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bulletin

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Agence spatiale européenne

european space agency

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agence spatiale européenne

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Cover: The launch of Rosetta – see pages 5 and 88.

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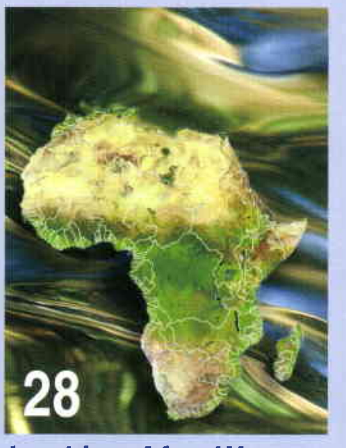
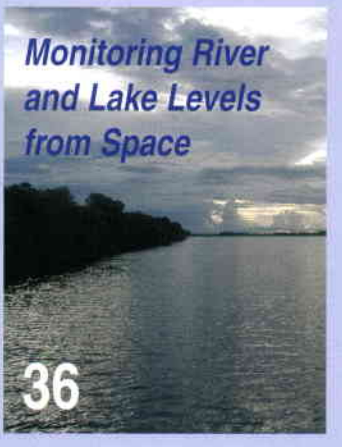
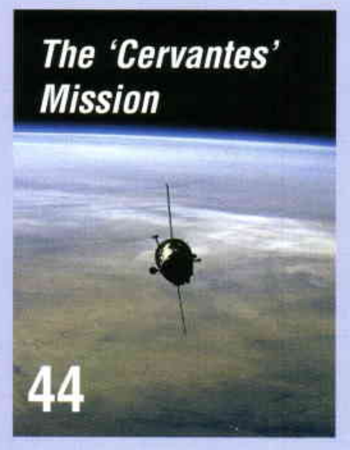
Rosetta's New Target Awaits



Looking After Water in Africa





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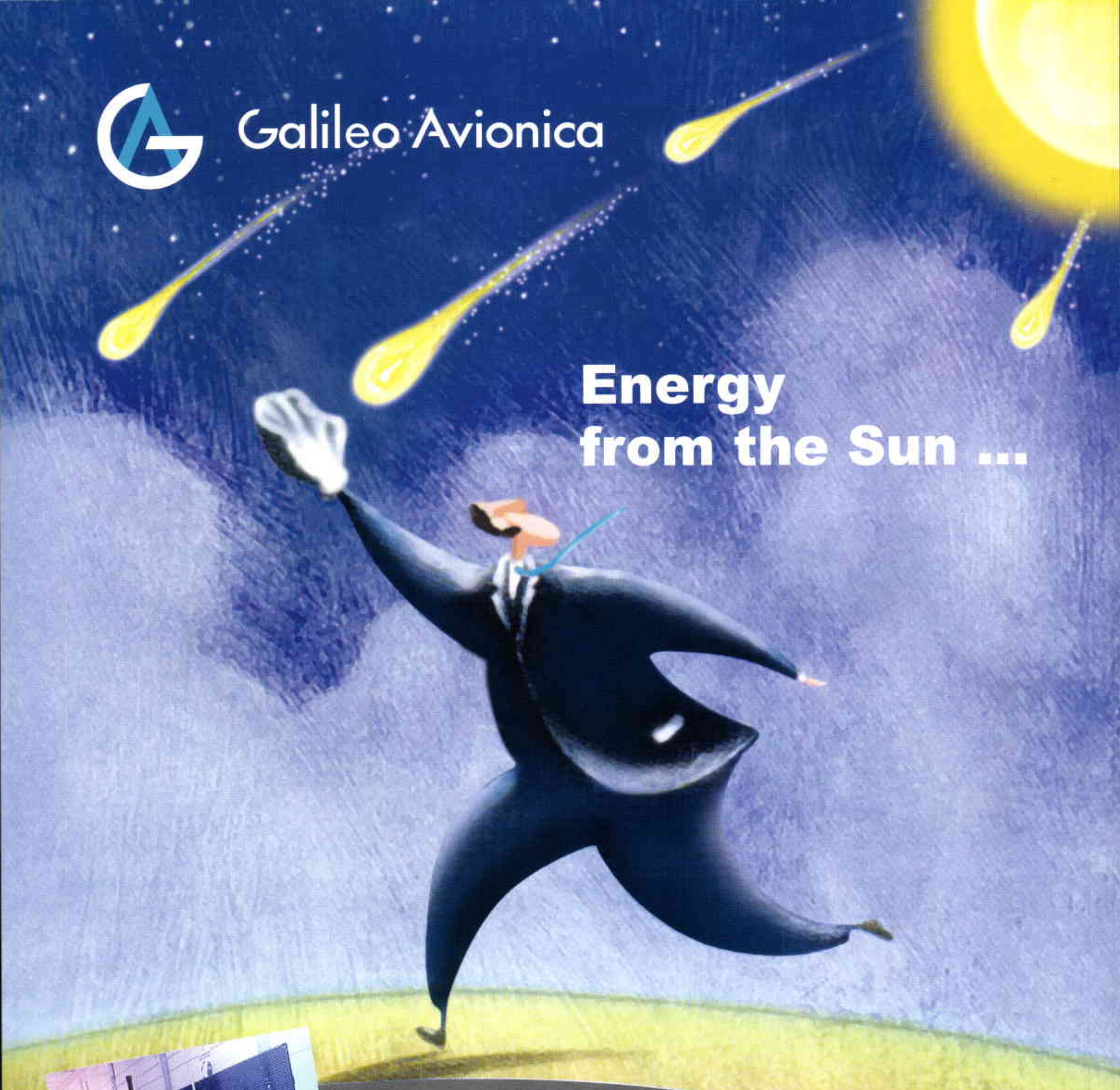
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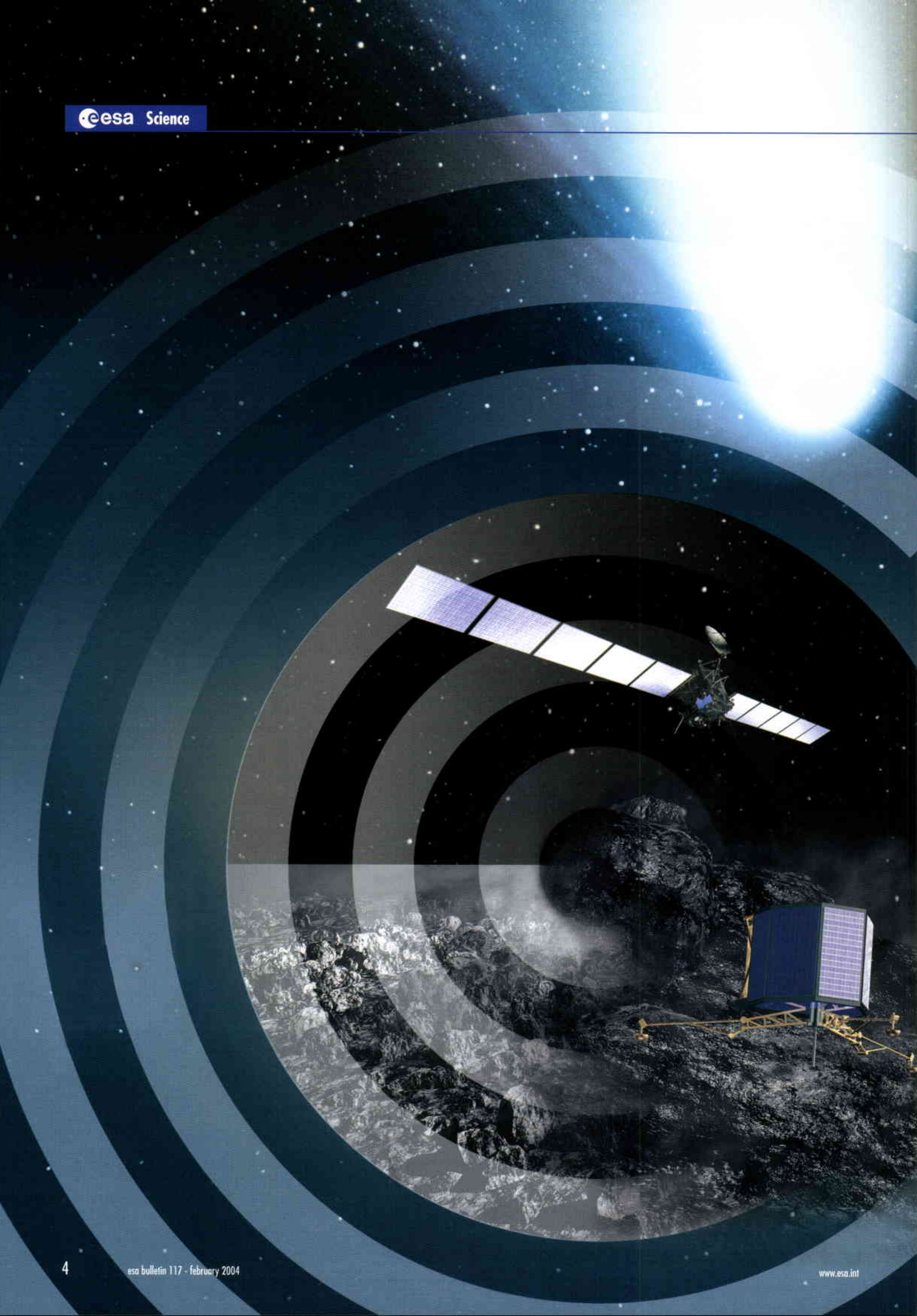


Rosetta's New Target Awaits

John Ellwood, Gerhard Schwehm & the Rosetta Project Team
ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

Peter Bond
Space Consultant, Cranleigh, United Kingdom

The countdown is under way once more for Europe's ambitious comet chaser. After the disappointment of a prolonged launch postponement in January 2003, engineers and scientists from all over the world are eagerly awaiting the February 2004 lift-off of ESA's Rosetta spacecraft and the start of its historic mission to orbit and land on a comet.

However, the lengthy delay has meant that Rosetta will no longer be heading for comet 46P/Wirtanen. Following careful analysis of the available comets and associated launch constraints for each mission scenario, the ESA Science Programme Committee accepted the recommendation to change the target comet, but not the scientific objectives. The new target is a cosmic iceberg known as 67P/Churyumov-Gerasimenko, a fairly large, active comet which sweeps through the inner Solar System once every six and a half years.

The revised mission scenario is even more challenging than the original one. In order to rendezvous with comet Churyumov-Gerasimenko, the spacecraft will now have to complete no fewer than four planetary flybys. During its circuitous 10-year odyssey around the inner Solar System, it will also have to endure long periods of hibernation, dramatic variations in sunlight and temperature, and two excursions through the main asteroid belt.

SEE PAGE 88 FOR LATEST INFORMATION

The Story So Far

After more than a decade of careful mission analysis and intensive hardware preparation, Rosetta was shipped to Europe's Kourou spaceport in French Guiana in September 2002, prior to its scheduled launch aboard an Ariane-5. After completion of spacecraft fuelling and testing, Rosetta was only weeks from lift-off when tragedy struck, with the launch failure of Ariane flight 157 on 11 December 2002.

Although Rosetta would not be using the same version of Ariane-5 that was involved in the accident, ESA and Arianespace immediately set up a Review Board to consider the options for the billion Euro comet mission. After careful consideration of all factors, they took the joint decision not to launch Rosetta during its January 2003 window, despite the fact that this would jeopardise its mission to rendezvous with comet Wirtanen.

While ESA waited for Arianespace to provide the necessary guarantees regarding the Ariane-5 system qualification procedures and review process, the Rosetta team was asked to identify comets that their spacecraft could reach if launched within the next two-and-a-half years. The targets were to be selected on the basis of three main criteria: the scientific return, the technical risks to the spacecraft, and the extra funding needed.

After careful scrutiny of more than 150 periodic comets, the team presented nine mission scenarios to the Rosetta Science Working Team. The three most favoured options were then considered by the ESA Science Programme Committee (SPC) on 25-26 February 2003.

One option was to prepare Rosetta for a January 2004 launch towards its original target, comet Wirtanen. Under this scenario, no modifications would have to be made to the Rosetta spacecraft, although a more powerful Proton launch vehicle would have to be used in order to reach the comet. The other two options (with possible launches in February 2004 or 2005, respectively) would take Rosetta to a different periodic comet, 67P/Churyumov-Gerasimenko. Since Churyumov-Gerasimenko was thought to be larger than Wirtanen, this would be likely to involve certain modifications to the Lander.

Rosetta in a clean room at the launch site in Kourou, French Guiana

The 2004 opportunity was favoured since it would mean that Rosetta would have to spend less time in storage and it would require only a standard Ariane-5 G+ launcher. The 2005 alternative would need a larger launch vehicle – either an Ariane-5 ECA (not yet available) or a Russian Proton – in order to provide sufficient energy for a rendezvous with the fast-moving comet.

After a favorable response from the SPC, the mission team continued to study the technical and scientific implications of the three options in more detail. In order to assist their deliberations, a campaign of observations to study comet Churyumov-Gerasimenko was conducted with both the NASA-ESA Hubble Space Telescope and facilities of the European Southern Observatory. The intention was to determine the main physical characteristics of the comet - especially its size - as inputs to a detailed mission analysis that would identify landing scenarios and make a thorough assessment of any hardware modifications that would be necessary.

Finally, during its meeting on 13-14 May 2003, the SPC decided to give the green light for a mission to explore comet Churyumov-Gerasimenko. Although a February 2004 launch was anticipated, the date could not be finalised until the ESA Council found a solution to a shortage of funds in the Science Programme's immediate budget, partly the result of an estimated 80 million Euro additional cost caused by the grounding of Ariane-5. A February 2005 launch to the same comet was to be investigated as a back-up plan.

"If the extra funding required for Rosetta was the only tab on the table, the ESA Science Directorate could have absorbed the cost," said Professor David Southwood, ESA's Director of Science, at that time. *"Unfortunately, we have to face a number of other financial challenges."*

Fortunately the financial conundrum was resolved at the end of May when the ESA Ministerial Council agreed to approve a redistribution of funds. The way was clear for Rosetta to be launched in February 2004 aboard an Ariane-5 G+ vehicle, the same rocket selected for the original 2003 launch to comet Wirtanen.

Landing on a Larger Comet

One of the major concerns arising from the change of target involved the ability of the small Rosetta Lander to touch down safely on a much larger object than originally planned.

"Comet Churyumov-Gerasimenko has three to four times the diameter of comet Wirtanen and its gravity could be at least 30 times greater," says Philippe Kletzkine, ESA manager for the Rosetta Lander. *"This means that the maximum landing speed will increase from 0.2 – 0.5 metres per second for Wirtanen to 0.7 – 1.5 metres per second for Churyumov-Gerasimenko."*

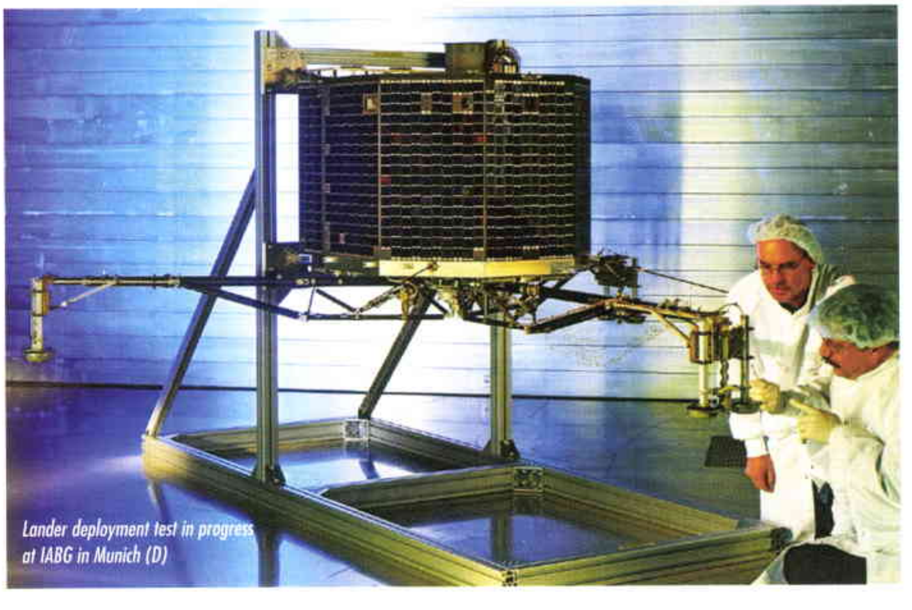
In the case of Wirtanen, the biggest problem was avoiding a rebound – the spacecraft only had to bounce slightly and its momentum would overcome the weak gravitational hold of the comet's nucleus. For Churyumov-Gerasimenko, there were also concerns about a faster landing, which would produce a greater shock on impact, and about the stability of the Lander upon touchdown. In the worst-case scenario of a 'hard' comet surface, rough terrain and relatively high gravity, it was possible that the Lander could topple over.

Hoping to avoid the necessity of removing either the landing gear or the entire Lander from the Rosetta Orbiter, the design team carefully analysed the descent profile and decided that it would be possible to achieve a successful touchdown by making a fairly simple modification to the landing gear. The solution came in the form of a small bracket, known as a 'tilt limiter', that could be attached to the bottom of the Lander.

The limiter was designed by Astrium GmbH in collaboration with ESA and the Max-Planck-Institute in Lindau, Germany. By carrying out pendulum tests with a model of the landing gear, it was possible to simulate landing on a wall at different angles of approach, and to verify that the spacecraft could successfully touch down at speeds of up to 1.5 metres per second on a 10 degree slope, or up to 1.2 metres per second on a 30 degree slope. Computer simulations of landings were run in parallel by the Max-Planck-Institute in order to determine more accurately the landing performances for various surface characteristics, impact velocities and Lander attitudes. The tilt limiter was delivered to Kourou and mounted on the spacecraft landing gear on 30 September 2003.

"By restricting the angle at which the landing gear can flex on touchdown to only 3 to 5 degrees, we improve the damping effect and reduce the possibility of a rebound," explains Philippe Kletzkine. *"This excellent collaboration between ESA, industry and MPAe enabled us to adapt to the new mission very quickly and efficiently."*

No major changes are envisaged in the Lander's descent profile. Under the new mission scenario, the rendezvous will take place at 4 AU – further from the Sun than planned for Wirtanen. As a result, there will be more time available for the Orbiter's instruments to map the nucleus at high resolution and find a safe haven for the 100 kg Lander before its historic touchdown on the comet's pristine surface in November 2014. Another advantage over the original scenario will be the ability to send data back to Earth at a much higher rate, since the Rosetta Orbiter will be nearer to Earth during the close encounter.


Lander deployment test in progress at IABG in Munich (D)

The Race Against Time – Part 2

Once the decision was made to ground Rosetta only weeks before completion of its launch campaign, engineers had to ensure that the spacecraft could be stored safely and cleanly until a new launch date was agreed. It was carefully moved to the empty S3B clean room in Kourou and a number of safety precautions were undertaken, including removal of the needle-sharp explosive harpoons on the Lander, the high-gain antenna and the huge pair of solar arrays. The mission team also decided to remove and refurbish five of the instruments on the Orbiter.

One of the main concerns was how to deal with the fully fuelled spacecraft. Eventually, it was decided to offload the 660 kg of monomethyl hydrazine (MMH) fuel, but leave the nitrogen tetroxide oxidiser on board in order to avoid potential corrosion of the titanium tanks.

With the new target comet now confirmed, the team also had to revalidate all flight system software in order to meet the requirements of the revised mission, and also to revalidate all flight system testing.

Fuel being offloaded from the Rosetta Orbiter after the first launch's postponement

"We had already prepared some software for uplinking to Rosetta in May, four months after its planned launch, so we decided to take advantage of the delay to include additional functionality and put the new software onboard the spacecraft while it was still on the ground," explains Jan van Casteren, Rosetta System Engineering Manager.

Other modifications had to be made to allow for the fact that during its monumental trek Rosetta would at various times be closer to the Sun or further away from it than originally planned.

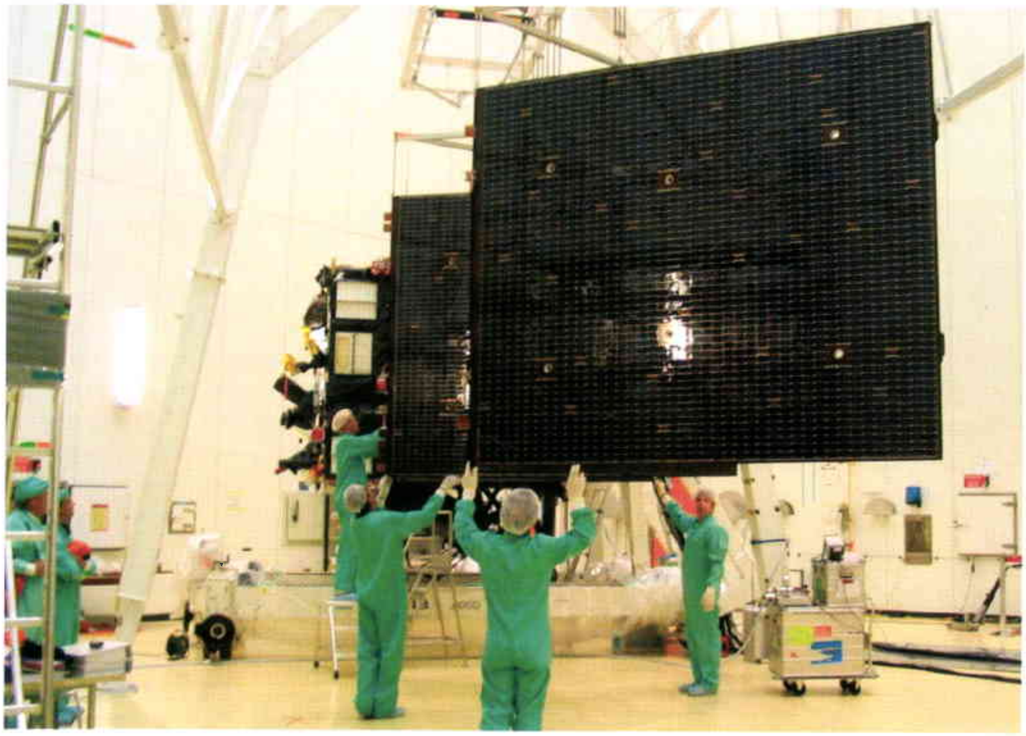
"We put reflective surfaces on the exterior of some thermal blankets to prevent overheating," explains Jan van Casteren. *"We also had to analyse the potential impact of spending longer in space during a period of maximum solar activity. By accumulating a larger overall dose of radiation, there was a likelihood that the solar arrays would be degraded more quickly, so we carefully studied the power situation to ensure that we would have a sufficient margin throughout the mission. This gave us confidence that Rosetta will have enough power even when it is beyond the orbit of Jupiter."*

Finally, the Launch Preparation Readiness Review Board gave the go-ahead for the start of the launch campaign on 24 October 2003. Over the next few weeks, the Orbiter took on a more familiar appearance as the high-gain antenna and the solar wings were reinstalled, and the thermal blankets were carefully sewn back into place.

The most critical milestones were scheduled for after the Christmas break. In late January, the Orbiter's tanks were to be loaded once again with MMH fuel and re-pressurised. Two weeks later, Rosetta is scheduled to be moved to the Final Assembly Building (BAF) for mating with the Ariane-5 booster.

Installation of the protective fairing on 18 February is to be followed by the launch countdown rehearsal and transfer of the launch vehicle to the ELA-3 pad on 24 February. The launch window lasts from 26 February until 17 March but, if all goes according to plan, Rosetta should begin its monumental trek to comet Churyumov-Gerasimenko at 08:16 CET on 26 February.

"The delay presented us with our second race against time to meet a launch deadline," says Claude Berner, Rosetta Payload and Operations Manager. *"This meant that we were faced with some unexpected challenges and risks, particularly in dismantling a flight-worthy spacecraft, but the ESA-Industry team has successfully overcome all of the obstacles and we are on track for a February launch."*



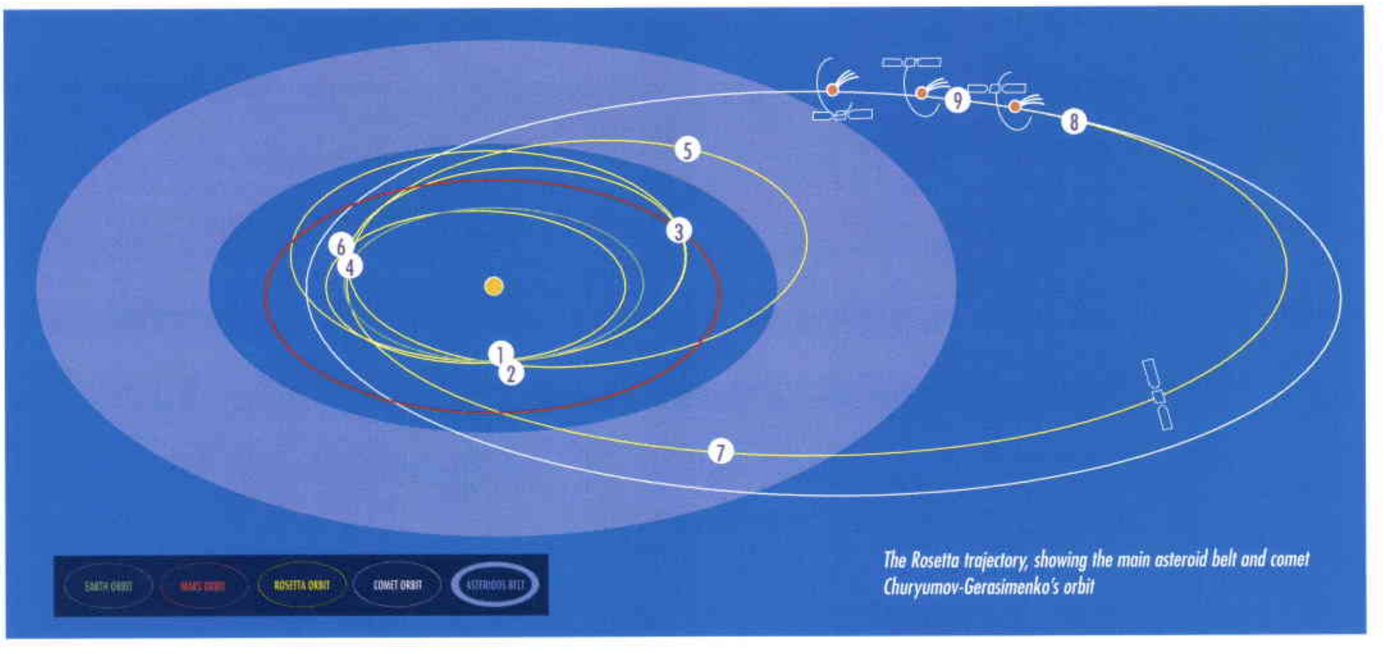
Remounting of the solar arrays in Kourou

Great Expectations

Despite the modifications mentioned above, most aspects of Rosetta's expedition to explore one of the most primitive objects in the Solar System have changed little over the past 12 months. After its launch from Kourou in February 2004, the 3 tonne spacecraft will be inserted into an elliptical, 4000 km x 200 km trajectory around the Earth. After about two hours, the Ariane-5 upper stage will be ignited to send the unique comet chaser on its way.

to comet Churyumov-Gerasimenko remains uncertain. The previous flight plan en route to comet Wirtanen included observations of Mars and two very unusual main-belt asteroids. Under the revised mission scenario, Rosetta will experience an eclipse during the Mars flyby, so limiting the scientific observations that can be made. However, there is likely to be at least one opportunity to study an asteroid at close quarters, and a number of possible candidates have already been identified. The final selection will be made after

Finally, after more than seven years of interplanetary travel, Rosetta will fire its thrusters to alter course towards comet Churyumov-Gerasimenko and then cross the orbit of Jupiter, some 800 million kilometres from the Sun. Handicapped by the low levels of sunlight – 25 times less than on Earth – Rosetta will be operating on minimal electrical power and relying heavily on its huge solar wings to capture every photon. However, as it begins to head sunwards and close in on the dormant nucleus, power levels will gradually rise.



The Rosetta trajectory, showing the main asteroid belt and comet Churyumov-Gerasimenko's orbit

In order to gain enough orbital energy to reach its target, one gravity assist from Mars and three from Earth will be required. The first planetary encounter will take place in March 2005, when Rosetta returns to Earth's vicinity for its initial orbital slingshot. Three years after launch, the spacecraft will fly past Mars, before completing its second Earth encounter in November 2007.

With its orbit now substantially more elongated, Rosetta will enter the asteroid belt prior to its third and final visit home in November 2009. Only then will it have picked up sufficient velocity to leave the inner Solar System behind and set course for the distant comet.

At present, the amount of science that can be conducted during the 10-year trek

launch, once the mission team has determined how much surplus fuel is available.

Since Rosetta will be launching to Churyumov-Gerasimenko with the same amount of oxidiser and fuel that it was carrying to Wirtanen, the mission team had to examine the spacecraft's propellant margins very carefully. Of particular concern was the extended thruster firing that will be required to rendezvous with the comet.

"We do not have too much fuel to spare," explains John Ellwood, the Rosetta Project Manager. *"Our capability to target one or more asteroids will depend on the efficiency of the launch and how much fuel we will need to conduct orbital manoeuvres and course corrections, so no decision will be made until after lift-off."*

By the time the second rendezvous manoeuvre burn takes place in May 2014, the electricity supply will be adequate for operation of the suite of 11 scientific instruments.

Once its target's position is pinpointed, Rosetta will edge towards the speeding comet, eventually braking into orbit around the coal-black nucleus in August 2014. From an altitude of just a few kilometres, its cameras will map the pockmarked surface at high resolution and search for suitable landing sites.

Once the surface of the comet's nucleus has been surveyed in unprecedented detail and a safe landing site has been selected, the Lander will separate from the Orbiter and slowly descend to the comet's surface.

Comet 67P/Churyumov-Gerasimenko

Comet 67P/Churyumov-Gerasimenko photographed by the European Southern Observatory (ESO)

Rosetta's new target, comet 67P/Churyumov-Gerasimenko, is one of more than 150 comets that follow fairly predictable, short-period paths around the Sun. It was discovered as recently as 1969, when several astronomers from Kiev visited the Alma-Ata Astrophysical Institute to conduct a comet survey.

On 20 September, Klim Churyumov was examining photographs of comet 32P/Comas Solá, taken by Svetlana Gerasimenko, when he found a fuzzy feature near the edge of the plate. At first, he assumed that the faint object was the expected periodic comet, but upon returning to Kiev, he studied the plates very carefully and eventually realised that a previously unknown comet had been found, less than two degrees from comet Comas Solá.

Comet Churyumov-Gerasimenko has a particularly unusual history. Up to 1840, its perihelion distance was 4.0 AU (four Sun-Earth distances or about 600 million km) and the comet was completely unobservable from Earth. Then a fairly close encounter with Jupiter caused the comet's orbit to move inwards to a perihelion distance of 3.0 AU (450 million km). Over the next century, the perihelion gradually decreased further to 2.77 AU. Then, in 1959, a further Jupiter encounter reduced it to just 1.28 AU.

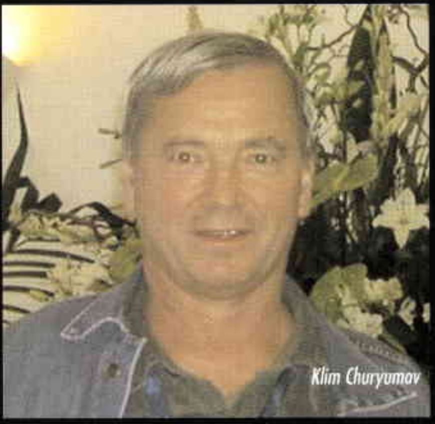
The comet's orbit is still evolving and, after another perturbation from Jupiter in 2007, the perihelion at the time of Rosetta's encounter in 2014 is expected to be only 1.24 AU (186 million km). It currently completes one orbit of the Sun in approximately 6.6 years.

The comet has now been observed from Earth on six approaches to the Sun - 1969 (year of discovery), 1976, 1982, 1989, 1996 and 2002. Unusually active for a short-period object, it displays a coma (a diffuse cloud of dust and gas surrounding the solid nucleus) and often a tail at perihelion. During the 2002-2003 apparition, the tail was up to 10 arcminutes long, with a bright central condensation in a faint extended coma. Even 7 months after perihelion the tail continued to be very well developed, although it subsequently faded rapidly. The comet typically reaches a maximum magnitude of around 12, usually as the result of marked bursts of activity at perihelion, observed during three of its last four returns.

Despite being a relatively active object, even at the peak of outburst the dust production rate is some 40 times lower than for 1P/Halley. The peak dust production rate in 2002-03 was estimated at approximately 60 kg/s, although values as high as 220 kg/s were reported in 1982-83. The ratio of gas/dust emission is thought to be approximately 2.

A model of comet Churyumov-Gerasimenko's nucleus derived from the Hubble Space Telescope observations made in March 2003

Facts about Comet 67P/Churyumov-Gerasimenko	
Diameter of nucleus (km)	5 x 3
Orbital period (years)	6.57
Perihelion distance from Sun in 2014	186 million km (1.24 AU)
Aphelion distance from Sun	858 million km (5.74 AU)
Orbital eccentricity	0.632
Orbital inclination (degrees)	7.12
Year of discovery	1969
Discoverers	Klim Churyumov, Svetlana Gerasimenko



Klim Churyumov

In an effort to improve our knowledge of the nucleus, 61 images of comet Churyumov-Gerasimenko were taken with the Wide Field Planetary Camera 2 on the Hubble Space Telescope between 11 and 12 March 2003. The HST's sharp vision enabled astronomers to isolate the nucleus from the coma and to discover that the comet's icy heart is ellipsoidal in shape, measuring about five by three kilometres. It rotates once in approximately 12 hours.

"Although 67P/Churyumov-Gerasimenko is roughly three times larger than the original Rosetta target, its elongated shape should make landing on its nucleus feasible, now that measures have been taken to adapt the Lander package to the new configuration," **says Philippe Lamy of France's Laboratoire d'Astronomie Spatiale.**

Pole

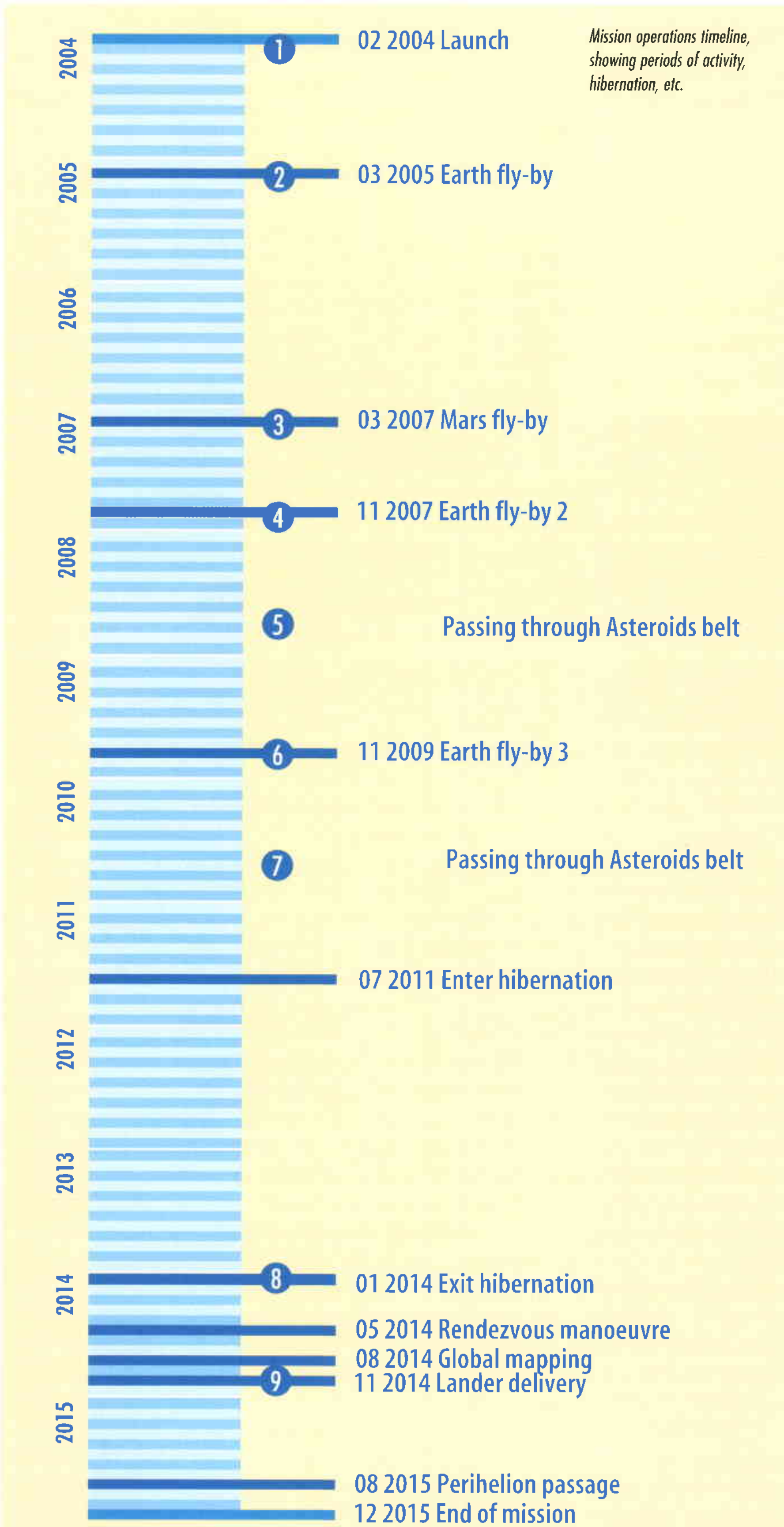
End

If all goes according to plan in November 2014, the Lander will anchor itself to the icy crust and begin a detailed survey of its surroundings. Over the next few months, it will provide a unique opportunity to conduct in-situ studies of a comet's nucleus – its temperature, composition, density and other properties. Even the internal structure of the dirty snowball will be probed as radio waves are passed through the comet nucleus from the Orbiter to the Lander and back again.

For the scientists, this 'ground truth' data will provide invaluable validation of the remote observations sent back by the Orbiter as its sweeps to within a few kilometres of the pockmarked nucleus. Over a period of about 18 months, the 11 experiments on the Rosetta Orbiter will examine every aspect of comet Churyumov-Gerasimenko during its high-speed journey towards the Sun.

According to the Rosetta Project Scientist, Gerhard Schwehm, it should be an exciting time for all concerned: *"Ground observations have shown that the comet becomes active at around 3 AU (about 450 million km from the Sun)," he says. "We see a lot of jets and surface activity with considerable structure in the coma. Since Churyumov-Gerasimenko has only made a few passes through the inner Solar System, it is still a fairly fresh, active comet, which produces a lot of gas and dust. By flying alongside it for more than a year, we will be able to observe the dramatic transformation that takes place as it is warmed by the Sun. It will also be intriguing to see how the activity dies down after it passes perihelion and begins the outward leg of its orbit. Working in unison, the Lander and the Orbiter will revolutionise our understanding of comets, leading to amazing discoveries about the most primitive building blocks of the Solar System."*

In particular, the enormous flood of data returned during Rosetta's remarkable voyage will provide new insights into such fundamental mysteries as the formation of Earth's oceans and the origin of life. It may even help the human race to survive in the long term. By transforming our understanding of the Solar System's icy wanderers, Rosetta will tell us more about how to deal with the threat from one of these unpredictable intruders that might one day head our way.



Mission operations timeline, showing periods of activity, hibernation, etc.

"We may separate at a lower altitude, since this means less acceleration," says Philippe Kletzkine. *"We anticipate a maximum separation speed of just 0.5 metres per second, so the overall descent time is likely to be between 30 minutes and 1 hour. We anticipate a landing on the 'summer' side of the nucleus, where there is maximum illumination."*

Over a period of several weeks, a treasure trove of data from the nine instruments on the Lander will be sent back to Earth via the Orbiter. For the first time, scientists will be able to study close-up pictures, drill into the dark organic crust, sample the primordial ices and gases, and probe the internal structure of the 4.5 billion-year-old celestial snowball.

Meanwhile, the Orbiter will continue to survey the dramatic changes in the nucleus during its headlong plunge towards the inner Solar System. Since Churyumov-Gerasimenko typically becomes much more active than Wirtanen, scientists expect to observe at close quarters for the first time the remarkable transformation of a comet from a tranquil iceberg into a world of turmoil. In particular, as its ices sublimate, bright jets will appear, ejecting gas and dust into space to create a coma

The New Norcia ground station in Western Australia. Rosetta operations will be controlled from ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany. Signals from the Orbiter will be relayed to ESOC via the 35 metre antenna at New Norcia and a similar one that is currently under construction at Cerebros in Spain

and a distinctive, diaphanous tail that stretches for vast distances in the anti-sunward direction.

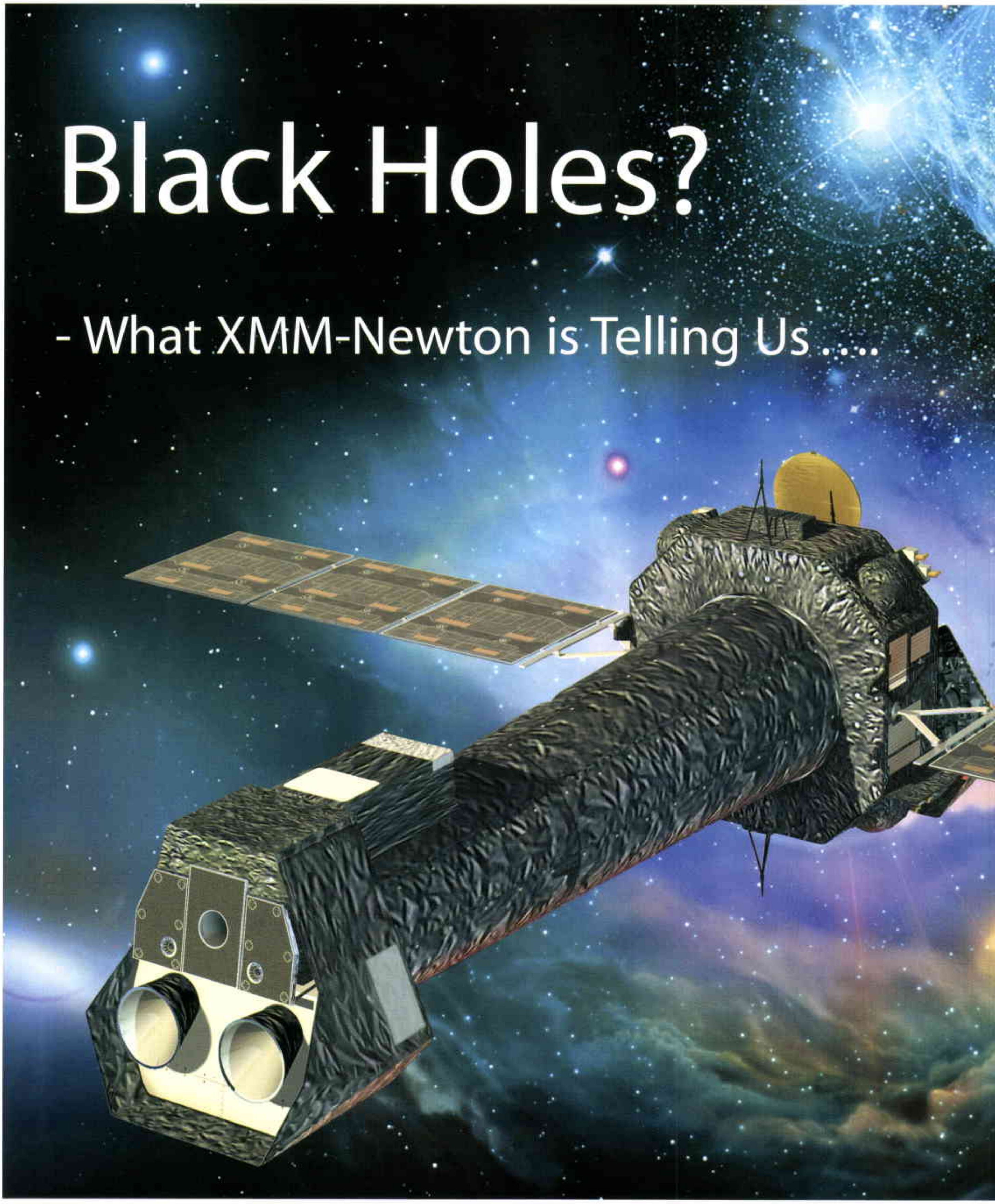
Despite Churyumov-Gerasimenko's generally more active nature, the dust environment close to the comet is probably little more hazardous for the spacecraft than it would have been in the vicinity of comet Wirtanen. Churyumov-Gerasimenko's larger perihelion distance means that its nucleus is heated less strongly by the Sun, so limiting the output of gas-laden dust that could threaten the Orbiter.

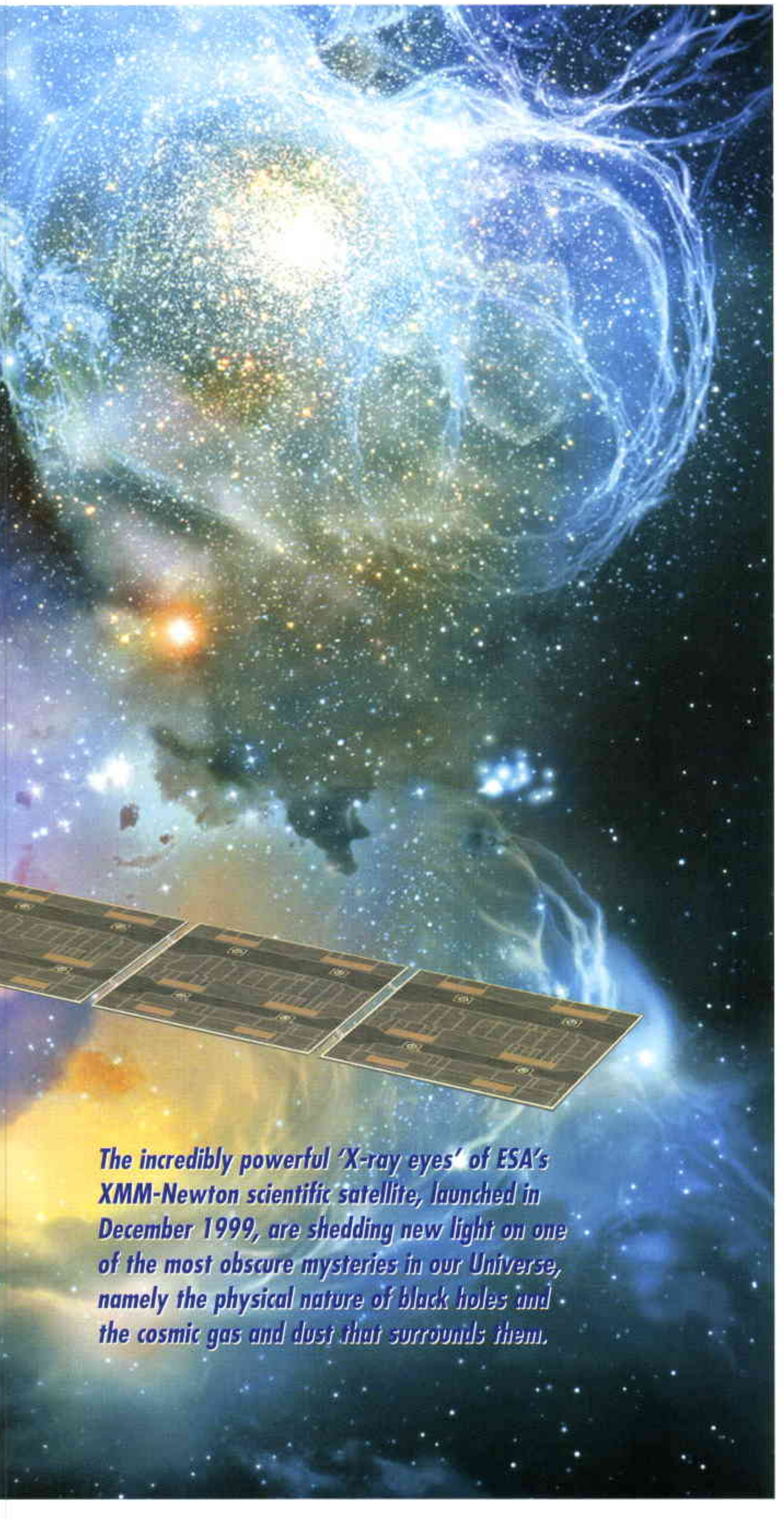
Rosetta's unique odyssey of exploration will terminate in December 2015, six months after the comet passes perihelion – its closest point to the Sun – and begins its retreat to the more frigid regions of Jupiter's realm. After a dramatic saga lasting almost 12 years, the curtain will fall on the most ambitious scientific mission ever launched by Europe. But, for the scientists, the work will only just be beginning !

The Rosetta Lander

Black Holes?

- What XMM-Newton is Telling Us .....





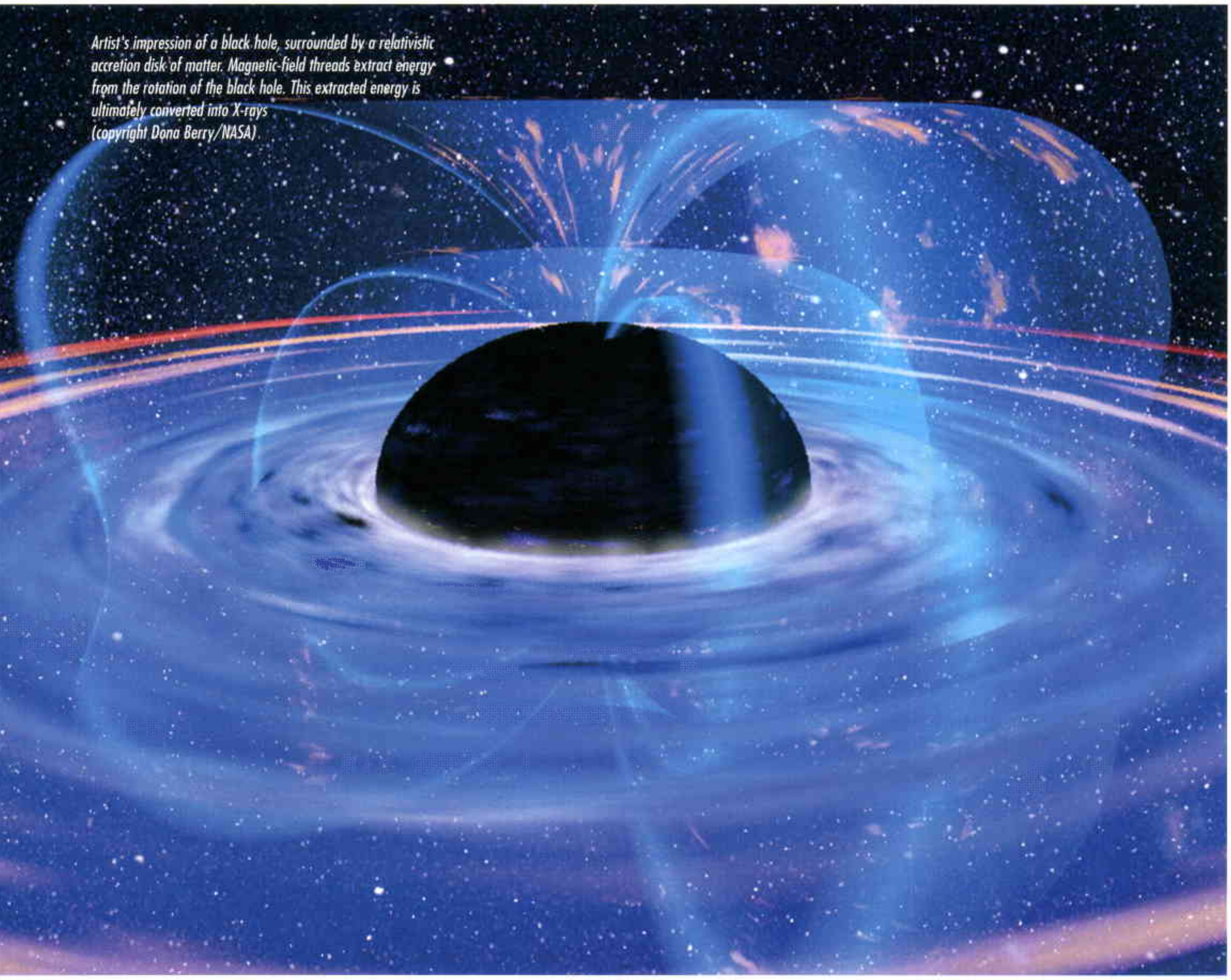
The incredibly powerful 'X-ray eyes' of ESA's XMM-Newton scientific satellite, launched in December 1999, are shedding new light on one of the most obscure mysteries in our Universe, namely the physical nature of black holes and the cosmic gas and dust that surrounds them.

Matteo Guainazzi
XMM-Newton Science Operations Centre,
ESA Directorate of Scientific Programmes,
Villafranca, Madrid, Spain

Black Holes: The Myth of Elusiveness

Most of the debate about the existence of black holes that took place during the 20th century was centred around the final states of massive stars. There are good reasons to believe that stars larger than four solar masses cannot avoid complete gravitational collapse. Under these conditions, the ultimate fate of stellar evolution is a 'space-time singularity' with infinite density. Nothing trapped within a black hole can escape the formidable pull of gravitation, so if black holes exist how could we observe them? By their very definition, black holes are invisible. How then can we hope to detect a celestial object that cannot communicate with us on any wavelength?

Indeed, isolated black holes are very hard to detect. Although one can speculate that some micro-lensing events might be associated with black holes in our Galaxy, the most efficient – and probably currently the only – scenario that allows their detection is through matter which is pulled in towards and eventually swallowed by them. Before encountering its ultimate fate beyond the 'horizon' of the black hole, the infalling matter is heated to temperatures of the order of 1 to 10 million degrees. The peak in the radiation emitted as a result of that



Artist's impression of a black hole, surrounded by a relativistic accretion disk of matter. Magnetic-field threads extract energy from the rotation of the black hole. This extracted energy is ultimately converted into X-rays (copyright Dana Berry/NASA)

cataclysmic heating lies in the X-ray band. X-rays are therefore the best available 'probe' with which to study the properties of cosmic black holes and their environment.

A black hole is a very simple object in mathematical terms in that it can be fully described by knowing just three parameters: its mass, its charge, and its angular momentum. We still have no experimental way to directly measure their charge, but X-ray measurements can tell us quite a lot about a black hole's angular momentum. Likewise, we know surprisingly little about the properties of the environment surrounding cosmic black holes, which are crucially shaped by the gravitational forces that are at work (the so-called 'gravitational well'). ESA's XMM-Newton mission is allowing us to make great strides in this respect.

Black Holes in Our Own Galaxy

The first experimental proof for the existence of black holes in our own 'neighbourhood' was obtained from the X-ray-emitting binary star system Cyg X-1, in which a 'normal star' orbits around an 'invisible object'. If the stellar mass, the orbital period, and the amplitude of the velocity curve are known, the mass of the invisible object can be estimated. This method yields values of between 7 and 17 times the mass of the Sun for Cyg X-1.

Today, a total of 18 black-hole binary systems are known, which represent only a very tiny fraction of the some 300 million black-hole systems that are believed to exist in our own Galaxy. The major contributions of XMM-Newton to our knowledge about such galactic black holes include the discovery of relativistically distorted emission-line profiles, and the study of large X-ray flares from the source Sgr A*, close to the Galactic Centre.

Key Concepts in Deciphering the XMM-Newton Data

Micro-lensing: According to the general theory of relativity, photons feel the pull of gravity like ordinary matter does. A light wave traveling close to a large mass concentration - such as a galaxy or a black hole - will be bent. This may produce multiple identical images of a background object or, in the extreme case of perfect alignment, a 'ring of light' around the foreground object.

Angular momentum: In classical mechanics, this is the product of the mass times the rotational speed.

Fluorescence: The physical process whereby absorption of a photon by the inner electron shells of an atom (photo-absorption) is followed by (mostly) line emission, produced by the cascade of higher level electrons onto the emptied level. 'K-fluorescence' refers to the fluorescence process involving the K atomic shell.

Doppler shift: If a source of light is moving towards us, the energy of the photons that we detect is higher than originally emitted by the source. This phenomenon is called 'Doppler blueshift'. The reverse, Doppler redshift, is observed in galaxies due to the expansion of the Universe. Matter distributed in spiraling disks may exhibit both blue- and redshift, as part of the disk approaches us and part recedes from us.

Gravitational redshift: Photons subject to a gravitational force lose energy, i.e. they become 'redder'. This effect is not negligible only when the pull of gravity is extremely strong, such as close to a black hole.

Resolution: This concept relates to an instrument's ability to discriminate between two events occurring very close together in an observational parameter space. Spatial resolution means being capable of distinguishing two celestial sources that are physically very close together in the sky. Energy resolution means distinguishing two absorption or emission lines that are very close in energy, while temporal resolution means distinguishing two events that happen very close together in time.

The Scientific Instruments aboard XMM-Newton

XMM-Newton carries two different classes of X-ray instrument. The three European Photon Imaging Cameras (EPICs) – two based on PN-CCD technology and one based on MOS-CCD technology – provide images of the X-ray sky, as well as spectra with moderate resolution and flux time series. Three Reflection Grating Spectrometers (RGSs) produce spectra with very high energy resolution. An Optical Monitor complements the X-ray instrumentation. The main scientific characteristics of the X-ray instruments are as follows:

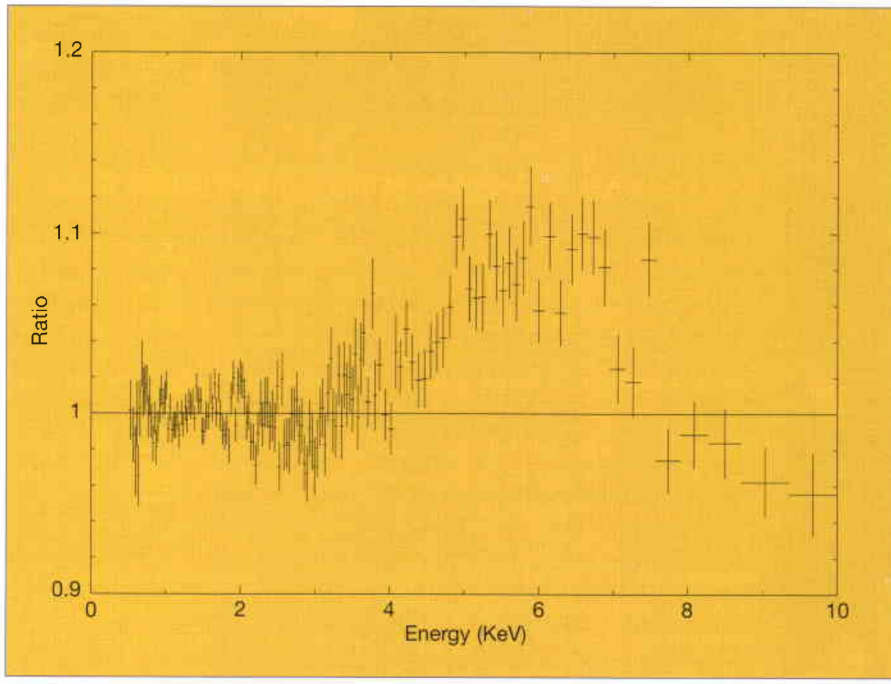
	PN-based EPIC	MOS-based EPIC	RGS
Energy Bandpass (keV)	0.15-15	0.15-12	0.35-2.5
Field-of-View (arcmin)	30	30	5
Spatial Resolution (arcsec)	6	5	N/A
Temporal Resolution (ms)	1.5	.03	16
Energy Resolution at 1 keV (eV)	80	70	3.2

Relativistic Effects in Galactic Black-Hole Systems

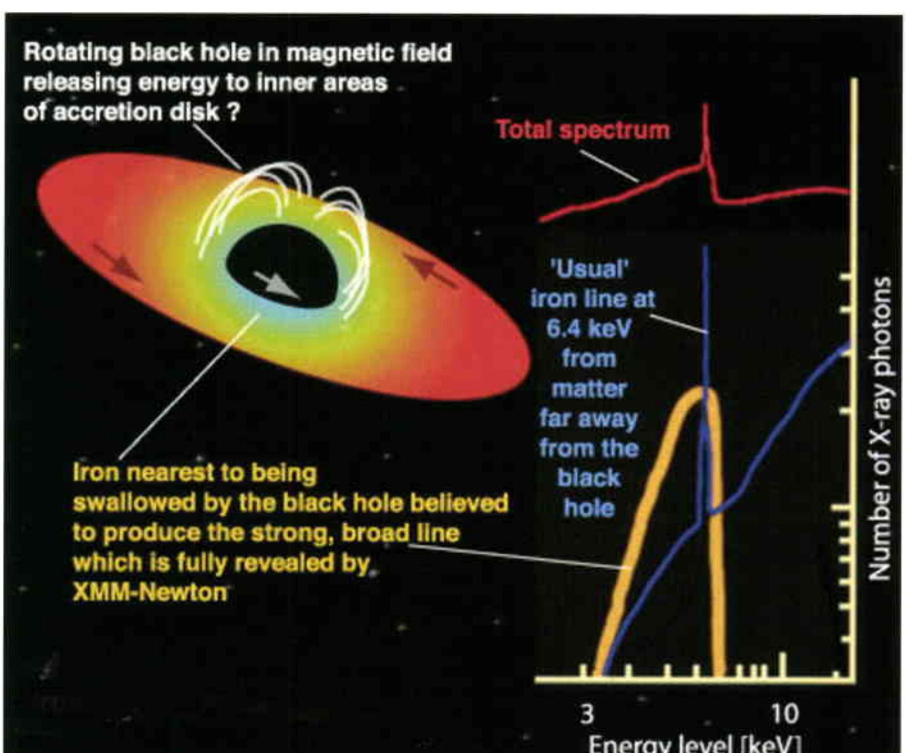
The accompanying illustration shows the energy spectrum of the black-hole candidate XTE J1650-500 as measured by XMM-Newton. The broad excess feature is interpreted as an iron K_α fluorescent emission line. The presence of this iron line is in itself neither news nor a surprise. Matter in the vicinity of super-massive black holes will most likely be illuminated by a large flow of X-rays, and produce fluorescent lines in the energy range of 6.40 to 6.96 keV, depending on the dominant iron ionisation stage. However, in XTE J1650-500 the excess feature extends to energies as low as 4 keV. How is this possible?

A scheme for the process responsible for the broadening of emission lines emitted close to black holes is shown in the illustration below. The combination of Doppler and gravitational-redshift effects in a disc of matter spiraling around the black hole could significantly distort the profile of an originally mono-energetic emission line. The line profile depends partly on the black hole's angular momentum: the larger the angular momentum, the closer the accreting matter can approach the event horizon. The iron-line profile observed in XTE J1650-500 is consistent with a black hole rotating at its maximum possible speed, according to the general theory of relativity. This result represents the first observational evidence that black holes in our Galaxy rotate, and it allows us to determine one of the three basic parameters that characterise their physical nature.

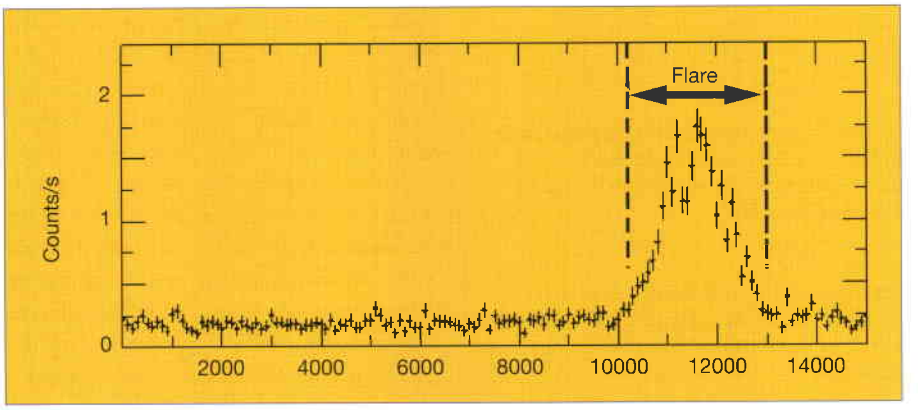
Another interesting conclusion could be drawn from the XMM-Newton measurements made by J. Miller et al. in 2002. The more photons (in relative terms) that are produced close to the black hole, the stronger is the relativistic distortion of the iron-line profile. The profile observed by XMM-Newton also requires an extreme concentration of photon-emitting matter close to the black hole, to be consistent with standard accretion-disk models. This



The XMM-Newton energy spectrum of the black-hole candidate XTE J1650-500 (from J. Miller et al., Astrophysical Journal, 2002)



This scheme shows how emission lines could be broadened, when emitted by matter orbiting in an accretion disk around a black hole (top left). Photons, originally emitted at a given energy (blue profile in the spectrum on the right) are shifted towards lower and higher energy by the Doppler effect, and towards lower energies by gravitational redshift (orange profile). The final line profile (red) looks very different from the original one. This particular figure refers to the active galaxy MCG-6-30-15, but the same phenomenon also occurs in galactic black holes like XTE J1650-500 (copyright ESA) is interpreted as evidence for energy being extracted from the rotating black hole, a fundamental general relativistic prediction, foreseen by R.D. Blandford and R.L. Znajek more than 25 years ago but never verified experimentally before. Once again, XMM-Newton's unique and powerful X-ray eyes have provided a glimpse of the basic properties of black-hole physics, which had previously only existed in the imaginative minds of the theoreticians.

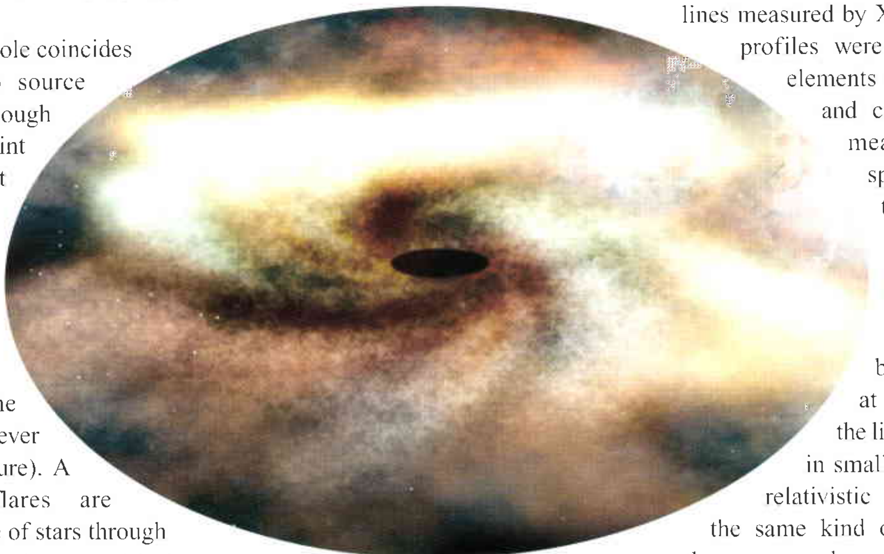


The Sgr A X-ray flare event in October 2002 as observed with XMM-Newton's EPIC instrument in the 2 to 10 keV energy band (from D. Porquet et al., Astronomy & Astrophysics, 2003)*

The Star-swallowing Monster at the Centre of Our Galaxy

The most massive black hole in our own Galaxy is probably located close to its centre. High-resolution infrared observations have shown that stars in the most central region of the Milky Way are orbiting around a 'dark mass' about 1 million times greater than that of the Sun, and concentrated within a region of space about 5×10^8 times smaller than our own Galaxy's diameter. A black hole is the only viable explanation.

The suspected black hole coincides with a compact radio source known as Sgr A*. Although Sgr A* is remarkably faint in optical terms, it undergoes extraordinary X-ray flaring events. After their discovery by the American X-ray satellite Chandra in October 2000, XMM-Newton detected the brightest Sgr A* flare ever (see accompanying figure). A scenario whereby flares are triggered by the passage of stars through an accretion disk surrounding Sgr A* is the most likely explanation for the massive event that XMM-Newton observed.



Black Holes at the Centre of Other Galaxies?

Around 10% of known galaxies are 'active' in that their luminosity is dominated by a very compact core close to their centre. The energy emitted from these so-called 'Active Galactic Nuclei' (AGNs) can be 10 000 times as great as the total stellar light from our Galaxy. Already in the late 1960s, the hypothesis was put forward that this enormous power must ultimately be produced by the accretion of matter onto a 'super-massive' black hole – where 'super-massive' means between 100 000 and 1 billion times the mass of the Sun.

Are Super-massive Black Holes Shy?

Although originally developed to explain the X-ray spectrum of Cyg X-1, the relativistic-line-profile distortion scenario has mostly been applied to nearby AGNs. The earliest results obtained by the Japanese Advanced Satellite for Cosmology and Astrophysics fostered the hope that relativistic effects could be studied in a large sample of nearby AGNs. This expectation has now been satisfied by XMM-Newton.

The accompanying figure (next page) shows one example of relativistically broadened and skewed iron K_α fluorescent lines measured by XMM-Newton. Similar profiles were observed for lighter elements such as oxygen, neon and carbon. Each of these measurements probes a specific characteristic of the accretion process onto a black hole. In MCG 6-30-15, energy extraction from a maximally rotating black hole is probably at work. In other AGNs, the line is probably produced in small local flares above the relativistic accretion disk, due to the same kind of magnetic processes that are at work on the Sun's photosphere.

However, what XMM-Newton has not observed is even more intriguing! Relativistically distorted lines seem to be much less common than expected (and hoped for) prior to the launch of XMM-Newton. The majority of AGNs in the largest sample observed by XMM-Newton so far (53 objects) do show K_α fluorescent iron lines, but their profile is not significantly distorted by relativistic effects. This provides firm proof for the bulk of these emission lines being produced by matter far away from the black hole itself. Consequently, only a small fraction of AGNs look to be suitable as probes of general relativistic effects. It is not clear why super-massive black holes are seemingly so 'shy' in the energy band where their power and glory should be most clearly manifested. It probably has to do with the physical properties of the accretion flow. Matter very close to a black hole could be too hot to be 'sensitive' to fluorescence stimuli.

These new XMM-Newton results are drastically changing the way we look at the behaviour of cosmic gas and dust close to black holes.

Black-Hole Winds

Recently XMM-Newton has discovered deep absorption lines in the spectra of two luminous quasars, PG 0844+349 and PG 1211+143 (see figure). These lines are significantly blue-shifted with respect to the systemic velocity of the host galaxy, suggesting that they occur in an outflow traveling at about one tenth of the speed of light. This evidence has been interpreted as a manifestation of the extraordinary power of black holes to generate relativistic 'winds' of matter, expelled from the cores of active galaxies.

'Intermediate-mass' Black Holes

One may ask why black holes should exist only in 'stellar-mass' or 'super-massive' form. Why isn't there anything in between? In recent years, evidence has been accumulating for the existence of 'Ultra-Luminous X-ray Sources' (ULXs), whose luminosity is significantly larger than that of stellar-mass black holes. One hypothesis is that these systems may be hosting black holes of 'intermediate' mass. XMM-Newton's contribution has been crucial in this field too, since it has clearly demonstrated that at least some of the known ULXs share the same basic qualitative properties with other black-hole accreting systems, such as galactic black holes or AGNs.

Conclusion

Though there turns out to much more in the sky than theoretical astrophysicists can today imagine, XMM-Newton seems very well equipped to discover and study it, even if it is the flickering ghost of a turbulent, elusive and shy black hole!

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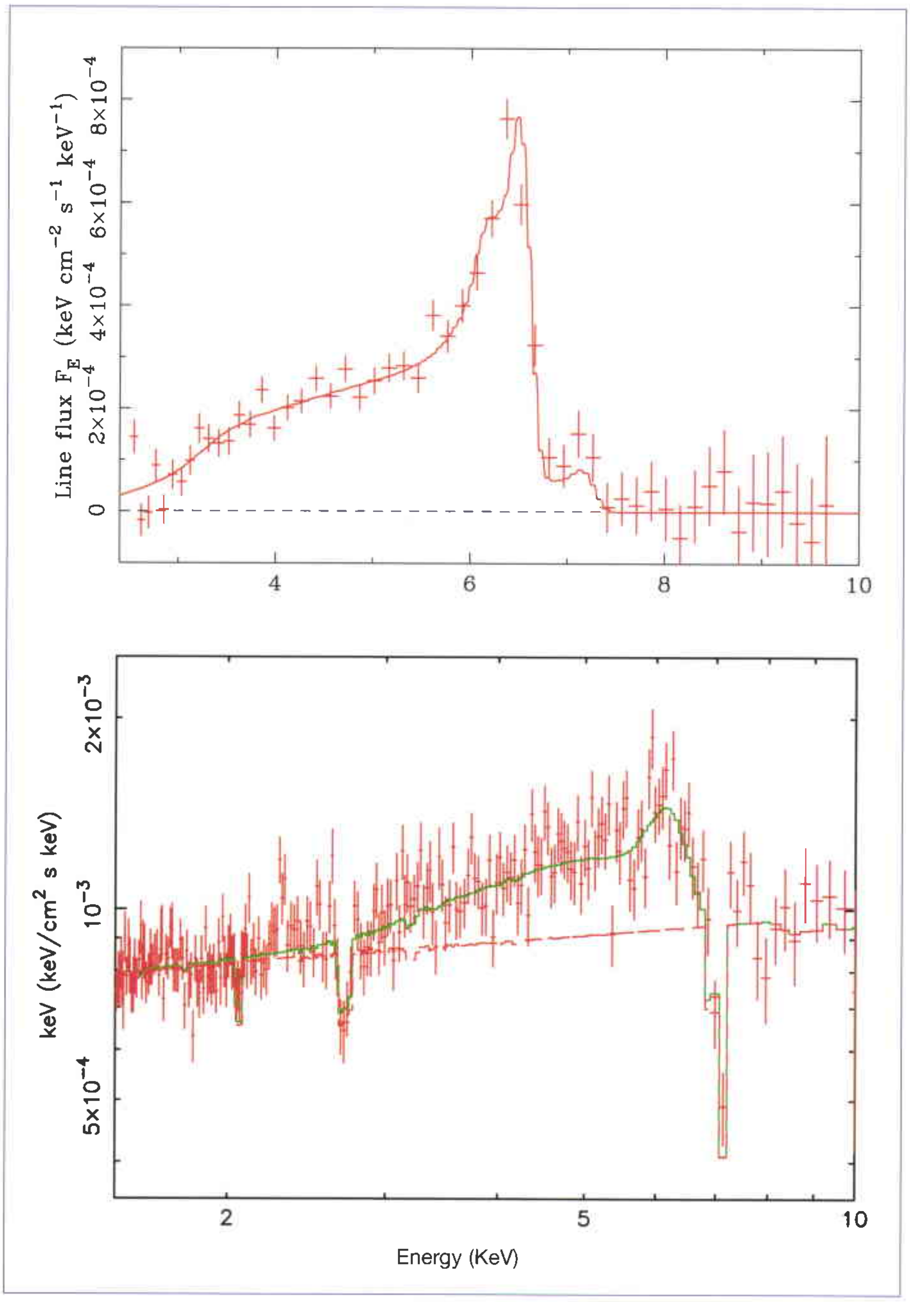
Top figure: The relativistically distorted K_{α} fluorescent iron-line profile of MCG-6-3-15 measured by XMM-Newton (from A.C. Fabian et al., Monthly Notices of the Royal Astronomical Society, 2002)

Bottom figure: Spectrum of the luminous AGN PG1211+143, showing the absorption lines discovered by XMM-Newton (from K. Pounds et al., Monthly Notices of the Royal Astronomical Society, 2003)



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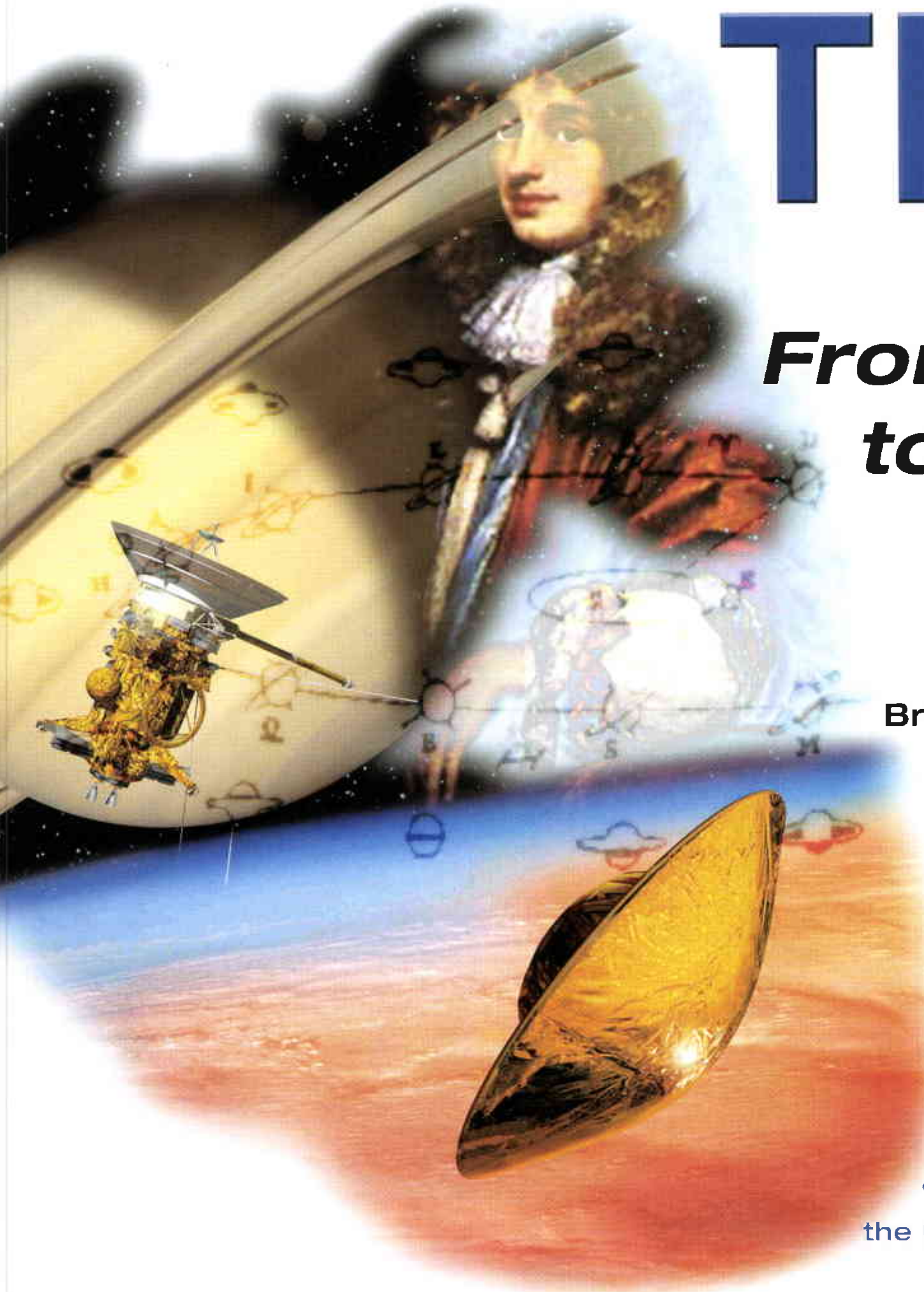

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NASA

Mars Express Returns Stunning First Images

Mars Express, ESA's first mission to Mars, has already produced stunning results since its first instrument was switched on, on 5 January. The significance of the first data was emphasised by the scientists at a Press Conference at ESA's Space Operations Centre (ESOC) in Darmstadt, Germany, on 23 January.

***"I did not expect to be able to gather together – just one month after the Mars orbit insertion on 25 December – so many happy scientists eager to present their first results"*, said Professor David Southwood, ESA's Director of Science.**

One of the main targets of the Mars Express mission is to confirm the presence of water in one of its chemical states. Through the initial mapping of the south polar cap on 18 January, OMEGA, the combined imaging and infrared spectrometer, has already revealed the presence of water ice and carbon-dioxide ice. This information was confirmed by the PFS, a new high-resolution spectrometer of unprecedented accuracy. The first PFS data also show that the carbon-dioxide distribution is different in the northern and southern hemispheres of Mars.

The MaRS experiment emitted its first signal successfully on 21 January. The signal was received on Earth through a 70-metre antenna in Australia, after it had been reflected and scattered from the surface of Mars. This new measurement technique allows the detection of the chemical composition of the Martian atmosphere, ionosphere and surface roughness.

ASPERA, a plasma and energetic neutral atoms analyser, is aiming to answer the fundamental question of whether solar-wind erosion led to the present lack of water on Mars.

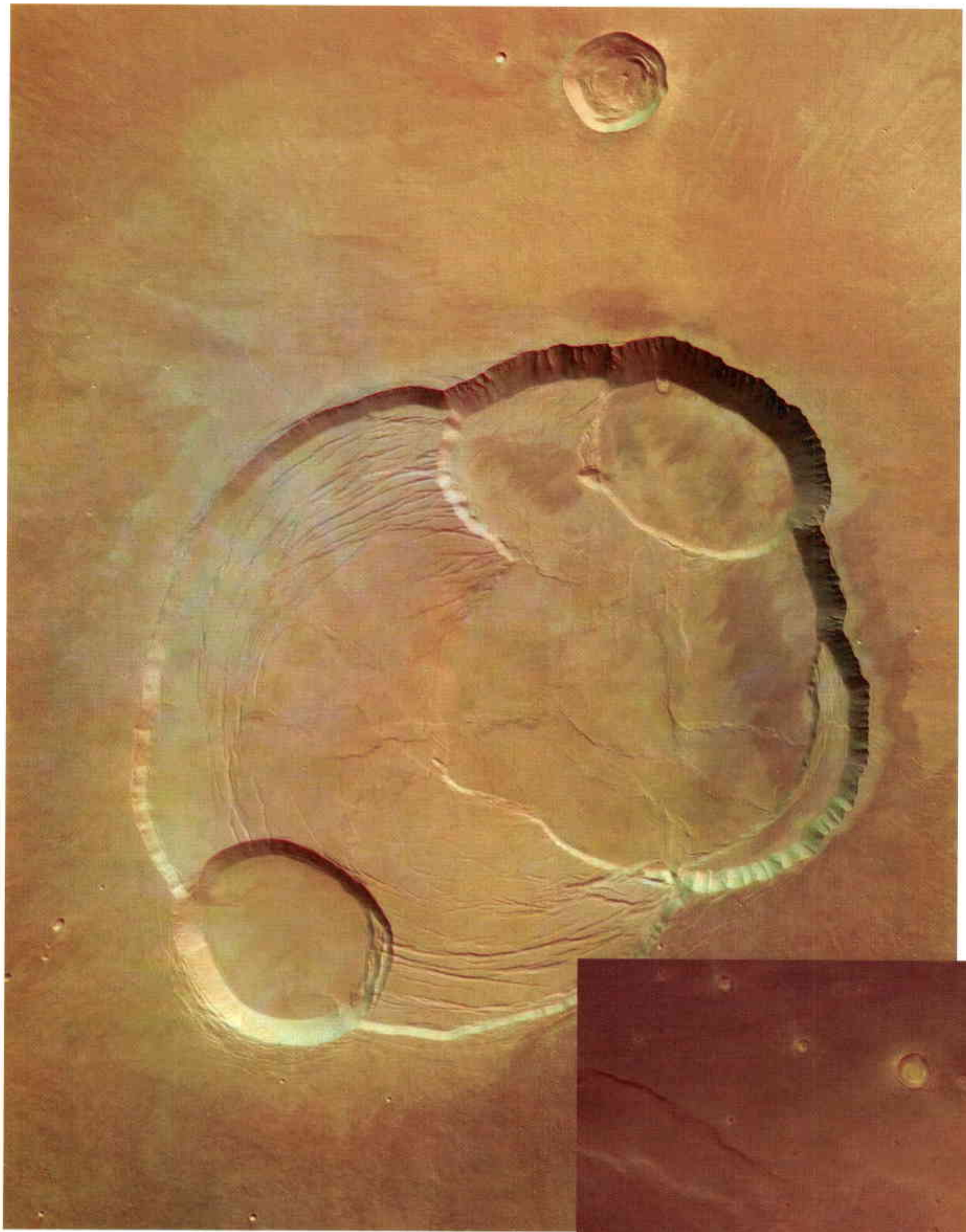
Another exciting experiment has been run with the SPICAM instrument (an ultraviolet and infrared spectrometer) during the first star occultation ever observed at Mars. It has simultaneously measured the distribution of ozone and water vapour, which has never been done before, revealing that there is more water vapour where there is less ozone.

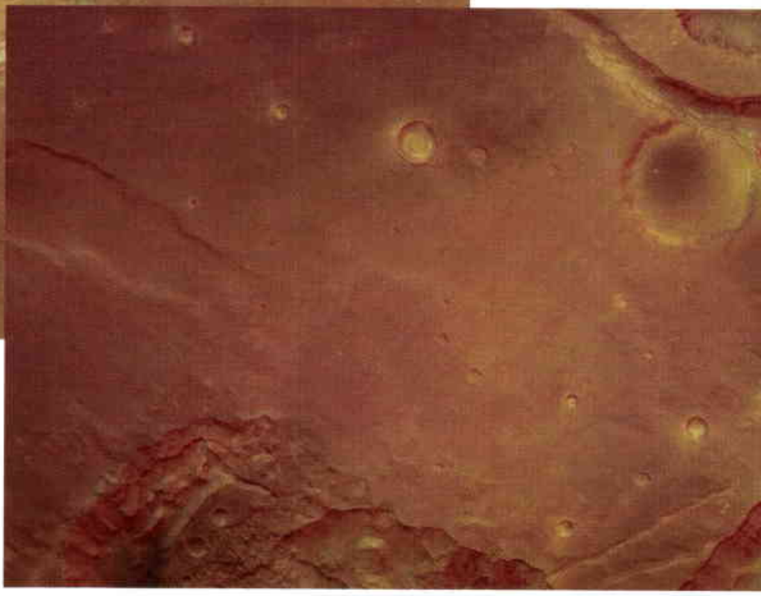
ESA also presented astonishing pictures produced with the High Resolution Stereo Camera (HRSC) on Mars Express. They represented the outcome of 1.87 million km^2 of surface coverage, and about 100 gigabytes of processed data. This camera was also able to record the longest swath (up to 4000 km) and largest area in combination with high resolution ever taken in the exploration of the Solar System.

The MARSIS (subsurface sounding radar) antennas will be deployed in late April, and initial results are therefore expected in May.

Mrs Edelgard Bulmahn, German Minister for Research and Education, who also currently chairs the ESA Council at Ministerial Level, said at the Press Conference: *"Europe can be proud of this mission: Mars Express is an enormous success for the European space programme."*

The pictures that follow here are just a sample of the imagery that has already been returned by Mars Express's High Resolution Stereo Camera during its first few weeks of operation. They have been selected by Agustin Chicarro, the Mars Express Project Scientist.





This vertical view shows the complex caldera at the summit of Olympus Mons on Mars, the highest volcano in our Solar System. Olympus Mons has an average elevation of 22 km and the caldera has a depth of about 3 km. This is the first high-resolution colour image of the complete caldera. It was taken from a height of 273 km (resolution 12 m per pixel) by the High Resolution Stereo Camera (HRSC) on 21 January 2004. The image is about 102 km across. South is at the top.
Credit: ESA/DLR/FU Berlin (G. Neukum)

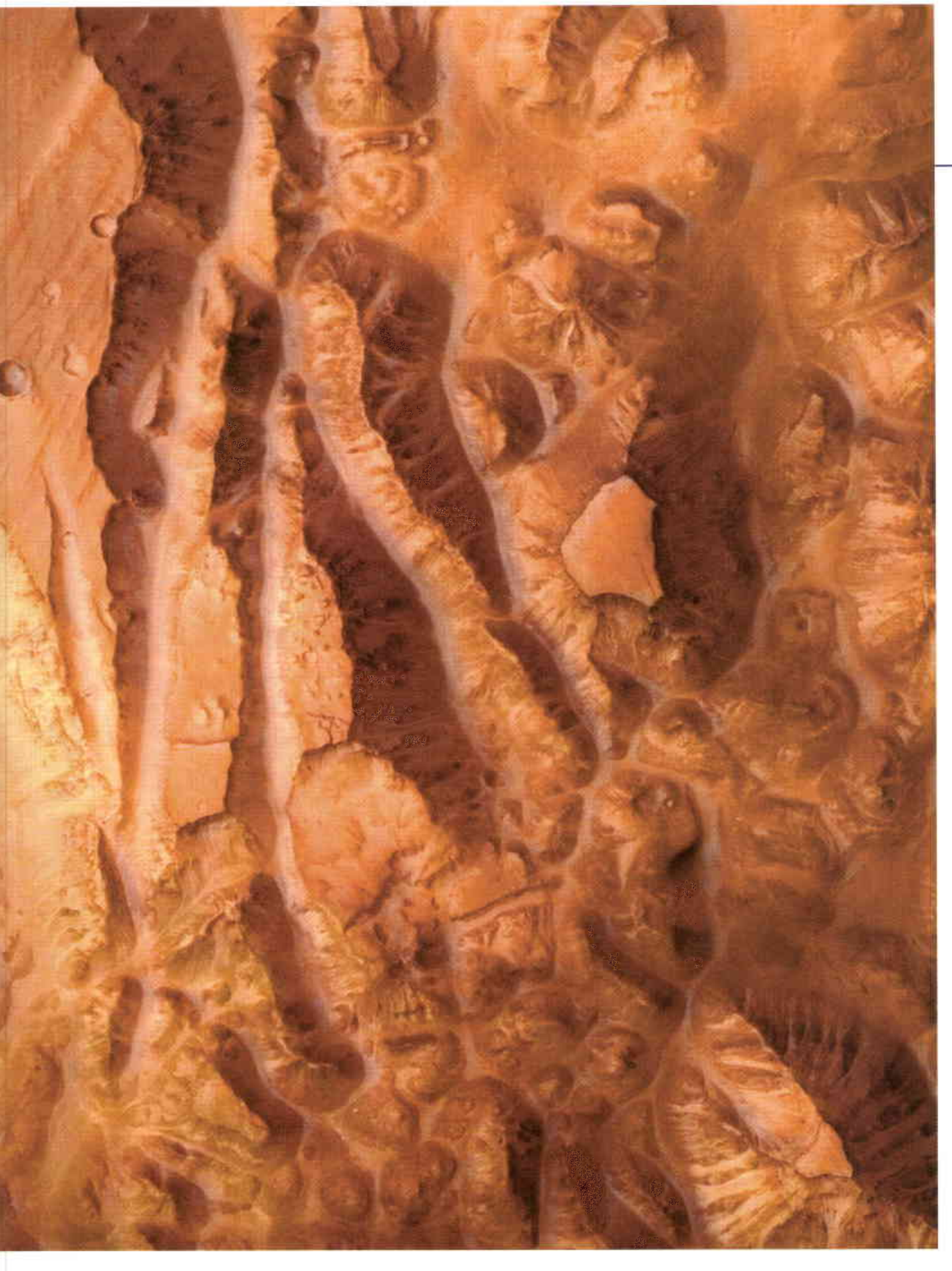
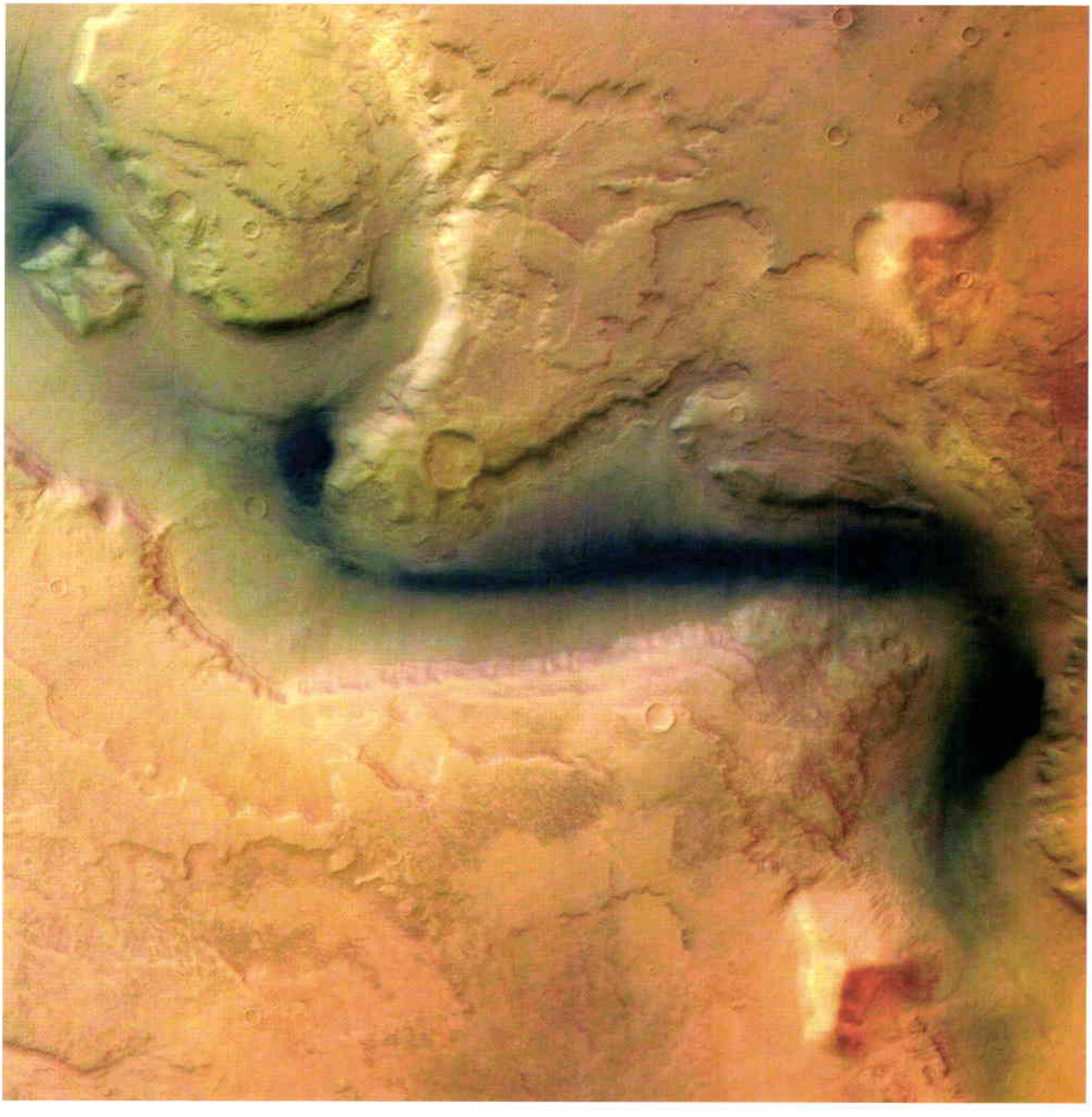


Image taken by the High Resolution Stereo Camera (HRSC) on 4 January 2004. It shows a portion of a 1700 km-long and 65 km-wide swath, which was imaged in the south-north direction across the huge canyon of Valles Marineris. It is the first image of this size that shows the surface of Mars in high resolution (12 metres per pixel), in colour and in 3D.
Credit: ESA/DLR/FU Berlin (G. Neukum)

Full-colour image, taken by the High Resolution Stereo Camera (HRSC) on 14 January 2004 from a height of 275 km (resolution 12 m per pixel). This image is 50 km across and shows the Martian equator north of Valles Marineris. In this landscape, mesas and cliffs are visible, as well as flow features indicating erosion by the action of flowing water.
Credit: ESA/DLR/FU Berlin (G. Neukum)

Full-colour image, taken by the High Resolution Stereo Camera (HRSC) on 14 January 2004 from a height of 275 km (resolution 12 m per pixel). The location of this landscape is north of Valles Marineris. It shows mesas and cliffs indicating erosion by the action of flowing water. North is to the right.
Credit: ESA/DLR/FU Berlin (G. Neukum)

Image taken by the High Resolution Stereo Camera (HRSC) on 15 January 2004 from a height of 273 km. The location is east of the Hellas Basin. The area is 100 km across (resolution 12 m per pixel), and shows a channel (Reull Vallis) once formed by flowing water. North is at the top.
Credit: ESA/DLR/FU Berlin (G. Neukum)



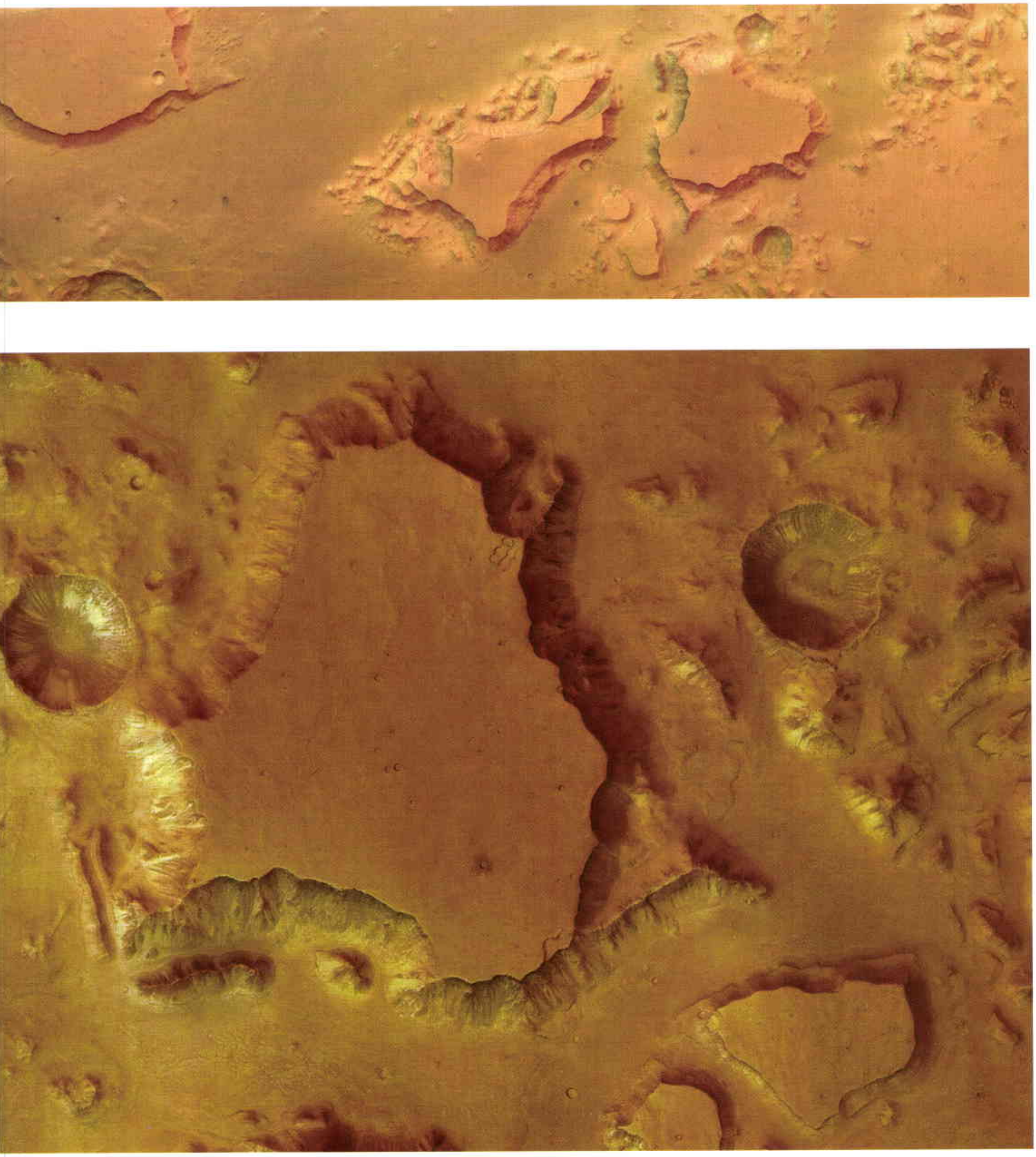
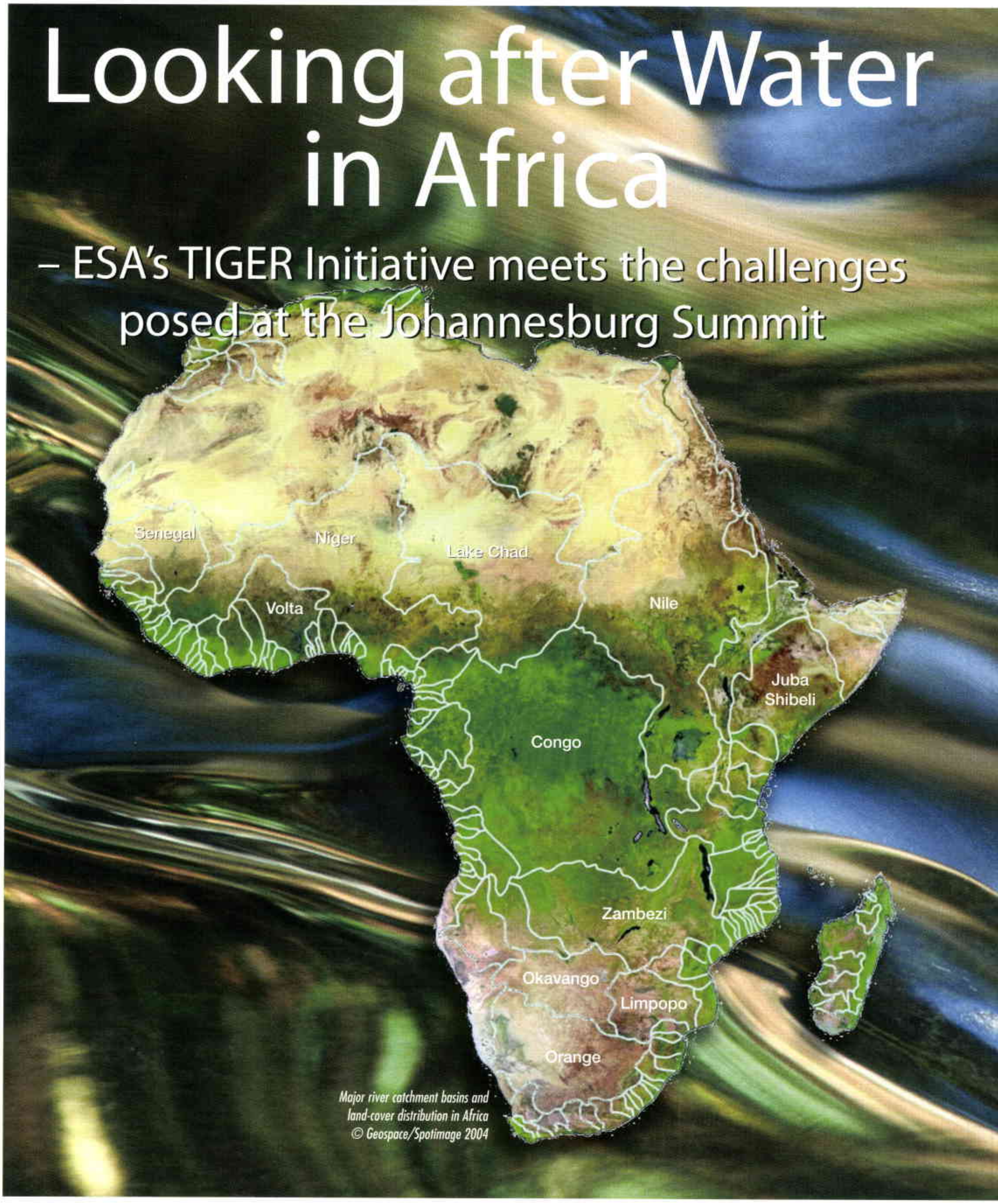


Image taken by the High Resolution Stereo Camera (HRSC) on 14 January 2004. It shows a vertical view of a mesa in the true colours of Mars. The summit plateau stands about 3 km above the surrounding terrain. The original surface was dissected by erosion, and only isolated mesas remain intact. The large crater has a diameter of 7.6 km. North is at the bottom.
Credit: ESA/DLR/FU Berlin (G. Neukum)

Looking after Water in Africa

– ESA's TIGER Initiative meets the challenges posed at the Johannesburg Summit



Major river catchment basins and land-cover distribution in Africa
© Geospace/Spotimage 2004

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Stephen Briggs
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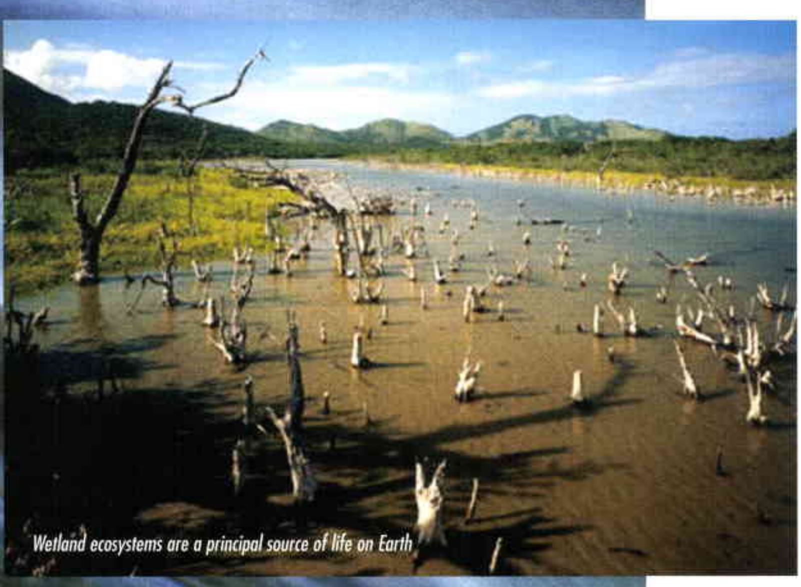
Water resources, the 'blue gold' of the 21st century, can be successfully monitored from space using Earth-observation technology. Satellites can measure precipitation, atmospheric water content, soil moisture, surface run-off, lake and river levels, groundwater reservoirs, as well as ice and snow cover. Improved sensors, better modelling and a deeper understanding of the underlying science have substantially advanced our knowledge of the global water cycle in recent years.

However, there are still major shortcomings in both the understanding and the observation of key parameters. The estimation of groundwater resources, for example, poses a major challenge, as they are not directly visible from space. Indirect methods based on gravity-field measurements, radar interferometery and altimetric monitoring of rivers need to be applied to gain knowledge of reservoir volumes and flows. In order to improve our capabilities and to offer this technology to people in developing countries, ESA has launched a new programme focusing on the use of space technology for water-resource management in Africa. The initiative, called 'TIGER', is a direct follow-up of ESA's strong engagement in the 2002 Johannesburg World Summit on Sustainable Development, and implements its recommendations through concrete actions.



Wetland ecosystems are a principal source of life on Earth

All Life Depends on Water

Almost all aspects of the Earth system involve or rely on water. Ours is unique among the planets because its water is maintained in vapour, liquid and ice forms. Water is, in fact, the only known substance that can naturally exist in gas, liquid, and solid form within the relatively small range of air temperatures and pressures found at the Earth's surface. In all, our planet's water content is about 1.39 billion cubic kilometres and the vast bulk of it, about 97%, is in the global oceans. Only about 3% resides as freshwater on the land.

Furthermore, two thirds of this freshwater exists in ice caps, glaciers, permafrost, swamps, and deep aquifers, where it is largely inaccessible. A very small fraction of the total is held in the atmosphere, but it plays a critical role in our climate and in the transport of ocean water that precipitates over land. The latter can be considered as the renewable part of the resource, determining the amount of water that can be used by humans without depleting the water stored in reservoirs or aquifers.

Water and energy are intimately involved in driving atmospheric circulation. Consequently, climate- and weather-prediction systems must consider water as a primary component. Humans affect the water cycle not only indirectly as global warming affects precipitation patterns, but also directly as river control, irrigation and general water-management practices reorganise the patterns of water movement. The drying out and over-salinisation of the Aral Sea and the construction of the Three Gorges dam are prominent examples of humans influencing regional water-resource management. The complexity of these interactions and the range of their space and time scales pose major challenges to hydrologists and decision-makers alike.

To represent these variables adequately, a mix of satellite and in-situ data is required. Remote sensing, especially from space, can provide spatial coverage for rainfall, soil moisture, snow cover, snow water equivalent, and vegetation conditions. Remote sensing does not, however, remove the need for ground-based measurements. Hydrologists use remote sensing as a major, and in many cases essential information source to better understand and monitor the global and regional water cycle. The challenge for space agencies lies in the adequate integration of space-based information into a holistic decision support system, which should lead to better decisions and ultimately to better lives for those who most depend on improved management of water resources.

The Johannesburg World Summit on Sustainable Development

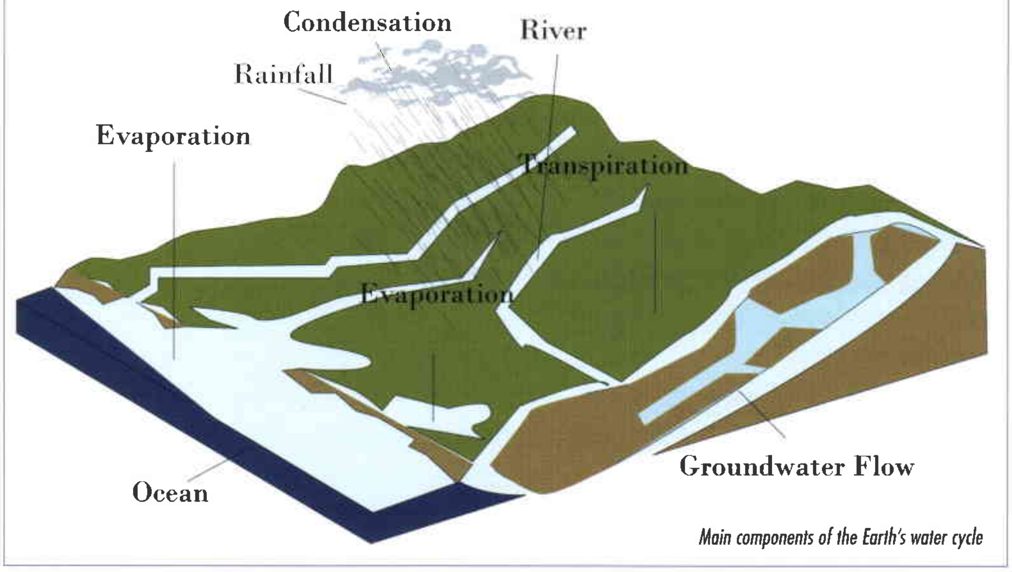
The 2002 Johannesburg World Summit on Sustainable Development recognised the importance of natural resources for development, and hence stability, on our planet. The biggest challenge mankind is facing over the next 50 years is that of coping with a predicted 50% increase in the Earth's population, from 6 billion today to 9 billion by 2050. Heads of State and Governments committed themselves at the Summit to the Johannesburg Plan of Implementation for Agenda 21, integrating the three pillars of sustainable development – economic development, social development and environmental protection – at local, national, regional and global levels.

Water is probably the most crucial among the issues prioritised in Johannesburg, which also include energy, health, agriculture and biodiversity. Freshwater is a finite and vulnerable resource. Over one billion people still do not have access to safe drinking water, and nearly two billion lack safe sanitation. An estimated 10 000 people die every day from water- and sanitation-related diseases, while thousands more suffer from a range of debilitating illnesses.

Humans currently appropriate more than half of the accessible freshwater run-off, and this proportion is expected to increase significantly in the coming decades. A substantial amount, namely 70%, of the water currently withdrawn from all freshwater resources is used for agriculture. With the rapid increase in the world's population, the additional food required to feed future generations will put further enormous pressure on freshwater resources. According to recent global water assessments, around 70% of the future world population will face water shortages, and 16% will have insufficient water to grow their basic food requirements by 2050. The impact of inadequate water and sanitation services falls primarily on the world's poor.

Earth Observation for Water-Resource Management

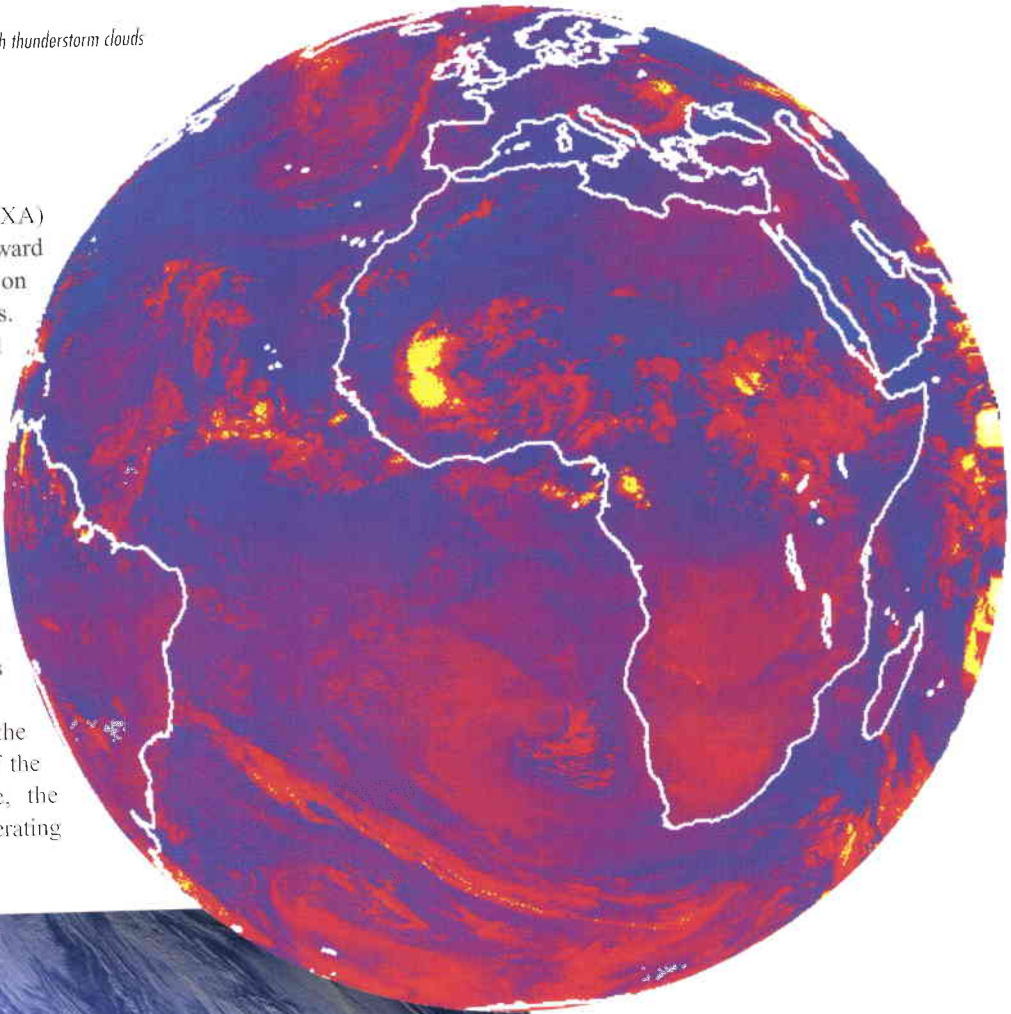
Earth-observation satellites play a major role in the provision of information for the study and monitoring of the water cycle.



Main components of the Earth's water cycle

Atmospheric-temperature, water-vapour and cloud-cover measurements are provided operationally by meteorological satellites such as MSG and MetOp. ERS and Envisat, for example, provide surface temperatures, ocean winds, wave heights, and ice-dynamics data, as well as information on vegetation cover, soil moisture, and geology over land surfaces.

Precipitation is clearly a key parameter, but given its high temporal and spatial variability it is a fundamentally difficult parameter to measure. Until recently, visible/infrared images from geostationary meteorological satellites provided the best source of information from space – with indirect but frequent estimates of rainfall derived from measurements of cloud-top temperature. The advent of the Tropical



Meteosat MSG-1 image taken on 14 July 2003 showing high thunderstorm clouds (yellow) 'overshooting' into the stratosphere
© ESA/Eumetsat 2003

Rainfall Mapping Mission (NASA/JAXA) in 1997 provided a major step forward with the provision of 3-D information on rainfall structure and characteristics. ESA has joined NASA, JAXA and other partners to continue this collaboration and to develop the Global Precipitation Mission (GPM), due for launch in the second half of this decade. The GPM constellation of satellites will provide global observations of precipitation every three hours to help develop our understanding of the global structure of rainfall and its impact on climate.

Recognising the central role of the water cycle in our understanding of the Earth system and climate change, the world's space agencies are already operating or are currently developing a number of new missions aimed at addressing key scientific objectives. These include the Aqua mission (NASA), Cloudsat (NASA), EarthCare (ESA/JAXA), GRACE (NASA/DLR) and ESA's Cryosat. Altimetric measurements provided by Topex-Poseidon and Jason from CNES and NASA, and ERS and Envisat from ESA, provide continuous monitoring of lakes and rivers with centimetre accuracy. Revolutionary new measurement capabilities will be provided in the future by ESA's Soil Moisture and Ocean Salinity (SMOS) mission scheduled for launch in 2006. Following GRACE, ESA's Global Ocean Circulation Experiment (GOCE) mission will determine the Earth's gravity field and its geoid with high accuracy and will allow the retrieval of water-table height measurements, one of the main parameters of interest to hydrologists.

Artist's impression of ESA's Soil Moisture and Ocean Salinity (SMOS) satellite

To ensure the necessary co-ordination between these many satellite programmes, the IGOS Partnership is developing an Integrated Global Water Cycle Observations (IGWCO) Theme. This Theme provides a framework for guiding international decisions regarding priorities and strategies for the maintenance and enhancement of water-cycle observations so that they will support the most important applications and science goals, including the provision of systematic observations of trends in key hydrological variables.

The first element of IGWCO is a Co-ordinated Enhanced Observing Period (CEOP), which is capitalising on the opportunity of the simultaneous operation of key European, Japanese, and American satellites during the period 2001-2004 to generate new water-cycle data sets.

New technologies for measuring, modelling, and organising data on the Earth's water cycle offer the promise of a deeper understanding of the cycle's processes, and of how different management decisions may affect them. Earth-observation satellites provide synoptic, high-resolution measurement coverage that is unprecedented in the geophysical sciences. The challenges to be faced in exploiting these new capabilities include:

- converting satellite measurements into useful parameters that can be applied in scientific models, and which can be inter-compared and inter-calibrated between the different satellite missions;
- providing consistent and accurate data over many years in order to detect the trends, which is necessary for climate-change studies;
- succeeding in the technology developments aimed at accurately measuring key parameters from space for the first time – including soil moisture and ocean salinity; and, above all,
- mobilising a large scientific community in the developed and developing countries to address this fascinating subject.

To complement the satellite data, existing ground-based measurement networks and systems must continue operating to obtain current data that can be compared meaningfully with past records.

ESA's TIGER Initiative

During 2002, under ESA's Chairmanship, the Committee on Earth Observation Satellites (CEOS) invested a considerable amount of effort in its participation at the World Summit on Sustainable Development, in Johannesburg. This Summit acknowledged the important role of Earth-observation satellites in assisting sustainable development. Altogether, 12 specific Articles in the 54-page WSSD Plan of Implementation that was adopted by Heads of State and Governments in Johannesburg refer to the use of Earth observation.

In November 2002, at its 16th Plenary Meeting held at ESA/ESRIN, in Frascati (I), CEOS adopted a WSSD Follow-up Programme. This Programme proposes action in a number of fields, which were identified in the Plan of Implementation as areas where Earth observation plays an important role for sustainable development.

It is within the framework of the WSSD Follow-up Programme that ESA has launched its TIGER initiative, as a direct response to the challenges identified in Johannesburg. TIGER is aimed at improving our scientific understanding of the water cycle and developing sustainable Earth-observation services for integrated water-resource management in developing countries, with a particular focus on Africa. It consists of two major elements:

(i) a set of individual projects with limited geographical coverage and scope, which are 'building blocks' for the

(ii) political process, which aims at developing long-term, large-scale, sustainable information services for better decision making in the water-resource management domain.

The Nile river delta captured by Envisat's MERIS instrument on 1 March 2003
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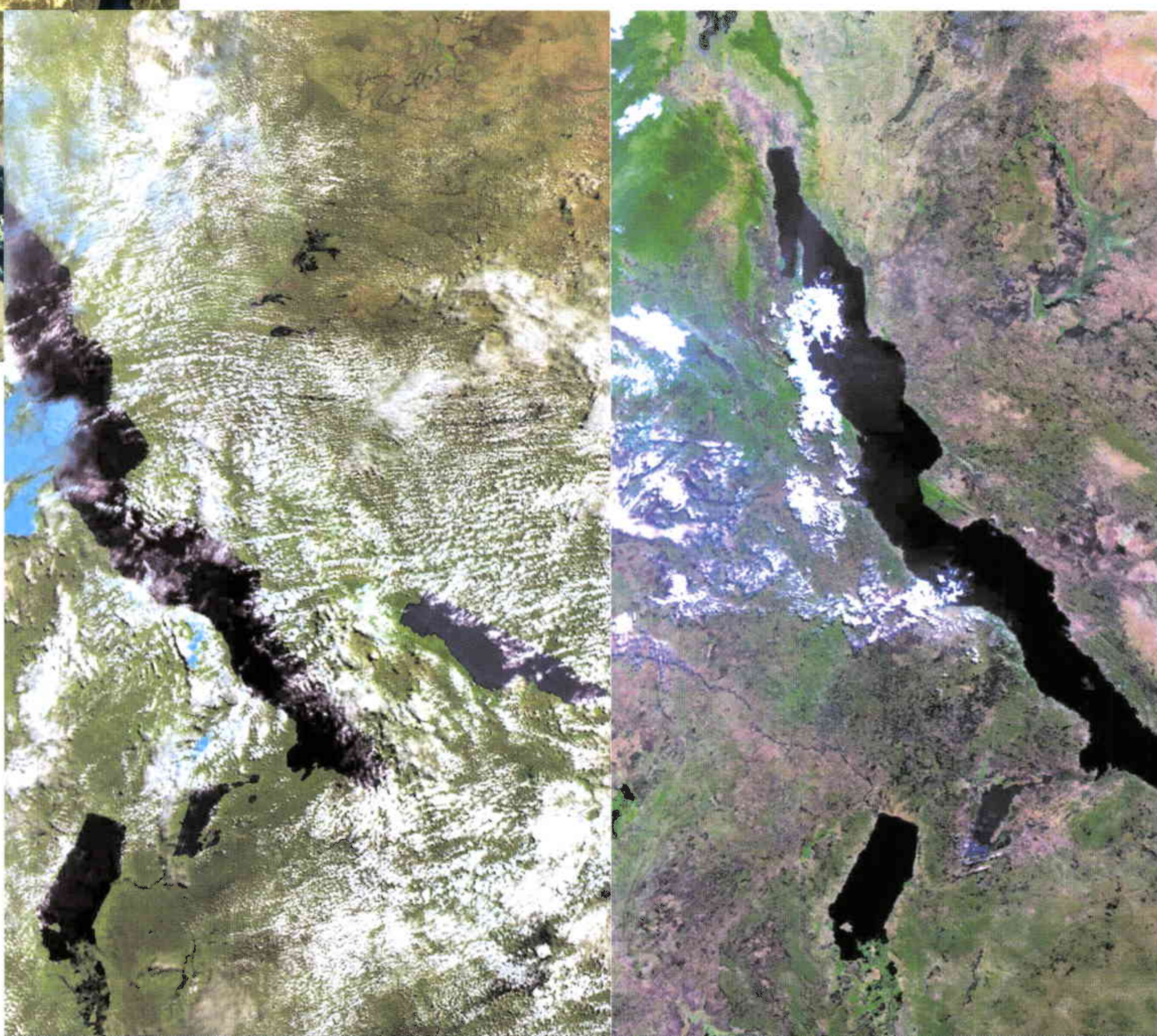
The Committee on Earth Observation Satellites (CEOS)

CEOS was created in 1984 under the auspices of the G7, with the goal of coordinating Earth-observation satellite missions among its Members. The 21 Members include space agencies that have active Earth-observation satellite programmes, while the 23 Associates include organisations that receive, process or use environmental data gathered from space. ESA is a founding member of CEOS and a permanent member of the Secretariat, which carries out the executive work in support of the annually rotating CEOS chairing agency. CEOS was chaired by ESA in 2002, followed by NOAA in 2003, China in 2004 and BNSC in 2005.



Lake Tanganyika, the deepest fresh water lake in the world, on the border between Tanzania and Zaire. These images were taken using Envisat's AATSR instrument during the rainy season in April 2002 (left) and during the dry season in July 2002 (right)
© ESA 2002

To achieve this long-term goal, strategic partners with a development mandate are involved, such as financing institutions or development organisations. Other partners include user organisations in Africa and beyond, as well as providers of space technology and services. Close co-operation with UNESCO has been established, thereby benefiting in particular from its International Hydrology Programme (IHP) and World Water Assessment Programme (WWAP), which provide access to a global network of hydrologists and field officers. UNESCO also supports training activities and develops educational material.

During 2003, the TIGER participants were identified and the organisational structure and work programme defined. Two major consultation meetings with stakeholders were held, one in May in Paris and one in October in Rabat. The topics identified as priorities for the first phase are groundwater resources, wetlands, epidemiology and food security; other topics may be added at a later stage. A two-phase approach was agreed, with Phase-1 (until end-2005) serving to demonstrate the usefulness of Earth observation for integrated water-resource management to African users and decision-makers, while Phase-2 (2006 onwards) will engage major donor and development agencies in order to turn the successful demonstrator projects into major development programmes. The precise content of Phase-2 will be defined in the course of 2005 on the basis of the Phase-1 results, as well as the results of reviews by African local and national authorities and potential international donor agencies. A key criterion will be the prospect of sustainability for selected services.

TIGER Demonstration Projects in Africa

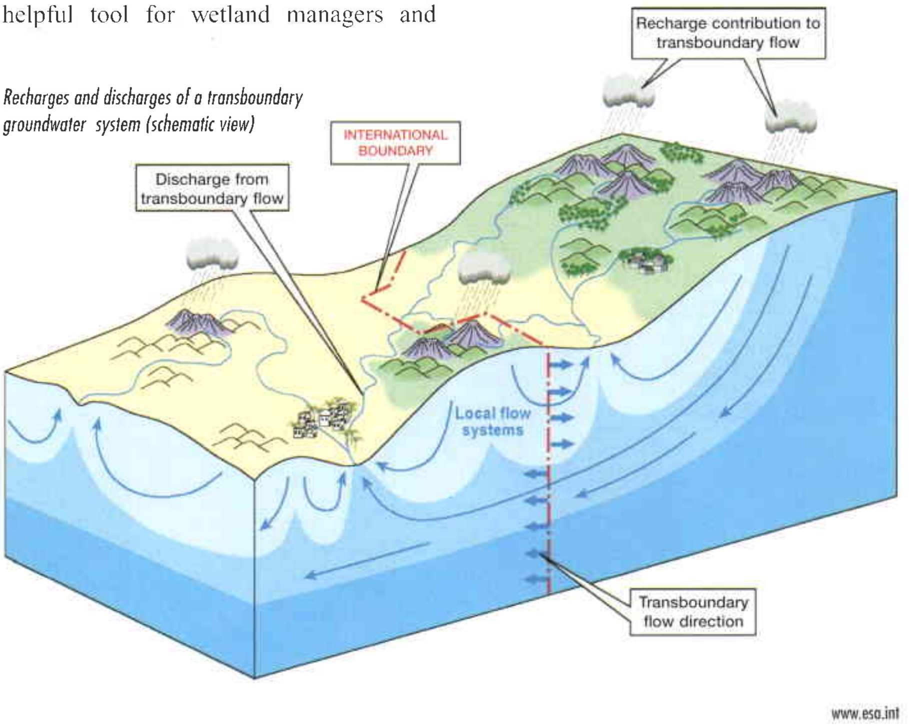
As of early 2004, ESA has launched or initiated four projects within the framework of TIGER, focusing on various aspects of water-resource management in Africa. These projects, implemented through the Global Monitoring for Environment and Security (GMES) and Earth Observation Data User Element (DUE) activities at ESRIN in Frascati, are:

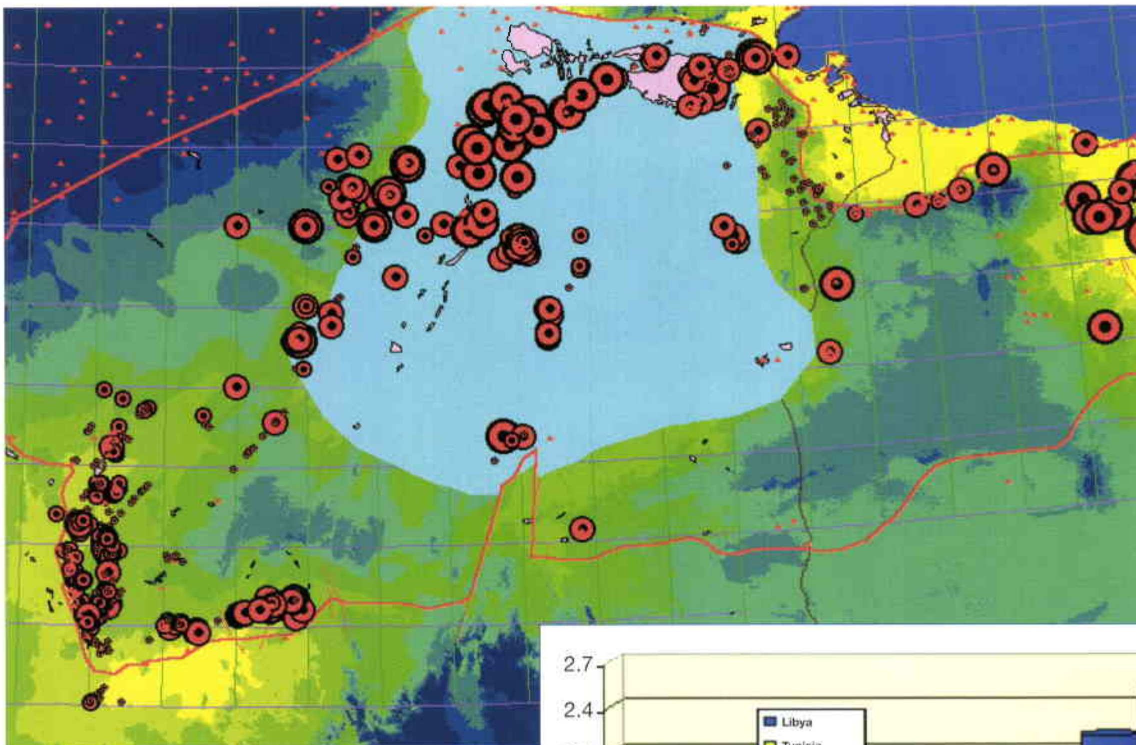
- Global Monitoring for Food Security
- Global Wetland Monitoring
- Epidomiology
- Groundwater Resource Monitoring.

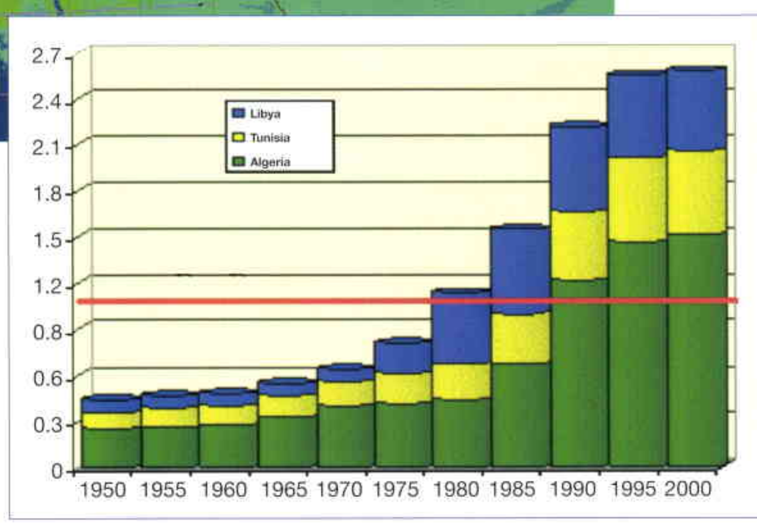
The goal of the *Global Monitoring for Food Security (GMFS)* project is to improve the provision of operational information services to assist food-aid and food-security decision makers. GMFS aims to consolidate, support and complement existing regional-information and early-warning systems on food and agriculture. It will concentrate initially on Sub-Saharan Africa, and will focus on end-users from regional organisations whose mandate is agricultural monitoring for food security and early warning of food crises. The project also aims to meet the needs of users in international organisations such as the UN Food and Agriculture Organization (FAO) and the EuropeAid Cooperation Office (AIDCO).

The *Globwetland* project is producing satellite-derived and geo-referenced products, including inventory maps and digital elevation models of wetlands and the surrounding catchment areas. These products will aid local and national authorities in fulfilling their obligations under the Ramsar Convention for wetlands conservation. They should also serve as a helpful tool for wetland managers and scientific researchers. For much of the last century, wetlands have been drained or otherwise degraded, but scientific understanding of their important roles in terms of biology and the water cycle has grown, spurring international efforts to preserve them. An assessment of the monetary value of natural ecosystems published in Nature in 1997 arrived at a figure of 27.7 trillion Euros, with wetland ecosystems making up 12.5 trillion - or 45% - of that total. Most of all, wetlands support life in spectacular variety and numbers: freshwater wetlands alone are home to four in ten of all of the world's species, and one in eight of global animal species. Much of human civilisation has been based around river valleys and flood plains. However, global freshwater consumption rose sixfold during the 20th century - a rate more than double that of population growth. With wetlands often made up of difficult and inaccessible terrain, satellites can help provide information on local topography, the types of wetland vegetation, land cover and use, and the dynamics of the local water cycle. In particular, radar imagery provided by ESA's Envisat mission is able to differentiate between dry and waterlogged surfaces, and so can provide multi-temporal data on how given wetlands change with the seasons.

Recharges and discharges of a transboundary groundwater system (schematic view)







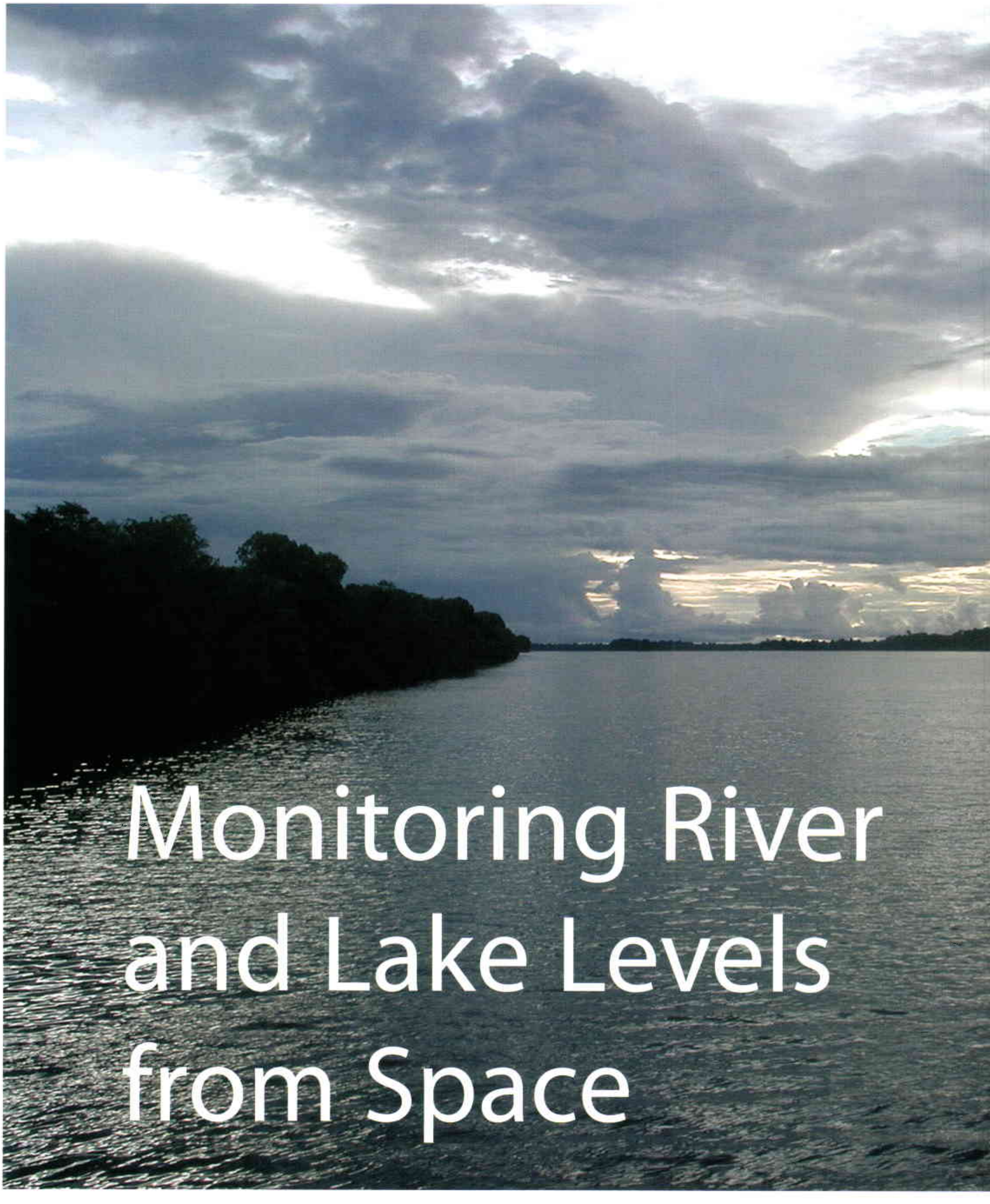
Left: Water-extraction points from the northwest-African aquifer
Below: Water extraction (in billions of cubic metres per year) from 1950 to 2000 for Libya (blue), Tunisia (yellow) and Algeria (green)
© OSS 2003

The *Epidemio* project is aimed developing Earth-observation services for epidemiologists, with a particular focus on malaria and Africa. Malaria affects 300 million people worldwide, and kills up to 1.5 million people annually. The incidence of the disease is influenced by local climate, which can be monitored by satellites to help in forecasting malaria outbreaks. The Epidemio project provides maps of water bodies - updated through the wet and dry seasons - as well as digital elevation models and weekly land-surface-temperature maps. Water mapping is especially useful for malaria risk prediction as mosquitoes begin life as aquatic larvae and the adults rarely travel more than 2 km from their breeding ground during their two- to three-week lifetime.

The above three projects were already started during 2003, but another new project will be initiated in early 2004 which focuses on the use of Earth observation for groundwater monitoring. This project, known as *Aquifer*, is aimed at using SAR interferometry measurements to derive the surface subsidence rates of the terrain above the northwest African aquifer, which is the largest in the world and spans three countries: Algeria, Libya and Tunisia. These subsidence measurements will be coupled with geomorphologic information and in-situ measurements to model water extraction rates from the aquifer. ERS and Envisat SAR data will be the main data sources used in this project.

Conclusion

There is no doubt whatsoever that the management of water resources will pose a major challenge in this century, particularly as the growth in the global population is greatest in regions with dry and semi-dry climates. With its TIGER initiative, ESA is addressing this challenge head-on by fostering a greater understanding of the water cycle, and by providing crucial information to decision makers at local, regional and global levels. Improved information about the use of water resources not only provides a better basis for life and health to local people, but is also a critical factor in supporting peace and stability among countries desperately concerned about the use of shared water resources. Hence, information from satellites is not only a tool for natural-resource management, but also a confidence-building resource by providing transparent information to people in the developing and developed world.



Monitoring River and Lake Levels from Space

Jérôme Benveniste
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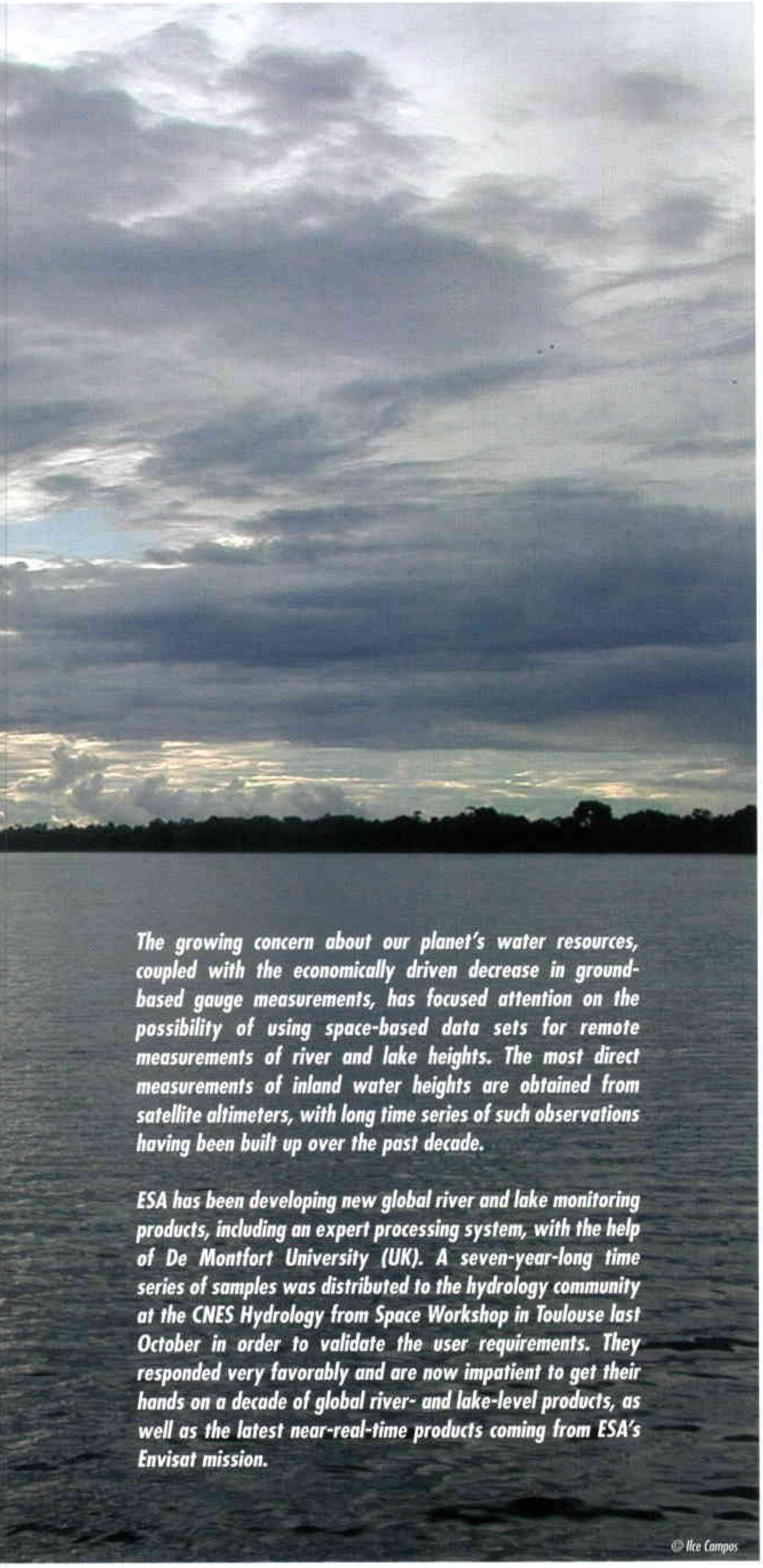


The growing concern about our planet's water resources, coupled with the economically driven decrease in ground-based gauge measurements, has focused attention on the possibility of using space-based data sets for remote measurements of river and lake heights. The most direct measurements of inland water heights are obtained from satellite altimeters, with long time series of such observations having been built up over the past decade.

ESA has been developing new global river and lake monitoring products, including an expert processing system, with the help of De Montfort University (UK). A seven-year-long time series of samples was distributed to the hydrology community at the CNES Hydrology from Space Workshop in Toulouse last October in order to validate the user requirements. They responded very favorably and are now impatient to get their hands on a decade of global river- and lake-level products, as well as the latest near-real-time products coming from ESA's Envisat mission.

The great majority of the World's population lives alongside, and is often dependent upon, continental water bodies. Inland water bodies – rivers, lakes, wetlands and floodplains – play important roles in a variety of interdisciplinary applications. They are a source of both water and protein, often a means of navigation and for the production of hydroelectric power, and have been shown to be good proxy indicators of local and regional climatic change. Many catchment areas are regions of great biodiversity and are often focal points in terms of environmental and conservation issues. Routine monitoring of these basins has further importance for regional and continental-scale hydrological, biochemical and climatological studies concerning, for example, the measurement of river discharges, the production of wetland methane, and the estimation of evaporation losses for land/atmosphere interactions.

Changes in the stored volumes of surface water also have geodynamical implications for the Earth's rotation and gravity, and for estimating the global water mass in relation to sea-level changes. With synergistic inundation extent measured by remote-sensing imagers, radar or optical, the monitoring of both surface level and area has relevance for studies of water-related epidemics such as malaria, cholera, and tuberculosis and the financial losses and human suffering therefrom.

The Rationale

ESA's ERS-1 and ERS-2 missions and the Topex/Poseidon satellite have been acquiring radar-altimeter data for more than ten years now. With the recent successful launch of Jason-1 and ESA's Envisat, this time series will be prolonged into the future, as well as being processed in near real time. It means that there is a wealth of long-term hydrological information at hand, but extracting meaningful products from the radar-altimeter signal echoes is a complex process due to the unpredictable nature of the echo's shape over continental surfaces. This is precisely why ESA launched the development of a new ready-to-use hydrological product as part of its 'River and Lake Project'.

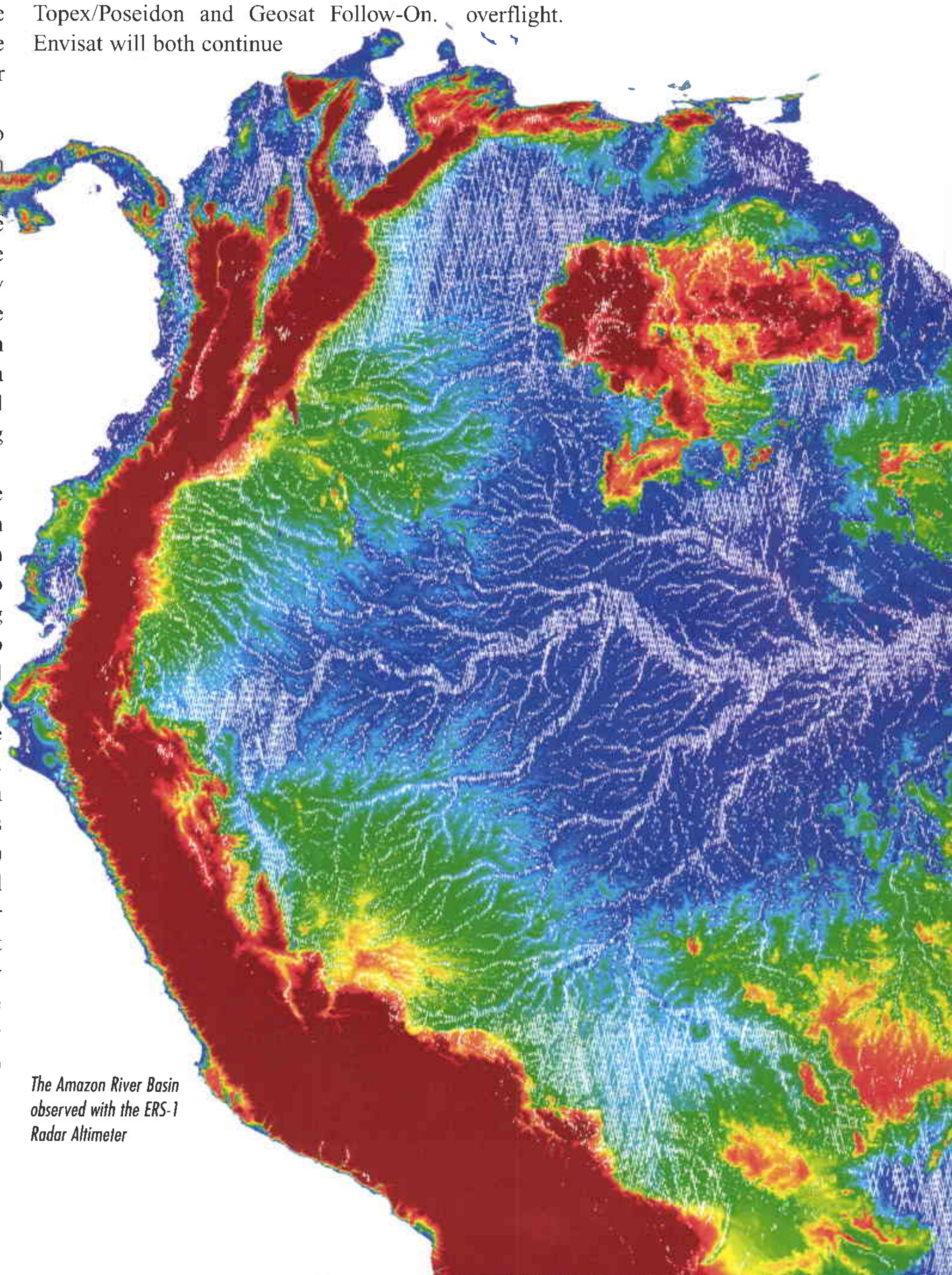
The project's main objective is to provide the scientific community with easy-to-use, effective and accurate river and lake level measurements from both the ERS and Envisat satellite altimeters. The hydrologist's requirements pose a very interesting challenge, because the traditional satellite products have been radically different from those based on ground data, with both the vertical precision and temporal sampling being more limited.

This new development will enable the valuable hydrological data encoded in satellite altimeter echoes returned from rivers and lakes to be translated into accurate height estimates, thus permitting time series of more exact water heights to be produced. Of the many potential applications of radar altimetry to hydrology, the simplest in concept is the monitoring of river and lake levels. Previous work on extracting such information from satellite data was constrained by mission limitations (Seasat) and a combination of data limitations and instrument and pointing difficulties over land surfaces (Geosat). This meant that only very limited applications of altimetry for surface hydrology could be demonstrated over land, with the primary targets being wetlands (for direct mapping) and large lakes (for water-level determination).

Considerable work has been done with Topex, which has also demonstrated the usefulness of such data, but only over a small number of selected targets. One key constraint for hydrological applications from these missions is that their altimeters, originally designed for ocean measurements, can 'keep track' only over very limited areas on land.

The major advance in land coverage provided by the inclusion of an 'ice mode' in the ERS-1 and ERS-2 Radar Altimeters has vastly increased the capabilities for monitoring the Earth's river and lake systems, compared with altimeters equipped only with an 'ocean mode', e.g. Topex/Poseidon and Geosat Follow-On. Envisat will both continue this valuable data stream and, potentially, extend it, as an additional tracking mode allows successful radar-echo capture over even rougher terrain.

The system developed by De Montfort University (UK) for ESA uses both ERS and Envisat data to produce two types of products: a River-Lake Hydrology (RLH) product and a River-Lake Altimetry (RLA) product. The first goal is to obtain 7 years of processed data for specific targets, then to propose the world-wide coverage of large rivers and lakes over 7 years, and finally to make all RLH and RLA products available to hydrologists in near-real-time, i.e. less than 3 hours after the satellite's overflight.



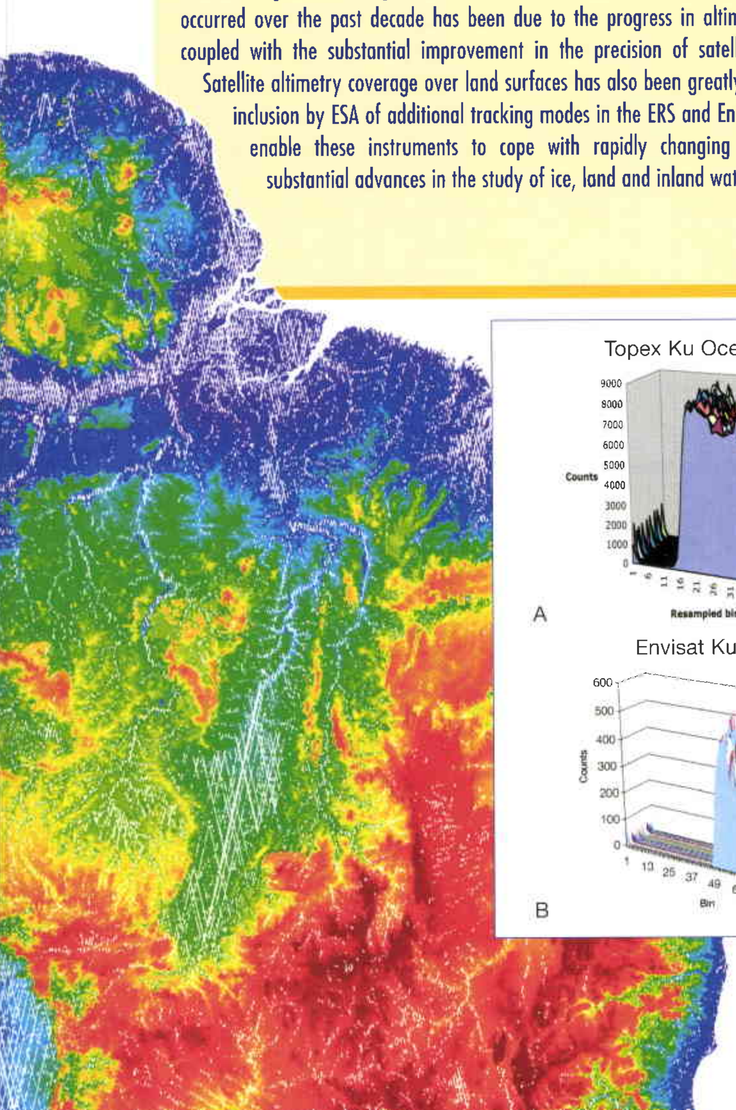
The Amazon River Basin observed with the ERS-1 Radar Altimeter

The Role of Satellite Radar Altimetry

Water bodies represent important economic and cultural resources, but also much economic activity and development takes place close to the shorelines of lakes and can be adversely affected by flooding. Moreover, lake volumes respond to changes in precipitation integrated over their catchment basins and so can act as important, though indirect, indicators of climate change on both regional and global scales. Major river systems are important targets for research covering a wide range of applications, such as transport, flooding hazards, water and food resource management, as well as studies of the hydrological cycle and the impact of land use and climate change.

For certain major rivers and wetlands, hydrological information can often be difficult to obtain, due to the inaccessibility of the region, the sparse distribution of gauge stations, or the slow dissemination of data. Satellite radar altimeters have the potential to provide accurate height measurements not only for lakes, but also for large rivers such as the Amazon, which has been a primary target of environmental studies over the last 10 years.

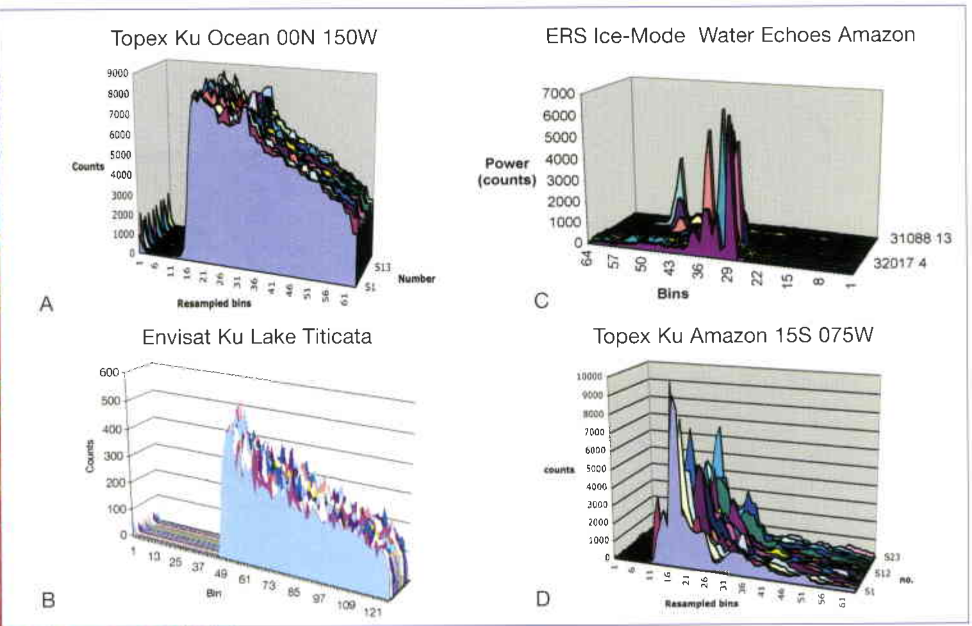
Research into the application of altimetry for monitoring river and lake levels has been carried out since 1982. It has highlighted the advantages of using data derived from satellites due to their global coverage and regular temporal sampling of the processed data, but has also identified the difficulties in interpreting radar-altimeter measurements made over inland waters. In general, the great improvement in altimeter measurement accuracy that has occurred over the past decade has been due to the progress in altimeter instrumentation, coupled with the substantial improvement in the precision of satellite orbit calculations. Satellite altimetry coverage over land surfaces has also been greatly improved due to the inclusion by ESA of additional tracking modes in the ERS and Envisat altimeters, which enable these instruments to cope with rapidly changing surfaces, leading to substantial advances in the study of ice, land and inland waters.



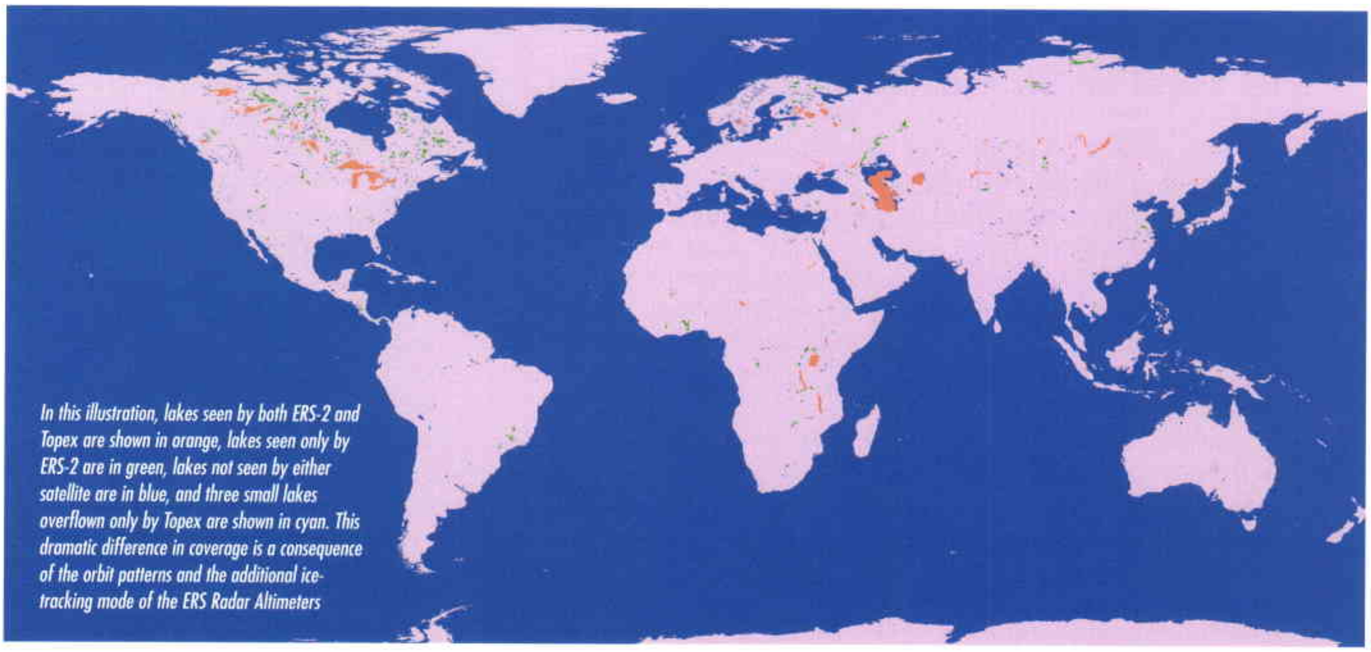
Sifting the Data

To optimise the recovery of inland water data from spaceborne altimeters, and gain access to the unique time series of inland water heights contained in the ERS and Envisat radar signals, it is necessary to reprocess the individual echoes to obtain an accurate 'range to surface'. The task is complicated by the wide variety of echo shapes returned, especially in the presence of land 'contamination'. In fact, several factors affect the accurate recovery of height data from inland water echoes. The first and in many ways the most serious limitation is the presence of very bright components within the echo resulting from still pools. Further complications include the presence of islands and sandbars within the water body, the surrounding still water from, for example, irrigation and rice paddies, and the effect of surrounding terrain. All of these factors affect the echo shape and complicate retrieval of the range from the satellite to the water surface.

The accompanying figure shows four sequences of echo shapes to illustrate the differences between the echoes from large lakes and oceans, and the rapidly varying radar returns from rivers and smaller lake systems: they are typical ocean returns from Topex, returns from Envisat over a large lake (Lake Titicaca), and two series



Envisat Radar Altimeter return-echo shapes over rivers

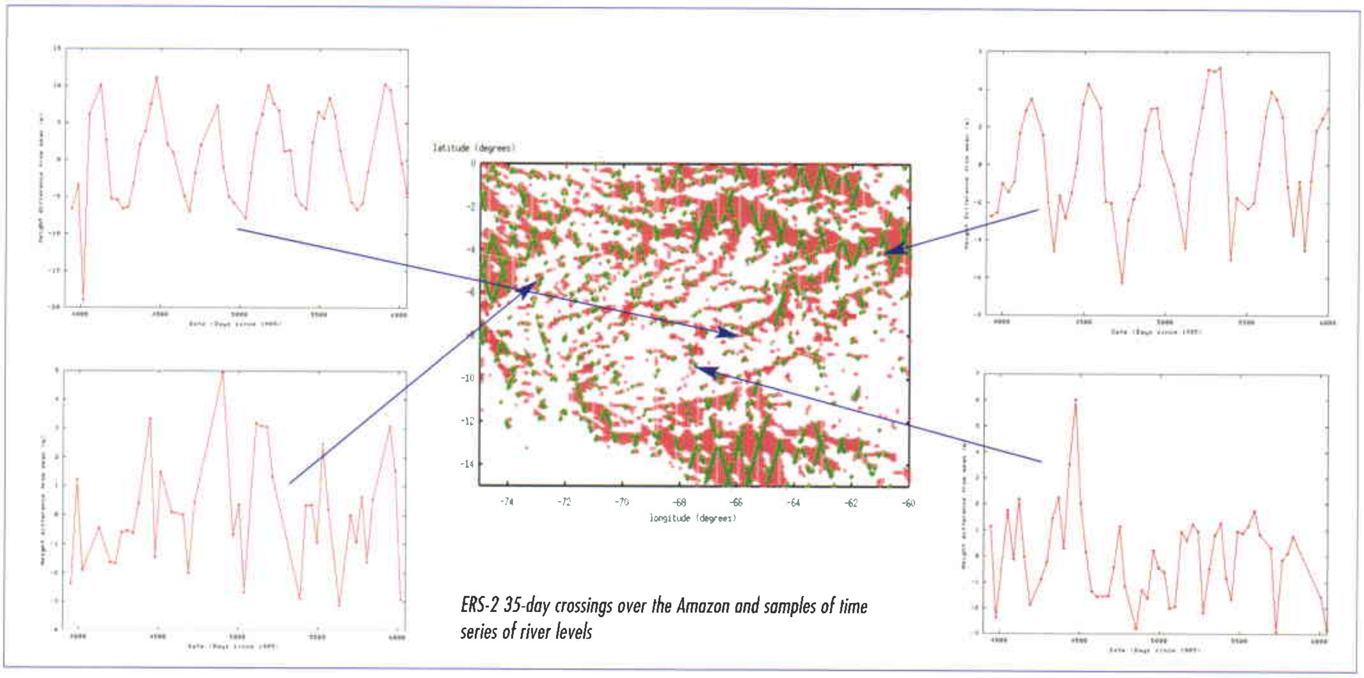


In this illustration, lakes seen by both ERS-2 and Topex are shown in orange, lakes seen only by ERS-2 are in green, lakes not seen by either satellite are in blue, and three small lakes overflown only by Topex are shown in cyan. This dramatic difference in coverage is a consequence of the orbit patterns and the additional ice-tracking mode of the ERS Radar Altimeters

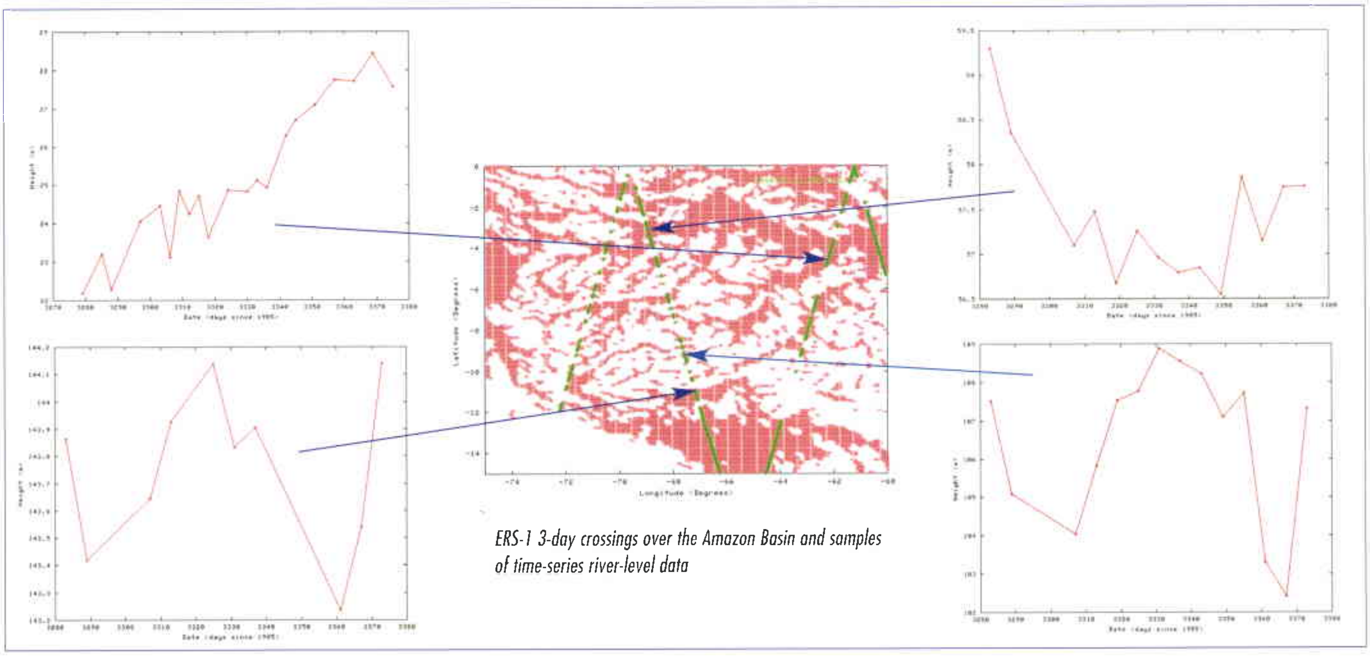
of returns from inland water/land composites over the Amazon Basin from ERS-2 and Topex. This diversity in echo shapes means that it has not been possible to design just one retracking algorithm to reprocess all waveforms optimally. Rather, a suite of such algorithms is required, and this is the approach that has been implemented for ERS-1/2, Envisat and Topex data using the expert system developed at De Montfort University.

Over rivers, ERS-2 shows significantly better performance than Topex, thanks to the Ice mode. The accompanying figure shows a typical 35-day cycle of ERS-2 crossings (green) superimposed on the Amazon Basin bright-targets map developed from the ERS-1 geodetic mission (red). Four sample time series of river-height variations derived from the ERS-2 retracked dataset are also shown. The large annual variation is clear.

To illustrate the relative performance of a higher sampling frequency with an ice-mode altimeter, the next figure shows a similar map for ERS-2 three-day crossings (green) over Amazon Basin bright targets. Again, time-series data have been included to illustrate the satellite altimetry's potential for identifying rapid temporal variations in river and stream height when using a satellite with a short orbit-repeat pattern.



ERS-2 35-day crossings over the Amazon and samples of time series of river levels



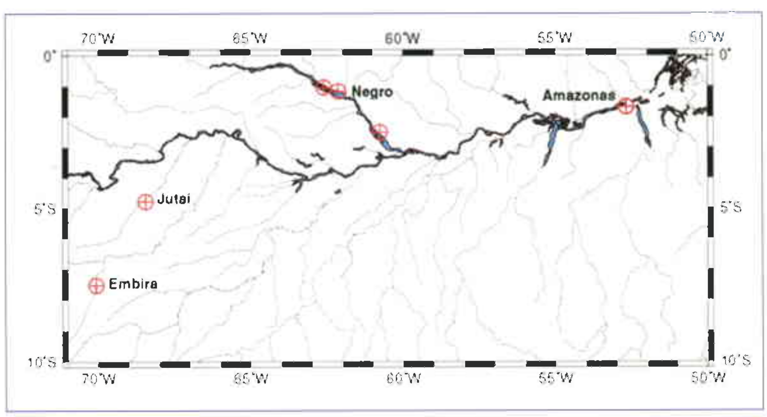
ERS-1 3-day crossings over the Amazon Basin and samples of time-series river-level data

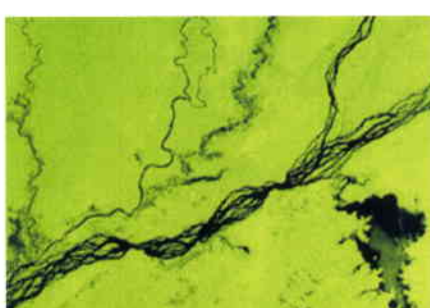
The Two New Products

As mentioned above, two novel types of product have been designed and are currently available as samples. The River-Lake Hydrology (RLH) product, intended for hydrologists with no special knowledge of radar altimetry, is grouped by river/lake crossing point (one product per crossing point). The RLH product is distributed in XML format, which makes access and visualisation very simple. The River-Lake Altimetry (RLA) product, designed for radar-altimetry experts, is grouped by satellite orbital revolution. A detailed product description can be found in the Product Handbook, downloadable from the River and Lake Project web site (http://earth.esa.int/riverandlake).

To familiarise the hydrology community with these novel products and to gather feedback concerning their suitability and use, a set of 22 representative seven-year-long time-series samples were distributed at the Hydrology from Space Workshop in Toulouse (F) last October. The 22 products focused on two regions:

- Africa: Lake Nasser, the River Nile including the Aswan Dam, Lake Tana, Lake Kyoga, Lake Victoria, Lake Mai-Ndombe and the River Congo.
- South America: Amazon Basin.

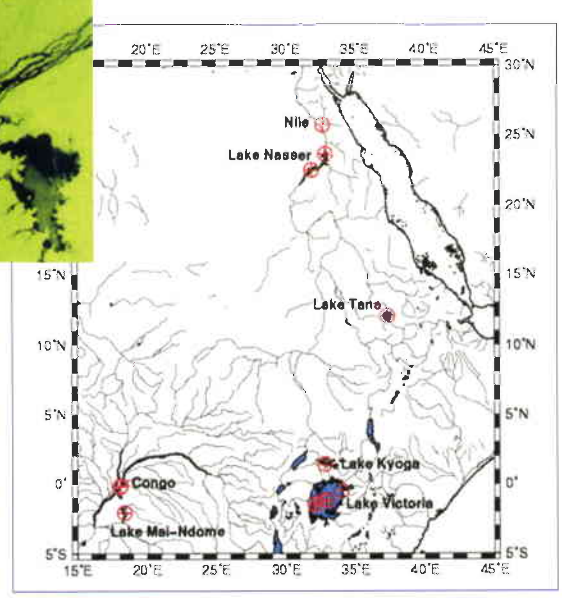




The River Congo as seen by Envisat's Advanced Synthetic Aperture Radar (ASAR)

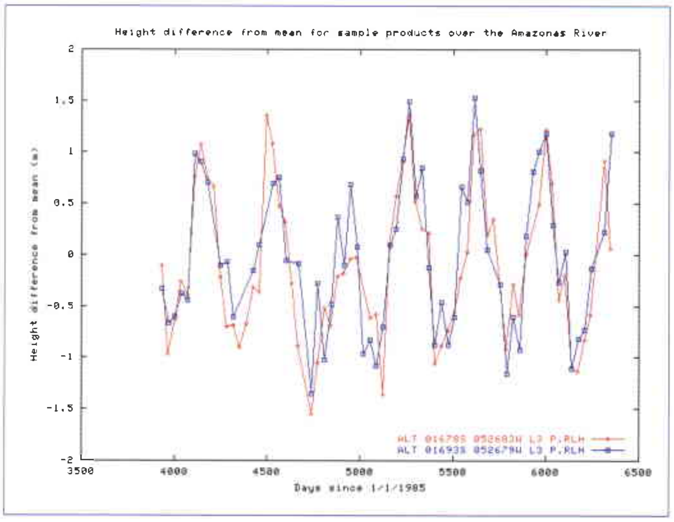
The accompanying location maps for both regions have the related product crossing points highlighted and the corresponding product samples can be downloaded at http:// earth.esa.int/riverandlake.

Maps of the African and South American sample-product locations



The shrinking Aral Sea, as seen by Envisat's MERIS instrument. Its water level has dropped 13 metres since the 1960's

The accompanying graph is a quantitative representation of the products over the River Amazon, showing the variation from the mean water level in the river at two crossing points. The annual cycle is clearly visible in this seven-year time series of data. The year-to-year variation in the annual cycle, which is of major importance for climatological studies, is also clearly detected.



Sample products over the River Amazon, which clearly show not only the annual cycle in water level, but also the year-to-year variation, which have both ecological and climatological consequences

Three New Processing Tools

To help the hydrology community to access and process the two new products, software tools have also been developed and made available. A software library, written in the C programming language, helps users to incorporate the reading/ writing of RLA products into their own programs. A new Graphical User Interface tool realised in IDL (Interactive Data Language) facilitates the plotting of both the RLA and RLH products. An RLH Demonstration Viewer, written in Java and therefore platform-independent, allows scatter, line and area plots to be made of more than one RLH product at a time. The River-Lake Viewer also includes a zoom facility and the possibility to export plots in Portable Network Graphics format.

Future Plans

Whilst the decade-long archive of satellite data is being processed, more samples for other geographical regions, focusing on specific user needs, will be prepared and distributed next April. The Envisat ground segment will be enhanced with the near-real-time river and lake level processor to provide products to the hydrology community in less than three hours after measurement. A second Hydrology from Space Workshop will be organised next year, as was strongly recommended by the participants in the first workshop, along with the establishment of a European scientific working group on Hydrological Observations from Space. The Working Group's objective is to promote the application of existing space observations to problems in hydrology and formulate the requirements for future spaceborne hydrology missions, as well as to organise the necessary ground-based observations to support the validation of the space-data products. The Working Group will also promote communication between ESA and the scientific communities represented within its membership. esa

The 'Cervantes' Mission

- Another European Astronaut at the ISS

Astronauts from NASA, NASDA and ESA in front of the Columbus module during the European part of their Space Station training

Training in the US Lab simulator

Press Conference at the Spanish Ministry for Science and Technology on 4 February 2003

Pedro Duque
ESA Astronaut, European Astronaut Centre (EAC),
ESA Directorate of Human Spaceflight, Cologne, Germany

How It Came to Pass

When Spain expressed interest in sponsoring a Soyuz to the International Space Station (ISS), I was informed that I might be assigned to such a mission. At the time I was a member of the Columbus Project team, where I had been working since 1999 in the areas of crew interfaces, maintainability, EVA/robotics interfaces and also to some extent NASA interfaces. In addition, I was one of a group of ESA astronauts training to operate the systems of the Space Station, with the four of us being candidates for the first Permanent Crews with ESA participation.

Several months passed between the initial flight idea and the official announcement by the Spanish Government, during which it became increasingly probable that I would have to train in Russia to operate the Soyuz TMA as Flight Engineer, learn how to execute experiments in the (as yet undefined) ESA Utilisation Programme, and therefore also hand over my Columbus duties. Our Training Division and the Gagarin Centre considered one year a reasonable time to devote to this, based on their experience with previous such projects (Cassiopée, Marco Polo and Odissea). By September 2002, therefore, the time pressure began to mount and so at the beginning of October I went to Russia to start training, six months before the flight. Then the adventure really began.....

The Framework Agreement

ESA and the Russian Aviation and Space Agency (Rosaviakosmos) have developed an extensive and fruitful cooperation in the area of human spaceflight activities, both on the Mir space station and through the current International Space Station (ISS) Programme. The resulting operational interaction and cooperation between Russian cosmonauts and European astronauts has proved beneficial to the strengthening of the human spaceflight expertise and experience of both agencies.

In order to further pursue common endeavours in the field, in May 2001 ESA and Rosaviakosmos established a Framework Agreement for European-Russian cooperation in the organisation of flights for ESA astronauts using Russian flight opportunities to the ISS. The goal was to undertake a number of flights in order to utilise the ISS for scientific research and applications through well-established experimental programmes. Two types of opportunities are foreseen in the Agreement: *ISS Taxi Flights*, which are defined as short-duration Soyuz flights to the ISS for exchanging the Soyuz docked with the Station, including a short-duration stay on-board, and *ISS Increment Flights*, which are defined as crew-exchange flights, including a stay of several months (one increment) on-board the Station.

Within the scope of the Framework Agreement, CNES (F) sponsored the first ISS Taxi Flight in October 2001, known as the 'Andromède' mission, with ESA astronaut Claudie Haigneré on board. In April 2002, ESA astronaut Roberto Vittori flew on the 'Marco Polo' Taxi Flight sponsored by ASI (I), followed by ESA astronaut Frank De Winne in October 2002 on the 'Odissea' mission, sponsored by Belgium.

With those precedents established, Rosaviakosmos offered ESA two further flight opportunities, in April and October 2003. At ESA's invitation, Spain decided to sponsor the first one, with ESA astronaut Pedro Duque in the role of Flight Engineer, and The Netherlands took the second one, with ESA astronaut André Kuipers also serving as Flight Engineer.

Following the Spanish decision, the experimental programme for Pedro Duque's flight, which subsequently became known as the 'Cervantes' mission, was then drawn up in close cooperation with the sponsoring organisation, namely the Spanish Ministry for Science and Technology, through the Centre for Technological and Industrial Development (CDTI). Pedro eventually performed more than twenty experiments during his stay aboard the ISS.

Pedro was fully engaged in his Cervantes mission training in Russia when, on 1 February 2003, tragedy struck the US Space Shuttle 'Columbia' during its return from the STS-107 mission. The days and weeks that followed saw the mourning space community considering its options following the grounding of the Shuttle fleet, and assessing the best way to proceed in order to keep the ISS safe. The outcome of the assessment in terms of the number of crew on-board ISS was that, as from April, it would be reduced to just two until the Shuttle's return to flight. It also meant that the next Taxi Flight had to become a crew-exchange flight and that Pedro Duque could not therefore fly as early as originally planned. Rosaviakosmos and ESA, together with the Spanish Ministry and CDTI, agreed to postpone his flight until October 2003. Similarly, the two partners and the Dutch government agreed to postpone André Kuipers' flight until April 2004. Agreeing to the two postponements was Europe's contribution to protecting the ISS crew.

The eventual successful completion of the 'Cervantes' mission is solid proof of the good co-operation between the sponsoring entities, in this case Spain, ESA and Rosaviakosmos, within the Framework Agreement, and marks another positive milestone in the long-standing relations between ESA and Rosaviakosmos.

With the forthcoming flight of André Kuipers in April 2004, the Framework Agreement continues to be a solid and stable basis for the strategic planning of the activities of the European Astronaut Corps, as well as an important tool in the further development of the operational expertise of ESA's astronauts prior to full European utilisation of the ISS with the launch of Columbus. While the Framework Agreement allows for attractive financial conditions commensurate with the number of flights actually implemented, at the same time it supports the Russian space effort through the involvement of ESA astronauts. It is therefore intended to continue with this mutually very fruitful approach.

Manuel Valls
Head of Programme Integration Department
ESA Directorate of Human Spaceflight

A Fast Pace

The astronaut colleagues who had preceded me in undertaking similar training – Jean-Pierre and Claudie Haigneré, Roberto Vittori and Frank De Winne – had already warned me that six months was a very short time in which to learn the Flight Engineer's job fully. Everybody was therefore braced for furious activity, with no time to relax, but the objective was clear to all: no half-hearted attempts, we must continue to show that Europe's astronauts make valuable crew members, able to cope with the full range of responsibilities, and at the same time continue to demonstrate our excellence in executing experimental programmes with commitment and precision. It's hard to be seen as a junior partner…but so far I believe that we all at ESA, in all of our relations with our partners, have been able to show that we compare favourably with the best from the other agencies. This time it was my turn! And I know that the people who were there to help prepare my training, the experiments, the overall programme for my flight, etc., and for whom the six months was even shorter, felt exactly the same way.

It was straight into the classroom and the simulator, and so October and November were already gone without noticing. I was starting to believe that I was actually going to make it at the beginning of December, when I was told that the Christmas holiday period in Russia followed the old calendar, and so only four or five free days were allowed around New Year. It was strange to spend the last week of December in the classroom and simulator, but it was all in a good cause – namely to fly in April in the knowledge that I had been fully trained.

The Columbia Accident Takes its Toll

Training as a complete crew started as early as December 2002. Gennadi Padalka was my Commander, and his very extensive Soyuz experience and his excellent operational skills both challenged me to keep up and accelerated my learning process. All was well, with the last examinations taking place in January (in Russia you take an oral examination for every system you are supposed to operate), and the rest of the learning programme being made up of simulator training for Soyuz and procedural training for the experiments.

At this stage in the flight-preparation process, the ESA programme of activities to be conducted aboard the ISS was not yet very full. The Announcement of Opportunity (AO) had only been issued to the scientists in late November and most of

About to go into the centrifuge for an 8-g test

In the barochamber

the experiment hardware was supposed to be transported to the Station on a Progress flight scheduled for 2 February. The short lead time available meant that very few of the potential instruments for that Progress flight would make the deadline. This was, of course, a cause for concern, but the programme's management was determined to make the best use of the equipment that would arrive, and to re-use almost all of the hardware that had already been delivered and proven during the previous three flights.

On 1 February 2003 the world of all of us involved in human spaceflight was turned upside down, when Space Shuttle 'Columbia' was destroyed during re-entry and seven colleagues died. Everything was in turmoil. It quickly became clear that the Shuttle would not be flying again any time soon, and so the current Space Station crew would have to return home in a Soyuz spacecraft. Obviously, there was no time to send a new one, and so they would have to use the one that Gennadi Padalka and I had been planning to use to return to Earth at the end of our visit.

Interesting times followed during which all of the various options were carefully studied. Two or three people had to go up, making up a long-duration crew, one of whom needed to be a Soyuz Commander and another a Flight Engineer according to crew-composition rules. Three would return, one of whom had to be a Commander. If an ESA astronaut was to go up and down, obviously only two of the three current crew members could return, so one would have to stay for another six-month tour of duty. Another option was for me to fly up and stay for the whole six months, making up the first three-nation permanent crew. The third option was to postpone the ESA flight for six months and fly up the next crew, but only with two astronauts, taking a NASA astronaut with a Flight Engineer qualification. Eventually the latter option was taken, but since no NASA astronaut was suitably qualified at that point, Edward (Ed) Lu was chosen to train at almost impossible speed between February and April. He worked extremely hard, including nights and weekends, and eventually the bare minimums were met, although no-one but Ed could have accomplished that much.

With Gennadi Padalka in the Soyuz simulator at the end of January 2003

Preparing for EVA teamwork...

...and executing it

The good news was that we had six more months in which to train, to prepare instruments for later Progress shipments, to define the procedures better, etc., and we all made very good use of that extra time. We even managed to fit in an EVA training course for Thomas Reiter and myself in Houston as part of our continued preparation for the first European long-duration expedition.

My Flight to the Space Station

It turned out to be a totally different kind of flight for me than for the ESA astronauts who had made similar trips previously. To start with, it was not very clear who were 'my crew'. I launched with the Expedition 8 and returned with the Expedition 7 crews. None of them was really involved in the ESA programme because they had their own jobs to do, both during training and at the Station. Being a technical person, I sometimes joked that I was the Commander of the Fifth Visiting Expedition, and its only crew member! This turned out to be more accurate than I thought.

Before Yuri Malenchenko left to command the ISS for six months, we spent a number of training sessions together in order to qualify 'as a crew' for a later descent. The position of Flight Engineer for both the outward and return legs was, I'm told, hotly debated, with both ESA and NASA proposing crew members. ESA eventually prevailed, probably in part because I had had the opportunity to devote much more time to my Soyuz training than my NASA colleagues.

Training with Alexander Kaleri turned out to be as enlightening as with Gennadi Padalka, but in a different way. Being the first non-military, non-pilot astronaut to be launched in the Commander's seat in Russia, a lot of attention was focused on his performance, and he did not let anyone down. Both being engineers, we tended to look at problems in the same way, and he always took just a little longer than the 'immediate-reaction approach' I have seen from other Commanders. He would always first assess how much time he had to available to make a decision, and only then start considering the options.

A little later, Michael Foale arrived following his last training session for the US segment of the ISS. His contributions during training were always helpful and his long experience as a Shuttle Mission Specialist was very apparent. During Station simulations, Michael assumed his role as Station Commander with a lot of character and always had his own approach, based on sound principles, to every problem.

The three-nation crew training for Soyuz launch and docking

Our launch vehicle lifted-off on 18 October, on a perfect sunny day on which, they say, our rocket was visible for hundreds of kilometres down range. Inside were the three of us – Alexander, veteran of three such flights, Michael and myself – on our first ride on the legendary 'Semyorka' rocket. Michael and I agreed that the launch was much smoother than on the Space Shuttle, especially compared with the first two minutes of Shuttle flight when you are being propelled by the very loud, resonating solid-rocket boosters. With the several detailed briefings that I had had from Alexander about the intricate workings of the Semyorka, I was not at all surprised by the falling sensation at the end of the first phase of flight, the noticeable roll oscillation during the second, or the loud separation charges at the end of the third.

The crew before launch

The Soyuz craft performed flawlessly during the forty-eight hours that we spent going around the Earth waiting for the 'gods of orbital mechanics' to pull us into the correct position with respect to the Space Station, using the minimum amount of propellant. Every system worked well, with the exception of a manual valve that had accidently been left closed during pre-launch ground processing. The approach and docking manoeuvre was also performed flawlessly, with the crew and ground staff supervising the automatic systems, which did all the work from start to finish.

Not much room in the Soyuz at lunchtime

The International Space Station Today

Opening the hatch was an unforgettable experience. It took some time to check for air tightness, equalise the pressures, plug the Soyuz into the Space Station's power, and carry out all the procedures that ensure that two spaceships could become one. We in the Soyuz were eager to meet the crew and to see the Station itself, about which we had heard so many stories. I can imagine that the Station crew were eager to open the door to anyone at all, as we were the first people they had seen in six months!

Our hatch was opened first and the characteristic smell of something like gunpowder filled the Soyuz; I don't know if anyone has ever succeeded in explaining why the space vacuum always seems to have this kind of smell. Then their hatch opened and we saw them to be in pretty good shape, shaved, with short hair and dressed in matching clothes – not the look of shaggy explorers seeing a ship come ashore, but the look of a pair of officers proudly welcoming visitors aboard a large vessel.

The size of the ISS, or more accurately its length, is staggering. One cannot see one end from the other; in fact one can hardly see either end from the centre. Both airlocks are attached sideways-on to the Station, so the structure is not completely linear. Contrary to the Russian Mir station, however, the ISS has not yet grown large enough for one to become disoriented when inside.

Opening the hatch also made us aware of the smell in own Soyuz: after the two days inside it, it was a relief to breathe the much cleaner and cooler air in the Station. Everybody on board agreed that during the eight days of our stay the air was perfectly clean. The ventilation is good and one does not see floating dust, the filters 'swallowing it' very efficiently.

Work started right away: there was no time to lose in getting experiment operations underway, because the investigators had done a lot of work in defining a meaningful programme for the whole eight days available, and data needed to be gathered from the very first moment. The biological samples were

The Expedition 7 crew opens the hatch for us introduced into the incubator, the protein crystal growth was started, the medical experiments prepared, etc.

Upon arrival at the Station, there is an unavoidable adaptation phase to be gone through, which can range from simply getting used to the crew restraints and how to move around, to even nausea and disorientation. Therefore, planning a very full first-day programme is always a risk, of which both the crew and ground control are well aware, so we all were very relieved to see all of the day's tasks get done.

The timeline for the eight days involved 21 different activities, as shown in the accompanying table. Every day there were eight to nine hours of scheduled activities, timelined by the ESA Operations Group resident in the Erasmus building at ESTEC (NL), within the constraints imposed by general Station operations. They were ready for any contingency, although there were luckily very few of those and we were able to execute the plan practically as originally envisaged. Nevertheless, space missions at ESA, whether automated or with astronauts, are always taken very seriously and means are always in place to cope with any foreseeable problems.

Every Space Station day starts with a planning conference, during which the American, Russian and ESA ground teams discuss very briefly with the crew the tasks of the day, and all make sure they will be working with the same information. Then all of the crew members 'fly' in different directions and start performing their planned activities, either alone or in pairs if required.

Discipline	Code	Experiment Name	Principal Investigator
Biology	AGE	AGEING	R. Marco (E)
	ROO	ROOT	F. J. Medina (E)
	GEN	GENE EXPRESSION	
Microbiology	MSS	MESSAGE	M. Mergeay (B)
Human Physiology	COG	NEUROCOG	G. Cheron (B)
	SYM	SYMPATHO	N. Christensen (DK)
	BMI	BMI	C. Gharib (F)
	RYT	CARDIOCOG	A. Aubert (B)
	MED	MEDOPS	R. Lentzen (ESA)
Physical Science	PRS	PROMISS	J. M. Garcia-Ruiz (E) A. Chernov (US) L. Wyns (B)
	NAN	NANOSLAB	J. Martens (B)

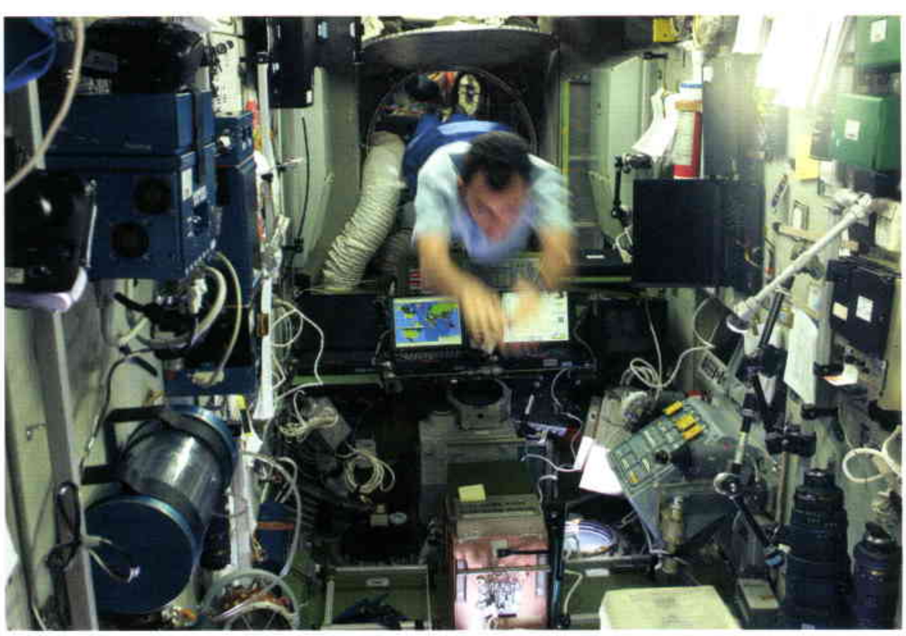
Discipline	Code	Experiment Name	Principal Investigator
Earth Observation	LSO	LSO	E. Blanc (F)
Educational	WIN	WINOGRAD	R. Dhir (UK)
	CHO	CHONDRO	University of ETHZ(CH)
	VID	VIDEO-2	M. Paiva (B)
	API	APIS	Universidad Politécnica de Madrid (E)
	THE	THEBAS	
	ARS	ARISS	G. Bertels (B) E.Grifoni (ESA)
Support Equipment	CRR	Crew restraint	P. Mitschdoerfer (ESA)
	3DC	3D Camera	D. Isakeit (ESA)
PR & Symbolics	PAS	PR and SYMBOLICS	C. Mattok/D. Isakeit (ESA)
Ground	CHR	CHROMOSOMES	G. Obe (G)

ESA activities during the Cervantes mission

In our case, most of the time the permanent members of the Station crew were working in pairs, with the newly arrived member looking over the shoulder of the one about to leave or being briefed about the various details they should keep in mind for their six-month stay. I was mostly working alone, on operations that were not particularly complex when taken one by one, but which nevertheless required my full attention. It is our responsibility as astronauts to be the eyes and hands of the dedicated groups on the ground, the success of whose experiments depends on our careful handling and accurate operation of their hardware.

The planners on the ground always try to schedule the lunch break so that we all meet at the 'table', and most days it was possible to get at least three crew members together there. The break is over all too soon, however, and off we go again in different directions. During the day there may be conversations with the ground at the request of the crew, for instance if we are having difficulties in performing a particular task or have any doubts about the correct way to proceed. Normally, ground control rarely calls the crew, because they know that reaching a headset and activating the correct lines can sometimes be difficult, depending on where we are working at a particular moment, and consumes valuable time. However, it is unavoidable once in a while and in the worst case can involve three crew members: the one who happens to be closest to the radio, the one who goes to find whoever is being paged, and the one who actually has to answer the call.

We conducted a number of television interviews during my time at the Station. Some were with all or several of the crew, but many were only with me. This was a



'Flying' back into the Service Module

Giving a TV interview from the Service Module

sign not only that the European public is generally much more interested than the American or Russian public in space missions, but also that Europeans fly very seldom and thus it was a rare media opportunity. Some days we gave several interviews, and we worked hard to make every one valuable and to prepare the cameras, backgrounds, etc. as appropriate. Interviews in the Service Module (where the living quarters are) were the most common, but also the hardest, since we were blocking the table, the drinking water, the exercise treadmill and access to the bathroom during those times!

The Space Station day also ends as it began, with a planning conference. During this one, we check that we have received all the necessary messages and instructions from the ground that may be useful in preparing for the next day, such as indications of any hardware that may be difficult to find, prior warnings of activities that require very tight co-ordination, etc. After the main working day is over, there are also unavoidable tasks that have to be done at specific times, sometimes during dinner or immediately thereafter. The control centres do a good job in minimising those needs as much as possible. Worthy of special mention in this context are the medical experiments that are supposed to run during the night. If one of those is planned, then we have to prepare any sensors, electrodes or whatever after dinner. Experiments of this kind are a severe test of any astronaut's work discipline!

Returning Home

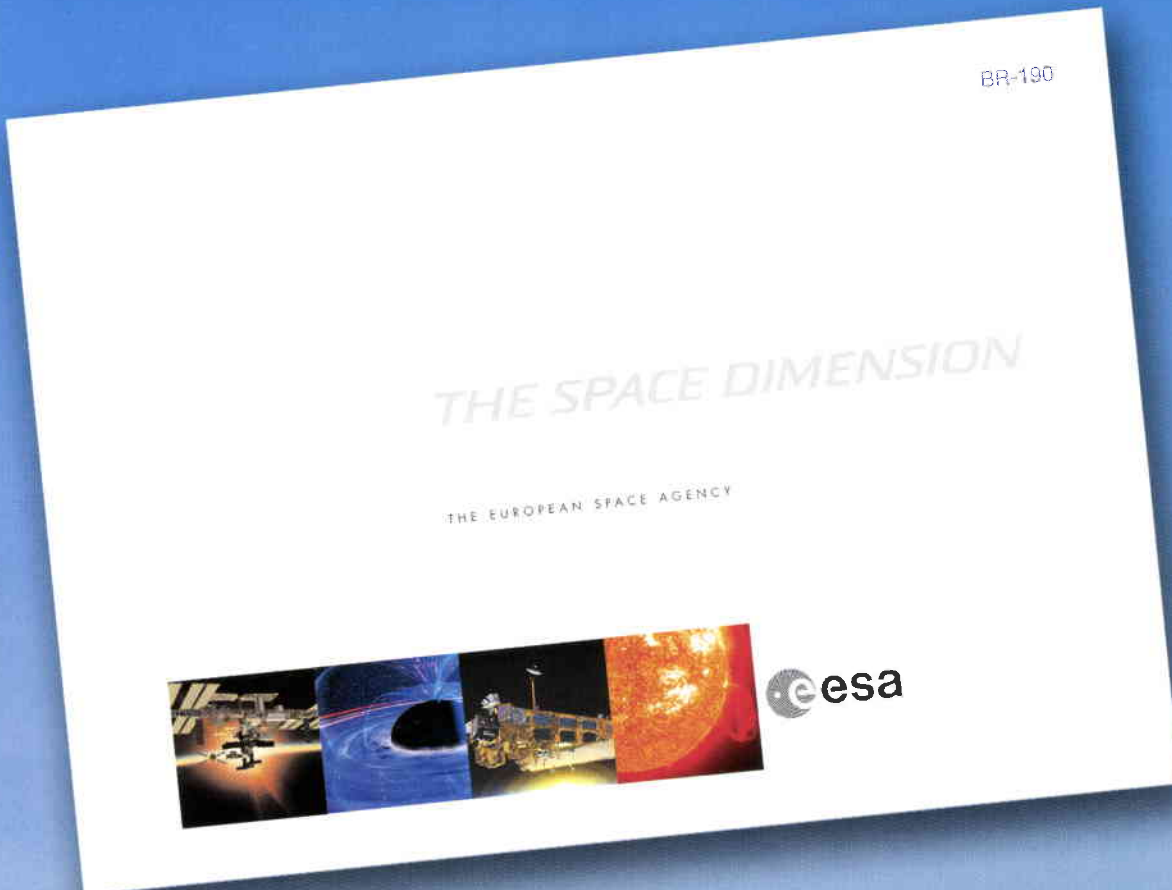
After eight days in the Station, it was time to return to Earth. The outgoing permanent crew was, of course, eager to see their families and friends after six months in space, although in no way did they give the impression of having lost their enthusiasm for work. As for me, I would certainly have stayed somewhat longer if I could. Ten days away from home is not so much, and opportunities like this don't come along often! But taking the next flight home was never a real option, so we three packed the results of our labours into the Soyuz on the last day.

The packing itself is not a simple task, since the spacecraft is very small and hardly anything else can be fitted in when you already have three crew members on board. Stowing the dozen or so items that we were returning for ESA, together with those for the Russian and NASA programmes, was very complex and required prioritisation. People are still discussing which priority should have been assigned to each item and whether the crew interpreted correctly the priorities sent from the ground. Packing for the return trip is therefore difficult, and only one person can really work on it because the space in the Soyuz capsule is so limited. Ed and I could only help by having everything ready, and by packing all the trash that had to be returned into the other part of the Soyuz, which burns up on reentry.

After an unexplained firing of the Soyuz thrusters had initially put everyone on edge, we detached normally from the Space Station and landed with no more malfunctions, exactly as planned and at the foreseen location. That was greeted by everybody with a sense of relief - not least we three inside - since this was only the second test of the new TMA landing avionics and the first one had suffered a failure that sent the crew more than 400 km off-course.

The Path Ahead

Now, with the flight debriefings having taken place and the medical people having completed all of their post-flight measurements, the ESA team is gearing up for the next challenge, Soyuz flight TMA-4 or 8S, which will carry our ESA colleague André Kuipers to the International Space Station on a mission, not unlike 'Cervantes', called 'Delta'. Have a good mission and a soft landing, André!



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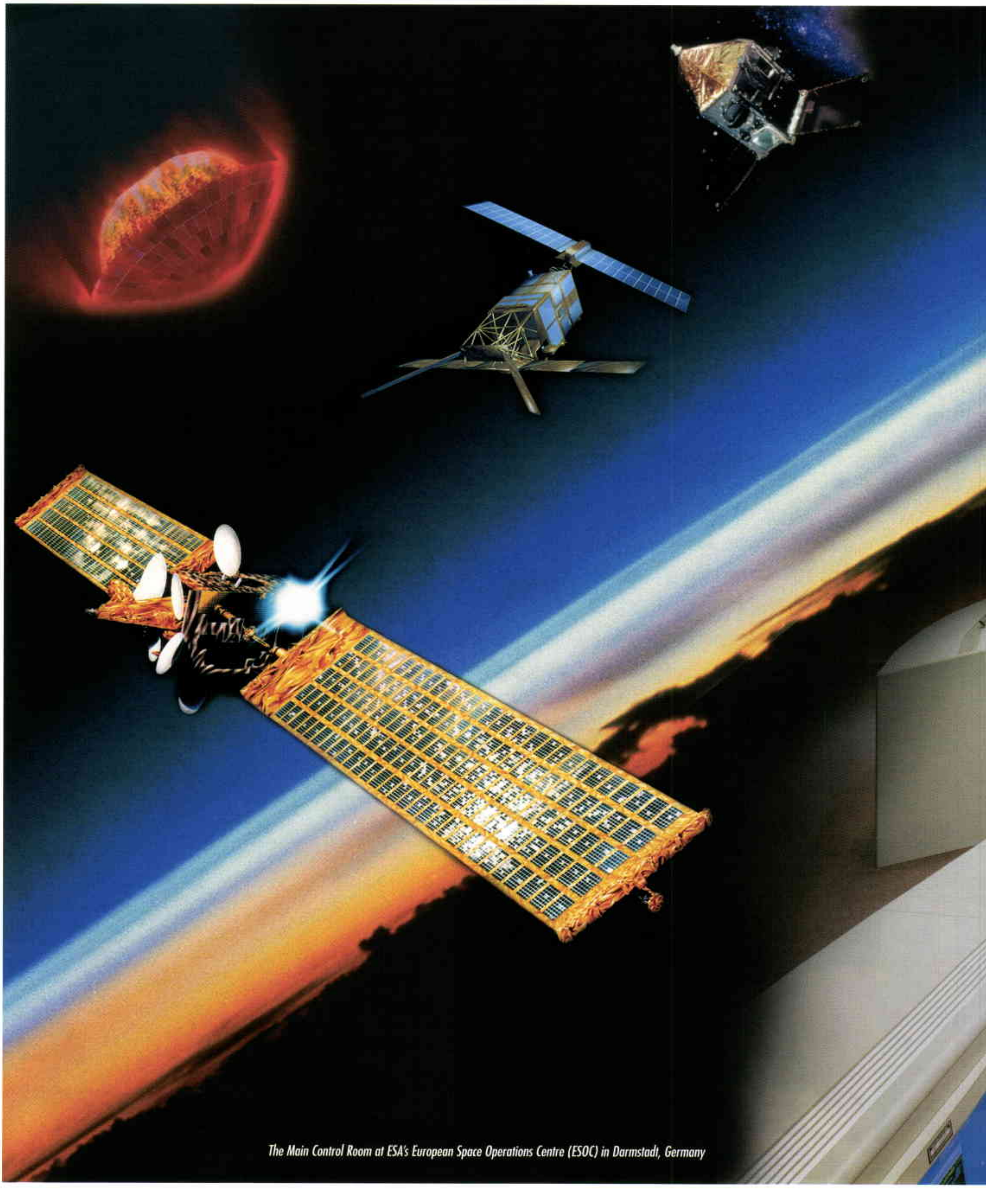
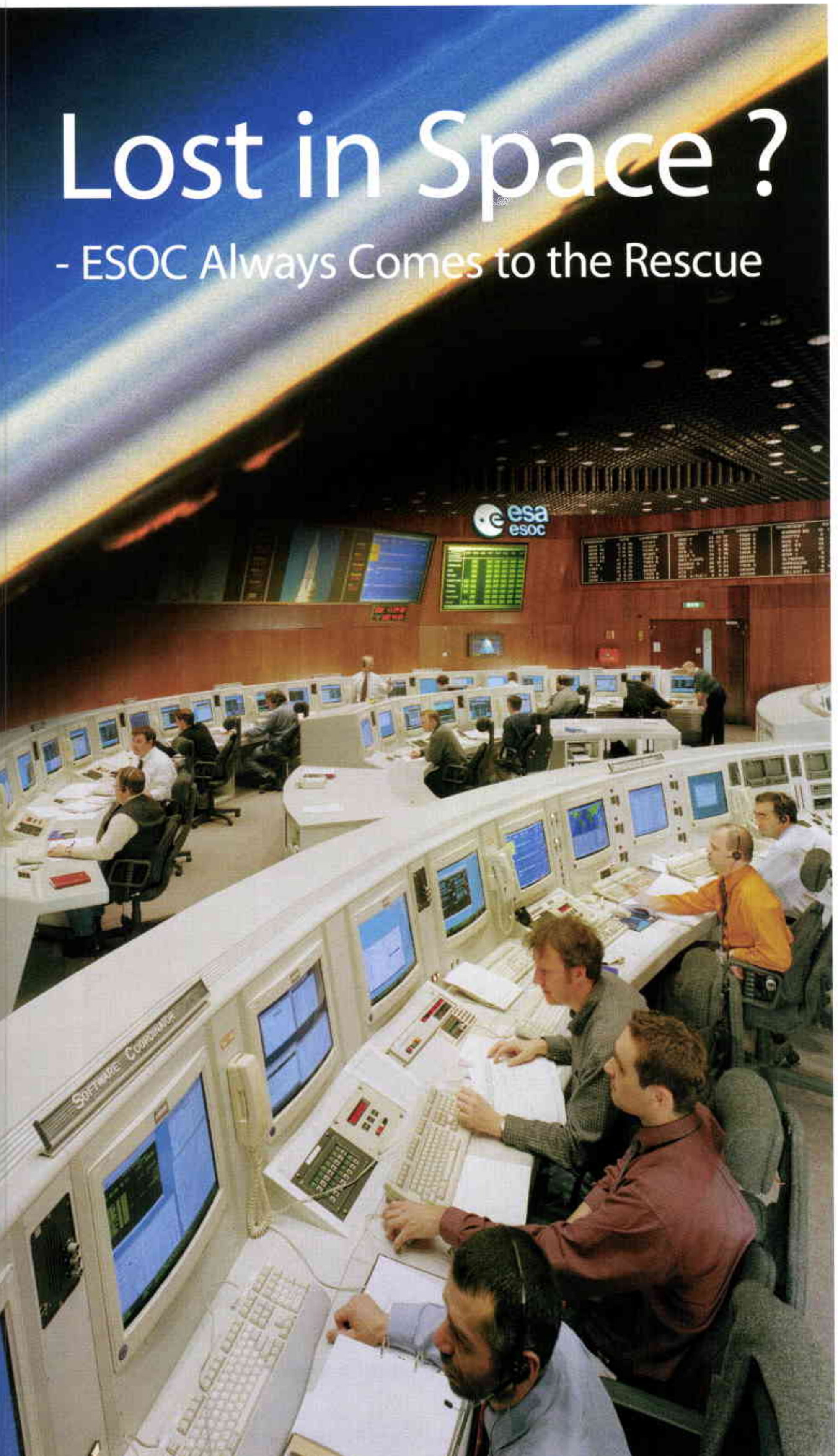


The Main Control Room at ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany

Lost in Space ?
- ESOC Always Comes to the Rescue



A. Smith, R. Muench, W. Wimmer, D. Heger, X. Marc, F. Bosquillon de Freschville, M. Rosengren, T. Morley, S.Pallashke, B. Smeds, C. Sollazzo & A. McDonald (Logica)
ESA Directorate of Technical and Operational Support, ESOC, Darmstadt, Germany

Since supporting its first launch in 1968, ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, has supported 51 spacecraft during the critical launch and early orbit phases of their missions, and nearly all of them throughout their subsequent operational phases. The great diversity of these missions has given ESOC a well-justified reputation as one of the world's leading control centres for unmanned spacecraft. Perhaps less well known is the contribution that ESOC has made to the rescue of many missions that have suffered major anomalies and would otherwise have had to be abandoned or would have failed to achieve their mission goals.

Background

In-orbit equipment malfunctions or failures are a fact of life for all space missions, which is reflected in the on-board redundancy and fault detection and isolation techniques used in spacecraft design. The Control Centre must therefore be able to deal with such situations and normally has contingency procedures in place to respond to them. Sometimes, however, the problems are of such a magnitude that they are beyond what would normally be expected, and require an extensive team effort to retrieve the situation. ESA missions afflicted by such major problems over the years have been:

- Geos-1 and Artemis: Launch-vehicle malfunctions
- TD-1A, Hipparcos, ERS, Huygens: Major spacecraft equipment failures
- Olympus, SOHO: Loss of attitude control.

ESOC's role in the recovery of these missions has ranged from providing emergency ground-station support, through to establishing an alternative mission concept, defining the strategy to achieve it, and ultimately conducting the rescue operations. ESOC has also been requested on several occasions to support other space agencies in rescuing their missions crippled by in-orbit failures.

When called upon, ESOC has been able to respond immediately, exploiting the facilities, experience and expertise that it has at its disposal to effect a rescue.

TD-1A

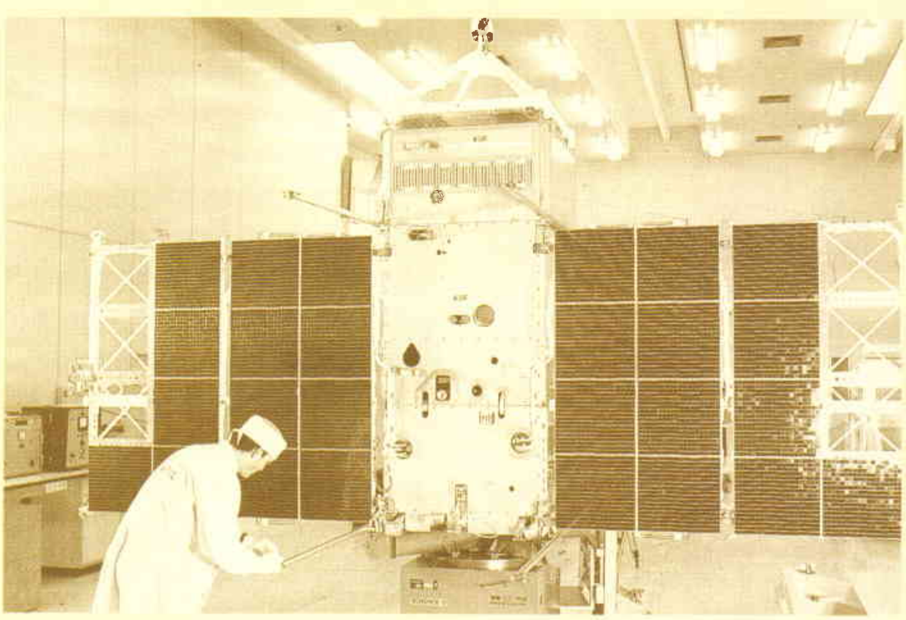
On 12 March 1972, TD-1A, Europe's hitherto largest and most complex scientific satellite, was successfully launched from Western Test Range in California. It was ESRO's first astronomical satellite and it was to look at the stars with two telescopes. However, just a couple of months later, towards the end of May, both on-board tape recorders failed. As it was impossible to repair them, an appeal for help was put out.

It was responded to immediately by NASA, CNES and CNR, who 'loaned' ESOC seventeen more ground stations to record the satellite's direct signals. In a 'fire brigade action', a further seven mobile stations were established, in Tahiti, Singapore, Easter Island, Fiji, Hawaii, Argentina, and finally on a former Dutch 'banana boat', the MS Candide, which was to position itself at 44 degS and 110 degE.

For almost two years, these mobile stations were manned around the clock by ESOC personnel, who had to battle not only against the technical problems but also the environment in many cases.

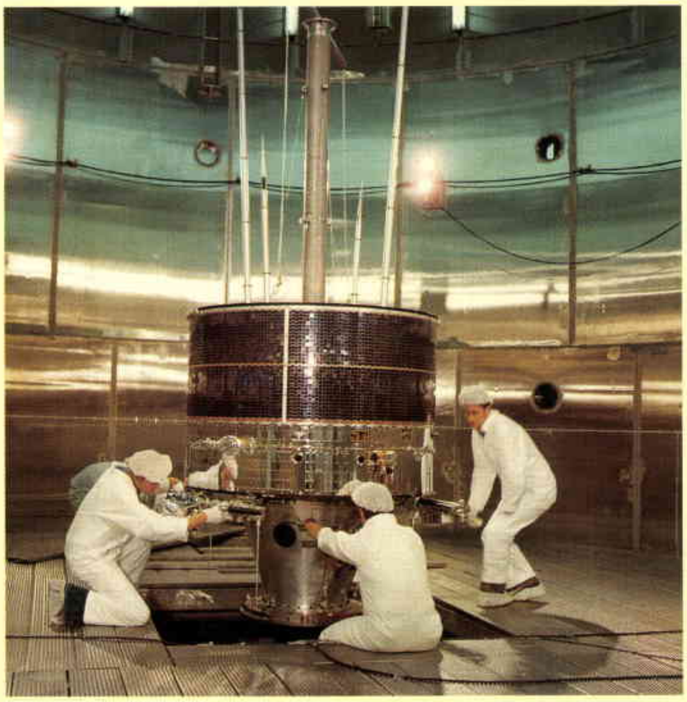
Despite hurricanes, storms, high waves and snow, the recovery operation was very successful. By the end of the mission, the scientific characteristics more than 30 000 stars had been investigated.

The launch of TD-1A from Western Test Range on 12 March 1972



The TD-1A satellite in the Integration Hall at ESTEC in Noordwijk in July 1971

The ESOC Control Room in the 1970s



The GEOS spacecraft being prepared for boom-deployment tests in the Dynamic Test Chamber at ESTEC in Noordwijk (NL)

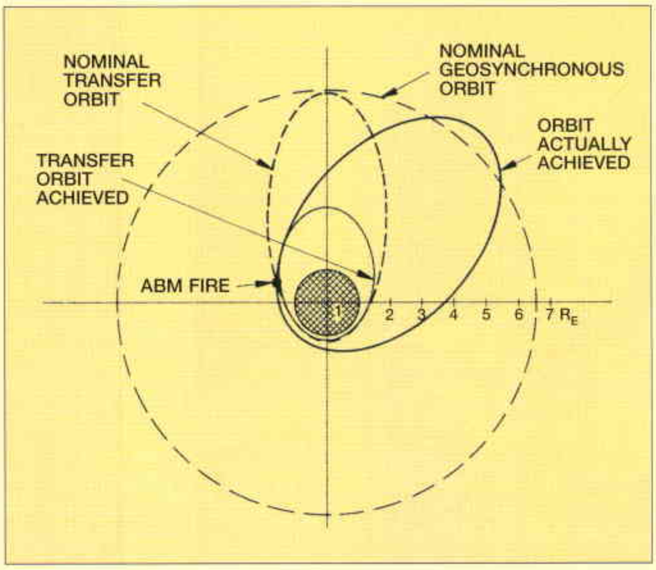
GEOS-1

GEOS was an ESA scientific satellite designed to investigate the Earth's magnetic environment. In April 1977, the Thor Delta launch vehicle should have placed the spacecraft, spinning at 90 rpm, into a 10.5 hour period transfer orbit. About 37 hours after launch, a single firing of the integral, solid-fuel apogee boost motor would then have achieved an orbit very close to geostationary. Due to a partial failure of the launcher, however, the orbit that was actually achieved had a period of just 3.8 hours, the satellite was spinning at only 1.5 rpm, and it was wobbling with a cone angle of 35 degrees.

Because the predicted pointing angles for the ground-station antennas were no longer valid, just a few attitude measurements and tracking data were received after the satellite's separation from the launcher. Only after an unplanned spin-up manoeuvre had been performed, and after extremely careful processing of the data, could the first rough orbit and attitude estimates be made. Attitude manoeuvres had to be executed as quickly as possible to improve the thermal and power situation. Steady degradation of the solar cells, and thus the available power, due to long periods in the radiation belts, was soon detected. The spacecraft had certainly to be manoeuvred into a different orbit, but a geostationary orbit was no longer reachable.

Over the next few days, a team of ESOC experts worked around the clock writing new software and amending existing programs in their search for the optimum orbit that could be achieved, depending upon when the apogee boost motor was fired and with what satellite orientation. The final orbit had to be the best compromise for meeting the needs of the scientific payload, but also had to take into account a whole range of constraints such as ground-station visibility and antenna tracking, the viewing angle of the spacecraft's antenna, orbit stability, eclipses, etc.

Five days after launch, the firing of the apogee boost motor put the spacecraft into an inclined elliptic orbit with a period of 12 hours. Mission planning is normally a matter of months if not years, so it is remarkable that later analysis clearly showed that the solution that had been found was indeed optimal. As a result, GEOS went on to provide very useful scientific data.



The originally planned and launch-failure-degraded GEOS orbits. The spacecraft's apogee boost motor was fired at the point indicated to achieve a 12 hour eccentric orbit as the best recovery compromise

Hipparcos

ESA's Hipparcos satellite, launched on 8 August 1989, was dedicated to making highly accurate measurements of star positions, distances and proper (apparent) motions. Due to the satellite apogee boost motor's failure to fire on 10 August, the planned geostationary operating orbit could not be reached and a complete mission redesign was neeeded to meet as many of the original Hipparcos objectives as possible. Thanks to a magnificent effort by ESOC, ESTEC, European Industry and the Hipparcos Science Team, this mission redesign was completed in just a matter of weeks.

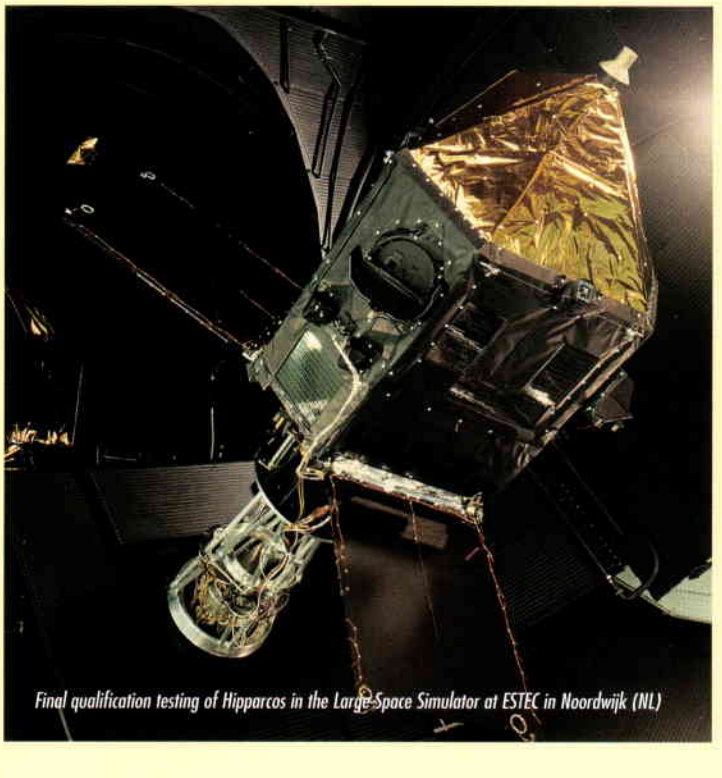
The ground-station network had to be enhanced, adding three ground stations (including a NASA station) where originally only one was originally foreseen. By using the remaining hydrazine fuel onboard the satellite, its orbit was adjusted to maximise ground-station coverage whilst also optimising the attitude scanning law derived from the observation strategy. The onboard software needed to be modified to increase the buffer space for time-tagged commands and star parameters, and a new torque model was needed to control the spacecraft around the orbit's perigee.

The ground software needed to be changed for the mission-planning products, a new attitude-control strategy was needed to cope with the non-geostationary orbit, the instrument had to be safeguarded during periods of non-visibility from Earth, command parameters had to be generated for the onboard torque controller, and a special control strategy was needed to cope with the extended eclipse durations. New predictions for payload occultation intervals and new real-time attitude-determination software also became necessary.

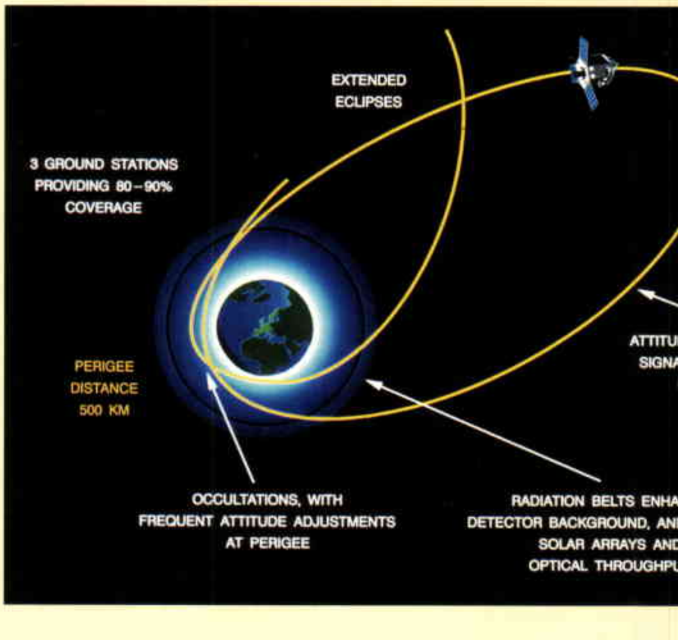
During its subsequent routine operations, Hipparcos relied on three out of its five gyroscopes for attitude control. Unfortunately, the stronger radiation environment in the revised orbit caused the degradation and eventual failure of all but one of the gyros, the first problems being seen just one month after launch.

ESOC, ESTEC, Industry and the Hipparcos Team therefore began immediately to develop an operational concept based on only two gyros, which required modified onboard software. In particular, the Real-Time Attitude Determination (RTAD) algorithm had to be re-designed to replace the missing gyro data by a dynamical model coupled with star-mapper measurements. Throughout the mission, due to the high radiation, RTAD performance around the orbit's perigee was degraded to the extent that useful science data could not be collected without ground intervention. In these cases, a significantly modified version of ESOC's Ground Real-Time Attitude Determination (GRTAD) system was

The ESOC Control Room in the 1980s

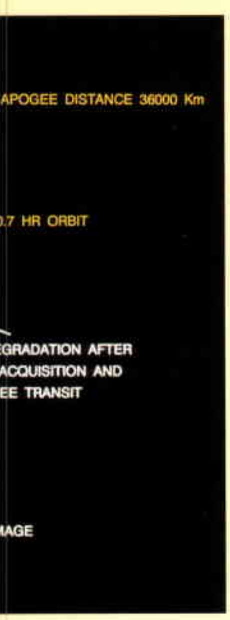


Final qualification testing of Hipparcos in the Large Space Simulator at ESTEC in Noordwijk (NL)



needed to determine the spacecraft's attitude after perigee and reset the onboard RTAD system. It was also necessary to compute and control the spin-rate after perigee passage, where the lack of control meant it could vary dramatically.

In August 1992 a further gyro failure caused Hipparcos to go into an emergency safe mode and increase its spin rate. Further recovery operations were postponed until October to allow the ESOC team time to make further improvements to the two-gyro ground system, resulting in a much higher data return once operations resumed. Hipparcos went on to collect a further seven months of science data, significantly increasing the accuracy of the final results, especially for the proper motions of the stars.



The revised Hipparcos orbit and the problems associated with it

The implementation of all of these changes to the mission's space and ground elements, together with a dedicated ESOC support team who 'lived with' the satellite for more than four years, made the revised Hipparcos mission a spectacular success. The unique Star Catalogues produced using its data have not only provided the World's astronomical community with a rich source for research for many years to come, but are also being used by many space missions requiring precise star information.

Olympus

Probably the most dramatic of all rescues of ESA spacecraft was the 1991 recovery of Olympus. Launched in 1989, Olympus was a large new-generation telecommunications spacecraft that carried several novel technology payloads for in-orbit testing. For example, it was ESA's first data-relay spacecraft and was used very successfully to provide two-way communications with ESA's Eureca free-flying experiment platform.

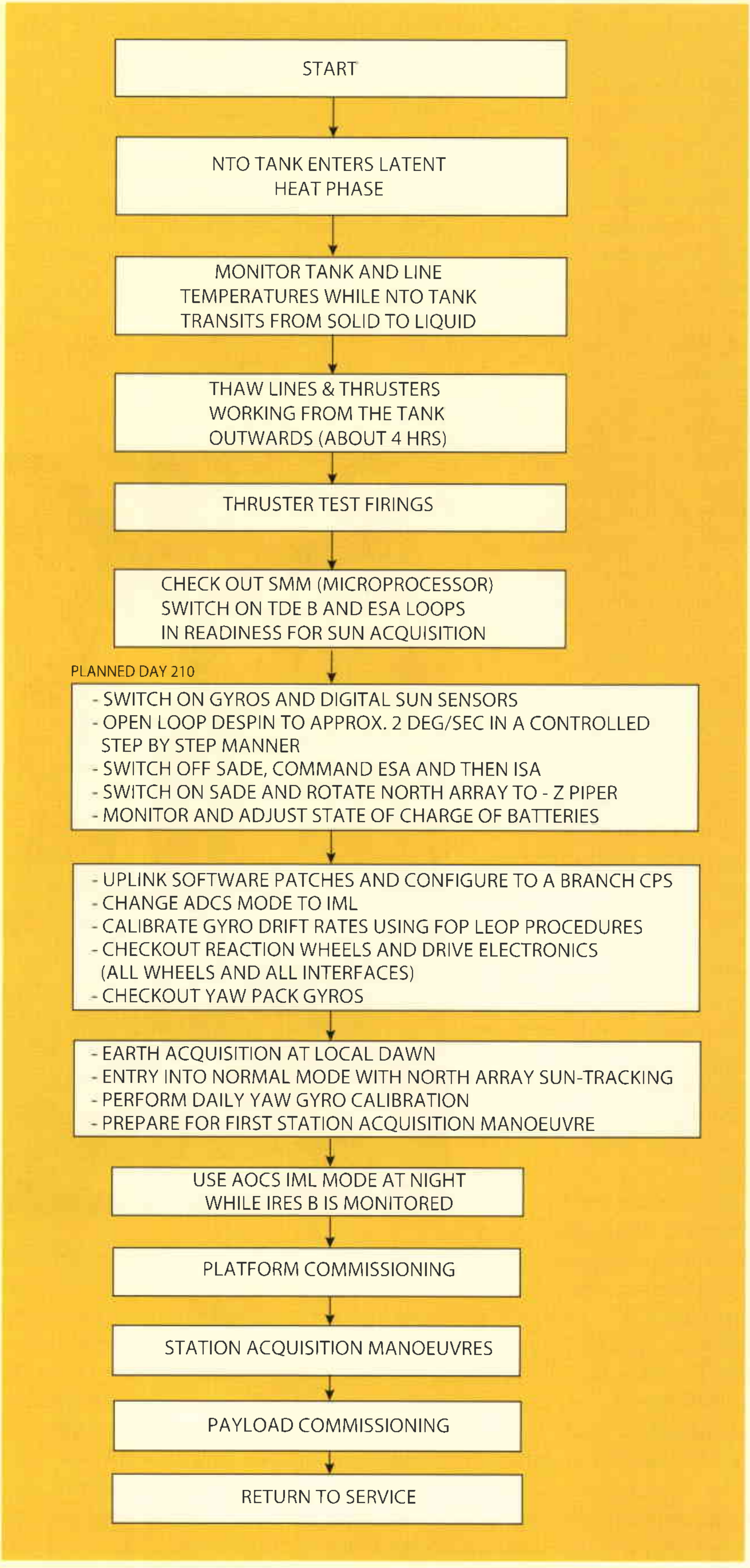
The Olympus launch and early orbit phase operations were conducted from ESOC and control was then transferred to Telespazio's control centre in Fucino, Italy, for the routine operational phase. The spacecraft subsequently suffered from several major onboard failures, including the loss of 50% of its solar-array power and significant performance degradation of its primary attitude-control sensors. Despite all of the problems, the operations team in Fucino managed to keep the communications payloads fully active.

On 29 May 1991, however, the spacecraft experienced further problems and tried automatically to enter its safe mode, but this failed. Attempts by the ground team to regain control of the situation were unsuccessful and 20 hours later, with the spacecraft tumbling through space, all ground control over Olympus was lost. The spacecraft was stranded and drifting eastwards by 5 degrees per day.

The only telemetry signal from the stricken spacecraft consisted of a partial frame of 15 seconds of data every 89 secs, but this was insufficient to allow the incoming telemetry to be decoded. It was observed, however, that the duration of the partial telemetry frame was increasing by 1 second per day, suggesting that the solar arrays were progressively getting longer exposure to the Sun and thereby producing more power!

Integration of Olympus with its Ariane launcher in Kourou, French Guiana

Industry successfully decoded the partial telemetry data on 5 June, and this indicated that the spacecraft was stable and spinning slowly about its roll axis. There were major problems, however, in that the satellite's propellants and batteries were frozen. Because of the steadily increasing solar-array power, however, ESA and Industry were optimistic that control of the spacecraft could be recovered and should indeed be attempted. The extent of any



damage to the communications payload was unknown at that point.

A joint ESA-Industry mission-recovery team was established headed by ESOC. The first task was to develop safe procedures to thaw out the frozen spacecraft. Industry conducted ground tests with representative hardware to validate the approach. Operational control was returned to ESOC in Darmstadt, where advantage could be taken of the extensive expertise and facilities available, including ready access to the ESA LEOP ground-station network.

The first telecommand access to Olympus was achieved on 26 June and the ground control team then began thawing out first the batteries and then the propellant tanks, lines and thrusters. Attitude control was regained on 31 July, and by 13 August Olympus was again back on station at 19 degW !

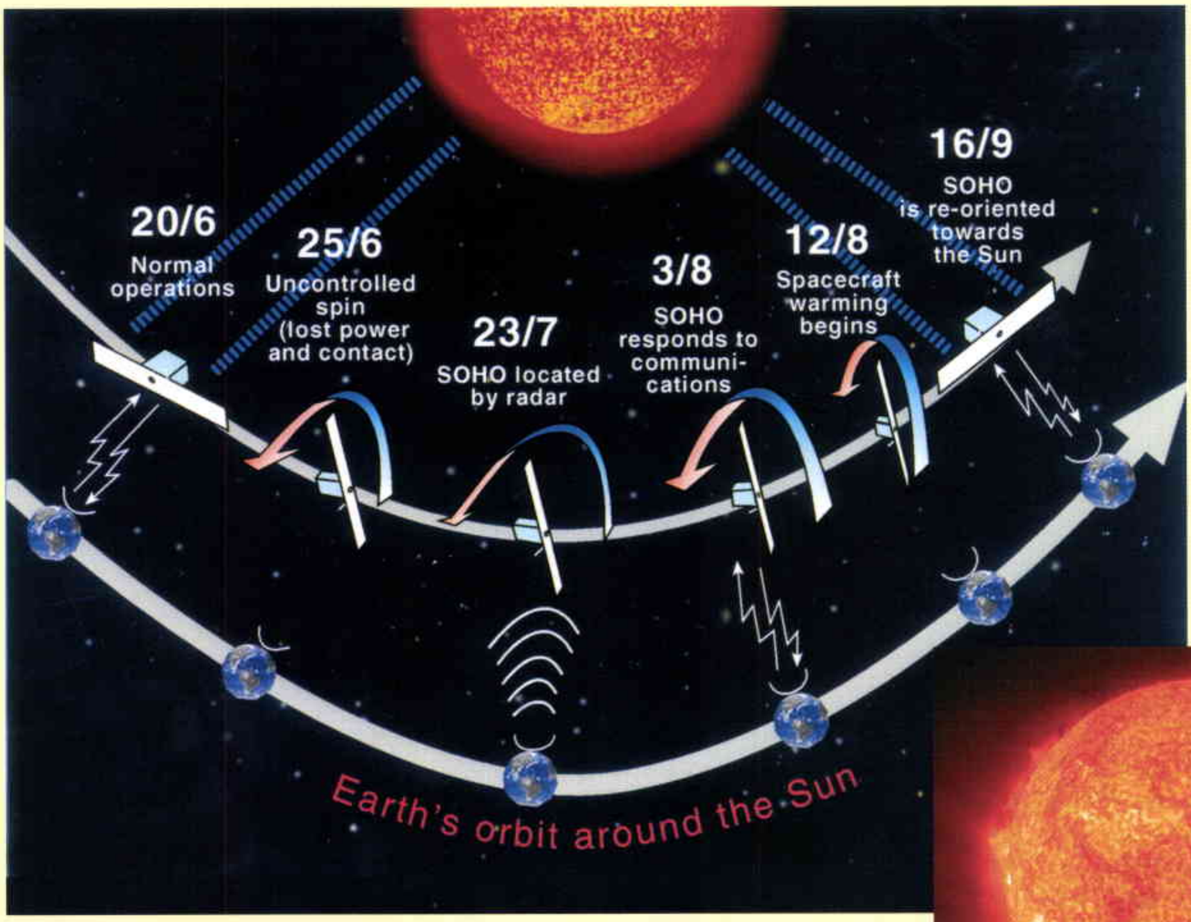
Surprisingly the spacecraft had suffered very little damage as a result of the extremely low temperatures that it had encountered, and following recommissioning of the payload it was returned to service and operations were transferred back to Fucino. The mission was eventually terminated in August 1993.

SOHO

The ESA/NASA SOHO scientific spacecraft was launched in December 1995, with day-to-day operations being conducted from NASA's Goddard Space Flight Center (GSFC) in Maryland, USA. On 25 June 1998, the spacecraft entered its back-up emergency Sun re-acquisition mode. During the subsequent return to normal operations, attitude control was lost. Five hours later all contact with SOHO was also lost.

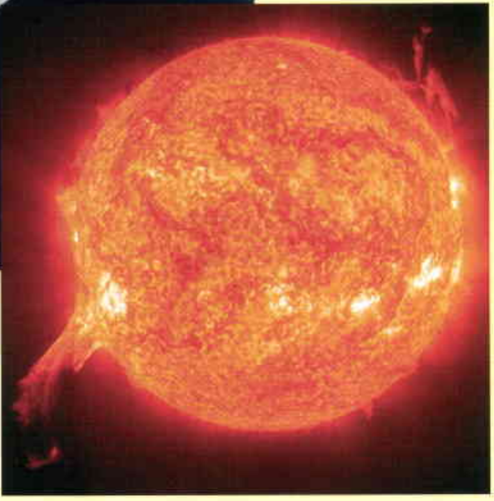
ESA and NASA engineers believed the spacecraft was spinning about a fixed axis with its solar panels edge-on to the Sun and therefore not generating any power. If that were indeed the case, the solar arrays

The outline Olympus Recovery Plan



Some of the key events in SOHO's recovery

SOHO continues to provide an unprecedented view of the Sun and its interior



would become progressively more illuminated due to the seasonal variation in SOHO's orbit, and ESA and NASA therefore concluded that a recovery operation should be attempted. A SOHO recovery team was therefore established which included several ESOC staff.

ESOC had itself not been directly involved in the SOHO operations, but it immediately joined the search for a signal from the spacecraft using its S-band tracking stations at Redu (B), Villafranca (E) and Perth (W. Aus.). On 3 August, after 6 weeks of silence, signals from SOHO were finally detected by Perth and by NASA's Goldstone station. The signal 'spikes' lasted between 2 and 10 seconds, but these bursts of data were insufficient to allow the telemetry to be decoded. A complex telecommand sequence was therefore established and uplinked in the blind to increase the length of the data bursts, but this proved unsuccessful and so ESOC's data-handling experts proposed a modified sequence. This one worked and the first telemetry was received on 8 August. The recovery team based at GSFC then developed and executed a complex plan to recover the spacecraft, and by 25 September SOHO was back in its normal operating mode.

Following the recovery of SOHO's attitude control, however, the short-term predictions of the evolution of the satellite's orbit were proving to be very inaccurate. A leaking thruster was feared, although there was no such evidence from the attitude dynamics. ESOC was again contacted to help explain the mystery, and within a few days came up with a logical explanation: since no tracking had been possible during the SOHO outage, the orbit-determination process needed to be re-initialised with carefully selected parameters. After this was done, SOHO operations returned to normal.

ERS-2

ERS-2 was launched in April 1995, four years after its almost identical predecessor ERS-1. Although ERS-1 had been flying without any major operational difficulties, ERS-2 began to suffer successive failures in its six gyroscopes, starting in February 1997. Since the original onboard attitude-control algorithms required at least three healthy working gyro units for accurate three-axis attitude control of the satellite, the chronology of these failures caused concern that the mission might not last much beyond January 2001 without upgrading the onboard attitude-control system.

Soon after the first failure, the ERS Project asked Astrium SAS to study, with ESOC's support, the feasibility of autonomous three-axis attitude control with fewer than three gyros. In February 2000, a new control mode using a single gyro for payload operations was patched onboard and successfully commissioned. In 2001, a zero-gyro attitude control algorithm was introduced, which allowed the mission's dependence on gyroscopes to be significantly reduced and the precious remaining working gyros to be reserved for backup and orbit-control modes.

As further insurance, a mono-gyro attitude-control algorithm for those backup and orbit-control modes was also patched and commissioned onboard during the last quarter of 2001. From that point onwards, active control of the orbit's inclination, which had been suspended a year before after the third full gyro unit failure, could be resumed.

ESOC and ESTEC, with active support from Industry, had therefore managed to steer the mission away from a nearly certain premature end and secure many extra years of mission lifetime for the Earth-observation user community.


The ERS-2 spacecraft being readied for launch

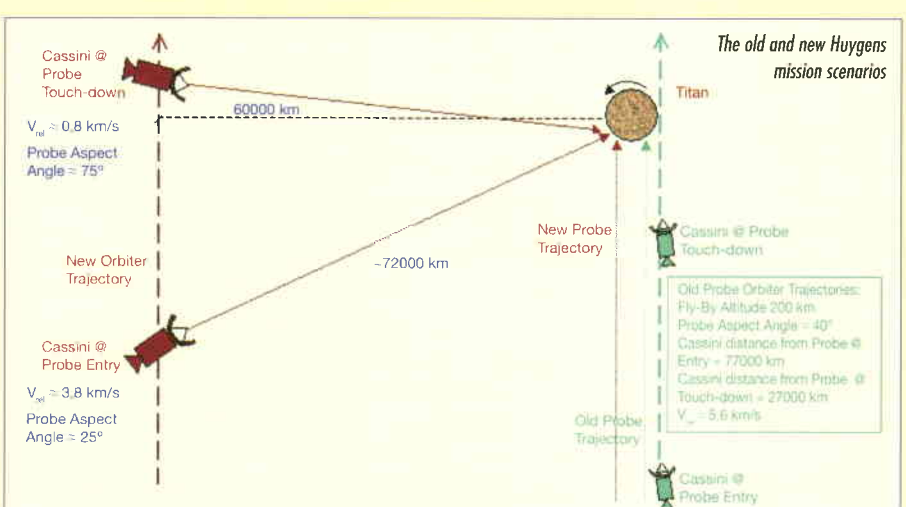
Huygens

Since its launch on 15 October 1997 as a passenger on NASA's Cassini mission to Saturn, the Huygens probe has undergone regular 'health checks' on its payload. Although these checkouts mimic as closely as possible the sequence of events during the probe's actual descent onto Saturn's moon Titan in 2005, the Huygens-to-Cassini radio link is simulated through an umbilical.

To check the radio link itself, special tests were conducted after launch in which ESOC simulated the probe's radio signals, using a NASA Deep-Space Network antenna to transmit to Cassini's high-gain antenna a signal equivalent to the one that the probe will send during its descent onto Titan. During the first such test in February 2000, ESOC discovered a major anomaly in that the Huygens telemetry receiver onboard Cassini was not performing as planned and would not be able to receive data with the degree of Doppler shift to be expected during the probe's descent phase. As a consequence, a very large percentage of the Huygens scientific data could be lost!

Further probe relay tests, complemented by several very comprehensive test campaigns on the Huygens engineering model housed at ESOC, were a major factor in understanding, characterising and resolving this anomaly. They showed that the problem could only be solved by a combination of actions:

- A new Cassini trajectory that minimises the radial component of the probe-orbiter relative velocity. This involves increasing the Cassini-Titan flyby distance from 1200 to 60 000 km and reducing the Cassini orbiter delay time from 4 hours to 2 hours.
- A probe pre-heating strategy, which will slightly reduce the transmitted data stream frequency, thereby providing greater margins. It requires specific changes to the probe and payload onboard software, which have been thoroughly tested and validated using to the Huygens engineering model.



The old and new Huygens mission scenarios

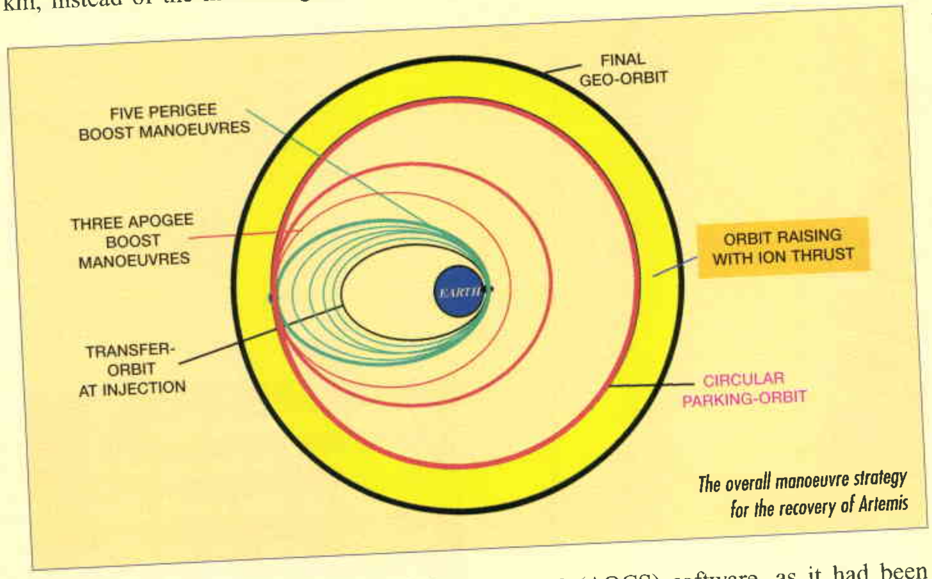

The Cassini spacecraft, with the Huygens probe mounted on the left side, being lowered onto its launch-vehicle adapter at Kennedy Space Centre (photo NASA)

The baseline recovery mission was finalised in September 2003 and is now being implemented by the ESA Huygens (ESOC, ESTEC and Industry) and NASA Cassini teams.

Artemis

ESA's Artemis spacecraft was launched by an Ariane-5 in July 2001. Telespazio was in charge of the operations, but ESOC had a role as adviser to the ESA Project Team, with one of its staff present in Fucino (I) as an observer. A launcher underperformance problem resulted in the Artemis orbit having an apogee radius of only 25 700 km, instead of the intended geostationary apogee radius of 42 164 km. In addition, the plane of the orbit was not correct.

Artist's impression of Artemis in orbit



The overall manoeuvre strategy for the recovery of Artemis

Although not directly participating in the launch and early orbit phase (LEOP), ESOC was informed, quickly made an analysis of the situation, and developed a recovery plan. The essential steps in this plan were to use chemical propulsion to put Artemis into a circular orbit about 5000 km below geostationary radius by first raising the spacecraft's apogee and then its perigee. The electrical propulsion system onboard would then be used to raise the orbit to geostationary altitude.

The use of the electrical propulsion system for orbit raising required a major reprogramming by Industry of the satellite's on-board attitude and orbit control (AOCS) software, as it had been designed only for inclination-correction manoeuvres.

The plan was successfully implemented by Telespazio, albeit with some delay due to difficulties resulting from the heavier than foreseen use of the electrical propulsion system, and Artemis is now fully operational.

Support to Other Agencies

As in the case of Artemis, ESOC has also provided emergency support to several other spacecraft operators in times of need. In late1997 and early 1998, for example, the Centre provided emergency support to NASDA for its ETS-VII and COMETS missions.

ETS-VII was launched at the end of November 1997 and full telemetry, tracking and command (TTC) support from Kourou (Fr. Guiana) and Perth (W. Aus.) was originally foreseen only for the first days after launch. However, because of contingency situations the full TTC support from Kourou and Perth was extended first by a week, then until the end of December 1997, and finally it was provided until the beginning of February 1998.

COMETS was launched at the end of February 1998, but a launcher malfunction meant that the spacecraft did not achieve the target geostationary-orbit apogee altitude, reaching only about 1900 km. ESOC was asked to provide full TTC support from Kourou and Perth for the necessary orbit-raising manoeuvres during the months of March, April and May.

Acknowledgements

The authors would like to acknowledge the professionalism and dedication of their colleagues in ESOC who have contributed so much to the Centre's success in ensuring that many missions that would otherwise have been lost have been recovered and have thereby been able to accomplish most of their planned objectives. The support of European Industry has been of paramount importance throughout.

A New Era in Kourou

– Industry Gets Ready for Vega and Soyuz

Kourou has been in the doldrums. With the current slump in satellite launch clients, local space industry has shifted into a lower gear for the time being – but around the corner the grass should be greener. The industrial contractors at the Centre Spatial Guyanais (CSG) are preparing to welcome Vega and Soyuz, which will boost the competitiveness of Europe's Spaceport........

Anne Gercke & Fernando Doblas
Kourou Office, ESA Directorate of Launchers, Kourou, French Guiana

"Politicians are the strategists and we the tacticians", says Jean-François Dairon, Alcatel Space's representative in French Guiana. His company has been among Kourou's pioneers when exploiting ELA 1, the launch zone dedicated to the first versions of Ariane, and has been adapting to the high and low tides of Europe's space endeavours over the last decades. While twelve Ariane launchers departed from Kourou in 2003, there were only four lift-offs last year. Currently, Europe's Spaceport is experiencing the sharp downturn in the global market, exacerbated by the resulting cut-throat pricing in the launcher sector, which is also causing major problems for Ariane's competitors.

Taking note of this downward trend, Europe's Ministers responsible for space affairs reacted quickly. At the ESA Council Meeting at Ministerial Level in May 2003, they committed the financial resources needed to qualify the Ariane-5 ECA launcher and to kick-off an ambitious programme sustaining Europe's Guaranteed Access to Space (EGAS). Moreover, they encouraged the reorganisation of the European launcher sector and gave the green light for launching Soyuz from CSG and to the starting of ESA's Future Launchers Preparatory Programme (FLPP). The legal and financial basis required to consolidate Europe's launcher sector was thereby laid.

Since then, Kourou has been given a new dynamism as it prepares for the creation of a fleet of launchers. In addition to Soyuz, there will be ESA's new small launcher Vega to complement Ariane-5, the three vehicles together providing Arianespace with the utmost degree of flexibility. Europe's Spaceport will therefore soon be offering launch services for all sizes of payloads, for all types of missions, to any kind of destination and, most importantly, with an attractive pricing structure. *"We wait impatiently for Vega and Soyuz"*, stresses Claude Lugand, head of the local office of the company Clemessy, because he knows that in the meantime stream-lining is on the agenda.

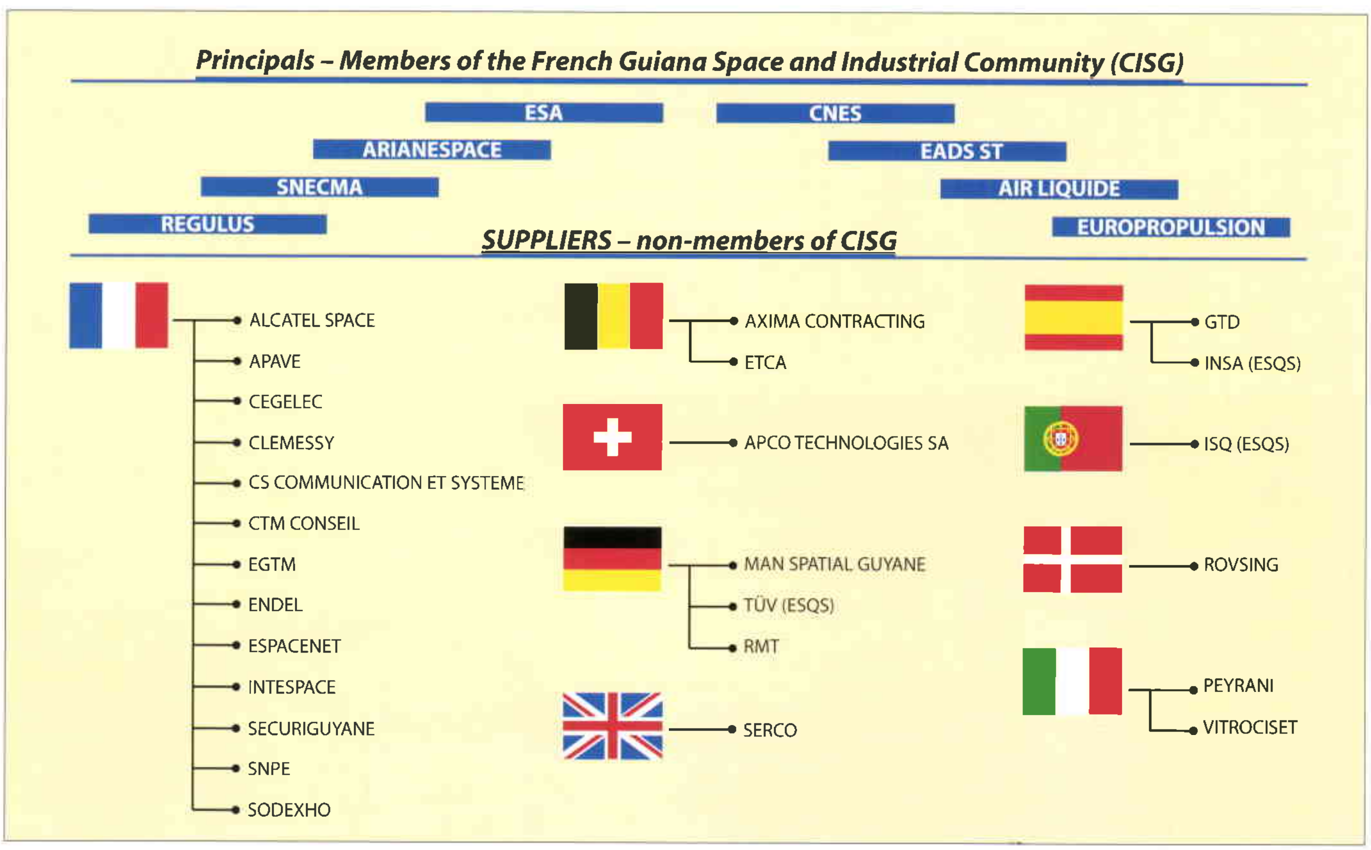
A Motor of Kourou's Past, Present and Future

When in 2001 the French national space agency CNES changed its contractual relations with its service providers on-site, the industrial contractors present at the launch base gained significant responsibilities. Still, industrial representatives expect the forthcoming reorganisation of CSG to transfer even more responsibilities to industry in order to provide it with room for manoeuvre to manage the demand for additional cost reduction.

The arrival of Vega and Soyuz coincides with the organisational redefinition of Europe's Spaceport. Hence, Kourou's industrialists are reluctant to let the cat out of the bag when asked about their positioning vis-à-vis forthcoming calls for proposals, not least because they do not want to add to the uncertainties. *"We need to develop a maximum of synergies,"* says Yann Chevillon, head of EADS Space Transportation in Kourou, and Jean-François Dairon adds, *"everybody will benefit so we should not provoke unrest among our partners."* At present, industrial cooperation at the launch base is characterised by consortia, in which a prime contractor usually coordinates a certain workload with its European partners. This type of relationship not only ensures that all parties involved benefit from collaboration, but also respects ESA's geographical-return requirement, an instrument that reflects the financial contributions from each of the Agency's Member States, but also the fact that Europe is a single coordinated actor in space.

At CSG, the often long-standing partnerships are well appreciated. They function as a security net and ensure the participation of small- and medium-sized enterprises – they even mean survival where withdrawal would be the result elsewhere. Furthermore, the prime contractors and subcontractors alike profit from the spillover effects of cooperation at CSG. Apart from technological and multicultural exchange, mutually beneficial relations can be exploited for further projects far beyond the launch base. The manner of economic cooperation at Europe's Spaceport is unique and crucial for the competitiveness of Europe's launcher industry. The launch campaigns at Kourou are renowned for providing outstanding customer service. The companies operate around the clock if necessary and simultaneously assure top-level quality. The latter aspect is of particular importance as the maintenance and exploitation needs of a launch base translate into zero tolerance of failures.

What can sometimes seem like difficult working conditions actually foster real team spirit. Passion and enthusiasm have certainly helped to create credibility for Europe's competence and a feeling of trust on the part of Arianespace's clients. There is no doubt about all actors involved being committed to maintaining these values in the future. Companies such as Vitrociset, which according to Paolo Cavallini, head of the local branch of the Italian enterprise, aims to diversify its current activities due to the arrival of Vega, are aware of the value of cooperation. *"We want to play a major role without neglecting synergies with others..."* he comments, *"...and we hope that Vega and Soyuz will raise all our games a bit."*



Raising the Game of Kourou's Space Industry

For Jean-Pierre Cournède, local representative of the French company ENDEL, the challenge of a transition period overlapping with the arrival of Soyuz and Vega translates into a chance to reposition as an industrialist. The companies at CSG currently predefine their roles according to their core business, national belonging, relevance of the project and the overall business strategy. Certainly, chances differ. Companies like Alcatel Space, which provide the launch base's telecommunications network, are able to offer this kind of service irrespective of the launcher itself. Their window of opportunity is to enlarge the scope of their penetration. In contrast, activities that are closely linked to the launcher entail the inclusion of new technologies, which requires investment and sophisticated specialisation. Here, the prospect is to focus on or specialise in one or even both of the new arrivals.

"Particularly, small- and medium-sized enterprises will profit from current developments", believes Pascal Sassot, local representative of APCO Technologies SA, a Swiss company involved in maintaining and operating the satellite-preparation complex, as well as providing mechanical engineering and public-relations services. There is no denying the fact that the possibility of enlarging the scope and range of activities is very promising, and all the more so if there is a snowball effect from Vega to Soyuz. *"If we gain the confidence of the possible clients for Vega, our participation in the Soyuz project would be more likely"*, says Antonio De Pace of the company Peyrani Guyane. Although the Italian firm has considerable motivation to participate in Vega due to Italy's pre-eminent role in the programme, it is also aware of the benefits of Soyuz at CSG. *"Maybe our role could be stronger for Vega than for Soyuz..."* De Pace adds, *"...but we are very happy about the Russian arrival because there are plenty of business opportunities concerning installations."*

Amongst the various industrial players, Regulus and Europropulsion welcome the competition. As contractor for the P-80 engine, the first stage of Vega, Regulus, a joint venture by the Italian company AVIO and the French company SNPE, is at the core of Vega's lift-off from Kourou and at the same time testing new technology for the boosters of Ariane. Having received the engines from Colleferro in Italy, the company will charge them with solid propellant. Afterwards, Vega will be transferred to the Italian-French company Europropulsion, which will add the nozzle and igniter. *"At Regulus the mindset has already changed"*, says Luciano Gamba, head of the company in French Guiana. Smiling, he adds: *"our major business is Ariane-5, but our staff are highly motivated to go beyond 'mono-production'. Imagine, if we can adapt our working tools to two different engines, we can enter a new production cycle!"*

Compared to Vega, Soyuz leaves a larger margin for manoeuvre, industrially speaking, due to the need to build a new launch zone, thereby making participation more attractive. Kourou's industry counts on exploiting past experiences in collaborating with Russia, whether on space-related or civil-construction projects. For example, Clemessy has already profited from a Euro-Russian partnership when building the clean rooms of the satellite-integration building for Soyuz at Baïkonur, and Peyrani intends to make use of its Russian relations stemming from a civil-construction project near Moscow.

However, such connections are not the only cards in play. ENDEL and MAN Spatial Guyane have also accumulated valuable experience. The French company, for example, has been dealing for 37 years with tariff and non-tariff barriers in French Guiana in the transport and logistics sector. The German subsidiary of MAN Technology maintains the Ariane-4 and 5 launch facilities, essential parts of which, such as the launcher table and the launcher integration building, had originally been designed and constructed by its parent company. The Ariane-5 prime contractor EADS Space Transportation too is already preparing to play an active role in setting up the Soyuz programme at CSG, and is also interested in another promising aspect of the vehicle's arrival, which is technology transfer.

Strategic Vision and Local Approaches

Doing business at CSG is important not only for financial and economic reasons, but also due to the image of progress and innovation associated with space activities, which has marketing and public-relations benefits. Individually challenged by the new dynamics in Kourou, companies situated on the launch base are responding with a variety of strategic approaches in order to maintain and improve their position vis-à-vis their competitors.

Some concentrate on the fulfilment of geographical return. They either collaborate locally by involving small firms such as Rovsing, which qualifies for the Danish return, or they Europeanise the holding company and create autonomous branches in other ESA Member States. Clemessy, a French company, for example, has been operating in French Guiana for more than 35 years and it introduced RMT Industrie- und Elektrotechnik GmbH, a German firm that is part of the same holding company, into the industrial landscape at CSG.

Others, like Cegelec, concentrate on diversification. Instead of focussing on one core business, the French company strives to offer a range of different services. Today, it is working in several domains at the launch base, including operation and maintenance of the satellite-preparation complex and the fluids systems, management of technical modifications to the launch facilities, and the provision of communication services. Cegelec's Bernard Assié is convinced it is the right approach for his company, saying that: *"Due to diversification, we are flexible, adaptable and autonomous."*

During a launch campaign, demand for manpower increases significantly. For several weeks CSG resembles an anthill, but once the launch has taken place the companies face a rapid decline in activities. *"A major challenge is the alternation of service needs,"* says Paolo Cavallini of Vitrociset. *"There is a peak of work, but afterwards fewer people are needed. You can let a certain number go, but you cannot go below a certain limit because you will need them for the next campaign."* Understandably, this becomes a real challenge whilst belt-tightening is also on the agenda. However, diversification has helped some companies to overcome this hurdle. Their workforces have been trained so that each employee can be assigned to more than one activity. In times of operational inactivity, these companies can then engage, for example, in providing maintenance services.

Last but not least, business opportunities in French Guiana have helped a few companies whose activities are not exclusively space-related to expand into the local market. *"The investment into the country itself is very important"*, explains Jean-Pierre Cournède of Endel. *"We will concentrate on the potential of French Guiana. We are already involved in projects at Rochambeau airport and in St. Laurent du Maroni and…"*, he adds with a wink *"…if there is a problem at CSG you have to know which way to turn. That is why we decided to externalise and respond to demand beyond the launch base."* In contrast, there are companies whose potential transcends the frontiers of French Guiana, but they are constrained by local trade barriers. Antonio De Pace, for example, would not mind integrating the Brazilian branch of Peyrani with the one in French Guiana. Inter-regional coordination would benefit both sides, especially in terms of tapping the Brazilian labour market but, he says, shrugging his shoulders, *"Brazil is not a member of the European Union. We would have too many difficulties in obtaining working permits."*

Between Verve and Reality

Two of the factors contributing to the competitive advantage of Europe's Spaceport are certainly the enthusiastic dedication of its employees and the clear identification of the size and value of their contribution. The successful launch of an Ariane-5 and the smile on the face of a satisfied client who has just received the first tracking signal from their satellite about forty minutes after lift-off tells the story! This makes it all the more difficult to reduce costs by reducing staff, which means shifting staff from the space to the civil sector or even back home to headquarters is the least painful option in the short term.

Today, managers dedicate a lot of their time to motivating their personnel. Stabilising what has been achieved and building confidence is currently the watchword that keeps EADS Space Transportation ahead. *"We need to listen, to be available for discussions, and to exchange ideas. We need to explain the reality, its past, present and future"*, says Yann Chevillon who is proud to

manage an enthusiastic team that is emotionally attached to Ariane-5. Vitrociset agrees: *"Our wealth is our staff. There are ambitious people among us and we need to create development opportunities for them."* The latter aspect has already been tackled at Clemessy, which provides internal education opportunities for its staff in order to encourage them to make an extra personal effort. This creates a concrete opportunity for ambitious staff members to benefit from the transfer of know-how and from personal development.

For some companies, the arrival of Vega and Soyuz at CSG will logically lead to an increase in personnel, but for others not. Nevertheless, their arrival will be extremely valuable for Kourou's local economy also, which is only too well aware of the yo-yo effect stemming from the rise and fall in the number of space missions being launched, and in the numbers of associated Ariane 'tourists' also. *"Here people are uncertain about their future"*, concludes Jean-François Dairon, *"but a fleet of launchers will boost team spirit and raise morale at the base."*

Rosier Prospects

Everyone at CSG agrees that Ariane will continue to be the main workhorse, but the arrival of Vega and Soyuz will certainly complement it and help to stabilise activities at Europe's Spaceport. The latter, which provides Europe's only guarantee of independent access to space, will thereby become more resistant to global downturns and other future crises. Two particular aspects will play an important role in the future of the launch base, which will no longer be dependent on a single launcher. Firstly, Arianespace will become more flexible in offering launch services to a broad range of satellite clients, including serving a niche market with Vega. Secondly, technological progress will lift Kourou into a new era.

While Vega will validate new solid-propulsion technologies for Ariane-5, Soyuz is the key to learning more about the production techniques that have already resulted in over 1600 successful launches. The outcome will be a pool of reusable and new technologies that will allow Europe to respond dynamically to an as yet unknown future environment. On the one hand, it will boost the development of the Ariane programme, while on the other it will reinforce and broaden ESA's cooperation with its international partners. It should also make it possible to benefit that bit sooner from recovering satellite markets. Today, there is no denying the fact that Soyuz is the basis on which to open a gateway to the east, where rapid developments are taking place in countries known for their low-cost manufacturing. The new launcher fleet will also provide Europe with a valuable enhancement of its image. Not only will it contribute to conveying the message that Europe is a unique actor in space, but it will also strengthen Europe's relations with Russia to an extent where eastwards expansion of the Union becomes a strategic reality.

In the meantime, Europe's Spaceport is about to undergo a metamorphosis, and Kourou's industrialists are optimistic. Even if today's markets are stagnating, even if clarifications are still needed, the political decisions that have been taken by Europe's Ministers have initiated a process of change that, once completed, will ultimately add value to the activities at CSG.

Acknowledgement

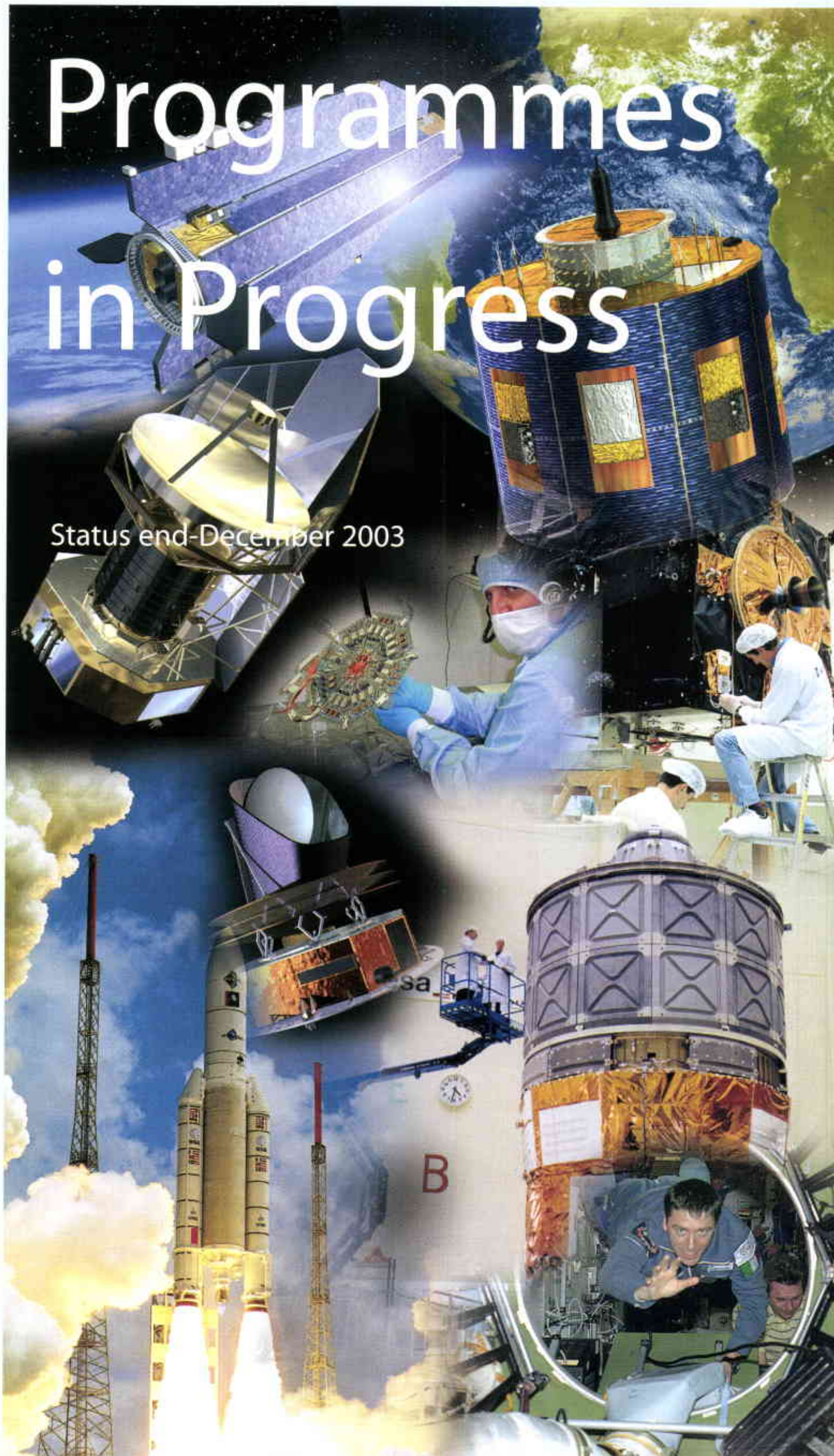
This article is based on a series of interviews with space-industry representatives based at Europe's Spaceport in Kourou, French Guiana. We would like to thank Alcatel Space, APCO Technologies SA, Cegelec, Clemessy, EADS Space Transportation, Endel, MAN Spatial Guyane, Peyrani, Regulus, RMT Industrie-und Elektrotechnik GmbH, Rovsing and Vitrociset for their kind cooperation. Regrettably, it has not been possible in this short article to refer to all of the companies that make up the CSG industrial landscape.

esa

Council Decides........

At the latest meeting of the ESA Council in Paris on 4 February, the Agency's Member States agreed to release the funds needed to put Ariane-5 back on track and actively prepare the development of future launchers. Moreover, cooperation with Russia in the field of launchers is now a reality through an Agreement that provides the framework for the 'Soyuz at the Guiana Space Centre' programme - with Soyuz launchers operated by Arianespace as of 2006 - and joint activities in the field of future launchers.

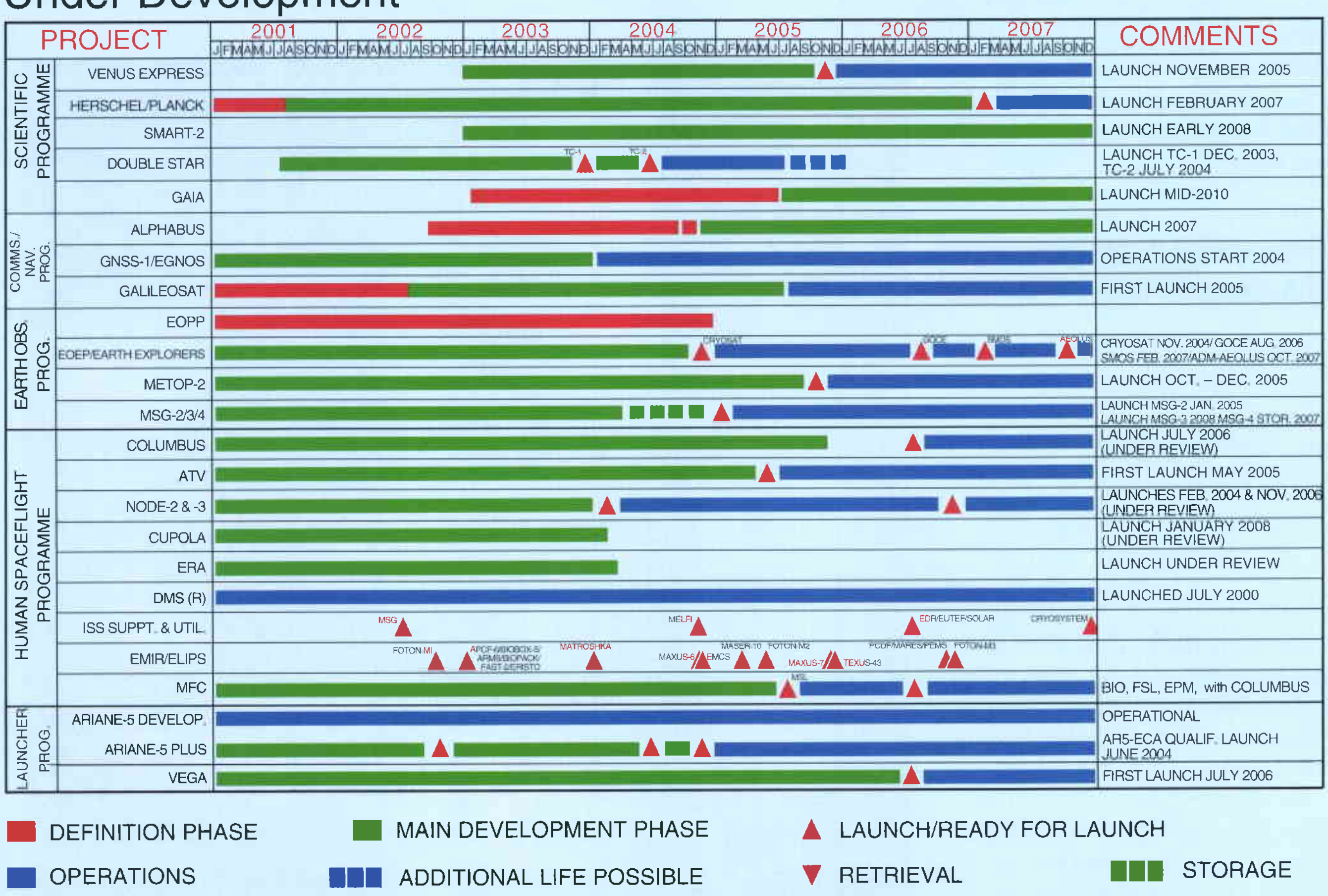
These decisions taken unanimously by the ESA Member States consolidate, now and for the longer term, Europe's access to space, enhancing its ability to meet the needs of its citizens. Europe can count on a strong and stable launcher sector while it works towards a new generation of launchers. The decisions also mean that its commercial launch operator, Arianespace, is now equipped to sustain Europe's guaranteed access to space while competing on the global launch-service market.



Programmes in Progress
Status end-December 2003

In Orbit

Under Development



Infrared Space Observatory

The ISO Data Centre Active Archive Phase activities continue to run smoothly. A new version of the ISO Data Archive (IDA V 6.1) has been released, associated with a new interoperability mechanism, fully compliant with the Virtual Observatories standards. It was demonstrated at the XIII ADASS Conference in Strasbourg in October, and will be an important element of the second demonstration of the Astrophysical Virtual Observatory planned for 27/28 January 2004.

Systematic data-reduction projects for ISO spectroscopic modes have been completed and the products ingested into the Archive. Detailed requirements for the observation data-quality reports have been consolidated, for the next major release of the IDA, planned for spring 2004.

The legacy version of the ISO Handbook (5 volumes, 1200 pages) has been released on the Web and is being distributed in hardcopy to all Principal Investigators of ISO observing proposals, as well as to some 300 libraries worldwide.

Ulysses

The spacecraft and all scientific instruments are in good health. Preparations are underway for the Jupiter Distant Encounter campaign that will take place between the end of January and mid-March 2004. During this 50-day period, 24 hour per day real-time coverage by the Deep Space Network has been scheduled to allow the on-board tape recorders to be switched off. This in turn will permit the majority of the scientific payload to be operated continuously, without the need for power-sharing. 'Closest approach' to Jupiter occurs on 4 February, at a distance of 1684 Jupiter radii (~0.8 AU or 120 million km) from the planet.

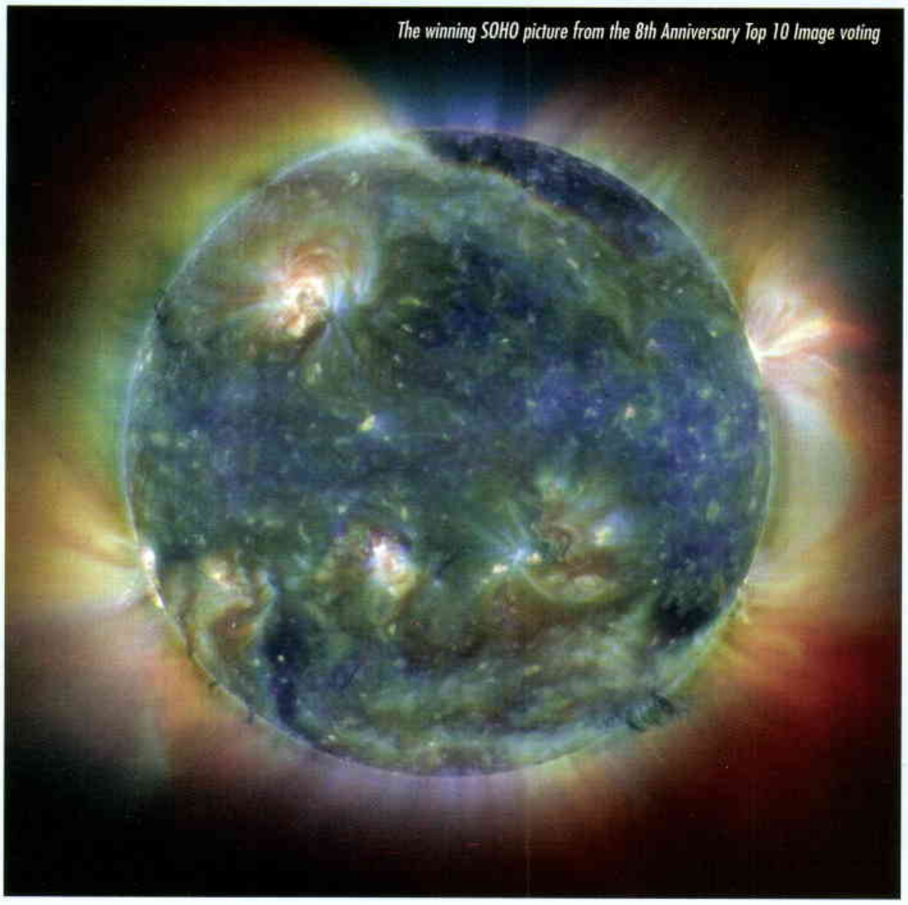
Even though the sunspot maximum of the current solar cycle (23) occurred in mid-2000, the Sun recently underwent a major surge in activity, starting at the end of October. Strong outbursts in the form of solar flares and coronal mass ejections (CMEs) are often seen during the declining phase of a solar cycle; however, the recent activity was unusual both in its intensity, and its relative lateness. The largest solar flare of the series, rated at X28, occurred on 4 November while the responsible active region was on the Sun's west limb, rotating off the visible disc.

Although quite far from the Sun (5.3 AU), Ulysses was well-placed to observe the effects of this violent outburst, being more or less in the 'line of fire'. Analysis of data from the event is still underway, but indications are that the fast CME that was associated with the X28 flare swept over Ulysses, driving a significant interplanetary shock wave. Impressive enhancements in the flux of energetic particles were seen at Ulysses throughout the period of increased activity. This unusual period of solar activity appears to have been the Sun's final outburst before settling into a more stable configuration, leading up to the next solar minimum.

SOHO

On 2 December, the Solar and Heliospheric Observatory celebrated the anniversary of its eighth year in space. As part of this celebration, 24 000 participants voted to select the top 10 images from the SOHO mission. The winning picture is shown here.

SOHO attracted lots of attention during the autumn as the Sun turned from an almost spotless orb, into an ominously scarred source of mighty fireworks in just a few days. Over a two-week period, it featured three unusually large sunspot groups (including the largest of this solar cycle), 11 X-class flares (including the strongest ever recorded; see accompanying image), numerous halo coronal mass ejections (CMEs) and two with near-record speeds, and two significant proton storms, which lasted for a total of five days. Satellites, power grids, radio communications and navigation systems were all significantly affected during this period.



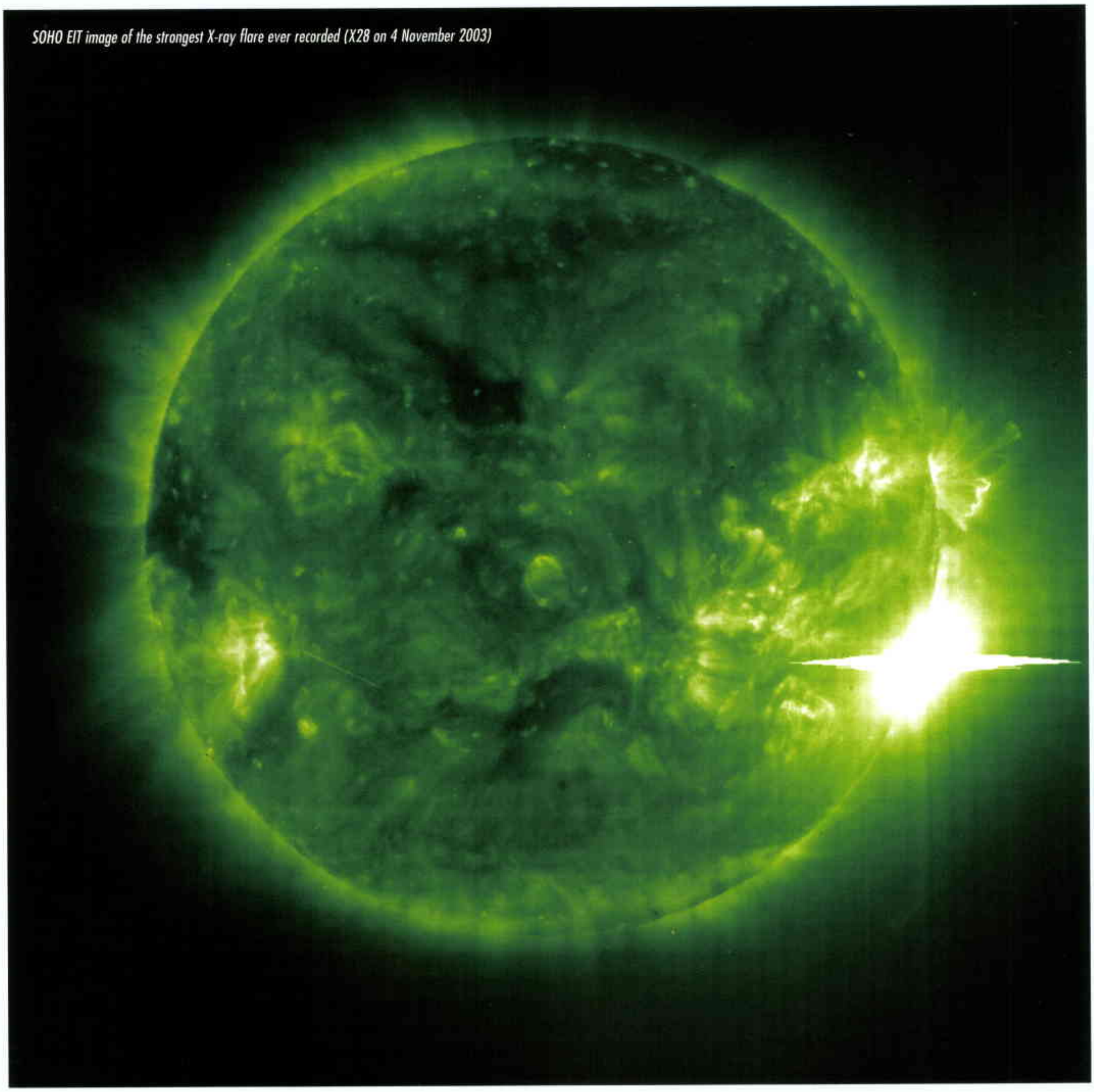
The winning SOHO picture from the 8th Anniversary Top 10 Image voting

Thanks to the invocation of a special Max Millennium coordinated observing campaign, these events are also among the best ever observed, with data available from multiple spacecraft and ground-based observatories. These data will be the subject of scientific analyses for years to come.

The spectacular events attracted unprecedented attention from the media and the general public. Images from SOHO as well as quotes from SOHO scientists were disseminated by nearly every major news outlet (CNN, BBC, Associated Press, Reuters, etc.). The amount of attention surpassed all previous SOHO web-traffic records (requests/ data volume) – monthly (31 million/ 4.3 TB), weekly (16 million/2.6 TB), daily (4.8 million/ 0.7 TB), and hourly (0.4 million/33 GB). In fact, the daily and hourly volumes became bandwidth-limited.

With its High-Gain Antenna z-axis-parked, SOHO continues to experience 'keyhole periods'. Unlike the autumn keyhole, the winter keyhole saw significant data losses due to overwhelming competition for the 34 and 70 metre ground stations from the Mars and Stardust missions. Important total-solar-irradiance calibrations were secured by carefully planned use of the onboard recording capacity. All in all, these keyhole operations are going very smoothly.

SOHO EIT image of the strongest X-ray flare ever recorded (X28 on 4 November 2003)



Huygens

Implementation of the Huygens recovery mission is progressing well. The decision was taken in September to proceed with the 'preheating option' as the baseline, i.e. to upload the required software patches to the flight Probe after a complete validation and testing campaign on the ground. The Probe onboard computer and payload software patches were therefore uploaded in early December and tested a few days later. The in-flight tests on 10 and 13 December demonstrated that all of the required patches had been successfully installed and were compatible with either option: preheating or no preheating. An Agency-level review of the new Huygens mission was kicked-off on 4 December, and the final Review Board Meeting is planned for 13 February.

Cluster

The fourth year of Cluster operations has started at the beginning of February. The four spacecraft are working nominally and the instruments are returning data as expected according to the Master Science Plan. The data return averaged 99.6% between September and December. The Vilspa-1 and Maspalomas ground stations are both operating nominally. The separation distance between the spacecraft is now 250 km, in order to investigate the small structures and measure the electric current at the Earth's magnetopause and bow shock.

Attitude manoeuvres were performed at the beginning of January for all four spacecraft. Their orbits are more stable than preliminary estimates suggested and a combination of large constellation manoeuvres with a decrease in perigee argument will allow the quartet of spacecraft to stay in orbit until at least mid-2009.

Recent scientific highlights include precise measurements of the size of the Earth's bow shock, and determination of the speed of magnetic flux ropes propagating towards Earth. Shock waves are very important for planetary and astrophysical objects since they accelerate particles to very high energies so that they can then be detected in-situ near the Earth or through x-rays for distant objects. Detailed study of the terrestrial bow shock is therefore one of the main objectives of the Cluster mission: measurements of the speed of the shock using the four spacecraft allow its thickness to be derived for the first time. A recent study of 98 bow-shock crossings has shown that the shock front's thickness is best parameterised by the gyro-radius of a small population of solar-wind ions trapped by, and gyrating around, the shock front itself. This is in contrast to earlier studies that suggested that the shock front was best characterised by a wave in a fluid.

Reconnection in the magnetotail is believed to occur at around 40 Earth radii from our planet. One of the consequences of the reconnection process is the release of plasmoids and flux ropes, big magnetic bubbles, which propagate away from the reconnection point. Cluster is located at a maximum distance of 20 Earth radii and is therefore ideally located to study the flux ropes propagating towards Earth. Recently, by using the four spacecraft, the speed and direction of propagation of such a rope could be determined very accurately (mean speed about 413 km/s). In addition, the centre of the magnetotail, the plamasheet, became thicker by about 1 Earth radii (6400 km) as the flux rope was passing by.

Preparations for archiving the Cluster data are progressing well. The Cluster Active Archive system specification review was successfully completed in November. The Review Board made recommendations regarding the archiving plans for the various instruments and the selection of the archiving team. The target for the end of 2004 is to have archived the data from the first year of operations (2001).

The Cluster spacecraft

Integral

The routine operations continue to run smoothly, except for an interruption due to high solar activity between 26 October and 7 November, when the instruments were switched-off. This interval included an X28 solar flare – one of the brightest seen this century. Other than the occasional loss of a guide star due to the enhanced background and increased solar-panel degradation (equivalent to that during about four months of normal operations), the spacecraft safely survived the enhanced solar activity. In particular, the energy resolution of the SPI detectors was unaffected, indicating that the Anti-Coincidence Shielding effectively protected them against the increased flux of solar protons.

On 6 December, one of the 19 SPI detectors suddenly stopped operating. Various attempts at recovery have been unsuccessful and analysis indicates that the fault is most likely a component failure in the detector's pre-amplifier.

A special issue of Astronomy & Astrophysics dedicated to Integral (Volume 411, November 2003) contains 73 papers covering mission and instrument descriptions and performances, and early science results.

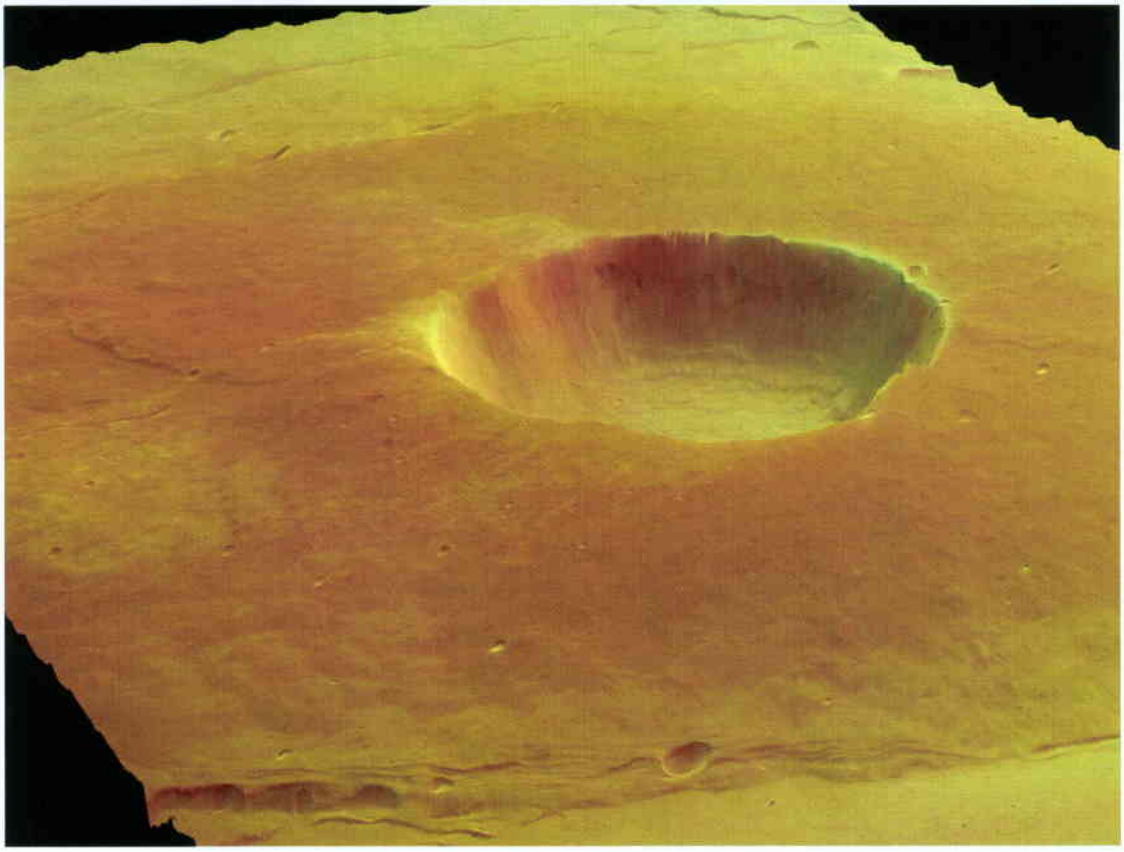
After observing one gamma-ray burst per month in Integral's field of view during the first six months of the mission, astronomers had to wait another six months before observing the seventh! This burst, GRB 031203, was detected and positioned automatically by the Burst Alert Software (IBAS) running at the Integral Science Data Centre. An alert was sent out within 20 seconds of the burst occurring and with an uncertainty radius of only 2.7 arcminutes. This allowed ESA's XMM-Newton spacecraft to observe the field within 6 hours of the event occurring, making it its fastest Target of Opportunity response to date.

A fading X-ray afterglow was detected, surrounded by an expanding ring of emission. Although predicted, such an expanding ring has never been seen before, and is most likely due to X-rays scattered off dust grains in our own Galaxy.

Mars Express

Mars Express went through its most difficult period between 19 and the 25 December without experiencing any problems. On 19 December, the release of Beagle-2 took place. At that time, the knowledge of the Mars Express trajectory was so accurate that the predicted landing ellipse for Beagle-2 could be reduced to just 30 km by 6 km. The release itself was problem free and an image taken seconds later confirmed the stable attitude of the Lander on its way to Mars. The Orbiter then flawlessly executed a series of manoeuvres that led it into a polar orbit with a period of 12 hours at the time of writing. The final orbit with a period of 7.5 hours will be reached by late January. The switch-on sequence for the scientific instruments has commenced and impressive early results were presented at a Press Conference on 23 January. Further results are being released on the web as they become available.

Unfortunately, the search for a signal from Beagle-2 has not yet been successful, but will continue until all possible search scenarios have been executed.



This image was taken by the High Resolution Stereo Camera (HRSC) onboard ESA's Mars Express orbiter on 19 January 2004. It shows a three-dimensional oblique view of the summit caldera of Albor Tholus, a volcano in the Elysium region. The volcano is 160 km in diameter and 4.5 km high, while the caldera is 30 km across and 3 km deep. On the far-left rim, a bright 'dust fall' seems to flow from the surrounding plateau into the caldera. Credit: ESA/DLR/FU Berlin (G. Neukum)

SMART-1

After the launch on 27 September, the spacecraft has been successfully operated by ESOC in Darmstadt (D). The initial part of the mission, involving SMART-1's exit from the Earth's radiation belts, was finally completed on 7 January. In October-November, the intense solar activity created disturbances in some spacecraft subsystems. The electric-propulsion system shut down several times due to the effects of the radiation on sensitive electronic components, and the star trackers suffered from the intense proton environment, causing the detection of false stars.

Despite these problems, which have been investigated and solutions identified, the spacecraft was able to thrust for more than 1500 hours, increasing the semi-major axis of its orbit by more than 14 000 km from the initial geostationary transfer orbit (GTO) to the present one with almost a 40 000 km semi-major axis. The engine's performance has been an average of 1.5% better than predicted. Power availability onboard is also higher than expected, and the other subsystems are also functioning very well, after some software patching was performed. The instruments have been pre-commissioned, verifying their electrical interfaces and basic functions.

The ground-control team has recently entered the routine operations phase, and the baseline of contacting the spacecraft only twice a week for 8 hours will be applied as soon as the few remaining anomalies have been fixed.

The Science and Technology Operations coordination team at ESTEC in Noordwijk (NL) is now handling instrument-operations requests in collaboration with the Principal Investigators. The seven instruments will be fully commissioned in the coming two months, when the electric-propulsion activities become less intense.

Arrival at the Moon is expected at the end of 2004. Detailed trajectory optimisation, taking into account the electric-propulsion performance and the scientific needs, will be performed shortly.

PROBA

PROBA operations are proceeding nominally and all instruments are providing good data. The operations plan in December also included analysis of the effect of the latest solar storms on the spacecraft hardware. Some degradations were observed, but they were found to have no significant impact on spacecraft performance or lifetime.

ESA is revising the CHRIS/PROBA acquisition plan to reflect the completion of some past projects and to possibly involve new participants. The CHRIS instrument and the High-Resolution Camera have also continued to be used for general-interest Earth-observation imaging.

Image from PROBA's CHRIS instrument showing the flooding of the city of Arles (F) in December

Rosetta

The Rosetta flight spacecraft, which has remained in Kourou (French Guiana) since the launch postponement in January 2003, entered its new launch-preparation campaign at the end of October. The solar arrays and high-gain antenna have been remounted and final functional tests have been performed to re-verify all spacecraft and payload elements. Final preparations, including the closure of all thermal blankets and the mounting of the anchoring harpoons on the Lander, are underway, so that the spacecraft will be ready for re-fuelling at the end of January.

A Mission Flight-Readiness Review in December confirmed that all spacecraft, payload and ground-segment elements were ready for flight.

At ESOC, the simulation campaign has restarted and the preparation of all ground-segment elements is on schedule.

The Ariane-5 launch vehicle has arrived in Kourou where, after a successful Acceptance Review, its launch campaign started in mid-January. The launcher qualification status has been completely re-addressed and the capability to launch the Rosetta mission has been confirmed. The launch window opens on 26 February.

Venus Express

The flight propulsion stage has been integrated into the spacecraft structure. Delivery of the flight model to Alenia (I) is planned for late February. The most critical tests on the new-technology solar array have been successfully completed and its flight-model production has been released.

Delivery of the flight-model instruments will commence shortly and their integration is planned over the next few months. Implementation of the ground segment and the provision of launch services is proceeding according to plan.

Herschel/Planck/ Eddington

The fourth quarter of 2003 saw finalisation of the last stages in the buildup of the Herschel/ Planck industrial consortium. As a result of this effort, which started in the summer of 2001, over 140 contracts have been awarded at various levels in 16 countries.

The main industrial activity in the reporting period has been the manufacture and assembly of engineering models for all electronic units, and the manufacture of structural/qualification-model cryostat hardware. The Planck Payload Module qualification-model structure has been assembled and is ready for testing. Similarly, manufacture of the flight-model hardware for the Herschel cryostat (e.g. helium tanks and cryostat vacuum vessel) is almost complete. Some details of the overall design baseline have been confirmed, e.g. cryo-interfaces for the Herschel instruments, Herschel star-tracker accommodation and corresponding pointing performance, LFI instrument back-end electronics design and accommodation on Planck.

Rosetta solar-array deployment at CSG in Kourou, French Guiana

The launcher Preliminary Design Review process has continued with Arianespace. The spacecraft injection strategy has been optimised taking into account the Ariane-5 ECA baseline, and the Sylda-5/Long Fairing launcher configuration has been agreed and worked into the spacecraft design.

Development of the scientific instruments is progressing with the assembly and start of testing of the qualification models. Some problems with national funding support still persist, but their resolution is expected soon.

Assembly of the Herschel primary mirror for the brazing process

The Herschel telescope has successfully passed a major milestone with the completion of the brazing of the twelve petals of the primary mirror. It will be finalised before the summer with the grinding and polishing of the new monolithic mirror. The Planck Telescope development effort is progressing well with good progress on the qualification model of its secondary reflector. After successful completion of the mechanical testing, it is now undergoing cryogenic optical performance tests. The primary reflector of the qualification model has been assembled and is undergoing mechanical testing.

Following the ESA Science Programme Committee (SPC) decision in November not to recommend the Eddington mission for implementation, the Project is closing down the development and design activities. The parallel Eddington system-definition studies have reached a good level of maturity and will be completed early in 2004. As far as development of the CCDs for the Eddington cameras is concerned, the first set of hardware has been delivered for characterisation and testing.

Double Star

The launch campaign for the first Double Star satellite, TC-1, began as planned on 25 November. All functional tests and preparation activities were completed with the support of a small ESA and Astrium team. The launch by an LM-2C/SM vehicle took place successfully on 29 December at 19:06:18 UTC from the Xichang launch site in southwestern China.

The orbit achieved has a higher apogee than originally planned, giving an orbital period of about 27.5 hours instead of the expected 22.3 hours. The scientific return is, however, maintained because the reduced number of spacecraft conjunctions is compensated for by longer coordinated observations with Cluster.

Commissioning of the three Chinese and five European scientific instruments started in early January, and will address in particular the spacecraft's background noise performance in view of the failure of one rigid boom to deploy initially. The spacecraft's attitude is nevertheless reported as stable and compatible with the mission design.

Delivery of the European payload (three instruments) for the DSP-Polar (TC-2) spacecraft started in November and will be completed by the end of January 2004. Subsequently, these three will be integrated together with five Chinese experiments and subjected to spacecraft-level testing. TC-2 will be launched on 20 July 2004 from Tai Yuan.

SMART-2

The Invitation to Tender (ITT) for the SMART-2/LISA Pathfinder Implementation Phase was released in April 2003. Two bids were received and a Tender Evaluation Board recommended entering into negotiation with one of the two bidding teams, headed by Astrium Ltd. (UK). In parallel, work has progressed on the definition of some critical subsystems, namely the drag-free attitude control, the micro-propulsion technologies, the avionics architecture, and the definition of the experiment interface documents.

The satellite will be designed for satellite-to-ground data communication via a 15 metre ground station operating at X-band. The Mission Operations Control Centre will be based at ESOC in Darmstadt (D), while the Science and Technology Operations Coordination will be performed from ESTEC in Noordwijk (NL), following the positive experience with SMART-1.

The development of the LISA Test Package, the main experiment and the core of the mission, which is presently at the engineering-model stage and being managed under Technology Research Programme (TRP) and Core Technology Programme (CTP) contracts, is experiencing some delays. These technology developments and associated tests will be completed in mid-2004 and will be followed by development of the flight model by a European consortium of industries and institutes, overseen by a dedicated management structure currently under discussion between ESA and the national agencies.

The kick-off of the satellite development contract is planned for February 2004, and the SMART-2 launch is foreseen for early 2008.

Gaia

Gaia builds on ESA's extremely successful Hipparcos mission (1989-93). Its goal is to map the three-dimensional positions and motions of more than a billion stars - a kind of 'Human Genome Project' for our Galaxy, impacting on all areas of astronomy and astrophysics. After its approval within the Science Programme in 2000, and confirmation during the Programme's re-evaluation in October 2003, Gaia is now halfway through a technology-development phase, in which the most critical elements of the payload and spacecraft are under detailed assessment. These studies will be completed at the end of 2004.

Among the challenges for the payload are the large (1.4 m x 0.5 m) telescope mirrors, which are being manufactured from silicon carbide, and for which a successful detailed design review was held in October. The focal plane comprises a large array of state-of-the-art CCD detectors. A feasibility study of the large, custom-made CCDs and the associated focal-plane assembly is in progress. The first batch of CCD wafers has been completed at e2v technologies in Chelmsford, UK. Among the largest area CCDs produced to date, they are nearly 50% bigger than the e2v astronomy products used so successfully in ground-based telescopes around the World.

Like all of ESA's 'Cornerstone' missions, Gaia poses great engineering challenges, but also great challenges in the area of data analysis. A large team of European scientists is participating in the active development of the mission, preparing for the hundreds of terabytes of data that will be sent to the ground during its five-year operational lifetime. A highlight during the last quarter of the year was the successful execution of tests of a

Some members of the e2v (UK) wafer-fabrication group which produced the initial batch of Gaia CCDs. Inset (and magnified): two CCDs on a silicon wafer

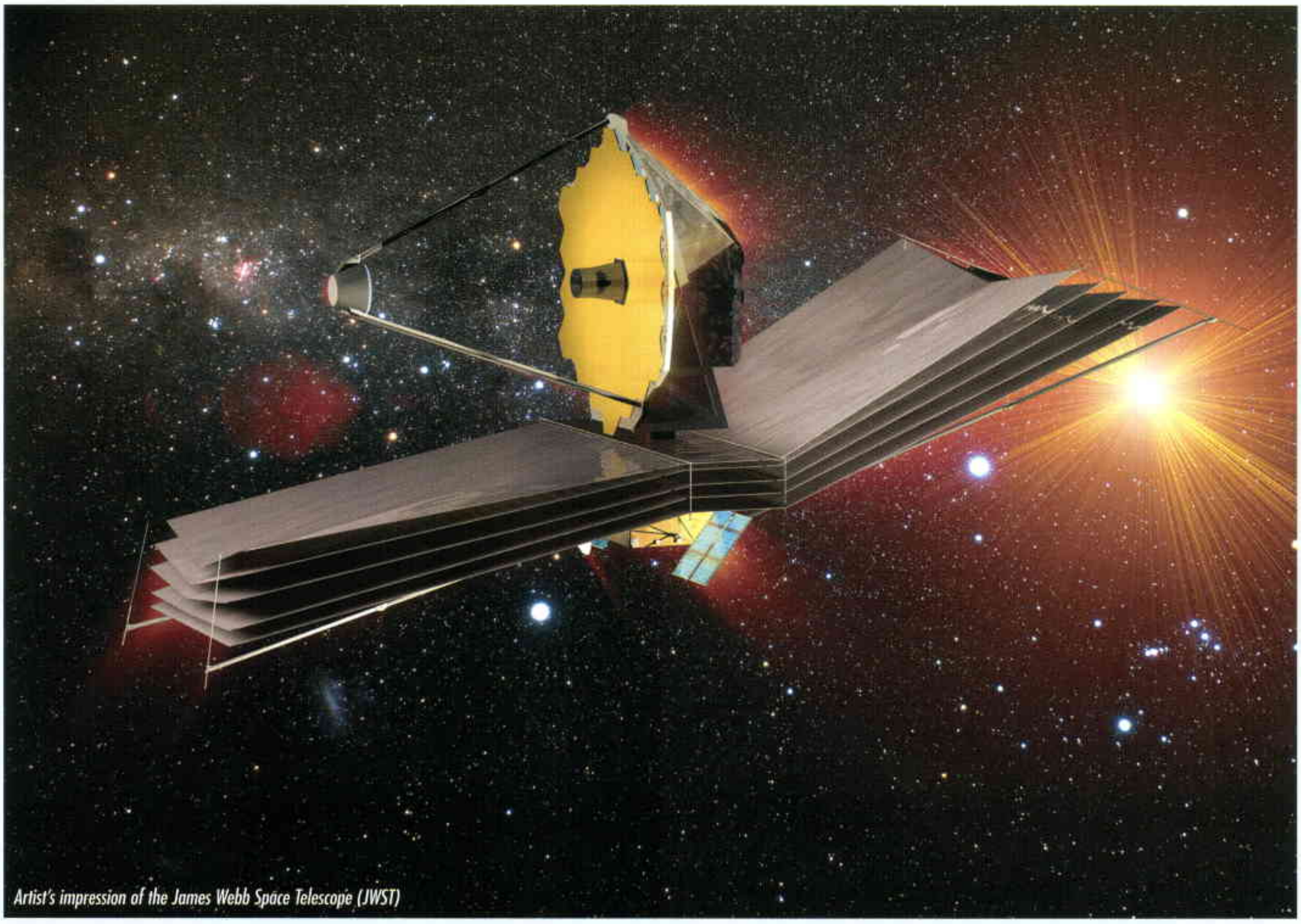
simplified global analysis of data, simulating six months of observations and comprising one million stars. These experiments, led by GMV (Madrid) and supported by the Gaia community, especially those at the University of Barcelona, are being run on super-computers in Barcelona and Madrid.

JWST

The James Webb Space Telescope, formerly called the Next Generation Space Telescope, is the follow-on mission from the Hubble Space Telescope. It is a large observatory-class mission with the primary task of exploring the early Universe back in time to the epoch of the birth of the very first stars and galaxies.

JWST features a deployable 6.6 metre-diameter primary telescope and a suite of three scientific instruments covering imaging and spectroscopy in the near- and mid-infrared wavelength range, from 1 to 28 microns. This payload is protected by a deployable sunshield in order to achieve an operating temperature of 35 K by passive means. The telescope, which will be operated at the L2 Lagrangian point, will be launched by an Ariane-5.

The JWST is a NASA-led mission with participation from ESA and the Canadian Space agency (CSA). The design phase (Phase-B) began last August, after a successful Mission Design Review that was preceded by a long re-planning effort on NASA's part and minor re-scoping activities.



Artist's impression of the James Webb Space Telescope (JWST)

Apart from providing the launcher, ESA is responsible for:

- the Near-Infrared Spectrograph (NIRSpec), which is a 200 kg instrument, the optics and structure of which are to be built using a ceramic material; and
- the optical assembly for the Mid-Infrared Instrument (MIRI), which is being developed by a consortium of European institutes. MIRI will be actively cooled to 7 K using a solid-hydrogen cryostat. The cryostat, detectors and instrument software are the responsibility of Jet Propulsion Laboratory (JPL) in California. Provision of the MIRI instrument is based on a 50/50 partnership between ESA and NASA. The MIRI design phase (Phase-B) was kicked off in June 2003.

ESA will also support the scientific operations phase.

The definition phase is competitive and is being carried out by two consortia, led by EADS-Astrium GmbH (D) and Alcatel Cannes (F). The implementation phase is due to start in July 2004.

Since August, there has been significant progress at both NASA and ESA. All of the major JWST system architectural design decisions related to the telescope's design and technology and the active cooling of MIRI have been taken. All of the NIRSpec-related technology studies are progressing on schedule, aiming for a conclusion in February 2004. The MIRI European Consortium is fully in place, with firm commitments from all participants.

The JWST, which is due for launch in mid-2011, is designed to operate for five years.

Alphabus

The Alphabus programme will establish the production line for a new European telecommunications platform. A multi-purpose platform capable of accommodating telecommunications payloads in the 12 –18 kW power range, it will be the top of the range product for both the Alcatel Space Spacebus and the EADS Astrium Eurostar series.

A combined team drawn from the two prime contractors is conducting the Alphabus preparatory phase. The Baseline Design Review (BDR) was completed in early November. The preparatory phase will continue until mid-2004 and will be finalised with a Preliminary Design Review (PDR). As part of the on-going activities, the prime contractors will also select equipment providers for the build-up of the industrial consortium for the platform's main development phase.

The new Alphabus platform will require the introduction of advanced technologies in several areas. To date, ESA has awarded seventeen contracts to European equipment providers as part of the preparatory activities for the platform's main development phase. A further set of critical developments will be secured in 2004. In parallel, work is also progressing on preparing the Request for Quotation for the main development phase.

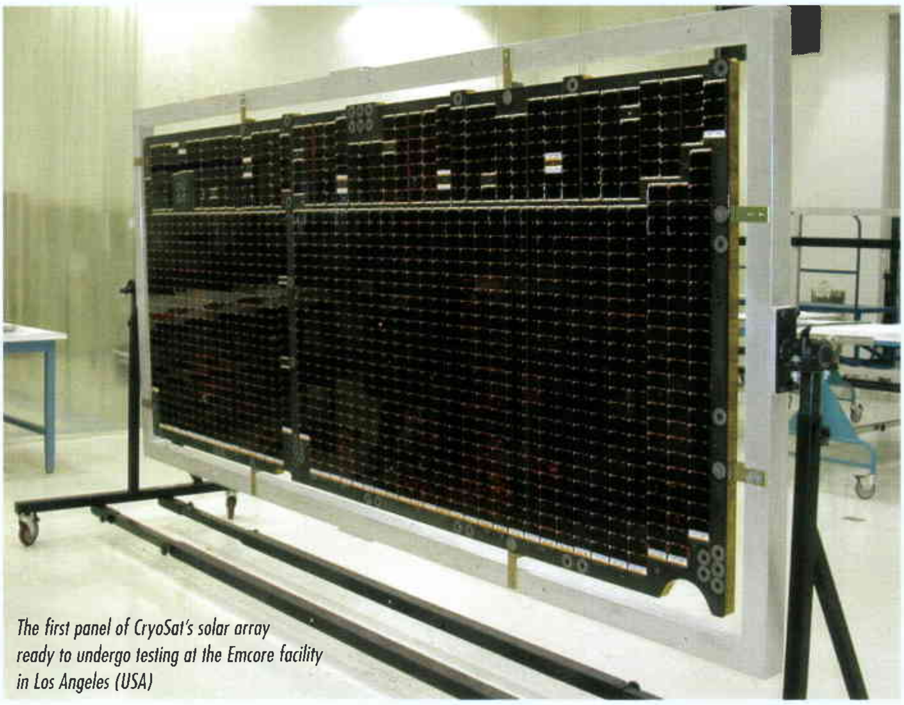
CryoSat

Development of the satellite is progressing well and all flight-model equipment items (except the solar array and onboard mass memory) have been delivered to EADS Astrium's facility in Friedrichshafen (D). Testing of the electronic boxes on the CryoSat Satellite Test Bed is also making good progress. This preliminary integration of the key spacecraft elements has proved to be very useful: a few anomalies have been detected and corrective actions applied, with minimum impact on the schedule. On the mechanical structure, integration of the cold-gas system and the electrical harness is almost complete.

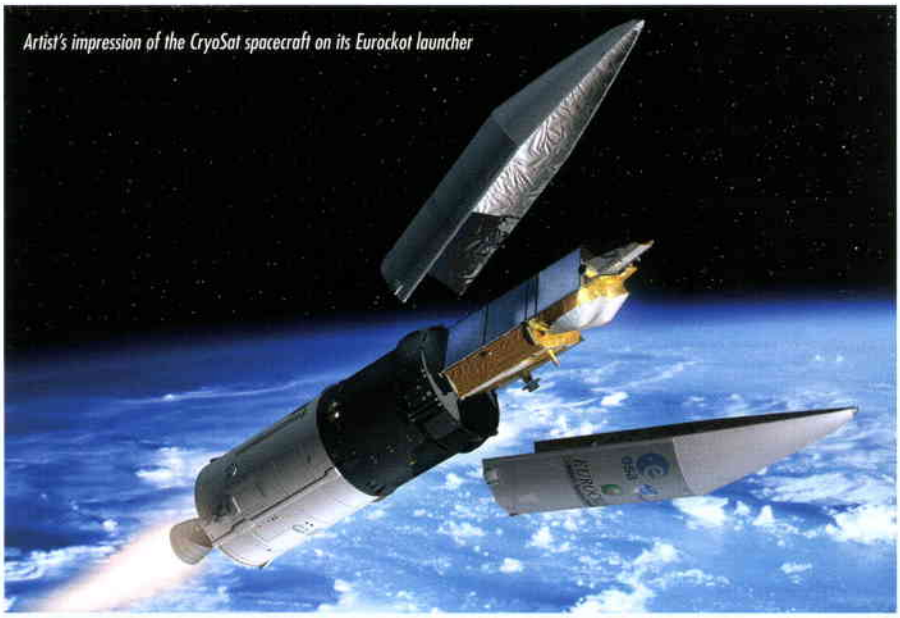
On the payload side, manufacture of the flight model of the SIRAL altimeter is close to completion. Extensive testing of the engineering model is making good progress, and one can anticipate from the preliminary results obtained that excellent performance will be achieved with the flight model.

The activities related to the CryoSat ground segment are also progressing according to plan. The Instrument Processing Facility hardware has been installed in Kiruna (S) and the on-site acceptance of the second version of the Payload Data Segment software was successfully completed in December.

The plans for the launch campaign are now being finalised, with lift-off scheduled to take place from Plesetsk in November 2004.



The first panel of CryoSat's solar array ready to undergo testing at the Emcore facility in Los Angeles (USA)


Artist's impression of the CryoSat spacecraft on its Eurockot launcher

Finally, a launch-services procurement contract has been signed with Eurockot and the related activities were kicked-off at the end of the year.

SMOS

The Phase-C/D proposal received from EADS CASA (E) for the SMOS payload has been evaluated and found to be acceptable. The contract proposal subsequently submitted to the Industrial Policy Committee (IPC) was endorsed unanimously, permitting the industrial work to get underway in December. Full contract signature is expected early in 2004.

GOCE

Work on the space segment has entered the main development phase (Phase-C/D), characterised by the execution of unit-level testing and the related Critical Design Reviews (CDRs). Such CDRs have been successfully completed for the battery, the first version of the platform software, the primary structure, the S-band antenna and several ground-support elements, and are about to commence for other units. Manufacturing and testing of various equipment breadboards have been successfully completed. In particular, the first compatibility check between the breadboards of the Ion Propulsion Control Unit (IPCU) and of the Ion Thruster Assembly (ITA) has been run successfully.

The design consolidation and equipment selection for the simplified cold-gas system to be used during the gradiometer calibration phase have been finalised. A new gradiometer calibration method has been worked out and validated through an extensive simulation campaign. Manufacture and testing of the structural model of the gradiometer has been completed. The electrical testing of the Accelerometer Sensor Head (ASH) demonstration model has started, and the first levitation of the proof-mass under 1-g conditions was successfully performed in October.

At platform level, preparatory activities have started for the integration of the engineering-model test bench that will be used to verify the platform's functional and electrical performance, including real-time closed-loop tests with the pre-validated flight software. In the solar-generator area, the substrate supplier has resumed manufacturing activities after completion of the investigation into the problems encountered during the testing of the samples used to validate the manufacturing process.

All ground-segment development activities are progressing according to plan. The System Requirements Review (SRR) for the Payload Data Segment has been concluded successfully. The in-depth study of the tasks to be performed by the Calibration and Monitoring Facility (CMF) is nearing completion. The ESA Industrial Policy Committee (IPC) has unanimously approved the procurement proposal for the Level-1 to Level-2 data-processing facility and the related Request for Quotation (RFQ) has been released to the European GOCE Gravity Consortium.

The GOCE gradiometer instrument (without harness)

In parallel, the technical baseline for the payload was reviewed in a Preliminary Design Review (PDR) at the end of 2003, and was generally found to be mature enough to start with the full implementation phase. Some areas identified as needing improvement (calibration, EMC) are being addressed by joint ESA/CNES/industry/science working groups.

The discussions with CNES about the Implementation Agreement between the two agencies are progressing, with the aim of submitting the finalised document to the ESA Programme Board in March. Progress is being made regarding the development effort for the science data processing at ESA's Villafranca station (E). Industrial contracts are expected to be placed in the first half of 2004.

ADM-Aeolus

The contract for the major spacecraft development effort (Phases-C/D and E1) was signed in October. Most of the subcontracts for both the satellite and instrument have already been kicked-off.

An assessment of the behaviour of the solid-state laser pump diodes under vacuum has shown no dramatic differences compared with similar tests in air. Information from NASA regarding the pump-diode failure on IceSat shows that it was due to diode construction failures, rather than the vacuum. The Aeolus diodes are free of the defect discovered. Despite this, a back-up design has been developed for a pressurised laser, which could be accommodated, if necessary, without changing the rest of the instrument or satellite design.

Delivery of the first flight-model pump diodes, which are on a critical path for the launch, is expected in January. An adequate number of the constituent solid-state diode bars have successfully passed their burn-in test.

The two halves of the 1.5 metre silicon-carbide flight mirror have been successfully brazed together. The mirror is therefore ready for the lengthy polishing process to begin.

All critical-path activities are proceeding nominally towards the Critical Design Review (CDR) planned for May 2005.

The project team has held discussions with Eumetsat about a desire to deliver Aeolus data, at least for the North Atlantic and Europe, within about half an hour of acquisition. The satellite as designed is able to meet this need, provided it is supported by an adequate number of X-band ground stations. The stations forming part of the Aeolus nominal mission will already allow half-hour delivery from this zone on ascending orbits. Eumetsat may be prepared to fund the corresponding capability for descending orbits. In any event, Aeolus data is likely to be provided to meteorological users via the Eumetsat broadcast system.

Discussions are also in progress with the European Centre for Medium-Range Weather Forecasting (ECMWF) concerning its involvement in the production of Level-2 Aeolus data products (winds). They intend in any case to assimilate Aeolus data and determine its effects on Numerical Weather Prediction.

MetOp

Excellent progress continues to be made on the integration of the MetOp-1 proto-flight spacecraft, with the completion of the acoustic and sine-vibration tests at Intespace in Toulouse (F). Preliminary results indicate that, as expected, the levels of excitation are lower than for the structural-model test, due to increased damping in the (fully representative) flight model. As a consequence, pending confirmation from the detailed analyses and post-vibration testing, the qualification for flight of the spacecraft and, especially, the US instruments appear to be assured.

The Aeolus flight-model primary mirror after brazing

MetOp-1 mounted on the shaker at Intespace in Toulouse (F)

After completing the mechanical test programme with the Starsem-executed launcher-separation shock test, MetOp-1 will enter its final set of functional and performance testing in the run-up to the Flight Acceptance Review, scheduled for May/June 2004. After this, MetOp-1 will go into storage, whilst MetOp-2, the first of the spacecraft to be launched, is prepared.

In parallel with the work on MetOp-1, integration of the MetOp-2 Payload and Service Modules continues, with their respective thermal-vacuum tests being prepared.

An important milestone was reached with the successful completion of the first Satellite System Verification Test, whereby the Eumetsat Ground Segment Mission Control System commanded MetOp directly.

Following Eumetsat's earlier request to examine the possibility of enhancing the MetOp-3 payload, sketch proposals were provided for an AVHRR-type replacement instrument, the VIRI-M, and for a range of spacecraft payload-complement adaptations, via Eumetsat to their Council meeting in November. Further activities in this respect await the completion of discussions between Eumetsat and NOAA.

Meteosat Second Generation (MSG)

MSG-1

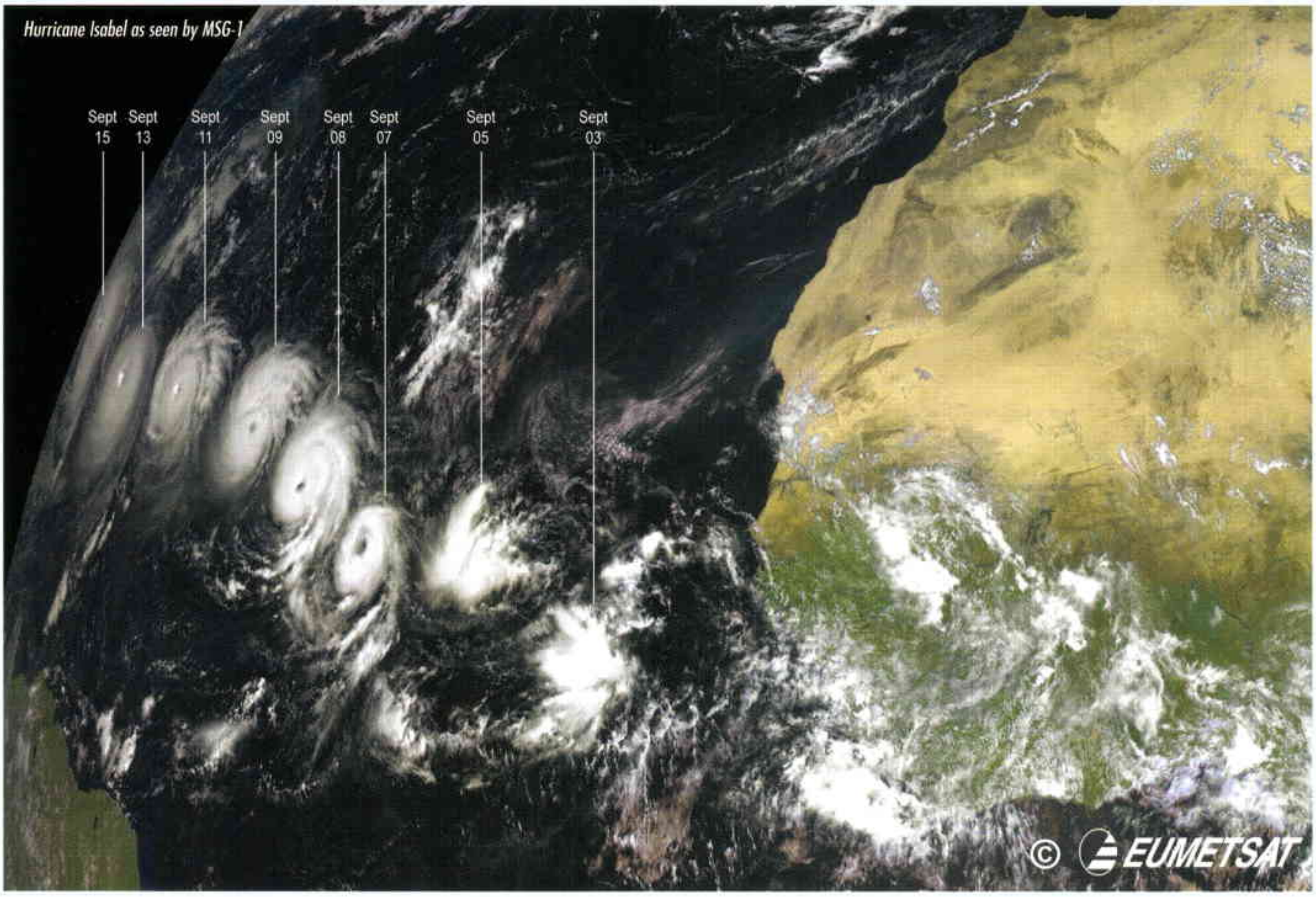
A period of commissioning, intensive in-orbit testing, ground-segment preparation and performance testing for the various MSG missions has been completed successfully. This was confirmed by the System Commissioning Results Review, which was held at Eumetsat. A successful Routine Operations Readiness Review, also held at Eumetsat in the same period, gave the green light for the MSG Routine Operations phase. This will start once the satellite has reached its operational longitude, which is currently planned for the end of January 2004.

MSG-2

The MSG-2 spacecraft is still in its storage configuration. The launch window is currently January-June 2005. Assuming a launch at the beginning of the window, de-storage activities and preparations for the launch will begin on 1 April.

MSG-3

During the last quarter, the MSG-3 satellite has successfully completed a number of important system tests at the Alcatel Space test facilities. The thermal cycling, a complex mechanical test sequence, and the optical vacuum test were performed in just two months. MSG-3 is planned to be stored before the start of MSG-2 de-storage activities for the assumed launch in January 2005. However, with this planning it does not seem to be feasible to



Hurricane Isabel as seen by MSG-1

MSG-2 in the Compact Antenna Test Range


The MSG-3 spacecraft at the Alcatel Space test facilities in Cannes (F)

finalise all MSG-3 performance tests before storage.

MSG-4
The delivery schedule for the EEE parts for the MSG-4 units is critical and has been analysed in detail. All other activities are going according to plan.

Artemis

The satellite has continued to provide data-relay, land-mobile and navigation services to the users as planned:
- SPOT-4 uses one optical link per day for SPOT Image data collection
- Envisat uses seven Ka-band links per day for background mission ASAR and MERIS data collection
- Telespazio uses 50% of the L-band payload (LLM) capacity under the EMS contract
- ESA advanced mobile applications have been using up to 50% of the LLM capacity experimentally
- The Navigation payload has been used by EGNOS for Scanzano station calibration and system phase tests.

Service statistics for the months of November and December were very good, with 100% service quality to SPOT-4, Telespazio and EGNOS. The service provided to Envisat has also been excellent, apart from two link failures in November due to spurious anomalies affecting the Artemis antenna controller.

The total data-relay-link operating time accumulated since 1 April 2003 reached 360 hours (1100 Ka-band links) for Envisat and 50 hours (260 optical links) for SPOT-4 by year's end.

As a result of the L-band operators meeting, which coordinates and allocates the L-band spectrum annually, Artemis will continue to use the same frequency bands in 2004 as in 2003. This situation is very satisfactory for the business demands of Telespazio and Eutelsat, and contracts with both parties are being finalised.

Artemis is now being operated under the routine-phase part of the overall satellite contract. The development and launch-phase part of the satellite contract will be formally closed in the near future. The additional operational support for system engineering required from Alenia and its main subcontractors is under negotiation. Preparations are also underway for the next big data-relay user – ESA's Automated Transfer Vehicle (ATV).

International Space Station

Highlights
The Space Shuttle programme management has recently reaffirmed that the Return to Flight (RTF) plans are based on a flight within a 12 September to 10 October 2004 window.

The in-orbit status of the ISS continues to be good, with all systems and equipment continuing to operate correctly, and just minor anomalies occurring from time to time.

The Expedition 8 crew launched by Soyuz flight 7S on 18 October will stay aboard the ISS until April 2004. The same Soyuz flight also hosted the Spanish Soyuz mission 'Cervantes' with ESA astronaut Pedro Duque, who conducted a successful programme of scientific, technological and educational experiments during his stay at the Station (see his article elsewhere in this issue). The next Soyuz flight, 8S, is still planned for April 2004, and will carry ESA astronaut André Kuipers who will conduct the 10-day Dutch Soyuz mission 'DELTA'.

Space infrastructure development
Columbus system qualification testing is still in

progress. The Materials Review Board has discussed a cold-plate manufacturing deficiency and a resolution to the issue has been proposed. The Microgravity and Audible Noise testing has been completed, and preparation of the System Validation Testing (SVT) has started.

Progress has been made on the Automated Transfer Vehicle (ATV) flight hardware, with all main assemblies now being at the integration site in Bremen (D). There are, however, significant delays in the completion of the flight software, and a flight-readiness date of mid-2005 has been assessed.

Significant amounts of debris (foreign objects) were found in Node 2 at Kennedy Space Centre. A contamination Technical Interchange Meeting has since identified an acceptable approach for solving the problem.

Both the updated Flight Safety Data Package and the Preliminary Design Review (PDR) Data Package for the Cryogenic Freezer (CRYOS) have been received and are under evaluation.

The flight-unit proof pressure test for the Cupola has been performed successfully and integration of the windows has started. The top window has already been installed and successfully leak-tested.

Regression testing on the Mission Preparation and Training Equipment (MPTE) for the European Robotic Arm (ERA) has been successfully completed, and closeout of the MPTE acceptance is now part of the ongoing System Level Acceptance Review.

Operations and related ground segments
The Automated Transfer Vehicle Control Centre (ATV-CC) Critical Design Review (CDR) and Columbus Control Centre (COL-CC) Systems Design Review Part 1 were successfully completed on 14 November, and the first System Validation Test 1a for the ATC-CC successfully took place from 18 to 20 November. Installation of the Wide Area Network for the Mission Control Center in Houston and the ATV-CC has also been completed.

The Ground Segment Data Services System Site Acceptance Review (SAR) for the Columbus Control Centre (COL-CC) was successfully completed on 16 December. The COL-CC Operations Preparation frame contract has been signed and the System Requirements Review for the Operations Planning System has been successfully conducted.

On 20 October, the Expert Panel reviewed the four Microgravity Applications Projects (MAP) continuation proposals received in September, recommending two for continuation, one for re-submission, and that the fourth not be continued.

A software update has been installed to correct errors encountered during the European Drawer Rack (EDR) functional testing, and a new set of performance tests is planned to start by mid-January 2004. Integration of the first sub-rack payload, the Protein Crystallisation Diagnostic Facility, is now foreseen for April 2004.

The Safety Review III for the European Transport Container (ETC) was successfully held at ESTEC on 4/5 December.

Biolab flight-model testing has been completed, and the training model has been installed and accepted at the European Astronaut Centre (EAC) in Cologne (D). Preparation of the Phase-3 Flight Safety Data Package is progressing and delivery is planned for mid-January 2004.

The Crew Review for the European Physiology Module (EPM), with ESA and NASA astronauts participating, was successful. The Cardiolab Data Management Control Unit was delivered and integrated successfully into the EPM rack, and the EPM Science Verification Test was also successful. Sustaining-engineering tasks are ongoing for the Human Research Facility (HRF-2), including the ESA Pulmonary Function System. Integration of science module of the Multi-Electrode Electroencephalogram Mapping Module (MEEMM) into the EPM carrier has been successfully completed.

The Rack-Level Test Facility (RLTF) interface-test campaign for the Fluid Science Laboratory (FSL) was successfully completed and completion of the flight-model functional testing has been adapted to match with the postponed delivery for Columbus integration in April 2004. Completion of the FSL Training Model Acceptance Review, and delivery to the EAC, is planned for end-January 2004. Delivery of the Microgravity Vibration Isolation System (MVIS) from the Canadian Space Agency is expected in early 2004.

NASA has confirmed that Flight Model 1 (FM-1) of the –80 degC Freezer (MELFI) will not now fly in LF-1, but in ULF1.1. The Test Readiness Review for FM-2 was completed in October, the system test campaign is progressing, and compatibility tests with the Japanese Experiment Module (JEM) were completed by mid-December. The integration of FM-3 is almost complete. An ESA/NASA Agreement, relieving ESA of the need to integrate the fourth MELFI flight unit, in return for compatibility verification of MELFI in the JEM, testing of the Human Research Facility in Bremen (D), and clarification on sustaining engineering and maintenance, was signed by both parties in early December.

Project activities for the Hexapod pointing system are proceeding, with the final testing taking place.

The SolACES instrument audit was successful and implementation of the SolACES recovery plan has commenced. The SOLAR CDR Second Board and Review closeout were held on 13 November.

The qualification tests for EXPOSE have been completed and the experiment hardware configuration has been agreed with all Principal Investigators. The fifth Interface Working Group was held on 20/21 November, and the Flight Acceptance Review is planned for 27/28 January 2004. The EXPOSE flight model (with dummy trays) is ready for delivery to the EuTEF (European Technology Exposure Facility) for system integration; production of the flight trays will start in January 2004.

Flight-model hardware manufacturing for EuTEF has continued and the Experiment

Flight Model Acceptance Review procedure is currently being finalised. The Atomic Clock Ensemble in Space (ACES) Payload Preliminary Design Review Board's report was issued on 11 October, and the PDR closeout activities have continued, aiming at completion in February 2004. A management meeting was held with the contractor and an outline plan was discussed for covering the period of the ceiling-price to firm-fixed-price conversion in May 2004. A proposal covering advanced Phase-C1/D tasks was received and evaluated, resulting in an Authorisation to Proceed (ATP). Evaluation of the technical and programmatic impacts induced by the ACES scientific verification plan commenced in November.

The Columbus External Payload Adaptor (CEPA) developed by NASA, which is required for mounting the external payloads, has been delivered to the contractors for Post Shipment Incoming Inspection (PSII) in Europe.

All 21 in-flight investigations/activities were successfully completed during the Spanish Soyuz mission 'Cervantes' to the ISS in October. Acceptance Test 2 for the Dutch Soyuz mission 'DELTA' was successfully completed in Moscow on 17-19 December, and all hardware has been accepted and declared ready for delivery and launch. Preparations for this mission are proceeding well.

The contract for Foton-M2 and -M3 (retrievable satellites) has been negotiated with Rosaviakosmos and was signed in Moscow on 21 October. A full Foton-M2 payload complement has been fixed and payload development has been started for a planned launch in May 2005.

The contract for the Maxus-6 sounding rocket has been finalised and signature is planned for January 2004.

The environmental test campaign and the full functional test for the European Modular Cultivation System (EMCS) flight model have been completed. Some software interface problems between the EXPRESS rack and the EMCS are currently under investigation.

Testing on the Protein Crystallisation Diagnostics Facility (PCDF) engineering module is in progress and assembly of the flight model has started. Delivery of the latter is planned for April 2004. The training model was accepted at EAC in December 2003.

ISS education

The first ESA education programme associated with an ESA/European astronaut ISS mission, 'Habla ISS', was conducted for the Spanish Soyuz mission 'Cervantes', with activities for all school levels. ISS Education was also represented at the 'Physics on Stage 3' festival at ESTEC (NL) in November, which attracted 450 European science teachers. The final version of the ISS Education Kit in English has now been distributed to more than 1200 teachers, with more than 700 requests received online.

Commercial activities

The first public-relations activity for prospective members of the ISS Business Club took place during the 'Cervantes' mission. ESA has delivered the second draft of the Partner Agreement on the Global Brand Management Programme to the ISS Partners. Contacts with major European companies regarding prime and mission sponsorship are continuing.

The Phase-A study for ISS-RapidEye has been concluded, and the programme will not be pursued.

Astronaut activities

The Spanish 'Cervantes' mission to the ISS was supported by EAC staff during launch and landing as well as during the mission itself, at TsUP (Russian mission control centre), EAC and ESTEC. The post-flight activities were completed in December.

Training models for the Biolab and the Fluid Science Laboratory (FSL) were delivered to EAC in October. In the same month, a Space Medicine Workshop, organised by EAC and the ESA Education Office with the support of the European Medical Association, was held at the EAC. Participants comprised space-medicine experts, scientists, astronauts, and 45 students, mainly from Europe. The objective of the Workshop was to foster a two-way exchange between experts and students.

Agreement has been reached with the Canadian Space Agency (CSA) that a Canadian astronaut could be assigned as backup for the first European Soyuz Mission 1 (ESM1). In exchange, an ESA astronaut would become backup for the Canadian increment.

Vega

The Vega main development contract has seen a number of subsystem Preliminary Design Reviews (PDRs), and progress in the negotiation of the subcontracts between the Vega Prime Contractor (ELV) and the other partners of the industrial consortium. The first major tools have arrived at the premises of ELV and Avio, the motor designer and manufacturer, respectively, at Colleferro, near Rome.

The System Design Review has been further postponed after a checkpoint before the Review's kick-off assessed the status of the documentation and compliance with the defined prerequisites as insufficient. Work is in progress to define recovery measures and minimise overall schedule impacts.

Work on the P80 first stage is also progressing, with the first major manufacturing tooling and machines having been pre-accepted at the supplier's premises.

Evaluation of the four Invitations to Tender for the various aspects of the Vega launch base was due for completion in December, after a number of actions requested by the Tender Evaluation Board had been completed. esa

In Brief

Rosetta begins its ten-year journey

Europe's Rosetta cometary probe has been successfully launched into an orbit around the Sun, which will allow it to reach the comet 67P/Churyumov-Gerasimenko in 2014, after three flybys of the Earth and one of Mars. During this ten-year journey, the probe will pass close to at least one asteroid.

Rosetta's mission began at 08:17 CET (07:17 GMT) on 2 March when its Ariane-5 launch vehicle lifted off from Europe's spaceport in Kourou, French Guiana. The launcher successfully placed its upper stage and payload into an eccentric coast orbit (200 x 4000 km). About two hours later, at 10:14 CET (09:14 GMT), the upper stage ignited its own engine to reach the escape velocity needed to leave the Earth's gravity field and enter heliocentric orbit. The Rosetta probe was released 18 minutes later.

"After the recent success of Mars Express, Europe is now heading to deep space with another fantastic mission. We will have to be patient, as the rendezvous with the comet will not take place until ten years from now, but I think it's worth the wait" said ESA's Director General Jean-Jacques Dordain after the launch.

ESA's Operations Centre (ESOC) in Darmstadt, Germany, which will be in charge of Rosetta orbit determination and operations throughout the mission, established contact with the probe immediately after launch as it flew away from the Earth at a relative speed of about 3.4 km/s. During the next eight months, the spacecraft's onboard systems will be checked and its science payload will be commissioned. It will then be put into 'hibernation mode' for most of the ten years of its journey through the Solar System. Rosetta will be reactivated for planetary flybys, which will be used to modify its trajectory through gravity-assist manoeuvres, or asteroid flybys, observation of asteroids being one of the mission's secondary objectives.

The first planetary encounter will be in March 2005, as Rosetta flies by the Earth for the first time. The resulting 'gravity assist' will boost Rosetta into an orbit that will take it on to Mars two years later. During its close encounter with Mars in February 2007, Rosetta will approach to within about 200 km of the planet and conduct scientific observations. This Martian flyby will be followed by a second Earth flyby in November of the same year. Both planetary encounters will increase the spacecraft's orbital energy and boost it well into the asteroid belt. A third and last flyby of the Earth in November 2009 will send Rosetta towards the orbit of comet Churyumov-Gerasimenko. esa

Rosetta lander named 'Philae'

A few weeks before the Rosetta launch, the spacecraft's lander was named 'Philae'. Philae is the island in the river Nile on which an obelisk was found that has a bilingual inscription including the names of Cleopatra and Ptolemy in Egyptian hieroglyphs. This provided the French historian Jean-François Champollion with the final clues that enabled him to decipher the hieroglyphs on the Rosetta Stone and unlock the secrets of ancient Egyptian civilisation. Fittingly, the Philae lander and the Rosetta orbiter have been designed to unlock the mysteries of comets, the oldest building blocks of our Solar System.

The main contributors to the building of the lander - Germany, France, Italy and Hungary, working together with Austria, Finland, Ireland and the United Kingdom - held national competitions to select an appropriate name for it. 'Philae' was proposed by 15-year-old Serena Olga Vismara from Arluno, near Milan (I). Her hobbies are reading and surfing the internet, from which she got the idea of calling the lander 'Philae'. Her prize was a visit to Kourou to attend the Rosetta launch. esa

UK and ESA announce Beagle 2 inquiry

Beagle 2, the British-built element of ESA's Mars Express mission, has failed to communicate since its first radio contact was missed shortly after it was due to land on Mars on Christmas Day. The Beagle 2 Management Board met in London on Friday 6 February and, following an assessment of the situation, declared the Beagle 2 lander lost.

On 11 February, the UK Science Minister Lord Sainsbury and ESA announced that an ESA/UK inquiry would be held into the failure of Beagle 2. Lord Sainsbury, of the UK Department of Trade and Industry, said: *"I believe such an inquiry will be very useful. The reasons identified by the Inquiry Board will allow the experience gained from Beagle 2 to be used for the benefit of future European planetary exploration missions."*

The Inquiry Board, which will report by the end of March, is to be chaired by the ESA Inspector General, René Bonnefoy. The UK deputy chairman will be David Link MBE, a former Director of Science and Radar Observation at Matra Marconi Space, now EADS-UK. esa

Cooperation agreement signed between ESA, Hungary and the Czech Republic

Hungary and the Czech Republic have signed European Cooperating State (ECS) agreements with ESA. Both countries will now be able to participate in nearly all ESA programmes. Hungary has even finalised its specific plan for collaboration and signed the "PECS" document – Plan of space collaboration activities for European Cooperating States. Both States will make an annual payment to ESA. Initially they will each contribute with 5 million Euro over a five-year period. 93% of this contribution will be returned to each country in the form of contracts to its industry and research institutes. The remaining 7% is an administration fee to ESA to cover the cost of integrating these two countries into the Agency. esa

Space Policy Institute founded

The new European Space Policy Institute, founded by ESA and the Austrian Space Agency, will create a virtual network of think tanks to promote European space policy in the world. It will be located in Vienna, Austria, and legally represented by a Secretary General. The tasks of the institute are building up know-how to provide comprehensive and independent policy research to space players in Europe, and identifying and developing research themes to initiate, support and promote debate to raise public awareness of the importance of space-based infrastructures and services. esa

ESA/Inmarsat agreement to improve satellite mobile phone and data services

An agreement signed by ESA and Inmarsat brings the reality of reliable mobile broadband communications services a step closer. For the first time, global mobile broadband services will be available for those at sea, in a plane or travelling on land virtually anywhere in the world.

This agreement marks the first collaboration between ESA and Inmarsat on system engineering activities and will extend the capabilities of the new Broadband Global Area Network System (BGAN) to be offered by the Inmarsat I-4 satellite constellation.

Following the launch of the first of the fourth-generation Inmarsat satellites in 2004, BGAN is expected to become operational for land services in 2005. Applications will include internet and intranet access, video on demand, web TV, video-conferencing, fax, e-mail and LAN access at speeds of up to 432 kbit/s from notebook-sized terminals almost anywhere in the world. The BGAN system will be compatible with third-generation (3G) cellular terrestrial systems and the project will adopt an 'Open Standards' approach.

Under the terms of the agreement, ESA has agreed to fund 50% of the project and to provide technical support. A number of companies will be involved in this agreement. EMS Satcom Ltd. (UK) is in charge of developing the aeronautical mobile platforms, Logica CMG (UK) will mainly be involved in multicast service-centre development, and the Norwegian company NERA ASA will be responsible for developing maritime platforms. The University of Surrey (UK) will work on BGAN performance analysis. esa

Aurora student design contest

'Aurora' is the name of ESA's initiative for robotic and human exploration of the Solar System and notably of Mars and the Moon. The Programme – currently in its preparatory phase – will define and implement a long-term exploration strategy with the final goal of landing a human on Mars by 2030. The road map that is being worked out includes a number of technology developments, robotic missions to Mars and manned and unmanned missions to the Moon in preparation for a human mission to Mars. A programme with such ambitious goals and spanning such a long period of time needs to ensure that there will be a constant in-flow of new ideas and concepts, as well as a new skilled and motivated workforce. This is why Aurora has an explicit provision for co-operation with European Technical Universities.

Aurora already has close relations with European University networks and the Future Space Exploration (FUSE) network that brings together top European universities with an interest and expertise in space exploration. The idea of a Student Design Contest was launched at the first Aurora/Academia Workshop, held in September 2002.

The contest is intended to:

- raise awareness and motivate students and young researchers concerning the issues of space exploration and the challenges that go with it, while offering an opportunity to tackle a design project with given requirements and in a given framework;
- stimulate new ideas, innovative concepts and unexplored approaches that can spring from the academic environment and that could later be applied to the missions or facilitate the solution of related technical problems.

The above goals match the mandate and objectives of the ESA Corporate Education Office, in cooperation with which the contest was launched and conducted.

The first deadline, for team registration and submission of a project outline, was the beginning of March 2003. Teams could be composed of a maximum of six students including one PhD candidate. The project outline was meant to make sure students had understood the scope of the contest and the Aurora Programme, as well as the five categories in which projects could be submitted. These were 'Flagship' and 'Arrow' class missions (major missions with a scientific interest in their own right, and smaller, cost-capped, mainly technology demonstrator missions, respectively); 'Human Missions'; 'New Enabling Technologies' and 'Surface Robotics'.

By the first deadline, 53 projects had been received. Once the teams had been notified that their project was eligible for the contest, they had five months in which to work on it and come up with a 20-page report and an executive summary to be submitted no later than the end of July 2003.

In the end, 36 projects were entered, which triggered a very intense reading, evaluation, discussion and selection process that occupied more than ten people from the Aurora Programme and ESA's Advanced Concept Team for one week. The quality of the work produced by the students was deemed to be so good that, in addition to the top three projects for each category, two additional projects were shortlisted in the 'Human Missions' category. Finally, 17 teams were selected to go to Barcelona and present their projects to ESA experts and members of the Exploration Programme Advisory Committee (EPAC) with representatives from industry and academia.

Students presenting their projects at the first Aurora Student Design Contest

The event was a great success, also thanks to the flawless organisation by the Universitat Politecnica de Catalunya. The jury's task to identify the winners in the five categories was not an easy one. Chaired by the EPAC Chairman, Prof. J.P. Swings, the jury finally awarded 11 prizes in total – two more than planned – and congratulated all students for their excellent work. While the students are resting from their efforts and looking forward to enjoying their prizes, the Aurora Student Design Contest team is back at work to publish the Proceedings, collect suggestions and have them integrated into the guidelines for the next Student Contest.

The extremely positive experience and response from students, professors and professionals alike has provided the thrust to start organising a second Aurora Student Contest.

Publications

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

ESA Newsletters

EDU NEWS NO. 5 (NOVEMBER 2003)
NEWSLETTER OF ESA'S EDUCATION OFFICE
WARMBEIN B. (ED.)
NO CHARGE

CONNECT NO. 04/03 (DECEMBER 2003)
NEWSLETTER OF ESA'S DIRECTORATE OF APPLICATIONS
MENNING N. & BATTRICK B. (EDS.)
NO CHARGE

ON STATION NO. 15 (DECEMBER 2003)
NEWSLETTER OF THE DIRECTORATE OF HUMAN SPACEFLIGHT
WILSON A. (ED.)
NO CHARGE

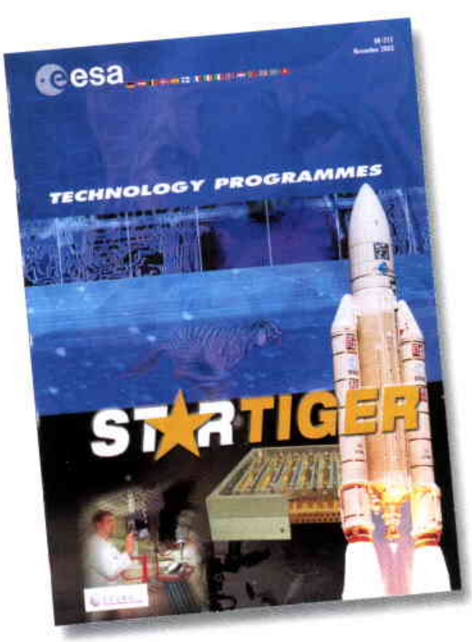
ECSL NEWS NO. 26 (DECEMBER 2003)
NEWSLETTER OF THE EUROPEAN CENTRE FOR SPACE LAW
MARCHINI A. & BATTRICK B. (EDS.)
NO CHARGE

REACHING FOR THE SKIES NO. 26 (JANUARY 2004)
NEWSLETTER OF ESA'S DIRECTORATE OF LAUNCHERS
LEBRUN F., LACOSTE H. & BATTRICK B. (EDS.)
NO CHARGE (AVAILABLE IN ENGLISH OR FRENCH)

ECSS NEWS NO. 7 (FEBRUARY 2004)
NEWSLETTER OF THE EUROPEAN COOPERATION FOR SPACE STANDARDIZATION
ASQUIER J. & BATTRICK B. (EDS.)
NO CHARGE

ESA Brochures

THE SPACE DIMENSION (NOVEMBER 2003)
WILSON A. (ED.)
ESA BR-190 // 66 PAGES
PRICE: 10 EURO



AGENDA 2007 – A DOCUMENT BY THE ESA DIRECTOR GENERAL (OCTOBER 2003)
BATTRICK B. (ED.)
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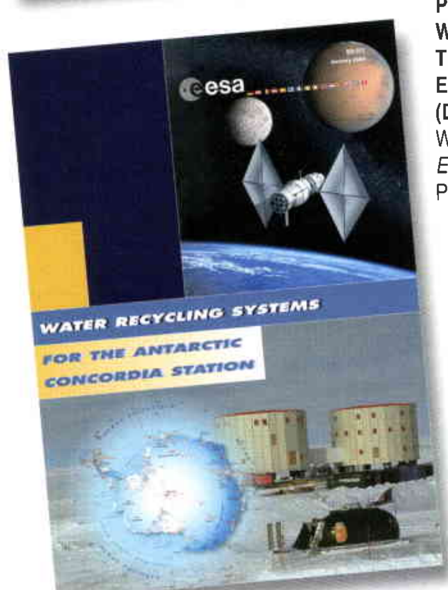

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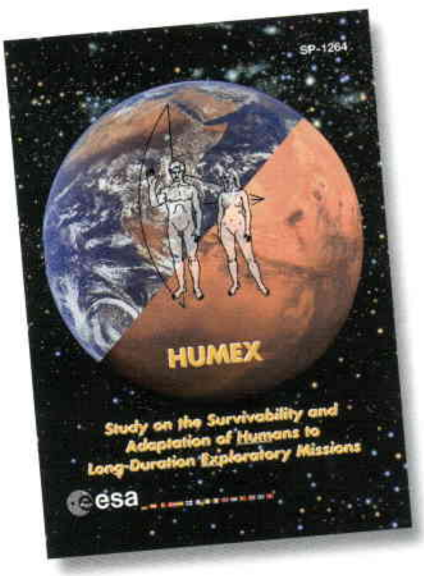

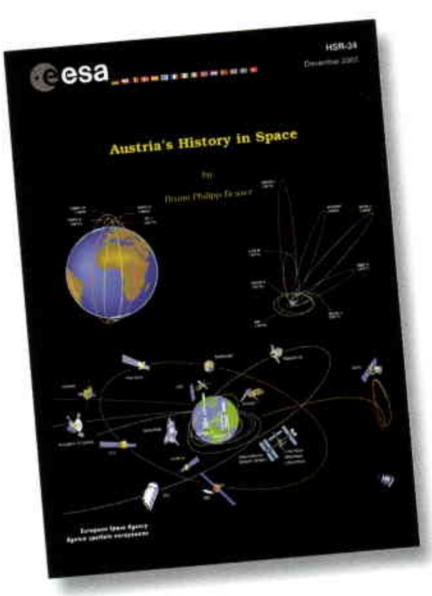

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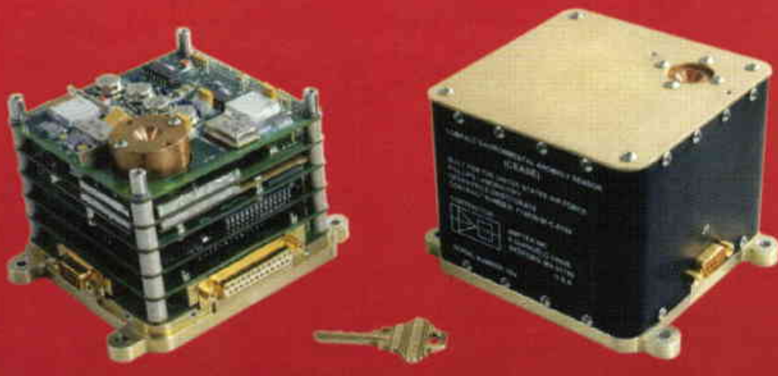

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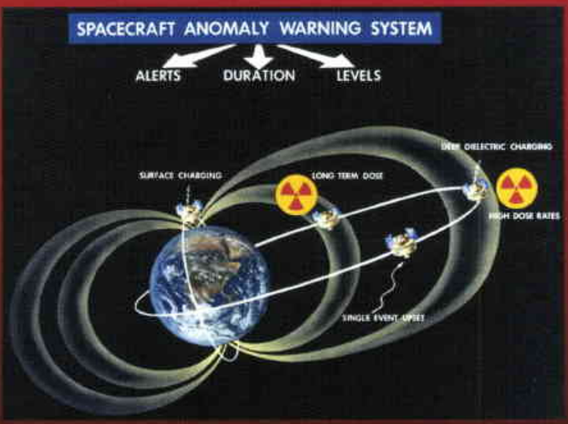

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