number 136 | November 2008

esa

bulletin

→ space for europe

European Space Agency

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

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

- 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;
- by elaborating and implementing activities and programmes in the space field;
- 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;
- by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

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

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

Chairman of the Council: M. Lucena

Director General: J.-J. Dordain

←

On cover:
ESA astronaut Frank De Winne, a Belgian test pilot, takes the next flight opportunity to the ISS and joins Expedition 19 to spend six months on the Station in 2009. In May, he will fly with Russian cosmonaut Roman Romanenko and Canadian Space Agency astronaut Robert Thirsk on the Russian Soyuz TMA-15 spacecraft to the ISS. The arrival of Frank De Winne and his two crewmates will for the first time expand the ISS crew size to six.

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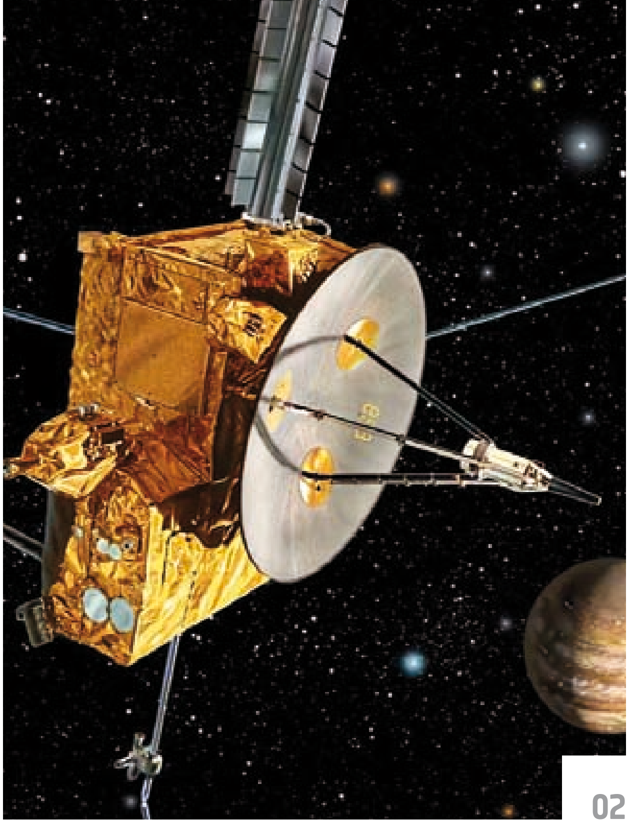

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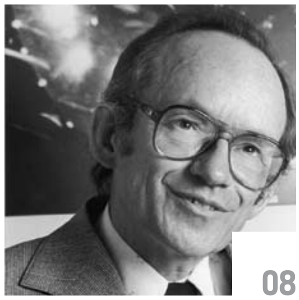

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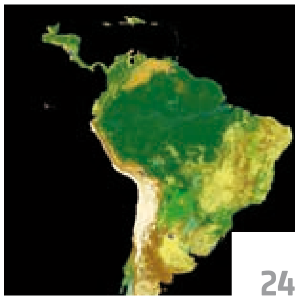

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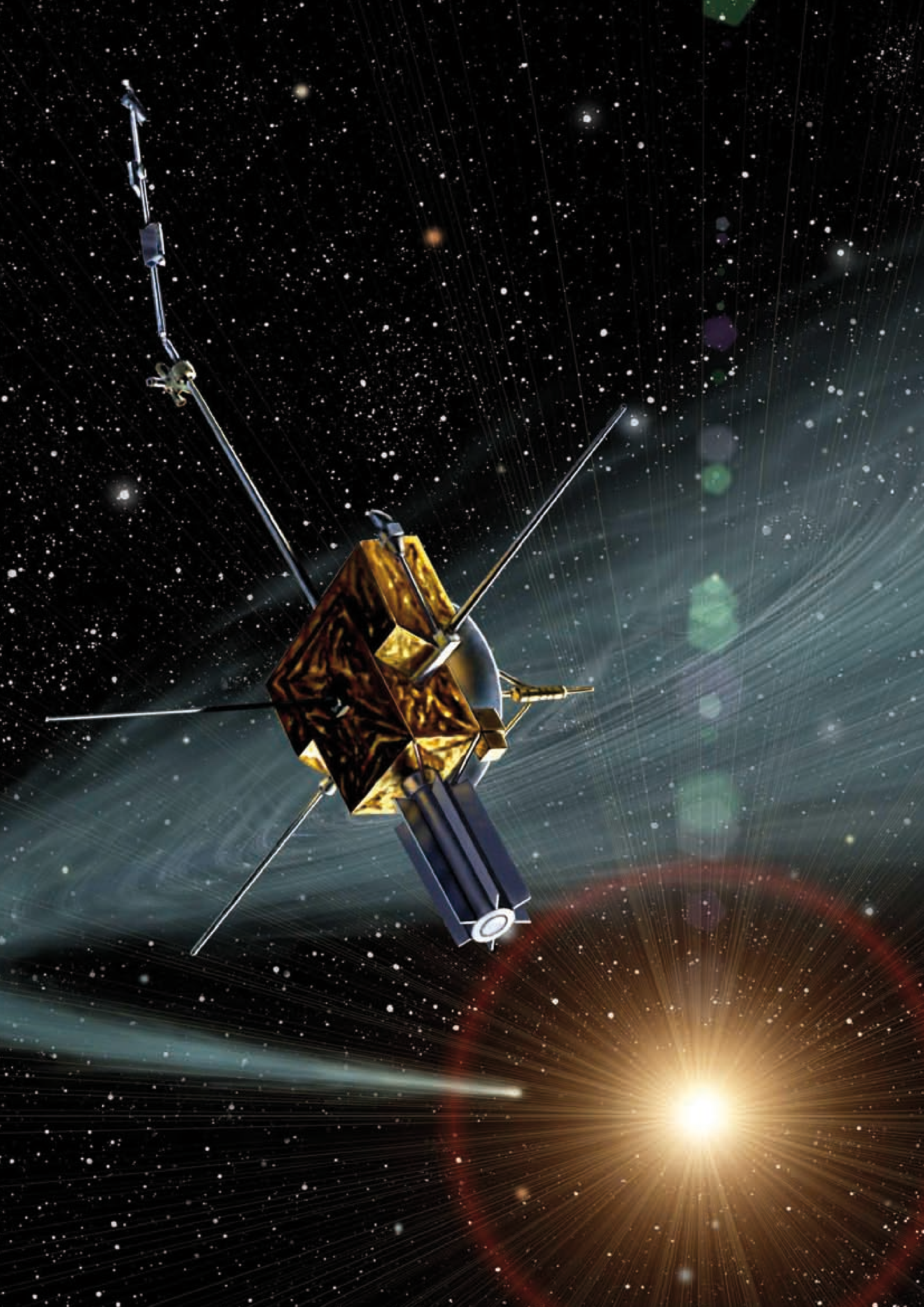


→ THE EPIC VOYAGE OF ULYSSES

Richard Marsden
Directorate of Science and Robotic Exploration,
ESTEC, Noordwijk, The Netherlands

Nigel Angold
Directorate of Operations and Infrastructure,
ESOC, Darmstadt, Germany

Ulysses has forever changed the way scientists view the Sun and its effect on the surrounding space. Here we look at the mission's major results and the legacy it leaves behind.

After almost 18 years of operation, the joint ESA/NASA mission Ulysses was officially due to come to an end in July 2008 because of the decline in power produced by its on-board generator. However, operations have continued since then on a day-to-day basis and will continue until the hydrazine fuel eventually freezes or runs out. Once that happens, it will be impossible to point the high-gain antenna towards Earth and Ulysses' voyage of discovery will be over.

The spacecraft, which studies the Sun and its effect on the surrounding space, has survived for almost four times its expected lifespan. Hurtling through space at an average speed of 56 000 km/h, Ulysses has now travelled a journey of over 8600 million km. The spacecraft and its suite of 10 instruments are highly sensitive, yet robust enough to have withstood the extreme conditions of deep space, as well as a close encounter with the giant planet Jupiter. This longevity is testament to a creative team of ESA and NASA engineers who have risen to every challenge.

Looking back

Exploring our star's environment is vital if scientists are to build a complete picture of the Sun and its effect on the Solar System. Ulysses was designed to study this environment, which scientists call the 'heliosphere' – the sphere of influence of the Sun – in three dimensions. To do this, the space probe was placed in a unique orbit that carried it over the poles of the Sun.

The heliosphere is in fact a bubble in interstellar space that is created by the solar wind – a constant stream of particles emitted by the Sun. This 'wind' is very different from the wind on Earth, but its gusts and shocks, causing aurorae and magnetic storms, may affect our weather and can harm satellites, power supplies, and communications. The key goal of Ulysses was to provide the first-ever map of the heliosphere from the Sun's equator to the poles.

Ulysses was launched on its unprecedented journey of discovery in 1990 by a NASA Space Shuttle. The gravity of the planet Jupiter then deflected it into an orbit taking it 300 million km above the Sun's southern and northern poles, regions never studied before.

During its 18 years in space, Ulysses has rewarded scientists with the unprecedented depth and breadth of its results. These have not just been about the Sun and its influence on nearby space, however: the mission has also provided surprising insights into the nature of our galaxy and even the fate of the Universe.

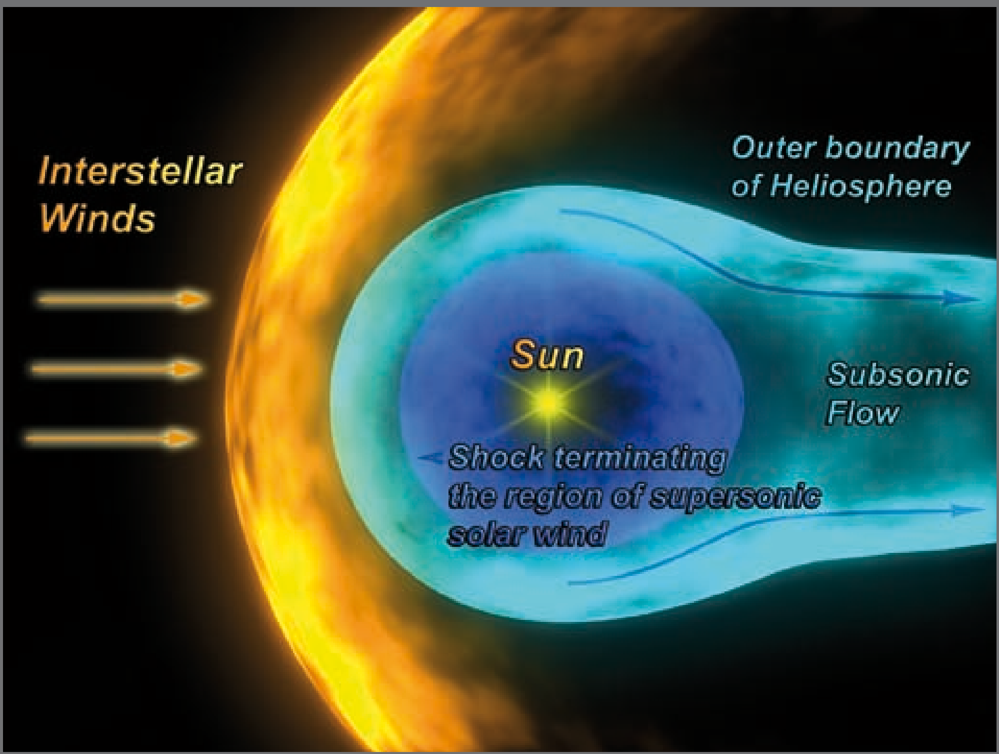
The discoveries

Solar winds

Prior to Ulysses, scientists had only been able to measure the solar wind near the ecliptic plane (the plane in which the planets and most spacecraft orbit the Sun). The picture that emerged was of a wind that had a speed of typically 400 km/s, with occasional higher speed gusts. Ulysses soon showed that for much of the sunspot cycle, there is a wind from the cooler regions close to the Sun's poles that fans out to fill two thirds of the heliosphere, blowing at a uniform speed of 750 km/s, much faster than the 'slow' wind that emerges from the Sun's equatorial zone. Rather than being 'typical', the slow wind is a minor player whose origin still remains unclear.

Magnetic field reversal

When the mission was extended beyond the original goal of one orbit of the Sun, scientists were then able to watch how the solar wind changed with time. The Sun does not emit solar wind steadily, but the emission varies through a cycle of magnetic activity lasting approximately 11 years. The cycle culminates in the reversal of the direction of the Sun's magnetic field. Ulysses saw that on a large scale, the complexity of the magnetic field near the solar surface simplifies into a field equivalent to that created by a bar magnet (a dipole) inside the Sun. When solar activity is at a



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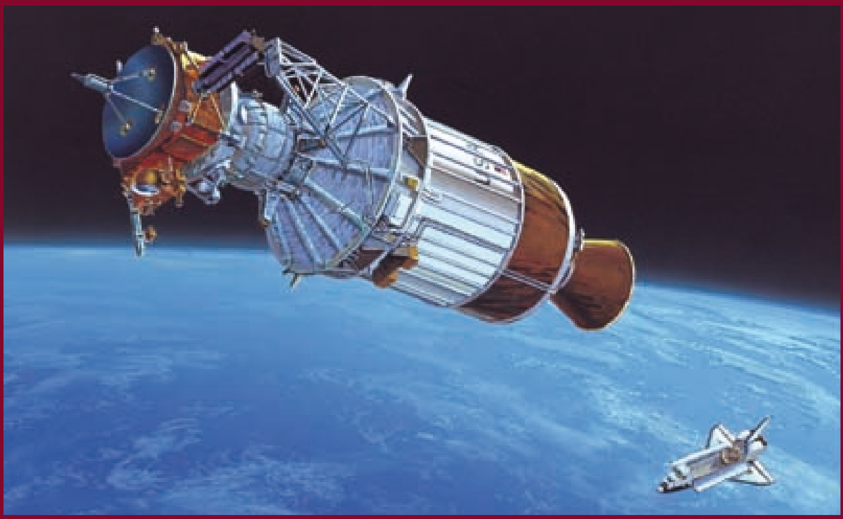
The outer boundaries of the heliosphere, the huge bubble in space created by the solar wind, are formed by the interaction with the interstellar wind, a continuous stream of gas of electrically-charged particles of interstellar origin. Ulysses found that the interstellar wind is fast enough to cause a shockwave outside the heliosphere

→ History of Ulysses

The idea of sending a probe to explore the regions of space far away from the Solar System's ecliptic plane is by no means new. The first mention of an out-of-ecliptic mission was made in 1959, only two years after the launch of Sputnik. At that time, however, many of the necessary tools were not yet available. For example, it was not known if it would be possible to navigate a spacecraft over such large distances in deep space. In particular, the technique of using a planetary body to provide a gravity assist had yet to be demonstrated.



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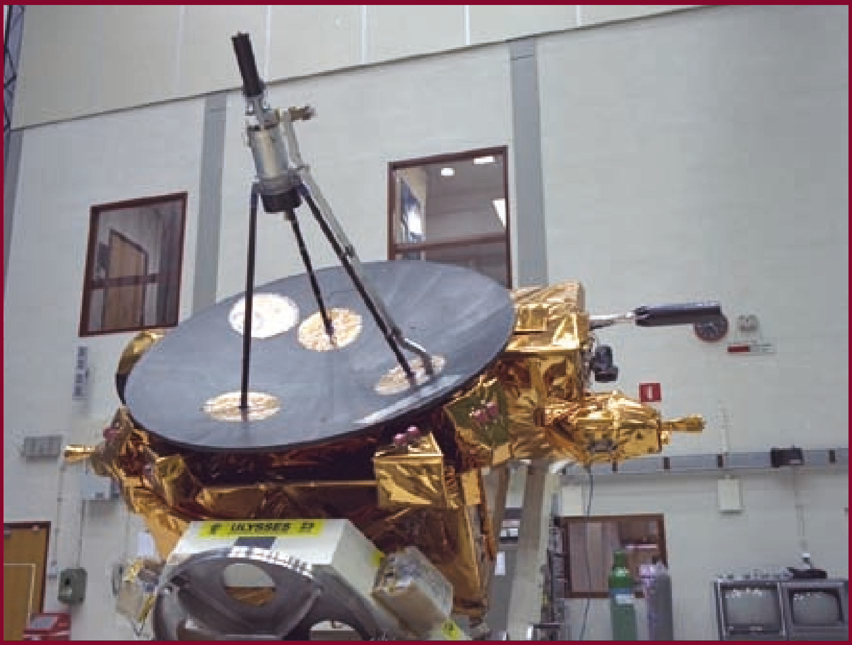
Artist's impression of the Ulysses spacecraft after separation from the NASA Space Shuttle

Missions in the early 1970s, particularly Pioneers 10 and 11, provided some essential knowledge – that gravity assists were possible and that high-radiation areas, such as the immediate neighbourhood of Jupiter, could be survived by spacecraft.

Europe and NASA studied the possibility of an 'out-of-ecliptic' (OOE) mission in the early 1970s. The mission would consist of two spacecraft flying in formation out to Jupiter and then one of them heading for the northern region of the Sun and the other for the southern region. Two spacecraft at opposite poles from each other would be able to almost completely map the Sun. The mission was approved in 1977, the payload approved in 1978 and a provisional launch date set for February 1983.

By 1980, NASA was concentrating on the Space Shuttle. Financial cutbacks were made in other areas of its space programme including delaying the launch of OOE, or International Solar Polar Mission (ISPM) as it was then called, until 1985. A year later, NASA cancelled its ISPM spacecraft and delayed the launch by a further 13 months. ESA decided, however, to go ahead with a single-spacecraft version of the mission, using the European-built spacecraft with half the instruments on board provided by the United States.



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Ulysses in the 'clean room' of ESA's ESTEC test facilities in 1985

Now renamed Ulysses, it was due to be launched on board a Space Shuttle in May 1986. In January 1986, the Ulysses spacecraft was shipped out to Kennedy Space Center to finally prepare for launch. On 28 January 1986, the Challenger disaster occurred and put an immediate stop to all Shuttle launches and therefore the Ulysses mission. The spacecraft had to be dismantled and shipped back to Europe.

When Shuttle launches were restarted in 1988, Ulysses was given a new launch opportunity for 1990 and was launched successfully on 6 October 1990.

Ulysses is a joint ESA/NASA mission. ESA managed the mission operations and provided the spacecraft, built by Dornier Systems, Germany (now Astrium). NASA provided the Space Shuttle Discovery for launch and the inertial upper stage and payload-assist module to put Ulysses in its correct orbit. NASA also provided the radioisotope thermoelectric generator that powered the spacecraft and payload.

ESA's ESTEC and ESOC managed the mission with NASA's Jet Propulsion Laboratory (JPL), with tracking by NASA's Deep Space Network. A joint ESA/NASA team at JPL oversaw spacecraft operations and data management. Teams from universities and research institutes in Europe and the United States provided the ten science instruments.

→ Launch of Ulysses on the NASA Space Shuttle *Discovery* on mission STS-41 in 1990

minimum, this dipole is aligned with the rotation poles. Six years later, at maximum, the dipole has moved to lie at 90° to the rotation poles. It then continues moving so that by the time of the next minimum, it is aligned with the rotational pole again, but in the opposite orientation. These results could only have been obtained from the unique perspective offered by Ulysses.

Dust, gas and energetic particles

Previously, the heliosphere was thought to be impenetrable to small dust particles from deep space, but Ulysses showed that this was not true. The spacecraft carried a superb instrument for diagnosing these invading particles. It found 30 times more dust from deep space in the vicinity of the Solar System than astronomers had previously expected.

Ulysses detected heavy atomic nuclei racing into the Solar System. Known as 'cosmic rays', these are thought to be accelerated by the explosions of high-mass stars. Ulysses estimated that the average age of a cosmic ray entering the Solar System is 10–20 million years and they have spent their lives streaming through the galaxy's outer regions before finding their way into the Solar System.

Measurements made by Ulysses showed that energetic particles originating in solar storms close to the Sun's equator are much more mobile than previously thought, and are even able to reach the polar regions. Since these particles are constrained to move along the magnetic field lines in the solar wind (much like beads on a wire), this in turn means that the structure of the magnetic field itself is more complex than previously thought.

Interstellar helium isotopes are especially interesting to cosmologists because theory predicts that their abundance was more or less fixed within a few minutes of the Big Bang. Ulysses collected rare samples of these isotopes, supplying evidence to support the idea that the Universe will expand forever because insufficient matter was created in the Big Bang to halt its outward march.

The engineering challenge

The Ulysses mission's life expectancy was five years. Thanks to a dedicated ESA/NASA engineering team, this turned into over 18 years, nearly 4 times longer than expected.

The mission officially began in 1977 and, after a number of delays, was launched from the Space Shuttle's payload bay on 6 October 1990. The first challenge for the team came soon after launch.

Shortly after a 7.5-metre axial boom was deployed, the spacecraft started wobbling. This was potentially disastrous. The spinning spacecraft was designed to point toward Earth with an accuracy of 0.5°, but was wobbling by several degrees, threatening to severely degrade all observations.

The team analysed the problem and discovered that the Sun's heat was causing the boom to flex as the spacecraft spun about its axis. This in turn induced the wobble. Once they had diagnosed the problem, they devised a way to use the spacecraft thrusters to correct for this anomalous motion, until the wobble eventually disappeared as the boom moved into the shadow of the spacecraft body. It was realized that the disturbance would return for a period of about a year once per orbit, as Ulysses came closer to the Sun and the boom became illuminated again. Each time, the team was successful in keeping the wobble to a minimum. In fact, the team got to know the wobble so well that they predicted its reappearance in February 2007 almost to the day.

After the first passes over the solar poles in 1994–95, the mission was extended and the team faced the task of keeping Ulysses alive. It was challenging because the power available to the spacecraft was constantly ebbing away. Ulysses uses a small Radioisotope Thermoelectric Generator and due to the half-life of the radioactive heat source, the amount of power available gradually decreases with time. Over its lifetime, Ulysses has lost almost a third of its available power so the operations team came up with ingenious ways of conserving energy.

Eventually, however, not all of the instruments and systems could remain switched on simultaneously. So, since 2002, the team has been running the spacecraft with one or more of the instruments turned off at any one time. Other systems have been turned off intermittently, too.

Switching instruments off robs the spacecraft of heat, so the team had to be extremely careful to make sure the power dissipation was distributed evenly throughout the spacecraft to avoid creating cold spots. Nursing Ulysses in this manner, they managed to coax it through a third solar orbit.

But, as the spacecraft began its fourth journey into deep space last year, the power drop became too serious and the team had no alternative but to switch off the main transmitter at times when there was no contact with the ground stations. Unfortunately, the transmitter power supply failed and it could not be turned back on again. This loss meant that data could only be sent back to Earth via a lower-power secondary transmitter, with a corresponding reduction in data rate.

More critically, both the dwindling power and transmitter failure have created a cold spot in a fuel line and hydrazine is close to freezing. Efforts to delay this freezing have included flowing fuel though the cold portion of pipework and this has resulted in much faster use of hydrazine than during the rest of the mission.

So, in the next few months, the fuel will either freeze or run out and it will no longer be possible to point the spacecraft towards Earth. Finally the voyage of Ulysses will be over but, true to its mythical namesake, Ulysses will have provided valuable scientific data up to the end, even under these adverse conditions.

The legacy

Ulysses has been a major scientific endeavour with many pay-offs. Up to 200 scientists across Europe and America have worked on the instrument teams and many more continue to access the mission's archived data, which is made available via the Internet. Around 1500 papers have been published so far using Ulysses data.

This rich treasure of unprecedented observations will keep the mission alive long after the actual spacecraft has died. ■

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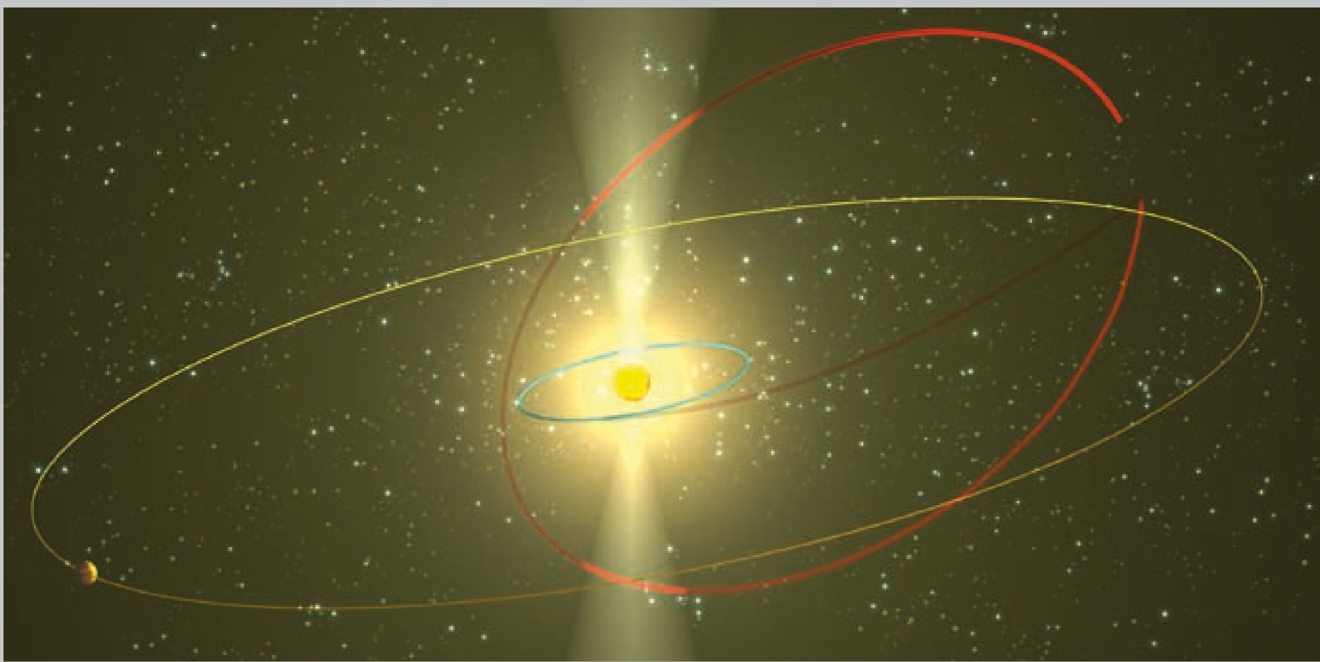
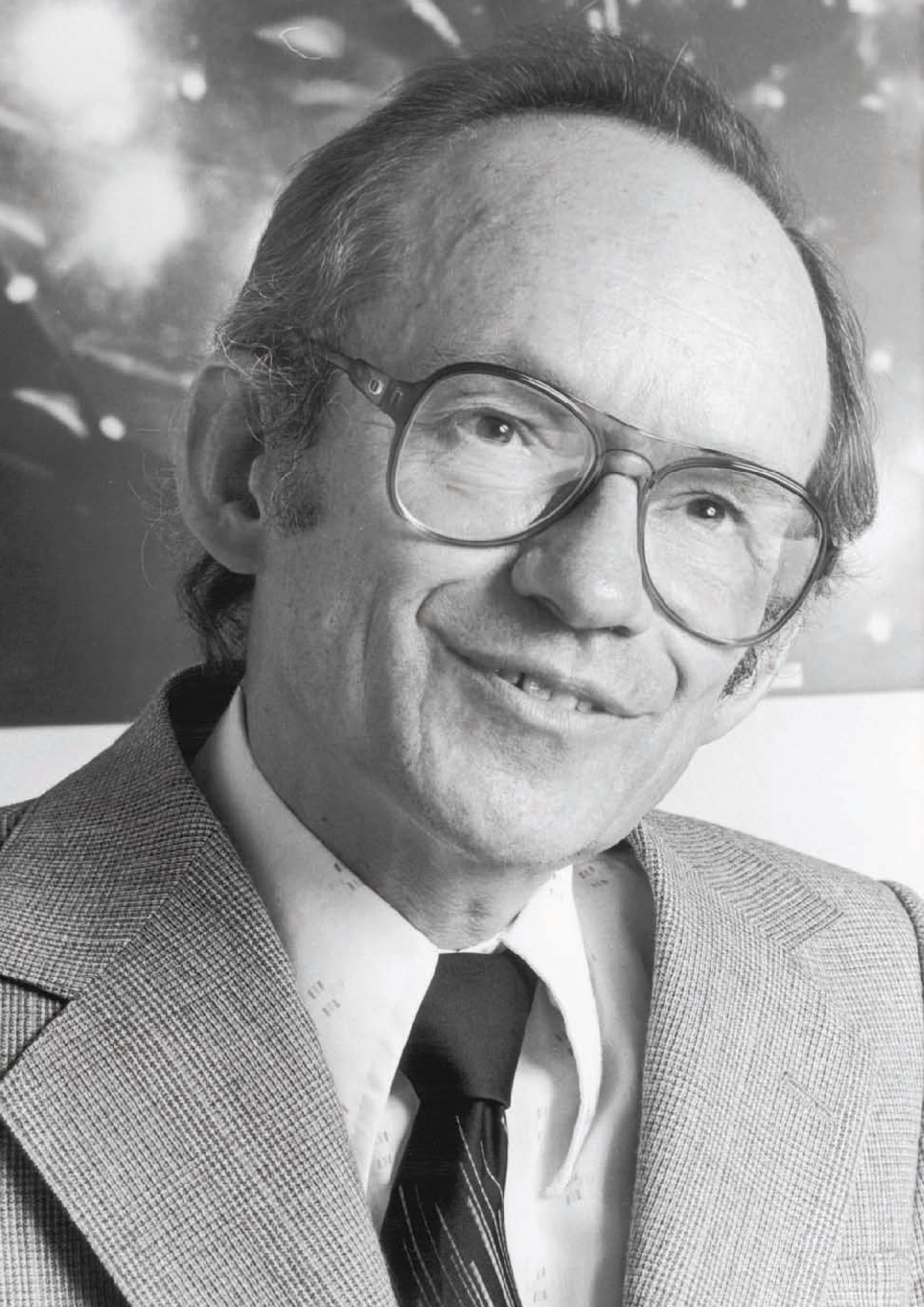
An artist's impression of Ulysses' journey. The gravity of Jupiter (yellow orbit) deflects Ulysses into an orbit over the Sun's northern and southern poles (red)





→ A LIFE IN SPACE

Jan Stiernstedt, 1925–2008

Kerstin Fredga
Chair and Director General
Swedish National Space Board, 1989–98

Jan Stiernstedt was the Chair of the ESA Council from 1978 to 1981. He passed away in January 2008, after devoting most of his life to space.

Jan Stiernstedt became fascinated by space early in life. "I became aware of outer space at an early age. On starlit autumn evenings my parents would take an evening stroll. We lived 20 kilometres from Uppsala. The dark plain spread out ahead but, beyond it, the Milky Way stretched out its glittering arc. Its millions of sparkling stars cast a soft light over the ploughed fields of autumn. My father was a keen amateur astronomer. He would point out the various constellations and nebulae and tell me about his picture of the world."

From 1959 working for the Swedish Ministry of Education and Culture, Stiernstedt became involved in the emerging Swedish space activities. From 1963 he was Swedish delegate in COPERS and later Head of Delegation in the European Space Research Organisation (ESRO) and ESA. From 1972 he chaired the Swedish Board for Space Activities, becoming

Director General in 1979 before retiring in 1989, after 25 years' commitment to space: "I was drawn into the magic circle of space, from which I have never wanted or been able to escape since."

First encounter with Europe

Stiernstedt gave a vivid description of his first encounter with the European space community at the ESA History Symposium in Palermo 1992. He recalled how he more or less accidentally slipped into European space affairs. He had been asked by his ministry to attend a COPERS meeting in The Hague in May 1963 on his way home from another meeting in Europe. One of the main items of the agenda was the COPERS budget, including the budget for Esrange, the planned sounding rocket range in Lappland in northern Sweden. He received only one instruction: to protect the Esrange budget. Particularly he had to look out for the Italians, who wanted to use that money for their sounding rocket facility at Salto di Quirra in Sardinia.

Stiernstedt recalled "When I arrived at the meeting it was like entering a new world. The group was rather small, all the delegates knew each other and they had a language that to me was almost incomprehensible. It was the specific space lingo and I understood only one thing – they wanted to cut the Esrange budget in favour of Salto di Quirra. As I did not understand their arguments, I had nothing else to do than to take a hard grip of the edge of the table and just say 'No, no, no!' I still remember the Italian delegate, General Cigerza, and the Director of Administration, Mr Crowley, despairing over the hopeless Swedish delegate who was absolutely unsusceptible to their probably logical arguments. In the end, some kind of compromise was achieved.

"That was my start, and when I went home I was rather happy that, as I believed, I would never see these people again. But destiny sometimes plays odd tricks with us, and in fact I was back already in September when I attended my first meeting in the COPERS administrative working group."

Kiruna and Esrange

Esrange was always key issue to developing the Swedish space programme. In the early 1960s, Stiernstedt became, together with Bengt Hultqvist, a strong advocate for the Kiruna rocket range. The international scientific community had become more and more interested in a launching range north of the polar circle, and it soon became evident to the Swedish Space Research Committee, which at that time included among others Hannes Alfvén, the future Nobel laureate, that here Sweden had a unique opportunity; something had to be done.

Support was soon forthcoming from scientists, but the politicians had also to be convinced. Stiernstedt played a vital role in all these negotiations and managed to persuade key politicians in Sweden and Europe. He had a particularly hard time at home, since the official Swedish policy excluded participation in anything with even the slightest military connection. For Prime Minister Tage Erlander had in 1961 declared, "Sweden was greatly interested in European economic cooperation, but only in such a way that it retained its non-alignment and sovereignty."

Consequently, negotiating became much easier for Stiernstedt once ESRO uncoupled from the European Launcher Development Organisation (ELDO) launchers. Sweden never became a member of ELDO, but later strongly supported the ESA launcher activities.

The main competitor was Norway of course, but the northern Swedish location, in the auroral zone as well, had the advantage. It was a land-based area well suited for recovery of the payloads and there was an excellent scientific environment due to the close connection with the Kiruna

> **"I was drawn into the magic circle of space, from which I have never wanted or been able to escape since."**

Geophysical Observatory headed by Bengt Hultqvist. One concern was the reindeer herding and the possibility of a reindeer being hit by a rocket or a burnt-out rocket stage. The Lapps got, and still have, a yearly compensation for this eventuality. Also, special impact-proof shelters supplied with food and dry fire wood had to be built for those who happened to be in the impact area, and the Lapps received a battery-powered radio for them to listen to the countdown of each rocket launch. These measures became quite popular and the shelters are still used as fishing and hunting huts by the local people and, so far, not a single reindeer has been hurt.

The agreement for Esrange was finally signed in 1964 and the construction of the first European launching facility could start the same year. The base was inaugurated in September 1966 in the presence of a large force of dignitaries headed by the Swedish Minister for Education, Ragnar Edenman. Spirits ran high and the wine flowed when Bengt Hultqvist smashed a bottle of champagne against a rocket launcher at the end of the ceremony. Sweden finally had its entrance ticket for space. Only two months later the first sounding rocket from Esrange was launched, carrying scientific payloads from the Universities of Utrecht and Liège.

However, in connection with the 'first package deal' in late 1971, the ESRO Council decided to abandon the sounding rocket programme, and Esrange was handed over to Sweden on 30 June 1972. Stiernstedt had the full powers from his government to accept responsibility over the range. Papers were signed and after the usual dinner at the Kiruna town hall, the participants gathered towards the middle of the night at the top of Kirunavaara to salute the midnight Sun. There, Stiernstedt recalled “Finally, the conditions had been met that Sweden would not be excluded from the future exploitation of space as a natural resource and as a vision. All the hopes of Swedish space researchers, space technicians and space enthusiasts from the beginning of the 1960s had been fulfilled. We had our launch site. We had a government space agency. We had a space budget.”

Vision and persistence

Esrange is now run by the Swedish Space Corporation. Within the Esrange/Andöya Special Project, nine European countries initially joined Sweden and Norway to support and use the two launch sites. To date (2008), more than 500 rockets (including some 150 from ESRO) have been launched from Esrange. A balloon-launching facility and several parabolic aerials for satellite communication and control have been added.

This may sound like a complete success story, but unfortunately that is not the full truth. However, I have recalled it in some detail since it gives an idea of the vision and persistence needed when you try to open up a new field in competition with more established areas. Jan Stiernstedt had both, and in combination with his diplomatic skills, he managed to carry the negotiations to a fruitful completion.

From the establishment of the first Space Science Committee in 1959, which was a joint venture by several research councils, there were many ups and downs in battling for government to take an interest in and fund a national space programme. In the mid 1960s the prospects turned out to be unusually bad and Bengt Hultqvist has described the time period from 1965 to 1972 as the ‘Wilderness years’. Many of the younger scientists left Sweden to get a chance to work in the field of space research or space technology. I myself spent three years at NASA Goddard Space Flight Center in the USA, and Fredrik Engström worked at the Culham Laboratories in the UK.

Swedish National Space Board

A proposal for an ambitious national Swedish rocket programme was rejected by the Government in 1964. There was a first Swedish national campaign from Esrange carried out in October 1968, but in 1971, after all those years of compromises and disappointments, when one of the successors of the Space Science Committee, the Space Panel, learnt that the research councils could not increase

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The Kiruna launch site in Sweden, set up by the European Space Research Organisation in 1966, is now owned and managed by the Swedish Space Corporation. ESA is a major research partner and regular user

the grants for the coming budget year, the Space Panel gave up and the members resigned en masse. They found it not possible to continue since the allocated funds would only pay for the preservation of the infrastructure but not to use it to conduct any research. The members of the Space Panel had had an impossible task.

The reactions in the Ministry of Education were split. Stiernstedt recalled, "The minister, Sven Moberg, saw the members' resignation as attempted blackmail, and this reinforced his determination to hold firm to the decision of 1964. As far as I was concerned, as an official, I of course had to observe a certain loyalty, but after eight years' involvement in space activities I really did not feel any inner loyalty to the decision."

Stiernstedt moved into action. He realised that with the current organisation and resources it would not be possible in the long run to have any space activity worth mentioning in Sweden. "If there was a desire to maintain a Swedish space activity, two things were necessary in my opinion – a coherent organisation and more money for a national programme which comprised not only fundamental research but also applications. Now I had to convince the government of that. I could not do it alone. My hope lay with the Ministry of Industry."

A new organisation came into being as of 1 July 1972. It consisted of a government agency, the Swedish Board for Space Activities (later the Swedish National Space Board) responsible for planning, policy and resource allocation, plus the independent state-owned company, the Swedish Space Corporation, with full executive functions, including the management of Esrange. The Board got its appropriations from the ministerial budgets for education and industry. On the whole, this organisation is actually still valid.

↓ A Skylark rocket is launched from the Esrange site at Kiruna

'Rymdlyftet'

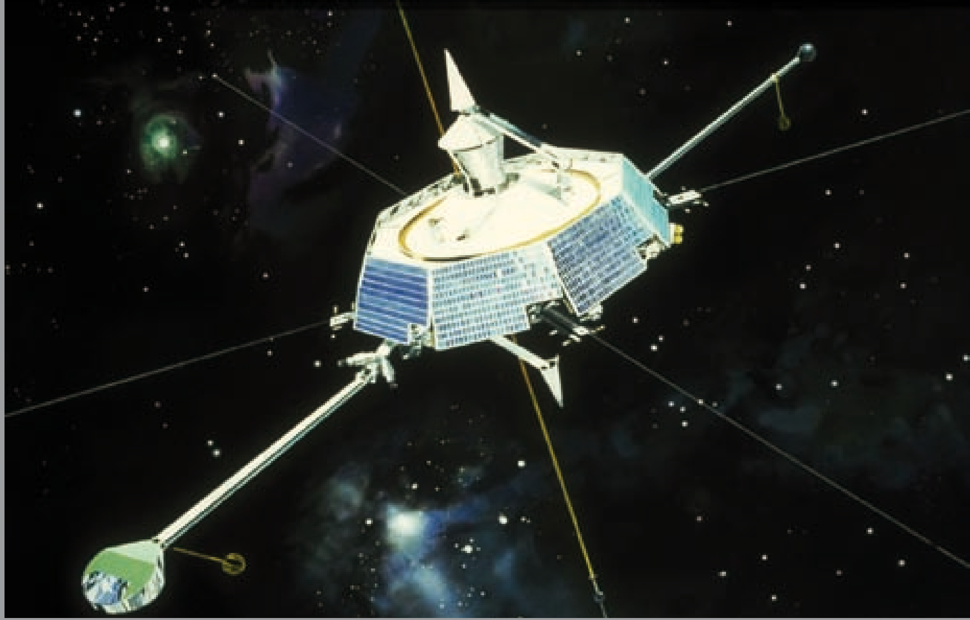
Stiernstedt became the first Chairman of the Space Board and from 1979 also Director General. The scene was set for a new era in Swedish space engagement. Science had paved the way, now it was time for applications, but this required a new financial set up. Stiernstedt's teaming up with the industrial side was successful. In 1979 the appropriations for the industrial involvement were substantially increased when the parliament in spring 1979 passed a Space Bill, in which the funding from the Ministry of Industry close to tripled. This extraordinary event in Swedish space history became in popular terms known as the 'Space take off' (in Swedish: Rymdlyftet).

> **Stiernstedt was a master mediator. With diplomacy and low-key authority, he found sustainable solutions.**

A small research satellite for auroral studies, Viking, was the first beneficiary of the 1979 Space Bill. Viking was decided in 1980 and launched in 1986 from Kourou in a piggyback launch with the French SPOT satellite on Ariane. Viking became a great success. The design lifetime was eight months but the actual operation time was nearly twice as long, and the scientists were overwhelmed by data. The twofold mission of both satisfying a research goal and at the same time promoting industrial development turned out to be a great success. The larger Tele-X, a telecommunication satellite, was also designed in parallel with Viking.

With Viking, Sweden had started its small satellite programme. Low cost, high reliability and fast turnaround characterised the small satellites for years to come. Design studies of Viking's successor. Freja, also a small research satellite for auroral studies, started in 1987. With the experience from the Viking project, Freja was completed at even lower costs, but with a much higher data transmission rate, which made it very efficient. The small satellite concept also attracted international attention and on board Freja there were experiments from Germany, Canada and the USA. The launch was successfully carried out in October 1992 on board the Chinese launcher Long March 2 from the Jiuquan launch base in the Gobi desert. Freja was operational until October 1996, nearly four times the design lifetime. Freja also became a major success scientifically, as well as technologically, and within the low-cost concept.

Several other projects were also accomplished in this period, for instance, the launch of the first Swedish national balloon



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Viking was Sweden's first satellite. It was launched on an Ariane-1 rocket as a 'piggyback' payload together with the French SPOT-1 satellite on 22 February 1986

Pirog in 1985 with an infrared telescope for observations of star formation. Microgravity research was started with the Maser 1 and 2 sounding rockets.

European solidarity and independence

Sweden is one of the founding members of ESA. From the first discussions in COPERS in the early 1960s, through the ESRO years and since the signing of the ESA Convention in 1975, Sweden has been an active supporter of Europe in space. Of course, there have been many ups and downs both at home and internationally, and tough negotiations along the way, but those involved always made great efforts finding constructive solutions. The watchwords are: European solidarity and independence in space.

The main part of the Swedish space activities is performed in international cooperation within ESA. In fact, 60–80% of the Swedish space budget has over the years been channelled through ESA. This gives an indication of how important the international cooperation is also when it comes to determining our national programme. Our delegates to ESA Council and all the different Programme Board members are constantly on the move to and from Paris.

In July 1978, with the experience of 15 years as Head of the Swedish delegation, Stiernstedt took over as Chair of ESA Council for a three-year period. He got a flying start: already on 14 July, ESA successfully launched GEOS-2. In 1979, an agreement was signed by Austria to become an Associate Member of ESA, followed by Norway in 1981. Keeping track of thirteen Member and two Associate States – each having their own vision and home constituency – demanded his special skills.

Above all, the late 1970s were dominated by the first launches of Ariane. The Ariane programme had been decided already in 1973, spearheaded by France. On Christmas Eve 1979 we witnessed the successful first test flight of the European-built launcher (L01). But rocketry is a tricky business. In May 1980, Ariane's second test flight (L02) failed and the German Firewheel satellite was lost. However, after a delay of only about a year, ESA was back on track and in 1981 both Ariane L03 and L04 were successful.

An issue continuously discussed in Council during Stiernstedt's chairmanship was the need for a second Ariane launching pad in Kourou and in 1981 Council decided to build ELA-2.

As is well known, the Chair's job in an international organisation consists of much more than what is recorded in the official minutes. In fact, it is a continuous dialogue with the representatives of the different countries. You have to understand their particular problems and find compromises acceptable to everybody. Stiernstedt was a master mediator. With diplomacy and low-key authority, he managed to find sustainable solutions to carry ESA's programme forward. However, we often discussed the drawback for ESA of having so many decisions requiring unanimity.

Stiernstedt retired in 1989 and I became his successor as Chair and Director General of the Swedish National Space Board as well as Head of the Swedish delegation to the ESA Council. We had then constructively worked together for more than 15 years promoting space activities in Sweden. My responsibility at that time had primarily been our research programme.

On 2 January 2008, Baron Jan Stiernstedt passed away. Ever noble, he never drew attention to himself, always focusing on the issues. We remember with respectful gratitude that rare combination: his genuine passion for space and dedicated public service. ■

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Rosetta

→ "HAPPY CHICKENS FROM FRESH EGGS"

Innovative technologies for mission operations

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Flying a successful mission means having the right technology ready for use at the right time. ESOC's Advanced Mission Concepts and Technologies Office is entrusted with infusing new and effective technology into ESA's mission operations.

Recognising the need to encourage and exploit new concepts and technologies, the Advanced Mission Concepts and Technologies Office, called Advanced Technologies Office for short, was established in 2001 to foster innovation in the field of information technology, with a strong focus on artificial intelligence (AI). The chosen paradigm is: innovate, demonstrate and transfer into the operational arena, with the needs of mission operations at the forefront.

'Chicken and egg'

One issue that had to be tackled immediately was to define an effective and low-cost approach toward achieving technology maturity through a pragmatic and consistent implementation framework. Mission managers do not want to be handed what they might call the technological 'fresh eggs' for implementation in their new missions.

At the same time, mature technological 'chickens' do not appear by themselves – they have to be incubated, hatched and fledged. Resources for producing 'eggs' are available, but the transformation into happy, mature 'technology chickens' is not as linear and natural as it might be on a farm.

Using new technologies involves certain risks: the time for a technology to mature is often longer than desired; or it is possible that a particular technology will not mature in time. Very few stakeholders are ready to allocate funds for this process, which is particularly true in the traditionally conservative domain of spacecraft operations.

In order to reduce the 'egg-to-chicken' development time so to speak, and to mitigate risks, a set of tactical measures has been implemented. The first was to make maximum use of available resources existing in-house: the expertise of operations engineers and accumulated data from ongoing missions. The engineers drive the identification of usage cases matching the new operations concept or workflow to be validated.

Mission control engineers are also a valuable and essential resource for validating any new prototype at a practical operational level. Live mission data become the benchmark against which the innovative algorithm or application is validated.

Another important element that helped to facilitate the process of introducing innovation was the use of proven working methodologies suitable for the process. So-called 'agile' software development approaches, such as 'extreme programming and egoless programming', were evaluated and adopted where possible. In fact, high-risk projects with dynamic requirements are perfect candidates for 'agile' methods, and egoless programming proved to be instrumental in establishing an open collaborative environment across stakeholders and within the development team. This has proven crucial for successful teamwork.

The innovation process at work

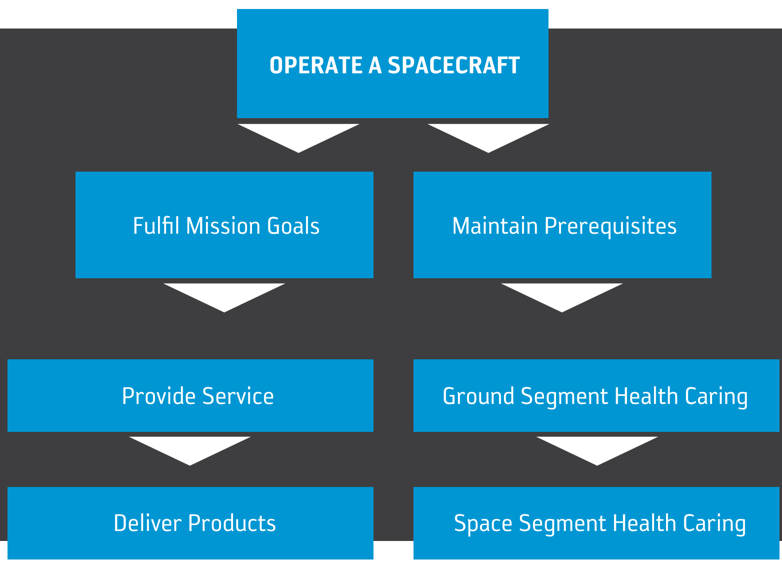
There are several motivators for introducing innovation into mission operations. The first is the goal of continuous improvement to provide progressively better and more cost-effective mission operations services, at an acceptable risk. Practically, this implies the design, implementation and validation of new operations concepts and workflows, with associated enabling tools and technologies.

For instance, the automation of recurrent manual operational tasks is a promising area. Examples are spacecraft monitoring and alarm filtering for an unmanned ground station pass, the generation of pre-formatted operations reports with data and graphics, operations activity logging and complicated planning and scheduling tasks. No one proposes replacing human expertise with machines, algorithms or automation but, through such innovation, the duties of specialised flight control personnel are raised from the (often routine) execution of manual processes to the more interesting supervision, investigation and optimisation of automated processes.

This not only makes better use of the engineers' expertise and intelligence, but they also remain trained and ready to intervene in non-nominal situations or when a final decision must be selected from several proposed solutions provided by a decision support system.

A second class of motivators is derived from the challenges presented by future missions. Exploratory missions, such as those in the Aurora programme, and their successors require that critical or tactical decision processes be relocated from ground to the space segment following a step-by-step transition of automation and autonomous functions from ground to space, with thorough validation of the process on ground beforehand.

This is associated with a significant increase in onboard autonomy compared to currently flying spacecraft.



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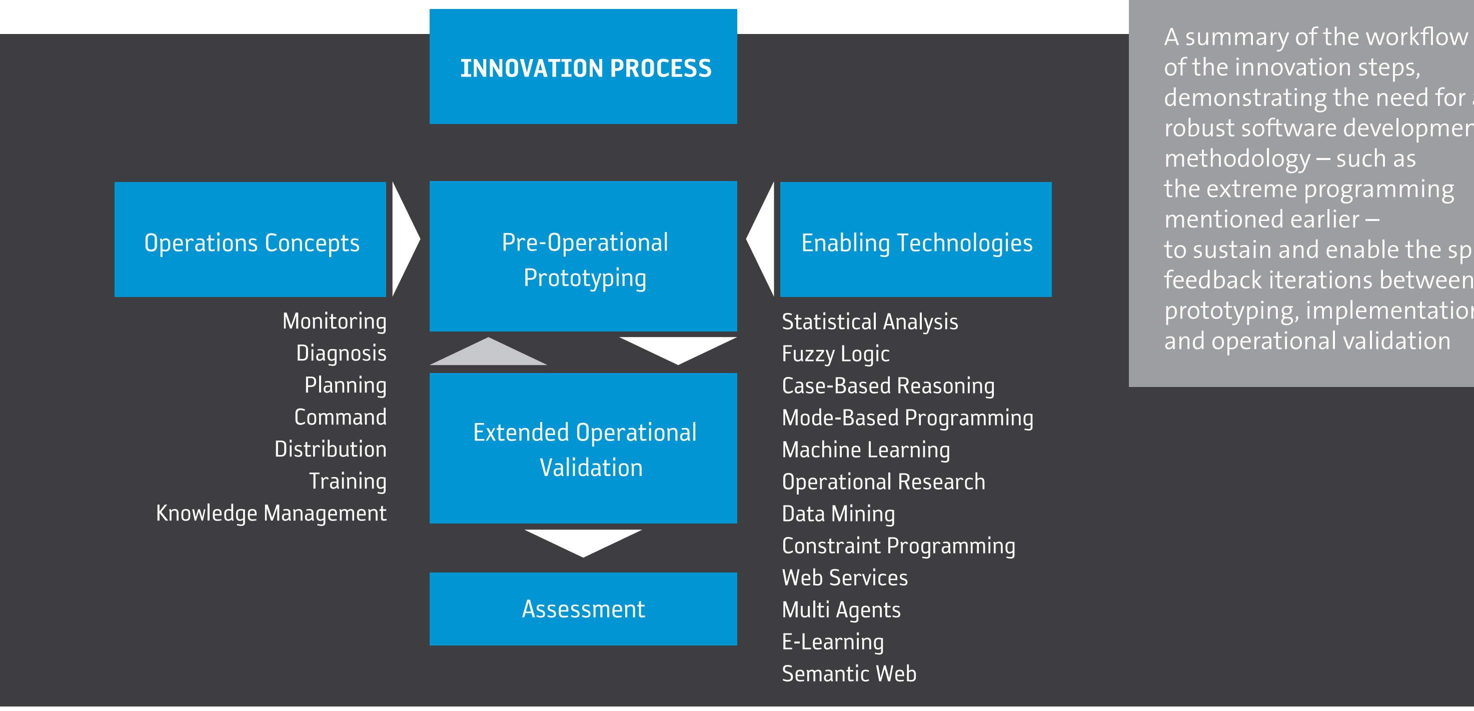
Operating a spacecraft means to fulfil the mission goals and guarantee that the prerequisites for smoothly and effectively running the mission are satisfied

Missions involving multiple elements, such as Earth observation or navigation constellation missions and rover fleets, as well as cooperative operations concepts, require significant enhancements in the flight planning and scheduling process. Today, this process still involves a lot of manual work. However, in order to ensure a good science return in such mission scenarios, tools that support the generation of optimised and robust plans will be required.

Continuing the route of exploration missions, there will be even cases where autonomy is the only technology enabling these missions, typically when the operational increments exceed the reach of the onboard sensing equipment between two communication windows. In the case of fleet missions, there will be so many degrees of freedom involved that it will be very difficult for humans to generate good plans in short time. AI algorithms are suitable to support these planning processes and they are able to generate optimised, conflict-free and robust plans.

Support Tools). This software package enables easy and safe (non-invasive) access, in near-real time, to spacecraft and ancillary data, and therefore permits the exercise and validation of prototype applications using online data. MUST is also the first example of prototype software to be transferred to actual operational infrastructure.

This innovation process affects the most relevant operations processes: monitoring, diagnosis, planning, commanding, training and knowledge management. The implementation of the innovation process makes use of a suite of available and suitable technologies. Most of them belong to the AI branch, such as case-based reasoning, 'fuzzy logic' or artificial neural networks. In addition, statistical analysis, operational research, e-learning and semantic web are among the complementary suite of technologies involved in the process.



↙ A summary of the workflow of the innovation steps, demonstrating the need for a robust software development methodology – such as the extreme programming mentioned earlier – to sustain and enable the spiral feedback iterations between prototyping, implementation and operational validation

As mentioned above, the Advanced Technologies Office has adopted the 'Innovate, demonstrate, transfer' approach. The innovation is defined by the requirements driving future mission scenarios, which are already identified by the Future Studies Section. Next, demonstration consists not only of a study of possibilities and recommendations, but also of practical implementing prototype applications that are validated under real conditions, i.e. the prototypes are applied to currently flying missions and to real data.

The transfer of validated technologies and concepts takes place by making available to ESA and industry the prototype applications, as well as consolidated requirements and blueprints, ready for operational reimplementation.

The demonstration and validation of technologies and concepts has been greatly facilitated by the Advanced Technologies Office-developed MUST (Mission Utilities and

In fact, the users, represented by mission control engineers, become part of the development team. Their contribution during the engineering phase is fundamental to keeping the focus on the essential part of the functionalities to be implemented. During validation, mission control engineers use the new prototype in parallel to the standard available operational tools.

The result of the process is a technological and operational assessment of the suitability and maturity of the technology with respect to implementing the particular innovative operations process, as well as a 'blueprint' for the validated solution – typically, algorithms, source code and executable code. This blueprint package is then transferred to the Ground Systems Engineering department, responsible for the implementation of the mission operations infrastructure and becomes a starting point for a formal operational implementation in support of a future target mission (or family of missions), as well as a valuable source in the applications library, reusable by any other mission.

Adhering to this technology infusion process is not always easy for the people doing the actual work. The job is demanding because novelty always brings unforeseen difficulties and challenges. At the same time, it is exciting and interesting. It requires strong teamwork, commitment, an open mind able to think 'outside the box' and a readiness to question one's own assumptions for the better. This is where the egoless programming style, mentioned previously, is essential.

Our core team at the Advanced Technologies Office comprises young information technology and artificial intelligence experts in various branches, consisting of a mix of on-site contractors, research fellows and young graduate trainees. In addition, the Advanced Technologies Office maintains close contact with external experts at universities, research institutes and innovative companies across Europe that provide their contributions through contracts financed by various ESA research and technology programmes. Currently, the Advanced Technologies Office oversees 13 ongoing projects with another nine under preparation.

> **"This work needs strong teamwork, commitment and an open mind able to think 'outside the box'."**

In order to successfully introduce innovation, it is necessary to coordinate activities with other organisational entities across ESA. The Advanced Technologies Office cooperates at a technological level with ESA's Advanced Concept Team, several other ESTEC-based sections, including the Robotic section and the Space Environment and Effects section, as well as with relevant sections within the Ground System Engineering Department.

At the strategy level, coordination takes place with the Future Studies Section, the Mission Operations Division, and with external teams, such as the Strategy and Architecture office in the Directorate of Human Spaceflight.

The Advanced Technologies Office also interfaces with supporting and coordinating research and networking activities funded by the European Union, and it participates in and helps organise specialised conferences and forums, such as the biennial 'SpaceOps' event; some of these focus on areas outside aerospace.

Case studies and achievements

Fuzzy logic

Fuzzy logic was the first technology to be assessed by the Advanced Technologies Office. It proved valuable for the diagnosis of failures and was deemed suitable for modelling the flight control engineers' experiences with specific unit degradation and anomalies. The fuzzy logic-based Gyro Monitoring Tool for Envisat has been in use since 2002, providing the capability to detect and diagnose early deviations from nominal behaviour, even if the telemetry is apparently normal. The same technology was also applied to the management of the Ulysses nutation anomaly.

SMART-1 automation

In 2003, immediately after the launch of SMART-1, the flight control team faced a series of anomalies that forced them to work well beyond normal working hours. As a consequence, an urgent request came to the Advanced Technologies Office and in less than two months a client-server tool was designed and implemented to allow remote monitoring and performance analysis of the spacecraft, as well as alarm notification via SMS. The new service greatly helped reduce stress and fatigue on the operations teams, who could then decide from home what to do in case of anomalies, without necessarily travelling back to the control room at ESOC. This also helped mitigate the risk for potential human failure/misjudgement.

The system was dubbed 'MUST', and after a re-engineering process based on pair programming methodology it was deployed to almost all ESA missions. MUST has since become the Advanced Technologies Office's standard platform for the implementation and validation of other advanced applications.

Mars Express planning

Another interesting project was automating a daily manpower-intensive task dealing with spacecraft downlink operations of stored science and housekeeping data.
An AI-based constraint satisfaction programming technique was implemented to generate the Mars Express downlink plans. Called MEXAR2, this tool has been in use since October 2005 providing valuable support to the Mars Express mission planners at ESOC. The generated plans are optimised and robust and provide a better capability to absorb last minute changes, allowing increased science return and contributing to reduced ground station usage. MEXAR2 was the first case in which AI technology was used to help solve the planning and scheduling problem.

MEXAR2 won the best application paper award at the ICAPS 2007 in Providence, Rhode Island, as well as a public recognition to ESA in a keynote speech at the iSAIRAS conference in Los Angeles in 2008. MEXAR2 is now paving the way – with the Advanced Planning and Scheduling Initiative – for further AI prototyping applications in mission planning for the science planning segment of Mars Express

→ Innovation at work
Examples of innovation and prototyping success

DigiLog – a web-based electronic logging system for operations

Most missions, as well as the ESTRACK Control Centre, still use paper logbooks. While this may be flexible, it lacks the possibility to make further electronic use of the information contained in the books. Using an electronic logging system not only makes it possible to search, filter and sort the information, but also to link the logging system to other applications, e.g. to mine stored information, to generate pass reports automatically or to export information automatically, for example to mission scientists.

GEMS – a messaging system currently under development

This system will provide a gateway for other applications to automatically send messages, e.g. alarms and notifications, to a configurable list of recipients via SMS and email. For example, if an anomaly is detected by a connected application, it would use GEMS to send an alarm to the operator on call. If the issuing application supports the functionality, GEMS will even enable the operator to trigger actions, e.g. restarting a machine. If the operator on call does not answer within a given time, the message is automatically forwarded to the next person in the list of recipients.

Fuel Saving

In the area of optimisation, an experiment was done applying a multi-objective genetic algorithm for the fuel consumption optimisation of the reaction wheels bias manoeuvre, implemented at perigee of the space observatory spacecraft. The algorithm was validated with the Integral and XMM-Newton. The result was a fuel saving up to 35% for the manoeuvres with respect to the simplex algorithm approach.

CERTAIN – a system that monitors and reports the health status of a spacecraft during unmanned periods

For missions with a 'dimmed-lights' operations concept. The system analyses telemetry data based on a set of rules defined by operations engineers and generates reports summarising the current status of the spacecraft. This will allow the engineers to get a quick overview of the current status, for example after a weekend.

Reporting

A lot of time is spent throughout ESA writing reports, including mission operations reports. Depending on the mission, reports are generated in weekly, monthly, quarterly or other intervals. Such recurrent reports always contain the same graphs, tables or other elements; the only difference is that they are updated with the newest data. Using state-of-the-art business intelligence tools, the Advanced Technologies Office created a system that largely automates the generation, as well as the distribution of these reports. In addition, the reports can be edited, viewed and downloaded from a web browser, therefore limiting the number of e-mails sent back and forth during the writing and distribution of the report.

ATHENA

A tool that automates the post-processing of telemetry data following specific procedures, for example to validate alarms and events. The procedures are entered into Athena as a set of rules directly by the flight control engineers. It then processes the latest data automatically and provides the results, therefore saving considerable time and effort.

Search Engines

Finding information is an issue in all large organisations, including ESA. Information is distributed in various databases, document management systems, web sites, files on personal computers, etc. It is a very time consuming task to find specific information or documents without knowing somebody who has it. To avoid reinventing the wheel, the Advanced Technologies Office is assessing various commercial off-the-shelf technologies and tools for searching easier and faster, e.g. semantic web and search engines such as 'Google in a box'.

Rover Monitoring & Control

In collaboration with the ESTEC robotics group, the Advanced Technologies Office is assessing the capabilities and challenges related to remote monitoring and control of a robot rover, in view of future missions such as ExoMars.

Virtual Flight Control Team

When people use online market places, such as eBay, they make use of software agent technology – usually unknowingly so. These agents carry out negotiations with other agents on behalf of the user, so that the user is spared exposure to complicated rules, algorithms and technical details. Software agents could also be used to take over parts of the spacecraft monitoring and diagnosis task. The Advanced Technologies Office is assessing the capabilities and usefulness of software agents for these purposes.

Auctions for Science Activity

Another Advanced Technologies Office project based on popular systems like eBay aims to use auctions to allocate time slots and resources to scientists. Each scientist responsible for a payload will have a budget of tokens (virtual money) with which he or she can 'buy' the time slot and the resources required for an observation. However, if another scientist requests the same resources at the same time (therefore causing a conflict in the plan), both of them have to bid against each other. The one bidding more will win the observation. This will allow the overall mission plan to be optimised in the sense that if an observation can be performed during a subsequent orbit, the scientist concerned will not bid many tokens because she/he is flexible enough to do the observation later. However, if a scientist has a unique opportunity for an experiment, he will be willing to pay more for it. This system will help circumvent the current complex and sometimes personality-based science activity negotiations.

E-Learning tools

These have matured over the last few years and sophisticated systems are now available. Operations team activities are a perfect example where it makes sense to use an e-learning system to train, retrain and possibly certify people. Knowledge is captured and transformed to e-learning training content. This includes multimedia animations, videos and interactive software tutorials. In addition, tests can be created to assess the knowledge of the trainees. The Advanced Technologies Office is implementing an e-learning system for the ESTRACK Control Centre, representing a first step into the 'e-learning world'. If useful, the system could easily be extended to other domains, such as spacecraft operations.

Data Mining – for classifying and forecasting anomalies

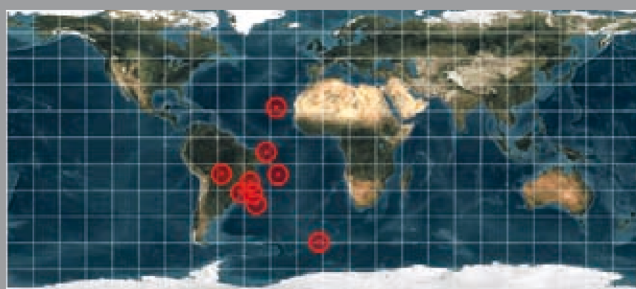
ESA has access to a wealth of data from the history of all its missions. Each current and past mission has an archive of telemetry and auxiliary data, as well as a database containing anomaly reports. Through data mining, it is possible to classify anomalies and even perform root cause analysis as well as to map patterns in the telemetry data to anomalies and therefore predict anomalies in the future. The latter process has already been tested and proven for several problems, including spacecraft leaks during certain manoeuvres and degradation of spacecraft components under certain conditions.

and SOHO, and for the long-term mission planning of Integral and Herschel.

Space weather

The Space Environment Information System (SEIS) is another project that responded to the needs of flight control teams. This system imports, processes and makes available through a data warehouse, data related to the space environment, e.g. radiation levels, as well as related critical telemetry and events data. The harsh space environment can have adverse effects on the performance and health of spacecraft, significantly reducing any mission's science return.

Normally, flight control teams are blind to spacecraft environment effects outside measurements generated from their own sensors, and they rely on other sources to estimate the current dangers, for example from a solar flare.



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An example display of the SEIS Reporting and Analysis Tool. This screen shows data from the French DORIS satellite system used for the determination of satellite orbits

SEIS gathers all relevant space environment data, taken from multiple spacecraft as well as ground sensor networks, into one single source.

The system provides two client applications, a real-time monitoring tool and an offline data analysis and reporting tool. SEIS has supported the Integral flight control team since October 2005, and an improved multi-mission version – named SEISOP – is currently under development.

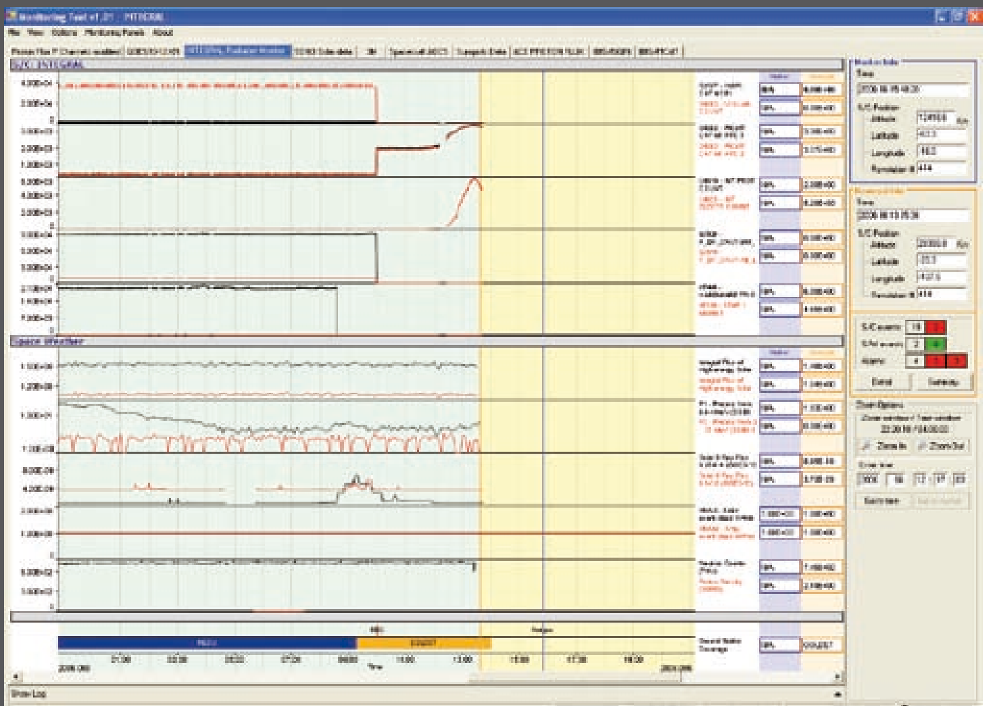
These prototype applications have been or are currently being developed in order to evaluate technologies and concepts against future mission requirements. However, because of the particular way in which the Advanced Technologies Office applies the technology infusion process, not only will future missions benefit from new technologies and proven concepts, but flight control teams of current missions will also reap rewards. They are actively recruited into the prototyping phase, providing feedback and validating the software in their (real) environment. This allows them to make use of the software early on and to benefit from the provided functionalities. Several flight control teams have been able to save time and resources in their daily activities due to the use of such prototype applications.

A considerable number of papers have been published to report on the results gleaned from the implemented prototypes, including publications in the IEEE's Intelligent Systems and in the *Encyclopedia of Decision Making and Decision Support Technologies*. A lot of positive feedback and appreciation has been received from the European academic world due to our success at bridging the gap between AI technology and its exploitation in space mission operations.

Prospect for the near future

A major goal for 2008–10 is consolidating and reinforcing operations technology networking within ESA, with outside research institutes and with European space industry. ESOC's recently established Research and Technology Management Office will be instrumental in this respect.

The Advanced Technologies Office will actively seek such collaborations within ESA and remain available to share and transfer experiences from the operational level as well as to work on joint inter-directorate prototyping projects. Various ideas have already been suggested in a wide range of application fields in ESA where AI could be introduced. Innovation will also continue to be fostered together with various European and international research institutes, particularly to encourage young researchers. We are particularly enthusiastic about a new collaboration started recently with GENSO (Global Educational Network for Satellite Operations), based on a new concept of networking low-cost ground stations in support of student missions worldwide.



← An example display from the SEIS Monitoring Tool for the Integral Space mission, indicating various parameters of 'space weather'

Conclusions

Over the years, we have confirmed a strong need for the benefits and efficiencies that are delivered through the Advanced Technologies Office innovation and prototyping process for both current and future missions. Both require light desktop software applications that are quickly developed and that address a specific problem they are facing. Our team offers this expertise, thus relieving active flight control teams from the workload of doing additional software development themselves.

Thanks to significant progress in technology, those responsible for missions and flight operations are starting to accept artificial intelligence. The benefits in the mission operation processes, primarily cost containment, increased science returns and resource optimisation, give a clear endorsement for the use of AI in future missions. We foresee that ongoing prototyping will sustain the technology infusion process, and joint research projects between those concerned with operations technology and space segment technology will further speed the process in the future, enabling European research institutes and industry to participate in the development of advanced technologies for space operations.

We also realise that being close to the users is of prime importance for our activities. This is why many of our projects are conducted on site and in close collaboration with the teams involved (after all, the best farmers visit their hen houses every morning to check on hatching progress?).

Given the needs and opportunities, as well as the past successes, it is clear that multiple benefits will result from the ongoing strengthening and formalisation of the Advanced Technologies Office workflow and of its collaboration within ESA. This will accelerate the infusion of beneficial technology, helping ESA remain at the forefront of technology application and supporting all the teams working to make our missions successful.

Further reading

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GlobCover land cover over South America

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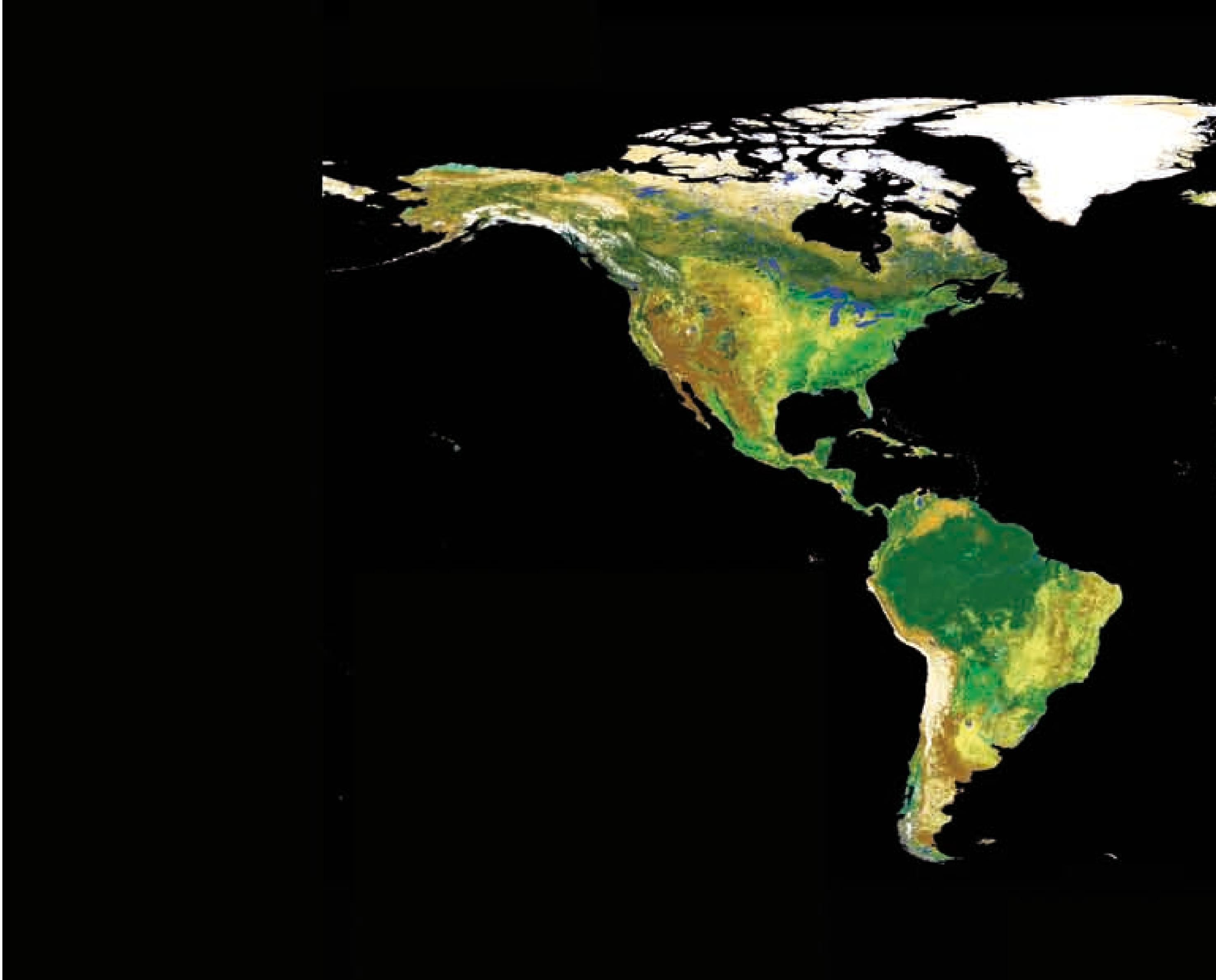
Ron Witt
UNEP, Chatelaine, Switzerland

Jean-Louis Weber
EEA, Copenhagen, Denmark

The most detailed maps ever of Earth's land surface have been created with the help of ESA's Envisat environmental satellite. Land cover has been charted from space before, but this global map has a resolution 10 times sharper than any of its predecessors.

The new global portrait is based on 40 terabytes of imagery – equivalent to the content of 40 million books – acquired by Envisat's Medium Resolution Imaging Spectrometer (MERIS) instrument. ESA made a continuous effort to ensure the acquisitions and the production of the MERIS 300 m Full Resolution Full Swath (FRS) products for the period from 1 December 2004 to 30 June 2006.

In addition to being made fully available to the public upon its completion in September this year, scientists will use the data to plot worldwide land-cover trends, study natural and managed ecosystems and to model climate change extent and impacts. They are hailing the product – generated under the ESA-initiated GlobCover project – as a 'milestone'.



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The GlobCover land cover product

More than a map

Bi-monthly products from January 2005 to June 2006 are available online. They can be accessed through a newly developed map server tool on ESA's GlobCover web site. In June 2007, additional bimonthly global composites were made available as well as the first part of a global land cover map over Eurasia.

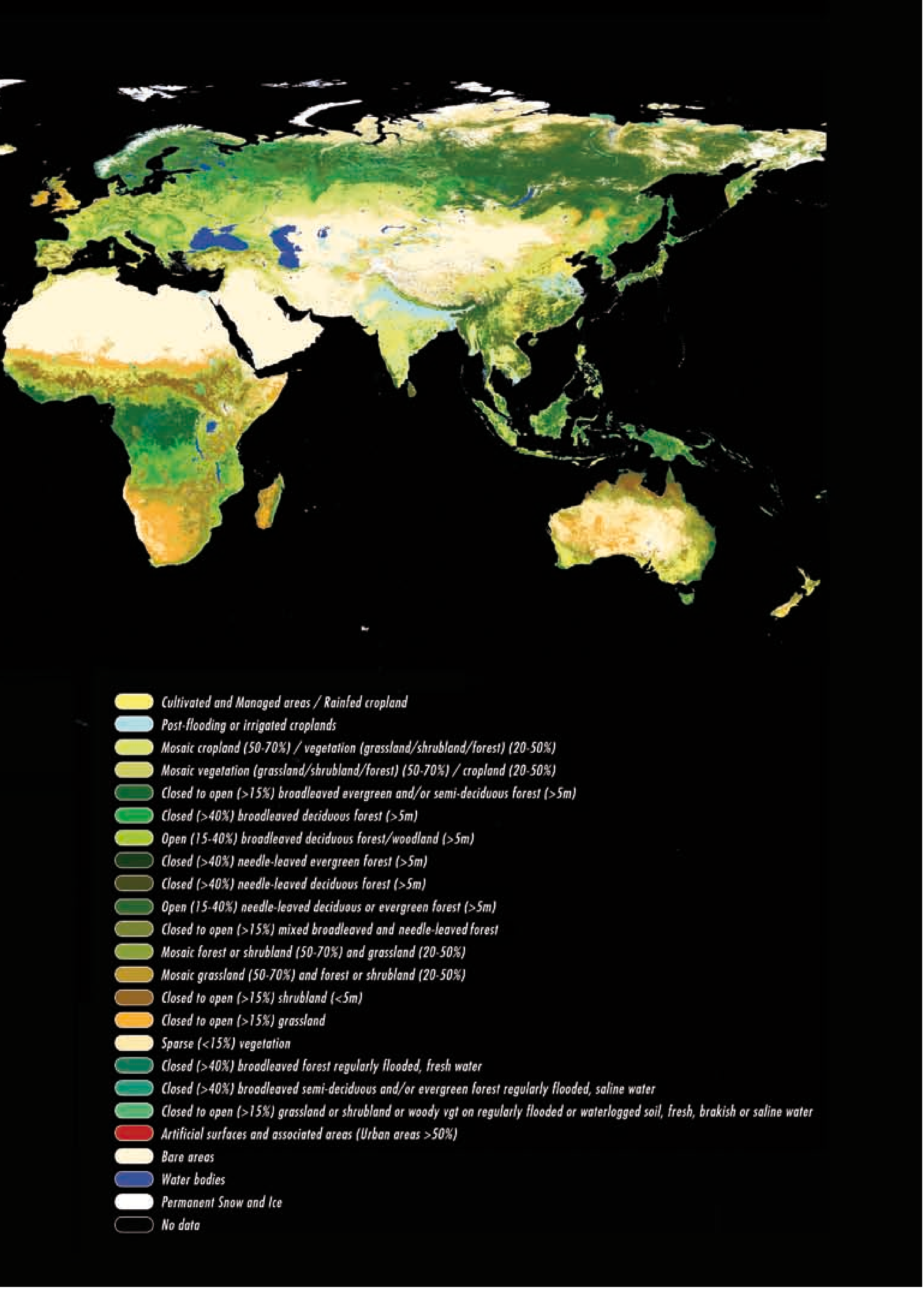
However the GlobCover product is much more than a map. It is a scientific and technical demonstration of the first automated mapping of land cover on a global scale, and provides a basis for the detailed description of the land surface states needed for regional climate modelling.

Information on land cover is an essential requirement of the sustainable management of natural resources, environmental protection, food security, climate change and humanitarian programmes. It forms a basis for ongoing studies of land-cover and land-use dynamics particularly to improve our understanding of the variation of the nature-society dynamics of land management, thereby facilitating the regional and global modelling that is vital for climate impact and sustainability research.

The land cover product

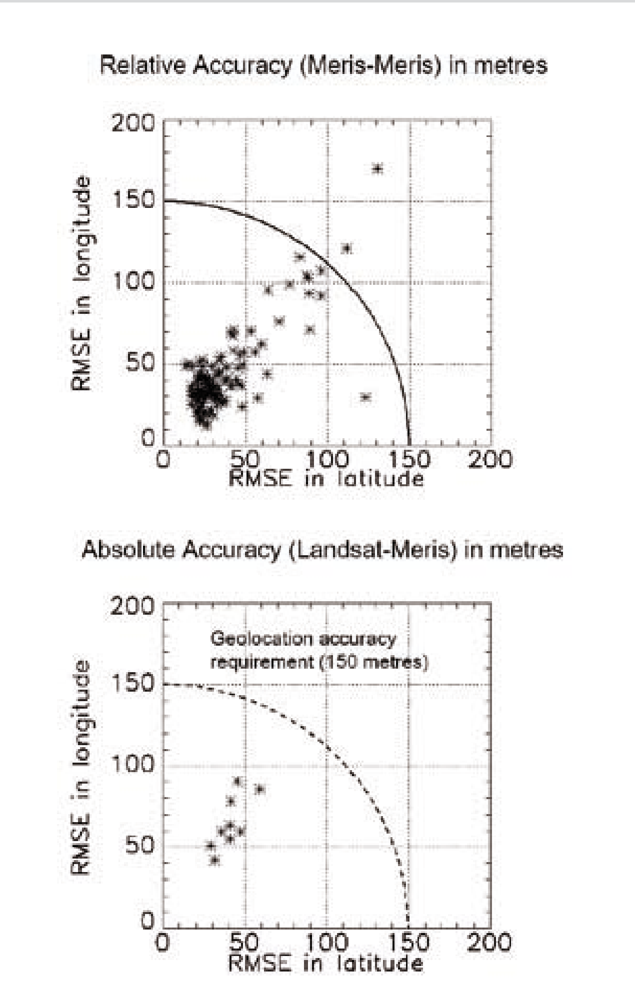
The GlobCover land cover product is the first freely available product at 300 m resolution and is therefore a milestone product that will be fundamental to a broad-level stakeholder community. There are 22 different land cover types shown in the map, including croplands, wetlands, forests, artificial surfaces, water bodies and permanent snow and ice. For maximum user benefit, the map's thematic legend is compatible with the UN Land Cover Classification System (LCCS).

In order to deliver the full dataset, the MERIS (FRS) acquisition capacities had to be dramatically increased. This was achieved through a better strategy of acquisition between ASAR and MERIS instruments outside the view of the Artemis Data Relay Satellite. Nevertheless some parts of the world (east of the Amazonian basin, Central America, the Philippines, north-east Quebec and Labrador, the Korean


Cultivated and Managed areas / Rainfed cropland
Post-flooding or irrigated croplands
Mosaic cropland (50-70%) / vegetation (grassland/shrubland/forest) (20-50%)
Mosaic vegetation (grassland/shrubland/forest) (50-70%) / cropland (20-50%)
Closed to open (>15%) broadleaved evergreen and/or semi-deciduous forest (>5m)
Closed (>40%) broadleaved deciduous forest (>5m)
Open (15-40%) broadleaved deciduous forest/woodland (>5m)
Closed (>40%) needle-leaved evergreen forest (>5m)
Closed (>40%) needle-leaved deciduous forest (>5m)
Open (15-40%) needle-leaved deciduous or evergreen forest (>5m)
Closed to open (>15%) mixed broadleaved and needle-leaved forest
Mosaic forest or shrubland (50-70%) and grassland (20-50%)
Mosaic grassland (50-70%) and forest or shrubland (20-50%)
Closed to open (>15%) shrubland (<5m)
Closed to open (>15%) grassland
Sparse (<15%) vegetation
Closed (>40%) broadleaved forest regularly flooded, fresh water
Closed (>40%) broadleaved semi-deciduous and/or evergreen forest regularly flooded, saline water
Closed to open (>15%) grassland or shrubland or woody vgt on regularly flooded or waterlogged soil, fresh, brakish or saline water
Artificial surfaces and associated areas (Urban areas >50%)
Bare areas
Water bodies
Permanent Snow and Ice
No data

peninsula) are still sparsely covered. A new methodology combining MERIS FR and MERIS RR is under investigation to cover these problematic areas.

In order to be able to use the time series of measurements properly, ESA also made a considerable effort to improve MERIS data geo-location accuracy. A resolution of 150 m was requested by the user community and, as a consequence, GlobCover can use MERIS only if such requirement is satisfied. For this purpose, ESA commissioned ACRI to develop the AMORGOS software that takes as input the Level 1B MERIS FR, the restituted attitude file and operational or precise orbit file. AMORGOS was integrated in the GlobCover processing chain by MEDIAS, complete with a projection toolbox.



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Geolocation accuracy of the MERIS products after AMORGOS processing. Upper plot shows the relative accuracy between MERIS-MERIS couples. Plot on the bottom shows the absolute accuracy between MERIS-Landsat couples. Semicircles represent the minimum accuracy requested by the GlobCover project

The quality of the geolocation accuracy was assessed using 146 pairs of MERIS products for the co-registration estimation. The absolute geolocation of the ortho-rectified MERIS FRS product was verified using 10 scenes from Landsat ETM+ (30 m spatial resolution) over a test area in Spain and Morocco. The result of this exercise was that the total RMS error associated with geolocation of MERIS FRS data was 77.1 m and thus the accuracy requirement set for the project was achieved, with only isolated images exceeding 150 m resolution.

The GlobCover system

The GlobCover system consists of three components: (1) the GlobCover software, (2) the execution environment and (3) the hardware. The system has to be capable to ingest all Level 1B MERIS FRS data acquired over a full year plus intermediate and final products of the pre-processing and classification chain. In total this amounts to a data load of 46 TB.

The pre-processing chain starts with the geometric correction of the MERIS Level 1B data. After the geometric correction, the data run through several processing steps to calculate surface directional reflectance (SDR). Algorithms have been implemented to adjust images for atmospheric influences (i.e. gaseous absorption, Rayleigh scattering, aerosol effects), to detect and flag clouds, snow areas and land/water bodies, and to correct the images for the smile effect inherent in MERIS data. Before archiving the resulting MERIS FR Level 2 data, the images are projected and resampled into the plate-carrée projection. The previous full swath images are also subset into 5° x 5° tiles, which represents the standard size for a GlobCover product (HDF format).

Level 3 processing computes bi-monthly, seasonal and annual mosaics. A compositing technique using the Bidirectional Reflection Distribution Function to correct the reflectance for different illumination and viewing geometries is applied for the bi-monthly mosaics. Temporal compositing is then used to generate seasonal and annual mosaics by averaging monthly mosaics over the selected period.

The classification subsystem generates a global land cover map out of these cloud-free mosaics. The classification runs separately for 22 equal-reasoning areas and is organised into five steps. The first process classifies the selected mosaics spectrally in a large number of classes. These classes are then temporally characterised by the computation of phenological parameters (start, end and duration of the vegetation period), using the time series of MERIS mosaics. The subsequent clustering algorithm uses the previous spectral and temporal information to group classes with similar characteristics in a manageable number of spectro-temporal classes. The fourth processor, the referenced-based labelling function, transforms these spectro-temporal classes into previously defined LCCS land cover classes. The final procedure is the expert-based labelling. This applies an upgraded set of labelling rules to improve the referenced-based labelling and to produce the final land cover map.

(Based on a random sampling of 2186 cases, the experts achieved the following results for homogeneous land cover. For the principal classes, the users' accuracies are as follows: 82.7% for cultivated and managed terrestrial land, 69.5% for natural and semi natural terrestrial vegetation, 19% for natural and semi-natural aquatic vegetation, 63.6 % for artificial surfaces, 88.1 for bare areas, 74.1% for water snow and ice, while that for producers accuracies are 69.6, 87.8, 19.0, 43.8, 77.1 and 82.2%, leading to an overall accuracy of 77.9%. This value is principally due to the difficulty in mapping aquatic vegetation and artificial surfaces, which is being addressed in version 2.)

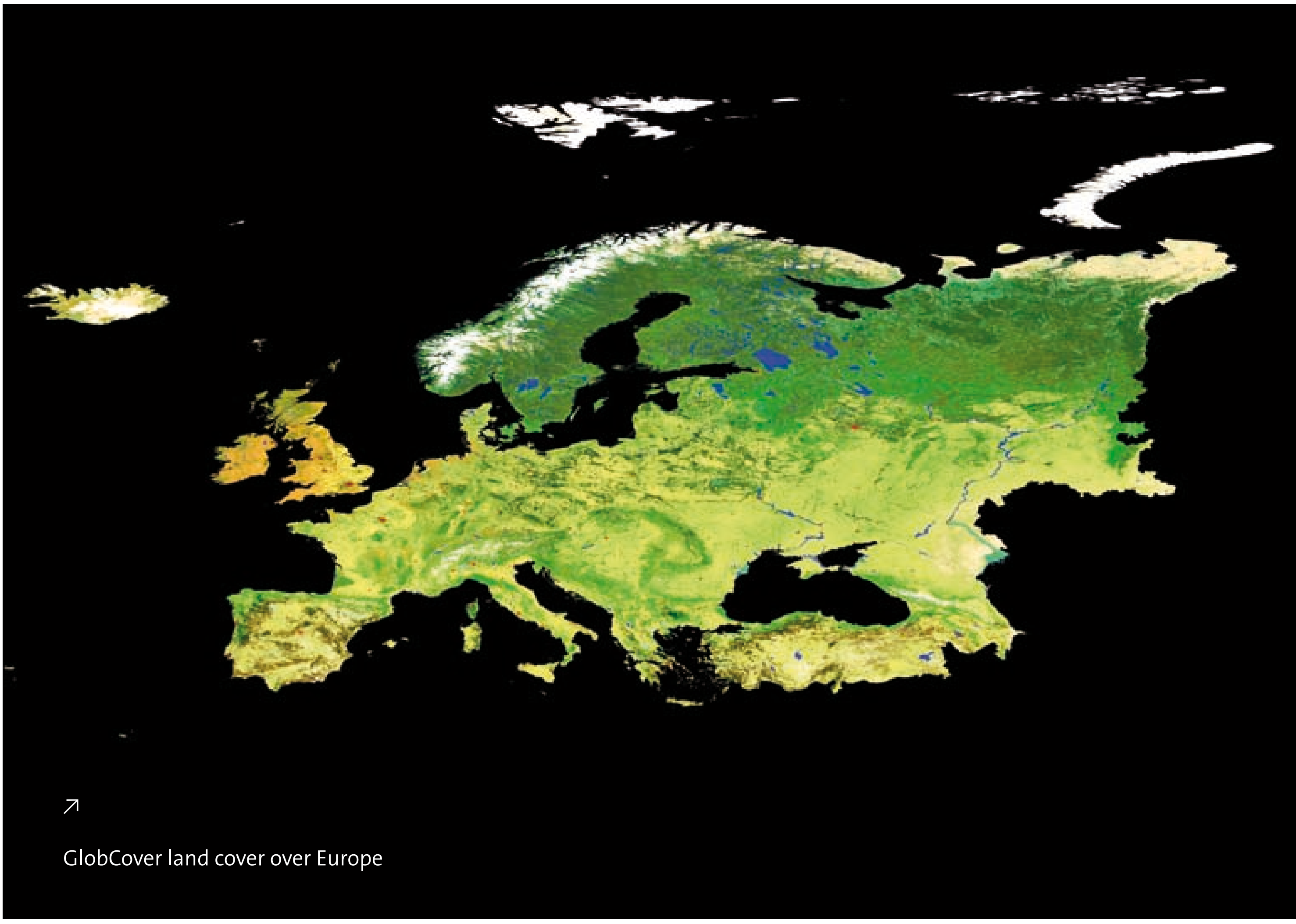
Interfacing with expert communities

An international network of partners is working with ESA on the GlobCover project, including the UN Environment Programme (UNEP), the UN Food and Agriculture Organization (FAO), the European Commission's Joint Research Centre (JRC), the European Environmental Agency (EEA), the International Geosphere Biosphere Programme (IGBP) and the Global Observations of Forest Cover and Global Observations of Land Dynamics (GOFC-GOLD) Implementation Team Project Office.

Building on the success of the GLC-2000 project (Global Land Cover map for the year 2000) coordinated by the JRC, ESA decided to launch the GlobCover initiative in the framework of its Data User Element (DUE). The GlobCover system, developed and operated by Medias-France, together with Brockmann Consult, the Université Catholique de Louvain and partners, is a great step forward in our capacity to automatically produce new global land cover products with a finer resolution and a more detailed thematic content than ever achieved in the past.

A unique and fundamental component of the project was the continuous interface with this community of eventual users and the land cover expert community, to make sure that the resulting products were 'fit for purpose' and that the user community was ready to exploit the products once they became available.

The user community is represented in the project by key individuals from UNEP, FAO, JRC, EEA, IGBP and GOFC-GOLD. Their involvement was managed through four user consultations held at ESRIN, JRC and FAO where all elements of the project were discussed and reviewed. The automatic rules were tuned according to feedback from the user community received at these meetings. In addition, a team of regional land cover experts was engaged to advise on the interpretation of the spectral-temporal classes and thus improve the automatic labelling procedure.



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GlobCover land cover over Europe

GlobCover land cover over Africa

Online distribution

The 'online' distribution of gigabytes of data was also a key issue that ESA had to face. The solution was provided by the development of the IONIA GlobCover Access Tool (GCAT) that provides easy and fast internet access to the GlobCover data products. It is accessible to any 'authorised web user' through a simple password-protected registration scheme. Once authorised, users can select any subset of the GlobCover data product through a Graphic User Interface from where the type of product (bi-monthly, seasonal, annual), geographical area and time period can be set.

Data distribution uses the BitTorrent protocol (P2P) to capitalise on the number of simultaneous users and reduce the overall stress on the server during peak user access. For this reason, the GlobCover team (ESA and partners) participating in the distribution operate as 'seeders', in bit torrent terminology. In other words, they share servers where GlobCover products are stored. To optimise distribution performance, each GlobCover composite is sub-divided in Macro Tiles (4x4 GlobCover Tiles). Users can select which type of GCAT product they wish to download (GlobCover tile, Macro tile, continental or world coverage). More information and data access can be found at : www.esa.int/due/ionia/globcover

Acknowledgements

The following people also contributed to this project:

Franck Ranera, Nigel Houghton, Philippe Goryl, Henri Laur & Stephen Briggs *ESA Directorate of Earth Observation, ESRIN, Frascati, Italy.*

Marc Leroy *MEDIAS France, Toulouse, France.*

Carsten Brockman *Brockmann Consult, Geesthacht, Germany.*

Sophie Bontemps, Pierre Defourny and Christelle Vancutsem *Université Catholique de Louvain, Louvain-La-Neuve, Belgium.*

Hugh Eva, Hans Jürgen Stiebig and Philippe Mayaux *JRC, Ispra, Italy.*

Antonio Di Gregorio *FAO, Roma, Italy.*

Jaap Van Voerden *UNEP, Chatelaine, Switzerland.*

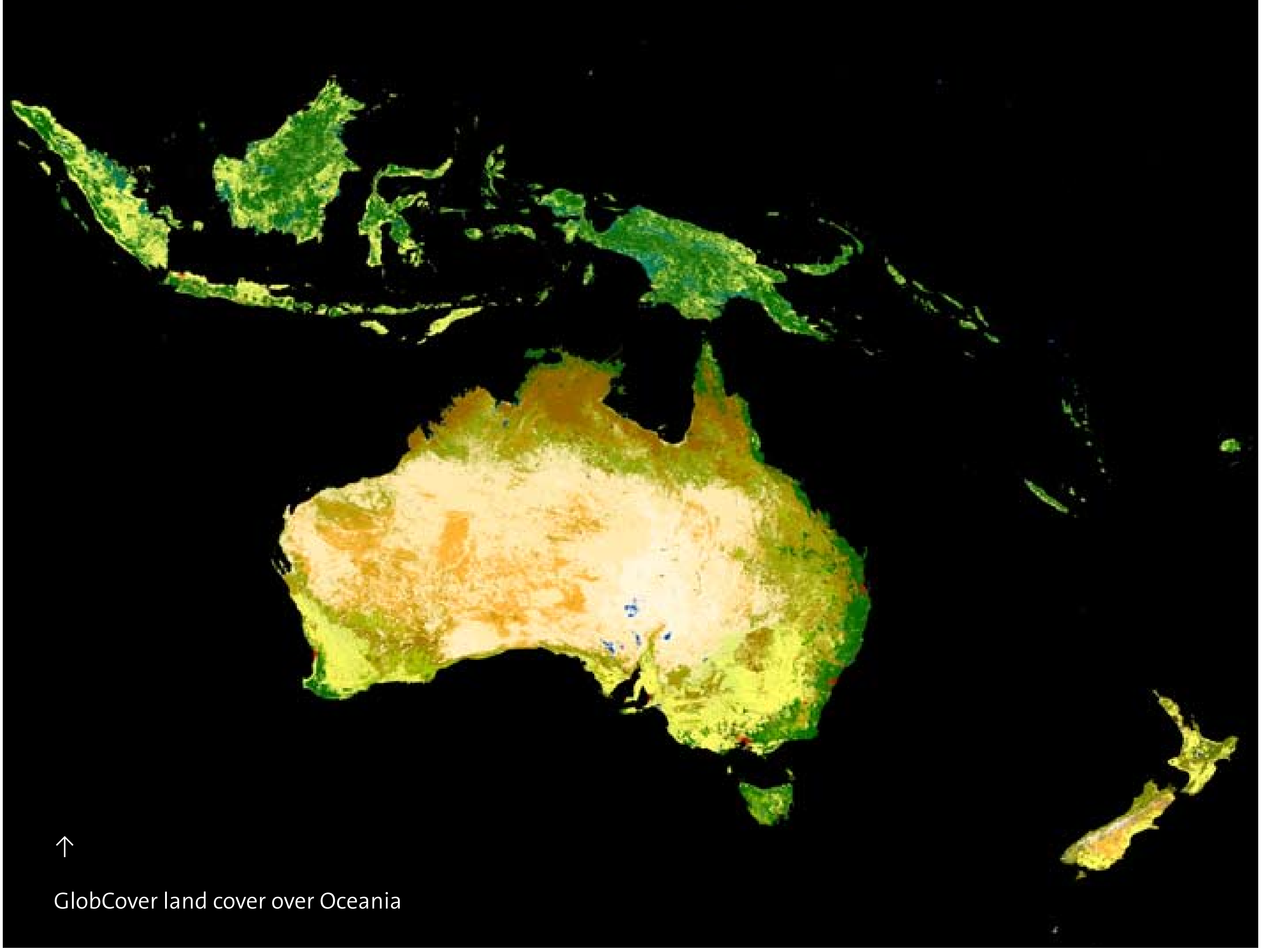
Andrus Meiner *EEA, Copenhagen, Denmark.*

Cristiana Schumullius Martin Herold, *GOFC-GOLD, Jena, Germany.*

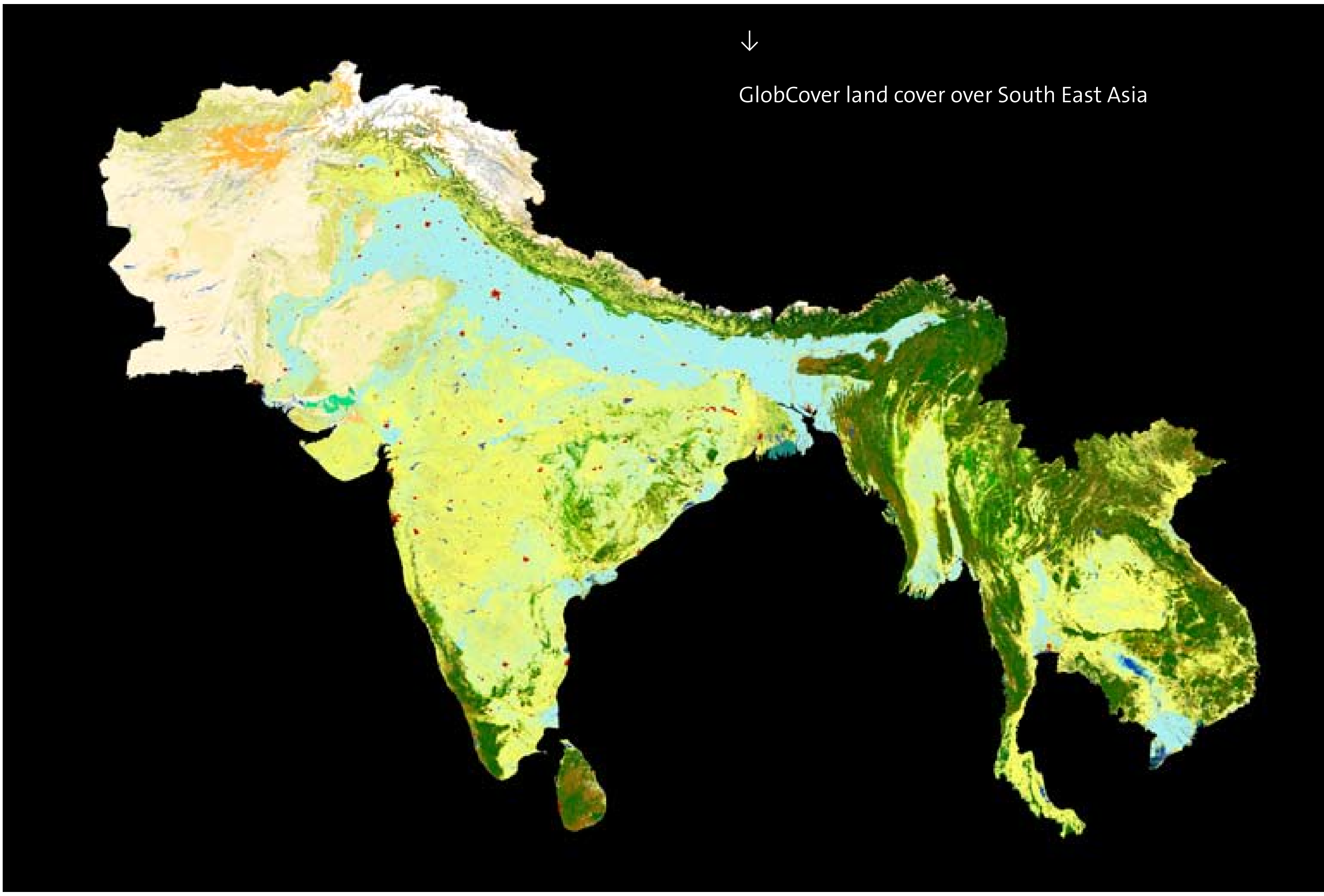
Stephen Plummer, Tobias Langanke *IGBP, Stockholm, Sweden.*

Leon Shouten *Infram, The Netherlands.*

Ludovic Bourg *ACRI-ST, Sophia-Antipolis, France.*



GlobCover land cover over Oceania



GlobCover land cover over South East Asia


esa
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esa

→ ESA'S 'REAL ESTATE' IN SPACE

Columbus in orbit

Martin Zell
Utilisation Department,
Directorate of Human Spaceflight,
ESTEC, Noordwijk, The Netherlands

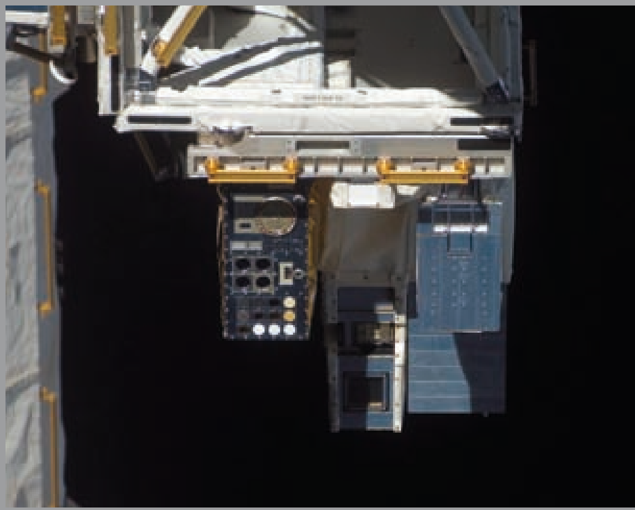
Jon Weems
Coordination Office,
Directorate of Human Spaceflight,
ESTEC, Noordwijk, The Netherlands

The European Columbus laboratory has now become an integral part of the International Space Station (ISS) since February 2008, and the scientific return from ESA's 'real estate' in space has started.

The initial part of the Columbus assembly and commissioning mission on STS-122 flight of Space Shuttle *Atlantis*, in which ESA astronauts Hans Schlegel and Léopold Eyharts played a major role, went a long way to realising the potential of Columbus's science capabilities. This was continued on orbit by Eyharts and the other permanent ISS crew members of Expedition 16 after *Atlantis* undocked, and is now continuing with the Expedition 17 crew. The hard work has continued on the ground as well, to bring Europe's laboratory up to fully functioning status.

It has been an extremely busy few months for all concerned: in the Columbus Control Centre in Oberpfaffenhofen, Germany, where overall Columbus operations are orchestrated; in the individual User Support and Operations Centres around Europe responsible for overseeing Columbus payload operations activities; for the science teams of the experiments taking place; and for the international ISS partners and everyone else involved in making the systems and science equipment of Columbus become a working reality in orbit.

In addition to all the Columbus system and payload commissioning activities that have taken place in the past months, an extensive amount of experiment data has been continuously provided by the external experiment facilities EuTEF and SOLAR. The first runs of experiments have taken place using Columbus internal multi-user facilities including the recent successful runs of the Geoflow experiment in the Fluid Science Laboratory. Adding this to the relocation to Columbus of experiment facilities from the US Destiny laboratory, additional European experiments taking place, and further science and commissioning activities to come, Columbus has already become the hub of European and even NASA utilisation on the ISS.



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EuTEF seen mounted on the Columbus External Payload Facility

First experiment and external facilities

The first steps in scientific utilisation of Columbus took place during the assembly and commissioning mission itself in February 2008. The external payload EuTEF (European Technology Exposure Facility) carried out the first Columbus experiment, and this was before it was even attached to the European laboratory. EuTEF houses a suite of experiments requiring long-term exposure to open space and covering a variety of disciplines including material science, plasma physics, astrobiology, astronomy and space technology.

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Léopold Eyharts works in Columbus, anchoring himself with his feet. An EVA suit is stored in spared space (left)

Table 1

→ EuTEF experiment performance

DEBIE-2	‘Debris In orbit Evaluator’, a standard *in situ* space debris and micrometeoroid monitoring instrument, still performing regular 24-hour experiment runs.
DOSTEL	Dosimetric Radiation Telescope, a small radiation telescope that continues to gather scientific data on the radiation environment outside the ISS.
EXPOSE	A series of five exobiology experiments, dealing with different elements of exposure, for example of lichens, fungi and micro-organisms to open space, continues to perform well.
EuTEMP	Completed science objectives
EVC	Earth Viewing Camera, a fixed-pointed Earth observation camera, previously returned good images but currently switched off awaiting a new data acquisition run.
FIPEX	This sensor continues with experiment runs that are helping to build a picture of the atmospheric environment in low Earth orbit by measuring atomic oxygen.
MEDET	Materials Exposure and Degradation Experiment, evaluating the effects of open space on materials being considered for future use on spacecraft in low Earth orbit.
PLEGPAY	Plasma Electron Gun Payload, studying the interactions between spacecraft and the space environment in low Earth orbit, with reference to electrostatic charging and discharging.
TRIBOLAB	A series of experiments in tribology, i.e. the research of friction in mechanisms and lubrication, under long-term open space conditions. Ball-bearing experiments 1, 2, 3 and 4 ran from June to present with a break in between to carry out ISS activities.

All 13 experiments on EuTEF have successfully produced research results so far according to the individual experiment protocols, the majority on a regular basis.

EuTEMP, a multi-input thermometer, was the first EuTEF (and Columbus) experiment to start and reach its objectives. During the final spacewalk of the Columbus mission on 15 February, when EuTEF and SOLAR were being deployed on the Columbus External Payload Facility, EuTEMP successfully measured EuTEF temperatures during transportation from the Shuttle’s cargo bay. This experiment is now inactive, having completed its science objectives, but scientific data continues to be acquired by other experiments housed on EuTEF (see Table 1).

The other external payload facility, SOLAR, has also carried out repeated study cycles of the Sun with unprecedented accuracy across most of its spectral range. It is located on the Columbus External Payload Facility along with EuTEF. Due to the nature of such a study, this is not a continuous process, because observations can only occur outside eclipse periods when the ISS is in a suitable orbital attitude and profile. The coarse-pointing device of SOLAR hosts three spectrometers (SOVIM, SOLSPEC and SOLACES) and tracks the Sun automatically with high precision. SOLAR will continue its measurement cycles in space for about two years.

Having the External Payload Facility installed outside Columbus has been a valuable asset in Columbus utilisation because it has enhanced the scientific return from the laboratory without significantly increasing the infrastructure cost, by exploiting automated operations with almost no crew intervention. The external surface of Columbus also provides an attachment location for two of NASA's Materials on the ISS Experiments, which evaluate the effect of the space environment on a large variety of exposed materials.

Fluid Science Laboratory and Geoflow

Looking at the research facilities inside the ISS, one of the experiments that successfully finished its first experiment runs in Columbus is the Geoflow experiment in the Fluid Science Laboratory (FSL). The FSL is a multi-user facility designed to study the dynamics of fluids in the absence of gravitational forces using advanced optical diagnostics for in situ observation of physics processes. The first run of Geoflow took place on 7 August and runs will continue in the next ISS Increment science programme into mid-2009.

The Geoflow experiment investigates the flow of a viscous incompressible fluid between two concentric spheres rotating around a common axis, under the influence of a simulated central force field. This is of importance for astrophysical and geophysical problems, such as global-scale flow in the atmosphere, oceans or the liquid cores of planets. Results from Geoflow will also be useful for making improvements in a variety of engineering applications, such as spherical gyroscopes and bearings, centrifugal pumps and high-performance heat exchangers.

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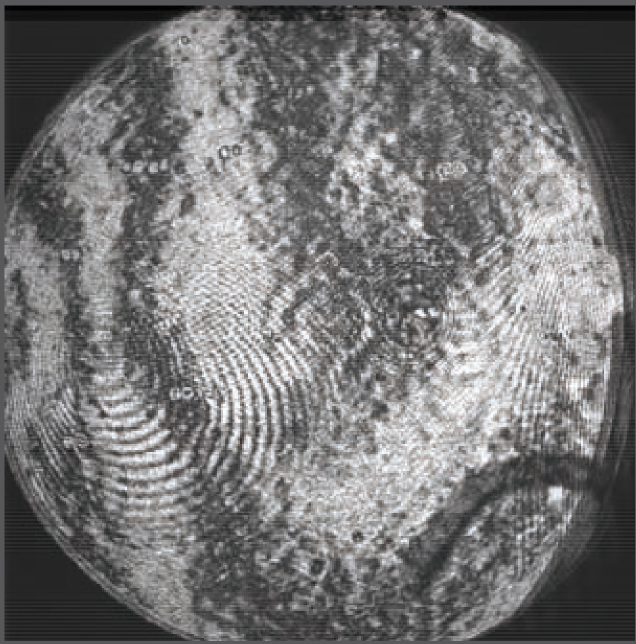
SOLAR mounted on the top of the External Payload Facility



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The first Geoflow interferometric images delivered by ESA's Fluid Science Laboratory (C. Egbers, BTU Cottbus)

Live interferometric images received during the experiment were very good and the scientific data stored in the FSL were downlinked to the Columbus Control Centre in Oberpfaffenhofen, Germany. This was then forwarded to the responsible User Support Operation Centres: MARS/Naples, E-USOC/Madrid and the User Home Base of the science team for detailed analysis.

Outside experiment runs, the internal accelerometers of FSL were used on 13 August to take measurements of the change in microgravity levels during a boost of the ISS to a higher altitude by the ATV *Jules Verne*. Data from the accelerometers are helpful in providing the range of vibration levels experienced by the Columbus internal payloads during such activity.

Though the commissioning activities of FSL finished later than originally expected, the fact that the facility was brought online and completed runs of the Geoflow experiment is a testament to the abilities of the control centre teams and the astronauts on orbit. They overcame any problems and carried out all necessary commissioning tasks as quickly as possible. This includes the ISS crew repairing damaged data cabling and replacing optical elements as well as ground-controlled software upgrades and functional performance testing of the facility's optical equipment in July.

Biolab and WAICO

The Biolab facility, designed to support biological experiments on micro-organisms, cells, tissue cultures, small plants and small invertebrates, ran the first experiment to take place inside Columbus. The experiment, called WAICO (Waving and Coiling of *Arabidopsis* Roots at Different g-levels) was activated by Léopold Eyharts on 29 February 2008. The experiment, which is due to have a second run in 2009, investigates the effect of gravity on plant root growth, concentrating on a wild type and genetically modified type of *Arabidopsis* seed.

The samples from WAICO developed well and the zero-g ones were returned to Earth on Shuttle flight STS-123, which landed on 26 March 2008. These were handed over to the lead scientist for the experiment who issued a report at the beginning of July stating that interesting and partially unexpected results had been achieved. The 1g reference samples on orbit could not be retrieved however due to a Biolab centrifuge blockage. The crew replaced the centrifuge locking pin at the end of May, and a power supply module at the end of July. With the facility now ready again for operations, the two centrifuges and Handling Mechanism will now be tested to confirm full functionality of Biolab prior to the second run of WAICO.

With an eye on future plans for long-term human exploration missions to the Moon and Mars, WAICO could contribute to our knowledge of growing crops in space, providing astronauts with fresh produce with enough nutritional value for a voyage that could last up to two years, and could also help increase the efficiency of agricultural processes on Earth by understanding growth issues at a cellular level.

European Drawer Rack and European Physiology Modules

ESA's remaining two experiment facilities in Columbus have been commissioned and are waiting to start their first experiments: the European Physiology Modules and the European Drawer Rack, which houses the Protein Crystallisation Diagnostics Facility. For the European Physiology Modules, which are designed to investigate the effects of long-duration spaceflight on the human body, final calibration of one of the facility's science modules (called the Multi-Electrode Electroencephalogram Measurement Module) will take place towards the end of September 2008. This module will be used for different types of non-invasive brain function investigations and can also easily be reconfigured to support research in the field of muscle physiology.

The SOLO experiment will carry out research into salt retention in space and related human physiology effects at the end of Increment 17 by the NASA crew member using certain capabilities of the European Physiology Modules and NASA's Human Research Facility. The first experiment to use the full capabilities of the European Physiology Modules facility is called NeuroSpat and will take place when the next European astronaut arrives on the ISS in May 2009. This will be ESA astronaut Frank De Winne (B), who will become a member of the first six-person ISS expedition crew. NeuroSpat will investigate the ways in which crew members' three-dimensional perception is affected by long-duration stays in weightlessness.

→ Léopold Eyharts

Test pilot, French Air Force
Born: 28 April 1957, in Biarritz, France

Experience: Engineer, French Air Force Academy, Salon-de-Provence, 1979. Graduate of French test pilot school (EPNER), Istres 1988, then Brétigny-sur-Orge Flight Test Centre near Paris, becoming Chief Test Pilot in 1990. Eyharts has logged 3800 hours flying time on over 50 types of aircraft and 21 parachute jumps including one ejection.

Selected by the French space agency CNES in 1990. Assigned to support the Hermes space plane programme. Pilot and engineer for CNES parabolic flights.

Trained at the Yuri Gagarin Cosmonaut Training Centre, Moscow, 1991 and 1993. Back-up crew, French-Russian Cassiopée mission, 1996. Prime crew, CNES follow-on flight Pegase, 1998.

Joined ESA: 1998. Assigned to NASA Johnson Space Center, as Mission Specialist for Shuttle flights. Back-up flight engineer, Astrolab long-duration mission to ISS, 2006. Prime crew STS-122 and Expedition 16, two-month ISS mission to deliver the European Columbus laboratory, 2008.

Married, one child.
Hobbies: jogging, mountain biking, tennis, reading and computers.

Further scientific utilisation in the area of physiology has already taken place in Columbus with the 3D Space experiment. This study investigates the effects of weightlessness on the mental representation of visual information during and after spaceflight. Accurate perception is a prerequisite for spatial orientation and reliable performance of tasks in space. Three sessions were carried out in June and July by NASA astronaut Greg Chamitoff and a fourth session is planned for about two weeks before his return on Shuttle flight STS-126.

For the European Drawer Rack, ESA's flexible multi-experiment carrier in Columbus, the Processing Unit of the Protein Crystallisation Diagnostics Facility containing various protein solutions will be flown to the ISS in active mode (for continuous conditioning of samples) on Shuttle flight 15A, which is due for launch in February 2009. This facility will provide precision-controlled conditions for the growth and *in situ* observation of sensitive organic protein macromolecules, and in the future potentially also inorganic zeolite crystals. The results generated will benefit various medical and industrial applications.

Software updates and testing

Complex software drives the Columbus laboratory and its systems. As in cutting-edge technological environments on Earth, this software must also be updated from time to time. Due to some updates in Columbus software, all the facilities (internal and external) and systems had to go through a functional check starting in August, to make sure that they were compatible with the new software. All the interfaces with the Columbus Data Management System were tested, and the systems of Columbus following the software upgrade are performing flawlessly.

Facilities relocated to Columbus from Destiny

Columbus was designed to get the maximum amount of research out of the minimum amount of space. Even though Columbus was launched with a full complement of European experiment facilities, the ingenious layout of its systems means that there are still five locations for additional experiment facilities from NASA.

After Columbus was attached to the ISS, the Microgravity Science Glovebox and the European Modular Cultivation System (hosted in US EXPRESS Rack 3) were relocated from the US Destiny laboratory to Columbus on 21 March. These are ESA-developed experiment facilities provided to or shared with NASA under barter agreements respectively. The Microgravity Science Glovebox can perform a wide range of experiments in the fields of material science, fluid science, combustion science, biotechnology and crystal growth research, in a fully sealed and controlled environment, and has already been used by ESA extensively for European science experiments.

The European Modular Cultivation System is dedicated to biological experiments, namely in plant physiology. Both facilities have been utilised since relocation for NASA and JAXA experiments, respectively. During the next Increment, maintenance of the European Modular Cultivation System will be performed in anticipation of the challenging Genara experiment during Expedition 19/20. Genara is an ESA experiment that will study plant (*Arabidopsis*) growth activity at a molecular level in weightlessness. This will help to find plant systems that compensate for the negative impact on plant growth in space.

European science outside Columbus

Even though Columbus is the principal focus of European

→ Hans Schlegel

Physicist
Born: 3 August 1951 in Überlingen, Germany

Experience: Second lieutenant, paratrooper, German armed forces, 1970-72. Masters degree, Physics, University of Aachen, Germany, 1979. Experimental solid-state physicist, Rheinisch Westfälische Technische Hochschule (RWTH) Aachen (University of Aachen) 1979-86. Specialist in non-destructive testing methodology Institut Dr. Förster Gmbh & Co., Reutlingen, Germany, 1986-88

Selected by the German space agency DLR in 1988. A qualified research diver, he also holds a private pilot's license, including instrument rating and aerobatics. Back-up crew, German-Russian Mir '97 mission, 1997. Payload specialist, STS-55/D2 Spacelab mission, 1993.

Joined ESA: 1998. Trained as Mission Specialist at NASA Johnson Space Center, 1998. Mission Specialist, STS-122 mission to deliver ESA's Columbus laboratory to the ISS, 2008.

Married, seven children. Hobbies: skiing, scuba diving, reading, and being a handyman.

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NASA astronaut Clay Anderson, Expedition 15 Flight Engineer, poses next to the ANITA equipment on the ISS science on the ISS, the European utilisation programme has extended outside the European laboratory while it has been attached to the ISS. In the Russian segment, the ALTCRISS experiment continues to monitor radiation measurements in the Russian Zarya module.

The Nitric Oxide Analyser (NOA) experiments have been monitoring exhaled nitric oxide levels in astronauts as an early sign of airway inflammation during normal activity, or signs of decompression sickness after extravehicular activity. The simulated human head and torso of the Matroshka experiment has been measuring radiation doses experienced by astronauts. The Global Transmission Service has been continuously determining the performance and accuracy of a specially coded time and date signal transmitted to earth from the ISS. The Eye Tracking Device, and Immuno and Sample experiments respectively returned a hard disk drive, blood and urine, and biological samples on Soyuz 15S in April 2008. In Destiny, the Analyzing Interferometer for Ambient Air (ANITA) was monitoring trace gas levels in the ISS cabin atmosphere. After almost a year of service as an operational ISS system device, ANITA will be returned to Earth on Shuttle flight ULF-2 in November 2008.

Europe's growing success in mission control

Control centres are the 'brains' driving each element of a mission and credit has to be paid to the Columbus Control Centre (responsible for overall Columbus mission control) and the individual USOC teams for their hard work in providing the level of achievement delivered so far, especially when taking into account the many complexities in the commissioning process and in the day-to-day running of such a space laboratory.

This is compounded by the fact that the three-person ISS Expedition 17 crew (two Russian, one American), who are the on-orbit operators of Columbus, have additional commissioning activities in connection with the Japanese Kibo laboratory, which arrived at the ISS after Columbus, as well as other ISS maintenance tasks and scientific activities. The changeover to the six-person expedition crew in the middle of next year will provide more astronaut resources on the ISS to devote to scientific activities.

→ Frank De Winne

Assigned as Flight Engineer, Soyuz TMA-15 and Expedition 19, a long-duration mission to the ISS, May-November 2009.

Test pilot, Belgian Air Force
Born: 25 April 1961, in Ghent, Belgium

Experience: Graduate of Royal School of Cadets, Lier, 1979. Masters degree in telecommunications and civil engineering, Royal Military Academy, Brussels, 1984. Graduate of Empire Test Pilot School, Boscombe Down, UK, where he was awarded the McKenna Trophy. Various assignments as test pilot from 1992, including Eglin and Edwards Air Force Bases, USA. Senior test pilot, Belgian Air Force, 1996-98.

Commander, 349th Fighter Squadron, Kleine Brogel, Belgium. Commander of the Deployable Air Task Force, a combined Belgian/Dutch detachment during NATO operation Allied Force. He has flown 17 combat sorties. De Winne has logged more than 2300 hours flying time on several types of high-performance aircraft including Mirage V, F16, Jaguar and Tornado.

Joined ESA: 2000. Trained at the Yuri Gagarin Cosmonaut Training Centre, near Moscow, 2001. Flight Engineer, Soyuz TMA-1 Odissea mission to ISS, 2002. Back-up Mission Specialist for STS-122 and Expedition 16, 2005.

Married, three children.
Hobbies: football, small PC applications and gastronomy.

←

The Columbus Control Centre in Oberpfaffenhofen, Germany

Further credit is due for the talent and professionalism that the operations teams have shown in dealing with unexpected situations in the past months, ensuring that the experiments on orbit can fulfil their objectives. Sometimes this only needed the equivalent of a system reboot, but occasionally it might be more complex.

With respect to the external facilities, data links are one example of an issue that the Columbus Control Centre and USOC teams have been successfully troubleshooting for certain experiments. A Local Area Network connection issue between Columbus and SOLAR was solved at the end of July by rerouting communications for a power feeder through a different Ethernet network switch. As soon as this was done by NASA astronaut Greg Chamitoff, the SOLAR facility started to resend data to the ground and full control of SOLAR was recovered.

Another data link problem was discovered with the DEBIE-2 and FIPEX instruments on EuTEF. While a software patch was being developed, the control centre teams developed a work-around solution that allowed regular acquisition of scientific data. The control centre teams are also working on a high-rate data link issue with the Earth Viewing Camera on EuTEF. In all these activities, the control centre teams have received important expert engineering support from the industrial operators.

In the context of European human spaceflight activities, being faced with and overcoming these kinds of unexpected on-orbit situations is a positive achievement in mission control scenarios, because they highlight the experience that Europe has built up and is continuing to expand in this area. This will be of immense importance when planning and flying future, longer-term European manned missions.

In the future

In the past months, since the arrival of Columbus at the ISS, there has been an upturn in the European utilisation on the ISS despite the limited crew resources and continued focus on ISS assembly. With Columbus, the infrastructure is now in place to further develop Europe's long-term science programme for the ISS in a variety of disciplines. New experiments and hardware are already in the pipeline for transport to the ISS on future flights and we will see two European astronauts flying to the ISS next year, with Christer Fuglesang (S) temporarily joining Frank De Winne to the ISS as a member of the STS-128 mission in August 2009. This mission also delivers ESA's Materials Science Laboratory.

In late September and early October 2008, before the next crew exchange, we will still see another two NASA facilities relocated to Columbus from the US Destiny laboratory. These are the two Human Research Facilities, one of which houses the ESA/NASA developed Pulmonary Function System, which can analyse exhaled gas from astronauts' lungs and provide near-instant data on the state of crew health. It is used to perform the Periodic Fitness Evaluation with Oxygen Uptake Measurements, part of the continuous crew medical operations and last happening on 21 August. Also on the issue of crew health, the Flywheel Exercise Device, which is now stowed in the European Transport Carrier in Columbus, will be deployed and checked out after Shuttle flight 15A in early 2009. This novel on-orbit training unit was launched to the ISS to become an advanced exercise device for astronauts on the ISS.

→ Christer Fuglesang

Assigned as Mission Specialist, STS-128 mission to ISS, July 2009.

Physicist
Born: 18 March 1957 in Stockholm, Sweden
Experience: Masters degree, Engineering Physics, Royal Institute of Technology (KTH), Stockholm, 1981. Doctorate, Experimental Particle Physics, 1987. Worked at CERN (European Research Centre on Particle Physics) in Geneva on the UA5 experiment, which studied proton-antiproton collisions.
Fellow of CERN, 1988; Senior Fellow and head of the particle identification subdetector, CERN, 1989. Lecturer in Particle Physics, University of Stockholm, 1991.
Affiliated Professor, KTH, 2006.
Joined ESA: 1992.
Trained at the Yuri Gagarin Cosmonaut Training Centre, Moscow, with a view to future ESA-Russian collaboration on Mir Space Station. Back-up flight engineer, Euromir '95 mission, 1993-96.

Qualified for flight assignment as a Shuttle Mission Specialist in April 1998 at NASA Johnson Space Center, Houston, in 1998. Qualified as Russian 'Soyuz Return Commander', enabling him to command a three-person Soyuz capsule on its return from space. Support crew, second ISS increment crew, Johnson Space Center. Mission Specialist, STS-116 mission to ISS, December 2006.

Married, three children.
Hobbies: sports, sailing, skiing, frisbee, games and reading.

→ Columbus rack facilities photogallery

← Fluid Science Laboratory (FSL)

← European Physiology Modules (EPM)

← Hans Schlegel working on the setting up of Biolab

← NASA astronaut Greg Chamitoff works with the European Microgravity Science Glovebox

← European Drawer Rack (EDR)

← European Modular Cultivation System (EMCS)

→ JULES VERNE'S JOURNEY FROM EARTH TO ISS

ESA's first space ferry

John Ellwood, Heinz Wartenberg, Jean-François Clervoy & Frederic Castel
ATV Project Office, Directorate of Human Spaceflight,
Les Mureaux, France

Alberto Novelli & Hervé Come
Directorate of Human Spaceflight,
ESA/CNES Toulouse Space Centre (CST),
Toulouse, France

With a perfectly controlled re-entry high above the Pacific Ocean on 29 September, ESA's *Jules Verne*, the first of five Automated Transfer Vehicles (ATVs), successfully completed its six-month inaugural mission – proving itself as Europe's space supply vessel.

Launched on 9 March 2008 on a modified Ariane-5, the most challenging and complex space vehicle ever developed by ESA has met all its objectives, with flying colours. Named after the visionary French author, ESA's first space ferry has ushered in a new era for European space transportation, achieving a milestone for human spaceflight and space exploration.

Together with Russia's Progress and the NASA Space Shuttle, the ATV has become the third spacecraft type with the capability to resupply the International Space Station (ISS) on a regular basis. The ATV cargo capacity is about three times that of Progress.

On 3 April, ATV *Jules Verne* became the first spacecraft ever to self-navigate in orbit and control its own rendezvous with a manned space station, based solely on the use of relative GPS and optical sensors. This unique capability of autonomous rendezvous is the main difference between ATV and Russian Soyuz and Progress spacecraft; ATV relies solely on its on-board sensors for the final approach, the Russian vehicles need data provided by the ISS radar sensors in addition to their own sensors. All US rendezvous and dockings in space have been performed manually and visually by astronauts.

Jules Verne then completed all its resupply tasks for the ISS and also provided propulsion support to the Station, such as giving it regular reboosts and even an unexpected debris avoidance manoeuvre for the 300-tonne orbital outpost.

Looking beyond 2010, when Shuttle flights are scheduled to end, the ATV is poised to become an even more critical and indispensable contribution for the Station and for the ISS partners. Moreover, the ATV is currently the only space vehicle capable of deorbiting the ISS at the end of its life. Together with the launch of ESA's Columbus multi-purpose science laboratory earlier this year, the success of the ATV means that Europe becomes a fully fledged partner of the ISS.

The ATV enables Europe not only to transport its own payload to the ISS, but also to carry propellant, gases and other goods for use by the entire ISS and its partners. It also ensures the delivery of experiments and scientific equipment to Columbus.

The five ATV missions are intended to cover in kind the European share of the common operational costs of the ISS, in the same 8.3 % contribution Europe has in the ISS programme. In particular, they allow a European astronaut to live and work aboard the station for six months every two years without any exchange of funds.

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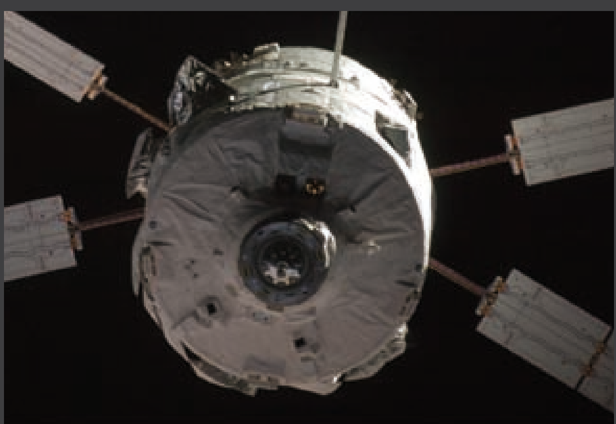
A close-up view of ATV taken from the ISS, with one of the partially detached thermal blankets visible on the left



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ESA's ATV compared to the Russian Progress Spacecraft

The mission

The first ATV rendezvous attempt with the ISS demanded strict safety protocols. Rendezvous operations were designed so that each critical step of the rendezvous would be demonstrated at a safe distance from the ISS before proceeding with the final approach. For each of these steps, the performance was reviewed by a dedicated team of NASA, RSC Energia and ESA experts.

The launch took place exactly as planned. Lifting twice its usual payload mass, the Ariane-5 upper stage performed an initial eight-minute burn over the Atlantic Ocean and entered a 45-minute coast phase, flying over Europe and Asia before reigniting for a 40-second circularisation burn over Australia. *Jules Verne* was delivered into the planned 260-km altitude orbit, and the critical early automatic operations to secure power autonomy (deployment and orientation of solar panels) were carried out as planned as the vehicle gently stabilised itself.

About two hours into the flight, a problem in the pressurisation of the propellant lines triggered the ATV on-board Failure Detection, Isolation and Recovery system. This failure management software executed its job correctly, switching to a back-up pressurisation device and shutting down one of the four propulsion chains after detecting a temporary discrepancy in pressure between the system's fuel lines and its oxidiser lines. An engineering investigation confirmed immediately that this problem would not affect the *Jules Verne* mission: it would be fixed for future ATVs.

During the free-flight phase, telemetry data indicated a thermal anomaly on the Integrated Cargo Carrier (ICC) shell and much higher than normal activity with some shell heaters. Engineers quickly concluded that several heat leaks existed on the ICC shell. The suspected cause was a partial detachment of the multi-layer insulation thermal blankets around the ICC cylinder. Because the thermal and power situation remained acceptable, this was not considered to be a problem and the mission continued normally.

→ History of ATV

For more than a decade, ATV has involved thousands of high-tech workers in dozens of companies from ten European nations under the prime contractor EADS Astrium. The top contractor companies include Thales Alenia Spazio, Contraves Space, Dutch Space, Snecma, Alcatel Espacio, Crisa and MAN. Eight Russian companies were also involved, with the main contractor, RSC Energia, in charge of providing 10% of the ATV development (docking and refueling systems and assorted electronics).

For the first time, the new ATV Control Centre (ATV-CC) in Toulouse acted as the lead Mission Control Centre in charge of man-rated operations for the ATV, while the Mission Control Centres in Moscow and Houston supported and authorised the rendezvous to the ISS. From 2008, a team of 80 people from the French space agency CNES, Astrium and ESA based in Toulouse will now coordinate all ATV operations on behalf of ESA for the next four ATVs planned until 2015.

1994 - 111th ESA Council in Paris agreed to the Manned Space Transportation Programme, including ATV.

1995 - The Ministerial Council in Toulouse formally approved full programme development.
Ten countries (France, Germany, Italy, Switzerland, Spain, Belgium, Netherlands, Sweden, Denmark, and Norway) commit to developing the Columbus laboratory and ATV, a new generation of spacecraft combining the fully automatic capabilities of an unmanned vehicle with human spacecraft safety requirements.

1998 - Full development contract signed with Aerospatiale, now EADS Astrium. Europe and Russia reach a general agreement on the integration of ATV into the Russian segment.

2000 - Manufacturing starts for the first ATV hardware, and a full structural mock-up is put through its paces at ESTEC, Noordwijk, The Netherlands.

2002 - ATV Service Module integrated with the Avionics and Propulsion module at Astrium in Bremen, Germany. The pressurised Cargo Carrier module, the ATV's forward half that provides cargo storage and a workplace for the astronauts, is built at Thales Alenia Spazio, Turin.

2003 - The Service Module and Cargo Carrier are first integrated in Bremen. The project passes the Critical Design Review, in which some 140 international space experts analyse 55,000 pages of technical documentation before announcing their full confidence in the vehicle design. This review certifies that the ATV design and operations concept meet requirements for performance, reliability, and safety. The Functional Simulation Facility (FSF) starts to test the ATV's electronic 'brain' and flight software in computer simulations at EADS Astrium, Les Mureaux.

2004 - ATV is transferred to ESTEC for extensive acoustic, thermal, electromagnetic and functional qualification tests.

2006 - Small technical problems occur in the processing of Jules Verne, including a minor fatigue failure on a propulsion valve and an anomaly on the drive mechanism of the solar arrays. In addition, the FSF testing does not progress as fast as planned. These discoveries had a cascade effect on the schedule, but other issues, especially after the Shuttle *Columbia* accident in 2003, add another year of delay. However, this is common in such ambitious and innovative projects.

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→ History of ATV

2007 – ATV is shipped to Europe's Spaceport, Kourou, French Guiana, ready for launch.

2008 – ATV is transported to the Final Assembly Building, where it is installed on top of the launcher on 13 February. On 25 February, the fairing is closed over *Jules Verne*, ready for launch.

Later, photos taken by the ISS crew confirmed the problem to be with the attachment of the external thermal blankets. Measurements of temperature inside the cargo carrier by the crew later confirmed the robustness of the system against any thermal problem such as condensation. Simple measures are underway to prevent similar problems on future ATVs.

Approach and docking

Five days after launch, and far away from the ISS, *Jules Verne* successfully demonstrated the Collision Avoidance Manoeuvre (CAM), which consisted of braking the orbital speed by 5 m/s, then stabilising the spacecraft in a safe orbit, in a minimal 'survival' mode pointing at the Sun, using a completely independent functional chain.

The CAM demonstration was necessary to prove, before the first approach to the Station, that the spacecraft could reliably move away from the ISS in case of major system problems during the final rendezvous. In case of safety-critical situation, which could not be handled by the nominal

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Volkov and Kononenko transferred 1150kg of dry cargo from *Jules Verne* to the ISS

two-failure control system, the spacecraft's Monitoring and Safing Unit is designed to isolate the ATV's nominal systems and initiate this manoeuvre.

Due to other traffic to and from the ISS, the free-flight phase was extended from 10 to 25 days before docking. This allowed NASA to launch the Shuttle *Endeavour* on a 16-day mission carrying the first element of the Japanese Kibo science lab and demonstrated the flexibility of the complete system. For future ATV missions, docking with the ISS will happen much earlier.

The mission plan then called for three successive approaches. A more elaborate 'escape' manoeuvre, than the CAM test, was planned for each of the first two approaches. These manoeuvres were to demonstrate that the ATV could safely back away from the Station during the rendezvous if it could not be completed, but with a still controllable vehicle without going into 'survival' mode.

The first approach (called Demo Day 1) on 29 March, demonstrated that the ATV could automatically calculate its position and manoeuvre with respect to the ISS using relative GPS navigation. It performed the 'escape' manoeuvre some 3500 m behind the ISS. Two days later, on Demo Day 2, the second approach tested close-proximity manoeuvring and control, including contingency manoeuvres for both the ATV Control Centre and the crew aboard the ISS. This required that the ATV first approached within 20 m of the ISS using its innovative optical proximity sensors, retreated, and then reapproached to only 12 m from the docking port of the ISS Russian module before again backing off to a safe 20 m. This last approach provided ultimate proof that Europe's resupply vessel was ready for final and safe rendezvous and docking.

During the third approach, leading to the first planned docking attempt, *Jules Verne* paused as planned at 250 m, 20 m and 12 m guided solely by its on-board high-precision optical navigation system. Jules Verne closed in with the ISS at a relative speed of 1.4 km/h, slowing to 0.2 km/h while both spacecraft were flying in close formation at an absolute speed of 28 000 km/h. It successfully docked with the ISS on 3 April at 16:41 CEST (14:41 UT), 341 km above the southern Atlantic Ocean, just south of the equator and east of South America.

The final phases of approach and docking were monitored under the watchful eyes of ISS Commander Peggy Whitson and Flight Engineer Yuri Malenchenko. "Right now the vehicle can be seen clearly. It's lit by the Sun," said Malenchenko, just before the two spacecraft docked. With *Jules Verne* securely attached, the ISS crew entered the pressurised cargo section and started to remove the payload.

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Expedition 17 crew Greg Chamitoff, Oleg Kononenko and Sergei Volkov retrieve original 19th century Jules Verne manuscripts. Because of its comfortable size, ATV was used by two of the crew as a new area to sleep and wash

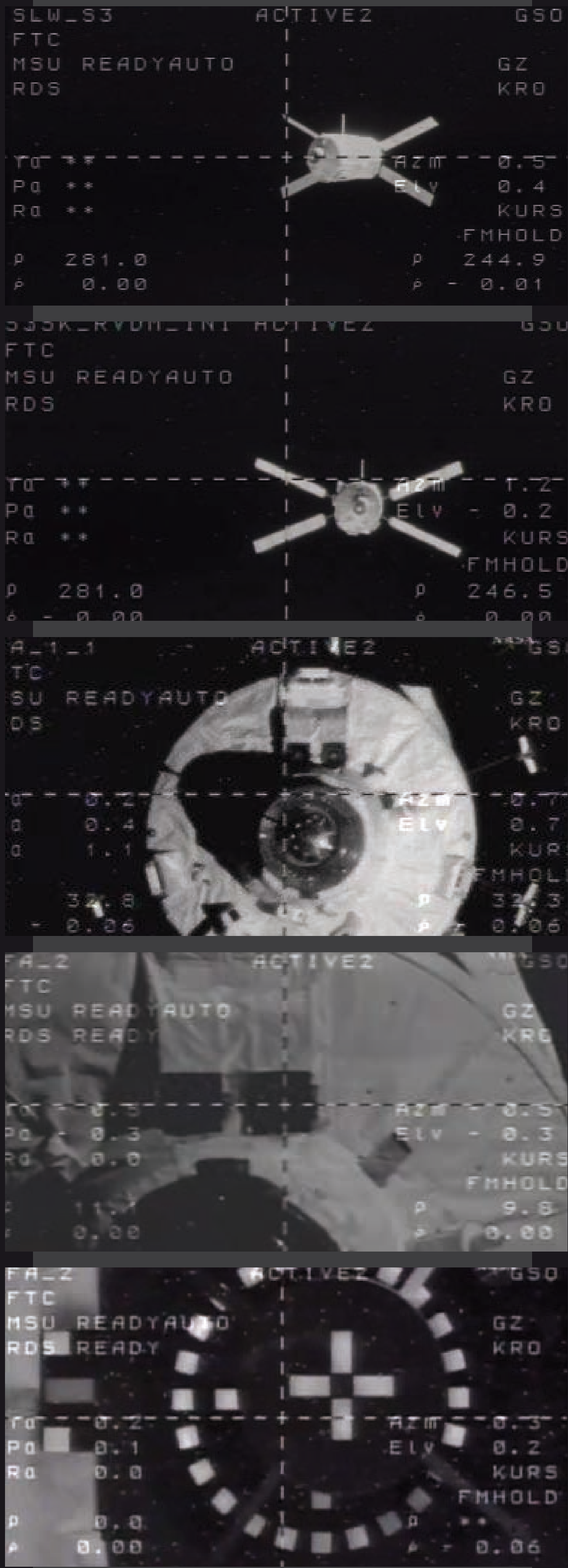
→ Docking in detail

For the first time, a supply vessel navigated as if it was 'on rails', flying straight to its moving target with an amazing accuracy superior to any manual piloting by astronauts. The position of the ideal centreline of the docking probe at the moment of docking has been estimated from telemetry to have been within 1–2 cm.

With its on-board capability to handle any combination of two failures and its one million lines of software code, Jules Verne used two types of optical sensors to guide this precise trajectory. The ATV videometer sensor analysed images of its emitted laser beam, reflected by passive reflectors located on the ISS near the Russian docking port reserved for the ATV. During the last 250 m of final approach, the videometer automatically recognised the reflector's target patterns and measured distance, position and closing rate, and finally the relative orientation of ATV to the ISS. As an extra precaution, distance and direction to the docking port were monitored based on another independent optical sensor, the telegoniometer.

During this 'clockwork' approach, Jules Verne stopped as planned at four holding points, waiting each time for a 'go' from the ground controllers to move to the next step. The automatic pilot had to respect the strict rendezvous safety corridors. These consist of a narrow virtual 'funnel' within which the ATV must stay or else an automatic escape manoeuvre would be triggered to prevent any risk of uncontrolled collision with the ISS.

In the highly unlikely case of multiple failures, exceeding the design requirements (i.e. more than two major failures), the ISS crew could also activate four types of pre-programmed actions to interrupt the ATV's approach.



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A sequence of images taken from the ISS TV camera monitoring the docking of ATV on 3 April, showing the spacecraft approaching the ISS

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Expedition 16 and 17 crew members inside ATV: Garrett Reisman, Peggy Whitson, Yuri Malenchenko, Sergei Volkov and Oleg Kononenko

The ATV's fuel tanks were connected to the plumbing system of the ISS, and the three ISS crew members, Sergei Volkov, Oleg Kononenko and Greg Chamitoff, manually transferred 269 litres of water and released 21 kg of oxygen directly into the ISS.

In June, the entire 811 kg cargo of refuelling propellant was automatically transferred to ISS. In August, the crew moved dozens of white cargo bags from the ATV, as well as two original manuscripts handwritten by author Jules Verne and a 19th century illustrated edition of his novel *From the Earth to the Moon*.

The crew also worked hard carrying items in the opposite direction, loading waste and excess equipment from the ISS into the racks and spaces left empty inside *Jules Verne*. The total dry cargo waste loaded into ATV represents 900 kg of material no longer needed on the ISS. On top of that, 264 kg of liquid waste was transferred from the ISS to the ATV in foldable plastic containers.

For five months, *Jules Verne* was a 48 m³ pressurised and integral part of the ISS, and had boosted the ISS orbit to overcome the effects of residual atmospheric drag four times.

Departure and reentry

The undocking of the ATV concluded the historic five-month attached phase of the Jules Verne mission. The ATV Control Centre sent the commands to open the hooks of the ATV, which then performed a fully automated undocking, on 5 September at 23:30 CEST.

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Image received from the DC-8 aircraft which observed the reentry of ATV over the Pacific Ocean

A few weeks later, on 29 September, *Jules Verne's* main engines used their remaining fuel in two separate deorbit boosts to terminate its three-week last solo flight. The 13.5-tonne spacecraft fell on a steep flight path, performing a controlled destructive reentry high above an uninhabited area of the South Pacific Ocean. Planning this event for the nighttime allowed the reentry to be observed by two aircraft equipped with a collection of NASA and ESA scientific experiments. The ISS crew was also able to observe the reentry with the Russian FIALKA ultraviolet and spectrometric instrument.

The success of *Jules Verne*

All *Jules Verne's* mission objectives were fulfilled, including all demonstration tasks specific to this first ATV flight. Preliminary post-flight assessment showed that *Jules Verne's* performance was well within predictions, and even better in certain cases, such as propellant consumption and the performance of the power system. After assessment of mission operations, very few design features have to be fine-tuned for future ATVs.

The ATV's pressurised cabin offered the crew a large space and a lot of additional privacy. Some crewmembers also enjoyed *Jules Verne* as their sleeping quarters or as a crew hygiene station to wash using their usual wet fabric towels and treated napkins. Last April, the ATV was also used by Yi So-Yeon, a nanotechnology engineer and the first South Korean astronaut, to perform experiments during her 11 days in space.

For the following ATVs, the capabilities will be slightly increased by improving the specifications for launch mass (20.7 tons) and cargo (7.5 tons). To ensure maximum flexibility for this demonstration flight, *Jules Verne* had carried more propellant and slightly less payload than on future ATV missions. In fact, future ATVs will carry at least one ton more than *Jules Verne*.

The future

With today's ATV technology, ESA has gained the capability for automatic rendezvous between spacecraft, which is crucial for future human planetary exploration, complex spacecraft assembly and robotic sample-return missions. The ATV is the largest automatic freighter ever built and, if future demands require, it could also evolve to carry tons of supplies into lunar or planetary orbit and beyond.

With the Space Shuttle retirement planned for 2010, the ISS partners will lose a major capability to transport crew into space and return experiments and equipment to Earth for exploitation or replacement. The next logical step for ATV would be to develop the capability to return payloads and goods from the ISS, with a final aim to develop a new crew space transportation system, based on an adaptation of the Ariane-5 launcher for manned spaceflight.

One possibility for cargo return could be to replace the pressurised ICC with a large cargo re-entry capsule with a thermal reentry shield, able to bring back hundreds of kilograms of cargo and valuable experiments. Such a project could use the flight-proven technologies of the ESA Atmospheric Reentry Demonstrator, which flew successfully in 1998.

The main advantage of such a vehicle is that its service module could be derived from the present ATV spacecraft, with the necessary adaptations. What remains is the development and qualification of the front part of the vehicle into a new reentry capsule.

Once the operational capability of bringing back cargo from space will have become routine, such a space freighter would boost confidence in continued ATV evolution. Its operational flights would also contribute to the flight qualification of a future European manned transportation system. The final step would then be a crew transportation system, which would require more complex modifications. The upper part would be transformed into a manned reentry capsule with the addition of all the subsystems required for protection and support of a crew. This second-step vehicle would require additional developments in flight safety, especially for the launch (launch escape system) and life support. A significant difference with the cargo-only variant would be the presence of this Crew Escape System, consisting of booster rockets able to pull the crew capsule away from the launcher in the event of an emergency. The crew variant of the ATV could seat four crew members.

Today, the ATV is already the most powerful space tug ever built. If required, in future programmes the ATV spacecraft could also evolve to be used as a transfer vehicle, carrying infrastructure elements and tons of supplies into orbit, including crew habitats and orbital infrastructures for successive assembly in low Earth orbit, in preparation for missions to the Moon and beyond. ■

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Martial Vanhove, CNES Flight Director for undocking, Kris Capelle, ESA Mission Director for undocking, and Hervé Come, ESA ATV Mission Director, celebrate after a successful departure from the ISS (F. Castel)

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ATV *Jules Verne* seen from the ISS after undocking, beginning 23 days of rephasing manoeuvres to prepare for reentry

→ NEWS

In brief

The International Space Station is seen from Space Shuttle Discovery as the two spacecraft begin their relative separation in June 2008. Earlier, the STS-124 and Expedition 17 crews concluded almost nine days of cooperative work on board the Shuttle and ISS

esa

Rosetta flies by asteroid

ESA's comet chaser Rosetta flew by asteroid Steins, a small body in the main asteroid belt, and collected a wealth of information about this rare type of minor body of the Solar System.

At 20:58 CEST on 5 September, Rosetta passed within 800 km of asteroid 2867 Steins, its first nominal scientific target on its 11-year journey to ultimately explore the nucleus of Comet 67P/Churyumov-Gerasimenko.

The success of this 'close' encounter was confirmed at 22:14 CEST, when ESA's mission control team at the European Space Operations Centre, Darmstadt, Germany, received initial telemetry from the spacecraft. During the flyby operations, Rosetta was out of communication because its antenna had been turned away from Earth. At a distance of about 360 million km from our planet, the radio signal from the probe took 20 minutes to reach Earth.

Steins is a small asteroid of irregular shape with a diameter of only 4.6 km. It belongs to the rare class of E-type asteroids, which had not been directly observed by an interplanetary spacecraft before. Such asteroids are small in size and are mostly found in the inner part of the main asteroid belt between Mars and Jupiter. They probably originate from the mantle of larger asteroids destroyed in the early history of the Solar System, and are thought to be composed mainly of silicate minerals with little or no iron content.

Through the study of minor bodies such as asteroids, Rosetta is opening up a new window onto the early history of our Solar System. It will give us a better understanding of the origins and evolution of the planets, and also a key to better interpreting asteroid data collected from the ground.

Together with the two navigation cameras, Rosetta's Osiris instrument was pointed towards Steins on 4 August and continued to observe the asteroid until 4 September, to assist Rosetta's navigation by optical means – a first in the history of ESA spacecraft operations.

ISS tenth birthday

Eight years of continuous manning

The International Space Station (ISS) celebrates its 10th anniversary on 20 November, and another major spa ce milestone on 2 November, as it clocks eight years of continuous human presence in space.

Today, the ISS is the largest cooperative project ever carried out in space, involving ESA, NASA, the Russian space agency Roscosmos, the Canadian Space Agency and the Japan Aerospace Exploration Agency.

The first launch of the ISS project took place on 20 November 1998, when a Russian Proton rocket lifted off from the Baikonur space centre in Kazakhstan carrying the Zarya module, the Station's first component. However, the project has its roots when the agreement to construct the ISS was signed on 29 January 1998 by representatives from ESA, Canada, Japan, Russia and the United States. On 4 December 1998, the Space Shuttle *Endeavour* delivered Unity, the second module, which docked with Zarya on 6 December. The Zvezda module was connected in July 2000, after being delivered by a Russian Proton rocket, enabling the ISS to be permanently habitable for the first time.

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The first ISS elements Zarya and Unity in December 1998

The ISS became manned by a resident crew for the first time on 2 November 2000, when the Expedition 1 crew arrived, consisting of American astronaut William Shepherd and two Russian cosmonauts, Yuri Gidzenko and Sergei Krikalev.

Since then, the ISS has continued to grow with the addition of the Italian-built Harmony Node-2 module in 2007, then ESA's Columbus laboratory and the Japanese Kibo laboratory in 2008. To date a total of 163 astronauts have visited and worked on the ISS, including the three Expedition 17 crewmembers currently on board the Station. These include European astronauts from Italy, France, Germany, Belgium, The Netherlands, Spain and Sweden.

The ISS now provides a significantly expanded orbital research and technology development facility, and serves as an engineering test-bed for flight systems and operations to be used in future space exploration initiatives.

"The ISS has grown and evolved into a sophisticated laboratory complex, the like of which has never been seen before. Operating in microgravity conditions that cannot be duplicated on Earth, the ISS gives us unique access to the space environment. It will continue to further our knowledge of science and how the human body functions for long periods of time in space. This will prove vital on future long-duration missions to the Moon and Mars," said Simonetta Di Pippo, ESA's Director of Human Spaceflight.

A few days before the flyby, most of the Rosetta orbiter instruments, as well as the Philae lander magnetometer, were switched on to collect science data as the spacecraft closed in.

On 17 December this year, Rosetta will reach the maximum distance from the Sun in its current orbit, and will then head back towards Earth for the next and last gravitational kick from our planet on 13 November 2009. This will give the probe its final push toward its cometary target.

Rosetta is scheduled to conduct another flyby, this time with the much larger (21) Lutetia asteroid, on 10 July 2010. Arrival at 67P/Churyumov-Gerasimenko is due by mid-2014. By that time the probe will have covered a distance of about 6.5 thousand million kilometres.

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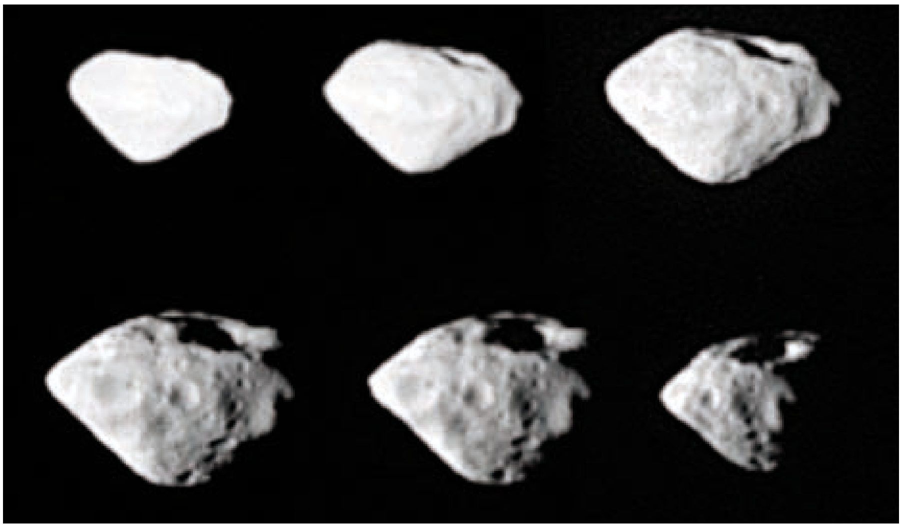
Asteroid Steins seen from a distance of 800 km by the OSIRIS imaging system on Rosetta from different perspectives



Procurement of Galileo begins

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Close-up view of the payload fairing of the launcher carrying ESA's GIOVE-B satellite

The procurement of Galileo by the European Commission – with the support of ESA – was launched in July. Galileo is Europe's global navigation system to be composed of 30 dedicated navigation satellites, a ground infrastructure and a network of dedicated stations deployed around the world.

The overall Galileo programme objective is the deployment, by 2013, of a European navigation system providing five main services, namely the Open Service, the Safety of Life Service, the Commercial Service, the Public Regulated Service and the Search and Rescue Service.

Political decisions made by the European Parliament and the Council last year resulted in the allocation of a budget for the European satellite navigation programmes EGNOS and Galileo (€3.4 billion for the period 2007–13) and provided for an agreement on the governance structure of the programmes.

This framework provides for the deployment of the Full Operational Capability of Galileo under a public procurement scheme, entirely financed out of the European Community budget. The European Commission (EC) acts as programme manager and contracting authority and ESA acts as its procurement and design agent.
The procurement initiated includes the following six work packages: system support, ground mission segment, ground control segment, space segment (satellites), launch services and operations.

The procurement of the Galileo infrastructure is particularly complex.
To this end, the EC has opted for the procurement procedure of 'Competitive Dialogue' as set out in the EC Financial Regulation Implementing Rules. The main steps of the competitive dialogue procedure will be managed by ESA in its capacity as delegated procurement agent, in close coordination with the EC as contracting authority.

Organisations interested in participating in the Galileo procurement can find more details on ESA's Galileo website and on ESA's invitation to tender (EMITS) system.

Envisat's 'North-west Passage'

Following last summer's record minimum ice cover in the Arctic, current observations from ESA's Envisat satellite suggest that the extent of polar sea-ice may again shrink to a level very close to that of last year.

Envisat observations from mid-August depict that a new record of low sea-ice coverage could be reached this year.

Current ice coverage in the Arctic has already reached the second absolute minimum since observations from space began 30 years ago. Because the extent of ice cover is usually at its lowest about mid-September, this year's minimum could still fall to set another record low.

Each year, the Arctic Ocean experiences the formation and then melting of vast amounts of ice that floats on the sea surface. An area of ice the size of Europe melts away every summer reaching a minimum in September. Since satellites began surveying the Arctic in 1978, there has been a regular decrease in the area covered by ice in summer – with ice cover shrinking to its lowest level on record and opening up the most direct route through the North-west Passage in September 2007.

The direct route through the North-west Passage - highlighted in by the orange line – is currently almost free of ice, while the indirect route, called the Amundsen North-west Passage, has been passable for almost a month. This is the second year in a row that the most direct route through the North-west Passage has opened up.

The polar regions, especially the Arctic, are very sensitive indicators of climate change. The UN's Intergovernmental Panel on Climate Change has shown that these regions are highly vulnerable to rising temperatures and predicted that the Arctic would be virtually ice-free in the summer months by 2070.

The Arctic is one of the most inaccessible regions on Earth, so obtaining measurements of sea ice was difficult before the advent of satellites.

Payload opportunity for Vega

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Artist impression of Vega on launch pad at Kourou

The opportunity to embark payloads on the second flight of the Vega small launcher, planned for mid 2010, was announced in July. This will be for the first of five flights to demonstrate Vega's versatility to the space community.

Vega is ESA's new, small launcher, composed of three solid propellant stages and a liquid bipropellant upper stage. Development started at the end of 2000 and the Vega launch system is now in its qualification phase.

The Vega qualification flight is planned for November 2009. A few months later, after the flight data has been analysed, a flight qualification review will be conducted paving the way for the second Vega flight, the VERTA-1 mission.

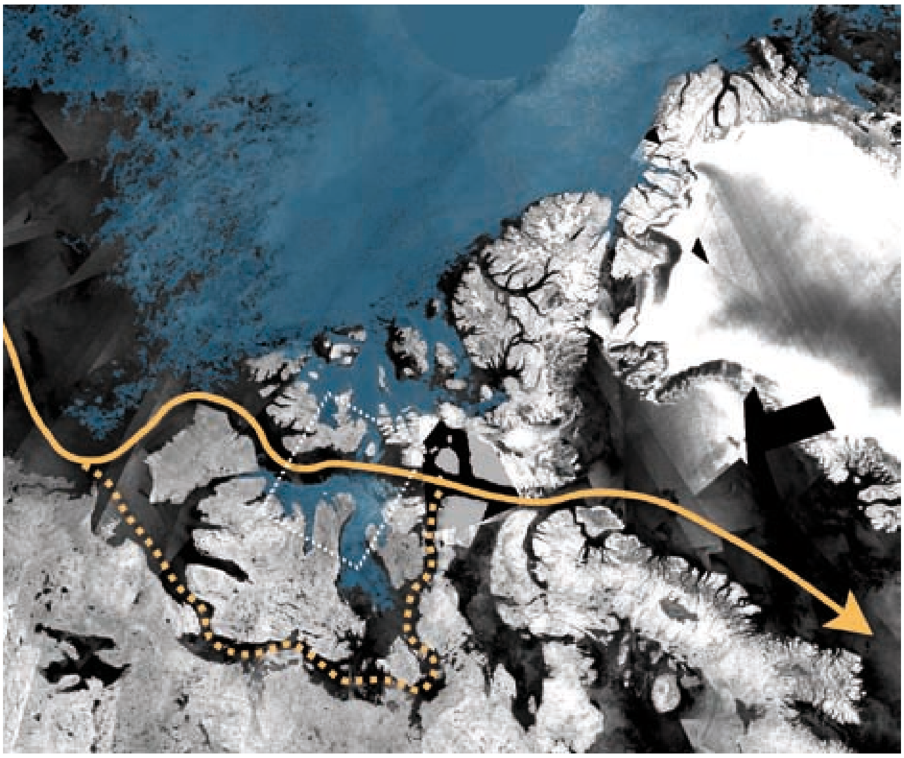
The Vega Research and Technology Accompaniment (VERTA) programme started in 2006. The objective of VERTA flights is to demonstrate to the space community the flexibility of Vega launch system. These launches will carry several ESA missions such as ADM-Aeolus, Swarm, LISA Pathfinder and Proba-3.

The Vega exploitation phase will start with the five VERTA flights, from early 2010. Arianespace will operate the Vega launch system from the European Spaceport in Kourou, complementing the existing launcher fleet of Ariane-5 and Soyuz, and providing the necessary capabilities and flexibility to cover all customer needs.

The VERTA-1 mission will also provide a flight opportunity for a number of very small educational spacecraft that will be managed by ESA's Education Office.

"Vega is now entering a new and exciting phase by offering this flight opportunity to the space community. I'm convinced that the service Vega has to offer will fulfil the expectations of users worldwide," said Stefano Bianchi, Head of the Vega programme.

Satellite measurements from radar instruments can acquire images through clouds and also at night. This capability is especially important in areas prone to long periods of bad weather and extended darkness – conditions frequently encountered in the polar regions. In 2009, ESA will make another significant contribution to research into the cryosphere with CryoSat-2. The observations made over the three-year lifetime of the mission will provide conclusive evidence on the rates at which ice thickness and cover is diminishing.



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The Arctic Ocean seen by the Advanced Synthetic Aperture Radar (ASAR) instrument aboard Envisat. Ice-free areas are dark grey, sea ice is blue

Perking up medical analysis and environmental protection

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The sensors are small enough to be incorporated into a mask and be used, for instance, in hospitals, clinics or by athletes during training

Miniaturised ceramic gas sensors, originally developed for measuring oxygen levels around spacecraft reentry vehicles, are improving breathing measurement apparatus and also able to help reduce pollution by better control of domestic heating systems.

Special ceramic gas sensors were developed in 1993 when the Institute of Space Systems (IRS) of the University of Stuttgart needed to measure oxygen distribution in the plasma wind tunnels while testing spacecraft heat-shield materials in extreme conditions.

“The sensors available at that time were no good for space systems because they were big, heavy and used a lot of power,” said Rainer Baumann, Technical University of Dresden, who worked on the development of this new sensor. “We had to develop a new type of miniaturised sensor to measure reentry conditions for spacecraft, capable of measuring oxygen at high altitudes.”

Since then this ceramic sensor has been developed for other space experiments, for example on board the Russian Inflatable Reentry and Descent Technology (IRDT) research capsule. The IRDT is a system that uses an inflatable cone-shaped heatshield and a parachute to return cargo to Earth.

Although the ceramic sensors were originally developed for space, ESA’s Technology Transfer Programme and its technology transfer network partner MST found that the novel technology attracted a great deal of interest from industry for use in terrestrial applications.

The ESCUBE Space Sensor Systems GmbH company was founded in 2000 to further develop and market the sensor for use in the field of modern gas analysis, both on Earth and in space.

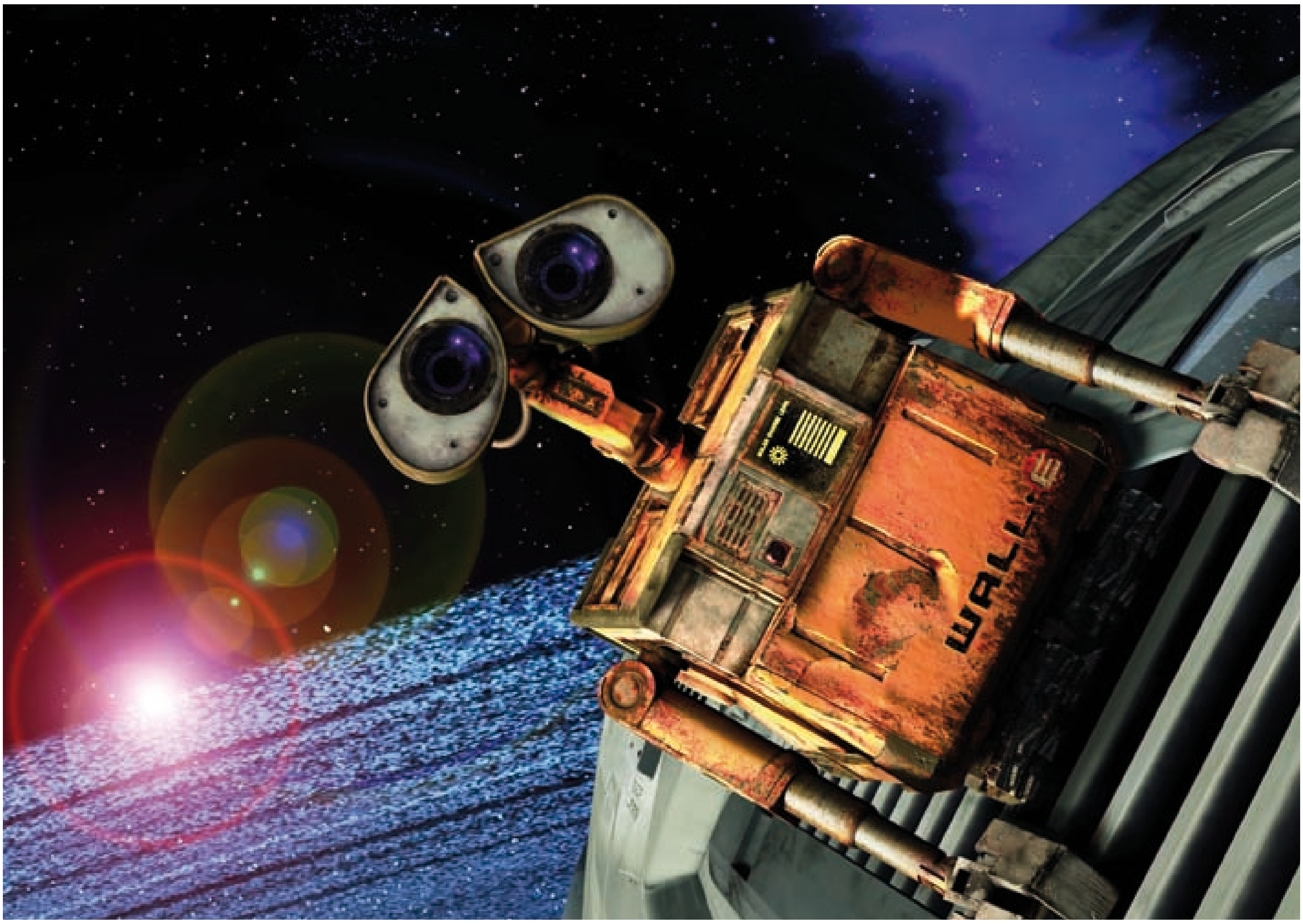
“One application where the sensor is particularly useful is measurement of breathing. With this sensor we can measure oxygen, carbon dioxide and breath flow, and get immediate results, something which is impossible with conventional systems,” said Baumann.

Another application is the control of exhaust gases in heating systems for home and industry. Most manmade pollutants on Earth originate from the burning process in automotive, industrial and domestic applications. These sensors can be used to control and optimise the combustion processes.

“By using these systems, it possible to reduce the exhaust gases that are harmful for the environment and at the same time, by ensuring heating systems work at an optimum level, reduce fuel consumption by up to 15%.”

Today these miniature sensors have found their way back to space again. They are now used in the small Flux Probe Experiment unit on the outside of the International Space Station where they measure the level of gases outside the station.

Explore space with WALL-E



↑ A still image from the WALL-E movie (Disney/Pixar)

To mark the European launch of Disney/Pixar's hit movie WALL-E, ESA launched a new web site that highlights a range of space-related educational resources and fun activities for children.

In the blockbuster movie, a lonely robot named WALL-E develops a deep curiosity that eventually inspires it to set off on a fantastic voyage across the galaxy in search of a probe-droid called EVE. As is often the case, science fiction is some years ahead of science fact. Although ESA is currently developing 'semi-intelligent' robots that can explore other planets and assist astronauts in space, relatively few Europeans have so far been lucky enough to leave planet Earth.

Fortunately, there are much easier ways for people – young and old – to follow in WALL-E's footsteps. To explore space from the comfort of your own home or classroom, all you have to do is log onto the WALL-E portal to enter a world of fascinating facts, animations, pop-ups, educational DVDs, DIY experiments, games, competitions and puzzles.

"As an extension to its existing outreach activities, ESA has developed this website in collaboration with Disney/Pixar," said Francesco Emma, Head of ESA's Education Office. "We see this as an exciting new way to introduce young people to the wonders of space exploration."

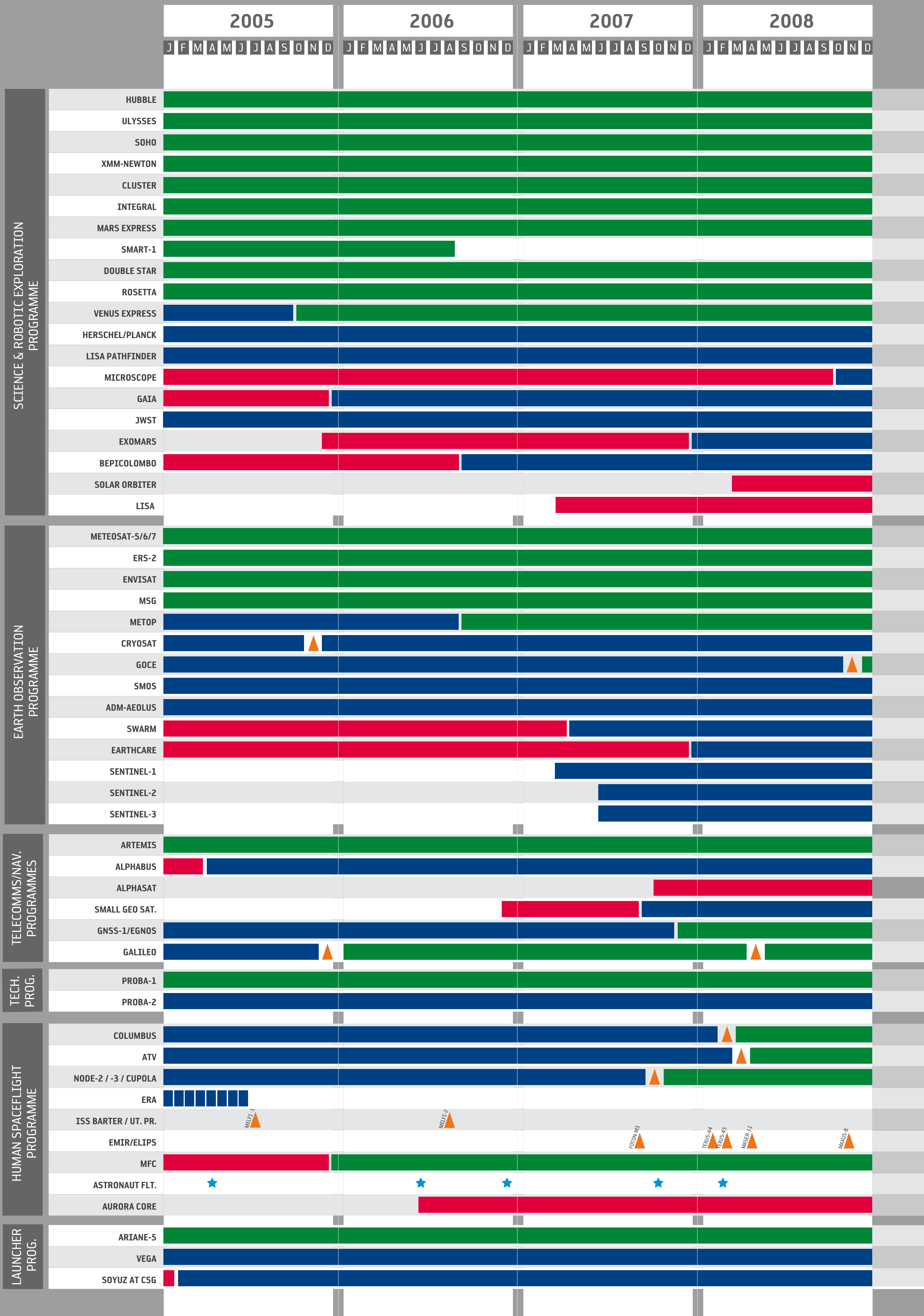
The WALL-E portal provides links to the ISS Education Kit for primary (8–10 year-olds) and secondary schools (12–14 year-olds) and various web lessons on line.

Through ESA's WALL-E web site, youngsters can find out about the wonders of the Universe, as well as exciting missions such as SOHO, which stares continuously at the Sun, the Huygens probe which made an historic landing on Saturn's moon Titan, and Envisat, the largest Earth observation satellite ever launched.

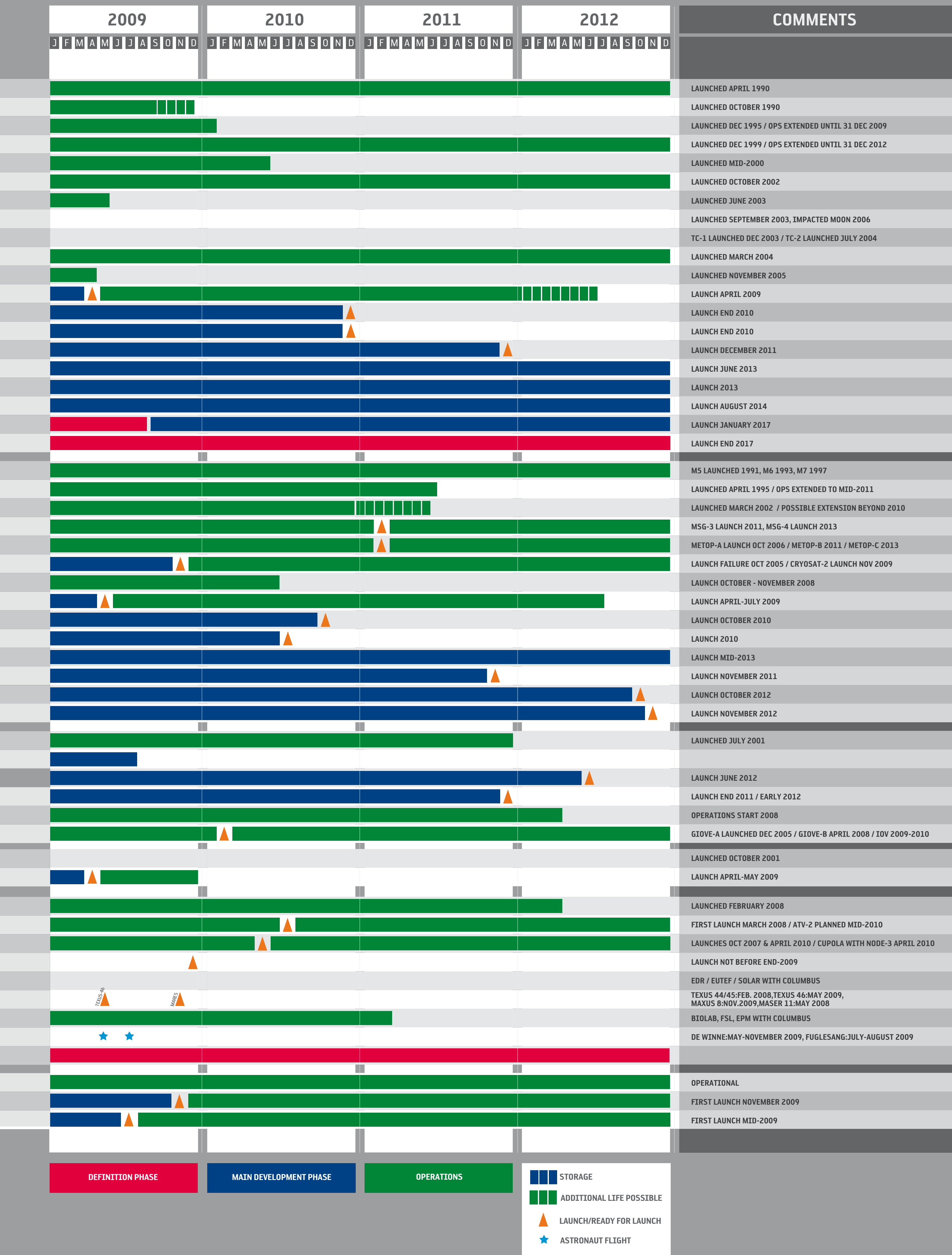
Like WALL-E, humans have always been driven by curiosity to discover more about our world and the Universe that surrounds us. Today, the exploration of space remains one of the most stimulating and exciting areas of scientific research.

→ PROGRAMMES IN PROGRESS

status at end September 2008



2005
2006
2007
2008
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
ULYSSES
SOHO
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
SMART-1
DOUBLE STAR
ROSETTA
VENUS EXPRESS
HERSCHEL/PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
EXOMARS
BEPICOLOMBO
SOLAR ORBITER
LISA
EARTH OBSERVATION PROGRAMME
METEOSAT-5/6/7
ERS-2
ENVISAT
MSG
METOP
CRYOSAT
GOCE
SMOS
ADM-AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
TELECOMMS/NAV. PROGRAMMES
ARTEMIS
ALPHABUS
ALPHASAT
SMALL GEO SAT.
GNSS-1/EGNOS
GALILEO
TECH. PROG.
PROBA-1
PROBA-2
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
ATV
NODE-2 / -3 / CUPOLA
ERA
ISS BARTER / UT. PR.
MELFI-1
MELFI-2
EMIR/ELIPS
FOTON-M3
TEXUS-44
TEXUS-45
MASER-11
MAXUS-8
MFC
ASTRONAUT FLT.
AURORA CORE
LAUNCHER PROG.
ARIANE-5
VEGA
SOYUZ AT CSG


2009
2010
2011
2012
J F M A M J J A S O N D
COMMENTS
LAUNCHED APRIL 1990
LAUNCHED OCTOBER 1990
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 31 DEC 2009
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 31 DEC 2012
LAUNCHED MID-2000
LAUNCHED OCTOBER 2002
LAUNCHED JUNE 2003
LAUNCHED SEPTEMBER 2003, IMPACTED MOON 2006
TC-1 LAUNCHED DEC 2003 / TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004
LAUNCHED NOVEMBER 2005
LAUNCH APRIL 2009
LAUNCH END 2010
LAUNCH END 2010
LAUNCH DECEMBER 2011
LAUNCH JUNE 2013
LAUNCH 2013
LAUNCH AUGUST 2014
LAUNCH JANUARY 2017
LAUNCH END 2017
M5 LAUNCHED 1991, M6 1993, M7 1997
LAUNCHED APRIL 1995 / OPS EXTENDED TO MID-2011
LAUNCHED MARCH 2002 / POSSIBLE EXTENSION BEYOND 2010
MSG-3 LAUNCH 2011, MSG-4 LAUNCH 2013
METOP-A LAUNCH OCT 2006 / METOP-B 2011 / METOP-C 2013
LAUNCH FAILURE OCT 2005 / CRYOSAT-2 LAUNCH NOV 2009
LAUNCH OCTOBER - NOVEMBER 2008
LAUNCH APRIL-JULY 2009
LAUNCH OCTOBER 2010
LAUNCH 2010
LAUNCH MID-2013
LAUNCH NOVEMBER 2011
LAUNCH OCTOBER 2012
LAUNCH NOVEMBER 2012
LAUNCHED JULY 2001
LAUNCH JUNE 2012
LAUNCH END 2011 / EARLY 2012
OPERATIONS START 2008
GIOVE-A LAUNCHED DEC 2005 / GIOVE-B APRIL 2008 / IOV 2009-2010
LAUNCHED OCTOBER 2001
LAUNCH APRIL-MAY 2009
LAUNCHED FEBRUARY 2008
FIRST LAUNCH MARCH 2008 / ATV-2 PLANNED MID-2010
LAUNCHES OCT 2007 & APRIL 2010 / CUPOLA WITH NODE-3 APRIL 2010
LAUNCH NOT BEFORE END-2009
EDR / EUTEF / SOLAR WITH COLUMBUS
TEXUS-46
MAXUS
TEXUS 44/45:FEB. 2008,TEXUS 46:MAY 2009,
MAXUS 8:NOV.2009,MASER 11:MAY 2008
BIOLAB, FSL, EPM WITH COLUMBUS
DE WINNE:MAY-NOVEMBER 2009, FUGLESANG:JULY-AUGUST 2009
OPERATIONAL
FIRST LAUNCH NOVEMBER 2009
FIRST LAUNCH MID-2009
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

→ HUBBLE SPACE TELESCOPE

Hubble and the NASA Chandra X-ray observatory have witnessed a powerful collision of galaxy clusters. This clash of clusters provides striking evidence for dark matter and insight into its properties. The observations of the cluster, known as MACS J0025.4-1222, indicate that a titanic collision has separated the dark matter from ordinary matter and provide an independent confirmation of a similar effect detected previously in a target dubbed the Bullet Cluster.

These new results show that the Bullet Cluster is not an anomalous case. MACS J0025 formed after an enormously energetic collision between two large clusters. Using visible-light images from Hubble, astronomers were able to infer the distribution of the total mass of both the dark and ordinary matter. Using the gravitational lens technique, Hubble was used to map the dark matter. The Chandra data enabled the astronomers to accurately map the position of the ordinary matter, mostly in the form of hot gas, which emits in X-rays.

As the two clusters that formed MACS J0025 merged at speeds of millions of kilometres per hour, the hot gas in the two clusters collided and slowed down, but the dark matter passed right through the collision. The separation between the materials therefore provides observational evidence for dark matter and supports the view that dark-matter particles interact with each other only very weakly or not at all, apart from the pull of gravity.

On 28 September, Hubble automatically entered a 'safe' mode when errors were detected in the Control Unit/Science Data Formatter-Side A. This component is essential for the storage and transmission of data from the telescope's science instruments back to Earth. Ground control attempts to reset the device and obtain a download of the payload computer's memory were unsuccessful.

NASA specialists were investigating the problem and are in the process of planning a switch-over to the redundant Side B. This is a complex task and requires that five other modules are also switched to communicating via the B channel. Many of these modules were last activated 20 years ago during ground testing prior to launch. If this transition is successfully completed the telescope could rapidly be returned to science operations.

NASA is now also evaluating the possibility of flying a back-up replacement system as part of the Servicing Mission 4 that was originally scheduled for 14 October. The replacement part, although already manufactured, needs to be fully checked and tested at the NASA Goddard Spaceflight Center, Maryland, and as a result will not be ready for delivery to the Shuttle before early January 2009.

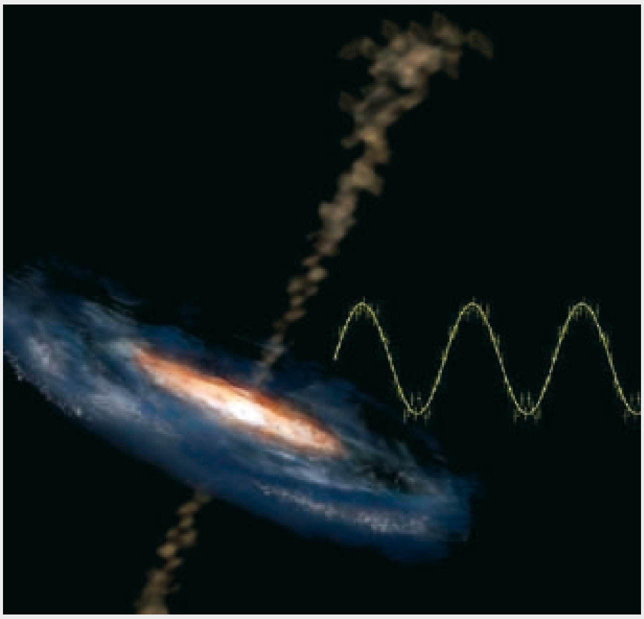
→ XMM-NEWTON

XMM-Newton has uncovered a well-tuned periodic signal from a super-massive 'black hole' at the centre of a galaxy, ending a 20-year quest for such an object. The super-massive black hole, whose signals XMM-Newton has overheard, is located at the centre of a galaxy RE J1034+396. The black hole itself is estimated to be a million times more massive than our Sun.

As matter is sucked in to a black hole, it is heated up and emits X-rays. The X-ray emission can then be modulated at a certain frequency, as matter falling in wobbles around the black hole, and this frequency is detected as a periodic signal. These periodic signals are widely observed in black holes of a lower mass, of the order of tens of solar masses, in our galaxy.

Scientists had suspected that the underlying physical processes behind black hole accretion mechanisms should be the same, regardless of the size of the black hole. This means that such periodic signals should also be emitted by super-massive black holes but, until now, no super-massive black hole displaying such a periodic signal had been seen.

XMM-Newton's sensitive instruments have now shown that the black hole at the centre of galaxy RE J1034+396 displays a periodic signal (called a 'quasi-periodic oscillation'), once per hour. The finding confirms that the fundamental physical processes behind black hole accretion mechanisms are indeed the same, giving them a powerful new tool to study active galactic nuclei.



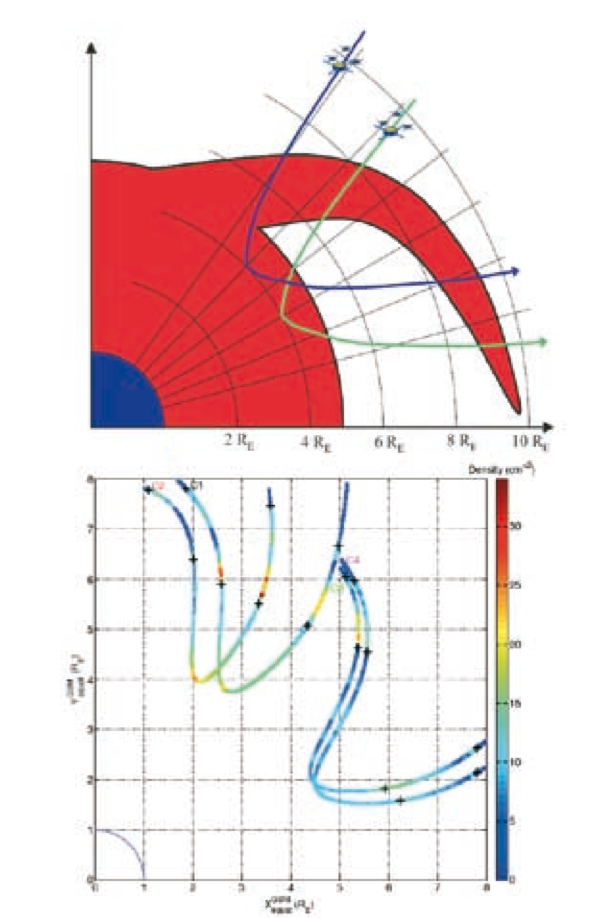
Artist's impression of material falling into a super-massive black hole, forming an accretion disc and jets, together with the averaged shape of the periodic X-ray signal from REJ1034+396 (A. Simonnet/M. Gierlinski)

→ ULYSSES

Predictions regarding the remaining operational lifetime of Ulysses made earlier in the year following the failure of the X-band transmitter in January have proven to be pessimistic, and the real-time S-band only science mission is still ongoing at the time of writing, despite the low on-board temperatures. This is largely due to the introduction of 'fuel bleeding', whereby two oppositely directed thrusters are fired simultaneously every two hours, causing hydrazine fuel to move through a short length of pipework where fuel is likely to freeze.

Spacecraft operations and science data acquisition will continue using the same strategy until no more fuel remains (which, given the uncertainties in the amount of fuel left, could be any time between early October and December), or freezing occurs. Real-time operations were temporarily interrupted on 19 September by an unexplained switch-off of the Sun sensors and resulting automatic closure of the fuel valves. Corrective actions were carried out and normal operations resumed, apparently without negative impact on the state of the hydrazine fuel. Investigation into the cause of the anomaly is hampered by the lack of data resulting from the real-time only nature of the spacecraft operations.

Recent science highlights from Ulysses include the publication of a series of papers showing that the solar wind is weaker now than at any time since detailed measurements from space began, some 50 years ago. This in turn could affect the degree to which the Solar System is shielded from cosmic radiation coming from elsewhere in our galaxy. A media teleconference presenting these results was held on 23 September that generated over 70 internet stories worldwide.



Top: the plasmasphere and its plume (red) together with two Cluster crossings (Earth in blue). Bottom: Plasma density profile along the four Cluster spacecraft trajectories on 18 July 2005. The plume entry and exit are marked with crosses (F. Darouzet, IASB/BIRA/*Annales Geophysicae*)

→ CLUSTER

The electron diffusion region at the heart of the reconnection Cluster constellation phasing manoeuvres were executed from early June to early August. The Cluster 1, 2 and 3 spacecraft were separated by 10 000 km and Cluster 3 and 4 spacecraft by 3000 km. Since April 2008, a slight acceleration in the degradation of the solar arrays has been observed, a result of the longer time spent in radiation belts due to the lower perigee (below 10 000 km). The Cluster long-eclipse season started on 17 September and finishes on 10 October.

A paper was published in *Annales Geophysicae* on a statistical analysis of plasmaspheric plumes in the inner magnetosphere. This study used the WHISPER wave sounder on Cluster to provide information on the occurrence rate of these plumes as a function of various magnetospheric indices. The study also provided information on the size, extent and density variation of these features. This work is important for magnetospheric physics, since plasmaspheric plumes are thought to affect the reconnection rate at the dayside magnetosphere, and hence the transfer of solar wind plasma into the magnetosphere.

→ DOUBLE STAR

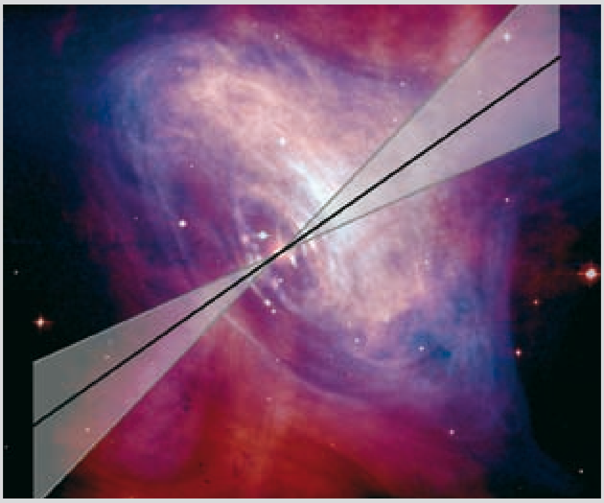
The spacecraft cannot be commanded from the ground at the moment due to the eclipse season, so science operations have been temporarily suspended. The eclipses will be finished in early November and the power should be nominal again.

Chinese scientists have investigated the possibility of further extending the mission. It seems that the spacecraft should be able to support payload operations when there is no eclipse and when there is sufficient power provided by the solar panels. These conditions will be met for three periods of two months each from November 2008 to the end of December 2009. Because of the science that could be performed during this period, in particular by collaborations with Cluster, Themis and Twins, the Science Working Team recommended extending the mission to the end of 2009.

→ INTEGRAL

The 12th annealing of Integral's SPI detectors was performed in early September resulting in a nominal recovery of the energy resolution. A major scientific highlight was the detection of polarised gamma-ray photons with energies above 100 keV from the Crab pulsar. This observation makes it possible that another piece of the jigsaw in understanding how neutron stars work has been put in place.

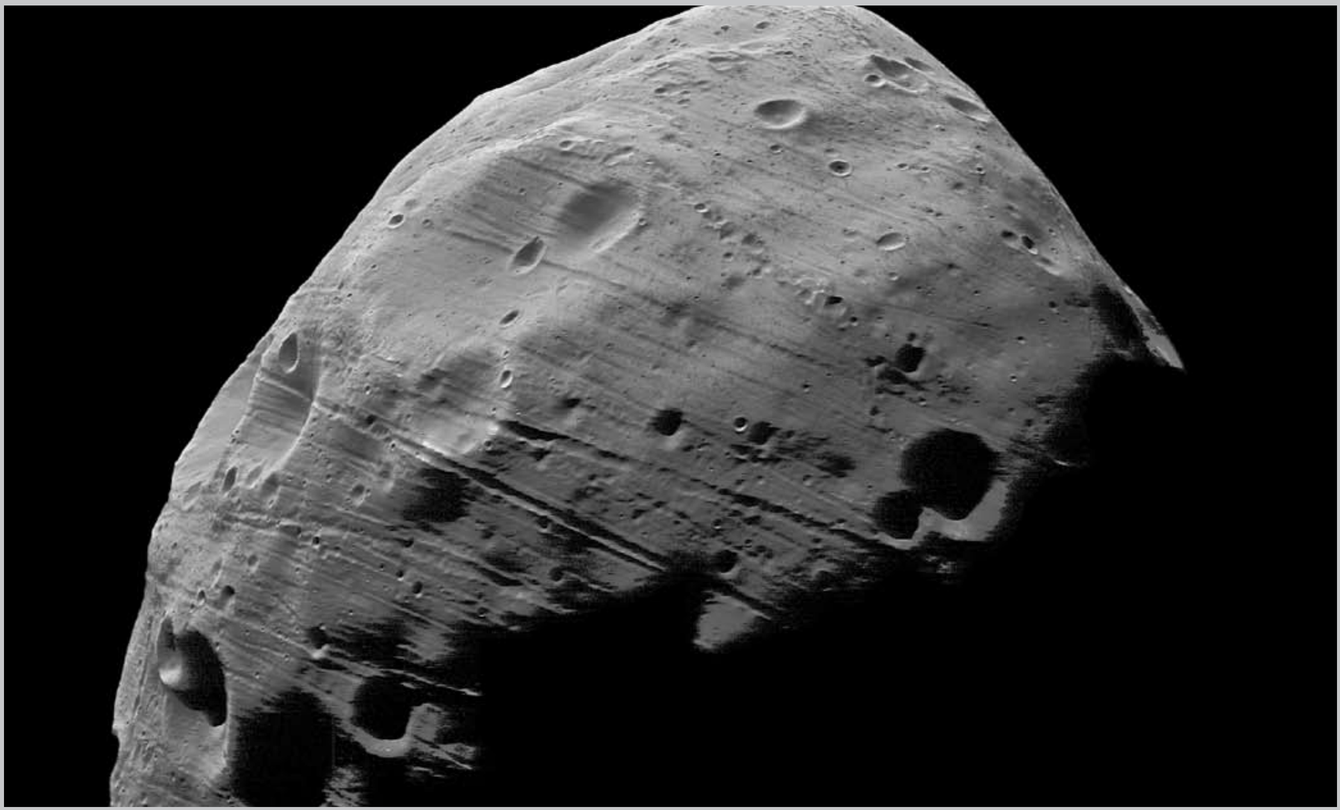
Pulsar systems containing neutron stars accelerate particles to immense energies, typically a hundred times more than the most powerful accelerators on Earth, but it is still uncertain how these systems work and where the particles are accelerated. Integral observations have now revealed that these energetic photons originate close to the pulsar.



The gamma-ray polarisation vector superimposed on a composite image of the Crab from Chandra (X-ray/blue) and Hubble (optical/red). The limits on the direction of the vector are indicated by the shading. The direction of the polarisation vector shows a remarkable alignment with the inner jet structure (A.J. Dean *et al*)

→ MARS EXPRESS

The martian moon Phobos is a very interesting Solar System body to study, mainly because its origin is a matter of debate (a captured asteroid, or made of surviving planetesimals, or maybe even the remnant of an impact of a large object on Mars). The main objective of Mars Express is obviously Mars, but thanks to its elliptical orbit, the spacecraft flew by Phobos many times and had a number of very close encounters in July 2008.



Mars Express took this image at the highest resolution yet of the surface of the Martian moon Phobos on 23 July 2008 (ESA/DLR/FU Berlin/G. Neukum)

On 17 July, a close pass at 274 km allowed the Mars Radio Science Experiment (MaRS) to derive the mass of the moon very accurately by measuring the small Doppler shift of the transmitted signal from the spacecraft to Earth.

One week later, at a closest approach of less than 100 km, Mars Express obtained the sharpest ever images of Phobos. These data, at a spatial resolution of 3.7 m/pixel, have surpassed all previous images from other missions. The other Mars Express instruments were operating as well, and results are expected in the coming months.

In August, the Mars Express SPICAM infrared and ultraviolet spectrometer team reported in *Nature* that 'heterogeneous chemistry' in ice clouds plays an important role in controlling the stability and composition of the martian atmosphere. Heterogeneous chemistry involves substances in different phases. In this case, solids (ice) and gas.

→ ROSETTA

The Rosetta spacecraft performed a close flyby of a main-belt asteroid, (2867) Steins, coming to within a distance of 800 km from it. Closest approach occurred on 5 September 2008, with a relative velocity of 8.6 km/s. Rosetta passed on the sunlit side of the asteroid in the plane defined by the relative velocity vector and the Sun direction. This flyby strategy allowed continuous pointing on the asteroid before, during and after closest approach as well as passing through phase angle zero.

To keep the small asteroid in the field of view of the scientific instruments during the closest approach, the spacecraft had to target it with accuracy better than 2 km and to perform an attitude flip manoeuvre of 20 minutes duration before autonomous tracking of asteroid (2867) Steins started.

Fourteen instruments were switched on during the flyby, providing spatially resolved multi-wavelength observations of the asteroid and in situ measurements of its dust, plasma, magnetic and radiation environment. All science data acquired during the flyby have been retrieved. The images show (2867) Steins is a small diamond-shaped asteroid, 5.9 km by 4.0 km in size and grey in colour. It has an albedo (visual reflectivity) of 35% and its surface is dominated by a very large crater of about 2 km diameter and a number of small craters, of which at least seven are arranged in a chain. It belongs to the rare class of E-type asteroids, which had not been directly observed by an interplanetary spacecraft before. The detailed compositional analysis of its surface from spectral observations is under way.

(2867) Steins was Rosetta's first nominal scientific target in its 11-year mission. After the analysis of the data obtained by Rosetta, it will be one of the best-characterised asteroids so far, and as such add to the understanding of the different types of asteroids and to solving the puzzle of how the Solar System formed and evolved. The flyby phase officially ended on 5 October. From 7 September, Rosetta entered a range of Sun distances that has never been reached so far in the mission.

→ VENUS EXPRESS

Observations of Venus continue at an intense level with all instruments and great progress has been made in the study of the super-rotation of the atmosphere. Measurements by the VIRTIS instrument have enabled the synthesis of a first-ever 3D picture of the venusian winds for an entire hemisphere. Using three different wavelengths as windows to three different atmospheric layers, VIRTIS tracked the movement of clouds and determined the speed of the winds moving them.

Images of the night-side were obtained at the infrared wavelength of 1.74 micrometres, which allows tracking of the clouds at the lower boundary of the cloud layer (about 45–47 km altitude) while day-side images were obtained both in the near-infrared at about 980 nanometres (a window to the clouds at about 61 km altitude), and in the blue ultraviolet at about 350 nanometres (about 66 km altitude).

Following a series of spacecraft manoeuvres during July and August, the pericentre altitude of the orbit has been changed from 250 km to 185 km. This will enable deeper measurements by the energetic particle instrument ASPERA and more detailed measurements by the MAG magnetometer. This occasion was also used to search for a hint of atmospheric drag acting on the spacecraft body which would slightly perturb the orbit. Following the best available models based on data from previous mission, such an effect should be clearly seen. An initial analysis has shown no appreciable perturbation to the orbit. Different parameters, such as latitude, time of day and phase of the solar cycle, play a role. An update to the existing model may be necessary.

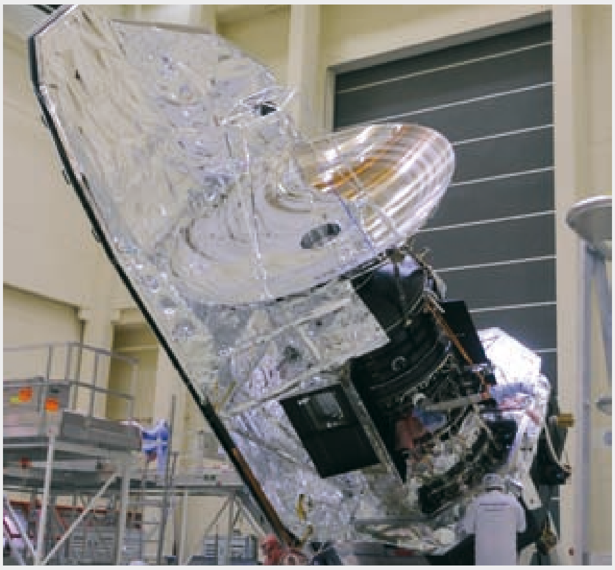
→ AKARI

AKARI continues observing in the 2–5 micrometre range in its post-helium phase. Guaranteed Time observations in this phase started on 1 June. As for the cold phase, 30% of the observing time is dedicated to Open Time observations (one third to Europe). Parallel Call for Proposals in Europe and Japan were issued in May. This resulted in 11 and 22 successful proposals respectively, peer reviewed by independent panels. Further to scheduling simulations, iterated with the users, the Open Time observations will start on 15 October. The survey catalogues shall be released this autumn to the project teams (and one year after to the public). The Pointing Reconstruction, contributed by ESAC (accuracy of one arcsecond, better than the requirement) facilitates the source identification. In the short wavelength bands, 700 000 sources have been detected.

→ HERSCHEL/PLANCK

After some major achievements in the last months, both spacecraft are now in final flight acceptance testing.

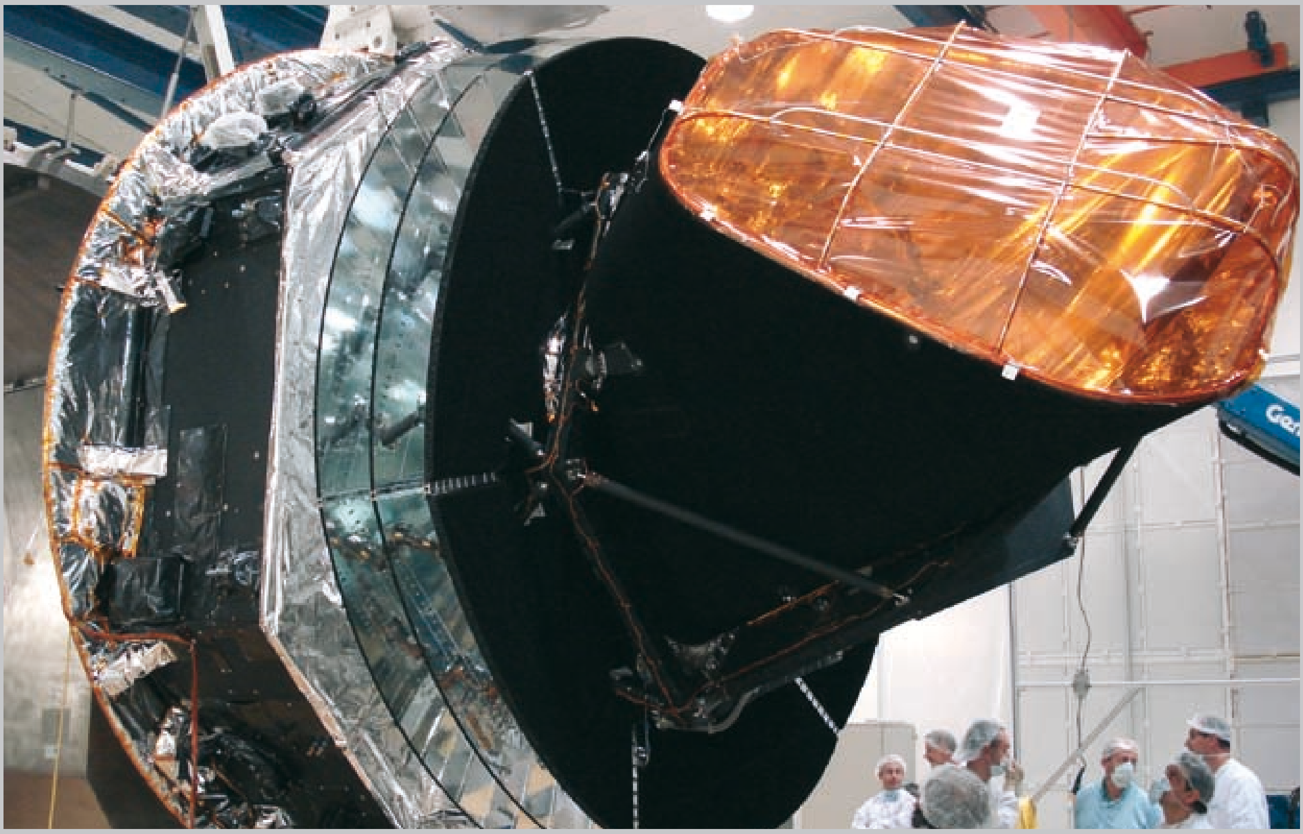
The functional testing of Herschel, especially the tests carried out with the main helium tank pumped to the 'superfluid' phase, has been the highlight. Operating the cryogenic system in the superfluid phase allows the creation of orbit-like conditions at the interfaces to the scientific instruments, and through this to verify the performance of their sensitive detectors. A further important milestone was the completion of the first full end-to-end test with the complete ground segment, the mission control centre in ESOC, the Herschel science centre in ESAC and the instrument control centres in the loop with the spacecraft. The satellite is now in final preparation for the thermal vacuum and thermal balance test later this year. This will then be the final environmental test on the spacecraft before shipment to Kourou.



Herschel during functional testing of payload

The Planck flight model satellite has completed its last big environmental test before flight, the thermal balance and thermal vacuum test at CSL, Liège. The two-month test allowed full verification of the performance of both scientific instruments with the full cryogenic cooler system under orbit-like conditions. The test was successful with the lowest temperature of 0.1K being reached and both instrument detector chains showing the expected nominal performance. The spacecraft is now in final functional performance testing.

The current plan is for both satellites to be ready for launch on an Ariane-5 ECA by April 2009.



Planck leaving the thermal vacuum facility at CSL after completion of the test

→ LISA PATHFINDER

The LISA Pathfinder development is in progress and approaching the completion of the Phase C, with the Critical Design Review to be held at system level by the end of the year and at mission level in the spring 2009. The main engineering activities have been devoted to the finalisation of the spacecraft design, in preparation for the CDR. All subsystems have had their own subsystem CDRs. Most of the equipment suppliers have delivered electrical units and flight models. The repaired FM structure of the science module, together with the propulsion module FM structure have undergone acoustic testing in ESTEC's LEAF facility. The new FM structure, built in parallel by Oerlikon Space (CH) and to be used for flight, will also come to ESTEC soon for testing. The on-board software is under validation testing at Astrium GmbH and Astrium Ltd in their two parallel test set-ups.

The two European micropropulsion technologies (needle indium thrusters and slit caesium thrusters) continue their challenging development to prove the readiness of the technologies. The slit technology has recently achieved substantial results to prove its readiness for a final validation expected to be reached by the end of the year. As planned, the technology that will not be selected for flight will be held as a back-up.

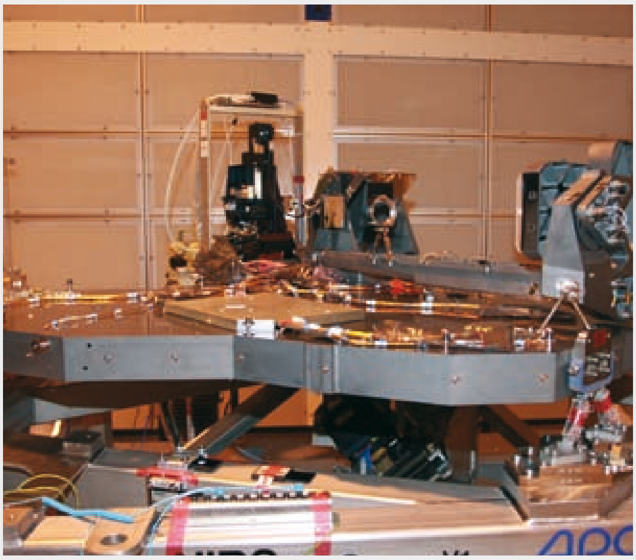
The LISA Pathfinder Flight Model structures in the ESTEC LEAF acoustic test facility. Several parts of this model are flight models, e.g. the solar array panel on top and the separation mechanism, but other subsystems are simulated by 'mass dummies', such as the MMH and nitrogen tetroxide tanks (the large white cylinders) and electronic boxes inside the science spacecraft.

As concerns the LTP, the work is focused on the most critical subsystems of the inertial sensors, e.g. caging mechanism and electrode housing and on the Data Management Unit software. Also in this case substantial steps forward have been performed, but the inertial sensor remains in the critical path. All the LTP Electrical Models (ELM) have been built and delivered to Astrium GmbH for the Real Time Test Bench. The electronic FM units are to be delivered between the end of the year and the first couple of months of 2009. The LTP schedule, driven by these critical subsystems, affects the overall schedule. The launch is expected at the end of 2010.

→ JAMES WEBB SPACE TELESCOPE

The JWST Engineering Development Mirror (EDU), one segment of the primary mirror, has finished fine polishing and is being integrated into a full flight mirror assembly with all the actuators. The EDU is a manufacturing process pathfinder for the flight mirrors and the process appears to converge faster than anticipated.

Integration activities on the Near Infrared Spectrograph (NIRSpec) development model are progressing, with many of the assemblies already aligned on the optical bench. The NASA Engineering Model of Detector System was delivered to the instrument prime contractor and the incoming inspection and preliminary tests were successful. Flight Detector Sensor Chip Assemblies (SCAs) have been selected and the integration of the flight detector module is now starting. The development of the two cryo-mechanisms remains on the critical path.



Integration of the JWST NIRSpec optical bench development model

GOCE inside its fairing mounted on the Rockot launcher's Breeze-KM upper stage

CryoSat-2 in the vibration test facility at IABG (Munich)

are awaited, but the progress of these activities means that launch is expected at the end of October or early November.

The readiness of the ground segment to support LEOP, commissioning and calibration, as well as regular science operations was confirmed in the Operations Readiness Review held on 20 August.

→ CRYOSAT

System-level testing of the satellite continued through the summer, despite the non-availability of both nominal and redundant units of a vital subsystem, the S-band transponder, used for communications between the control centre and the satellite. An engineering model was used in place, allowing a large amount of testing to proceed. Progress has been very good, partly due to the accumulated experience gained during the earlier CryoSat development.

In early September, the second System Validation Test (SVT-2) was successfully performed, with very few anomalies detected thanks to the extensive preparation. Immediately afterwards the satellite was moved to IABG in Munich (D) to begin the environmental testing. This test programme has been tailored to ensure that tests that can be performed without the missing equipment are scheduled first. The planning of the remaining activities is dependent on the eventual delivery of the late units, which is expected in October. Testing of the overall ground segment continues, with extensive testing of the interfaces between facilities.

→ SMOS

The satellite is in storage at Thales Alenia Space, Cannes, and will be retrieved at the end of the year for final flight software upload, System Validation Test 3 and a repeat of the launcher adaptor fit check. The Satellite Qualification Review was successfully concluded with recommendations by the panel and board members being pursued as normal work.

The ground segment development proceeds, with the version 2 on-site acceptance test of the data-processing ground segment scheduled for November.

→ ADM-AEOLUS

A critical review of the ALADIN laser design and its technological margins was concluded in July 2008, which identified the need for a number of design improvements in order to achieve the required stability of the laser and adequate design margins. The implementation of these measures has been initiated. Procurement of upgraded optical components with increased robustness against laser-induced damage has started and a number of improved components are available already.

A design modification will be implemented at the level of the laser master oscillator, which allows reduction in the fluency level of the laser beam without impact on the laser output energy. This modification increases the margins against laser-induced damage within the master oscillator.

The second cryogenic test campaign of the Mid Infrared Instrument (MIRI) Verification Model was successfully passed. The Spectrograph Pre Optics (SPO), the Calibration Source Assembly and the Dichroic Wheel Assembly have passed their Qualification Reviews and all MIRI imager flight mirrors have completed their manufacturing and are within specifications.

→ MICROSCOPE

The Microscope T-SAGE accelerometer Phase C1 review was performed in July this year following the electromagnetic testing campaign. The Phase C1 was not closed due to complications in the levitation test, which has to be repeated. In any case, CNES authorised Phase C2 under which the QM T-SAGE will be built and tested.

Concerning the cold-gas option, CNES issued the ITT for the Phase B cold-gas propulsion system activities in agreement with ESA. The Phase A activities were completed this summer, lead by ESA. The objective is to reach by the middle of next year a Phase B status on both FEEP and cold gas and then select the propulsion technology taking due account of their development status and suitability or the mission.

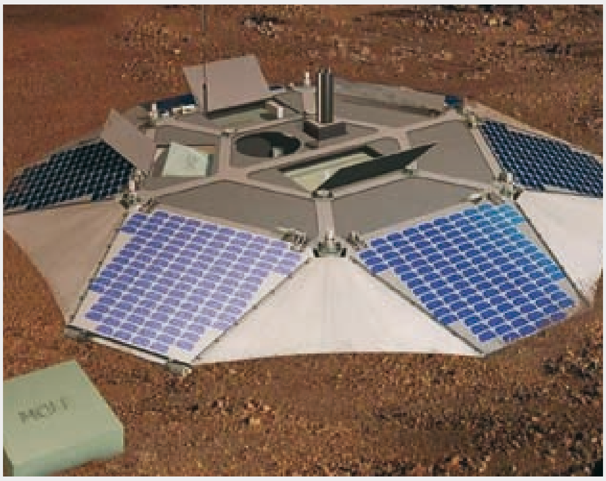
→ GAIA

The Gaia spacecraft is taking shape. Subcontractors have started delivering hardware to the Avionics Verification Model test bench at Astrium Ltd. In parallel, the focal plane test set up is being put together in a dedicated vacuum chamber at Astrium Toulouse. The first flight models are also already coming off the production line. About half the number of flight model CCDs have already been accepted. The delivery of the first flight mirror is imminent. All other mirrors are also in an advanced state of production.

The delivery of the 17 individual elements forming the 3m diameter 'torus', or optical bench, has also started. The brazing of the torus, the extremely delicate process to 'weld' all torus elements in one step, will take place in March 2009.

The Gaia Science Team meets at regular intervals to follow closely the progress on both space and ground segment. The Data Processing and Analysis Consortium (DPAC) has established all its management and engineering layers. All interfaces within the Consortium as well as external interfaces to the project have been defined and established. The staffing of the DPAC Office makes also very good progress.

The entire ground segment, i.e. the mission operation and science operations systems, are heading for their second comprehensive project review.



Artist's impression of the Enhanced ExoMars lander base station

→ EXOMARS

Phase B2 work continued to progress well during this period with the selection of key subsystem and equipment contractors. Significant breadboard results have been achieved, e.g. for parachute, drill and sample crushing and dosing. PDRs have been conducted at module level, e.g. carrier, lander, rover vehicle, leading up to the ExoMars system PDR beginning of 2009.

The Humboldt and Pasteur Instrument developments continue to achieve increases of their Technology Readiness Level. This has been confirmed by pre-PDR site reviews, completed for nearly all 23 instruments. Two instrument PDRs have already been conducted with 21 still to come in the next four-month period.

A programmatic review has been started with the objective to confirm the technical, cost and schedule baseline as input to the Programme Proposal. The financial envelope will be decided by the Ministerial Council in November 2008. In the meantime the Programme Board of HSF has been invited to release early funding for technical developments in order to safeguard the 2013 launch date.

→ BEPICOLOMBO

The mission design for the Ariane-5 launch has been further consolidated. The separated mass, which is constrained by the maximum thrust level of the electric propulsion system, could be increased while maintaining the six-year cruise phase. The system design has advanced to the state that the analysis campaign for the preparation of the Preliminary Design Review (PDR) has started. A Critical Equipment Review has been conducted in order to review the technology status. The majority of the technology developments specific to BepiColombo were found to be not critical, however the most critical item, the demonstration of a solar cell assembly for use in Mercury orbit is still outstanding. A series of tests on different solar cell assemblies at various conditions is ongoing and the situation is expected to be much clearer by the end of 2009. Back-up solutions have been identified for the critical technologies.

The Science Working Team discussed scientific aspects of the mission within the user community. Presentations included the results from the recent flyby of Mercury by Messenger and it was decided that the scientists of both projects will cooperate to maximise the scientific return of Messenger and BepiColombo. The Instrument Preliminary Design Reviews (IPDRs) were conducted according to plan with 7 of 11 completed. Generally, an adequate payload definition status and compliance with spacecraft interfaces was demonstrated.

The hardware for the Structural and Thermal Model of the Mercury Magnetospheric Orbiter (MMO) is being produced in Japan. The MMO detailed design is completed and characterisation tests of thermal hardware and solar cells are ongoing.

→ LISA

The Mission Formulation contract started in January 2005 with Astrium GmbH has been extended of 18 months until end of 2009. The scope of the work will be extended to the overall system and mission, encompassing initiation of an end-to-end performance simulation, apportionment and iterations on the performances required by the various subsystems, in relation with the CTP technology development activities, consolidation of the system design and interface requirements.

The LISA Technology Development Plan (TDP) update has been approved by the SPC and IPC as part of the overall Cosmic Vision TDP.

The main focus of the joint ESA/NASA team is concentrated on the preparation of the Astro2010 Decadal review. The team has made a detailed plan identifying and coordinating the required activities. Europe will provide a substantial support to the review, as was already the case for the BEPAC review. The situation looks very positive, especially in the technology. The majority of the LISA technology elements are currently at Technology Readiness Level 5 (TRL5), some already at TRL6, which is uncommon for a project at this stage of development.

→ SOLAR ORBITER

The Solar Orbiter Definition Phase (Phase B1) is being performed by an industrial team led by Astrium Ltd, which includes Astrium GmbH and Thales Alenia Italy. Design trade-offs have addressed all major subsystems and the spacecraft heat shield upon which the survival of the spacecraft will depend when it gets close to the sun. The Preliminary Requirements Review is in preparation. The spacecraft baseline design relies heavily on the re-use of technology and equipment from the BepiColombo project.

Early artist impression of Solar Orbiter

The instrument proposals received from Europe and the USA in response to the Solar Orbiter Payload Announcement of Opportunity in October 2007 had a scientific and technical evaluation by both ESA and NASA. The spacecraft definition has been adjusted to take into account the detailed payload complement as proposed. In parallel, technology development activities are advancing the readiness level of several key elements.

→ GOCE

GOCE was ready for launch on 10 September following a flawless launch campaign, from the transportation to the Plesetsk Cosmodrome, Russia, through to the final mating and integration with the Breeze-KM upper stage and the assembly of the Rockot launcher. However, three days before launch an anomaly was identified in the gyro package of the Breeze upper stage of the launcher system. This gyro platform forms an essential part of the guidance, navigation and control of the upper stage, and the correction of the problem required the replacement of the unit. To perform this operation, it was necessary to demate the launcher's upper composite and transport it from the launch pad back to the integration room.

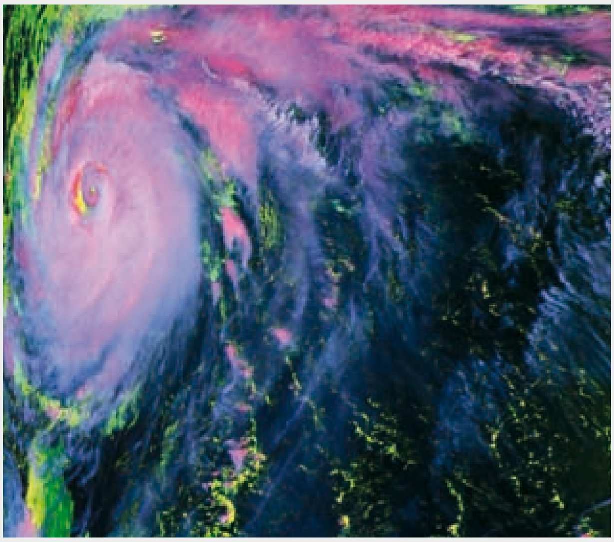
Once in the clean room, the protective fairing that shelters the satellite was opened and the spacecraft and its adaptor system was dismounted in order to allow access to the Breeze-KM equipment to be replaced. The unit was replaced and the final results of the launcher system tests as well as the investigation of the root cause of the unit failure

The satellite application software has successfully passed the software qualification review. Using the latest version of the application software the formal system level test campaign has made good progress. Several data-handling system tests were successfully completed.

→ SWARM

The manufacturing of the structure of the satellite and the boom assembly and its mechanisms is in progress with the delivery for assembly of some structural panels and the deployment mechanism. Most of the MGSE and test jigs are already delivered. This paves the way for the assembly and testing of the satellite structural model still scheduled for the first quarter next year at the test facility of IABG, Ottobrunn (D).

The testing of the structural model of the optical bench was completed in September. The engineering models of the on-board computer and the power unit were delivered and are being integrated with the electrical ground support equipment in order to initiate the verification of the software and the functional test of the satellite units and instruments. The ground segment preliminary design review for the development of the payload data and the Flight operation system is ongoing.



Sinlaku was category 4 typhoon and the tenth of the 2008 Pacific typhoon season. The storm brought torrential rain over most of the Philippine island of Luzon in September and caused floods, forcing people to evacuate (Eumetsat)

→ METOP

MetOp-A

MetOp-A continues to perform excellently in orbit. Investigations into the failure of the MetOp-A AHRPT side A have concluded that the root cause was heavy ion radiation causing the failure of a component of the HRPT Solid State Power Amplifier (SSPA). The investigations additionally concluded that the redundant MetOp-A HRPT-B sub-system is likely to suffer a similar problem.

To minimise the risk of failure to the HRPT-B unit while still offering a service to users, Eumetsat has decided to implement a 'partial' HRPT service in those areas where the risk of damage from heavy ion radiation is reduced. For southbound passes, HRPT side B will be activated for all orbits over the North Atlantic and European area starting at around 60°N. The HRPT will then be switched off before the spacecraft reaches the Southern Atlantic Anomaly region, at around 10°N. It is planned to have a trial period for two months, following which the activation scenario will become operational.

MetOp-B/MetOp-C

Although the MetOp Payload Modules, PLM-1 and PLM-3, are in long-term storage, there are still Assembly/Integration/Test (AIT) activities to be performed that require dismounting of the instruments for repair, re-calibration and/or alignment.

The MetOp Service Modules are kept in hard storage at Astrium Toulouse premises, waiting for the restart of AIT activities in 2009 for a planned MetOp-B launch in 2011.

→ METEOSAT

Meteosat-8/MSG-1

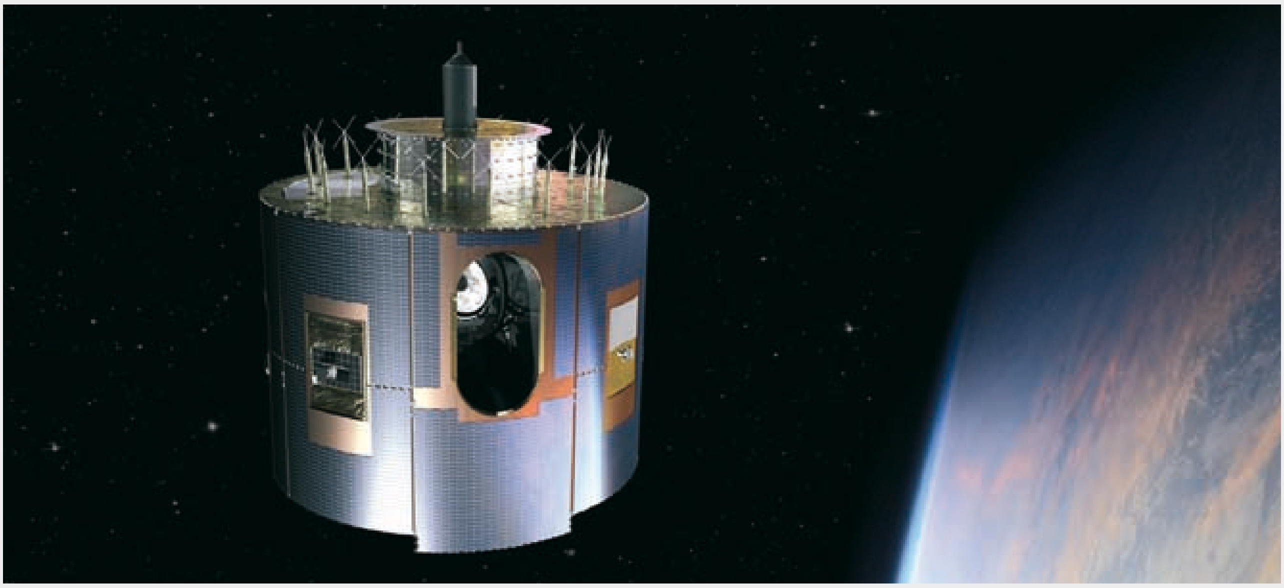
Meteosat-8 has just finished its sixth year in orbit, with the satellite in good health and all instruments still performing flawlessly. Investigations now confirmed that the un-commanded orbit change of the Meteosat-8 spacecraft could only have been caused by the loss of two thermal frames, on the side of the radial thrusters, due to the 'centrifugal' forces experienced by these frames of about 17g (with the satellite spinning at 100 rpm). Although the satellite is now experiencing larger thermal gradients during eclipse nights, all parameters still remain in the nominal area. The satellite serves as back up for MSG-2 and performs the Rapid Scan Service.

Meteosat-9/MSG-2

Meteosat-9 is Eumetsat's nominal operational satellite at 0º longitude, with Meteosat-8 as its back-up. Satellite and instruments performance are excellent.

MSG-3/MSG-4

Both MSG-3 and MSG-4 are in intermediate storage at Thales Alenia Space, Cannes, awaiting the restart of the AIT campaign begin 2010, to prepare MSG-3 for its launch, currently planned for early 2011. MSG-4 is still awaiting its completion of the MSG-4 Pre-Storage Review (PSR). MSG-4 launch is planned not earlier than 2013.



Artist's impression of MSG in orbit (Medialab)

→ SENTINEL-1

The system PDR was declared successful in July. Among its main findings were: the predicted full compliance of the proposed design to all performance requirements; the recognition of the importance of an ITAR-free design and the endorsement of the project policy to seek replacement of ITAR affected items to the maximum possible extent.

The System PDR was followed by the SAR Instrument PDR and SAR Subsystems PDR (Antenna and Radar Electronics). Equipment level PDRs will take place in the next couple of months. A preliminary launcher coupled analysis is expected in October.

Delays have been experienced on the two most critical antenna technologies (namely the Antenna Radiating Element and the Transmit-Receive Modules). Recovery plans have been put in place – with no impact on completion dates for the EM and FM programmes – and their progress is being closely monitored.

The procurement of the equipments via the 'best practices' procedure was almost completed, with more than 50% of the procurement actions being open to FP7 Participants and a number of equipments (namely X-Band S/S, S-Band S/S and GPS receiver) being procured in coordination with the other Sentinels projects.

The Ground Segment Requirement Review (covering both the Flight Operation Segment and the Payload Data Ground Segment) is ongoing, with the Review Board in October. The negotiation of the ceiling price conversion for the Phase C/D is ongoing.

→ SENTINEL-2

Following prime contract signature for the delivery of the first satellite model between ESA and Astrium GmbH in April 2008, Phase B2 procurement activities are intensifying. Some contractors are already delivering hardware (e.g. development models of the Short-wave Infrared (SWIR) detectors) and first tests have been carried out (e.g. black coating process of the Visible and Near Infrared (VNIR) detectors).

Astrium SAS presented the Multi-Spectral Instrument PDR in mid-September, stating an overall satisfactory performance of the mission. The PDR data package has been delivered and is under review. The system PDR procedure was signed, with the PDR process scheduled for November with the final Board session in late November.

The GMES programme proposal that will be submitted for approval by ESA Ministerial Council in November 2008 contains the provisions to initiate the procurement of the second satellite model in order to reach full operational capacity by 2015.

→ SENTINEL-3

Phase B2 activities proceeded as planned and the PDR process has started. The first PDR, for the OLCI instrument, began in July, followed by the Satellite and Platform PDRs in August and the SRAL Instrument PDR in September. The remaining two instrument PDRs (MWR and SLSTR) are planned during the last quarter of the year. These reviews will allow an evaluation of the satellite and instrument technical consolidations performed during the Phase B2, and will lead to the freezing of the design that will be then considered during the subsequent Phase C/D as the basis for the detailed definition, manufacturing and testing.

On the technical side, two major achievements were the consolidation of the SLSTR thermo-mechanical design, such to satisfy the operational constraints required to reach the desired instrument performance and the decision of the radio frequency (RF) switch configuration to be implemented on the MWR instrument. At satellite level, the main task has been the gradual introduction of specific unit technical data that became available after start of the selected sub-contracts.

The execution of the procurement tasks through competitive Invitations To Tender (ITTs) is proceeding in all fields and, together with the PDRs, it still represents the main effort in this phase of the programme. Of the 100 or so procurement contracts to be placed, 33 have been concluded and other 25 are under negotiation. In line with the objectives established at the beginning of the Phase B2, the remaining ITTs to be issued after the PDRs are not related to procurement of flight hardware but mostly ground support equipment and test facilities.

→ EARTHCARE

The EarthCARE Phase B activities are progressing and the major trade-offs addressing spacecraft, platform and instruments configuration are being finalised. As part of Phase B1, industry is consolidating the satellite, base platform and instrument specifications and the first version of the support specification is being iterated. Similar activities have started in Japan for the Cloud Profiling Radar and JAXA, together with the Japanese industry, is consolidating the instrument configuration and interfaces in close cooperation with ESA.

The first major review of the programme is the System Requirements Review planned for the end of 2008.

→ VEGA

Several milestones were achieved on the launch vehicle side: the Thrust Vector Control CDR steering board was held (both launch vehicle and P80), the architectural definition of additional telemetry for P80 has been finalised and the measurement plan for the qualification flight has been delivered. In parallel, the P80 Qualification Model (QM) Level 1 exploitation steering board has been concluded.

The Z23 QM firing test Level 1 was performed on 23 July. The mechanical qualification campaign of the Z23 case has been completed, with the successful completion of mechanical tests on the QM2 model (after firing) on 15 and 16 July. The Z23 Qualification Review started on 3 September. The acceptance tests for ground segment subsystems are ongoing. An Announcement of Opportunity for payloads on the VERTA-1 flight was issued and several declarations of interest received.

→ SOYUZ AT CSG

The CDR of the Air-conditioned Equipped Payload Trailer took place 3–5 June followed by the steering board of the CDR for Soyuz Launch System Ground Segment on 20 June. After CDR of the Mobile Gantry in February, production is ongoing. The first set of Russian equipment arrived in French Guiana on 27 July followed by the arrival of the 90-strong team of Russian technicians. The second sea-borne arrival, with the launch mechanical system on board, was postponed to the end of November. The European Infrastructure On-site Acceptance Review was planned for the beginning of October.

→ FLPP

System activities relevant to Period 2.1 NGL-ELV, BBLV together with Building Block System Activities and NGL System Studies have been completed. The second set of activities, as well as the relevant test campaign, for the Expander Demonstrator was completed. Negotiations for Expander Demonstrator third set of activities were completed and activities started. Test campaign for M2R has been completed. A total of 4675 seconds of cumulative hot-firing test duration was demonstrated on the Vinci engine.

The LOX/LH2 coupled (Pre-burner/Main Combustion Chamber) hot-firing tests on the Main Stage Propulsion/ Subscale Propulsion Demonstrator were completed. A workshop dedicated to avionics systems for the next-generation launchers was held on 16–17 September. The Cryogenic Upper Stage Technologies (CUST 1.1) industrial activities have started.

→ INTERNATIONAL SPACE STATION

The on-orbit commissioning of ESA's Columbus laboratory payloads has been completed with the successful troubleshooting of Biolab and the repair of the Fluid Science Laboratory (FSL).

Europe's first Automated Transfer Vehicle, ATV *Jules Verne*, has had an exceptional and flawless six-month mission. It has displayed the full range of its capabilities, including automatic rendezvous and docking, four reboosts of the ISS to a higher orbital altitude to offset atmospheric drag, ISS attitude control, performing a collision-avoidance manoeuvre on 27 August 2008, and on its final journey, offloading 2.5 tonnes of waste.

On 5 September, *Jules Verne* undocked from the ISS at 23:29 CEST. It then spent 23 days carrying out 'rephasing' manoeuvres to bring it to the correct position behind and underneath the ISS. This predefined position allowed the ATV's controlled destructive reentry on 29 September to be viewed and recorded from the ISS itself, as well as from two specially-equipped observation planes located in the vicinity

ATV *Jules Verne* following undocking from ISS

A still image of *Jules Verne's* reentry from a high-definition TV camera on one of the aircraft taking part in the ATV reentry observation campaign

of the ATV's flight path in the skies above the South Pacific Ocean.

Following a final deorbit burn at 14:58 CEST on 29 September, which slowed its velocity by 70 m/s, Jules Verne entered the upper atmosphere at 15:31 CEST, at an altitude of 120 km. It then broke up at an altitude of 75 km, with the remaining fragments falling into the South Pacific some 12 minutes later.

The way ATV *Jules Verne* performed has highlighted extremely well how the benchmark of European space technology has been raised. It has demonstrated how far European capabilities have developed in building, launching and controlling space infrastructures. This bodes well, not only for future ATV missions to the ISS, but also for developments of this kind of technology that will eventually provide Europe with an autonomous access to space for its astronauts.

→ SPACE INFRASTRUCTURE DEVELOPMENT AND EXPLOITATION

Infrastructure Development

A study on a Columbus external platform capability for small payloads (SPERO) is on-going with industry.

ATV Production

The ATV-2 integration is progressing well; the launch date is scheduled for the second quarter of 2010. The ATV-3 equipments have been released for procurement with a few exceptions. The ATV-3 launch is scheduled for October 2011.

Operations Status

The Columbus laboratory operations have continued nominally. The ESA/CNES team at the ATV Control Centre in Toulouse were busy in the last period of the *Jules Verne* mission, updating ATV system parameters and defining the orbital profile that the ATV would take on its journey back into Earth’s atmosphere.

→ UTILISATION

The European Technology Exposure Facility (EuTEF) science and technology programme is progressing well; with all nine instruments continuously delivering science data. Full SOLAR functionality was re-established on 18 September after the temporary communication link failure was resolved. The last of the Sun observation cycles ended on 7 September and the next one is due to start on 26 September.

The first four runs of the Fluid Science Laboratory experiment, Geoflow, were completed in Increment 17, with excellent interferometric image data. The experiment investigates the flow of a viscous incompressible fluid between two concentric spheres rotating around a common axis under the influence of a simulated central forced field. A large sequence of additional runs of Geoflow will continue throughout Increment 18.

The second run of the Biolab ‘Waving and Coiling of Arabidopsis Roots’ (WAICO-2) experiment, aimed to investigate the effect of gravity on plant root growth, was deferred. This is because Biolab’s full functionality must

The Fluid Science Laboratory rack, containing the Geoflow experiment, in Columbus

(Arabidopsis) growth activity at a molecular level in weightlessness.

ESA's complementary experimental programme in the ISS segment is nominally progressing with five experiments in respiration, radiation and technology. The Nitric Oxide Analyser (NOA) experiment series, aimed to monitor exhaled nitric oxide levels in astronauts, was fully completed.

The ANITA cabin atmosphere monitoring system completed its ten-month operational phase as system device in the Destiny module, and will be returned on the Space Shuttle ULF-2 flight in November.

The European Drawer Rack, which houses the Protein Crystallisation Diagnostics Facility (PCDF), is now ready for the start of the four-month protein science programme of the first PCDF experiments which will be uploaded on Space Shuttle flight 15A in early 2009.

→ ASTRONAUTS

The selection campaign for new ESA astronauts is entering in its final phase. Of the more than 8400 completed applications received, 920 applicants were retained and invited to the first round of psychological tests in Hamburg, which were completed in August. After a review of medical questionnaires, 192 candidates were invited for the Psychological Test Phase 2, which started on

Frank De Winne (right) and back-up André Kuipers in the full-size Columbus and Node-2 training model at EAC

15 September at ESA's European Astronaut Centre in Cologne, Germany.

On 17 July, ESA announced the assignment of astronaut Christer Fuglesang (S) as a Mission Specialist on board the 11-day STS-128 mission, currently scheduled for launch on Space Shuttle *Atlantis* on 30 July 2009.

On 11 September, ESA launched an online competition open to all citizens of ESA Member States, to propose a name for ESA astronaut Frank De Winne's (B) next ISS mission in May 2009.

Crew training at EAC for the 17S crew, Yuri Lonchakov (RUS) and Mike Fincke (US), and for the ULF2 Shuttle rotating ISS crewmember, Sandra Magnus (US), was completed in July. Training for Expeditions 19 and 20 is underway. On 5 September, crews including ESA astronauts De Winne and Andre Kuipers (NL) received Columbus system and ESA experiment training at EAC. Kuipers is a back-up Flight Engineer for Expedition 19.

→ CREW TRANSPORTATION AND HUMAN EXPLORATION

Technological and System Activities

Work continued on the technical and scientific aspects of the MoonNEXT and MarsNEXT mission Phase A studies, which reached intermediate review level at the end of June.

Architecture and Stakeholder Studies

Phase 1 of the Joint Comparative Architecture Assessment with NASA was completed with a final meeting held in July. The outcome of the meeting was a joint assessment of the Moon Exploration Architecture with a first assessment of the potential European contribution. The NASA/ESA Comparative Architecture Report was finalised and formally approved by NASA.

A two-day meeting of the Interface Standards Working Group (ISWG) of the International Space Exploration Coordination Group (ISECG) was held in Bremen on 17/18 September. Representatives of ESA, NASA, JAXA, CSA, KARI and CNES attended. Initial scenarios for lunar exploration have been developed at the meeting and the follow-on work was agreed together with specific actions for each of the agencies. Consolidated lunar exploration scenarios and related architecture elements will be reviewed at the next ISWG meeting at the end of October.

Crew Space Transportation System

Additional detail concerning the CSTS vehicle concept proposed in June is yet to be provided by Energia.

European industry has worked at the finalisation of the work performed on their side. A summary report is in preparation and a final collocation of Energia staff to the European industry location (Bremen) will take place in early October.

Advanced Return Vehicle

In parallel with the CSTS activities, a growing interest has arisen in the development of an autonomous transportation system, the Advanced Return Vehicle (ARV) that could make use of the European assets (Ariane-5, ATV and CSG).

A stepped approach has been proposed, leading to a cargo version in 2015, capable of evolving into a crew version by 2020. Based on the results of several previous studies, a preparatory activity aiming at a correct definition of the requirements and an initial optimisation of the vehicle configuration have been initiated with European industry as part of the General Study Programme.

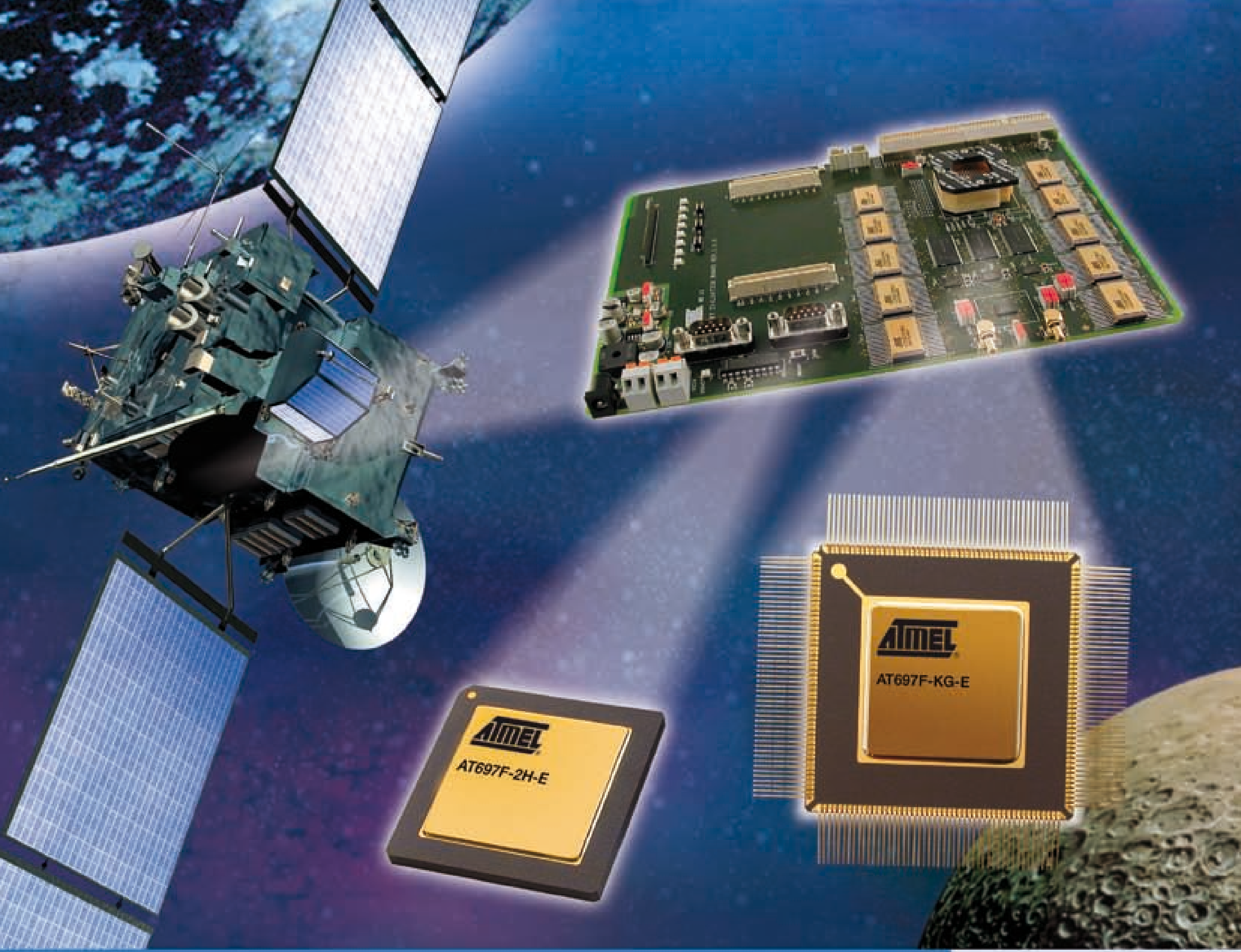
International Berthing Docking Mechanism

All the major sub-assemblies of the IBDM development model's Soft Docking System, (load-sensing ring, linear electromagnetic actuators and avionics) have been integrated for the first time at SENER, Madrid. The ability to raise and lower the table with the actuators driven by the avionics has also been demonstrated.

The new activity for the design and development of the hard-docking structural latch for the IBDM Hard Docking System has been placed with Verhaert (B) and the conceptual design review held. The selected new design is based on an individually mechanised hook-on-hook concept and is a simplified evolution of the generic latch previously tested.

EXPERT

Phase C/D activities of the European Experimental Reentry Testbed (EXPERT) programme were restarted, aiming to complete the subsystems CDR before the end of 2008. In the meantime, the qualification of the experiments is progressing. The launch contract is being negotiated with the Russian organisations involved. ■



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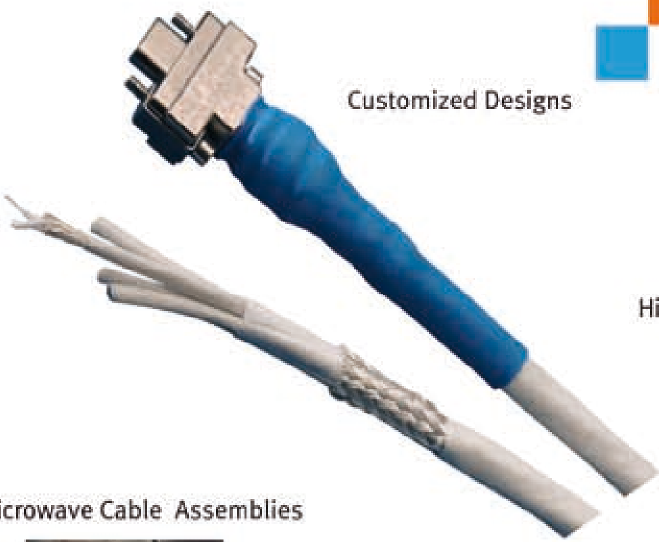

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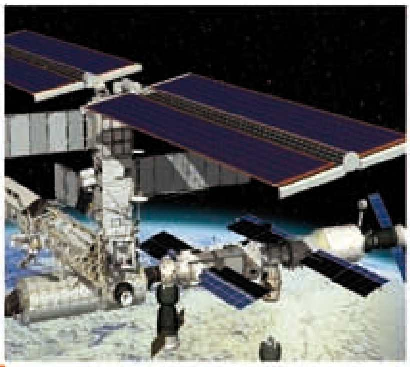

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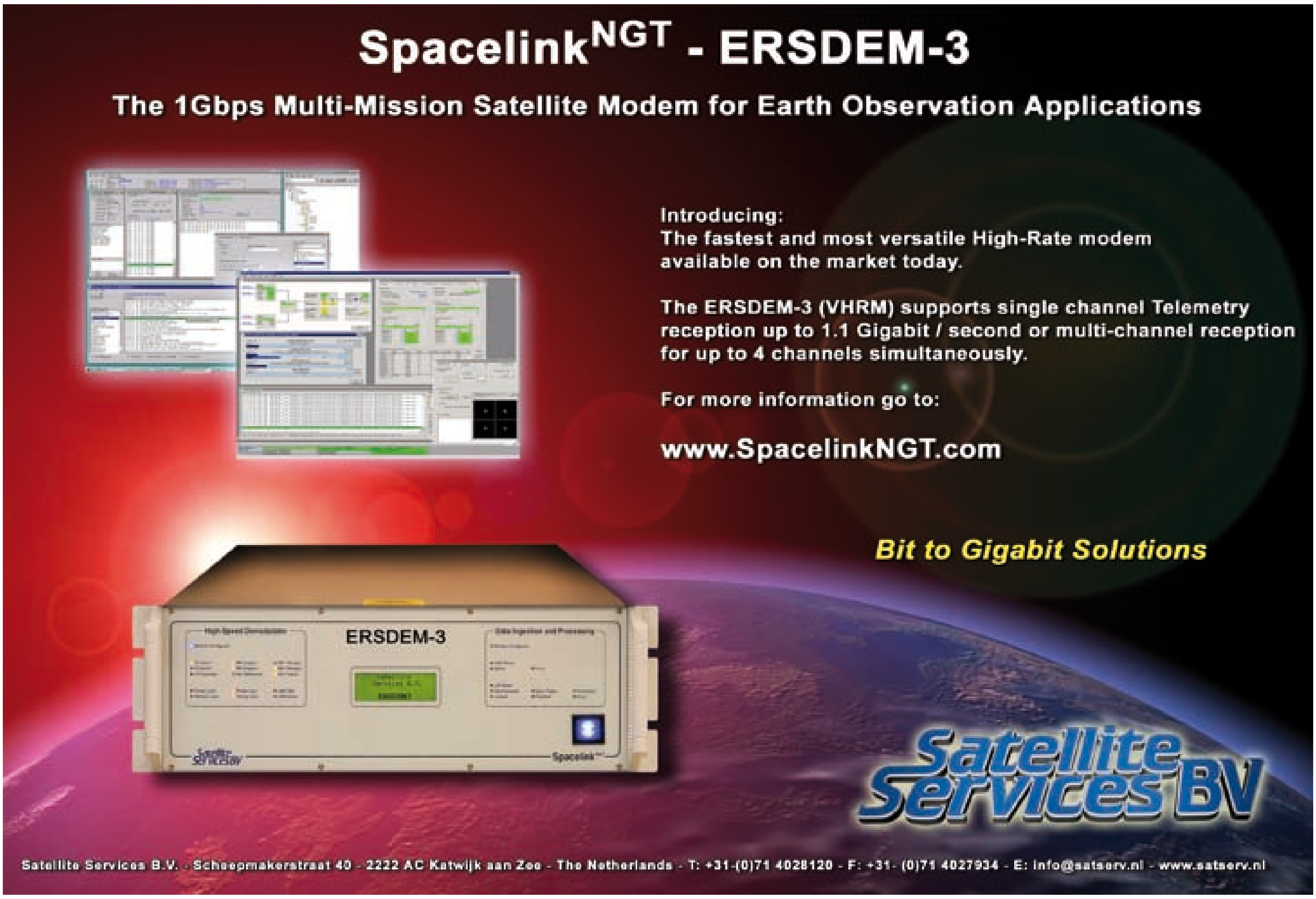
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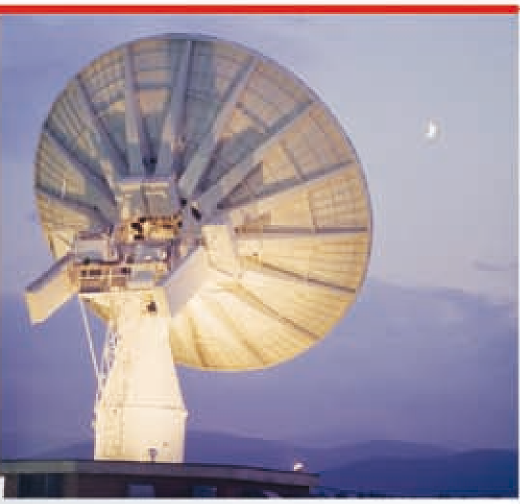

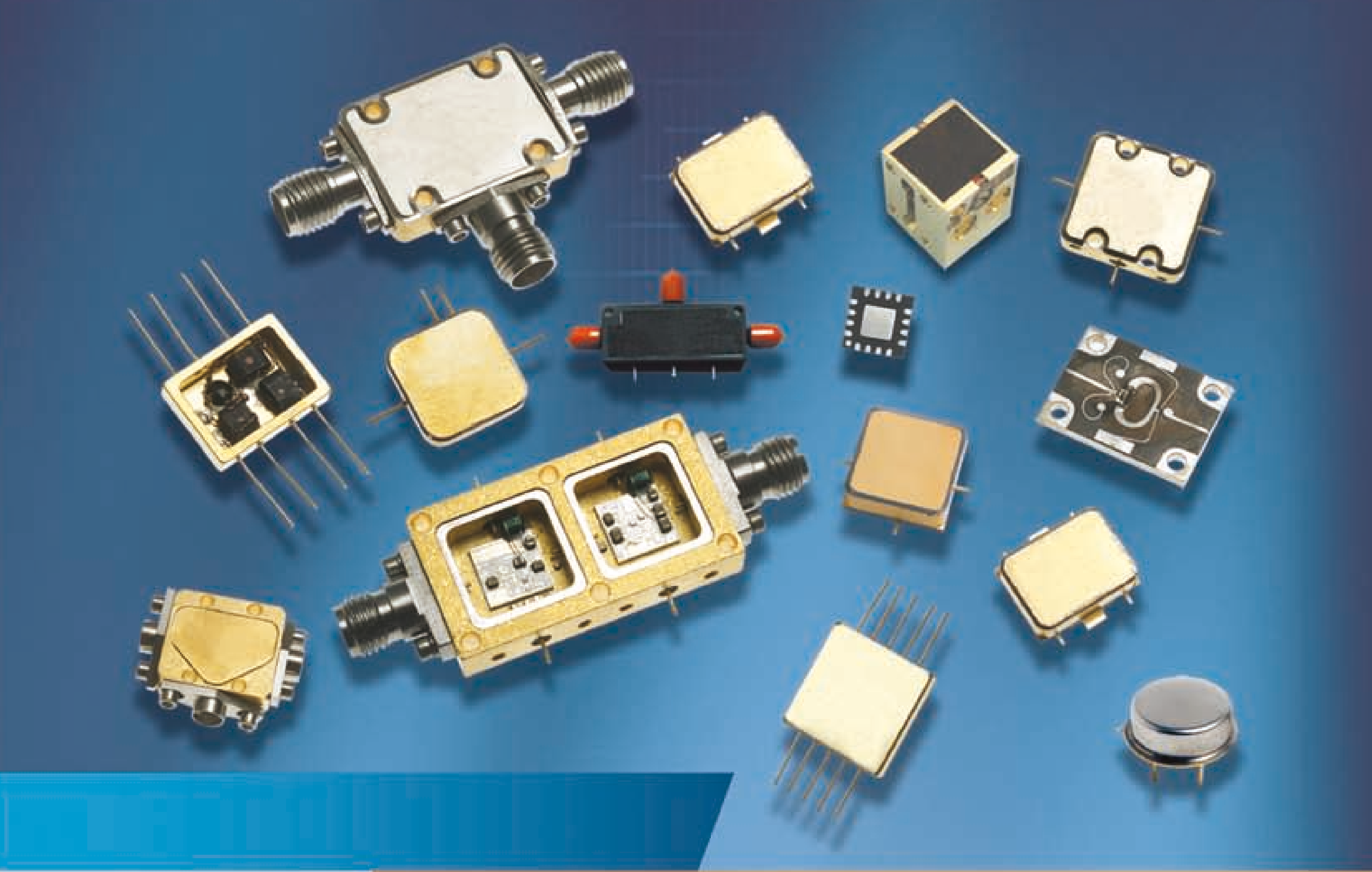

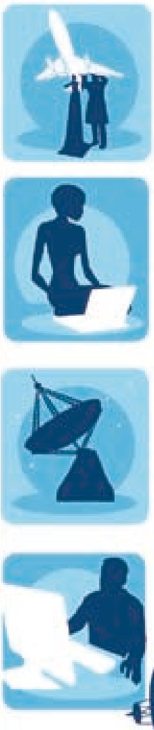


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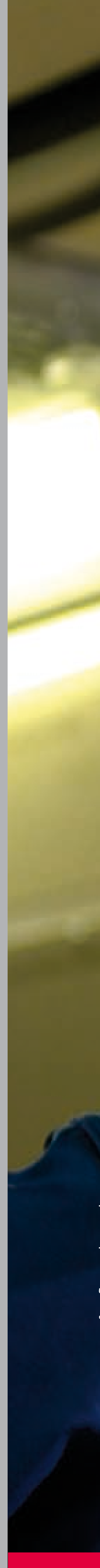

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