination of LASCO C2 and C3 images of the corona in visible light, and the blank ring represents the occulting disc of the C2 camera. LASCO also reveals the comet in the optical, as the fuzzy white dot to the right of the Sun. The zoomed-in images at right depict the comet in the H I Lyman-alpha 1216 Å line (blue) and the C III 977 Å line (red-orange). The C III emission has never been seen before in a comet. At upper right, the comet's main plasma tail has disconnected and is drifting anti-sunward even as a new, dim plasma tail is born from the nucleus. By the time of the second UVCS image, the new plasma tail has brightened and is beginning to turn as the comet heads away from the Sun

even greater margin of safety. This made SOHO the first 3-axis-stabilised spacecraft to operate without a gyroscope. A third crisis occurred in June 2003, when SOHO's main antenna became stuck. Using the secondary antenna and software for intermittent recording, however, even this problem was overcome, and the observations continue.

In complex areas of research such as solar physics, progress is not made by just a few people. The scientific achievements of the SOHO mission are the results of a concerted, multi-disciplinary effort by a large international community of solar scientists, involving sound investment in space hardware coupled with a vigorous and well-coordinated scientific operation and interpretation. The interplay between theory and observations has delivered many new insights and will continue to do so for many years.

In its 10 years since launch, SOHO has provided an unparalleled breadth and depth of information about the Sun, from its interior, through the hot and dynamic atmosphere, to the solar wind and its interaction with the interstellar medium. Research using SOHO observations has revolutionised our understanding of the Sun and space weather. The coming years promise to be similarly exciting and rewarding, when SOHO observations are complemented and enhanced by those from NASA's STEREO and Japan's Solar-B missions, affording new opportunities for improved understanding of the Sun-heliosphere system. After the launch of NASA's Solar Dynamics Observatory, SOHO's direct descendant, the capabilities of some SOHO instruments will be eclipsed. But not all: the LASCO coronagraph observations and VIRGO total solar irradiance measurements will continue to make crucial and unique contributions to the International Living With a Star (ILWS) programme.

Acknowledgements

The great success of the SOHO mission is a tribute to the many people – too many to name here – who designed and built this exquisite spacecraft and its excellent instruments, to the engineers who brought it back from the dead (twice), and to the many people who diligently work behind the scenes to keep it up and running.

Further information on SOHO and its achievements can be found at http://soho.esac.esa.int/

The International Space University

Roger Elaerts & Walter Peeters
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The International Space University (ISU) offers, with the support of the world space community and within an international and intercultural environment, interdisciplinary post-graduate programmes in space studies. These graduate programmes prepare professionals from all sectors to meet the challenges of international space cooperation and the restructuring of the space sector. Although it was created as recently as 1987, the ISU is remarkably successful: by 2005 it had around 2400 alumni, forming a strong network in the space community.

Introduction

Whereas many universities in the world have excellent space departments, the International Space University (ISU) at its campus in Strasbourg (F) concentrates exclusively on the ‘space’ aspect in its curriculum. Another difference is that space is treated as interdisciplinary rather than as a specialised area by looking at all aspects related to space. Diversity is ensured by selecting students and faculty on the ‘3I principle’: international, intercultural and interdisciplinary. Indeed, a specific effort is made to ensure that groups are as international as possible, typically composed of more than 20 nationalities.

The intercultural character creates a microcosmos in which the participants, even if they are nationals of highly competitive (space) nations, work closely together. Another goal is to improve gender

The three founders of ISU. From left: Peter Diamandis, Todd Hawley and Bob Richards

distribution in the future space world by aiming at 30% female participation, which is far superior to today's gender distribution in the space sector.

The interdisciplinary character is unique. It is reflected in the distribution of the participants, faculty and lectures over the different disciplines. All space-related aspects are covered in each programme, ranging from science and engineering, life sciences and medicine, business and management, policy and law and even pure humanities topics such as philosophy and art. Students with backgrounds in any discipline may be accepted for the programme, on condition that they clearly demonstrate their interest in space activities to the admissions committee.

ISU Milestones

1987	ISU Founding Conference and Incorporation in USA
1988	First Summer Session at MIT in Cambridge, MA
1993	Strasbourg selected to host ISU Central Campus
1993	First Affiliate Conference, Huntsville, USA
1994	ISU relocates to Strasbourg and Incorporates in Alsace
1995	First Master in Space Studies (MSS) Program based in Strasbourg
1996	First Short Programs (Symposium, Workshops and PDP)
2000	Groundbreaking for Central Campus Building
2002	Official Opening of Central Campus Building
2003	First Introductory Space Course (ISC) held in Strasbourg
2004	Official Accreditation by French Ministry of Education
2004	First Master of Space Management (MSM) Program

The ISU Programmes

The programmes offered by the ISU are dedicated to the career development of graduate students and professionals from all nations seeking advancement in space-related fields. Tailored to the needs of postgraduates and professionals in the space sector or those who wish to work there, ISU offers two kinds of programmes:

Programmes delivered each year on a regular basis

three graduate programmes: a 12-month Master in Science (MSc) of Space Studies (MSS), a 12-month MSc of Space Management (MSM), and a 2-month Summer Session Programme (SSP);

an Introductory Space Course: a 1-week course providing a basic introduction to space topics;

two annual conferences: the Alumni Conference (organised by the alumni) and the ISU Annual Symposium.

Short programmes (1-day to 2-weeks)

Delivered on demand and/or to respond to a specific need, these programmes include professional development programmes, workshops, short courses and forums.

Participation in ISU programmes is open to individuals and institutions of all nationalities. They are presented in more detail in the programme handbooks and at *www.isunet.edu*

In order to meet the needs expressed by industry, the courses aim at giving each ISU student:

– an understanding of the interactions between all the space-related disciplines, leading to a coherent view of space and related activities, understood as a complex system;
– an appreciation of the global perspective and of the challenges presented by the international character of space activities and their applications, including the differences in method and logic underlying planning and decisions, largely influenced by cultural and disciplinary backgrounds.

In addition, the active participation of the students is encouraged through hands-on exercises, in order to give them the ability:

An ISU symposium room

A hands-on workshop under way

- to make appropriate decisions at the appropriate time, using critical thinking and foresight;
- to understand the methods of working and of management in various countries;
- to lead international teams and to manage international projects by taking account of the different cultural approaches, the political and legal implications and the budgetary and financial issues;
- to communicate with the different partners and the public, while accommodating the industrial, governmental and academic perspectives.

Master of Science Curriculum

MSS and MSM are graduate-level degrees designed for individuals seeking professional development or further academic study. They entail 12 months of highly intensive graduate study, including a 3-month professional internship and several trips of professional interest. The main elements of the programmes are:

- a balanced series of lectures covering all major disciplines related to space, with workshops and roundtables;
- a series of lectures on contemporary space-related issues and events which as a whole provides an interdisciplinary and intercultural education;
- Design Team Projects involving most, if not all, of those disciplines;
- Individual Projects performed during the academic year and during an internship period;
- professional visits and participation in the ISU Annual Symposium;
- skill training.

This broad programme is complemented by more detailed study in the area of the individual student's main interest, via advanced lectures, specialised seminars, Individual Projects and a Student Internship for practical training at a chosen ISU partner.

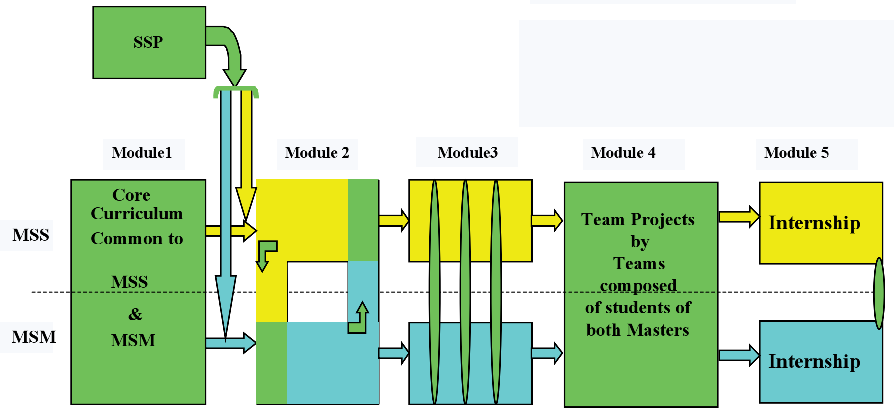
The course is divided into five modules, which can be taken over a period of up to 7 years. Students who have completed a Summer Session can begin on Module 2.

The curriculum is structured to build progressively upon the knowledge assimilated during each module, simultaneously broadening the cross-disciplinary range and acquiring more specific knowledge in each field. The programme ensures that students understand the relationships and interactions between the various components and disciplines at each phase of a space programme or mission.

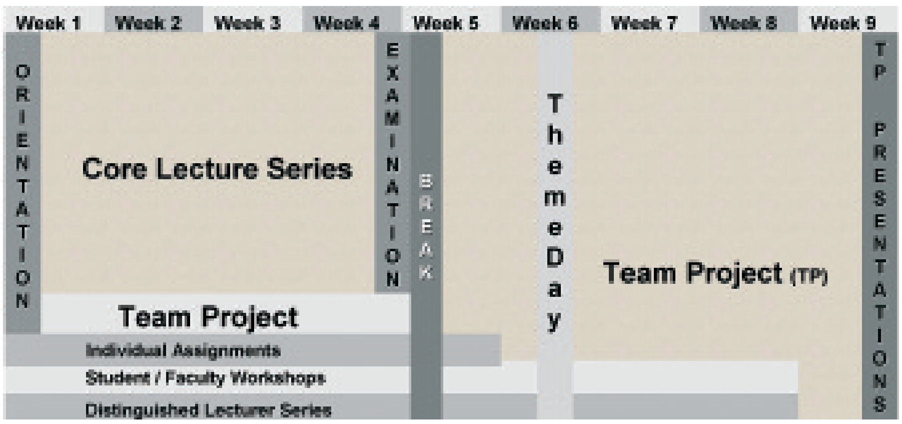
The programme also provides for the acquisition of skills such as efficient team-working, international project management, presentation and computer skills, and information retrieval.

Summer Session Programme (SSP)

The SSP is an intensive 9-week academic experience at the post-graduate level, providing an overview of international space activities. The interdisciplinary curriculum offers the students new perspectives on the world's space activities. All the major space disciplines are studied through interaction with international faculty members, eminent in their respective fields. This, in combination with the teamwork of a Design Project, broadens the participants' knowledge and gives them a greatly improved awareness and understanding of all space activities.



The structure of the Master programmes and the interrelation with the Summer Session Programme



The general structure of a Summer Session Programme

The SSP class of 2004, Adelaide, Australia

Why go into Space? What is up there?	How to go up there?	Design and cost issues plus legal aspects	What to do in space?	How to make use of space?
Monday 24 April	Tuesday 25 April	Wednesday 26 April	Thursday 27 April	Friday 28 April
Welcome and Introduction to Space Policy	Introduction to Astrodynamics	Space Mission Planning and Development	Principles of Space Telecommunications	Introduction Space Marketing
History of Space Activities Overview	Fundamentals of Space Propulsion	Space Cost Engineering and Risk Management	Telecomm Regulations, TV and Media Applications	Workshop on Special Project (continued)
Organization of the Space Sector	Introduction to Space Systems Design	General Space Legal Framework	Principles of Navigation Systems	Workshop on Special Project (continued)
Lunch	Lunch	Lunch	Lunch	Lunch
Space Economics and Future Trends in Space Markets	Space Transportation Systems	General Space Legal Framework	Principles of Earth Observation	Presentation of Special Project
Space Environment	Requirements and Trade Offs	Dual-Use Aspects	Human Space Flight	Presentation of Special Project Closing Ceremony
Microgravity Sciences	From Launch to Orbit	Commercial Space Programs	Workshop on Special Project	
Welcome Reception		Introduction to the Special Project	Workshop on Special Project	
Open	Boat tour of Strasbourg : 18:45-20:15	Guest Lecturer : 19:00-19:30	Open	
	Alsatian Dinner : 20:30	Dinner		

Example of an Introductory Space Course

The SSP curriculum comprises:

- a Core Lecture Series, providing fundamental knowledge on space and related activities;
- theme days, presenting key issues in space with an interdisciplinary approach;
- a Distinguished Lecture Series, giving the point of view people who have made outstanding contributions to space;
- faculty/student workshops, giving students the opportunity to discuss problems of interest with faculty or to demonstrate practical applications of the knowledge gained in the lectures;
- individual assignments performed under the supervision of the Faculty;
- a Design Team Project, performed within an international team of students, allowing them to practise team-working and project management within a Phase-A project;
- experience different cultures and problem-solving within activities and Design Team Projects.

The Introductory Space Course

Questionnaires identified the need to organise a 5-day introductory course to provide a synopsis of space topics. The target group is highly diversified, including:

- non-technical space managers from finance, legal affairs, outreach, etc.;
- technical specialists looking for a refresher course and an extension into other domains, such as space law and policy;
- space enthusiasts in general;
- policy-makers from (inter) governmental organisations involved in space-related applications.

The ISU is an international 'Network University', composed of an institutional network, a professional network linked by an electronic network;

The ISU Network

- the Central Campus at Illkirch, a city of the Strasbourg Urban Community in France, where the Headquarters are located;
- ISU North American Office, in Washington DC;
- 21 Affiliate Campuses on five continents;
- 18 Summer Session Host Institutions;
- Internship Host Institutions, on four continents;
- National Liaisons and Foundations spread throughout the world,
- ISU Faculty and Lecturers from around the world, who form an invaluable international resource of knowledge and experience;
- Sponsors and Partners (university and research institutes, industry, space agencies);
- ISU alumni, who form a vibrant and global network of 2400 highly dedicated professionals, grouped within different Alumni Associations;
- Governing members;
- Members of the various ISU governing boards and councils.

Achievements

The ISU is increasingly recognised as a forum where space activities can be discussed internationally, unconstrained by national or political conditions and unencumbered by any particular bias. As such, the yearly symposium is growing in importance and attracting participants and decision-makers from different space organisations and companies.

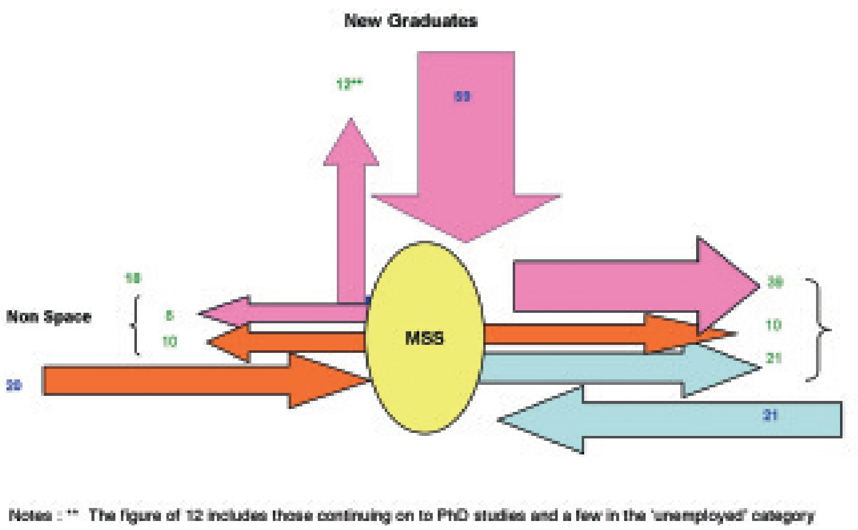
Many organisations have discovered this 'independent platform' function of ISU's symposium and strongly support it. It is appreciated in cases where policy issues are concerned. For example, it was the case in 2003 when US and European experts openly discussed compatibility issues of satellite navigation systems, in particular Galileo.

Similarly, in 2005, exploration was the topic. The theme of cooperation between the International Space Station partners and the leading role of the US in such an endeavour led to interesting debates and exchanges of opinions. These included contributions from Russian and Chinese space experts at the symposium.

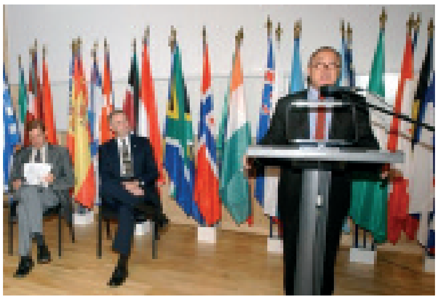
The origins of SSP and MSS/MSM participants are fundamentally different. Whereas the first category is a mixture of graduates and professionals, the latter consists mainly of recent graduates and professionals from space-related areas interested in 'reconverting' to the space sector.

The success of the ISU as a provider of managers for the space sector is better measured by the Master's programme flow. In 2004, extensive research traced the 'transfer function' of the MSS programme in terms of which sectors students came from and where they went to after graduation. This was done by a questionnaire to the three previous Master classes, followed up by calls and contacts that provided data on some 104 past students from a total of 128 members.

Participants had previous working experience in the space sector (21%), the non-space sector (20%) or were fresh graduates (59%). Whereas those from the space sector – mainly from space agencies



The origins and destinations of 104 graduates of the MSc programme 2002-2004



ISU Chancellor Jean-Jacques Dordain at the ISU academic closing ceremony

or other governmental organisations – returned there, a large portion (39%) of those without previous working experience found a job in the space sector. Half of the participants from the non-space sector (20% incoming) found jobs in the space sector, bringing the overall percentage of new graduates directly entering the space workforce to 70%. Added to this should be those continuing their academic careers by pursuing PhD programmes and entering the space sector later, as well as those still looking for jobs at the time of the survey.

Indeed, a longer-term survey shows that 83% of all ISU alumni eventually pursue space careers. Since many of them reach important management functions, it demonstrates the role of the ISU as a prime provider of space professionals.

ISU and ESA

From the beginning, ESA has strongly supported the creation of the ISU. ESA's then Director General, Reimar Lüst, gladly became a member of ISU's advisory board. ESA's present DG, Jean-Jacques Dordain, accepted the invitation to become the second Chancellor of the University.

ESA annually provides a number of scholarships for young European graduates to attend the ISU. Complemented by an equivalent number of scholarships sponsored by ESA Member-State delegations or national space agencies, space industry and satellite operators, these scholarships guarantee strong participation by European students.

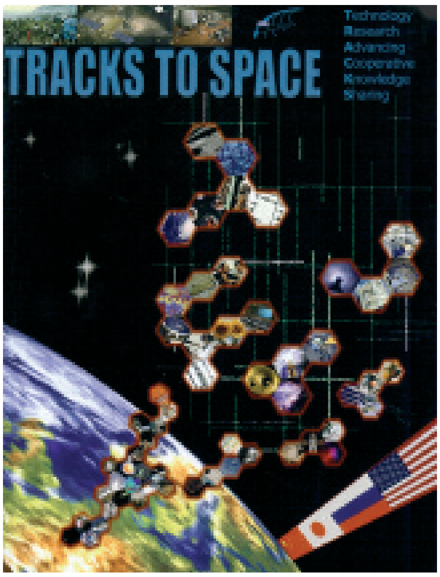
Thanks to a collaboration with ESA's Human Resources Department, ISU students from ESA Member States can perform their internships under the supervision of experienced practitioners at various ESA establishments.

As part of ESA's internal training programme, a number of staff attend the Introductory Space Course or Summer Session Programme. ESA experts regularly give lectures at MSc or summer courses and participate in ISU conferences and symposia.

As a Governing Member, ESA has a strong interest in the major decisions affecting the future of the ISU. It therefore plays a very active role in the 2-yearly meetings of the Board of Trustees.

Another example of ESA/ISU interaction was a Team Project to survey the space technology R&D roadmaps of major space agencies and to suggest possible models for cooperation. In addition to the major assistance provided by specialists from ESA's Directorate of Technology & Quality Management as part of the Agency's Technology Harmonisation and Strategy Process, the value of the 'Tracks to Space' final report was considerably increased by the participation of Chinese space professionals and staff members of other agencies in the project.

ISU intends its alumni to develop their careers and meet new challenges. Their experience in the ISU Design Team Projects certainly enhances their capabilities to negotiate with new partners such as China and India.



How to Apply for the ISU Programmes

The ISU Admissions Committee assesses applicants to the MSS, MSM and SSP programmes primarily on the basis of their academic and professional qualifications, their achievements, their motivation and their proficiency in English.

Candidates can apply online by visiting the ISU home page at www.isunet.edu and clicking on the 'New User' button in the upper right corner. Queries on scholarships, the equivalence of academic qualifications and English proficiency certificates can be sent by email to admissions@isu.isunet.edu

Conclusion

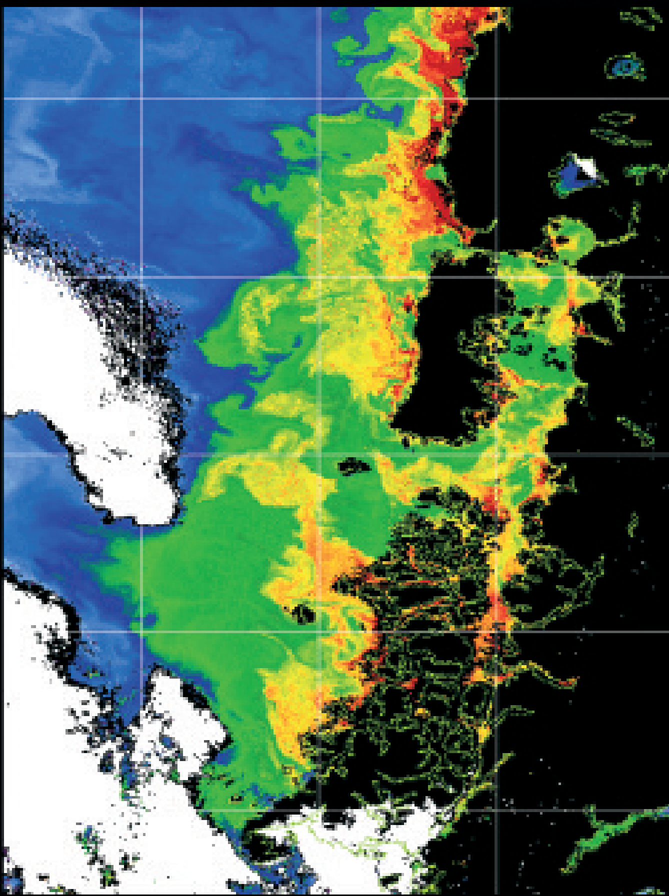
The prime focus of the ISU is to develop a future generation of space professionals to satisfy the needs of space agencies and industry. To achieve this, a spectrum of programmes has been developed, ranging from 1-year MSc courses to 1-week introductory courses. All the programmes involve international groups taught by an international faculty in space-related topics.

Surveys have shown that 83% of ISU's 2400 alumni are working in the space sector and forming a strong network. The ISU and ESA have developed a strong partnership with clear mutual benefits.

Nevertheless, the changing space world does not allow the ISU to stand still: it continues to adapt its programmes to meet new circumstances. Constant feedback from space agencies and companies is essential to ensure the quality of its programmes and the provision of space professionals to meet the needs of its principal stakeholders. esa

Monitoring Marine Life from Space

Envisat Experience in Chile



Cristina Rodríguez & Christian Haag
Mariscope Chilena Ltda, Puerto Montt, Chile

Maurizio Fea
Science and Applications Dept., Directorate of Earth Observation Programmes, ESRIN, Frascati, Italy

Héctor Gutierrez
Applications of Earth Observation, Chilean Space Agency, Santiago, Chile

The use of satellite data, primarily from instruments aboard ESA's Envisat, together with* in situ *sea measurements, provides a powerful tool for monitoring the environmental conditions of coastal waters and the health of southern oceans. Ocean monitoring by satellite remote sensing to protect public health and the fishing industry started in southern Chile in 2002. Last year, a major advance was achieved when Envisat data products were received in near-realtime, allowing early detection of marine conditions that favoured harmful algal blooms and the growth of dangerous bacteria.

Dramatic Events Detected from Space

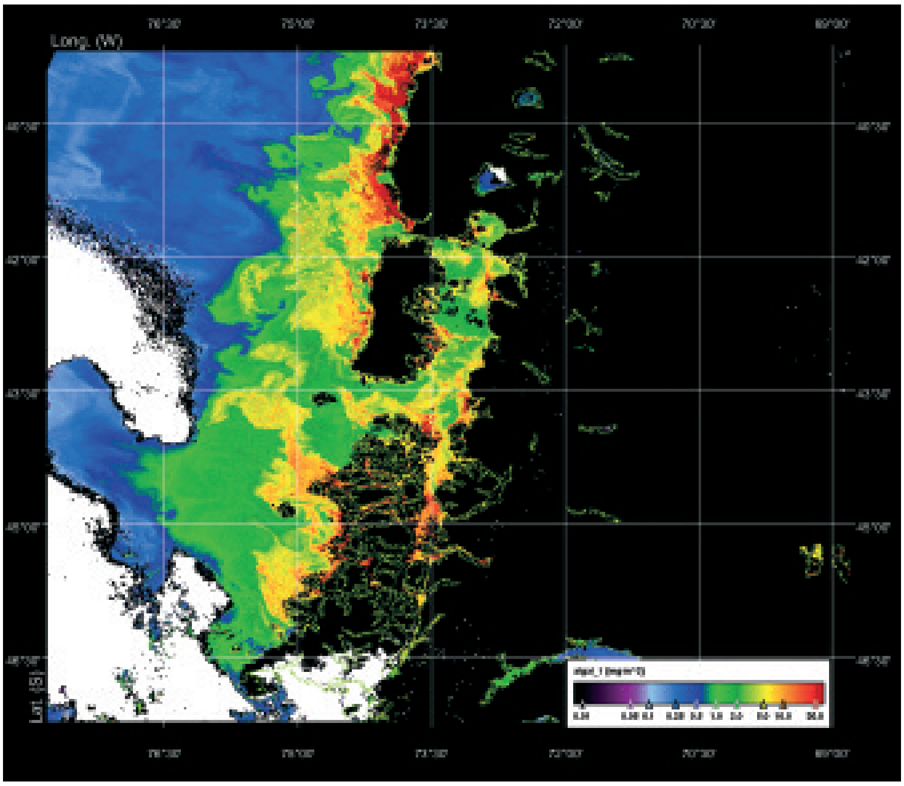
South of Chiloe Island, where the Pacific Ocean meets one of the most beautiful areas of Chilean Patagonia, some micro-algal cells grew and proliferated in the Gulfs of Ancud and Corcovado. Measurements in the sea could not reveal the extent but, from space, satellite instruments detected how this population of micro-organisms evolved. These organisms are lethal to human beings in doses of only 80 micrograms per gram of shellfish. After two people died and a hundred were poisoned in 2002, the harvesting of shellfish was forbidden in the whole area and the President declared a national disaster.

This type of event tends to occur most years. It is normally well documented by the press, particularly because the people of the region depend on natural marine resources and agriculture. Nowadays, the SeaSTAR, Terra, Aqua, ERS-2 and Envisat satellites can study the whole southern Chilean region, where the

Puerto Montt has the highest growth rate in Latin America. For the first time since 2002, this region is being observed from space.

Having established the usefulness of satellite data in monitoring ocean surface conditions, significant progress is now being made in relating satellite observations to the bulk characteristics of sea water when they are properly integrated with underwater measurements, particularly in ocean models.

This is very important because, as with humans, the health of marine life depends largely on environmental conditions. Very often, this dependency is critical and even a minor change in the value of a physical or chemical parameter, such as temperature or oxygen content, can lead to dramatic consequences. That is why satellite coastal monitoring is indispensable, particularly in regions with exponential economic growth in tourism or industrial activity, and where systematic environmental monitoring is very difficult owing to complex regional geography.



Phytoplankton concentration derived from Envisat MERIS measurements of 9 February 2005. Red is equivalent to about 30 mg per cubic metre of seawater. Strong gradients in the fronts around Chiloé Island match the sightings of blue whales and other cetaceans

Characteristics of the Project Area

The western Patagonian coast offers ideal conditions for salmon farming, to the point where the country became the world's top producer by the end of 2004. In addition, shellfish and algae farming is growing further south, in Region XI of Chile, where the economic prospects indicate explosive development in the next few years.

The area of investigation is in the south-eastern part of the Pacific Ocean. Here, the coast of the South American continent is broken up into thousands of islands, which create a special environment of bays, fjords and channels with a complex geomorphology. The ocean dynamics produce great environmental variability, enhanced by the strong influence of fresh water from heavy rainfalls and continental glaciers. The region has hydrographical and ecological peculiarities that are not well understood, but which determine the biological variability of its marine communities.

The eastern boundary of the Pacific Ocean's general circulation is strongly influenced by the atmosphere's dynamics. These meteorological conditions cause great variability in the surface wind structure. Offshore, the winter circulation from the east subdivides into two branches: the Humboldt Current off Peru and Chile, and the current off Cape Horn. The first is responsible for probably the most important upwelling region on Earth; the high inorganic nutrient influx from deeper levels creates the conditions for a major fishing area.

The Humboldt Current flows from below 40ºS, up to the equatorial region in two branches: oceanic and coastal. Under the coastal branch at depths of 100 m to 400 m there is the equatorial current, characterised by low oxygen concentration (anoxia, or severe hypoxia). The distribution of these water masses has been measured from the north of Peru down to the latitudes of Chiloé Island.

Some researchers have found anoxic conditions in the area damaging to aquaculture, relating the conditions to these water masses that occasionally arrive during parts of the year. These are new areas for future oceanographic investigation.

Envisat Helps to Monitor Ocean Conditions

Combining data in the visible and infrared spectral bands from Envisat's MERIS (Medium Resolution Imaging Spectrometer) and AATSR (Advanced Along-Track Scanning Radiometer) instruments, respectively, has made it possible to describe dynamic aspects of both the open ocean and the Gulf of Corcovado in Chile's Region X. Some of the most important observations identified areas where thermal fronts in the ocean originate, with strong temperature and probably salinity gradients. These zones retain nutrients and provide phytoplankton with optimal conditions for development.

These areas, as well as other locations, are risk areas for the development of marine algae blooms. Depending on the composition of the phytoplankton population, these blooms can be harmful to humans, and they are generally harmful to fish farming. It has also been possible to develop risk maps for other marine agents, as detected during the outbreak of *Vibrio parahaemolyticus* in the southern summers of 2004 and 2005.

Harmful Algal Blooms

Micro-algal blooms are natural phenomena known since ancient times. However, they have increased in frequency and now appear more widely around the planet. Furthermore, the growth in human population and coastal settlements means that the socio-economic impact of these phenomena has become more dramatic in recent decades. In Chile, a major example is the paralytic poisoning of marine shellfish, first seen in Punta Arenas in 1972.

During 2002, an outbreak of *Alexandrium catenella* was detected in the research area and was responsible for 73 poisonings and two deaths. The outbreak affected an area where 60% of the shellfish are destined for export. As a result, the zone to the south of 43ºS was closed for shellfish extraction during 2002 and 2004. An intense control programme is now under way for marine products, and a permanent sanitary area has been established that prohibits the export of shellfish products without certification to national and international destinations.

There is a clear need for a deeper understanding of the toxic micro-algal outbreaks in the area.

MERIS and AATSR

The MERIS instrument on Envisat has several mission goals, one of which is to generate data for the analysis of the spatial and temporal distributions of marine biological activity in the surface layers of the ocean. AATSR's key task is to provide data in the thermal-IR band, to generate sea-surface temperature maps.

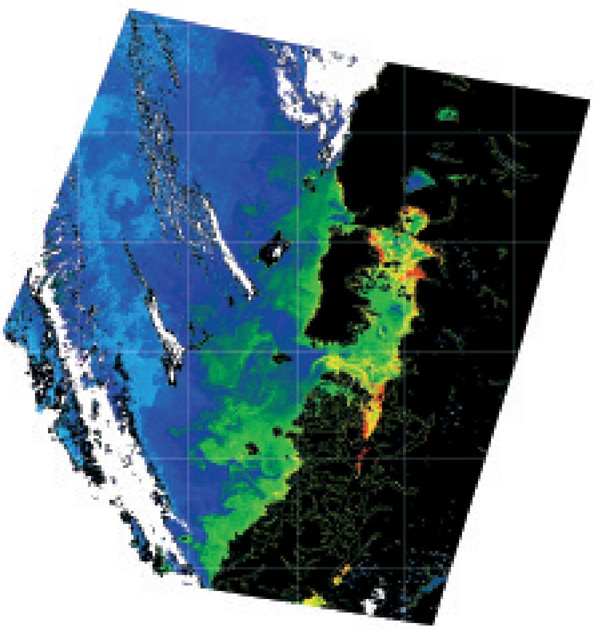
The results from this project confirm that both instruments have achieved those objectives. In the south of Chile, the combined use of MERIS and AATSR data provides early alerts of local and regional algal blooms, as well as of other marine phenomena. However, this is not an easy or automated task, because it requires a detailed knowledge and experience of interpreting satellite data, integrated with other information from different sources.

Envisat data were acquired as part of an ESA Category 1 project. During the pilot phase, data were received with a time delay of several weeks. After the implementation of new ground segment procedures by ESA, images were received from the servers at ESRIN (I) and Kiruna (S) in near-realtime, within 3 hours of acquisition by Envisat. Thanks to those improvements, it was possible to monitor large coastal areas in one of the remotest parts of Patagonia, where rapid social and economic development can be affected by natural phenomena.

The support provided by satellite information for daily activities in the sea also led to the parallel development of small pilot applications. These were aimed at evaluating and then demonstrating the usefulness of remote sensing for the aquaculture industry, insurance companies and governmental organisations in monitoring potential toxic outbreaks through the consumption of tainted seafood.

Benefits from New Technologies

Research into phytoplankton monitoring using remote sensing began in 2002 with the use of SeaWiFS and then MERIS and MODIS (Moderate Resolution Imaging Spectroradiometer on Terra and Aqua) satellite products, with the purpose of applying sea-surface temperature and ocean-colour information.



Algal bloom of Gymnodinium chlorophorum, *occurring every year since 2003 and detected by MERIS on 26 April 2005*

Initial results indicated that it was possible to focus research funding on selected specific areas.

Later, the use of Envisat satellite data demonstrated that it is possible to predict the occurrence of critical algal bloom periods, in order to mitigate the damage to aquaculture. Advance warnings of only 4 days allow enough response to reduce the effects of an algal bloom. Experimental early warnings sent to selected companies enabled them to make key decisions in time. For example, 'smolts' (young salmon) were not introduced into areas affected by the algal bloom: a small delay at this stage of the production process avoided the loss of several million dollars later on.

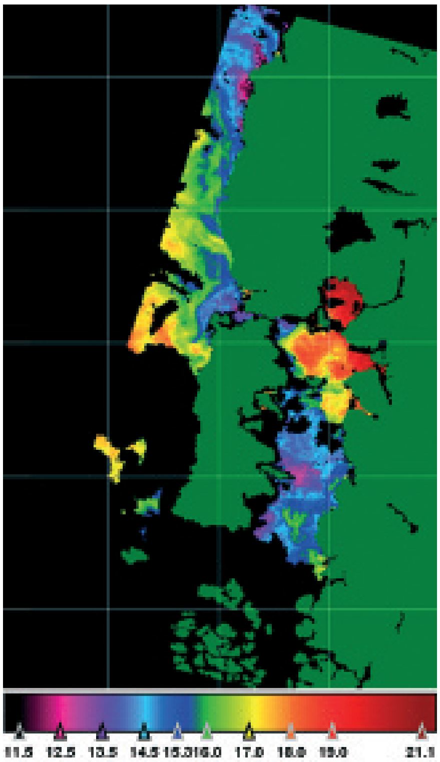
In addition, Envisat observations detected areas of maximum phytoplankton activity in a zone where marine mammals such as the blue whale had been recently seen. This zone was thus proposed as a new protected marine ecosystem. MERIS images have shown high phytoplankton concentrations connected with thermal fronts detected by AATSR. These observations fit well with the positions of the whale sightings.

Threats to Aquaculture

Aquaculture in southern Chile mainly concerns the production of salmon and shellfish. Algal blooms of different spatial and temporal characteristics have been observed. In some cases, these explosive growths of micro-algae lasted for several weeks, as with the bloom of a new species, *Gymnodinium chlorophorum*, during southern autumn 2005. Whether toxic or not, these micro-algae are solely responsible for changes in the feeding behaviour of fish, slowing their growth.

After the exponential growth of algae, bacterial development follows through decomposition of the algae. Metabolic reactions reduce the concentration of dissolved oxygen (hypoxia) in the seawater, killing the fish. In the case of the shellfish industry, the threat comes from species carrying toxins that then accumulate in the shellfish. Paralytic, diarrhoeic and amnesic toxins have also been found between Regions III and XII in Chile, with some isolated cases in the central zones of the country.

In 1993, the amount of exported blue mussels (*Mytilus chilensis*) was 3000 t, increasing to 60 000 t in 2003, and an estimate of 100 000 t for 2008. Careful management of the exploited areas is required for sustainable development. For this, it is necessary to integrate all the methods available for monitoring coastal zones, in particular multi-disciplinary programmes involving satellite data.



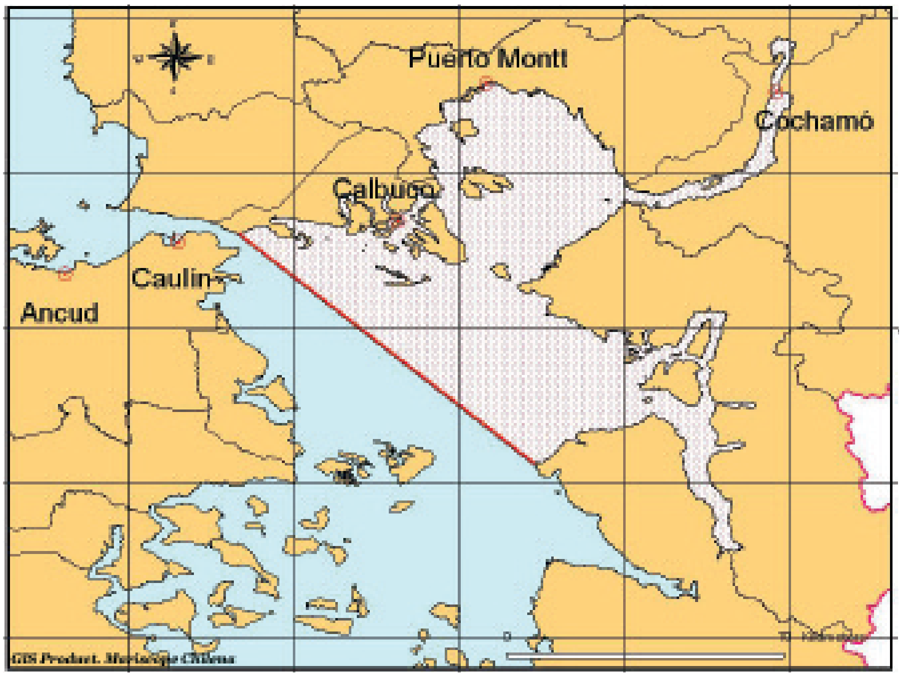
Sea-surface temperature derived from Envisat AATSR data of 21 February 2004. The thermal situation favoured the exponential growth of V. parahaemolyticus. *The highest temperature (°C) is shown in red*

Earth Observation and Epidemiology

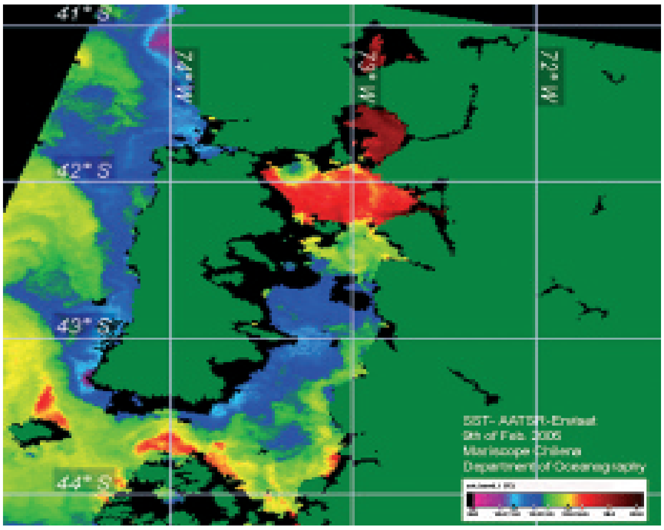
In 2003, some bacterial species were detected for the first time in the area. One was identified as *V. parahaemolyticus*, responsible for more than 1500 poisonings during the southern summer of 2004 and more than 10 000 cases in 2005, including one death. The origin of these bacteria in the region was probably ballast water spilling from other countries. This hypothesis is supported by the results of the genetic analysis of the bacteria strains found in Chile, which corresponds to the pandemic complex seen in some Asian countries after 1996.

V. parahaemolyticus is a bacterium of the same genus as *V. cholera*, which lives in marine environments. Several parameters influence its life cycle; water temperature has been demonstrated to be one of the most important factors that accelerate its growth. Envisat AATSR data showed the rise of sea-surface temperature during January 2004 in that area. The seafood areas at most risk of being infected with this bacterium were determined through the analysis of AATSR and ancillary data. Eventually, remote-sensing data helped local health authorities to establish a well-defined region of increased risk, and to avoid closing low-risk areas.

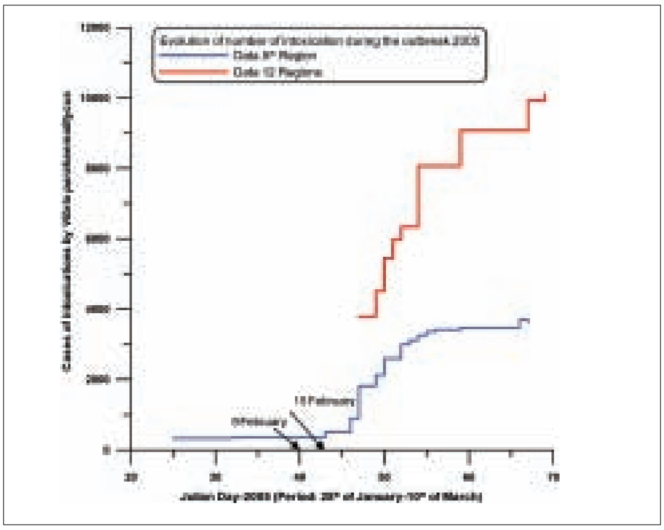
Unfortunately, during the southern summer of 2005, preventive action was limited to advising people to avoid raw shellfish during the critical period. No sanitary barriers were established, and no restrictions were imposed on the shellfish extraction by area; such a difficult decision would have strongly affected local families dependent on the industry. This led to more than 10 000 cases of poisoning all over the country, and one death. The region is a key zone for extracting and exporting shellfish. This could explain how the outbreak rapidly turned into a national epidemic.



Envisat data helped local authorities to define the region of high risk of poisonings and to avoid closing low-risk areas



Sea-surface temperatures derived from AATSR data of 9 February 2005, some days before the exponential growth in poisonings from raw shellfish consumption



Evolution of the number of poisonings during the 2005 outbreak of V. parahaemolitycus

Through remote sensing, it was possible to demonstrate that the water temperature was above 18°C on 9 February 2005 around the coastal zone with the highest population density, which is also the principal area of shellfish extraction. The temperature could have been one of the main reasons for the exponential growth of the bacteria. The Health and Consumer Protection Directorate General of the European Commission recommends avoiding the extraction of marine resources during the critical period in summer. This recommendation should be considered in equivalent regions beyond Europe.

By using satellite data, it is possible to forecast the most critical periods of contamination up to a week in advance. That certainly allows time to create at least temporary sanitary barriers, minimising the effects on the workers in the seafood industry, and on the regional and national population. This technology adds value to the exported products, in that it provides a sort of quality certification to the monitoring conducted during the extraction period.

Routine work of divers in the salmon industry. Remote sensing data help to plan their daily work and prevent decompression sickness

Novel Application to Human Health

Another recent application of satellite data with a positive effect on public health is the prevention of decompression sickness in working divers of the region. The link between divers and satellites may appear surprising, but it confirms the value of space data in multi-disciplinary applications.

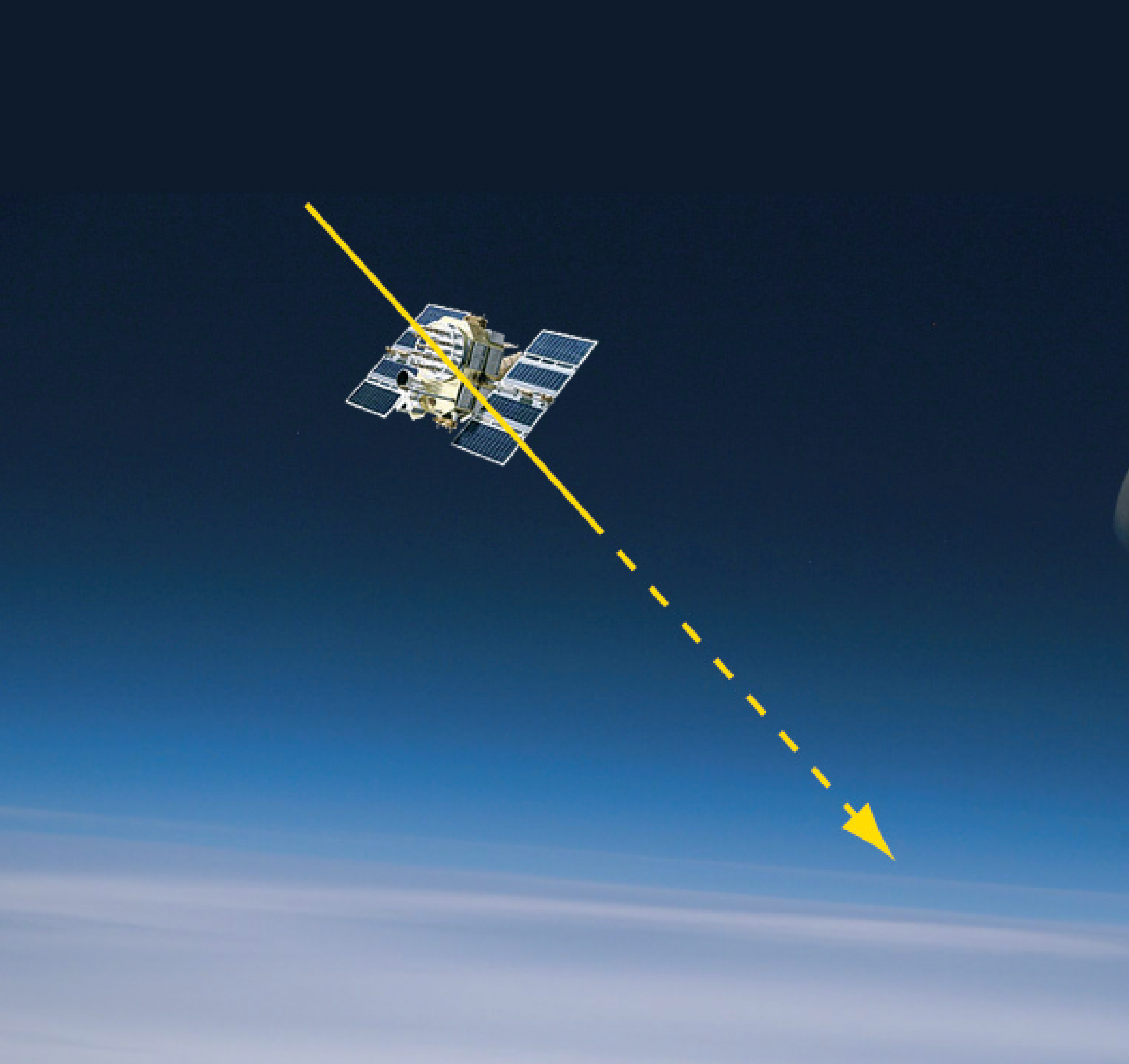
One of the routine tasks of divers in the salmon industry is the daily clearing of dead salmon from nets to prevent disease in the remaining fish. An average of 10 salmon are taken out of each cage every day. A single diver normally does the job in up to 30 cages per farm. This level of effort already affects the diver's health owing to the repetitive diving and the accumulation of nitrogen bubbles in the body.

During and after algal bloom events, these divers have to cope with massive fish starvation in the cages. The amount of dead salmon is often so high that the load on the bottom of the net is too great for the installation to remain afloat. When the nets collapse and sink, they damage the surrounding nets. During these events, divers work for hours in the cages, often not following the necessary decompression procedures afterwards. Serious decompression accidents sometimes kill the divers. The insufficient number of divers to cope with these emergencies in the more remote regions of southern Chile means that the situation is not improving.

The use of satellite information to warn of an algal bloom can help to reduce accidents and losses, as demonstrated in 2005 through the use of Envisat MERIS and AATSR data. This is an important example of the many ways in which satellite information is of real daily benefit to people around the world.

Conclusion

The integrated use of satellite and *in situ* sea measurements is an important aid to decision-making for public and industry administrators. However, data integration and interpretation by skilled professionals is a fundamental prerequisite given the major socio-economic and public health impacts of their decisions.



Sounding the Atmosphere

Ground Support for GNSS Radio-Occultation Processing

As seen from a low-orbit satellite, the GPS satellite disappears below the horizon (motion indicated by the yellow arrow). The radio signal is affected as it slices through the atmosphere. The case shown here is a 'setting occultation'

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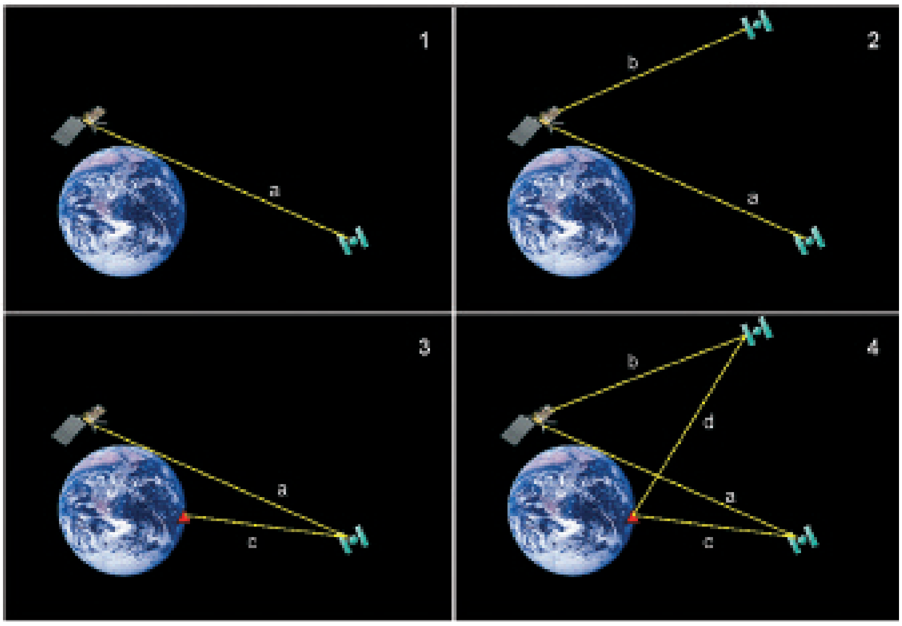
The conditions in Earth's upper atmosphere are important for predicting the weather but they are difficult to monitor. The region can be probed by measuring the effects on radio signals slicing through it from navigation satellites. ESOC's Navigation Support Office is contracted by Eumetsat to provide crucial supporting data to allow the analysis of the signals received aboard Europe's new MetOp polar-orbiting weather satellites, due to debut in 2006.

Introduction

Earth-orbiting satellites have been equipped with Global Positioning System (GPS) receivers for many years now, mostly as an aid for orbit determination. The receiver processes the signals from visible GPS satellites through one or more antennas mounted on the satellite. For GPS satellites that appear to the receiver to be close to the Earth's horizon, the signals travel through the Earth's atmosphere and are therefore less useful for orbit determination. However, such signals can be exploited for sounding the upper atmosphere by measuring how they are affected.

MetOp-A, the first satellite to be launched as part of the ESA/Eumetsat MetOp polar system, in mid-2006, is



The geometry of undifferenced (1), single-differenced (2 and 3) and double-differenced (4) occultation data processing. By computing the difference [a-b, a-c, (a-c) – (b+d)] between several signals, the uncertainties in the atomic clock offsets are eliminated

equipped with a receiver to be used for atmospheric sounding. Its data will be converted in near-realtime to atmospheric products that can be fed into numerical weather-forecasting models at European meteorological institutes. The creation of these products requires significant amounts of near-realtime supporting data, including the very precise orbits of the GPS satellites. Eumetsat has awarded the Navigation Support Office at ESOC a contract to set up the system for the generation and delivery of such data.

Atmospheric Sounding

Atmospheric sounding is based on signals from Global Navigation Satellite Systems (GNSS) that pass through the atmosphere. GNSS includes the American GPS, Russia's GLONASS and Europe's Galileo. The GPS constellation consists of 28 active satellites orbiting the Earth at an altitude of 20 000 km, transmitting navigation signals at 1575 MHz and 1228 MHz.

During occultation of the transmitting satellite by the Earth's horizon, a large part of the signal path traverses the atmosphere. This slightly reduces the speed of the radio waves compared to the speed of light in vacuum, apparently increasing the measured distance between the GPS satellite and the receiver aboard the low Earth orbit (LEO) satellite. The effect is greatest at the point where the signal is nearest to the Earth. As a result of the relative motion of the two satellites, the altitude of this point will decrease (in the case of a setting occultation) or increase (in the case of a rising occultation).

While this atmospheric effect on the signal is a source of error when the data are used for precise positioning or orbit determination, it can yield useful information about the the upper atmosphere, such as temperature and pressure. Tracing the effect with time generates an atmospheric profile. For the case of MetOp, orbiting at an altitude of around 820 km, the profile will be generated in up to 100 sec.

MetOp satellites are equipped with a GPS receiver called 'GRAS' (GPS Receiver for Atmospheric Sounding), which can process data received through its three antennas. One antenna on the zenith side (pointing away from Earth) receives signals that are hardly affected by atmospheric effects, so they can be used for precise orbit determination. The other receivers are mounted on the fore and aft sides of the satellite, facing in the direction of motion and against it, respectively. Each of these antennas monitors only radio occultations, and can track up to two occulting GPS satellites at the same time.

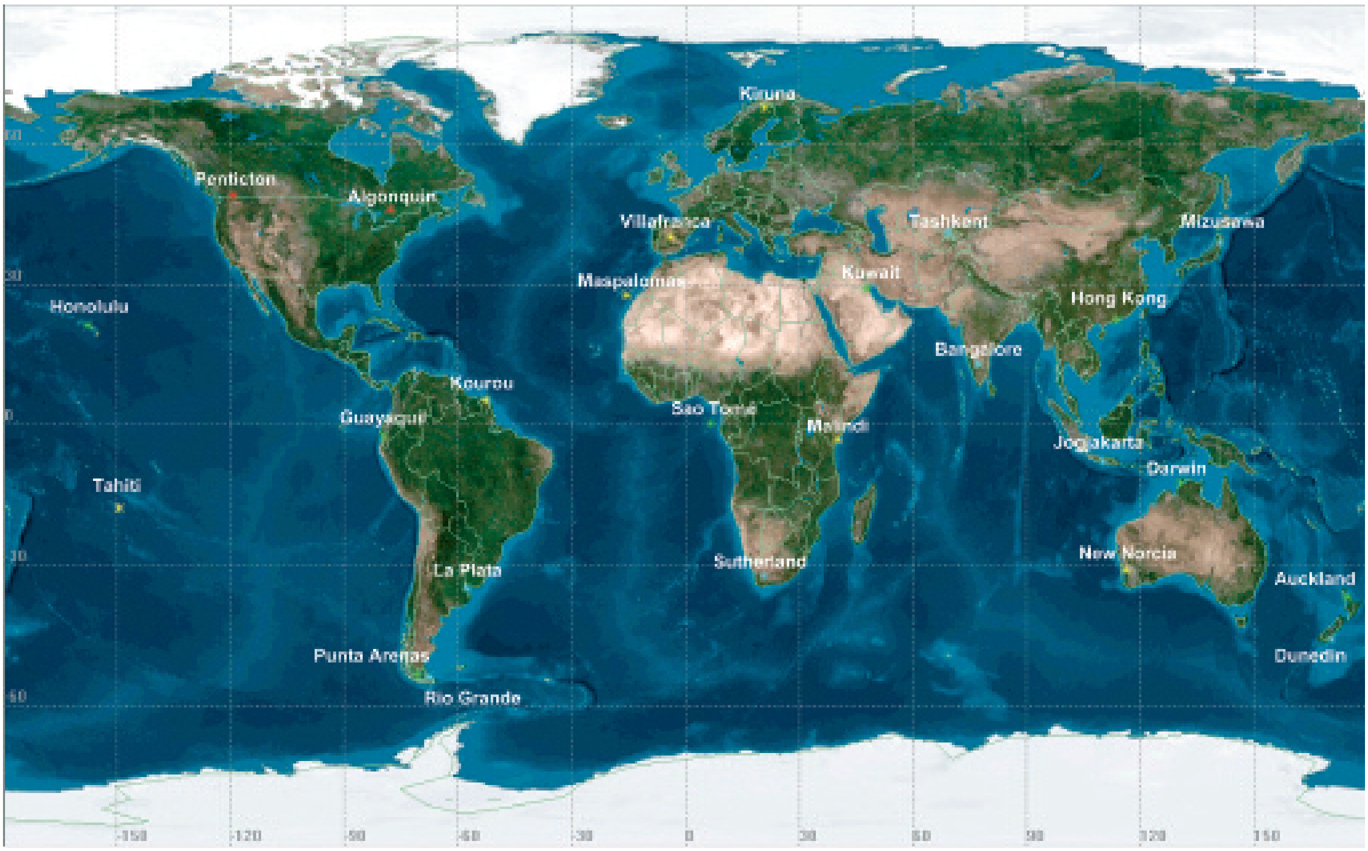
Through the geometry of the MetOp and GPS orbits, some 500 radio occultations will be observed on an average day – making around 500 atmospheric profiles available to meteorological scientists daily.

Sounding Data Processing

The radio occultation data will be collected aboard MetOp and downlinked to the ground once per orbit, for analysis at Eumetsat. To compute the effect of the atmospheric refraction, the processing software requires highly precise knowledge of the true distance between MetOp and the occulting GPS satellite, and a highly precise measure of the signal delay. The first is obtained from orbit determinations of MetOp and GPS, and the second from the time difference between transmission and reception of the signal. This relies on a very precise determination of the offsets of the atomic clocks used by the satellites; these offsets are measured with respect to the GPS reference time, which is accurately maintained with respect to coordinated universal time (UTC).

The quality of the products from this process depends on the accuracy of the GPS orbit and the clock offset data that are fed into it. The atomic clocks must be extremely stable: clock offset and their accuracies are measured in nanoseconds (10^{-9} s). The radio signals travel about 30 cm in 1 ns; the most advanced processing centres can now achieve accuracies of the order of 0.1 ns.

If the atomic clocks are not stable to this level over several tens of seconds (the duration of an occultation), slightly more complicated alternative processing techniques may be employed. These compute range differences, such that the variations of one or more atomic clocks



The receiver sites of the GRAS Ground Support Network. ESOC sites are indicated in yellow, GFZ in light blue, Fugro Seastar in green and NRCan in red (only the prime sites are shown)

with respect to the reference time are eliminated from the calculations. The data-processing scheme described earlier is known as 'undifferenced' processing. If it is suspected that MetOp's clock is not stable enough, it can be eliminated from the calculations by computing the difference between the ranging signals coming from the occulting GPS satellite and an unocculted GPS satellite received through the zenith antenna, and using this in the occultation processing. If the clock of the occulting GPS satellite is suspect, it can be eliminated by computing the difference between the range from this satellite to MetOp and the range from this satellite to a ground station. We can even eliminate all clock offsets by computing a double difference.

Support Data

Through more than 10 years' participation in the International GNSS Service (IGS), ESOC's Navigation Support Office has become one of the most experienced producers of high-precision GPS orbit and clock offset data. The IGS makes available its data (GNSS ground receiver data from a global network comprising several hundred sites) and products (orbit and clock solutions from seven analysis centres) freely to the user community. From this, it is known that the most precise orbit solutions that can be made available are of the order of 3 cm, with a corresponding clock offset accuracy of the order of 0.1 ns. This type of accuracy is sufficient for the support data needed by the radio occultation data processing. There are, however, some constraints put on the support data by Eumetsat, namely:

- the radio occultation data are to be fed into near-realtime numerical weather simulations, so they must be available within 3 hours of the occultation;
- clock data should be available at the highest possible rate (ideally 50 Hz) during occultations;
- the support data should be provided with a guaranteed availability for up to 15 years (covering the first three MetOp missions).

In 2001 the Navigation Support Office completed a study on a system that could deliver the required support data against the strict requirements on accuracy, timeliness and availability. The primary support data required include:

- near-realtime GPS orbit and clock offset solutions, available within 60 minutes. The driving accuracy requirement is a 0.5 ns clock offset accuracy for each supported GPS satellite;
- for single difference processing: near-

realtime ground station clock offset solutions with the same accuracy and timeliness as the GPS clock offset solutions.
- also for single difference processing: GPS ground receiver data (one measurement set per second) for each occulted GPS satellite, during the occultation event. These data should be available within 60 minutes of the occultation;
- off-line orbit and clock offset solutions with enhanced accuracy, which are of interest for climatological research.

Other auxiliary products are also included in the support data to be delivered.

As a result of this study, ESOC was awarded a contract to develop, validate and operate a GRAS Ground Support Network for all three MetOp satellites. The network must also be extendable to support similar missions.

The ESOC Navigation Facility, hosting the GRAS GSN

The GRAS Ground Support Network (GSN)

The feasibility study concluded that, to be able to deliver receiver data for all GPS satellites being occulted, and to compute sufficiently accurate near-realtime GPS orbit and clock offset solutions, a dedicated ground receiver network with redundant global coverage was required. At that time, ESOC operated seven GNSS receivers, deployed at the ESA ground station sites worldwide, with some overlapping visibility. The required network needs at least 25 well-distributed receivers, even before allowing for redundancy.

The data from these receivers are routed continually, either as a realtime data flow or in frequent batches, to a processing centre at ESOC, where automated procedures pre-process, edit and select the data, generate all required products and deliver them to Eumetsat. Significant parts of the highly complicated software required for this processing were already available in the Navigation Support Office, through its participation in the IGS, but modifications and additions were made to make the system satisfy the customer's requirements.

For the receiver network, contracts were established with the German GeoForschungsZentrum (GFZ) in Potsdam and the Norwegian commercial operator Fugro Seastar, who both operate their own global networks of GNSS receivers. A contract with the Canadian government institution Natural Resources Canada (NRCan) allowed the inclusion of some important sites in North America. In addition, Météo-France agreed to deploy a GPS receiver on their site in Tahiti. There is a scarcity of sites in the Pacific, so it is a key element in the GRAS Ground Support Network.

Each network operator is responsible for collecting the data from its own receiver sites. Permanent data lines have been established between ESOC and the three operators, and all the data are delivered in files covering 15 minutes of 1 Hz data, delivered within 5 minutes of the last observation in each file. Data from all 40 sites (44 receivers) are collected at a new facility in ESOC.

With these, GPS satellite orbits are computed and predicted in near-realtime every 3 hours. Based on these orbit solutions, high-rate clock offsets are computed every 15 minutes for all active GPS satellites and for all GSN stations.

Based on daily predictions from Eumetsat, indicating which GPS satellites have radio occultations at which times, ground receiver data for single-difference processing are selected and prepared for delivery to Eumetsat fully automatically.

All near-realtime products are delivered to Eumetsat as soon as they have been computed or prepared, and are stored in parallel on a file server at ESOC. These, and a number of additional products, such as the offline enhanced products, are kept online for 6 months, after which they are archived. A procedure for restoring archived data has been agreed with Eumetsat.

The entire GRAS GSN, including the network of receivers, the processing centre at ESOC and all software involved, was developed and deployed in the period from September 2003 to March 2005. It went through a validation phase from May 2005 to December 2005, and on 15 February 2006 it was officially declared 'ready for operations'. The network can support two MetOp satellites in parallel, and was designed to be easily adaptable to support other missions with similar requirements.

The GSN Processing Centre

The high availability requirements placed on the GRAS GSN made it necessary to operate it from a secure environment with built-in redundancy. Plans existed for a dedicated Navigation Facility as part of ESOC's operations infrastructure, and it became clear that the GRAS GSN would become its first major project.

The Navigation Facility was first used in May 2005. All hardware is divided into two independent chains ('A' and 'B'), which are physically separated such that the loss of one chain will still allow full operability of the system.

Connectivity to the outside world, a critical component of the GSN owing to the large amount of data being continually retrieved, is based on a relay system through a demilitarised zone, making it impossible for unwanted traffic from the internet to reach the operations infrastructure.

The Navigation Facility was inaugurated on 17 February 2006. The six operator positions are not all used by the GRAS GSN, which is a fully automated system requiring only minimal manual intervention. Other projects will be operated from this facility in the near future.

Since the GRAS GSN was completed some months before the first MetOp launch, ESOC and Eumetsat agreed that the project should go into hibernation for about 3 months. Operations will start up a month before the MetOp-A launch, which is planned for mid-July 2006.

Acknowledgements

The authors wish to acknowledge the excellent work of the GRAS GSN development team (A. Ballereau, OPS-GN; C. Garcia Martinez, I. Romero, Y. Andres and E. Rojo, GMV). Eumetsat is thanked for the opportunity to implement this system, and the excellent collaboration throughout the project. Thanks are also due to our partners: GFZ, Fugro Seastar, Natural Resources Canada and Météo-France Tahiti, for the outstanding quality of their work and data products.

Making European Industry More Competitive

The Example of ESOC's Operational Software

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For Europe to remain competitive, the capabilities of its industry in ground operations software must continue to grow. Building on the expertise of ESOC, the ultimate goal is a suite of 'plug and play' software that users could call on by selecting the various components from European suppliers.

Introduction

ESA's mission is to shape the development of Europe's space capability and to ensure that investment in the space sector continues to deliver benefits to Europe's citizens. In practical terms, this means that ESA has to ensure that Europe's space industry develops and maintains these capabilities. They must cover a wide range, spanning the space segment, launchers and ground segments. Another challenge is to supply space systems at competitive prices. Ambitious space programmes with limited budgets make this essential everywhere. Another significant aspect is the globalisation of the space business and the growth and improvements of technical standards that enable global inter-operation. To be a player in the world space market, European industry must offer competitive solutions. This article describes an initiative to develop and strengthen industry capabilities in operations software for the ground segment. This involves promoting reusable software products originally developed for ESA purposes. The effort began around 5 years ago with the SCOS-2000 mission control kernel. This initial effort was very successful and is now being extended to the much wider palette of products forming the ESOC Ground Operations Software (EGOS). The article also draws together the various threads that make such an endeavour possible; these include standardisation and

Working in the ESOC backup Mission Control Room

ground segment technology harmonisation. The ultimate aim is to encourage the emergence of a European suite of ground operations software, from which users meet their needs in a 'plug and play' manner by selecting components from European suppliers.

Ground Segment Operations Software

For many years, ESOC has been developing high-quality software for its core business of spacecraft operations. This includes software for:

– mission control: command and control of the spacecraft;
– simulators: providing support for testing the system and training the operations personnel;
– flight dynamics: controlling the attitude and orbit of the spacecraft;
– mission analysis: designing the mission for manoeuvres and flybys to achieve mission aims.

Much of this software is used and rigorously tested for the demanding tasks of preparing and supporting spacecraft operations. Because of ESOC's need to apply it to many missions, much of it was designed for reuse, as one of the most effective ways to increase productivity.

Risk reduction is another important advantage, since reused software has already been validated operationally.

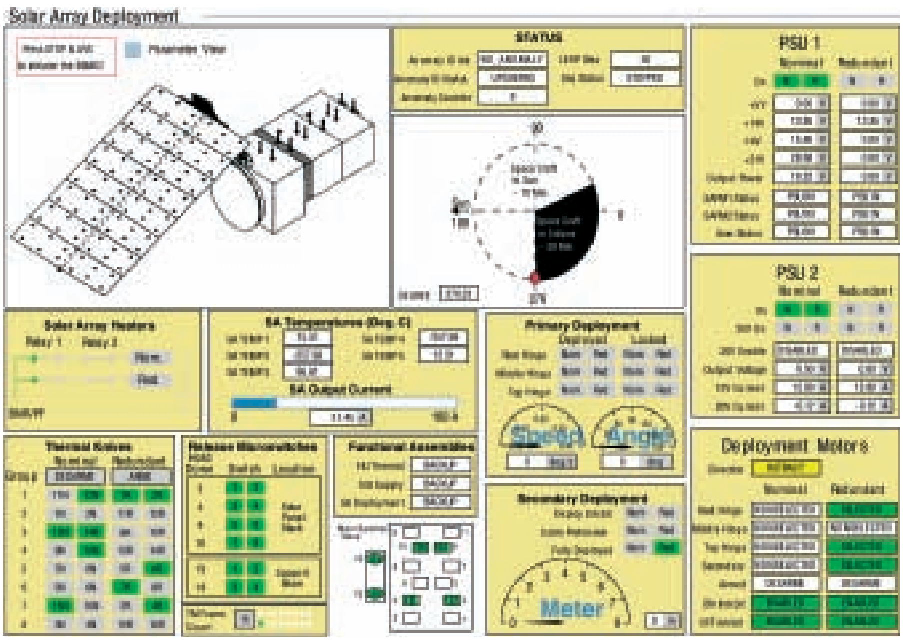
The idea then arises: why not encourage other spacecraft operators to use this software and take benefit of the investments already made? Linked to this is the consideration that suppliers of such software are also looking for business with other spacecraft operators, so this would open up new markets. Indeed, this could apply not only to ESOC's suppliers, but also to any European company able to exploit the software. It follows that such reuse could help to make European industry more competitive.

In fact, ESA has been doing this for many years via the licensing of a wide range of software developed for ESA purposes, although it was left to the initiative of the licensees to exploit the software, commercially or otherwise. Furthermore, in the last 5 years or so, ESOC has been promoting certain software as supported 'products'. The seed for this was ESOC's SCOS-2000 mission control kernel, but the idea has now been broadened. As described later, it will eventually include the full range of ground systems software.

Reusable Software

Reusable software has to be designed and developed for reuse from the outset. There is a rule of thumb that if more than about 20% of a software module has to be rewritten when reusing it, then it is more effective to design and rewrite the whole module from scratch. The challenge of developing reusable software is to stay well below this threshold. This can be achieved via various techniques, such as;

– allowing configurability via the setting of parameters or a via database;
– allowing extension of functionality using software engineering techniques



Mimic Display from the MetOp Mission Control System, based on SCOS-2000. ESOC will support the Launch and Early Orbit Phase of Eumetsat's MetOp weather satellites

A session in ESOC's Simulation Studio

such as inheritance in object-oriented methods. This allows the reused software to remain unchanged, the additional functions being provided via the use of 'derived classes'.

Standardisation

Another enabling factor for reusable ground systems software is standardisation. Space agencies and industry have invested in engineering standardisation as a means of decreasing project risks and reducing development and operations costs. Risks are reduced because standardisation offers proven and consolidated processes, methods and interfaces. Cost is reduced because standardisation permits reuse of processes, solutions and components.

For space engineering, there are two main bodies concerned with standardisation: the Consultative Committee for Space Data Systems (CCSDS), and the European Cooperation for Space Standardisation (ECSS)

The CCSDS is an international standardisation body primarily addressing communications and data-handling techniques for interoperability between different space agencies, and standardisation of space-related information technologies. Today, membership of CCSDS includes ten space agencies and several other participating organisations in the form of observers, associates and liaisons.

The ECSS was established in 1993 to develop a coherent, single set of standards for use in all design and development of space systems in Europe. It involves ESA and the national space agencies, and, importantly, it includes European industry under the umbrella of Eurospace. Eurospace is a non-profit organisation that fosters the development of space activities in Europe and promotes a better understanding of space industry-related issues. This means that, in ECSS, both the institutions and industry are stakeholders in the standards.

CCSDS and ECSS have between them produced a large body of engineering standards that are now in regular use, particularly in ESA. A number of these standards have allowed the development of standard components (or infrastructure) for ground systems software. Examples are:

– from the CCSDS, the Space Link Extension (SLE) services, which provide standard interfaces to ground stations, permitting one agency to use the ground station of another;
– from the ECSS, standards of particular relevance are ECSS-E-70A, which is the top-level standard defining the process lifecycle of developing and using operations systems, and the Telemetry & Telecommand Packet Utilisation Standard, ECSS-E-70-41, which identifies a set of services for using telecommand packets and telemetry source packets in the remote monitoring and control of payloads space systems.

These examples merely scratch the surface but the point is that software developed to support such standards is naturally reusable.

Early Days: MSSS and SCOS

At ESOC, it has been the practice for some 30 years to use a generic mission control system as the basis for the control system of each mission. This was first done in the mid-1970s with the Multi-Satellite Support System (MSSS). The basic concepts of this system were that:

– it could be configured to support several missions at the same time;
– it was table-driven. The data structures of the commands and telemetry data of the each spacecraft were defined in tables, so customisation to a new spacecraft could be done largely by updating tables.

These were novel concepts for the time. MSSS was highly successful and remained in use for well over 20 years. It was also used as the basis for some systems developed commercially for other spacecraft, in particular the Inmarsat Mission Control System (MCS).

The next MCS generation was the Spacecraft Operations Control System (SCOS). The first generation SCOS-I was developed in the mid-1980s and had a centralised architecture based on VAX minicomputers. Like MSSS, it was implemented mainly in FORTRAN. SCOS-I systems continue to support several major ESA missions: Envisat, ERS-2 and Cluster.

Growing Maturity: SCOS-2000

The successor to SCOS-I was SCOS-II, later renamed SCOS-2000. Early versions were used for the control system of the Huygens Titan probe, the control system for the launch and early orbit phase of Meteosat-7, and a low-cost control system for the Teamsat young engineers' satellite. The launches of all of these were successfully supported in 1997. In the case of Huygens, the system remained in use until its successful landing on Titan in January 2005.

Despite the similar name, SCOS-2000 was completely new. It used client server technology in a distributed system of Sun Solaris workstations. Designed using object-oriented methods, it was written in C++, and developed with the following strategic aims:

– ease of configuration and/or customisation, therefore lowering associated costs;
– functional richness, reducing the need for mission-dedicated functions and lowering mission-specific costs;
– scalability, allowing the system to be adapted to missions of any size or for any phase of a mission;
– vendor independence, which reduces or avoids the need for periodic migration exercises as hardware platforms or Commercial Off The Shelf (COTS) software becomes obsolete.

All four aims have been achieved. Vendor independence was fully achieved in 2002 with the introduction of a SCOS-2000 version that could run on either Sun Solaris or Linux platforms.

Promoting SCOS-2000

As a consequence of using SCOS-2000, costs of ESOC control systems have come down by a factor of 2–3, and more in some cases. This reinforced the thoughts about the possible wider use in the space sector. SCOS-2000 had some clear advantages for this.

Firstly, it was classed by ESA as 'operational software', which meant that ESA owned the Intellectual Property Rights. According to the ESA Convention, this gives the ESA Member States and bodies under their jurisdiction the right to have a licence to it free of charge.

Secondly, continuity of support is guaranteed since SCOS-2000 is used by ESA on all missions supported by ESOC. In particular, the ESA Investment Plan funds basic maintenance and keeping of the product in step with evolution of the underlying technology and platforms. ESA is using SCOS-2000 on major programmes such as Rosetta (launched in 2004, due to arrive at its target comet in 2014), Mars Express, Venus Express and the Galileo constellation of navigation satellites. Thus the product necessarily has a long time horizon. The promotion of SCOS-2000 began in 2000 by:

– ensuring that experience with SCOS-2000 and its technology was well spread among ESOC's frame contractors. The contractors carry out all the development of mission control system infrastructure and of mission control systems at ESOC;
– encouraging these contractors to use SCOS-2000 in their bids to other customers within and beyond ESA;
– holding regular workshops to share experience on the use of SCOS-2000 between its users;
– providing training courses.

As a result of these and other measures, SCOS-2000 is now in use by many operators. The table shows that the overwhelming choice for the operating system is Linux, which resoundingly confirms the correctness of the decision to make Linux one of the SCOS-2000 operating systems. The list includes several examples of using the system for spacecraft checkout. There is also an example of reuse in a different but related field to that for which it was originally developed. This came as an initiative from the ESA Directorate of Science, which chose SCOS-2000 as a platform for the Central Control System supporting assembly, integration and test activities on the Herschel/Planck platform and its payloads.

In the Eutelsat case, 'NEO' controls a fleet of satellites from European, US and Russian manufacturers. NEO replaced a 'park' of different control systems with a single solution based on the SCOS-2000 platform. The NEO project also resulted in a joint venture called 'hifly©' between two European companies, SciSys (UK) and GMV (E). According to the companies, hifly© product is an MCS solution for commercial satellite operations that is *"powered by SCOS-2000"*.

In the case of DLR's German Space Operations Centre at Oberpfaffenhofen, near Munich, SCOS-2000 was selected as a cost-effective solution to replace an ageing Compaq/VAX architecture.

Organisation	System/Project	Industrial supplier	Operating System
Eutelsat	NEO	GMV (E)	Linux
CSA	Radarsat	Terma (D)	Linux
ASI	Agile	Telespazio	Linux
DLR	CHAMP TerraSAR-X Central Check-Out System TerraSAR-X Mission Operations System	Siemens Austria	Linux
SES Astra 1 M	MCS	GMV	Linux
ESA	Herschel/Planck Central Checkout System	Terma	Linux
ESA	Vega launcher EGSE	Vitrociset	Linux
ASI	Cosmo-SkyMed	Dataspazio	Solaris

Projects using SCOS-2000 outside of ESOC

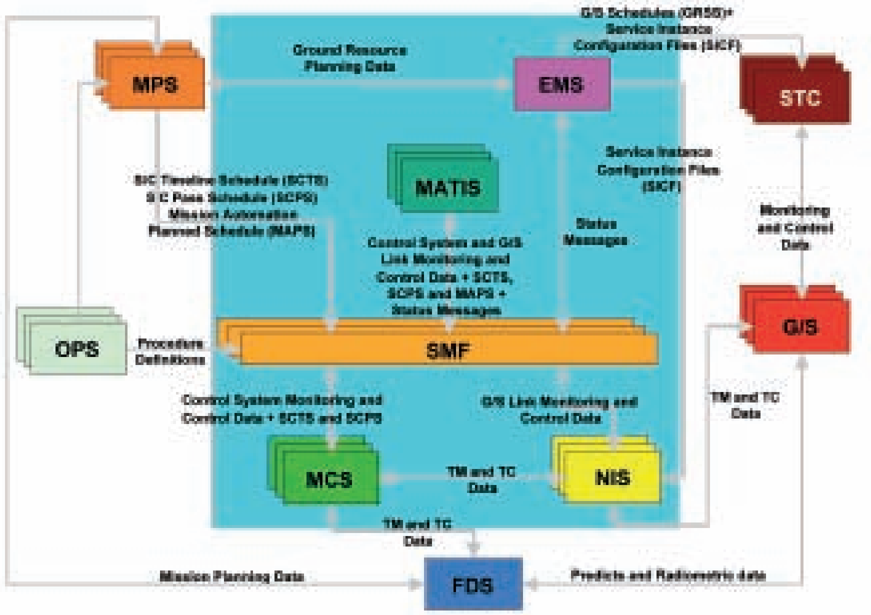
Expanding the Scope

It is clear that SCOS-2000 has become a 'best-selling' software product, with some 70 licenses granted over the last 6 years. In fact, it is now a world-leading MCS product.

By 2002, it became obvious that there were other candidate products, such as:

– ESOC's generic simulator infrastructure SIMSAT (Software Infrastructure for Modelling Satellites), which also has a pedigree stretching back over 20 years;
– the SLE Application Programmer Interface package, which provides a standard means of communicating with the ground station backend over the TCP/IP communications protocol, and also provides cross-support capability with other agencies.

It was also becoming clear that synergies could be achieved between the various products. For example, SIMSAT was



The envisaged future architecture of ESOC ground segments, including operations automation. EMS: ESTRACK Management System. FDS: Flight Dynamics System. G/S: ground station. MATIS: Mission Automation System. MCS: Mission Control System. MPS: Mission Planning System. NIS: Network Interface System. OPS: Operations Preparations System. STC: Station Computer. TC: telecommand. TM: telemetry

originally developed to run on MS Windows, which apart from limiting synergy with the UNIX/ Linux systems of SCOS-2000, also implied the support of a further information and communications technology infrastructure at ESOC.

Organisational Considerations

Differences in organisational responsibility led to the divergences mentioned above, including the use of different platforms, different COTS software, and different software solutions for common problems such as logging and error handling. The various responsible units had independently developed parts of the infrastructure without considering potential commonalities in technology, design and implementation.

In 2002, the management of ESOC's Ground Systems Engineering Department decided to add two new divisions:

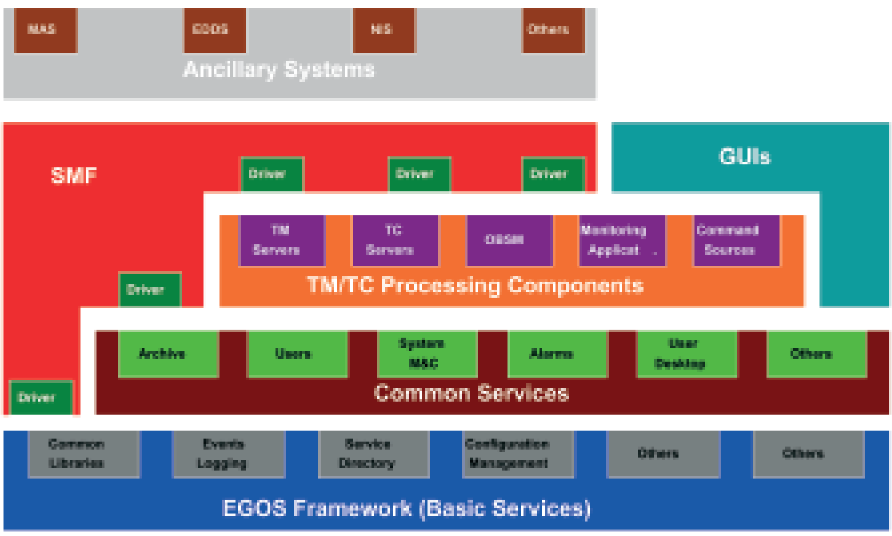
– the Data Systems Infrastructure Division, responsible for the implementation and maintenance of the generic mission data system infrastructure, including mission control systems, simulators and ground station backend software;
– the Mission Data Systems Division, responsible for implementation and maintenance of mission control systems and simulators for missions. This division is also the counterpart to the 'customer', which for an ESA mission is represented by the flight control team and its management.

This reorganisation had two main effects. First, it put mission control, simulator and ground station infrastructure software under the control of a single unit. This unit, the Data Systems Infrastructure Division, has the mandate to ensure consistency and synergy between infrastructure products. Secondly, it allows that unit to focus on reuse, be it of infrastructure or of software developed specifically for particular families of missions.

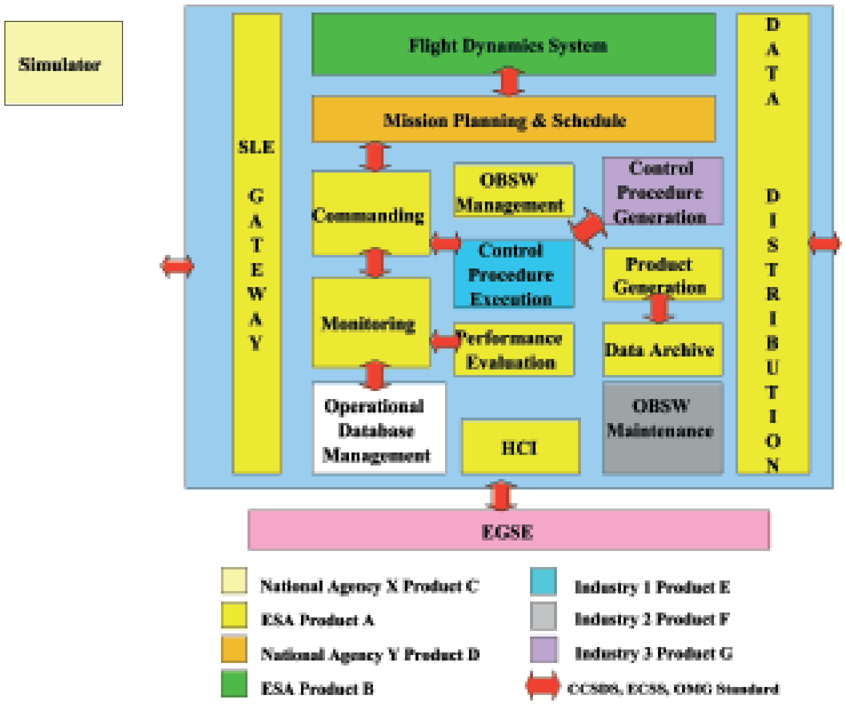
ESA/ESOC Ground Operations Software

In the 3 years since the new organisation was set up, the process of expanding the scope and coherence of the infrastructure has proceeded rapidly. Notable achievements have been:

– porting of the simulator infrastructure to Linux/PC platforms;
– the development of a new generation of telemetry and telecommand encoders, integrated in one package, TMTCS, and supporting the SLE services;
– extension of SCOS-2000 to support multiple spacecraft. This is essential for constellation missions such as Galileo and for future formation-flying missions.



EGOS components, with layering into low-, middle- and high-level components. EDSS: EGOS Data Distribution System. GUI: Graphical User Interface. MAS: Mission Automation System. NIS: Network Interface System. OBSM: On-Board Software Management (System). SMF: Services Management Framework.



How a system can be built up in alternative ways as 'plug and play'. EGSE: electrical ground support equipment. HCI: Human-Computer Interface. OBSW: On-Board SoftWare. OMG: Object Management Group. SLE: Space Link Extension

This also enables server consolidation

– reducing the number of servers;
– reengineering of EGOS components, involving the identification and layering of common functions and services, with the aim of reducing the amount of 'middleware' and low-level software, and avoiding duplication.

Work has started on a Mission Automation System (MATIS) and the ESTRACK Management System (EMS; ESTRACK is the ESA ground station network).

Evolution not Revolution

The general philosophy followed for EGOS is 'evolution not revolution'. This emphasises reuse or, more broadly, reengineering of existing software. New products and product lines are developed to respond to new services or needs. However, even in this case, available products are taken as the basis for new product lines wherever feasible. Bearing in mind that reusable software is in effect a repository of knowledge, we try to avoid redevelopment from scratch, since this risks losing this embedded knowledge and may even create new problems if the redevelopment is based on wrong assumptions or requirements.

Technology Harmonisation

The process of devising an improved strategy for the evolution of European space technology began in 2000 in response to a resolution at the ESA Ministerial Council of May 1999 entitled *Shaping the Future of Europe in Space*. This resolution included the statement *"… the new and demanding challenges of the 21st Century call for a concerted European effort, so that Europe achieves its fullest potential for international cooperation and world competition"*. This resulted in a Technology Harmonisation initiative. Broadly speaking, its approach was to:

– identify the technology needs for European space programmes. These were set out in the *European Space Technology Requirements Document* also referred to as Dossier 0. This covers some 22 technology areas, one of which is ground systems software;
– make a consolidated plan of all relevant technology-development activities in Europe, including an overview of all planned institutional space technology programmes, with related strategic plans ('roadmaps'). This is the *European Space Technology Master Plan*.

The idea, therefore, is to ensure that the R&D contributions of the partners are complementary, avoiding wasteful overlaps or the spreading of resources too thinly. In the ground systems software area, the problem of lack of strategic control had been evident for many years: many suppliers were producing incompatible solutions, even though they addressed the same problem.

In the particular case of ground systems software, the harmonisation approach was done in three phases:

1. define, in agreement with the users, a common system standard architecture with common requirements for the identified blocks ('modules') in the architecture;
2. define standard interfaces between the models;
3. produce the needed solutions responding to the common requirements and using the standard interfaces, reusing or reengineering as far as possible existing products. This, of course, is in line with the 'evolution not revolution' philosophy.

The outputs of Phases 1 and 2 are intended to be inputs to the ECSS standardisation process.

The Steering Board of European Technology Harmonisation on Ground Systems Software was set up to oversee this plan. Contracts were let under ESA's Technology Research Programme to carry out the work. The Steering Board has representatives from ESA and national agencies (ASI, CNES, DLR, BNSC, CDTI, ASA) and the European software industry (Critical, Dataspazio, GMV, LogicaCMG, Terma, SciSys, Siemens, VCS, Vega).

Phase 1 has been completed, with a reviewed set of documents comprising the High-Level Requirements and the architecture. Phase 2 is under way to define (as proposed standards) by the end of 2006 the following four major interfaces:

– monitoring and control to flight dynamics;
– flight dynamics to mission planning;
– mission planning to monitoring and control;
– simulator to electrical ground support equipment (EGSE).

The vision is that technology harmonisation of ground systems software will enable EGOS to become a European Ground Operations System.

Conclusions

The benefits that reusable software can bring to an organisation like ESA have been shown. A consequence is that other spacecraft operators can use this software and European industry can use it to gain a competitive edge, as demonstrated by the number of successful projects based on ESA/ESOC products, in particular SCOS-2000. Success has depended on a strong strategic vision, exploiting the advantages that standardisation brings, and having an appropriate organisation to develop the products and apply them. The success has also depended on strong cooperation with industry, in particular from ESOC's in-house suppliers, who have been active in selling solutions based upon ESOC operations software products. The European Technology Harmonisation on Ground Systems Software is expected to expand this initiative further, both by resulting in further standardisation of services, architecture and interfaces and by bringing in the institutional and industry players at the European level.

Fit for a PRINCE

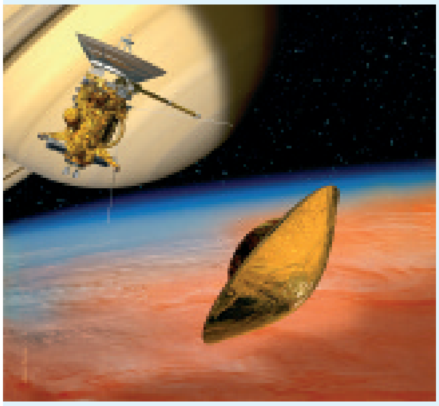
The Network of European Centres on Project Reviews

Jacques Candé
Review Coordination Office, Directorate of Technical & Quality Management, ESTEC, Noordwijk, The Netherlands

The Project Review Integrated Network of Centres (PRINCE) is a simple agreement between space centres to 'share' experts to complement the expertise of their own project review teams.

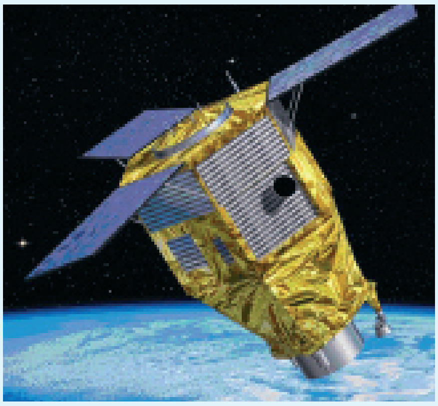
Introduction

PRINCE is an initiative of the Network of Centres in charge of project reviews: these are currently the British National Space Centre (BNSC, UK), Centre National d'Etudes Spatiales (CNES, F), Centre for the Development of Industrial Technology (CDTI, E), Deutsches Zentrum für Luft- und Raumfahrt eV (DLR, D), ESA and Eumetsat. Since it began in 2000, PRINCE has provided every type of space project review with experts from a wide range of technical disciplines, ranging from system/ mission engineering to specialists in very specific technical fields. The diversity of the various centres guarantees that the experience missing from a review team will be found. PRINCE began with a preparatory phase, followed by a qualification phase in which the rules and procedures of the initiative were defined. The operational phase began after approval by the ESA Council in October 2003.



"PRINCE was a good opportunity to compare viewpoints originating from various horizons and experiences with a fresh look at Huygens, a great asset for revalidating the Huygens mission recovery design and giving the Cassini-Huygens team good confidence that it had done it right. The successful Huygens landing on Titan in 2005 just demonstrated it."

Jean-Pierre Lebreton, Huygens Mission Manager



"In the frame of the Command and Control Centre Preliminary Design Review, Mr Mullet from Eumetsat brought to CNES a very interesting contribution, enlightening the CNES approach with his own expertise, related to other European Command and Control Centres."

Eric Boussarie, Pleiades Project Manager

"The external PRINCE Reviewers who participated actively in the Nanosat-01 Critical Design Review at INTA provided an external view on our development and verification activities. This was especially important, given the fact that we have developed all the spacecraft subsystems, onboard software and the ground segment 'in house'."

Manuel Angulo, Nanosat INTA Project Manager

PRINCE has proved to work very efficiently and to be extremely convenient for the users. Project managers and chairs of review boards use PRINCE because it:

- improves the quality of the reviews. The experts have solid backgrounds based on their involvements in a wide spectrum of projects;
- supplies technical and managerial expertise to complement and extend that of the internal review team;
- provides the review with new and independent points of view on the challenges faced by the project;
- can lead to significant reductions in project risk, and hence cost-savings, through the early detection of potential problems.

Also, participating in project reviews at other centres allows the selected experts to:

- experience projects with technical challenges new to them;
- exchange knowledge with staff of other centres and to establish useful professional relations;
- discover novel solutions;
- learn new ways of organising project reviews that could improve those of their organisations.

PRINCE ensures efficient cross-participation of specialists because their selection does not impose additional constraints on the requesting project. Confidentiality is guaranteed by written agreement, and the external reviewers are cost-free to the projects.

Experience in using PRINCE

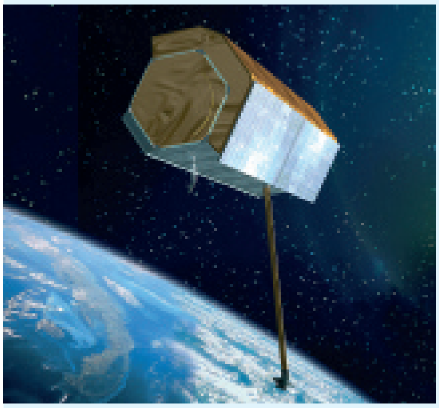
During its 2-year qualification phase, PRINCE worked smoothly and effectively. Feedback from chairs of review boards, project managers and reviewers was extremely positive. The process has proved to be flexible enough to deal with urgent requests and for the continuous involvement of specific reviewers. Feedback comments included:

- the fresh insights brought by truly independent reviewers were helpful to projects;
- 80% believed that PRINCE is likely to improve pan-European cooperation;
- 75% of chairs of review boards believed that PRINCE is likely to improve the quality of Europe's space programme;
- 95% of participants were willing to use PRINCE in future reviews.

The total number of reviews opened to external participants in the first 4 years was 40; 85 reviewers were exchanged, with no exchange of funds.

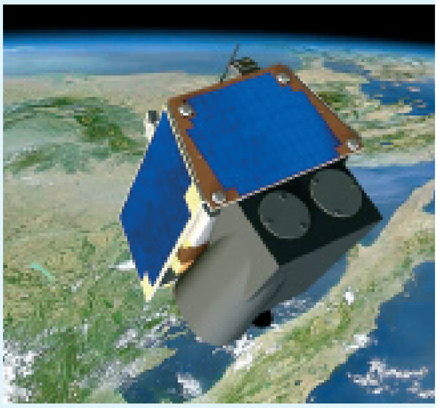
PRINCE has been used in a wide range of projects, including launchers (Ariane-5), meteorological satellites (MetOp), scientific probes (Huygens), scientific satellite ground segment (GERB), remote-sensing satellites (SPOT-5), balloon-mounted payloads (IMaX), synthetic aperture radar instruments (TerraSAR-X), air-breathing propulsion systems (ASSC2) and optical-imaging small satellites (Topsat). In each of these widely-differing projects, PRINCE was able to provide a review member with the expertise requested by the project.

The individual expertise includes satellite operations, systems engineering, security requirements, satellite thermal and structural engineering, propulsion, attitude and orbit control, onboard data handling, ionospheric modelling, cryogenics, aerothermodynamic modelling, optical and radar instrumentation and mission control software.



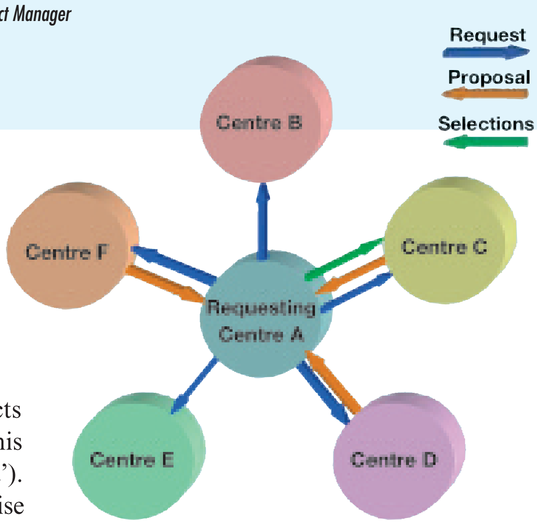
"The experts from ESA, CNES, CDTI and BNSC added essential experience to the review team, which turned out to be very helpful for the project. The continuity of personnel provided for subsequent reviews was highly appreciated."

Rolf Werninghaus, TerraSAR-X Project Manager



"The involvement of a PRINCE external reviewer contributed substantially to the credibility of the review."

Bill Levett, Topsat Project Manager



How to Request Support

The process has three simple steps. Each centre has a 'correspondent' who, as an expert in project reviews, coordinates the PRINCE process.

First, a project manager contacts the PRINCE correspondent of his centre (see 'Points of Contact'). Together, they define the expertise profile required for the review. A specific request is issued for each required external reviewer. Each request contains a description of the project under review, the required skills and the review dates. The correspondent distributes this official request to the correspondents of all other participating centres.

Second, after receiving a request, the correspondents search for appropriate specialists/reviewers and send suitable proposals to the requesting centre correspondent.

Third, the final selection is made by the project manager and the review board chair. In principle, they do not have to justify their decision. The correspondent sends positive and/or negative responses to the proposing centres. Identification of the review authority and the point of contact is specified only in the case of a positive response. The selected reviewers are informed by their correspondents about their roles and duties in the review. In particular, reviewers act *ad personam* and sign a confidentiality agreement that secures any technical or programmatic information accessed during the review. At this point, an external reviewer behaves like any other member of the review team and any further contacts are made directly between the team leader and the reviewers.

The mandate of external reviewers expires at the end of the review and they must return all the review documentation to the project. esa

Frequently-asked questions

Does PRINCE impose a specific review procedure?
No. It is assumed that all the participating centres apply standard or tailored ECSS methodology to the conduct of the reviews. PRINCE does not add any specific feature to the nominal review procedure.

Does PRINCE impose the use of a specific language?
No. The requesting centre specifies the language used in the review.

Does PRINCE ensure confidentiality?
Yes. All external reviewers Sign a non-disclosure agreement.

Does PRINCE add to the cost of a review?
No. Involving external participants from PRINCE in a review has no cost to the project under review. However, each centre bears the costs of its own staff sent as external reviewers. PRINCE balances the exchanges of external participants between participating centres, thus avoiding an exchange of funds.

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A Step Forward in ESA Budgeting

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The new FINPOL ('Financial Policy') system in use since 1 January 2006 is helping ESA to adapt itself at a time when most countries face restrictions in their national budgets and their contributions need to be justified and used as efficiently as possible. The various flexibility systems put in place beginning in 1998 produced important improvements in the yearly consumption of ESA budgets, but they had drawbacks. FINPOL is a simpler, more transparent system, providing greater flexibility for programme managers and Member States.

Introduction

ESA programmes are legally independent from each other. Each has its own separate declaration, contributions scale and programme envelope that provide the legal basis for the yearly budgets. Practically, this means that ESA has one budget per programme – and that means more than 60 budgets must be managed in parallel.

In the past, programme managers had to include margins when planning their yearly budgets in order to cope with most of the risks inherent to any programme. But this approach created artificially high budgets with a high risk of under-consumption at the end of the year because, statistically, not all the risks for each programme materialised in the same year. This situation was unsatisfactory.

To handle that problem, while recognising that a programme must absorb risks, the Accompaniment Fund was set up in 1998, followed by the Budget Management System (BMS). They led to an important reduction in under-consumption, while introducing flexibility into the Agency's budget management.

The BMS had some drawbacks, however. Its two-level approach was complicated, thus preventing transparency. Not all the budgets were included; mandatory activities and technology programmes were excluded. To improve the system, the FINPOL reform was introduced in 2006.

Basics of the FINPOL Flexibility Mechanism

The main changes from the former Budget Management System are:

– it allows simple transfers of income and allocation between programmes, resulting in transparent management and easy reporting;
– it involves all budgets financed by contributions;
– it is closely linked to long-term planning;
– it uses the new corporate control procedures.

This combination is expected to bring major improvements for the in-year and multi-year management of ESA's budgets and programmes because, through it, the Director General can manage the yearly budgets at a corporate (Agency) level. It also ensures that resources are used by the programmes that need them, when they need them and within the approved limits.

Of course, budgetary flexibility must be limited to current activities and programmes – it is not a tool to finance new activities. It must also respect the commitments made by the Member States and prevent any transfer from one state to another at the end of the programme. Flexibility should also protect the cost-at-completion of a programme and not allow any unauthorised increase.

The degree of flexibility has set limits. Each programme is constrained by upper and lower margins that reflect the programmatic 'reality' (based on the assessment of programmatic risks and/or uncertainties); the total flexibility allowed during a given year cannot exceed 25% of the contributions.

Flexibility Framework

The flexibility mechanism is in place to manage the programmes and optimise the use of resources. However, it does not change any former commitment made by the Member States to ESA programmes, as reflected in the programme declarations. This implies constraints on the flexibility.

Guaranteeing commitments

Whatever the transfers of contributions and allocations between programmes, transfers in the other direction have to be made before the end of the programme so that the total contributions of each Member State to each programme are constant and correspond to their original commitment.

Cost-at-Completion (CAC)

Flexibility is designed to support the management of the programmes through upward or downward adjustments of their budgets during a given year. The difference is recovered during the following years before the completion of the programme. There should be no increase in CAC as a result of using the flexibility measure.

Activities covered

Flexibility covers only the activities planned in the normal course of the programme as defined in the declaration, or problems deriving from it. At no time will it be used to finance new activities in a programme or the start of a new programme.

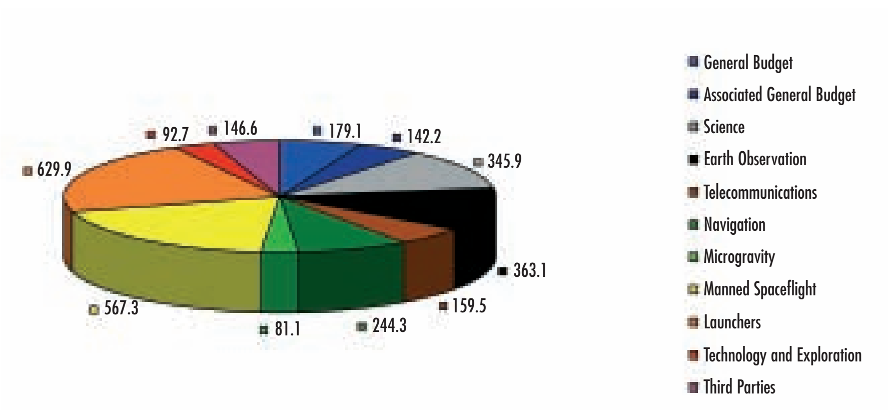
The Flexibility Process

The basic feature of flexibility is to move allocations from one budget to another during the year, depending on the real needs of the programmes, so that the best use is made of the contributions from the Member States, while respecting the commitments of the Member States in each programme. Practically, this means that when a programme receives or gives income and allocation during the course of a year, its future planning is adjusted to maintain a constant CAC.

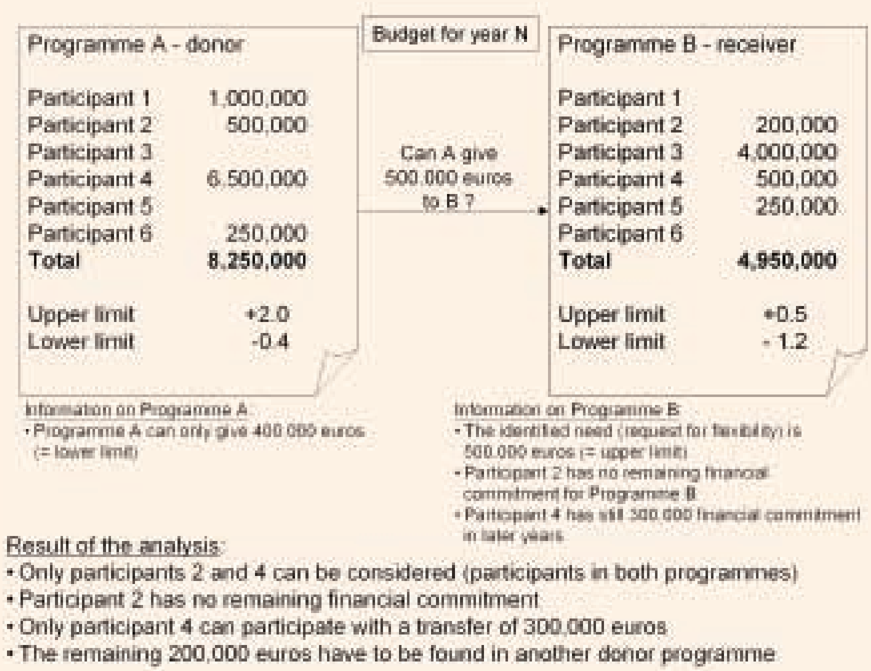
The main steps of the process are described below.

Establishing budgets and margins

At the time of budget preparation for year N+1 (during the spring of year N), the programme managers update their planning, and the data are integrated into the new long-term plan, prepared in parallel. The first year of this new plan is the basis for the next year's budgets. The level of Member States' contributions is first checked at that time, ensuring at the Agency level that the



The ESA budget by programme for 2005 (in € million)



An example of budget flexibility

planned contributions reasonably fit the needs of the programmes.

At the same time as fixing the appropriate budget level for each programme (corresponding to the normal course of development), an assessment of the risks and uncertainties associated with the activities planned for year N+1 is performed. This identifies the upper and lower margins, which could potentially modify the initial level of the budget.

The identified margins are submitted to the ESA Council at the time of budget approval. In addition, the overall flexibility limit is set, at no more than 25% of the budgeted contributions.

Execution of the budgets

During the course of the year, the planning and actual consumption of payment appropriations are closely monitored to anticipate the need for flexibility measures (increasing or decreasing a budget).

When an increase via the flexibility is requested, it is necessary to identify one or several 'donor' programmes, i.e. programmes that are anticipating under-consumption in their budgets. However, this is not enough to allow the transfer of allocations because the flexibility applies to the individual contributions per Member State and not to the allocations as such. Flexibility is not only about transferring allocations, but transferring allocations from one or more countries to the same countries with the same amounts, between programmes. So when donors are identified, the viability of transferring allocations while respecting the contributions of the Member States has to be investigated and confirmed.

Elements for processing a request

The receiver and donor programmes will not have the same size of contributions. An analysis is necessary to ensure that a transfer of contributions is possible. For example:

– an amount can be transferred only if the country is a participant in both programmes (donor and receiver). So even if potential donor programmes have been identified for the right amount, it does not mean that their structure of contributions is compatible with the receiver;
– the remaining obligations for a Member State must be considered. The amounts that have still to be paid by the state before the end of the programme must be equal or higher in the receiver programme than the amount to be transferred;
– in some cases, Member States wish to limit the flexibility on their contributions. This might occur when contributions are paid from different national sources – flexibility could create internal difficulties;
– flexibility measures should not create imbalances in the structure of contributions. This avoids having some countries with highly unbalanced contributions scales for a given year when compared to the scale in the declaration, unless the Member State agrees or wishes so.

Reporting to the Member States

A report on budget execution, highlighting how much flexibility has been given each year, is submitted to each Administrative and Finance Committee meeting for information. It allows Member States to follow the use of flexibility during the year, with information on receiver and donor programmes and the evolution of their contribution per programme (the overall figure for the year being constant).

Processing a Request

A request from a programme to Corporate Planning & Controlling is processed as follows:

- the request is analysed to confirm the need and that there is a margin available for flexibility;
- the potential donor(s) are identified (the Directorate requesting the increase provides this information, if possible);
- the contribution structure and availabilities are analysed, of both the receiver and the donor(s) to validate the possibility of flexibility and to identify the detailed transfers to be implemented;
- a go/no-go decision is taken on the feasibility, with the arbitration of the Director General and the Directors if priorities have to be defined;
- the transfer is executed, and the income and expenditure budgets are updated.

Specific Exclusions

The monies to be considered for flexibility are those from contributions of the ESA Member States. All other income is excluded, in particular the amounts financed by the European Union or third parties.

In addition, the Member States can indicate specific exclusions, mainly when contributions are from specific national sources (for example, when another Ministry or organisation funds programmes in specific domains).

Conclusions

FINPOL allows the Director General to adjust, in a very simple and transparent way, each individual annual budget to the real needs of a programme as it evolves during the year, within limits agreed by the Council and without putting an additional burden on the Member States while, at the same time, guaranteeing that the overall commitment of each state to each programme is respected. It can only serve to improve the efficiency of running the Agency and its programmes.

Introducing Competency Management at ESA

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Competency management is central to every organisation's ability to maintain and enhance its human resources. This approach is directly linked to improving competitiveness – organisations need to stay at the forefront of technology, starting with the development of their human capital.

Introduction

This overview of ESA's research and understanding of competency management introduces the work conducted so far on the ESA Competency Management Project, in particular the Generic Competency Model and the Technical Competency Model. The Human Resources (HR) Department is now consolidating the positive results and experience gained to date to develop its Technical Competency Model further and extend its potential applications. Based on lessons-learned, we present suggestions as how best to extend the project to encompass the whole Agency.

What is Competency-Based Management?

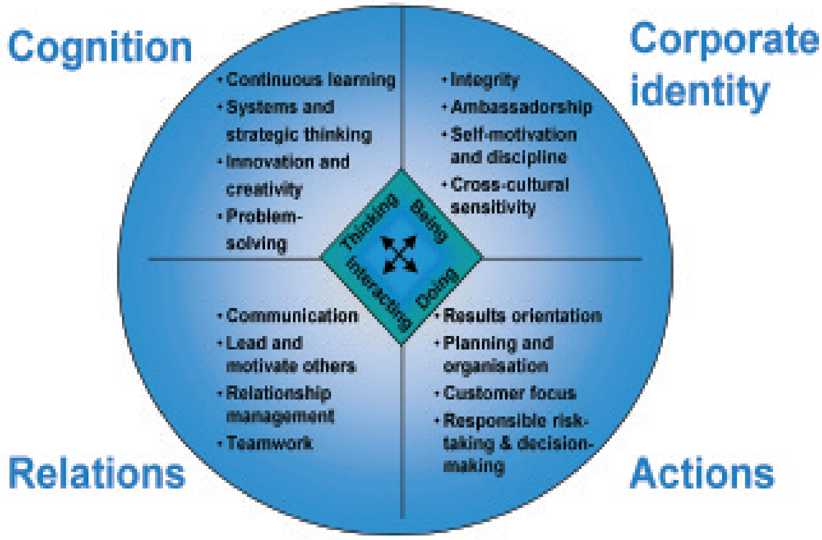
Competency-Based Management (CBM) is a set of theories and processes aimed at identifying, classifying and managing the competencies that people need to perform specific jobs. It sets a conceptual and practical framework that drives the management of human resources to contribute efficiently and effectively to the results of an organisation.

By linking human resources processes to desired competencies, organisations can shape the capabilities of its workforce and achieve better results. In short, CBM is a means of ensuring that there is the right person in the right position at the right time. In the recruitment process, it helps, in a structured manner, to define the selection criteria that identify the competencies required for a given position as the basis for selecting the best person for the job. Competency management can also be used to support career management by ensuring that employees are aware of the competencies needed for a particular career path. It is also very important to ensure that employee competencies are maintained and/or improved, which contributes to staff development.

Before competencies can be managed, they should first be classified and their scope of application defined. Initially, they can be divided into two types: behavioural and technical. The behavioural competencies include all those 'soft' skills that enable a person to perform well in a specific function, such as communicating effectively, achieving tangible results and creative problem-solving. These are generic because they can be applied to a variety of different functions and technical specialties. Accuracy, for example, could be as essential for flight dynamics engineers as for payroll officers, but less important for some scientific and engineering roles. The capacity to lead and motivate others is independent of domain; it could be equally important whether you head a team of scientists or a section of contract officers.

Technical competencies are specific to a given function. Depending on the job, this could range from knowledge of the rules and regulations related to payroll and the software that transfers the money to your bank account, to knowledge of Maxwell's laws and the software for the electromagnetic compatibility analysis of some equipment.

There are many models of behavioural competencies that can be applied widely to different specialties. However, the classification of technical competencies could be unique to a specific sector or, in some cases, to a specific organisation. Some common general principles apply to most of these classifications.



The ESA Behavioural and Cognitive Competency Model

The most common principle is the top-down approach. This means first identifying the broader categories and then refining them into sub-groups. In the case of scientific and technical organisations like ESA and NASA, three main levels have been identified:

Level 1: the broad job communities, such as Engineering, Scientists, Astronauts and Administrative Services;
Level 2: the job families, such as Electrical Systems Engineering, Space Science, Project Management and Audit;
Level 3: specific jobs, such as Avionics Engineer, Planetologist, Ground Segment Manager and Auditor.

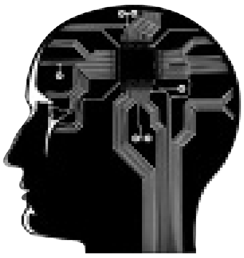
An additional Level 4 further details the specific technical and behavioural skills required for the given job. Once defined, Level 4 competencies may also be ranked according to proficiency levels (such as expert, master, junior) and can be used to define both the requirements of a job as well as the degree to which the person has mastered the various competencies.

The ESA Generic Competency Model

The development of a competency model within the Agency started in 2001 with the definition of the ESA Generic Competency Model and its associated recruitment and assessment tools.

This model describes the cognitive and behavioural skills identified as important and relevant to the Agency. It identifies four broad categories of skills: cognition (thinking), relations (interacting), actions (doing) and corporate identity (being). Each category contains four specific skills. These 16 skills do not necessarily apply to all posts and a selection is made depending on the nature and characteristics of the post.

The model was based on the feedback from interviews and focus groups of over 120 staff members. The intention of this model was to use it as a foundation for HR practices such as self-assessment, training, recruitment, career management development and mobility. It has been used as the basis for two concrete tools: the



Competency-Based Interview Recruitment Tool, and the Competency-Based Tool for Setting and Assessing Behavioural Competencies. While the first model is widely used in the recruitment process, the second is being promoted for staff assessment and development.

Towards the ESA Technical Competency Model

Competency-Based Management cannot rely alone on cognitive/behavioural skills but must accompany and be integrated with technical competencies. The competency aims to support ESA's goals by identifying staff with the required competencies for a given project or post, as well as identifying potential opportunities best suited to individual competencies. Knowing the capabilities of ESA's internal resources is all the more critical now given the expected departures of a large number of experienced staff and experts in the near future.

Feasibility study

A study on the technical competencies of the Agency was launched in September 2004 with the objectives to:

– define a methodology to describe the technical competencies associated with the various posts and/or required by future needs;
– assess the reusability of the ESA Competency Dictionary developed in recent years and used by some Directorates for manpower planning. It contains definitions for most important technical functions at ESA, such as Propulsion Engineer, Micro-electronics Engineer and Thermal Engineer;
– verify the suitability of the HR Management System (HRMS) software already in use by HR to support properly the CBM data model and functions;
– validate the selected approach through the development of a prototype.

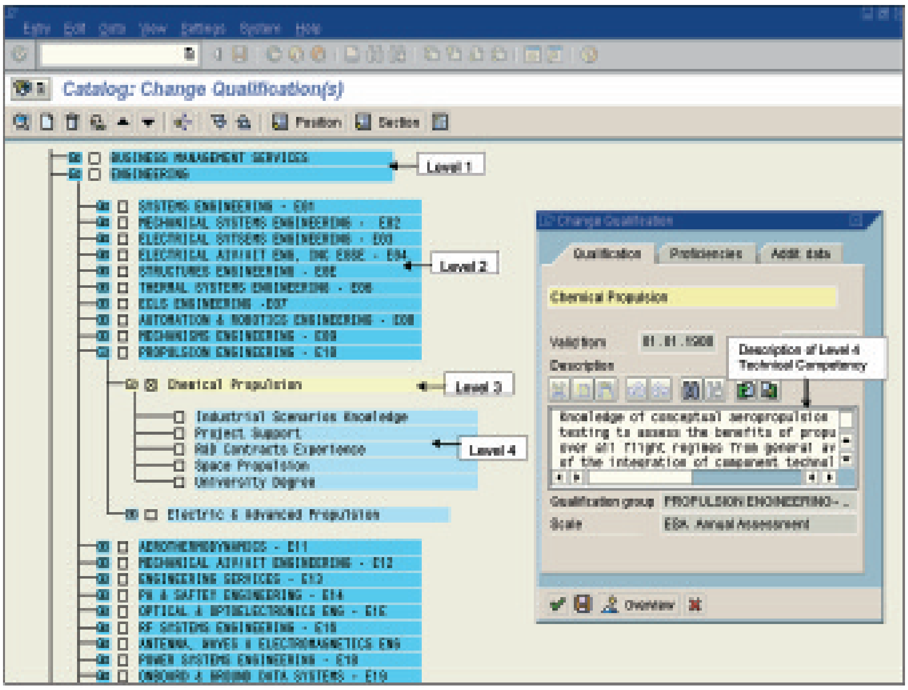
The study started with a comprehensive review of the best practices used in similar organisations, such as the European Organization for Nuclear Research (CERN), Compagnie Général De Géophisique (CGG), the Organisation for Economic Cooperation and Development (OECD), and the United Nations Industrial Development Organisation (UNIDO), to name a few. The technical model used by CERN was considered to be the most promising. This model, like ESA's Competency Dictionary, is based on NASA's Workforce Competency Dictionary. We can gain from the lessons learned and discussions with CERN and NASA about their approach.

Once the model was defined as far as Level 3, it was decided to verify the possibility of including Level 4 competencies. At that point, it was necessary to verify the suitability of the HRMS software to manage the task. A small prototype was developed for 12 positions where the technical and behavioural competencies were identified. The technical, managerial and behavioural selection criteria were obtained from the interview report forms and the qualification requirements and task descriptions were taken from the Vacancy Notices.

HRMS for competency management

In 2000, the Directorate of Resources Management decided to implement a new HRMS to provide HR staff with an integrated tool to support most of their administrative and management processes, including recruitment, organisational management, career management, training, payroll and leave management. ESA selected the SAP/R3 (HR module), after evaluating other options.

The Personnel Development module enables the planning and implementation of specific personnel and training measures to promote the professional development of staff. It also allows the possibility to assign qualifications and competency requirements to a post to ensure they are met. It also allows tracking



An example of how the Technical Competency Model is implemented in SAP's HRMS. It shows the breakdown of the classification derived from the model in the top-down approach from Level 1 down to Level 3, where the competencies associated with the post of Propulsion Engineer are further detailed into Level 4 skills of the qualifications, skills and competencies of staff as they evolve through training, certifications and work assignments.

The module is based on a 'qualifications catalogue' that is first populated with a variety of Level 4 skills and then assigned to either jobs or persons.

The prototype has confirmed that SAP's HRMS is compatible with and can fully implement both the ESA Generic and Technical Competency Models. It has also shown the potential to support career development, succession planning and job matching in the future.

Concept verification with end-users
Once the software prototype was completed, it was time to test the results with potential end-users. The natural choice was to involve the Directorate of Technical & Quality Management (D/TEC), where the management of skills and competencies required to support projects is part of its day-to-day mandate. D/TEC was also heavily involved in using the Competency Dictionary, with 56 competencies. Identified at division and section level, these competencies can be mapped to the Level 2 and Level 3 competencies of the Technical Competency Model.

Three D/TEC divisions participated in the verification: the Data Systems Division, the Propulsion and Aerothermodynamics Division, and the Test Centre Division. Each identified a maximum of 10 posts that could be mapped on to the Technical Competency List, and identified a maximum of 14 technical and non-technical competencies per post. At the end of the exercise, 14 new posts were finally populated into SAP's HRMS.

The divisions also provided feedback on the accuracy of the competency list and recommended improvements. They also provided feedback and suggested improvements for the methodology used.

Lessons Learned and Conclusions

The pilot project provided the HR divisions with important feedback and a number of lessons-learned in the four areas outlined below.

Incremental development
One of the most important factors was deciding on the most effective way to identify Level 4 competencies. Two solutions were identified. The first was to ask managers to identify the Level 4 competencies required for each of the posts in their team in one exercise. In this way, the model is populated quickly, although it can be rather time-consuming. The second option was to identify the competencies incrementally, by identifying competencies for a post as Vacancy Notices are published or when terms of reference are updated. This second option was chosen. A new layout for Vacancy Notices is under development, to encourage managers to think more about competencies and qualifications rather than simply on tasks and duties.

Consistency of the top-down approach
In order to collect the data for the whole Agency efficiently, it is essential to have a pre-defined Level 3 competence list. The process of developing this list for the other Directorates is necessary prior to collecting any data. It is important to consolidate, review and update the list regularly to ensure its accuracy. The relevant manager should be responsible for identifying the competencies in their domains of expertise. Level 4 competencies should be held to a manageable number to keep the model simple. As a guideline, 7-10 technical and 4-6 behavioural competencies should be associated with each (Level 3) post.

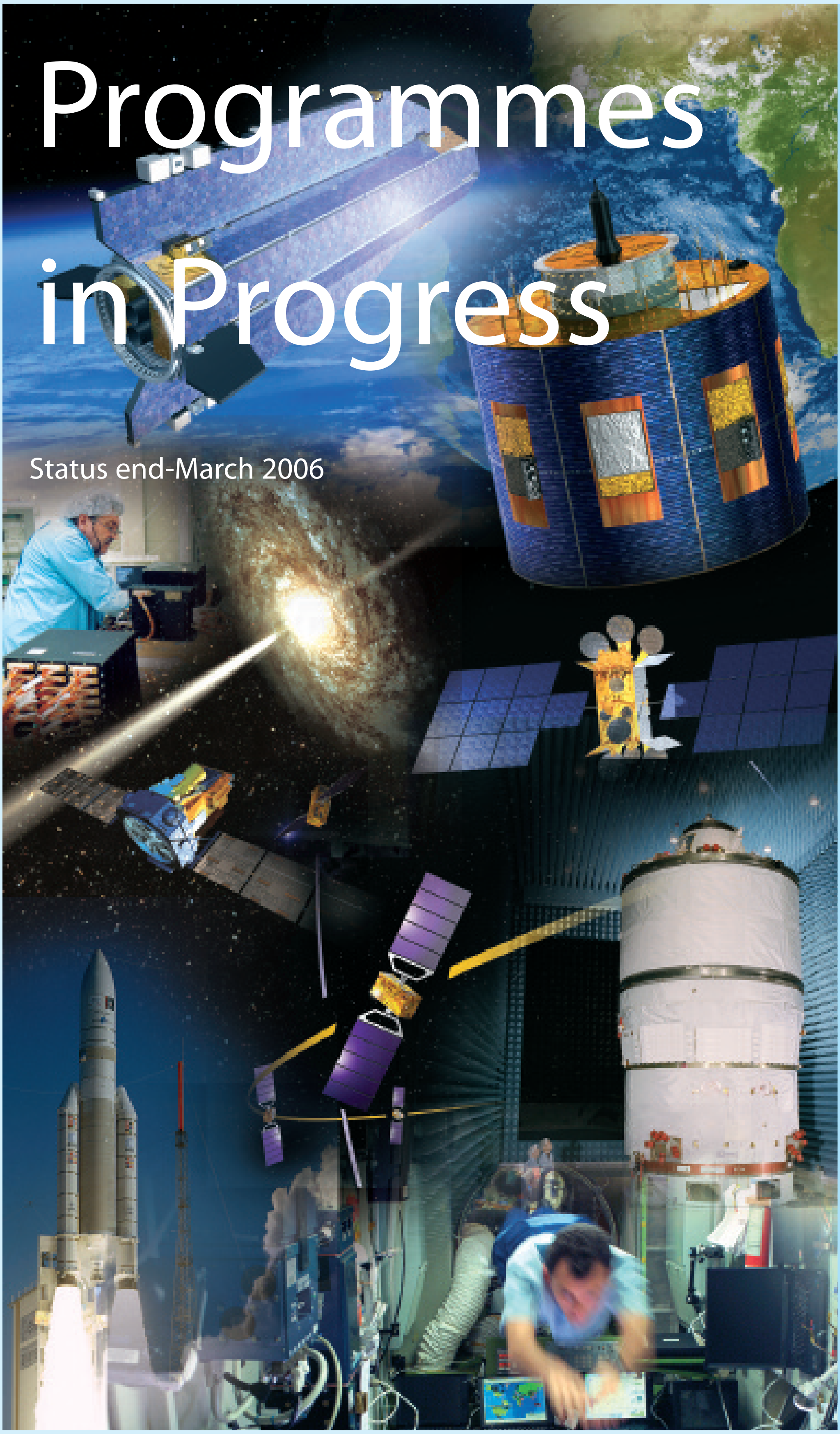
Processes
Another important issue was the manner in which the competency model should be used. Competencies can be linked to posts and/or persons and are often independent of each other. Competencies linked to a post are those required to perform the job and do not change dramatically until the post requirements change. A person's competencies, on the other hand, are those skills and abilities obtained over time; they can either improve with experience and training or diminish if not maintained. Post competencies are of a different nature to those of people and therefore have to be identified and maintained by different processes.

Currently, Level 3 and Level 4 competencies are being identified only for posts. As a result, the primary use of the competency model will be for recruitment, and specifically for the creation of Vacancy Notices. Eventually, when competencies are identified for a person, Level 4 competencies could also be used to support other processes, such as gap analysis, workforce planning and career development. Post competencies, however, must first be defined so that they can be presented to staff as a pre-defined model to be used to create individual competency profiles.

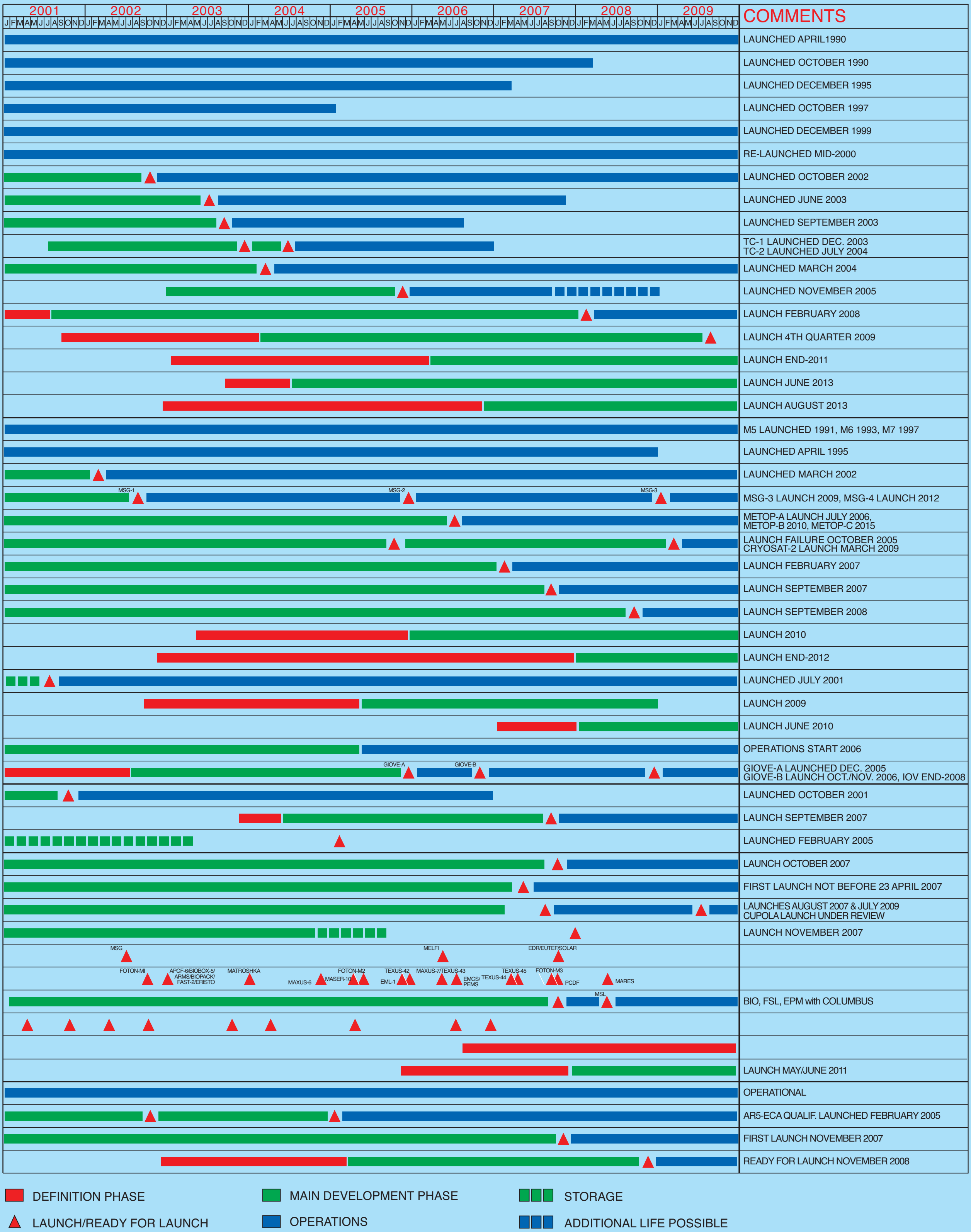
Communication
The benefits that Competency-Based Management can bring to our organisation are numerous. The challenge ahead is to develop the model further and to communicate and promote the benefits within the Agency to staff and managers alike.

Programmes in Progress

Status end-March 2006



	PROJECT
SCIENTIFIC PROGRAMME	SPACE TELESCOPE
	ULYSSES
	SOHO
	HUYGENS
	XMM-NEWTON
	CLUSTER
	INTEGRAL
	MARS EXPRESS
	SMART-1
	DOUBLE STAR
	ROSETTA
	VENUS EXPRESS
	HERSCHEL/PLANCK
	LISA PATHFINDER
	GAIA
	JWST
	BEPICOLOMBO
EARTH OBSERVATION PROGRAMME	METEOSAT-5/6/7
	ERS-2
	ENVISAT
	MSG
	METOP
	CRYOSAT
	GOCE
	SMOS
	ADM-AEOLUS
	SWARM
	EARTHCARE
COMMS./NAV. PROGRAMME	ARTEMIS
	ALPHABUS
	SMALL GEO SAT.
	GNSS-1/EGNOS
	GALILEOSAT
TECHNOL. PROG.	PROBA-1
	PROBA-2
	SLOSHSAT
HUMAN SPACEFLIGHT, MICROGRAVITY & EXPLORATION PROGRAMME	COLUMBUS
	ATV
	NODE-2 & -3 & CUPOLA
	ERA
	ISS SUPPORT & UTIL.
	EMIR/ELIPS
	MFC
	ASTRONAUT FLT.
	AURORA CORE
	EXOMARS
LAUNCHER PROG.	ARIANE-5 DEVELOP.
	ARIANE-5 PLUS
	VEGA
	SOYUZ AT CSG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COMMENTS
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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 AUGUST 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-A LAUNCH JULY 2006,
METOP-B 2010, METOP-C 2015
LAUNCH FAILURE OCTOBER 2005
CRYOSAT-2 LAUNCH MARCH 2009
LAUNCH FEBRUARY 2007
LAUNCH SEPTEMBER 2007
LAUNCH SEPTEMBER 2008
LAUNCH 2010
LAUNCH END-2012
LAUNCHED JULY 2001
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LAUNCH JUNE 2010
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GIOVE-A LAUNCHED DEC. 2005
GIOVE-B LAUNCH OCT./NOV. 2006, IOV END-2008
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LAUNCH SEPTEMBER 2007
LAUNCHED FEBRUARY 2005
LAUNCH OCTOBER 2007
FIRST LAUNCH NOT BEFORE 23 APRIL 2007
LAUNCHES AUGUST 2007 & JULY 2009
CUPOLA LAUNCH UNDER REVIEW
LAUNCH NOVEMBER 2007
MSG
MELFI
EDR/EUTEF/SOLAR
FOTON-M1
APCF-6/BIOBOX-5/
ARMS/BIOPACK/
FAST-2/ERISTO
MATROSHKA
MAXUS-6
FOTON-M2
MASER-10
EML-1
TEXUS-42
MAXUS-7/TEXUS-43
EMCS/
PEMS
TEXUS-44
TEXUS-45
FOTON-M3
PCDF
MARES
MSL
BIO, FSL, EPM with COLUMBUS
LAUNCH MAY/JUNE 2011
OPERATIONAL
AR5-ECA QUALIF. LAUNCHED FEBRUARY 2005
FIRST LAUNCH NOVEMBER 2007
READY FOR LAUNCH NOVEMBER 2008
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
STORAGE
LAUNCH/READY FOR LAUNCH
OPERATIONS
ADDITIONAL LIFE POSSIBLE

HST

The Hubble Space Telescope has produced images of dense knots of dust and gas in our Galaxy. This cosmic dust is a concentration of elements that are responsible for the formation of stars in our Galaxy and throughout the Universe. These opaque, dark knots of gas and dust are called 'Bok globules' after astronomer Bart Bok, who proposed their existence in the 1940s. They are absorbing light in the centre of the nearby emission nebula and star-forming region, NGC 281.

Bok hypothesised that giant molecular clouds, on the order of hundreds of light-years in size, can become perturbed and form small pockets where the dust and gas are highly concentrated. These small pockets become gravitationally bound and accumulate dust and gas from the surrounding area. If they capture enough mass, they have the potential to create stars in their cores. However, not all Bok globules will form stars; some will dissipate before they can collapse to form stars. That may be what is happening to the globules seen here in NGC 281.

Near the globules are bright blue stars, members of the young open cluster IC 1590. The cluster is made up of a few hundred stars. The cluster's core, off the image towards the top, is a tight grouping of extremely hot, massive stars with an immense stellar wind. The stars emit visible and UV light that energises the surrounding hydrogen gas in NGC 281. This gas then becomes superheated via ionisation; it glows pink in the image.

Bok globules in NGC 281

The Bok globules in NGC 281 are located very close to the centre of the IC 1590 cluster. The exquisite resolution of these Hubble observations shows the jagged structure of the dust clouds as if they are being stripped apart from the outside. The heavy fracturing of the globules may appear beautifully serene but is in fact evidence of the harsh, violent environment created by the nearby massive stars.

The Bok globules in NGC 281 are visually striking. They are silhouetted against the luminous pink hydrogen gas of the emission nebula, creating a stark visual contrast. The dust knots are opaque in visible light. Conversely, the nebulous gas surrounding the globules is transparent and allows light from background stars and even background galaxies to shine through.

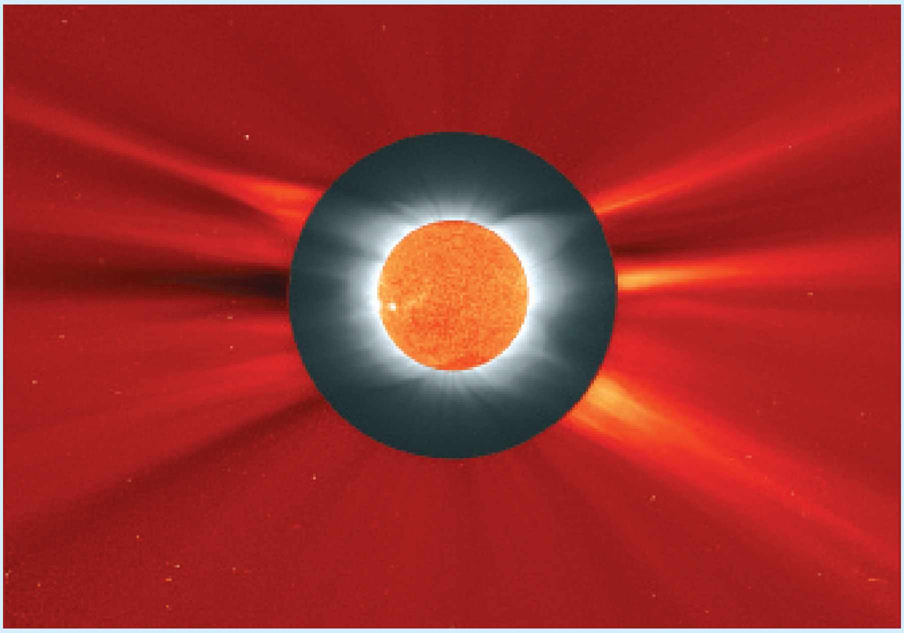
These images were taken with Hubble's Advanced Camera for Surveys in October 2005. The hydrogen-emission image that clearly shows the outline of the dark globules was combined with images taken in red, blue and green light in order to establish the true colour of the stars in the field. NGC 281 is located nearly 9500 light-years away in the direction of the constellation Cassiopeia.

Ulysses

The outcome of the NASA Sun-Solar System Connections 2005 Senior Review held on 14-15 November was positive for Ulysses. The panel recommended continuation of the mission until March 2008, as proposed. This is reflected in the NASA budget allocation for the project. All spacecraft subsystems are operating nominally.

All science operations during the reporting period have been nominal. The spacecraft team has performed a thorough review of the onboard power and thermal situation, taking particular account of recent experience when platform temperatures reached their lowest values during the mission to date. Based on this, it has been decided to modify the current payload power-sharing plan. As a result, instruments that are not part of the 'core payload' (and are presently turned off) will be switched on again for short periods this year, sooner than anticipated.

After a journey of 12.5 years and more than two complete orbits of the Sun, Ulysses is once again fully immersed in the fast solar wind from the coronal hole that covers the Sun's southern polar cap around solar minimum. This time around, the spacecraft had to climb higher in latitude, to almost 50°S, before leaving the slower, more variable wind behind. In mid-1993, the transition occurred nearer to 35°S. The explanation is related to the fact that the Sun's magnetic equator is still more highly inclined with respect to the rotational equator, even though the solar activity cycle is closer to its minimum, compared with the previous occasion. (At solar minimum, the Sun's rotational and magnetic axes are most closely aligned). Since the slower, more variable solar wind is mainly confined to the magnetic equator, this in turn means that, until recently, Ulysses continued to encounter slow wind once per solar rotation. Observations from the solar wind instrument on Ulysses over the past year showed regular excursions from slow (~400 km/s) to fast (~700 km/s) wind every rotation. At the start of the year, however, the speed profile began to show a systematic increase in the minimum speed encountered with each subsequent solar rotation, and since early March, the speed has remained high. Given the fickle behaviour of the Sun, with large outbursts of activity occurring relatively late in the declining phase of the present cycle, it will be interesting to see whether Ulysses remains in the fast wind until its trajectory brings it to lower latitudes again after traversing the southern pole in February 2007.



A composite of SOHO and ground-based images of the total solar eclipse of 29 March 2006

On 1 June 2006, Ulysses will be at a radial distance of 3.85 AU from the Sun, and heliographic latitude 50° south of the solar equator.

SOHO

With a unique view from the first Lagrangian point, outside the disturbing influence of Earth's atmosphere, SOHO's Large Angle Spectrometric Coronagraph (LASCO) produces its own eclipse all the time by simply blocking direct light from the solar disc. Other instruments onboard SOHO look directly at the Sun, with the same advantage of an uninterrupted view – there are no nights for SOHO, and the Moon never gets in the way.

So, when a total solar eclipse happens to be observable from Earth, SOHO is the primary source of information about what lies in wait for the eager observers in possibly remote locations. This was the case on 29 March 2006, when several eclipse expeditions went to Niger, Libya, Egypt, Greece and Turkey to catch the magic moment. Several groups collaborated with SOHO, requesting special observations that will be used for comparisons with the ground-based data.

The figure above is a composite of SOHO images and one taken at Kastellorizo, Greece, by the Williams College Eclipse Expedition. The central image from SOHO shows the Sun's disc at temperatures around 60 000–80 000K. The outer image from SOHO shows gas at a million degrees, typical of the Sun's corona. Combining the eclipse image with images from SOHO allows scientists to trace features in the corona from their bases on the Sun's surface up until the gas escapes into interplanetary space; some of this gas ends up hitting Earth's upper atmosphere.

XMM-Newton

XMM-Newton operations are continuing smoothly, with the spacecraft, instruments and ground segment all performing nominally. The completion status of the observing programme is:

– AO-3 programme: 99.7%
– AO-4 programme: 89.5% (A & B priority)
– AO-4 programme: 14.4% (C priority)

Completion of the above programmes is expected by April 2006, in line with the planned start of AO-5 observations. The Principal Investigators of AO-5 proposals have been informed of the Observation Time Allocation Committee decisions and observation of AO-5 targets will start on 1 May 2006.

A scientific workshop at ESAC (E) with the title *Variable and Broad Iron Lines around Black Holes* is planned by the XMM-Newton Science Operations Centre for 26–28 June 2006.

In January 2006, XMM-Newton celebrated its 1000th refereed paper with an ESA science and technology news release. In total, 1070 papers – either completely or partly based on XMM-Newton observations – had been published in the refereed literature. Of these, 286 were published in 2005; and 65 so far in 2006.

Cluster

The four spacecraft are in a tetrahedral configuration of 10 000 km to observe the polar cusp and the bow shock regions at large scales. All four spacecraft and instruments are operating nominally and the short eclipse season has just finished. Although a few anomalies have been observed due to the ageing of the batteries, it has been confirmed that the spacecraft can successfully endure short eclipses with minimum power from the batteries, which is providing experience for the coming long eclipses of September 2006.

JSOC and ESOC operations are continuing nominally. The data return from mid-November 2005 to mid-March 2006 was on average 99.5%. The Perth station has been used nominally since 1 January 2006, together with the Maspalomas station.

The Cluster Active Archive (CAA) opened as planned on 1 February 2006. A total of 136 users were registered at the end of February and more than 5 Gbytes of high-resolution data were downloaded. The CAA also delivers all raw data to the Cluster PIs and Co-Is; a total of 97 Gbytes was downloaded during the last four weeks.

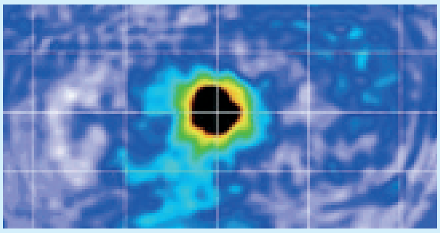
Fundamental 3-D properties of magnetic turbulence observed in the shocked solar wind were published in February 2006 in *Physical Review Letters*. These properties are of prime importance to model magnetic turbulence in the shocked solar wind, which plays a key role in the dynamical coupling between the solar wind and the magnetosphere. These results were obtained by combining the magnetic measurements on all four spacecraft using a method known as ‘k-filtering’. The magnetic turbulence is a fundamental process that also occurs in astrophysical and laboratory plasmas.

Integral

Cosmic space is filled with continuous, diffuse high-energy radiation. To find out how this energy is produced, the scientists behind the Integral gamma-ray observatory have tried an unusual method: observing the Earth from space. During a four-phase observation campaign lasting from 24 January to 9 February, Integral looked at Earth. Needing complex control operations from the ground, the satellite was kept in a fixed orientation in space, while waiting for the Earth to drift through its field of view.

Unusually, the main objective of these observations is not the Earth itself, but what can be seen in the background when the Earth moves in front of the satellite. This is the origin of the diffuse high-energy radiation known as the cosmic X-ray background. So far with Integral, this was never studied simultaneously with such a broad band of energy coverage since the 1970s, and certainly not with such advanced instruments. A preliminary analysis of the Integral results shows that the gamma-ray background intensity is about 20% higher than measured earlier.

Astronomers believe that the cosmic X-ray background is produced by numerous massive accreting black holes, distributed throughout deep space. Their powerful gravitational fields attract matter, which is then accelerated to high energies, thus producing the observed gamma- and X-rays.



The 25–50 keV image of the Earth obtained with Integral’s SPI spectrometer. The Earth stands out as a dark ‘hole’ in the middle of the image. (J.-P. Roques, CESR, Toulouse)

Mars Express

Final commissioning operations for the MARSIS instrument – primarily the commissioning and calibration of the monopole antenna – are being completed. Following these activities, the MARSIS radar will be fully operational.

Good progress is being made by ESOC and industry in identifying additional power margin required for the autumn 2006 eclipse season. The overall power budget for this period, however, still has a margin comparable to the known daily variation. More elaborate savings scenarios are being examined to create a better power margin.

Some problems in operating the ASPERA scanner and the PFS instrument are currently being investigated.

Science operations are proceeding well, albeit that the MARSIS commissioning operations placed a heavy burden on the Mars Express flight control team. Planning of future observations is progressing smoothly, although the limited power and ground station availability for the period currently being planned necessitates choosing between different kinds of science observations.

Further instrument data deliveries were recently made to the mission’s data archive, and a new level of HRSC data products (map projected data) has been added.

The dedicated Mars Express session (*Mars Express: Probing the Depths*) opening the 37th Lunar and Planetary Science Conference in Houston, Texas, USA on 13 March was a great success; attendance broke all records. Participation from the HRSC, OMEGA and MARSIS teams was higher than before. In particular, the MARSIS team is hard at work processing their data and interpreting the results. After initial analysis of the northern plains, where buried tectonic structures and impact craters were discovered, analysis is focusing on the southern polar cap, revealing a very fine layering and confirming the presence of pure water-ice layers (initially mapped by OMEGA). The penetration depth of the radar is well in excess of 5 km. The other instruments also continue to provide valuable science.

Double Star

The two spacecraft (TC-1 and TC-2) and the instruments are operating nominally. The Chinese proposed to extend the lifetime of TC-2 to end-2006, the same as the current lifetime of TC-1. This was due to the better-than-expected thermal behaviour of the spacecraft.

The European Payload Operation System (EPOS) coordinates the operations for the seven European instruments on TC-1 and TC-2, and is running smoothly. Data are acquired using the VILSPA 2 ground station and the Chinese stations in Shanghai and Beijing.

A study on surface waves in the magnetotail was published in the special issue of *Annales Geophysicae* on Double Star on 8 November 2005. The study used five spacecraft: Double Star TC-1 and the four Clusters. Cluster demonstrated that they were surface waves and fully characterised them, while Double Star, 30 000 km away, showed that these waves extended over a large region of the magnetotail.

ISO

The ISO Active Archive Phase activities continue with a new release of the ISO Data Archive, featuring automatic querying facilities to other archives, interoperability with the XMM-Newton and Integral archives and Virtual Observatory tools. Two new Highly Processed Data Sets have been ingested as default products. A first version of the ISO Astrophysical Spectroscopic Database has been released. It contains extensive information gathered from the literature for a number of spectral lines.

ISO continues to have a significant presence in the literature, with over 1330 refereed papers published to date. Recent highlights include the discovery of two very cold and massive molecular cloud cores suggested to represent initial conditions for the formation of monstrous stars, shining 100 000 times more brightly than the Sun. This result, based on the 170-micron ISOPHOT Serendipity Survey (ISOSS) was obtained from follow-up sub-mm continuum and molecular line measurement. The first core is at 16.5K and contains 75 times the mass of the Sun and shows signs of gravitational collapse. The second one is around 12K and contains 280 solar masses. The conditions necessary to form high-mass stars are difficult to deduce because such stellar monsters form far away and are shrouded behind curtains of dust. Only long wavelengths of infrared radiation can escape from these obscuring cocoons and reveal the low-temperature dust cores that mark the sites of star formation. The discovery allows astronomers to begin investigating why only some regions of space promote the growth of these massive stars.

Akari (Astro-F)

ESA contributes to the JAXA Astro-F infrared sky survey mission via provision of tracking support and assistance with the survey data reduction, in return for 10% of the observing opportunities during the non-survey and post-helium parts of the mission, to be made available to European astronomers via a Call for Proposals.

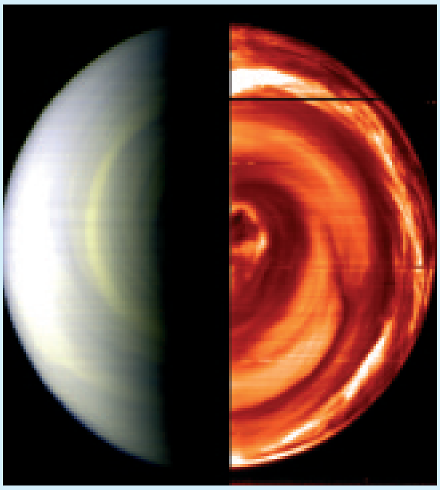
The launch of Akari (JAXA)

Astro-F was successfully launched on 21 February 2006 at 21:28 UT from the Uchinoura Space Centre by JAXA's M-V-8 rocket and renamed Akari ('red faint light'). The ESA Kiruna antenna has successfully tracked Akari for a number of passes. The telescope aperture lid was ejected on 13 April and the satellite declared ready for observations. The pointing reconstruction software, developed at ESAC, was used in an initial calibration of the spacecraft attitude.

The European Call for Observing Proposals was released by ESAC on 20 September 2005 and resulted in 50 proposals from 42 different Principal Investigators from 32 institutes in nine European countries plus ESO and ESA. The oversubscription factor was 7. The proposals were peer-reviewed by an ESA appointed Time Allocation Committee in December and merged with those resulting from the parallel Japanese call (48 proposals) in January.

Venus Express

The Venus Express spacecraft performed all of its cruise phase tests flawlessly, as well as the critical Venus Orbit Insertion. It successfully entered orbit around the target planet on 11 April 2006 and performed initial observations with the instruments while in the highly eccentric capture orbit. The capture orbit had a period of about 9 days, which took the spacecraft out to an apocentre altitude of the order 350 000 km. This was an ideal opportunity for the instruments to view the full Venus disc over a wide range of altitudes before settling into the 24-hour operational orbit expected to be reached by 7 May.

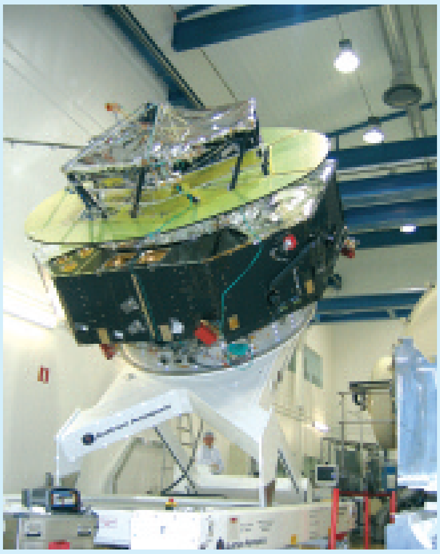


The dark vortex seen over the south pole of Venus by the Visible & Infrared Thermal Imaging Spectrometer (VIRTIS) of Venus Express from a distance of more than 200 000 km the day after Venus Orbit Insertion

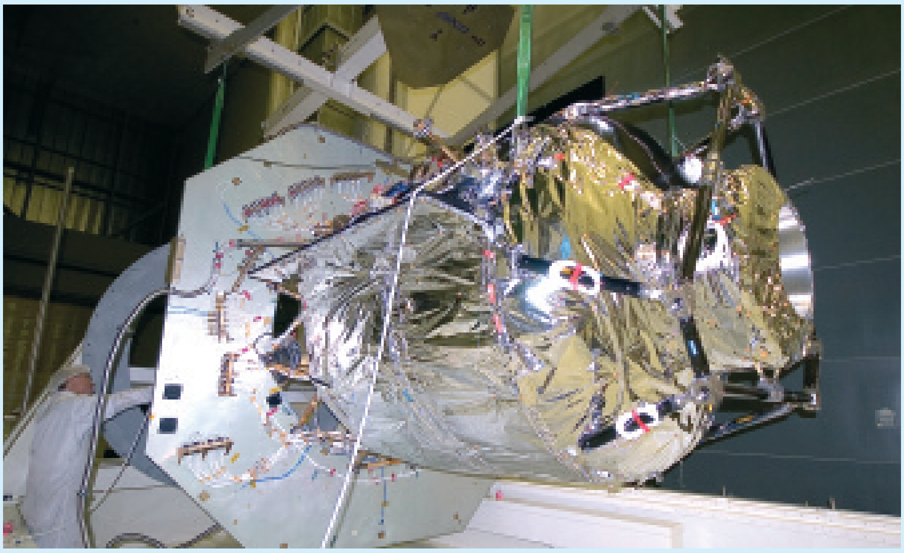
To reach its final orbit, the spacecraft has to perform a series of manoeuvres to reduce its apocentre altitude down to the desired operational orbit of about 66 000 km, and its pericentre down to 250 km. It requires two additional main engine firings and a number of finer adjustments using the reaction control thrusters. Once the operational orbit is achieved, the final parts of the instrument commissioning will take place, leading to routine science operations status in June.

Herschel/Planck

Major progress has been made in the satellite development programmes at industry in the past months. For Herschel, the satellite-level mechanical testing with the cryostat at launch conditions, i.e. filled with liquid helium, has been completed successfully. The satellite has been demated



The Planck flight model (without its top payload) ready for transport to CSL and cryogenic testing



The Herschel cryostat during loading into its satellite transport container, in preparation for a complicated 5-day transport through Europe back to Friedrichshafen (D)

and the cryostat returned to Astrium. The cryostat will be warmed up and opened for refurbishment. A further cryogenic test has been included in the flight model test sequence to validate the success of these activities. This will include the use of the SPIRE and HIFI instrument qualification model units.

The flight model of the Planck spacecraft has completed the first thermal vacuum test of the flight satellite at CSL in Liège (B). This included the operational testing of one of the two flight models of the hydrogen sorption coolers as well as the overall thermal testing of the Planck Service Module.

The flight model integration of the Herschel Service Module has been completed and the module acceptance testing is ongoing.

The acceptance testing of the scientific instrument flight model units continue at full swing, with a delivery to satellite integration later this year. Necessary actions have been put in place to stabilise the instrument deliveries. The instrument flight model deliveries and the optimised test sequences of the spacecraft flight models lead to the launch date of end-February 2008.

The final cryogenic optical testing of the Herschel telescope is close to completion and the telescope can be delivered to the satellite integration planned later this year.

On Planck, the flight model reflectors have completed their optical verification programme and are to be integrated with the telescope structure, with the final cryo-optical test coming up.

LISA Pathfinder

The SMART-2/LISA Pathfinder Implementation Phase contract is well in progress, with all activities proceeding according to schedule. The main system activity in the reporting period has been the preparation and the successful accomplishment of the Mission System Preliminary Design Review, whose Board met in February 2006.

In parallel, Industry and ESA have prepared and issued the majority of the Invitations to Tender for the spacecraft subsystems and equipment. At the time of writing, 22 ITTs have already been issued. Thirteen subsystem/equipment have been selected. Eight proposals are at various stages of evaluation. The remaining two ITTs will be issued as required during 2006. The proposal for the procurement of the micropropulsion subsystem, which requires a parallel phase 1 development of the two candidate technologies, is under evaluation and will be kicked-off in mid-May 2006. The spacecraft schedule has been continuously reworked to take into account the LISA Technology Package (LTP) delivery dates and the incurred delays in the micropropulsion development.

For the LTP, the subsystem PDRs have raised important technological and programmatic issues, which have been discussed with the parties concerned. Some have entailed extra cost. However, good progress is being made, despite the many technical challenges. Some subsystems are particularly critical, e.g. the inertial sensor vacuum enclosure, the electro-static suspension front-end electronics and the caging mechanism. The project is aware that the activities leading to a timely delivery of the LTP remain very challenging and require the full commitment of all parties involved.

The NASA-descoped Disturbance Reduction System (DRS) contribution to the LISA Pathfinder mission was analysed, reviewed and confirmed in an ESA-NASA review in mid-January 2006; the review was declared successful. The detailed implementation of the new configuration is ongoing.

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

Microscope

The Microscope spacecraft Preliminary Design Review at CNES has been concluded. The project has reached a satisfactory level of maturity after Phase-B. However, there are two main concerns before starting Phase-C: one related to the electric propulsion system (discussed below), and the other to the ONERA accelerometer, which is on the critical path of the schedule.

CNES has been informed of the reorganisation of the Field Emission Electric Propulsion (FEEP) activities in coordination with LISA Pathfinder and in particular of the parallel phase 1 in LISA Pathfinder with both FEEP technologies. CNES will evaluate in the coming months if Microscope can also be made compatible with the alternative FEEP technology (lower thrust delivered and more power needed).

The Alta FEEP development activities will be carried out within the LISA Pathfinder parallel phase 1. The decision concerning the continuation of the Microscope FEEP development activities will be taken at the end of this phase 1.

Gaia

Following approval of the contract proposal for the implementation phase of Gaia by the Industrial Policy Committee in late January and approval of the overall project cost by the Science Programme Committe in February 2006, the project held a kick-off meeting with Astrium SAS, Toulouse, on 17 February. The big challenge ahead is now to place 78 subcontracts competitively within about a year from contract signature. The related process is already planned in detail and the first four Invitations to Tender have been released on time.

Some of the technology activities are still ongoing and constitute a good source of lessons learned for the flight model productions. As requested by the scientific community, the project is actively pursuing the option of implementing L3CCDs in the Radial Velocity Spectrometer instrument. A technical and financial proposal is expected from the single-source supplier in order to place the required technology development activity.

Meetings of the Gaia Science Team take place at regular intervals. During their last meeting, on 20/21 February, the newly selected Prime Contractor presented for the first time the detailed design of the spacecraft.

JWST

NASA has successfully completed the System Definition Review (SDR), which is typically held midway between the System Requirement Review and the Preliminary Design Review (PDR). The SDR demonstrated a solid system design and that all the critical developments are well advanced in terms of design and verification approach.

Specific system-level problems related to stray light suppression and long-term stability of the main telescope are under resolution with involvement of ESA.

NASA budget allocation for 2006 and budget request for 2007 for JWST are in line with a launch date of mid-2013. The JWST Memorandum of Understanding (MoU) is in the final review cycle between ESA and NASA HQs.

NIRSpec has successfully passed the instrument-level PDR. The subassembly PDR campaign has been started with all the involved subcontractors. Two more subcontracts have been placed: the Calibration Assembly and the Mechanical Ground Support Equipment. The remaining nine procurements are under preparation. The manufacturing of the first ceramics mirrors is ongoing.

The MIRI subsystem Critical Design Review (CDR) campaign is ongoing with seven reviews completed and seven still to go. This leads to the instrument-level CDR in September, giving sufficient time to clarify the issues and concerns raised at the lower level CDRs. Parts and subassemblies for the instrument Verification Model are under manufacturing and testing. The need for design improvements has been identified in a few cases.

BepiColombo

BepiColombo is an interdisciplinary mission to the planet Mercury selected as the fifth cornerstone in the Cosmic Vision programme. Owing to the high scientific potential related to the planet and its environment, the mission will open a new frontier in the study of the Solar System. BepiColombo is a collaboration between ESA and the Japan Aerospace Exploration Agency (JAXA). It consists of two scientific orbiters: the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO), which will study the origin and evolution of the planet, Mercury's interior dynamics and the origin of the magnetic field. The launch configuration consists of a stack of the two spacecraft and the chemical and electrical propulsion modules.

The consolidated BepiColombo mission scenario foresees a Soyuz-Fregat launch in August 2013 and arrival at Mercury in August 2019 for a nominal 1-year scientific mission. The 6-year cruise phase is achieved with a combination of 6 flybys (Moon, Earth, 2 Venus, 2 Mercury) and electric propulsion. The spacecraft design employs lightweight technologies and materials that are compatible with the aggressive thermal environment at Mercury.

ESA is responsible for the overall project, including the mission design, the MPO, the electrical and chemical propulsion modules, the launch, the cruise operations up to delivery of the two spacecraft in their respective Mercury orbits, and the MPO mission and science operations. JAXA is responsible for the procurement of the MMO and for its mission and science operation at

Mercury. The mission definition has been completed and the scientific payload of both spacecrafts has been selected.

Following confirmation of the mission by the SPC in early February 2006, the Invitation To Tender for the Implementation Phase of BepiColombo was issued by the Agency on 15 February 2006. The proposals from Industry are expected by 17 May 2006. After this date, the Tender Evaluation Board, supported by expert panels, will perform a detailed assessment of the proposals. The recommendations of the Tender Evaluation Board will then be submitted to ESA's advisory structure for final approval.

LISA

The LISA Mission Formulation Study led by Astrium GmbH and started in January 2005 is producing very good results. Many system- and payload-level trade-offs have been completed and the overall mission design was consolidated in the Mission Architecture Review (MAR) in October 2005. Since then, the detailed design of the payload and of the rest of the system has progressed, especially in the areas of the scientific performances assessment, of the Interferometric Metrology System and of the Disturbance Reduction System design. In April 2006, the Mid-Term Review will take place: the coherence of the system design performed since the MAR will be checked before entering the phase of the subsystems requirements definition.

The cooperation with NASA is progressing well. The management tools established to ensure design coordination – the Technical Interchange Meetings and the Quarterly Progress Meetings – and the effort spent in coordinating the activities are effective. All the architecture design elements firmed up so far, such as strap-down, arm locking, end-to-end data flow and optical architecture, have been agreed by the two agencies to be part of the new baseline architecture design.

A joint technology plan has been finalised between ESA and NASA. This ensures that, even with the limited resources available, all the critical technologies needed for a successful LISA design will be covered either by NASA or ESA.

GOCE

Work is continuing to integrate, test and finally accept the flight models (FMs) of the Accelerometer Sensor Heads (ASHs) for the Gradiometer instrument. Significant effort continues to be made at all levels to recover from the technical setbacks encountered during the initial phases of the ASH acceptance testing. The second part of the functional testing involving the FM Gradiometer Accelerometer Interface Electronics Unit, three Front-End Electronic Units and the Gradiometer Thermal Control Unit is progressing nominally.

The integration of the Proto-Flight Model of the Platform is nearly complete. Following the integration of the ion propulsion electronics, the remaining units to be integrated are only the ion thrusters and the associated xenon gas-feed system. Functional closed-loop testing of the Drag-Free and Attitude Control System is continuing on the Platform Engineering Model Test Bench.

The Flight Operations Segment development activities have continued nominally at ESOC. In particular, a System Validation Test has been conducted, where the telemetry and telecommand interfaces with the satellite have been tested using the Platform Engineering Model Test Bench. Work is also progressing nominally on the Payload Data Segment side. Version 2 of the system is under final coding and testing, and will be installed in ESRIN before summer. System tests of the ground segment elements located in ESRIN are also progressing according to schedule.

SMOS

Delivery of subsystem units for the payload protoflight model continues. All LICEF receivers have been delivered, and are being used to populate the arm segments of the structural model to undergo the 'on farm' antenna pattern characterisation at the antenna measurement facility of the Technical University of Denmark. All three arm measurements have been successfully completed; still to be measured is the central hub structure with one adjacent segment of each arm. Once all the antenna characterisation activities are completed, the LICEF receivers will be transferred to the flight model arm segments that are under integration with electrical, RF and optical harness, thermal control hardware, and other subsystems such as the noise sources of the calibration subsystem.

Integration of the SMOS protoflight model arm at EADS Casa Espacio

Platform integration of the recurrent Proteus platform has progressed significantly at the Alcatel Alenia Space, Cannes (F) facilities. It is now interrupted owing to the resumption of the Calypso launch campaign.

Rockot launcher interfaces have been reviewed in the Preliminary Mission Analysis Meeting involving ESA, CNES, Alcatel, Eurockot and Khrunichev. The final Board Meeting for this review is scheduled for second half of April.

For the overall SMOS Ground Segment, the Preliminary Design Review has been completed. While the elements of the flight operations ground segment, both on the CNES and the ESA side, were found to be in an adequate development state, the payload data ground segment, including the data processors for level-1 and -2 data products, were judged to be rather schedule-critical. Backup solutions were suggested by the Board for investigation and eventual implementation by the project.

The building refurbishment and preparations for the X-band receive antenna are progressing nominally for installing the ESA-part of the ground segment at ESAC (E).

ADM-Aeolus

The Flight Model (FM) propulsion system, including tanks and pipework, has been fitted to the FM Platform at EADS-Astrium, Stevenage (UK). A version of the flight software that includes all the data-handling functions is working on the Real-time Test Bed in EADS Astrium, Friedrichshafen (D). This allows the Electrical Ground Support Equipment (EGSE) to be used to send commands to the software, to execute them on the onboard computer, and to observe the result on the EGSE. Operationally, the satellite therefore now exists.

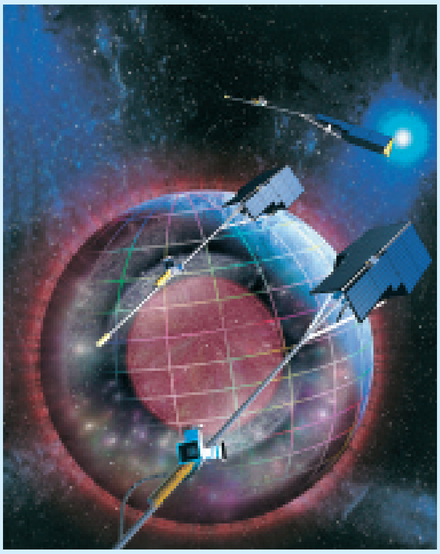
The coatings of the FM mirrors are excellent. They have been delivered to EADS Astrium, Toulouse (F) where they are being assembled with the FM Structure. The first step is to assemble the telescope.

There have been some difficulties preparing the Qualification Model of the laser for testing. Some minor design improvements have been identified as a result. The first 2 weeks of vacuum testing have therefore been somewhat postponed.

Launch of the satellite remains scheduled for September 2008.

Swarm

Swarm is the fifth ESA Earth Explorer Mission. The Swarm concept involves placing a constellation of three satellites in three different near-polar orbits at altitudes of 450 km to 530 km to provide high-precision and high-resolution measurements of



Artist's impression of the Swarm satellite constellation (EADS Astrium)

strength and direction of Earth's magnetic field.

Phase-B of the satellite activities with EADS Astrium, Friedrichshafen (D) is under way, with a consolidation at system level of the Phase-A trade-off, satellite conceptual design and performances. This consolidation takes into account the new elements to be considered since the completion of Phase-A. In particular, a new orbit scenario, instruments in a pre-development phase with performances and interfaces under definition, breadboard results and satellite-to-launcher interfaces are being closely examined and consolidated.

Phase-B1 of the Electrical Field Instrument (C-EFI) is completed. A preliminary instrument concept and design has been defined based on the heritage from sounding rocket instruments (GEODESIC). Following the successful Phase-B1 final meeting, Phase-B2 has been kicked off with Comdev (CND) as prime for this instrument, associated with the University of Calgary for the SII, the University of Uppsala (S) for the Langmuir probe and CAEN (I) for the high-voltage power supply.

The Absolute Scalar Magnetometer (ASM) Phase-B is under way with LETI, Grenoble under the leadership of CNES. A qualification programme is ongoing on two technologies: the optical bench for the laser and a piezo-electric motor for the polariser of the magnetic probe.

The Preliminary Design Review is planned in January 2007.

MetOp

The MetOp launch campaign at the Baikonur Cosmodrome started on 11 April 2006 with the arrival of the first of the three Antonov-124 transportation aircraft carrying the extensive MetOp equipment. The Satellite Payload and Service modules (PLM and SVM) arrived a week later with the second Antonov plane on 18 April; after a 5-hour train transfer, the satellite was transported safely into the MIK 112 integration area.

During the period preceding the launch campaign, the activities at EADS Astrium, Toulouse (F) concentrated on the reactivation of the satellite following a 6-month storage period, the closure of some open anomalies and the demonstration of the flight-worthiness of the thruster flow-control valves. During the final testing, a problem with the NOAA AMSU-A1 instrument necessitated its replacement just before the departure of the satellite.

In parallel, the first part of the (Eumetsat) Launch and Operations Readiness Review (LORR) was held in mid-February, followed by a successful satellite system verification test in March. The second part of the LORR confirmed a launch date of 17 July, with the delay from the nominal 30 June launch date being mainly due to ground segment readiness issues.

The Qualification Process for the new elements of the Soyuz-ST/Fregat launch vehicle is continuing as planned. The activities necessary to validate the modified launcher infrastructure at the Cosmodrome have been successfully performed in February by a dry-run, with the launcher and its extended ST fairing being rolled out and erected at the launch tower, during a period with extremely low


Unloading MetOp-A from the Antonov


MetOp-A on the train from Yubileiny Airport to the Baikonur Cosmodrome

temperatures ranging between –25°C and –38°C. The pre-shipment of the Fregat was successfully performed at NPO-L in March.

System and operations activities are intensifying, shared between ESOC for Launch & Early Orbit Operations (LEOP) and Eumetsat for Satellite In-Orbit Verification (SIOV) and routine operations preparation. ESOC is close to delivering the last flight control procedures, and the ESOC Ground Segment development is progressing on schedule. Rehearsals for LEOP and SIOV will take place during the last 3 months before launch, with the goal of training the operations and project support teams.

Two major Satellite System Validation Tests (SSVTs) have been successfully performed in March. These tests have fully validated critical operations procedures, and give good confidence in the robustness of the respective Mission Control Systems.

MSG

MSG-1

After an anomaly on the SSPA in October 2002, it was decided, although the satellite was designed with a 4/3 SSPA redundancy, to end its use. With MSG-2 also in orbit, it was decided to activate the Data Collection Platform (DCP) link again through SSPA-D. This reactivation was successful and shows nominal performance. The instrument performance remains of excellent quality.

MSG-2

The MSG-2 spacecraft, successfully launched in December 2005, is undergoing its commissioning phase, which is planned to last until the end of June 2006. Performance of the main instrument, the SEVIRI imaging radiometer, is of similar high quality to that on MSG-1.

MSG-3

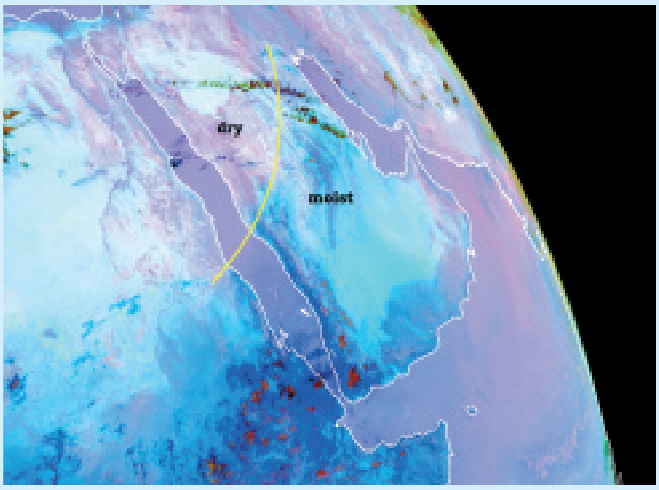
During this reporting period, some open work on MSG-3 has been performed. It is planned to put MSG-3 in long-term storage by the end of the year, awaiting its own launch, currently foreseen for early 2011.

MSG-4

The Mission Communication Package (MCP) platform has been delivered to Cannes (F) for system integration. The electrical integration on SEVIRI has been performed. The Unified Propulsion System (UPS) hardware has been integrated, and baffle and cooler covers have been installed. Preparation for the MSG-4 thermal vacuum test has started with the vacuum GSE preparation and thermocouple installation.

GIOVE

After its launch on 28 December 2005, followed by its platform commissioning, GIOVE-A began transmitting navigation signals on 12 January 2006. The quality of these first Galileo signals was then checked by several facilities, including the Navigation Laboratory at ESTEC (NL), the ESA ground



Composite red-green-blue images from MSG, besides monitoring dust storms and tracking thin, high-level clouds, can also be used to detect low-level moisture boundaries. This MSG-1/Meteosat-8 image shows a mostly cloud-free Arabian Peninsula; the southern part of the Peninsula appears with a strong blue colour while the northern part is a pale blue to cyan. The colour difference can be attributed mostly to an airmass/moisture boundary (yellow line) crossing the Peninsula from south-west to north-east (Eumetsat) station at Redu (B), and the Rutherford Appleton Laboratory Chilbolton Observatory (UK). GIOVE-A achieved the first goal of its mission: satisfying the licence for the frequencies allocated to Galileo by the International Telecommunication Union (ITU).

The conformity of the GIOVE-A signals to the Galileo system's design specification was demonstrated. The quality of the signals transmitted by GIOVE-A have an important influence on the accuracy of the positioning information that will be provided by the user receivers on the ground, so a detailed check of the signal was mandatory. The quality can be affected by the environment of the satellite in its orbit and by the propagation path of the signals travelling from space to ground. Additionally, the signals must not interfere with services operating in adjacent frequency bands; this is also being checked. Several measurements were performed on the transmitted signal power, centre frequency, bandwidth and the format of the navigation messages generated onboard. This allowed the analysis of the satellite transmissions in the three frequency bands that are reserved for it; it confimed that GIOVE-A is transmitting as designed.

The GIOVE-A mission also provides an opportunity for testing a key element of the future Galileo system: the user receivers. The first experimental Galileo receivers, manufactured by Septentrio (B), were installed at the Redu and Chilbolton In-Orbit Test Stations and at the Guildford (UK) premises of Surrey Satellite Technology Limited (SSTL), the manufacturer of the satellite and now in charge of its control in orbit.

The mission of GIOVE-A now is to check the new critical technologies designed for the Galileo system, such as the rubidium clock and signal generator.

The perfect results registered so far for GIOVE-A provide confidence that Galileo can offer the value-added services that fundamentally depend on the quality of the signals.

Human Spaceflight, Microgravity & Exploration

Highlights
Following a series of meetings involving the Space Station Control Board and the Multilateral Control Board, a Heads of Agency meeting took place at the Kennedy Space Center (KSC) on 2 March. The partners endorsed a revised ISS configuration and an assembly sequence for the ISS that includes 16 Shuttle flights as well as two Shuttle-equivalent flights for logistics. Columbus is advanced in the sequence to the 7th Shuttle flight which, with the current planning, could result in its launch, complete with its two external payloads and five payload rack facilities, in late 2007. The associated transportation strategy was also agreed, which includes the use of a combination of transportation systems provided by Europe, Japan, Russia and the US in order to complete ISS assembly and to ensure full utilisation of the ISS. Furthermore, the partners agreed to implement 6-person crew operations in 2009.

Following approval of amendments to the Iran Non-proliferation Act, which now allows NASA to procure goods and services from Russia for the ISS until 2012, NASA and Roskosmos have reached agreement on the transportation by the Russians of crew and some cargo, during 2006, and negotiations for future years' services are under way. NASA announced 1-19 July 2006 as the new launch planning window for Shuttle mission STS-121. The window gives the agency time to replace the External Tank fuel sensors and to perform additional engineering work and analysis to ensure a safe flight for *Discovery* and its crew, which will include ESA astronaut Thomas Reiter.

Space infrastructure development
Columbus activities are proceeding to plan. A final end-to-end system validation test involving the User Support and Operations Centres has been performed. The Final Acceptance Review (FAR1) is planned for April/May and shipment to KSC for end-May 2006. The module itself has achieved its Certificate of Qualification from ESA.

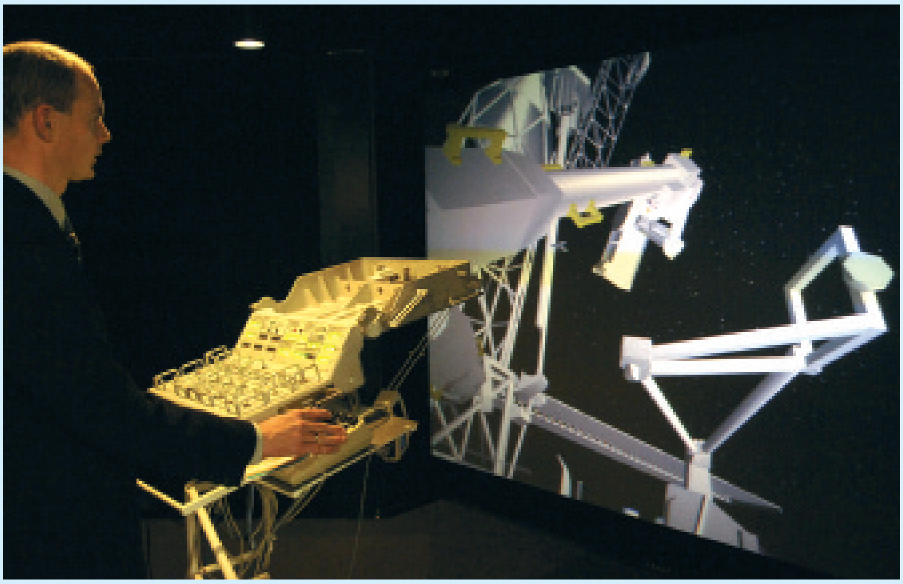
On ATV Jules Verne, hardware problems identified in summer 2005 have now been rectified. All latch valves have been refurbished and the new designs of the camera target and solar array drive have been requalified. The spacecraft is now being prepared for the acoustic test in May 2006 and subsequent thermal-vacuum and end-to-end control loop tests prior to being reviewed for readiness to ship to the Kourou launch site by the end of 2006. Significant progress has been made on the functional testing, with most hardware/software chains now successfully validated. The formal functional qualification testing is now scheduled from end-May to November 2006. Detailed technical discussions on the launch strategy are taking place with the launch authority, which should lead to a launch readiness in spring 2007.

The European Robotic Arm (ERA) Mission Preparation & Training Equipment was shipped to Russia in February, and activities are under way in preparation of the shipment of the ERA flight unit early this summer. Node-3 integration has been completed and initial testing activities have started.

ISS operations and related ground segments
Work on the Mission Operations Implementation Plan for Increment-13 and the Astrolab Long-Duration Mission has been carried out. ESA's human physiology research programme on the ISS is ongoing, with four experiments supported by the Russian Expedition-12 cosmonaut V. Tokarev. Additionally, a protein crystallisation experiment was performed using PromISS in the Microgravity Science Glovebox in the Destiny laboratory. The passive Matroshka (human phantom) radiation dosimeters have been installed in the Russian ISS segment and Phase-IIA of the experiment is under way.

The Columbus Control Centre (COL-CC) Qualification and Acceptance Review Part 2

ERA displayed during the media day at Dutch Space in Leiden (NL) on 5 April 2006



The ERA training simulator at ESTEC. Cosmonauts will be able to operate the arm from a console fixed to the end of one of ERA's limbs

(Q&AR#2) plan is being prepared. The System Validation Test (SVT) Post-Test Review, between the Columbus Flight Segment and COL-CC has been carried out and some open actions have been identified. The planning for SVTs 4.2 and 4.3 activities is under discussion.

An ATV Control Centre (ATV-CC) operations preparation and qualification schedule has been defined to be compatible with a Jules Verne launch in Spring 2007. In order to introduce robustness into the schedule, ESA and CNES will investigate introducing an extra Flight Control Team.

Utilisation planning, payload developments and preparatory missions

Preliminary results from the second WISE (Women's International Space Simulation for Exploration) bedrest study, which was completed at the end of November 2005, indicate that the tested countermeasures (exercise and nutritional countermeasures) had beneficial effects on the health of the volunteers. The scientific teams are now processing the raw data, and the first publications are expected in the second half of 2006.

An information day on ESA's proposal to use the ISS as a research infrastructure (the 'SURE' project), attracting some 60 participants, was held in Prague as part of a promotion campaign.

The 42nd parabolic flight campaign was performed mid-March and 13 experiments were carried out. The 43rd campaign was performed 2 weeks later and 14 experiments in physical sciences, life sciences and technology, as well as two student-proposed experiments, were performed.

New payload developments and refurbishment activities for Foton-M3 are under way; launch is planned for September 2007.

The –80°C Freezer (MELFI) and the European Modular Cultivation System (EMCS) have been reintegrated in the Multi-Purpose Logistics Module (MPLM) for launch on ULF-1.1; refurbishment has been accomplished. The Columbus payload rack facilities (Biolab, Fluid Science Laboratory, European Physiology Module, and European Drawer Rack including the Protein Crystallisation Diagnostics Facility) have concluded their integrated testing and end-to-end System Verification Testing (SVT-2) successfully. Open work on these facilities is continuing in Bremen, Germany, and is expected to be completed in April. The Portable Glove Box is needed for experiments in autumn 2006 and its preparation for Progress-22P is under way. The External Payloads (SOLAR and EuTEF) have also been successfully tested with Columbus and have been returned to the developers for final closeout activities before their separate shipment to KSC. Activities on the Atomic Clock Ensemble in Space (ACES) ground segment definition have started; the ACES Mission-PDR is now scheduled for September 2006.

ISS education

The Dutch Ministry of Education has offered to sponsor and widen the distribution of ISS Primary Education Kits to all 7500 primary schools in the Netherlands.

The opening ceremony of EuMAS (European Master in Aeronautics and Space) took place on 19 January; the programme is supported by the European Commission/Erasmus Mundus, and the Universities of Pisa, Toulouse SupAero, Munich, Madrid and Cranfield are participating.

The preparation of AstroLab Mission Education Experiments is under way. The Exploration Kit for Primary Schools project was started in March.

Commercial activities

The annual review of the Commercial Agent was completed with the review of the strategy plan for 2006. An agreement was reached on a more market-focused organisation for the Commercial Agent.

Various commercial proposals for the Astrolab Long-Duration Mission have been received and are being evaluated. The SURE Promotion campaign was performed in nine East European capitals, always with e xcellent support from local authorities. Each event was attended by 30-70 people. The campaign was mirrored by a stream of information via the Commercial Project Office website. A total of 37 notifications of interests were collected, including five from industry.

Preparation for participation in the Biosquare exhibition in Geneve (CH) is under way.

Astronaut activities
Thomas Reiter and his backup Leopold Eyharts are completing their training for the Astrolab Long-Duration Mission. They have trained at the Johnson Space Center (JSC) and at the Gagarin Cosmonaut Training Centre, accumulating 1600 hours on the US and Russian orbital segments, Soyuz and payloads. They will be at JSC for final training during the 6 weeks before launch on Shuttle mission STS-121/ULF-1.1.

Payload rack simulators for Biolab, the European Drawer Rack and the Fluid Science Laboratory have been delivered to the Euopean Astronaut Centre and are being integrated into the Columbus simulator.

Exploration
At the Ministerial Council in Berlin, in December 2005, subscriptions to the Aurora Space Exploration Programme were decided, amounting to €73.2 million for the Core Programme (2006-2009) and €650.8 million for the ExoMars mission (2006-2013); this latter amount exceeded the proposed envelope by almost 10%. The ongoing ExoMars Phase-B1 contract is being extended in scope and duration to accommodate the decisions taken at the Ministerial Council, in particular with respect to the study of mission configuration options and the conduct of an Implementation Review. A work plan for the Core Programme component of the Exploration Programme is being established; a series of discussions with participating states will be initiated in order to optimise activities.

Roskosmos has been informed that the Clipper programme has not yet been subscribed; the Russian agency has agreed to leave the possibility open for a few months for European participation in the programme. To avoid missing out on the opportunity to participate, a small internal ESA budget is being made available so that the Agency can work with the Russians until June 2006 to refine the proposal on Clipper so that Member States can take a positive decision on participation in the summer.

Soyuz at CSG

The complementary Preliminary Design Review for flight-safety took place in Guiana in February: the location of the 'launch centre' (CDL) has now been fixed.

Earthworks at the future Soyuz Launch Site have advanced at a rapid pace. This has translated to completion of works ahead of schedule; the only zone not completely finished at the end of March is 'zone 13', which represents the 'surrounding areas' around the 12 platforms.

Excavation of the flame chute (carneau) has proceeded as planned. The next step will involve explosives to penetrate the layer of granite that surfaced as a result of the 5 m-deep excavation, in early April.

On the contractual side, an open competitive tender for the industrial activities in the areas of fluids and low-currents has been issued. In addition, small contracts for modification of the launch base necessary for operating the Soyuz launcher from CSG were negotiated and finally signed with several European companies.

As far as the Industrial Design Reviews are concerned, the programme witnessed two major events: the Industrial Preliminary Design Review for the civil, electrical and mechanical installation that took place in Toulouse, and the Industrial Critical Design Review for the first lot of Russian equipment that took place in Moscow. A number of actions were launched to move to the next phase.

Finally, a management committee ('Consultative Committee') was assembled to look at the progress of the programme. ESA, CNES and Arianespace meet on a monthly basis, while Russian partners are invited on an *ad hoc* basis. Its aim is to identify and resolve any critical programmatic issue that goes beyond the normal programme and contractual thresholds.

Excavation of the flame chute for the Soyuz Launch Site

In Brief

Tributes

Former ESA Director General **Antonio Rodotà** passed away in Rome on 23 February, aged 70. The ESA Council appointed him as Director General in June 1997 and he served in this position until June 2003. Mr Rodotà was the Agency's first Director General to come directly from industry.

Antonio Rodotà, 1935–2006

Mr Rodotà's fervent advocacy of international cooperation was widely recognised and he will be remembered for fostering the European dimension of space activities and as one of the founding fathers of Galileo, Europe's satellite navigation system. He will also be remembered for his strong personality and charisma, and that he brought his long and valuable experience of working in industry to ESA. His key words for the Agency were: efficiency, competence and Europe.

After graduating from the University of Rome as an electronics engineer, Mr Rodotà began his career with Selenia (1966–1980), followed by three years as head of Compagnia Nazionale Satelliti. He moved on to Alenia Spazio in 1983, where he held a series of senior positions before becoming Chief Executive in 1995. Before taking over the reins at ESA, he was director of the Space Division of Finmeccanica and a member of the boards of several international companies, including Arianespace.

Mr Rodotà left a long list of significant accomplishments at ESA. He put space on the agenda at the highest level in Europe and led the basis for ESA's growing and ever-closer relationship with the European Union. He introduced a new human resources policy, and expanded the Agency with the accession of Portugal and by building partnerships with the countries of central and eastern Europe.

"*Antonio Rodotà led ESA into the 21st Century. I feel honoured to have had the opportunity to follow his path and to build on the foundations he laid for a renewed Europe in space*," said ESA's present Director General, Jean-Jacques Dordain.

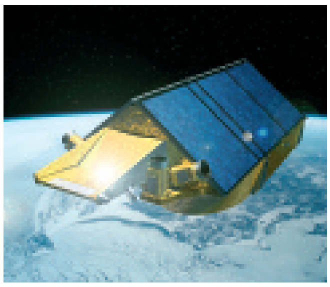
During his term of office, 14 ESA spacecraft were launched: Meteosat-7, Huygens (1997), ISO, ARD (1998), XMM-Newton (1999), Cluster (2000), Artemis (2001), Envisat, MSG-1, Integral (2002) and Mars Express (2003). There were 61 Ariane launches, and 13 European astronauts travelled into space. esa

Mr Adalbert W. Plattenteich, a former Director of Administration at ESA, passed away on 28 March 2006, aged 71. Mr Plattenteich served in ESA from December 1991 to January 1997. Before joining ESA, he was Vice-President of the Management Board at the Research Center in Juelich, Germany. After leaving ESA, he joined the German Ministry of Research and Technology. "*Thanks to his considerable knowledge and experience in the scientific domain, both at national and international level, he was very much appreciated by all his collaborators. Throughout his career, he was always attentive and open-minded towards his colleagues*," said Jean-Jacques Dordain, Director General. esa

CryoSat-2 Mission Confirmed

ESA's Earth Observation Programme Board received the green light from its Member States on 24 February to build and launch the CryoSat-2 recovery mission. The first CryoSat was lost on 8 October 2005 when its Russian Rockot launcher failed.

With a planned launch in March 2009, CryoSat-2 will have the same mission objectives as the original mission. It will monitor the thickness of land and sea ice and help to explain the connection between the melting of the polar ice and the rise in sea levels and how this is contributing to climate change. esa



CryoSat in orbit (ESA/P. Carril)

Romania Cooperation

Jean-Jacques Dordain (left), ESA Director General, and Marius-Ioan Piso, President and CEO of the Romanian Space Agency, signed the European Cooperating State Agreement in Bucharest, Romania

Romania became the third country to sign the European Cooperating State Agreement, on 17 February. Hungary was the first, in April 2003, followed by the Czech Republic in November 2003.

The agreement defines the basis for developing a Plan for European Cooperating State (PECS) Charter, describing the activities, projects and budget for Romania's cooperation with ESA. It is expected that the PECS Charter will be signed within 12 months.

Romania has a long aerospace tradition and has contributed to more than 30 space missions. During the 1970s and 1980s, it was an active member of Interkosmos, an international programme of Soviet-bloc countries. In 1992, Romania was one of the first eastern European countries to sign a space cooperation agreement with ESA, paving the way for its participation in several research projects with other European countries.

Romania is already involved in ESA's Cluster and Planck missions. Recently, the country joined the EC-funded SURE project (the International Space Station: a Unique Research Infrastructure). This project will provide research opportunities on the ISS, primarily for researchers and small- and medium-sized enterprises in eastern European countries.

Romania and ESA are now defining the specific areas and projects for cooperation, and the budget for the next 5 years. Major participation will be in ESA's Science programme and the ESA/EC Global Monitoring for Environment and Security (GMES) initiative. Participation in GMES will strengthen the country's use of Earth observation data for agricultural planning, crop forecasting and flood monitoring. esa

MetOp at Launch Site

The first MetOp meteorological satellite arrived at its launch site, the Baikonur Cosmodrome in Kazakhstan, on 18 April following shipment from the industrial prime contractor, EADS-Astrium in Toulouse (F). The launch is targeted for 17 July aboard the latest Soyuz-ST/Fregat launcher operated by Starsem.

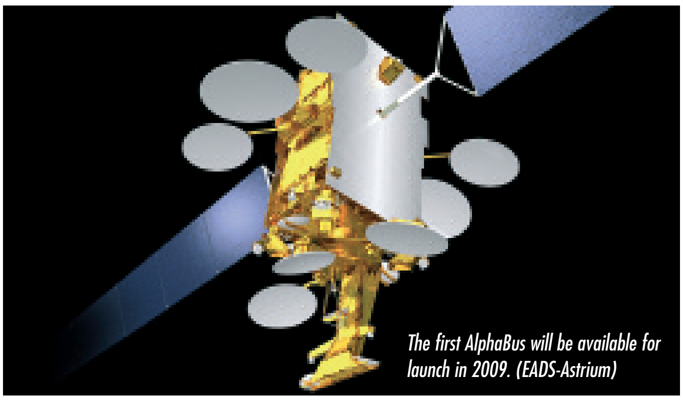
MetOp-A is the first in a series of three polar-orbiting satellites developed by ESA for Eumetsat. The mission includes a total of 12 instruments developed in cooperation with CNES and the US National Oceanic and Atmospheric Administration (NOAA). It is the first polar satellite dedicated to operational meteorology. Flying at a height of 837 km, it will provide data of unprecedented accuracy to improve global weather forecasting and climate monitoring. esa

MetOp-A undergoing final testing at EADS-Astrium in Toulouse

ESA/CNES AlphaBus Agreement

ESA and CNES signed a cooperation agreement on 15 March for the development of AlphaBus, Europe's next generation of telecommunication satellites. CNES will manage the development of this generic line of large platforms for geostationary telecommunication satellites, with ESA co-financing the development of the selected European equipment.

This agreement follows the signature of a contract in June 2005 between ESA, CNES, EADS-Astrium and Alcatel Alenia Space for the AlphaBus development programme and the production of the first flight model, to be ready in 2009. The platform offers a payload power consumption of 12–18 kW and a launch mass of 6–8 t, suitable for Ariane-5 ECA. esa



The first AlphaBus will be available for launch in 2009. (EADS-Astrium)

To celebrate the NASA/ESA Hubble Space Telescope's 16 years of success, the two agencies released this mosaic of the magnificent 'Cigar Galaxy', M82. It is the sharpest wide-angle view ever obtained of M82, a galaxy remarkable for its webs of shredded clouds and flame-like plumes of glowing hydrogen blasting out from its central regions, where stars are being born 10 times faster than in our own Galaxy. *(NASA, ESA, Hubble Heritage Team (STScI/AURA*))

Titan's Source of Methane

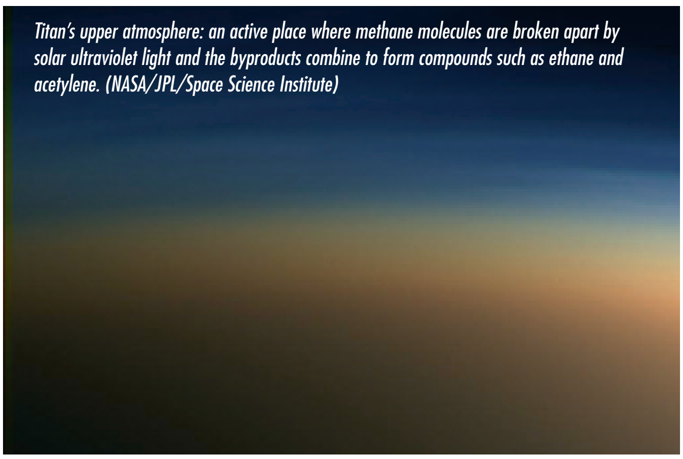
Data from ESA's Huygens probe have been used to validate a new model of the evolution of Titan, Saturn's largest moon. The model shows that Titan's methane supply may be locked away in methane-rich ice.

The presence of so much methane in Titan's atmosphere is one of the major enigmas that the NASA/ESA/ASI Cassini-Huygens mission is trying to solve. The mission showed that there is not a lot of liquid methane on the moon's surface, so it is not clear where the atmosphere's methane gas is coming from.

Using the Cassini-Huygens findings, a model of Titan's evolution focusing on the source of the atmospheric methane has been developed by scientists from the University of Nantes (F) and the University of Arizona in Tucson (USA). "*This model is in agreement with the observations made so far by both the Huygens probe that landed on 14 January 2005 and the remote sensing instruments aboard the Cassini spacecraft*", said Gabriel Tobie, of the Laboratoire de Planetologie et Geodynamique de Nantes.

There is a difference between volcanism on Earth and 'cryovolcanism' on Titan. Volcanoes on Titan would involve ice melting and ice degassing, which is analogous to silicate volcanism on Earth. Methane, playing a role similar to that of water on Earth, would have been released during several outgassing episodes, and may be stored on Titan in methane-rich ice. The scientists suggest that the ice – 'clathrate hydrate' – forms a crust above an ocean of liquid water mixed with ammonia.

"*As methane is broken down by light-induced chemical reactions over a timescale of tens of millions of years, it can't just be a remnant of the atmosphere present when Titan itself was formed, and it must be replenished quite regularly. According to our model, during the last outgassing episode, the dissociation of the methane clathrate and hence the release of methane are induced by thermal anomalies within the icy crust, which are generated by crystallisation in the internal ocean*," said Tobie. "*As this crystallisation started only relatively recently (500–1000 million years ago), we expect that the ammonia-water ocean is still present a few tens of kilometres below the surface and that methane outgassing is still operating. Even though the outgassing rate is expected to decline now (it peaked about 500 million years ago), the*



Titan's upper atmosphere: an active place where methane molecules are broken apart by solar ultraviolet light and the byproducts combine to form compounds such as ethane and acetylene. (NASA/JPL/Space Science Institute) *release of methane through cryovolcanic eruptions should still occur on Titan*," explained Tobie.

Parts of the crust might be warmed from time to time by cryovolcanic activity on the moon, causing it to release its methane into the atmosphere. These outbursts could produce temporary flows of liquid methane on the surface, accounting for the river-like features seen by Huygens.

Cassini's instruments, in particular its Visible and Infrared Mapping Spectrometer (VIMS), should detect an increasing number of cryovolcanic features and may eventually find eruptions of methane. If the researchers are right, then Cassini and future missions to Titan should also be able to detect a possible subsurface liquid water-ammonia ocean. Later in the mission, Cassini will make measurements that could confirm the presence of the internal water ocean, and also of a rocky core. esa

Infrared Survey

In a collaborative effort involving ESA and scientists across Europe, Japan's new astronomy satellite Akari ('light') will make an unprecedented study of the sky in infrared. Akari was successfully launched on 21 February from the Uchinoura Space Centre by the Japan Aerospace Exploration Agency. Prof. David Southwood, ESA's Director of Science, said, "*The successful launch is a big step. A decade ago, our Infrared Space Observatory opened up this field of astronomy, and the Japanese took part then. It is wonderful to be cooperating again with Japan in this discipline.*" esa

ISS Partners Agree on Assembly Plan

The heads of space agencies from Canada, Europe, Japan, Russia and the US met at the Kennedy Space Center, Florida, on 2 March to review International Space Station (ISS) cooperation and endorse a revision of the ISS configuration and assembly sequence.

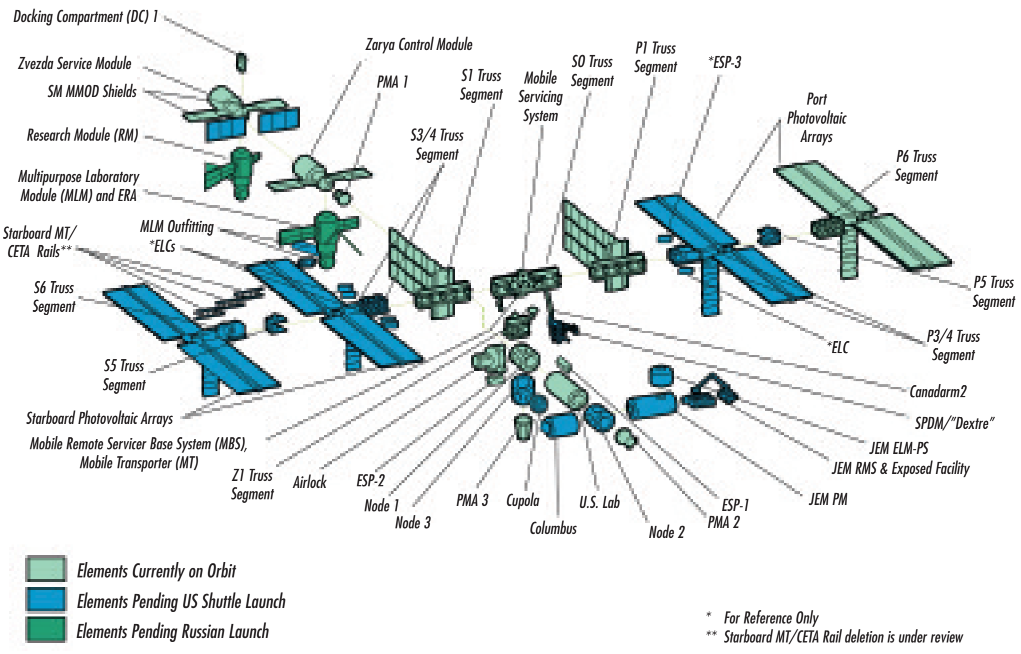
The partners reaffirmed their commitment to meeting their mutual obligations, to begin 6-person crew operations in 2009, and an adequate number of Shuttle flights to complete the assembly of ISS by the end of the decade.

The partners also affirmed their plans to use a combination of transportation systems provided by Europe, Japan, Russia and the US to complete ISS assembly on a timescale that meets the needs of the partners and ensures full use of the unique capabilities of the ISS throughout its lifetime.

ISS Assembly Sequence

Flight	*Vehicle*	*Main Payload (European Elements in* ***Blue****)*
ULF1.1	STS-121	**MPLM**
12A	STS-115	P3/P4 port truss; solar arrays
12A.1	STS-116	P5 port truss; Spacehab
13A	STS-117	S3/S4 starboard truss; solar arrays; radiator
13A.1	STS-118	S5 starboard truss; Spacehab
ATV-1	Ariane-5	**Automated Transfer Vehicle**
10A	STS-120	**Node-2**
1E	STS	**Columbus**
1J/A	STS	Kibo Logistics Module; Dextre Manipulator,
1J	STS	Kibo Experiment Module & Manipulator
15A	STS-119	S6 starboard truss; solar arrays
ULF2	STS	**MPLM**
3R	Proton	MLM with **European Robotic Arm (ERA)**
2J/A	STS	Kibo Exposed Facility & Logistics Module Exposed Section
17A	STS	**MPLM**; 3 crewquarters, galley, CHeCS-2
6-person crew capability achieved		
HTV-1	H-IIA	Japanese H-II Transfer Vehicle
ULF3	STS	Logistics
19A	STS	**MPLM**
ULF4*	STS	Logistics
20A	STS	**Node-3** with **Cupola**
ULF5*	STS	Logistics
ISS Assembly Complete		
9R	Proton	Research Module

Excludes Soyuz and Progress crew and logistics flights.
* contingency. CHeCS: Crew Health Care System. MLM: Multipurpose Laboratory Module. MPLM: Multipurpose Logistics Module

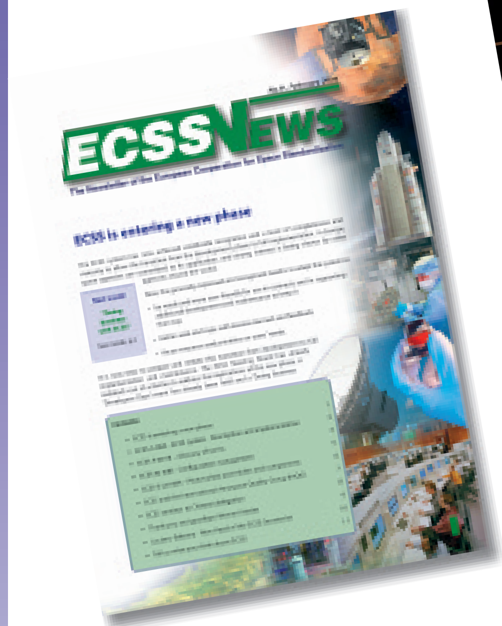


Publications

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

ESA Newsletters

CONNECT NO. 01/06, FEBRUARY 2006 – THE NEWSLETTER OF ESA'S DIRECTORATE OF EUROPEAN UNION AND INDUSTRIAL PROGRAMMES
N. MENNING & B. BATTRICK (EDS.)
NO CHARGE



ECSS NEWS, NO. 9, FEBRUARY 2006 – THE NEWSLETTER OF THE EUROPEAN COOPERATION FOR SPACE STANDARDIZATION (FEBRUARY 2006)
J. ASQUIER & C. WALKER (EDS.)
ESA ECSS NEWS, NO. 9 // 12 PP
NO CHARGE

ESA Brochures

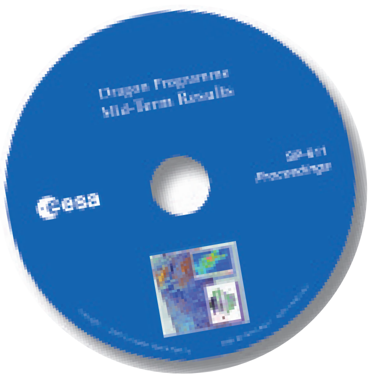
ESA TELECOMMUNICATIONS, SELECTED PROJECTS (FEBRUARY 2006)
B. BATTRICK (ED.)
ESA BR-234 // 92 PP
PRICE: 20 EURO

LES PREMIERS SATELLITES GALILEO – ÉLÉMENT DE VALIDATION EN ORBITE DE GALILEO – GIOVE (NOVEMBRE 2005)
A. WILSON (ED.)
ESA BR-251/F // 19 PP
PRICE: 10 EURO

VEGA – THE EUROPEAN SMALL LAUNCHER (FEBRUARY 2006)
B. BATTRICK (ED.)
ESA BR-257 // 20 PP
PRICE: 10 EURO

ESA Special Publications

PROCEEDINGS OF THE X-RAY UNIVERSE 2005, 26-30 SEPTEMBER 2005, MADRID, SPAIN (JANUARY 2006)
A. WILSON (ED.)
ESA SP-604 // 460 PP & 539 PP
PRICE: 100 EURO (2 VOLUMES)



PROCEEDINGS OF THE 6TH INTERNATIONAL ESA CONFERENCE ON GUIDANCE, NAVIGATION AND CONTROL SYSTEMS, 17-20 OCTOBER 2005, LOUTRAKI, GREECE (JANUARY 2006)
D. DANESY (ED.)
ESA SP-606 // CD-ROM
PRICE: 50 EURO

PROCEEDINGS OF FRINGE 2005, 28 NOVEMBER – 2 DECEMBER 2005, FRASCATI, ITALY (FEBRUARY 2006)
H. LACOSTE (ED.)
ESA SP-610 // CD-ROM
PRICE: 50 EURO

PROCEEDINGS OF THE 2005 DRAGON SYMPOSIUM - DRAGON PROGRAMME MID-TERM RESULTS, 27 JUNE – 1 JULY 2005, SANTORINI, GREECE (JANUARY 2006)
H. LACOSTE (ED.)
ESA SP-611 // BOOK AND CD-ROM (427 PP)
PRICE: 60 EURO

10TH ISU ANNUAL INTERNATIONAL SYMPOSIUM ON SPACE EXPLORATION: WHO, WHAT, WHEN, WHERE, WHY, 30 NOVEMBER – 2 DECEMBER 2005, STRASBOURG, FRANCE (MARCH 2006)
L. CONROY (ED.)
ISU // CD-ROM
NO CHARGE

POSITION PAPER ON SPACE DEBRIS MITIGATION – IMPLEMENTING ZERO DEBRIS CREATION ZONES (FEBRUARY 2006)
D. DANESY (ED.)
ESA SP-1301 // 62 PP
PRICE: 20 EURO

ESA Scientific & Technical Memoranda

PRINCE – THE PROJECT REVIEWS INTEGRATED NETWORK OF CENTRES, USERS' GUIDE, ISSUE 10 (FEBRUARY 2006)
B. BATTRICK (ED.)
ESA TM-20 // 17 PP
NO CHARGE

ESA Procedures, Standards & Specifications

COMPILATION OF ECSS STANDARDS (JANUARY 2006)
ECSS SECRETARIAT (B. BATTRICK ED.)
ESA ECSS STANDARDS // CD-ROM
PRICE: 25 EURO

ESA Contractor Reports

STUDY ON THE QUANTIFICATION OF THE IMPORTANCE OF THE SEA ICE BUDGET IN THE CLIMATE SYSTEM – FINAL REPORT (NOVEMBER 2001)
NERSC, NORWAY
ESA CR(P)-4501 // 153 PP
PRICE: 30 EURO

SPAAS: SOFTWARE PRODUCT ASSURANCE FOR AUTONOMY ON-BOARD SPACECRAFT – FINAL REPORT (APRIL 2004)
EADS ASTRIUM, FRANCE
ESA CR(P)-4502 // 32 PP
PRICE: 10 EURO

STRUCTURAL DESIGN OF ADVANCED SOLAR ARRAY – ABSTRACT AND FINAL REPORT (AUGUST 2004)
HTS, GERMANY
ESA CR(P)-4503 // 8 PP & 27 PP
PRICE: 10 EURO

STRUCTURAL DESIGN OF ADVANCED SOLAR ARRAY – ABSTRACT AND FINAL REPORT (OCTOBER 2004)
EADS
ESA CR(P)-4504 // 6 PP & 46 PP
PRICE: 10 EURO

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SATSERVICE, GERMANY
(CONTRACT NO. 16628/02/NL/US)
ESA CR(P)-4505 // CD-ROM
PRICE: 25 EURO

ACECLIM – ACE + CLIMATE IMPACT STUDY – FINAL REPORT (JUNE 2005)
MAX PLANCK INSTITUTE, GERMANY
ESA CR(P)-4506 // CD-ROM
PRICE: 25 EURO

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ESA CR(P)-4507 // CD-ROM
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INST GMBH, GERMANY
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REQUIREMENTS DEFINITIONS FOR FUTURE DIAL INSTRUMENTS – FINAL REPORT (JULY 2005)
DLR, GERMANY
ESA CR(P)-4513 // CD-ROM
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ARTES 1 SHORT MESSAGING SERVICE STUDY, DELIVERABLE ITEM 2: SYSTEM ARCHITECTURE REPORT – FINAL REPORT (NOVEMBER 2004)
COM DEV LTD., CANADA
ESA CR(P)-4514 // CD-ROM
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A PRE-PHASE A STUDY OF LEO MICROWAVE RADIOMETERS FOR OPERATIONAL METOROLOGY AND CLIMATOLOGY (2005)
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