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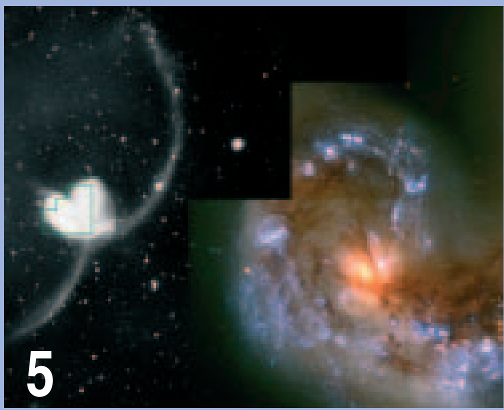
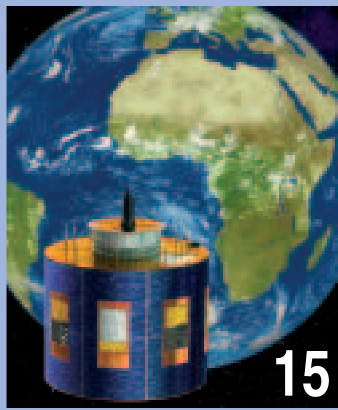
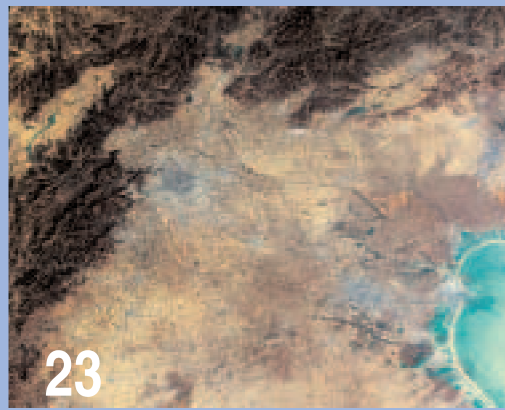


Gravitational Waves and Massive Black Holes?

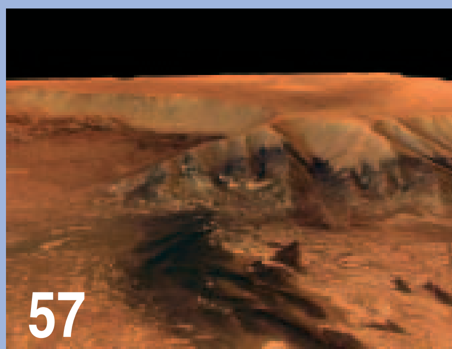


Meteosat Second Generation Becomes Operational



The Dragon Programme

What Happens to the Human Heart in Space?



ESA Portal Brings Europe's Mars Adventure to Millions

Keeping Track of Geostationary Satellites

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Ground-based telescope view (left) of the collision between the galaxies NGC4038 and NGC4039, which reveals long arcing insect-like 'antennae' of luminous matter flung from the scene of the accident. Investigations using the Hubble Space Telescope have revealed over a thousand bright young clusters of stars – the result of a burst of star formation triggerd by the collision. The green outline shows the area covered by the higher resolution Hubble image (right). Dust clouds around the two galactic nuclei give them a dimmed and reddened appearance, while the massive, hot young stars of the new formed clusters are blue
(Image courtesy of B. whitmore (STSci), F. Schweizer (DTM), NASA)

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Though they have not been directly detected so far, gravitational waves are a necessary consequence of Einstein's theory of General Relativity. They distort space and time, changing the perceived distances between free macroscopic bodies. A gravitational wave passing through the Solar System creates a time-varying strain in space that periodically changes the distances between all bodies in the Solar System in a direction that is perpendicular to that of wave propagation. These could be the distances between spacecraft and the Earth, as in the case of Ulysses or Cassini (attempts were and will be made to measure these distance fluctuations), or the distances between shielded 'proof masses' inside spacecraft that are separated by a large distance, as in the case of LISA.

The collaborative NASA/ESA Laser Interferometer Space Antenna (LISA) mission, planned for launch in 2012, will be the first space mission to search for these elusive gravitational waves. As the technology needed for the project is highly demanding, a precursor technology-demonstration mission is considered to be a necessary pre-requisite. Called LISA Pathfinder (formerly SMART-2) and planned for launch in 2008, it was given the go-ahead on 7 June by ESA's Science Programme Committee (SPC).

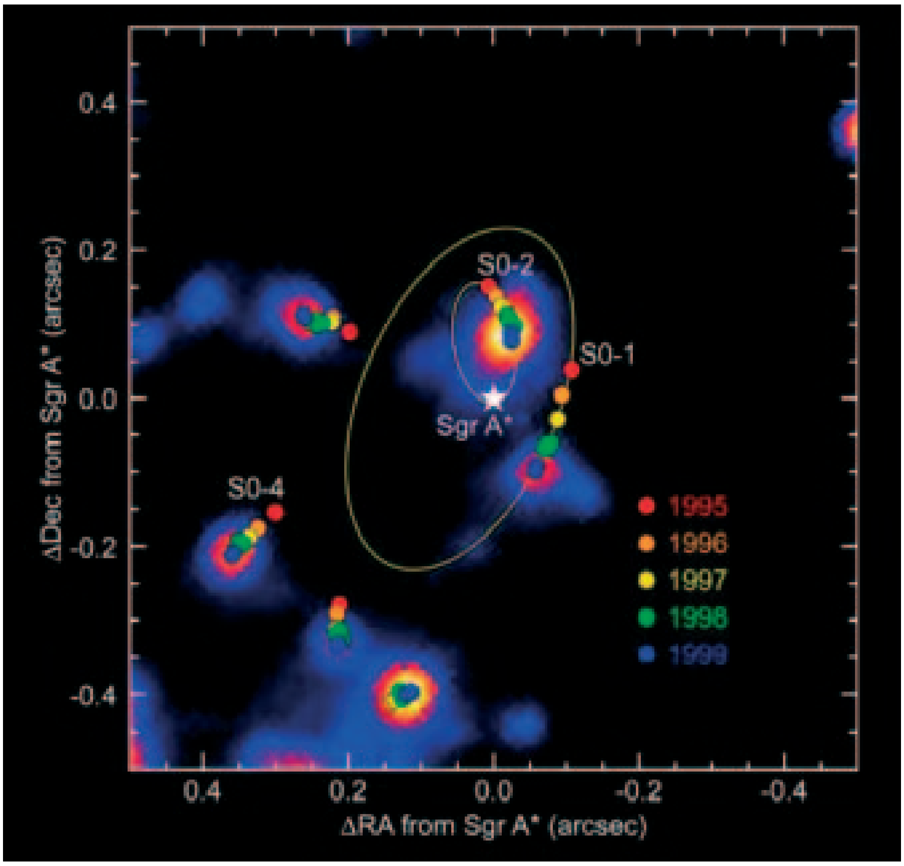
What Are Gravitational Waves ?

In Newton's gravitational theory, the gravitational interaction between two bodies is instantaneous, but according to Special Relativity this should be impossible because the speed of light represents the limiting speed for all interactions. So, if a body changes its shape the resulting change in the force field should make its way outwards no faster than the speed of light.

Einstein's paper on gravitational waves was published in 1916, and that was about all that was heard on the subject for over forty years. It was not until the late 1950s that some relativity theorists, and in particular Herman Bondi (before he became the first Director General of ESRO, ESA's forerunner), proved rigorously that gravitational radiation was in fact a physically observable phenomenon, that gravitational waves carry energy, and that, as a result, a system that emits gravitational waves should lose energy.

Einstein's Theory of General Relativity replaces the Newtonian picture of gravitation by a geometric one that is very intuitive, if we are willing to accept the fact that space and time do not have an independent existence, but rather are in intense interaction with the physical world. Massive bodies then produce 'indentations' in the fabric of 'spacetime', and other bodies move in this curved spacetime taking the shortest path, much like a system of billiard balls crossing a spongy surface. In fact, Einstein's equations formally relate mass (energy) and spacetime curvature in just the same way that Hooke's law relates force and spring deformation. Put more poignantly, spacetime is an elastic medium and if a mass distribution moves in an asymmetric way, then the spacetime indentations travel outwards as ripples in spacetime called 'gravitational waves'.

Gravitational waves are fundamentally different from the familiar electromagnetic waves: the latter are created by the acceleration of electric charges and propagate in the framework of space and time, whereas gravitational waves are created by the acceleration of masses and are waves of the spacetime fabric itself. As early as 1805, Laplace, in his famous Traité de Mécanique Céleste stated that, if gravitation propagates with a finite speed, the force in a binary star system should not point along the line connecting the stars, and the angular momentum of the system must slowly decrease with time. Today we would say that this happens because the binary star is losing energy and angular momentum by emitting gravitational waves. 188 years later, in 1993, Hulse and Taylor were awarded the Nobel Prize for Physics for their indirect proof of the existence of gravitational waves using exactly the kind of observation that Laplace had suggested, on the binary pulsar PSR 1913+16. However, the direct detection of gravitational waves has still not been achieved.



Stellar motions in the vicinity of Sgr A. The orbital accelerations of stars close to the Galactic Centre have been studied with near-infrared high-resolution observations. The resulting data allow constraints to be placed on the position and mass of the central supermassive black hole*

Gravitational waves are only very weakly coupled to matter and, therefore, suffer negligible scattering or absorption. This makes them an ideal cosmological and astrophysical 'information carrier', because all of the gravitational waves that have ever been emitted in the Universe are still traveling untouched through space. The main problem is that the 'straining' of spacetime, i.e. the fractional change in the distance between masses, due to the passage of a gravitational wave, is exceedingly small.

For example, the periodic change in distance between two proof masses, separated by millions of kilometres, due to a typical white dwarf binary at a distance of 50 parsec* is only 10^{-10} m. This is not to say that gravitational waves are weak in the sense that they carry little energy.

** A parsec is a measurement unit for astronomical distances, equivalent to 3.084 x 10^{13} km. There are 3.26 light years in 1 parsec. The nearest star is approximately 1.3 parsec from Earth, the Sun's distance from the centre of our galaxy is about 8500 parsec, and the farthest known galaxy is several billion parsecs away.*

Complementarity with Ground-based Observations

Astronomical observations of electromagnetic waves cover a range of 20 orders of magnitude in frequency, from ULF radio waves to high-energy gamma-rays. Almost all of these frequencies (except for visible and radio) cannot be detected from the ground, and therefore it is necessary to place detectors optimised for a particular frequency range (e.g. radio, infrared, ultraviolet, X-ray, gamma-ray) in space.

The situation is similar for gravitational waves. Ground-based detectors will never be sensitive below about 1 Hz because of terrestrial gravity-gradient noise. A space-based detector is free from such noise and can also be made very large, thereby opening the range below 1 Hz, where both the most certain and the most exciting gravitational-wave sources radiate most of their power.

Ground-based interferometers can observe the bursts of gravitational radiation emitted by galactic binaries during the final stages (minutes and seconds) of coalescence when the frequencies are high and both the amplitudes and frequencies increase quickly with time. At low frequencies, which are only observable in space, the orbital radii of the binary systems are larger and the frequencies are stable over millions of years. Coalescences of Massive Black Holes (MBHs) are only observable from space. Both ground- and space-based detectors will also search for a cosmological background of gravitational waves. Since both kinds of detectors have similar energy sensitivities, their different observing frequencies are ideally complementary: observations can provide crucial spectral information.

The experimental search for gravitational waves was started by Joseph Weber in the early 1960s, at a time when very little was known about their possible sources. He developed the first resonant-mass detector, made of a massive aluminium bar 1.53 m long and 0.66 m in diameter. Weber's bar was at room temperature, had a mass of 1400 kg and a resonant frequency of 1661 Hz. A passing gravitational wave would cause the bar to oscillate at that frequency; a system of piezoelectric transducers would then convert the oscillations into an electrical signal. In order to exclude stochastic noise sources, Weber employed two identical experimental setups, one at the University of Maryland, the other at the Argonne National Laboratory near Chicago, 1000 km away. He recorded several coincident signals and claimed evidence for observation of gravitational waves. These and subsequent observations by Weber were greeted with great excitement in the early 1970s; however, there was also growing scepticism as the observations implied that the strength of the gravitational waves was very much in excess of what was expected for supernovae explosions in our Galaxy.

The sensitivity of the bar detectors can be improved by increasing their mass and by lowering their temperature. Today, three decades after Weber's pioneering experiments, there are five operational bar detectors in different parts of the World all working at cryogenic temperatures and having a higher mass than Weber's bars: EXPLORER at CERN (CH), ALLEGRO in Louisiana (USA), NIOBE in Perth (Aus), NAUTILUS in Rome (I), and AURIGA in Padua (I). They all are about 3 m-long aluminium bars with a mass of 2300 kg and a resonant frequency of about 900 Hz (NIOBE is made of niobium, has a mass of 1500 kg and a resonant frequency of 700 Hz). So far, gravitational waves have not been detected.

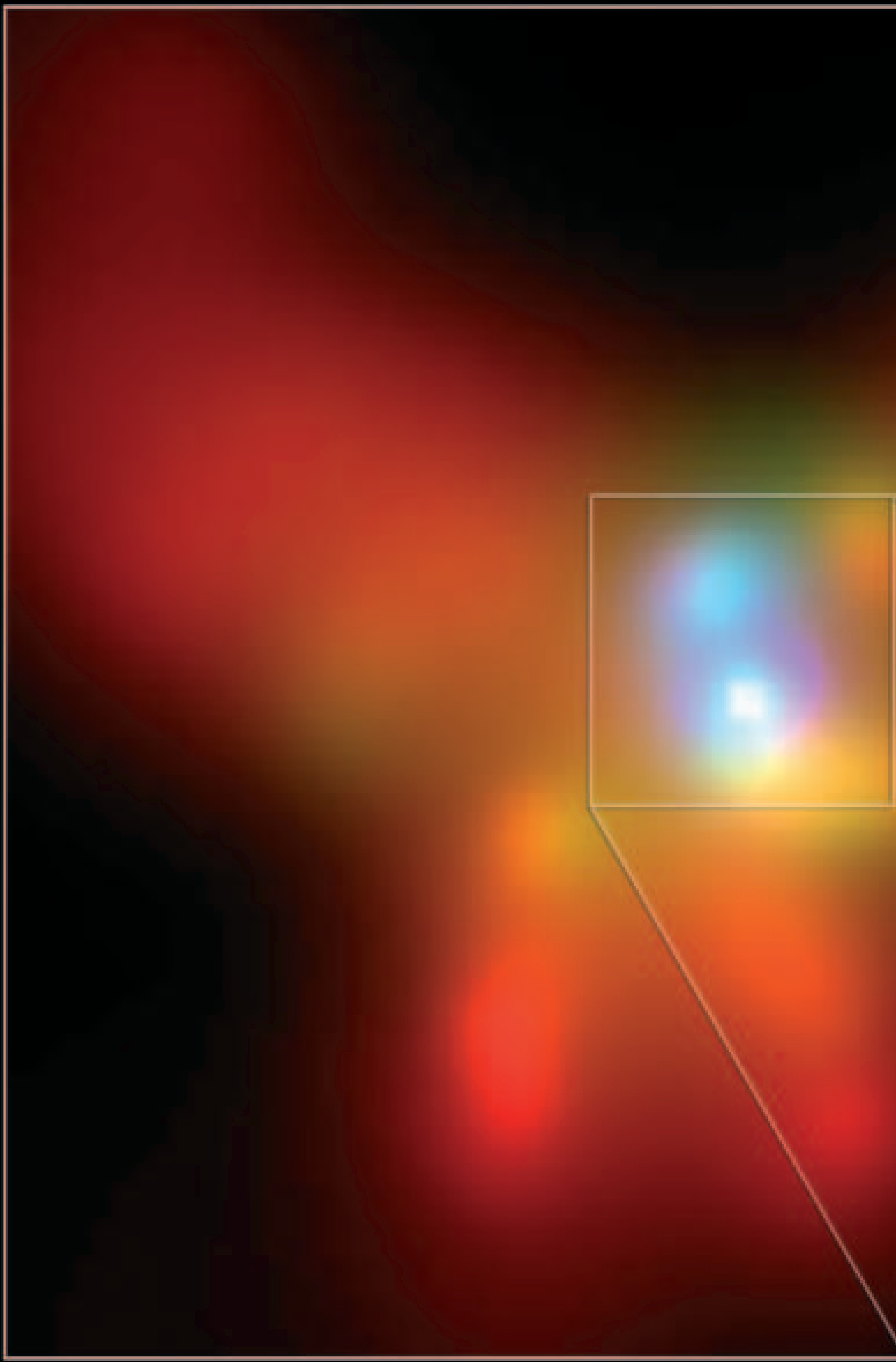
Spherical detectors have several advantages over cylindrical bar detectors. At present small (65 cm diameter) cryogenic spherical detectors (resonant frequency 3250 Hz) are becoming operational at Leiden University in The Netherlands and at the University of São Paulo in Brazil as precursors for later large spherical detectors up to 3 m in diameter.

In the early 1970s the idea emerged that Michelson interferometers using laser light might have a better chance than bars of detecting gravitational waves. The technology and techniques for such laser interferometers have now been under development for nearly 30 years. Today, six interferometers are either under construction or already operational:

in the USA		*In Europe*	
Hanford (Washington):	4 km arm length (LIGO)	near Pisa, Italy:	3 km arm length (VIRGO)
	2 km arm length (LIGO)	Hannover, Germany:	600 m arm length (GEO600)
Livingston (Louisiana):	4 km arm length (LIGO)		
in Japan			
Tokyo, Japan:	300 m arm length (TAMA300)		

LIGO, GEO600 and TAMA300 have already begun data runs. However, the sensitivity of the first-stage detectors may be only marginally sufficient to detect gravitational waves. Therefore, step-by-step improvements will be made until the network finally reaches the advanced detector sensitivity goal sometime between 2005 and 2010.

On the contrary, a supernova in a not too distant galaxy will drench every square metre here on Earth with kilowatts of gravitational radiation intensity. The resulting length changes, though, are very small because spacetime is an extremely stiff elastic medium and so it takes extremely large energies to produce even minute distortions.



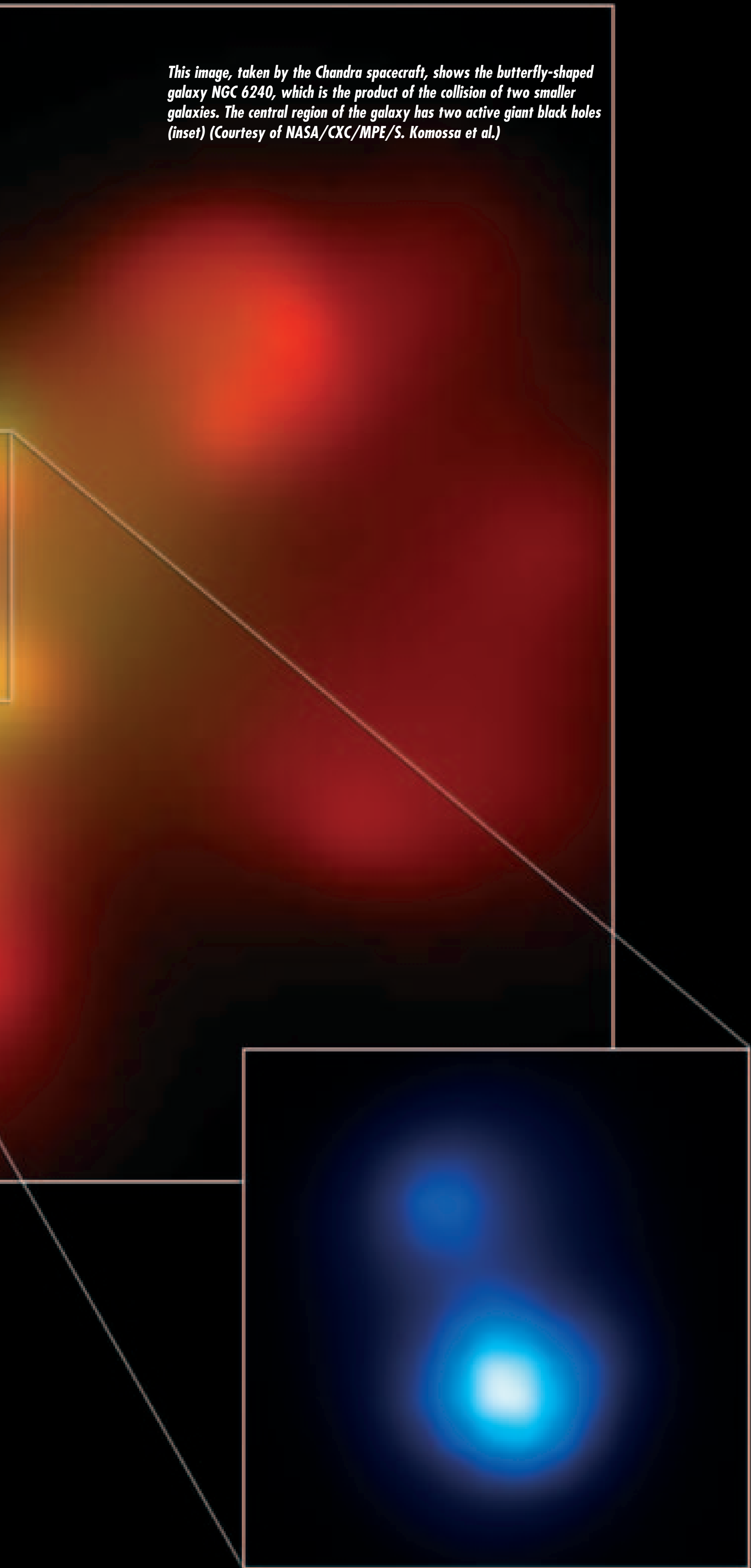
Where Do Gravitational Waves Come From ?

The two main categories of sources for the gravitational waves for which LISA will be searching are galactic binary star systems and massive black holes expected to exist in the centres of most galaxies. Because the masses involved in typical binary star systems are small (a few times the mass of the Sun), the observation of binaries is limited to our own Galaxy. Galactic sources that can be detected by LISA include a wide variety of binaries, such as pairs of close white dwarfs, pairs of neutron stars, neutron-star and black-hole (5 to 20 solar masses) binaries, pairs of contacting normal stars, normal-star and white-dwarf (cataclysmic) binaries, and possibly also pairs of black holes. Some galactic binaries are already so well studied that they are considered to be 'calibration sources'. One such example is the X-ray binary 4U1820-30, located in the globular cluster NGC 6624. If LISA would not detect the gravitational waves from such known binaries with the intensity and polarisation predicted by the Theory of General Relativity, it would shake the very foundations of gravitational physics!

The main objective of the LISA mission, however, is to learn about the formation, growth, space density and surroundings of massive black holes. There is now compelling indirect evidence for the existence of massive black holes with masses 10^6 to 10^8 times that of the Sun in the centres of most galaxies, including our own. The most powerful sources are the mergers of massive black holes in distant galaxies. Observations of signals from these sources would test General Relativity and particularly black-hole theory to unprecedented accuracy. Little is currently known about black holes with masses ranging from about 100 to 10^6 times that of the Sun and LISA can provide unique new information throughout this mass range.

During the gravitational capture of a star by a black hole, gravitational waves will be continuously emitted, allowing an accurate map to be made of the spacetime surrounding the black hole. It will therefore finally be possible to verify whether the 'black holes have no hair' theorem* is true.

* *The 'black holes have no hair' theorem was introduced by John Wheeler in the early 1970s as a principle predicting the simplicity of the stationary black-hole family. The theorem shows that mass, charge, and angular momentum are the only properties that a black hole can possess.*



This image, taken by the Chandra spacecraft, shows the butterfly-shaped galaxy NGC 6240, which is the product of the collision of two smaller galaxies. The central region of the galaxy has two active giant black holes (inset) (Courtesy of NASA/CXC/MPE/S. Komossa et al.)

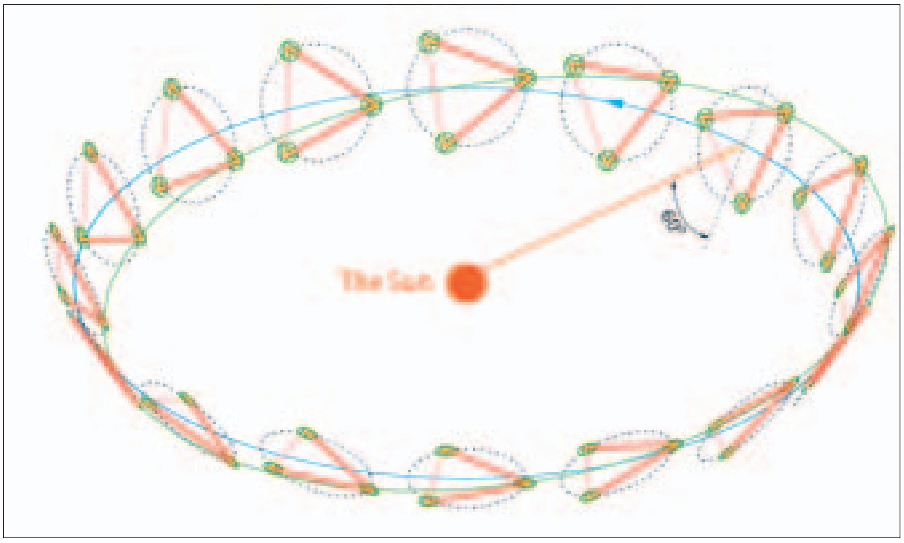
The LISA Mission

The key scientific goals for the LISA mission are to:

- determine the role of massive black holes in galaxy evolution by observing gravitational waves emanating from their coalescence
- make precise tests of Einstein's Theory of General Relativity by observing gravitational waves from the capture of dense compact objects by massive black holes
- determine the population of compact binaries in our Galaxy by observing the gravitational wave signals that they emit
- probe the physics of the early Universe by observing cosmological backgrounds and bursts.

Achieving these scientific goals requires three identical spacecraft positioned 5 million kilometres apart at the corners of an equilateral triangle. The distance between the spacecraft (the arm length of what is effectively a Michelson interferometer) determines the frequency range in which observations can be made. The centre of the triangular formation is in the ecliptic plane, at the same distance from the Sun as the Earth, and trailing the Earth by approximately 20 degrees. This position behind the Earth is a result of a trade-off between minimising the gravitational disturbances from the Earth-Moon system and the communications needs. Going farther away would further reduce the disturbances, but the greater distance would require larger antennas or higher transmitter powers. The plane of the spacecraft triangle is inclined by 60 degrees with respect to the ecliptic, which means that the formation is maintained throughout the year, with the triangle appearing to counter-rotate about the centre of the formation once per year.

While LISA can be described as a Michelson interferometer in space, the actual implementation is somewhat different from that of a ground-based interferometer. The laser light going out from the prime spacecraft to the other corners is not directly reflected back because very little light would be received that way. Instead, the laser on the receiving spacecraft is phase-locked to the incoming light, generating a



LISA consists of a constellation of three spacecraft flying in formation at the corners of an equilateral triangle, inclined at 60 degrees with respect to the ecliptic plane, in a heliocentric orbit. The equilateral triangle performs a complete rotation around its centre during one year, while rotating around the Sun. This concept permits detection of the direction of the gravitational wave sources

return beam of full intensity. The transponded light from the spacecraft is received by the other one on the same arm and superposed with the onboard laser light that serves as the local oscillator in a so-called 'heterodyne detection'. As this entwines laser frequency noise with a potential gravitational wave signal, the signal from the other arm is used to take out the laser frequency noise and obtain the pure gravitational wave signal.

The nature of the elliptical orbits flown by the three spacecraft, and to a lesser extent the gravitational perturbations caused by the Earth, the Moon and the large planets, are sufficient to perturb the triangular formation and cause relative velocities between the spacecraft of up to 20 m/s. In the course of a year, therefore, the distances between the spacecraft can change by many thousands of kilometres. The relative velocity causes the transponded light to be Doppler-shifted by up to 20 MHz. The resulting signal is well outside the LISA detection band and can be removed by onboard data processing.

As each spacecraft has a launch mass of approximately 460 kg (including the payload, propulsion module, propellants and launch adapter), all three can be launched by a single Delta-IV. After launch, the trio separate and use their own propulsion modules to reach their operational orbits 13 months later. Once there, they will jettison their propulsion modules and their attitude and drag-free control will be left to the micro-Newton thrusters on each spacecraft.

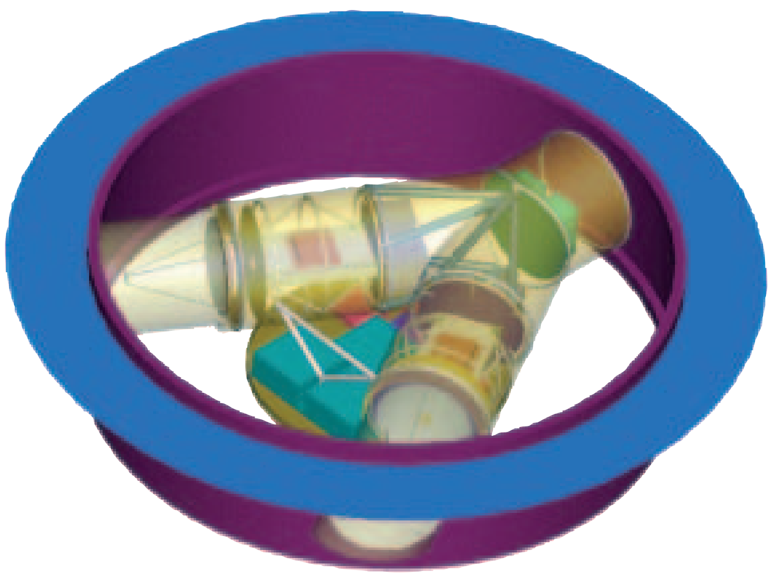
Each spacecraft carries two 30 cm-diameter, steerable high-gain antennas for communication with the Earth. Using the 34 m antennas of the Deep-Space Network and 5 W transmitter power, data can be transmitted (in X-band) at a rate of 7 kbit/s for 8 hours every two days, and stored onboard in 1 Gbyte of solid-state memory at other times. The nominal mission lifetime is 5 years once the spacecraft have reached their operational orbits.

How Will the Gravitational Waves Be Detected ?

The principle of a gravitational wave detector in space is relatively simple: the distances between two or more test masses free to follow geodesics (i.e. in free fall) are changed by the passing of a gravitational wave. The detection of the gravitational wave and the measurement of its strength are directly derived by the interferometric measurement of the distance between the test masses.

Each spacecraft carries two optical assemblies, which point towards an identical assembly on the other two spacecraft. In this way, the three spacecraft form two independent Michelson interferometers, thereby providing redundancy. An infrared laser beam (1 W and 1064 nm wavelength) is transmitted to the corresponding remote spacecraft via a 30 cm-aperture f/1 Cassegrain telescope. The same telescope is used to focus the very weak beam (a few pW) coming from the distant spacecraft and to direct the light to a sensitive photodetector (a quadrant photodiode), where it is superimposed with a fraction of the original local light.

At the heart of each assembly is a vacuum enclosure containing a free-flying polished



Each of the three LISA spacecraft will carry two telescopes arranged in a Y-shaped tube, with associated lasers and optical systems, pointing in directions separated by 60 degrees. The telescopes will communicate with the spacecraft at the other two corners of the equilateral triangle. Central to each optical system will be the 'proof mass', a 4.6 cm-sided cube made from a gold-platinum alloy. This proof mass acts as a reflector for the laser beams

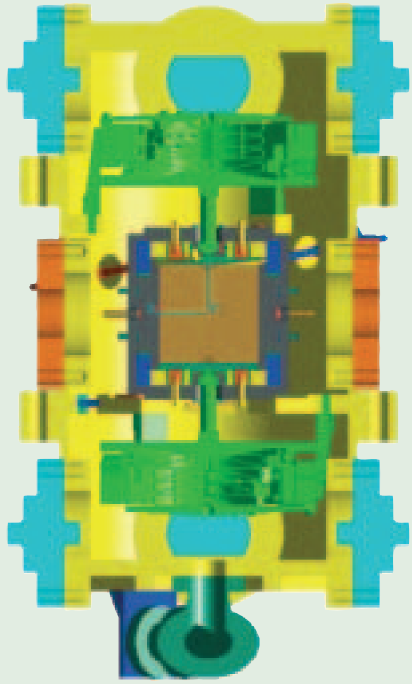
The LISA Technology Package

The LTP represents one arm of the LISA interferometer, in which the distance between the two proof masses is reduced from 5 million km to about 30 cm. As for the LISA mission itself, the proof masses play a double role, serving as optical references (mirrors) for the interferometer and as inertial sensors for the Drag-Free Attitude Control System (DFACS).

The two identical proof masses (4.6 cm cubes) are housed in individual vacuum cans. Capacitive sensing in three dimensions measures their displacement with respect to their housings. These position signals are used in a feedback loop to command micro-Newton thrusters to enable the spacecraft to remain centred on the proof mass. Field Emission Electric Propulsion (FEEP) thrusters and cold-gas proportional thrusters will be used as actuators. Although the proof masses are shielded from non-gravitational forces by the spacecraft, cosmic rays and solar-flare particles can significantly charge them, leading to electrostatic forces. A system of fibre-coupled UV lamps will discharge the proof masses at regular intervals. As surface effects can also cause electrostatic forces, the proof masses have to be coated very carefully to avoid contamination.

As each proof mass is designed to 'float' in space, surrounded by gaps of several millimetres, a caging mechanism is needed to maintain them in a safe position during launch. The mechanism must apply the necessary loads without damaging the coating of the proof masses and the surrounding electrodes. It must also be capable of repositioning the masses correctly afterwards, in order to allow the weak capacitive actuators to re-take control.

The positions of the proof masses with respect to the spacecraft or each other are measured by an interferometric system that is capable of picometre precision in the frequency range 10^{-3} Hz – 10^{-1} Hz. The residual temperature fluctuations aboard the spacecraft require the use of materials with very small coefficients of thermal expansion.



The LTP inertial sensor. The proof mass is surrounded by the electrode housing and is located in a vacuum enclosure. Optical windows allow the laser beam to be reflected by the face of the cube. UV optical fibres within the enclosure illuminate the cubes in order to discharge any charging produced by cosmic rays. The proof mass is kept in a safe position during launch by a 'caging' mechanism.

The Disturbance Reduction System (DRS) is a NASA-supplied system with the same mission goals as LTP, but using slightly different technology. Its baseline design foresees two inertial sensors and an interferometric readout similar to that planned for LTP. However, the thrusters for the drag-free control system use ionised droplets of a colloid accelerated in an electric field to provide propulsion. In this way LISA Pathfinder will effectively test two drag-free attitude control systems and three different micro-propulsion thruster technologies.

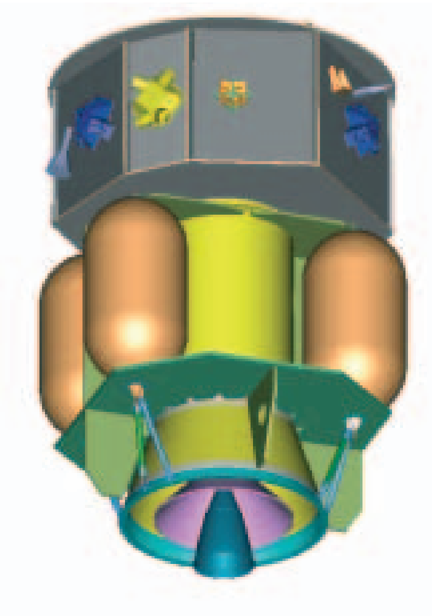
platinum-gold 46 mm cube - the so-called 'proof mass' - that serves as the optical reference (mirror) for the light beams. A passing gravitational wave will change the length of the optical path between the proof masses of one arm of the interferometer relative to the other arm. The distance fluctuations are measured to a precision of 40 pm (averaged over one second) which, when combined with the large separation between the spacecraft, allows LISA to detect gravitational wave strains with great accuracy (down to a level of order $\Delta L/L = 10^{-23}$ in 1 year of observation with a signal-to-noise ratio of 5).

The spacecraft serves mainly to shield the proof masses from the adverse effects of solar radiation pressure, so that they follow a purely gravitational orbit. Although the position of the spacecraft does not enter directly into the measurement, it is nevertheless necessary to keep all spacecraft moderately accurately centred on their respective proof masses to reduce spurious local noise forces. This is achieved by means of a 'drag-free' control system (explained below) consisting of test-mass position sensors and a system of micro-Newton thrusters.

Capacitive sensing in three dimensions measures the displacements of the proof masses relative to the spacecraft. These position signals are used in a feedback loop to command Field Emission Electric Propulsion (FEEP) thrusters to follow the proof masses precisely. As a reference point for the drag-free system, one of the masses (or any point between) can be chosen. The FEEP thrusters are also used to control the attitude of the spacecraft relative to the incoming optical wavefronts.

The LISA Pathfinder Mission

Despite the simplicity of the LISA mission concept, the technological challenges faced to achieve it are enormous. The main difficulty is to make the test masses follow



CAD drawing of the LISA Pathfinder spacecraft, with the science package containing the LTP and the DRS sitting atop the propulsion module, which will carry it out to the L1 halo orbit

a geodesic, near-perfect free-fall trajectory by employing a so-called 'drag-free' system. This implies keeping each proof mass within an enclosure that suppresses the disturbances from the external forces (e.g. aerodynamic, radiation pressure and other disturbances of the surrounding space environment) and the internal forces (e.g. self-gravity, electro-magnetic forces and other forces coming from the spacecraft itself).

This protection is achieved by a combination of extremely accurate construction of the entire spacecraft and the use of a sophisticated Drag-Free Attitude Control System (DFACS). The DFACS is based on measurements of the displacement of the test masses inside their enclosures using capacitive sensors and a laser metrology system and it controls the motion of the spacecraft surrounding the proof masses by means of ultra-precise micro-propulsion thrusters.

On Earth, one can never reproduce the free-fall conditions required to quantitatively prove the correct working in space of the DFACS. It was to demonstrate this and the other key technologies needed for the LISA mission that ESA decided to undertake the LISA Pathfinder precursor project (formerly the SMART-2 mission). The Pathfinder will accommodate a LISA Technology Package (LTP) provided by European institutes and industry, and a Disturbance Reduction System (DRS) that is very similar to the LTP and has the same goals, but is provided by NASA.

The LTP (see previous page) will:

– demonstrate DFACS in a spacecraft with two proof masses with a performance of the order of 10^{-14} $ms^{-2}/\sqrt{Hz}$ in the bandwidth 10^{-3} – 10^{-1} Hz (the LISA requirement is an order of magnitude higher at 10^{-15} $ms^2/\sqrt{Hz}$)
– demonstrate the feasibility of performing laser interferometry in the required low-frequency regime with a performance as close as possible to that required for the LISA mission ($10^{-11}m/\sqrt{Hz}$ in the frequency band 10^{-3} Hz – 10^{-1} Hz)
– assess the longevity and reliability of the LISA sensors, thrusters, lasers and optics in the real space environment.

As the environment on the LISA Pathfinder spacecraft will be comparatively 'noisy' in terms of temperature fluctuations and residual forces, the Pathfinder technology demonstrator is deliberately aimed at meeting specifications that are about a factor of 10 more relaxed than those for LISA itself.

The LISA Pathfinder spacecraft is a simple-looking octagonal box, about 1 m high and 2.1 m in diameter, with a small fixed solar array mounted on the top). The LTP is mounted above the DRS, inside the central core of the spacecraft, the two experimental packages being separated by a horizontal floor.

LISA Pathfinder will be launched in early 2008 by a small European vehicle into a low Earth orbit. Like LISA, it will use its own propulsion module to reach its operational 'halo orbit' around the Sun-Earth Lagrangian point (L1) about 1.5 million km from Earth. This orbit has been selected because it provides a quiet

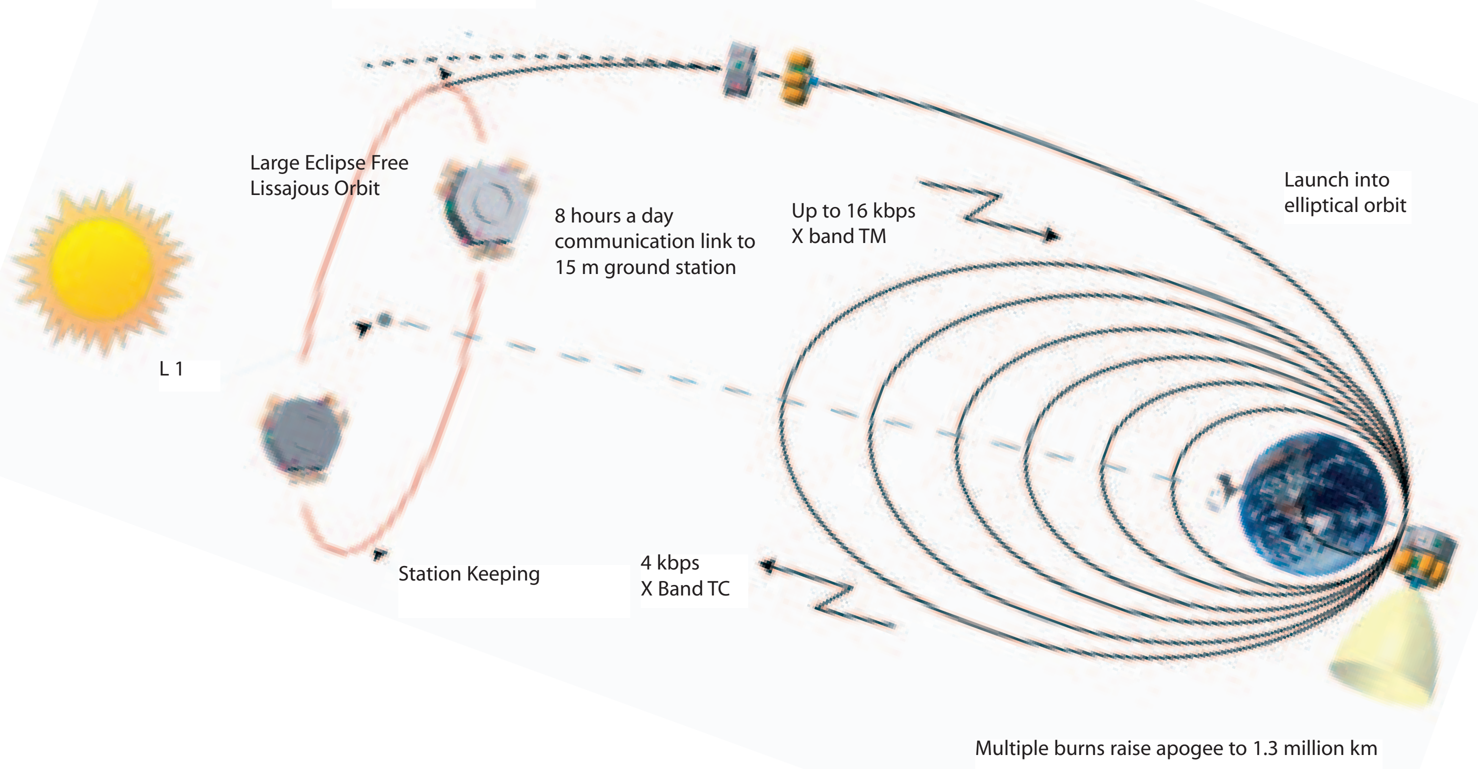
Current Project Status

LISA is a NASA/ESA collaborative project that is currently under development. The sharing of management responsibilities and provision of mission elements between the two agencies is presently being negotiated on the basis of ESA taking responsibility for overall payload integration and testing and NASA for the provision of the three spacecraft, the launch vehicle, and the ground segment (Deep Space Network), including the mission operations. The science operations will also be shared.

The payload will be shared 50/50, with the European elements funded by national space agencies in the ESA Member States. The scientific data will be analysed by two independent data-analysis teams, one in Europe and one in the USA.

In November 2003, ESA's Science Programme Committee (SPC) decided to include ESA's share of the LISA mission in the Agency's long-term plan for space science. Preparations for a two-year system level industrial study, starting in October this year, are in progress. The SPC also decided to include the LISA Pathfinder precursor project, subject to affordable Cost at Completion and formally secured LTP payload funding. In June 2004, the SPC approved the financial envelope for the project and recommended to Council to approve the draft LTP Multilateral Agreement between ESA and those Member-State funding agencies providing elements of the LTP.

Since March 2004, LISA Pathfinder has been in the Implementation Phase, with Astrium (UK) as the Prime Contractor. The industrial contract was officially signed at a ceremony on 23 June. The System Requirements Review, the first milestone during the Implementation Phase, was completed with the Board meeting on 25 June.



The transfer trajectory sequence, for which 11 separate burns of the propulsion module are needed to progressively raise the orbit's apogee and achieve injection into the L1 halo orbit

environment in terms of 'tidal forces' (produced in the vicinity of massive bodies, from which L1 is sufficiently far away), thermal stability, magnetic field, and radiation, is reachable year-round, and also allows daily visibility from a single ground station. The 'halo' in fact is a three-dimensional orbit with a shape similar to the contour of a potato chip.

Following the orbital transfer, initial set-up and calibration phases, the in-flight demonstration of the LISA technology, consisting of 90 days of LTP, 70 days of DRS, and 20 days of joint operations, will take place in the second half of 2008, thereby providing timely feedback for the development of the LISA mission itself.

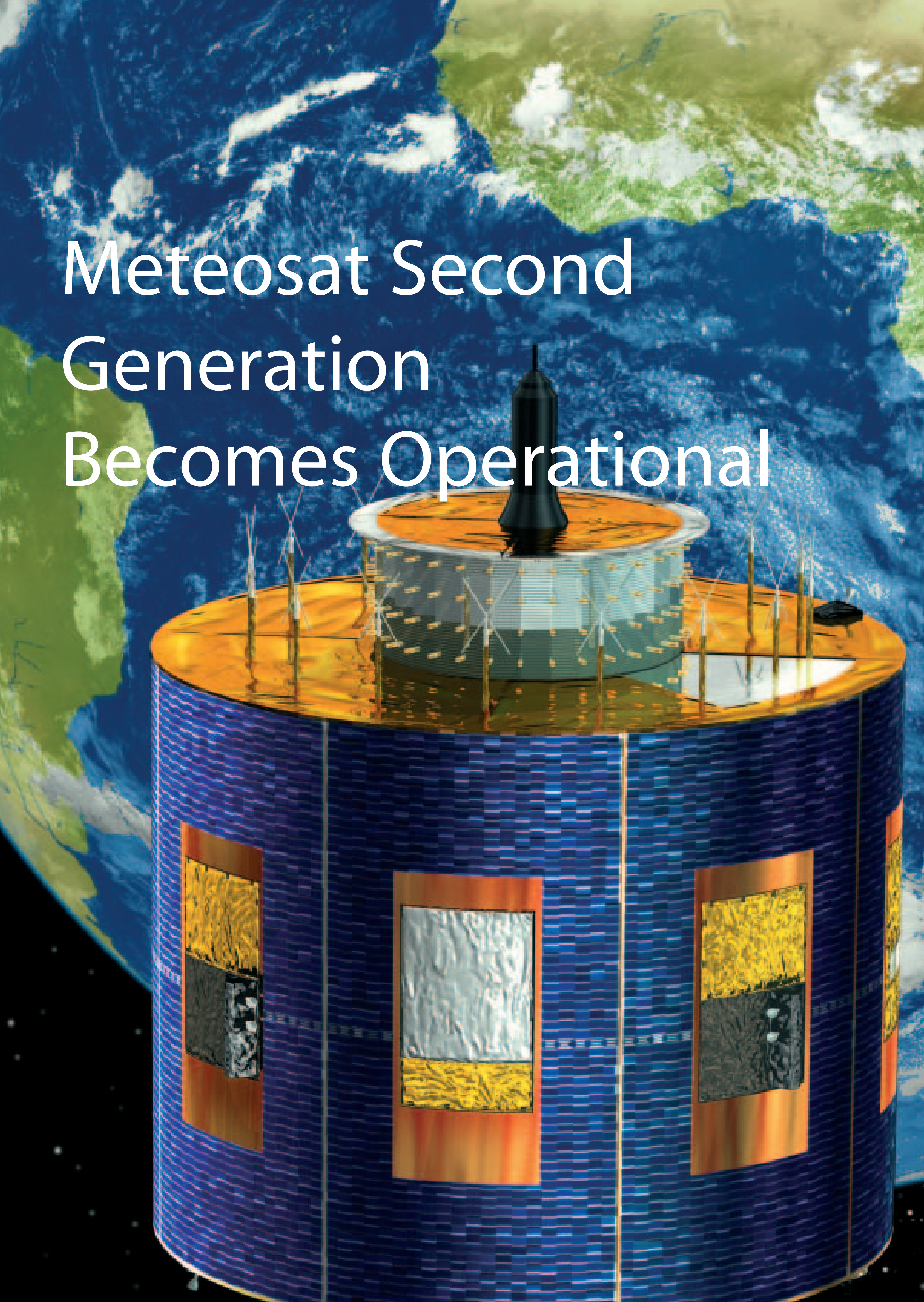
What the Future Holds

As the first space-based gravitational wave detector, LISA is an extremely ambitious programme that has the potential to open a radical new window on astronomy. We will be able to look at the Universe in a completely new way and we are expecting great discoveries, possibly even a quantum leap in our present understanding of the most powerful cosmic events. The technological challenge, however, is enormous. Extremely delicate measurements will have to be performed by highly sophisticated spacecraft, capable of harnessing all of nature's forces and yet still able to listen for the 'whisper' of gravitational waves.

LISA Pathfinder, though not able itself to detect gravitational waves due to its single spacecraft configuration, will thoroughly test the gravitational wave detection technologies and pave the way for the unique LISA gravitational wave observatory, which will be the largest ever manmade 'construction' in space.

On 2 April 2004, ESA's Directorate of Scientific Programmes issued a Call for Themes for the Agency's Cosmic Vision 2015-2025 Programme. Among the 150 proposals submitted by the scientific community were several for research themes to follow up the LISA mission. They range from studies of gravitational-wave cosmology, to the search for dark matter and missing baryonic matter, to the search for super-massive black holes in the Universe. These proposals illustrate just how much interest the LISA mission is generating in the astronomy and astrophysics communities with its inherent promise of providing a completely new view of the Universe, perhaps heralding a revolution similar to those brought by the births of radio and X-ray astronomy.

Meteosat Second Generation Becomes Operational



Wolfgang Schumann & Rob Oremus
Projects Department, ESA Directorate of Earth Observation,
ESTEC, Noordwijk, The Netherlands

Sergio Rota & Jochen Kerkmann
EUMETSAT, Darmstadt, Germany

A series of four Meteosat Second Generation (MSG) satellites will provide more comprehensive and more frequent data to meteorologists and climate-monitoring scientists for at least the next 14 years. They will bring about a step change in the accuracy of our weather forecasting systems, with considerable benefits for people both in Europe and further afield.

These four geostationary satellites are being developed based on the combined expertise of ESA and EUMETSAT (the European Organisation for the Exploitation of Meteorological Satellites). With a thorough understanding of users' needs, EUMETSAT is making a major investment in the overall programme, including development of the ground segment, procurement of the launchers and follow-on satellites and operation of the MSG system from its own Mission Control Centre in Darmstadt, Germany.

Geostationary meteorological satellites deliver frequent and high-quality images of one quarter of the Earth's disc. In this orbit, a satellite circles the Earth at the same speed as the planet rotates, and therefore seems to 'hover' in one place – in the case of MSG above the Gulf of Guinea at 3.4 degW off the west coast of Africa. From this vantage point it provides imagery of Europe, Africa, part of the Indian Ocean, and the eastern part of South America.

With its first-hand experience from the first generation of Meteosats, ESA was ideally placed to develop the MSG satellites for EUMETSAT. For the development of the first of the four satellites, MSG-1, ESA contributed two-thirds of the initial investment, with the remaining third coming from EUMETSAT. The satellites are built by Alcatel Space, involving more than 50 subcontractors from 13 European countries. EUMETSAT funds all of the MSG-2/3/4 related activities, with ESA retaining the technical and procurement role for the satellite prime contractor.

The Launch and Early Life of MSG-1

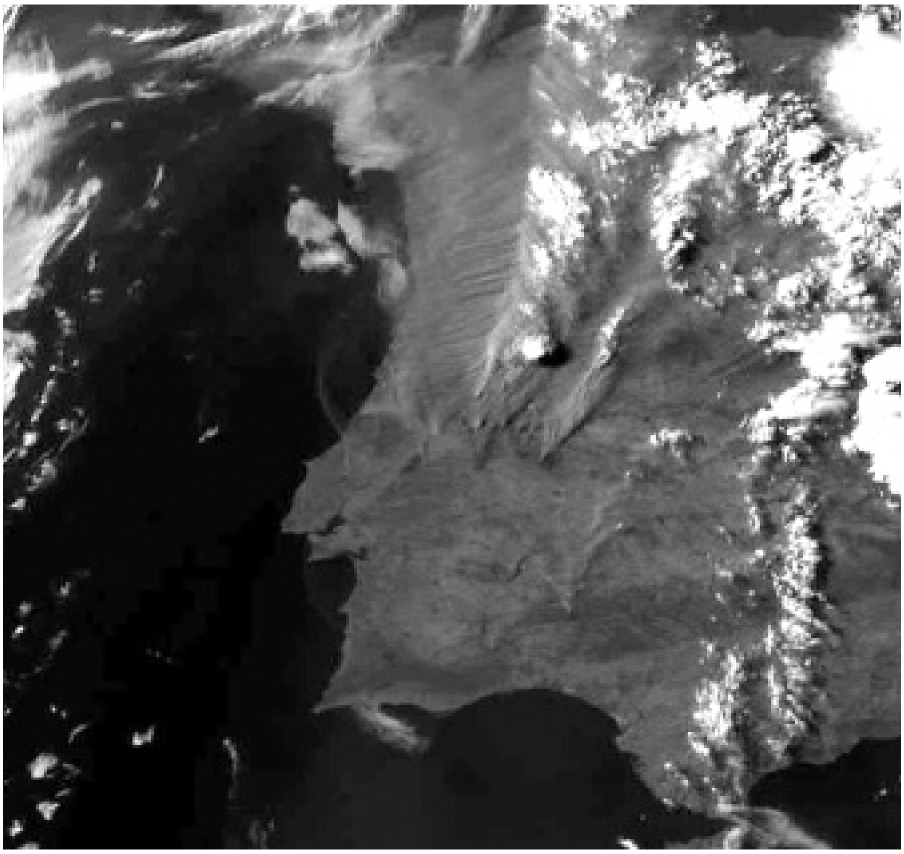
MSG-1 was successfully launched, with its co-passenger Atlantic Bird, on 28 August 2002 by an Ariane-5. The accuracy of the orbital injection provided by Ariane was excellent. ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, assumed control of the spacecraft after its separation from the launcher and successfully performed the manoeuvres required to take it from the Ariane injection orbit to a quasi-geostationary orbit drifting slowly towards the commissioning longitude of 10.5 degW. During this drift phase the spacecraft successfully survived several eclipses, the protective covers of its main instrument, SEVIRI (Spinning Enhanced Visible and Infrared Imager), were jettisoned, and the Imager's launch-locking device was released.

MSG-1 sets out on its mission, with its Ariane-5 launch on 28 August 2002

Following a successful Commissioning Readiness Review, Eumetsat assumed control of MSG-1 on 25 September 2002 as planned, after two days of interleaved spacecraft operations with ESOC. EUMETSAT began commissioning the satellite at the beginning of October, with spacecraft platform and communication payload tests.

The MSG-1 spacecraft in the Integration Hall in Kourou, French Guiana, shortly before launch

In the early hours of Thursday 17 October, an amplifier on the satellite switched off unexpectedly, at a time when operating conditions were otherwise nominal. After the occurrence of this anomaly, the solid-state power amplifier (SSPA) in question could not be switched back on, causing substantial delays and changes in the execution of commissioning tasks. An Inquiry Board was set up by ESA and, following its initial recommendations, commissioning activities were restarted in November 2002 with the communication payload in minimum-output-power mode supporting only the raw data downlink. The onboard data-dissemination capability was not reactivated, although redundant SSPA units were available, in order to safeguard the mission. The first SEVIRI



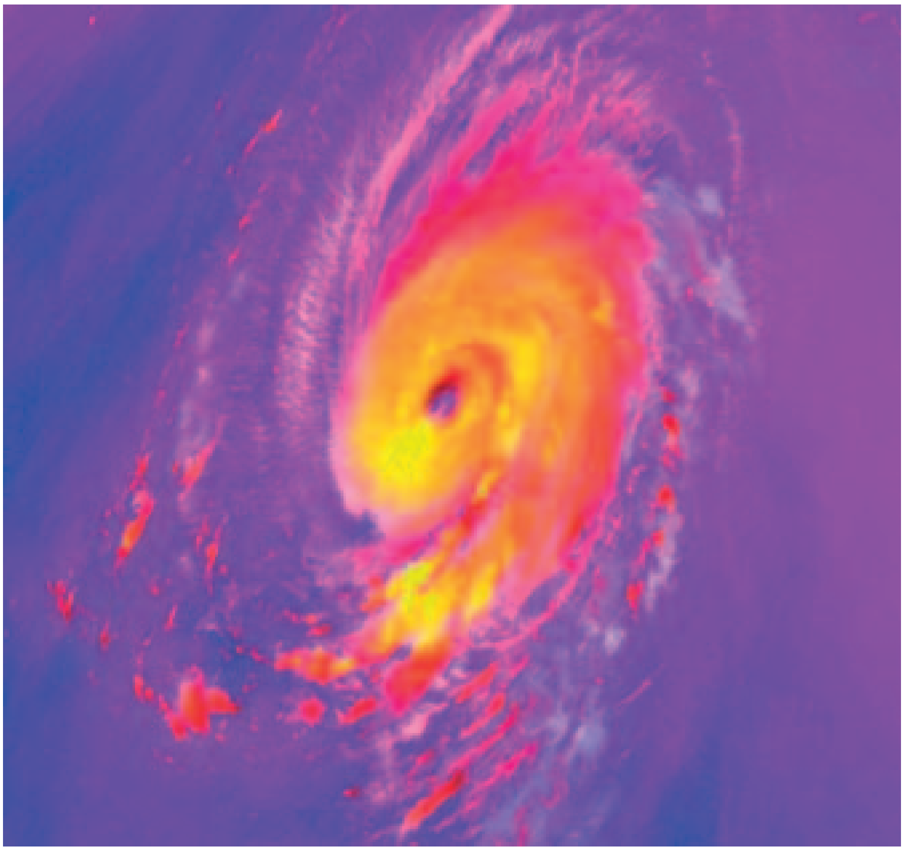
At the beginning of August 2003, in conjunction with the heat-wave over Western and Central Europe, Portugal was hit by the most devastating forest fires of the last 100 years. Thousands of firemen battled for weeks to keep the blazes under control. More than 10 people were killed and more than 50 000 hectares of forest were burned. Spain was also affected, but to a lesser extent. MSG, with its channels in the visible and near-infrared spectral range, provided near-real-time information concerning the locations of the fires and the extent of the smoke plumes.
Meteosat-8, 03 August 2003, 17:00 UTC, Channel 12 (HRV)

image was successfully acquired on 28 November, and the first GERB (Global Earth Radiation Budget) instrument image on 12 December 2002.

The results of the SSPA Inquiry Board investigations were presented on 7 April 2003. Extensive analyses and a testing campaign at equipment and component level followed, resulting in proposed design modifications to the SSPAs destined for the MSG-2/3/4 satellites. For MSG-1, the initial precautions that had been taken were substantially confirmed as correct and the onboard data-dissemination capability was not re-activated, maintaining the spare SSPA for the Raw Data channel instead. EUMETSAT therefore assessed alternative dissemination methods, based on commercial services providing Digital Video Broadcasting (DVB). The dissemination trial began over Europe at the end of April 2003 using the Ku-band. In parallel, a C-band dissemination service was studied and its implementation over Africa initiated.

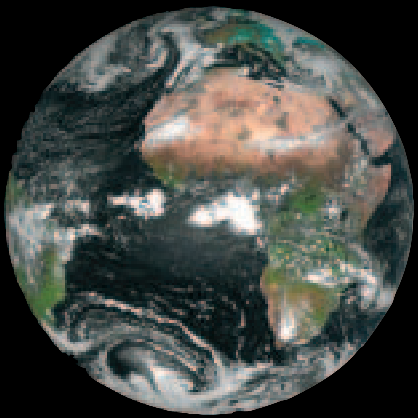
The Satellite and System Commissioning

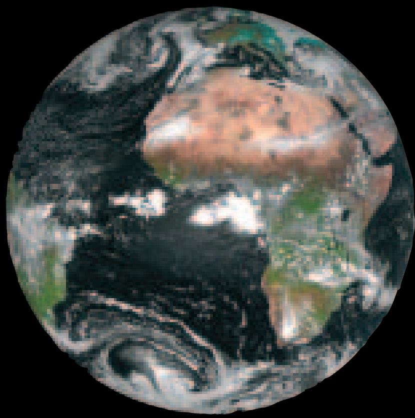
Commissioning is the final phase of verification of the performance of the complete system versus the applicable

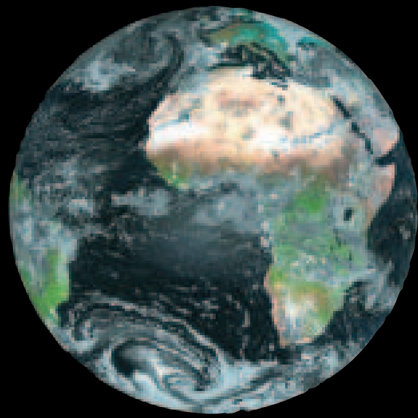


In September 2003, MSG monitored the development of Hurricane Isabel, which was 'born' on 7 September southwest of the Cape Verde Islands. On 13 September, it developed into the first category-5 hurricane (mean wind speed of more than 260 km/h) since Hurricane Mitch in 1998. It then degraded to a category-2 hurricane on 16 September, before making landfall in Northern Carolina and Virginia on 18 September, with winds of up to 160 km/h. In this image, orange to red shows high-level ice clouds with large ice particles, while yellow represents high-level ice clouds with small ice particles. The most active parts of the hurricane with the most severe precipitation are visible in an intense yellow colour to the southwest of the eye of the storm, and in the spiral band further to the south of the storm centre.
Meteosat-8, 8 September 2003, 12:00 UTC, RGB composite WV6.2-WV7.3, IR3.9-IR10.8, NIR1.6-VIS0.6

The Applications of Met







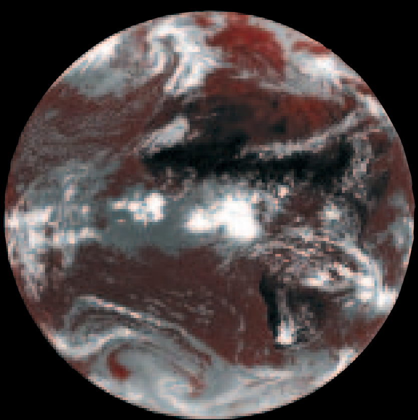
CHANNEL 1: VISIBLE 0.6
(0.56 - 0.71 µm)

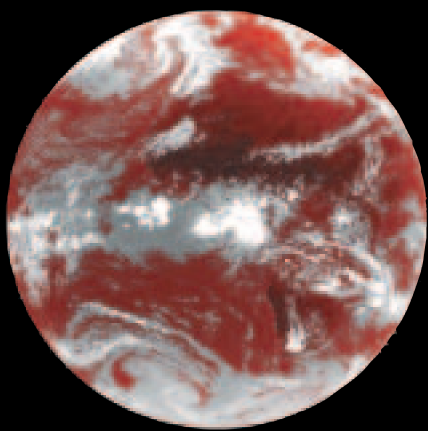
CHANNEL 2: VISIBLE 0.8
(0.74 - 0.88 µm)

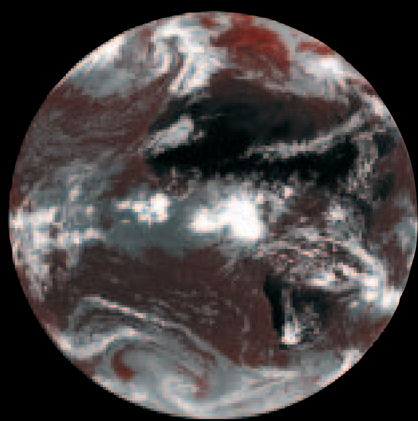
These channels are essential for cloud detection, cloud tracking, scene identification and the monitoring of land surfaces and aerosols. Together with channel 3 they can be used to generate vegetation indices.

CHANNEL 3: NEAR-INFRARED 1.6
(1.50 - 1.78 µm)

Helps to discriminate between snow and cloud, and between ice and water clouds. Also provides aerosol information.







CHANNEL 7: INFRARED 8.7
(8.3 - 9.1 µm)

Used mainly to provide quantitative information on thin cirrus clouds and to support the discrimination between ice and water clouds.

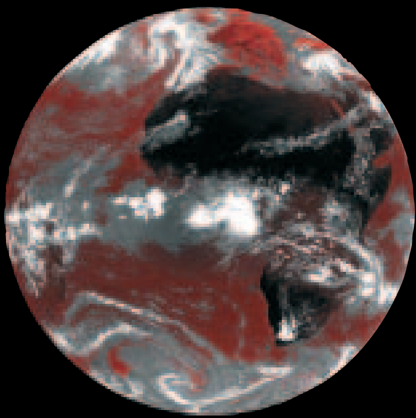
CHANNEL 8: INFRARED 9.7
(9.38 - 9.94 µm)

Responsive to ozone concentration in the lower stratosphere. It will be used to monitor total ozone and assess diurnal variability. Potential for tracking ozone patterns as an indicator of wind fields at that level.

CHANNEL 9: INFRARED 10.8
(9.8 - 11.8 µm)

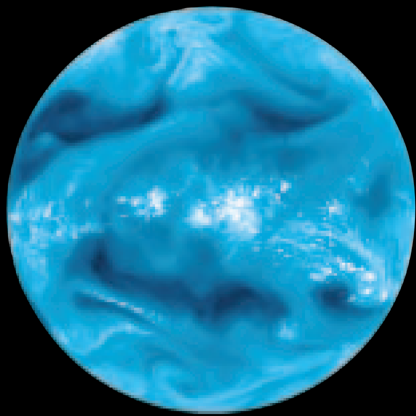
The so-called split-window thermal infrared channels. Each responds to the temperature of clouds and the surface. By splitting this part of the thermal infrared, each channel has a slightly different response with respect to clouds and the Earth's surface. Used together helps to reduce atmospheric effects when measuring surface and cloud top temperatures. Also used for cloud tracking for atmospheric winds and for estimates of atmospheric instability.

teosat Second Generation

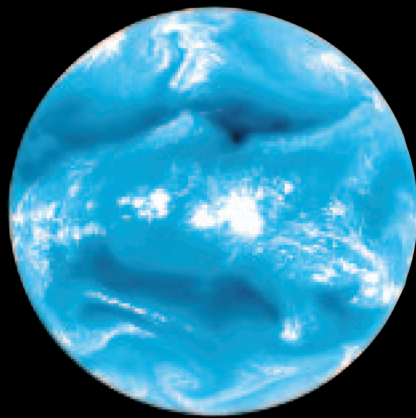


CHANNEL 4: INFRARED 3.9
(3.48 - 4.36 μm)

Primarily for detection of low cloud and fog at night, but also useful for measurement of land and sea temperatures at night and the detection of forest fires.

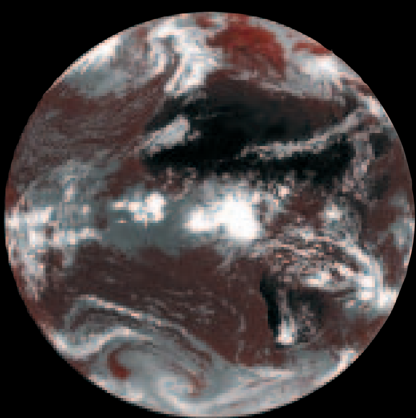


CHANNEL 5: WATER VAPOUR 6.2
(5.35 - 7.15 μm)

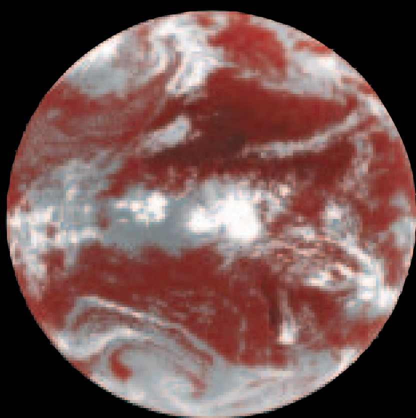


CHANNEL 6: WATER VAPOUR 7.3
(6.85 - 7.85 μm)

Provides continuity of the Meteosat first generation broadband water vapour channel to measure mid-atmospheric water vapour and to produce tracers for atmospheric winds. Also supports height assignment for semi-transparent clouds. Two separate channels representing different atmospheric layers instead of the single channel on Meteosat.



CHANNEL 10: INFRARED 12.1
(11 - 13 μm)

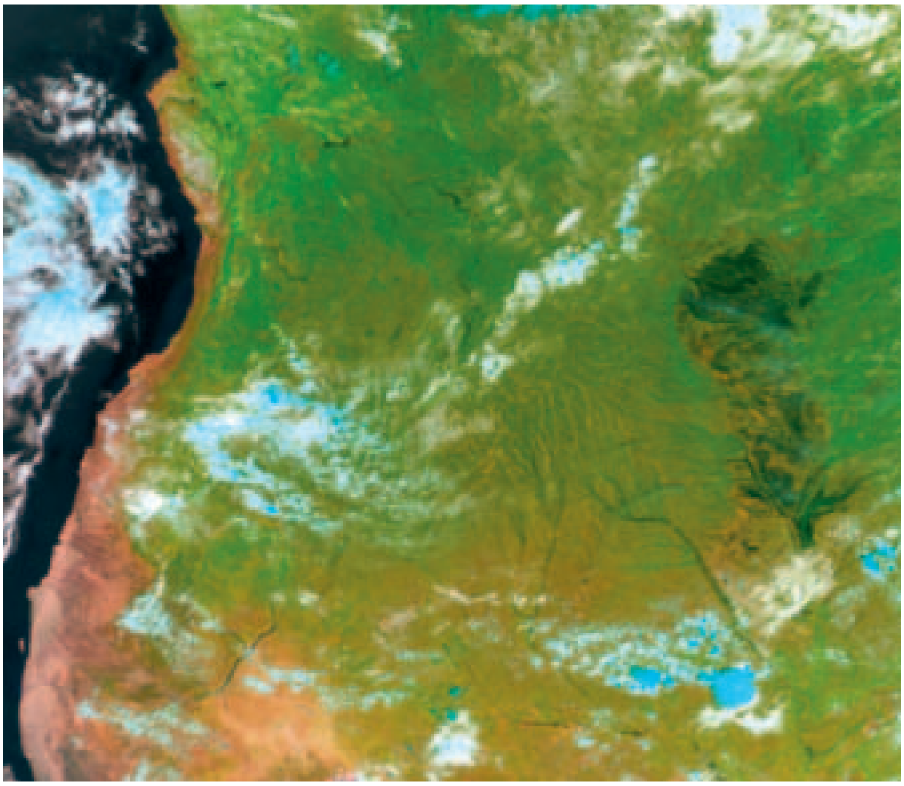


CHANNEL 11: INFRARED 13.4
(12.4 - 14.4 μm)

CO_2 absorption channel, to be used for the estimation of atmospheric instability, as well as contributing temperature information on the lower troposphere.

CHANNEL 12: HIGH RESOLUTION VISIBLE
(0.6 - 0.9 μm)

Broadband visible channel, as the current Meteosat VIS channel, but with an improved sampling interval of just 1 km (compared with Meteosat's 2.5 km).

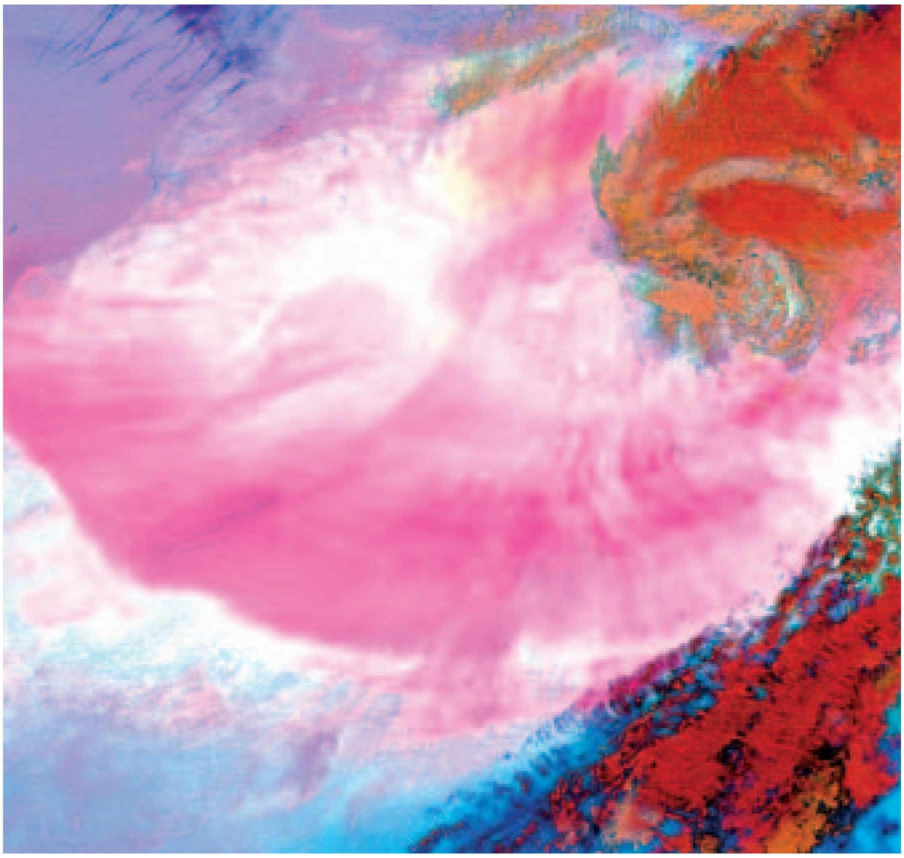


Between 1 and 10 February 2004, after days of torrential rainfall, large parts of Eastern Angola, Western Zambia and Northern Namibia were heavily flooded by the Okovango, Zambezi and cuando Rivers. In total, an area of about 600 000 sq km was affected by the floods. On 6 February 2004, floods inundated crops in the Kavango and Caprivi regions of Namibia, with the Okavango River reaching its highest levels in a decade.
Meteosat-8, 03 February 2004, 11:30 UTC, RGB composite NIR1.6, VIS0.8, VIS0.6

requirements, involving both the space and ground segments. It includes validation of the procedures to be used during the routine operations, calibration of the instruments in space, fine-tuning of the ground facilities, validation of the meteorological products themselves (e.g. comparisons with other satellite measurements), etc.

The Satellite Commissioning Results Review, begun in March and completed in June 2003, confirmed the good performance of all but the data-dissemination capability. The performance of the SEVIRI instrument was particularly promising. The Commissioning Operations Readiness Review was also successfully completed in the second half of June. Commissioning activities then continued in the second half of 2003 with the preliminary tuning and testing of the image-processing chain.

Once the satellite-commissioning phase had been completed and calibration both of the instruments and the imaging chain between satellite and ground was well underway, validation of the meteorological



In early March 2004, the passage of cold air from Europe to Western Africa caused a major dust storm over large parts of West Africa. As it travelled southwards, the cold air fanned out across the Sahara, diverging greatly over subtropical regions and giving the dust front (magenta colour) the form of a Spanish fan. In the following days, the dust was blown out across the Atlantic Ocean and reached the coast of South America. Due to the low emissivity of desert surfaces in the IR8.7 infrared channel, dust 'clouds' are clearly distinct from cloud-free desert surfaces in the IR10.8 - IR8.7 brightness-temperature-difference images (shown in green in this image). This feature, which was not well known before the launch of Meteosat-8, plus the brightness-temperature differences between the IR3.9, IR12.0 and IR10.8 channels, helps in monitoring dust storms over the deserts both during the day and at night.
Meteosat-8, 03 March 2004, 12:00 UTC, RGB composite IR12.0 - IR10.8, IR10.8 - IR8.7, IR10.8

products was begun. Dissemination of those meteorological products started via EUMETCast (the system name given to the alternative dissemination) on 21 October 2003, and was subsequently upgraded with the addition of other data and products. For example, Meteosat-5 images (over the Indian Ocean) were added in November, along with the dissemination in C-band for Africa.

The MSG-1 System Commissioning Results Review and the Routine Operations Readiness Review were both successfully completed on 18 December 2003 and the raw images from MSG-1 were confirmed to be of excellent quality and rectifiable within the specified accuracy, and the specified radiometric and geometric performances were being met with ample margins. Relocation of the spacecraft to the closest possible position to the Equator (0 deg) was therefore authorised ready for the start of routine operations. By 27 January 2004 the satellite had reached 3.4 degW and the operational service was initiated from this orbital position two days later. The satellite was renamed Meteosat-8 as a sign of continuity within the geostationary meteorological service being provided by EUMETSAT.

The satellite's Search & Rescue secondary payload was also tested successfully and from the end of the year was being used pre-operationally by COSPAS-SARSAT. In fact, several people's lives have already been saved thanks to the acquisition of rescue signals by MSG-1.

The long-term calibration and validation of meteorological products has continued according to plan, with the Image and Product Validation Review (IPVR) being completed between February and early March 2004.

The commissioning of a meteorological system is, as the above story shows, a somewhat lengthy process compared to that for a telecommunications system. Extensive calibration of the instruments and validation of the images and products is essential before the users can start to apply the products with confidence. Despite the unforeseen problems experienced with MSG-1 during the satellite and system commissioning phases, these tasks have ultimately been completed according to the initial plans.

The MSG Operational Service

Significant benefits to society from the MSG mission are to be found in its contribution to the Global Observing System (GOS) of the World Weather Watch (WWW) as part of the global system of geostationary satellites fulfilling the new European requirements in terms of better weather forecasting methods, meteorological observations and climate monitoring. In support of these objectives, the MSG system provides multispectral imaging of cloud systems, the Earth's surface and atmospheric emissions with significantly improved capabilities compared with existing systems in terms of extraction of meteorological products and image and data dissemination to users. It is an operational mission designed to provide a high-quality, readily available and cost-efficient data service fully adapted to meeting the needs of the user, in this case primarily the national Meteorological Services and the World Meteorological Organization.

The agreed service availability figure for MSG is 95%. Given that predicted system availability always decreases with time, the problem is then to determine the critical availability threshold that represents an unacceptable risk to users. This leads in turn to the concept of an in-orbit configuration with a satellite performing the nominal mission and another one in standby mode just in case. The foreseen launch date for the replacement satellite needs to be defined such that it can be commissioned and available in orbit in time to maintain the statistical availability above the agreed threshold.

It was on the basis of such considerations that MSG-1's entry into operation was targeted for early 2004, to maintain a minimum overlap of two years with the first-generation Meteosats in order ensure a smooth transition for users to the new system. The same logic is driving the definition of launch dates for the other three satellites in the series, MSG-2, 3 and 4.

MSG-2, 3 and 4

In parallel with the commissioning of MSG-1, work on the other three MSG satellites has been progressing well. On 1 March, EUMETSAT took the decision to take MSG-2 out of storage and to resume work on its final preparation for launch some time between February and April 2005.

The concept of storage and de-storage became part of the MSG-2 baseline after the launch of MSG-1 was rescheduled. All MSG satellites are essentially the same from a technical standpoint, with most of the industrial production work being done in parallel after the end of the development phase. Following MSG-1's entry into storage, MSG-2 and MSG-3 were integrated, and to a large extent tested, in order to optimise the work at industry level. The satellites then remain in storage until their de-storage and preparation for launch is initiated by EUMETSAT.

The planned launch date for MSG-3 is in the period 2008-2009. Work on MSG-4 has also started, in April 2003, and it will be ready to enter storage in spring 2007, for a launch in the period 2010-2011. Together, the four MSG satellites will ensure continuity of the geostationary operational service from this unique mission until 2018.

Information on how to access MSG data can be found by visiting www.eumetsat.de, or by contacting the EUMETSAT User Service via e-mail at Ops@eumetsat.de.

The Dragon Programme

– ESA and China Cooperate in Earth Observation

High-resolution satellite image of the Beijing area taken with Envisat's MERIS instrument

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Science and Applications Department, ESA Directorate of Earth Observation, ESRIN, Frascati, Italy

Karl Bergquist
International Affairs, ESA, Paris

Li Zengyuan
National Remote Sensing Centre of China (NRSCC), Ministry of Science and Technology, Beijing

ESA has been cooperating with China's National Remote Sensing Centre (NRSCC) in the development of Earth Observation (EO) applications for the last 10 years. Following recent high-level meetings between Chinese and ESA officials, it was decided to reinforce this cooperation, which has now been given new momentum with the creation of a dedicated three-year EO exploitation programme called 'Dragon'. This programme forcuses on the development of EO science and applications in China using data primarily from ESA's ERS and Envisat missions.

Introduction

As China has a land surface of more than 9.6 million square kilometres, satellite-based Earth observation is clearly an ideal tool for the monitoring and overall management of the country's resources. Another important factor is that today China accounts for one-fifth of the World's population, with 1.45 billion inhabitants, and is also currently the World's fastest growing economy. With this rapid growth and the stress that it implies on the country's natural resources and its environment, remote sensing can provide precise data to help decision-makers at all levels.

Satellite data can be used in land-resource mapping applications such as forest inventory and management, rice-production monitoring, and water-resource assessment and management. A new element in the Dragon programme is the extension of techniques and methods for monitoring oceans and atmosphere as well

Prof. Jose Achache (left), ESA's Director of Earth Observation Programmes, and Prof. Zhang Guocheng (right), Deputy Director of China's NRSCC, giving their opening addresses at the Dragon Symposium in Xiamen, People's Republic of China, on 27 April 2004

as land using the full complement of Envisat's instruments.

Satellite data can also contribute to the mitigation of the effects of natural disasters by providing timely information to local and national authorities. The natural disasters that affect China are often on a gigantic scale and include flooding of the Yangtze River, earthquakes on the Tibetan plateau, and droughts, which are particularly acute in China. When such calamities occur, Earth Observation can be the key to understanding and managing the ensuing crises. Hopefully, in the near future it will also help us to predict such events through the use of assimilation models and long time series of historical data to establish trends and alert the appropriate authorities when changes in those trends are first observed.

Early Cooperation

ESA's first contacts with China in the Earth Observation domain were established when the Chinese authorities expressed an interest in cooperating on ERS data applications. China's remote-sensing ground station in Beijing was subsequently upgraded to receive ERS data in 1994 and the two sides signed an Agreement to that effect.

In May 1997, China and ESA decided to begin a cooperation project for the increased operational use of ERS data. In order to stimulate exploitation of the Synthetic-Aperture Radar (SAR) data from ERS-1 and 2, five pilot projects were created, addressing:

- Rice Mapping in Southern China
- Land-use Mapping for the Beijing Area
- Flood Monitoring
- an Oceanographic Study, and
- Mapping China's Forests.

The following year, when China experienced its worst floods of the Century, ERS radar imagery was used for operational mapping of the flood events. The Beijing ground station was able to process and deliver ERS images to end users just 24 hours after their acquisition.

This first cooperation was considered so successful by ESA and NRSCC that it led to discussions on how to consolidate and increase it in the future. In a meeting with ESA's Director General, China's Minister of Science and Technology, Mr Xu Guanhua, commented that space applications were recognised in his country as a key tool for the development of the Chinese economy and improved living conditions for its people.

In the light of the above progress, ESA's Earth Observation Directorate and their Chinese counterparts at NRSCC began a consultation process on how to reinforce and improve the cooperation to also include joint research. The result is 'The Dragon Programme', which was officially launched in Xiamen, China in April 2004.

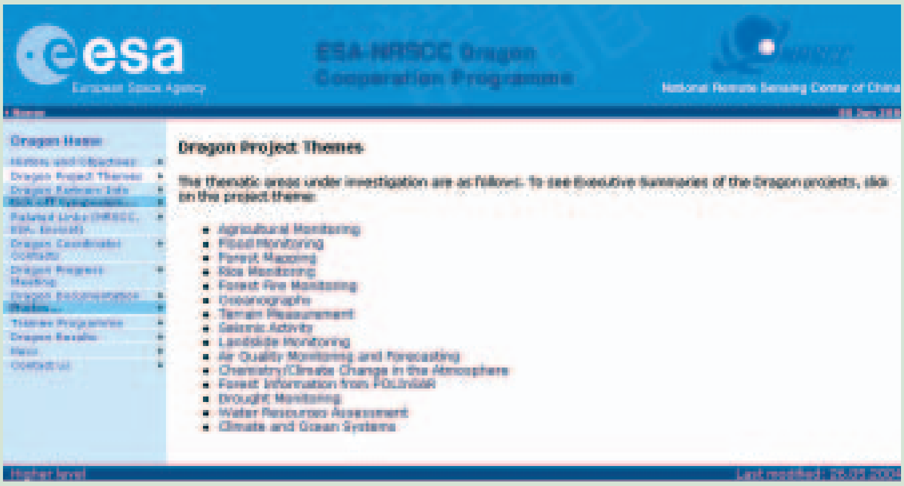
The Dragon Programme

Objectives

The Dragon Programme's main objective is to establish joint Sino–European teams for the exploitation of data from ESA's ERS and Envisat satellites for science and applications development. The teams, with lead scientific investigators from Europe and China, will be addressing the following identified priority themes: Agricultural Monitoring, Flood Monitoring, Forest Mapping, Rice Monitoring, Forest-Fire Monitoring, Oceanography, Terrain Measurement, Seismic Activity, Landslide Monitoring, Air-Quality Monitoring and Forecasting, Chemistry/Climate Change in the Atmosphere, Deriving Forest Information from POLInSAR Data, Drought Monitoring, Water Resources and Hydrology, and Climate and Ocean Systems

First achievements

Programme preparation began with special briefings for European scientists in September 2003 in Rome, and for Chinese scientists in October 2003 in Beijing. The response from both the European and Chinese scientists who attended was very positive. The Dragon Call for Proposals was then jointly prepared by ESA and NRSCC and issued in November 2003. Some 25 responses were received and



The ESA–NRSCC Dragon web site http://earth.esa.int/dragon

The Dragon brochure

peer-reviewed from the scientific and technical feasibility viewpoints, resulting in the final selection of 15 integrated projects covering the priority themes defined by ESA and NRSCC.

In order to facilitate the preparations, an ESA–NRSCC Dragon web site was officially launched in March 2004 (http://earth.esa.int/dragon). It carries technical documentation on the Programme and serves both as an information and reporting portal. A programme brochure was also prepared and widely distributed in both Europe and China.

As part of the Dragon Programme, training courses will be organised and exchanges of trainees working within the projects are also anticipated. This will strengthen both the cooperation and the technical exchanges. The first trainees from the Chinese Academy of Forestry have already spent three months at ESRIN in preparation for the two projects related to forest monitoring using spaceborne Synthetic Aperture Radars (SARs). In October this year, a week-long training course entitled 'ESA MOST Dragon Programme Advanced Training in Ocean Remote Sensing' will be organised in Qingdao, where the three major Chinese oceanographic institutes are located.

The recent Dragon Symposium (27-29 April 2004) was organised by ESA and NRSCC and hosted by the local authorities of Xiamen. It was attended by 130 scientists representing more than 60 institutes in Europe and China, and was effectively the formal kick-off for all 15 joint projects. The joint teams have now started their work, their data requests have been refined, and detailed work plans have been established.

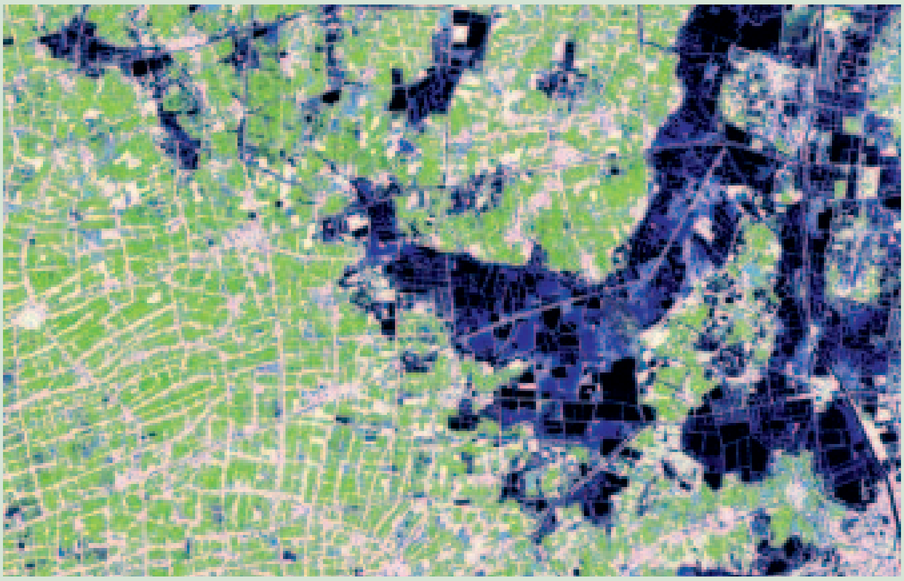
Participants in the Dragon Symposium

Research Areas within the Dragon Programme

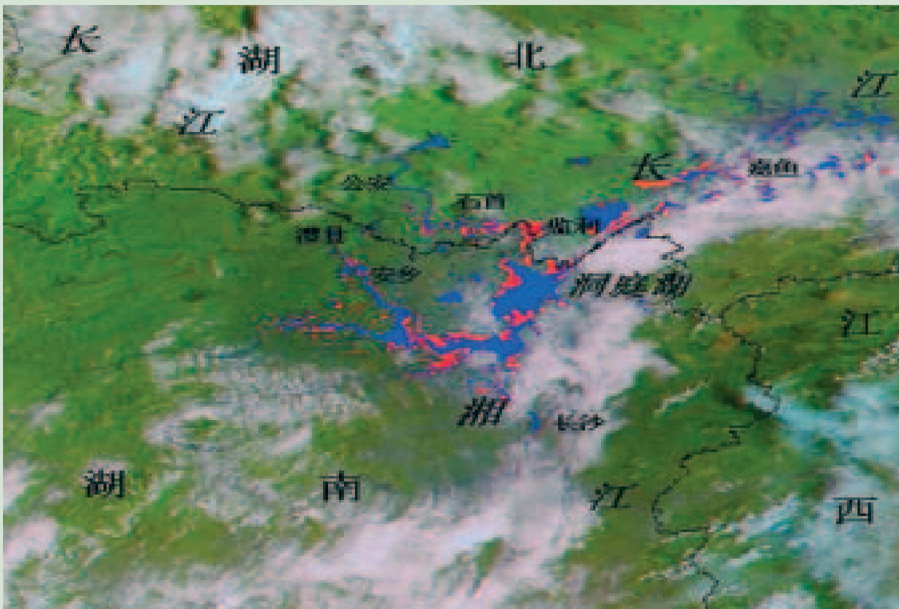
The Dragon Programme includes projects focusing on monitoring natural land resources, on supporting natural-disaster management, and on studying the atmosphere and ocean in China. The following are just a small selection:

Rice production monitoring
The United Nations has declared 2004 the 'International Year of Rice'. China is the World's largest rice producer, accounting for 35% of global output. At the same time, harvest areas are declining and demand is forecast to increase by 70% over the next 30 years.

The rice-monitoring project will use Envisat's Advanced SAR (ASAR) capability to observe rice-growing areas day and night, regardless of cloud cover. This is particularly important because persistent cloud cover in China's rice-growing regions is currently limiting the amount of information that can be gathered using optical satellite sensors. The anticipated outcome of the project is to improve rice-monitoring techniques through better yield modelling and regular



Rice fields in China imaged with Envisat's ASAR instrument using alternating polarisations



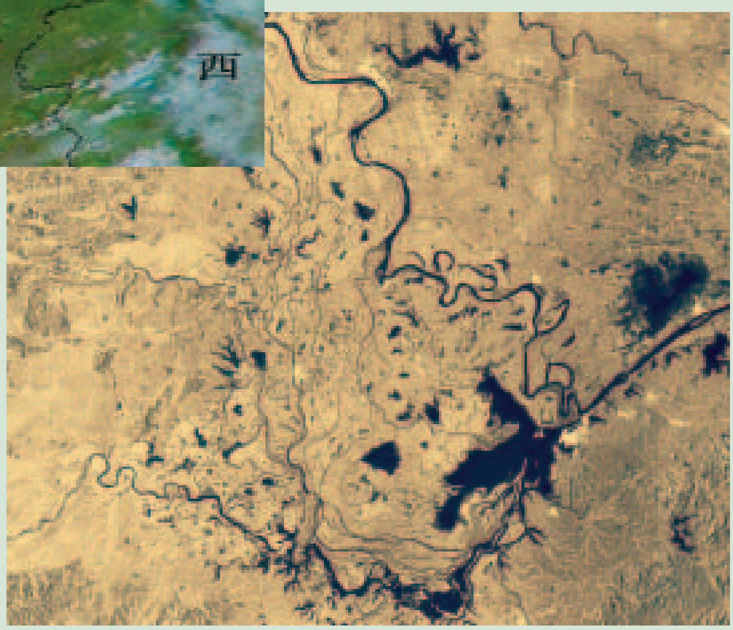
NOAA AVHRR image of Dongting Lake taken on 7 July 1999. Flooded areas are displayed in red

and accurate rice-field mapping at provincial level.

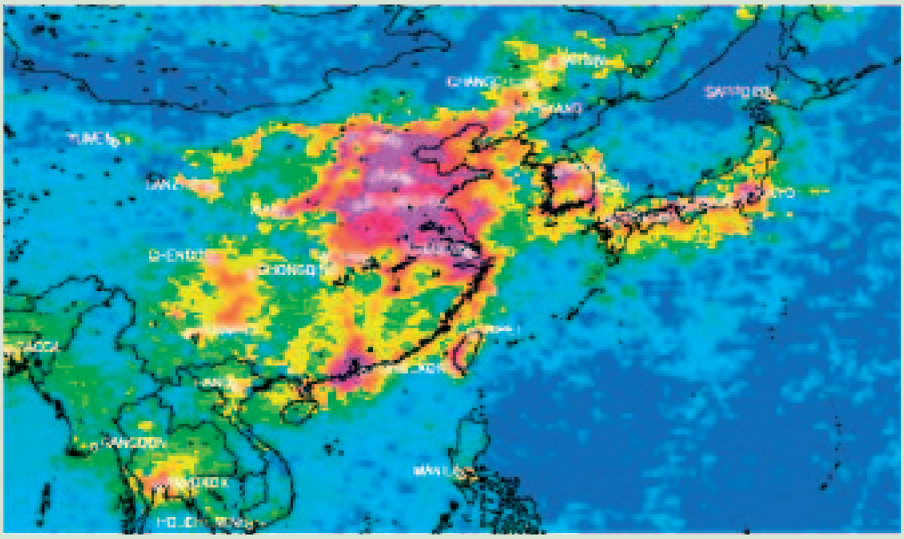
At the same time, rice fields produce methane, which is a major greenhouse gas, and both methane distribution and seasonal concentrations can be monitored and better understood using the SCIAMACHY instrument carried by Envisat. Improved water management can help to reduce methane emissions during the crop's growth cycle. Some areas have two to three crop cycles per year and so changing the water-management regime could significantly reduce methane emissions in the rice-growing regions.

Flood mapping and monitoring

Severe floods are estimated to have cost China 32 billion US$ in 1998 and 20 billion US$ in 2003. Improved flood forecasting and monitoring is therefore very important for the country. In the Dragon project titled 'Flood Plain Disaster Rapid Mapping and Monitoring', Envisat's ASAR will be used to great advantage, thanks to its all-weather, day-and-night imaging capability. The project will also have a flood-prevention element, by exploiting existing ERS SAR (since 1991) and optical data archives to assess the vulnerability of particular geographical areas to inundation and reassessing particular flooding events that have occurred over the years.



Envisat ASAR image of Dongting Lake and the surrounding area taken in 2003



Tropospheric nitrogen-dioxide concentrations over the People's Republic of China

For disaster evaluation and recovery actions, airborne and spaceborne SAR data will provide such vital information as estimates of flooded areas per region, population numbers affected, arable land inundated, oil wells inundated, extent of railway lines submerged, and the locations and extent of breaches in embankments and flood dykes.

The project will benefit from the impressive rapid-alert system that has been put in place in China. The response time from the taking of the satellite imagery to the arrival of the relevant information on the desk of the responsible authority has been improved from a few days to just 5 hours. The model developed in China will also be tested in Europe with a view to further improving response times here too.

For forecasting purposes, EO data will be used in combination with meteorological data in the modeling chain. The goal is to be able to provide flood forecasting maps on an hourly basis.

Air-quality monitoring

The 'Air-Quality Monitoring and Forecasting' project will include the compilation of historical time series of atmospheric gas concentrations using GOME observations (from 1995 to 2003 from ERS-2), and the more recent data from Envisat's SCIAMACHY instrument (2003 to date). Maps showing the mean annual concentrations and distributions of nitrogen dioxide in China have already been made using SCIAMACHY data. When they are compared with population-density maps, it is possible to see the correlation between areas with high population densities and those with high concentrations of atmospheric pollutants. It is due to the burning of fossil fuels and the byproducts of industrial processes.

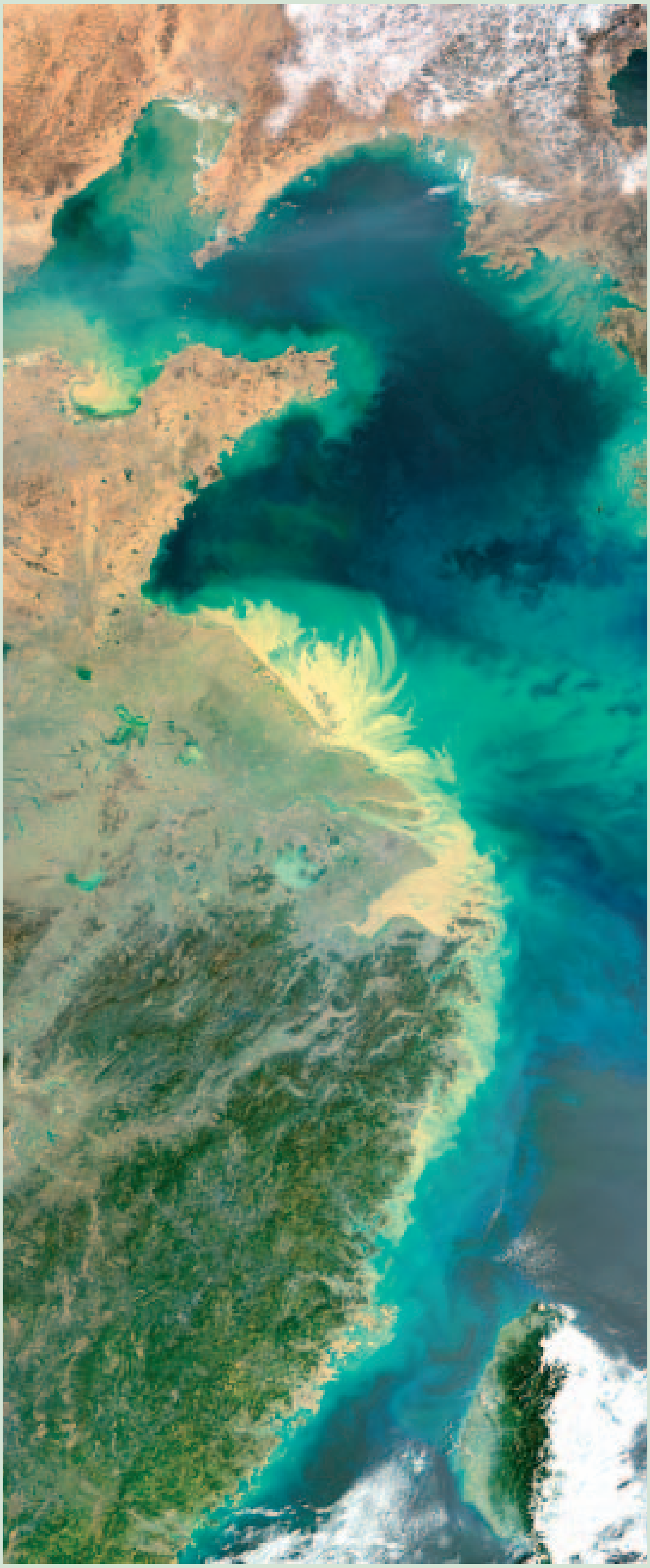
Such maps produced from temporal series of satellite observations are important tools for governments, and policy makers in assessing trends in atmospheric pollutant concentrations and implementing the necessary controls. The effectiveness of the pollution controls introduced can also be evaluated using long-time-series data sets.

Red-tide monitoring

The 'Ocean, Environment and Climate' project is a multi-disciplinary effort aimed at studying ocean waves, currents and colours, and ocean-bottom topography using a combination of SAR and optical remote sensing.

One element is the monitoring using MERIS data on 'red tides' in the China Seas. These tides occur mainly in coastal areas around the World and can have a devastating impact on the local fishing and shellfish industries. Red tides, which are caused by dense growths of bacteria and algae, can even be toxic for humans. They are becoming increasingly common in China (see accompanying table) due to the heavy sewage and industrial pollution along the country's densely populated east coast and from the Yangtze River. One of the project's goals, therefore, is to develop techniques and data sets using MERIS data to map the extents and durations of such tides so that fisheries can be provided with accurate and up-to-date information.

A so-called 'red tide' photographed from a ship off Fu Ding City, in China's Fujian Province, on 6 May 2002. This particular red tide covered an area of more than 500 km^2



Occurrences of red tides in the China Seas in 2002 and 2003

	Times		Area (km²)	
Site	2002	2003	2002	2003
Yellow Sea	3	5	310	410
Bohai Sea	14	12	300	460
East China Sea	51	86	9 000	12 990
South China Sea	11	16	540	690
Total	79	119	10 150	14 550

Future Outlook

The Dragon Symposium in Xiamen brought together top scientists from Europe and China who are teaming up together with clear objectives and work plans to address serious environmental issues. The excellence of the joint teams, the quality in-situ data available for validation, and the timely availability of Envisat multi-sensor data sets provides confidence that the Dragon Programme will result in innovative developments in the Earth Observation science and applications domains. Having been demonstrated and validated in the China context, they can also be put to excellent use in Europe and elsewhere in the World.

The second Dragon Symposium will take place in Europe in Spring 2005 and will be the opportunity to review and assess the achievements after the first year of this joint cooperative programme with the People's Republic of China. esa

MERIS image showing river-discharge and sediment loading in the East China Sea

What Happens to the Human Heart in Space?

– Parabolic Flights Provide Some Answers

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Aircraft parabolic flights provide up to 20 seconds of reduced gravity repeatedly during ballistic flight manoeuvres. They are used to conduct short microgravity investigations in the physical- and life-sciences, to test instrumentation and to train astronauts for forthcoming space flights. As the only Earth-based facility for conducting investigations on humans in real weightlessness, their use is complementary to simulated weightlessness techniques, such as bed rest and water immersion, and therefore a valuable step in preparing for space missions. The real value of parabolic flights lies, however, in the verification tests that can be conducted prior to taking experiments into space, in order to improve their quality and success rate.

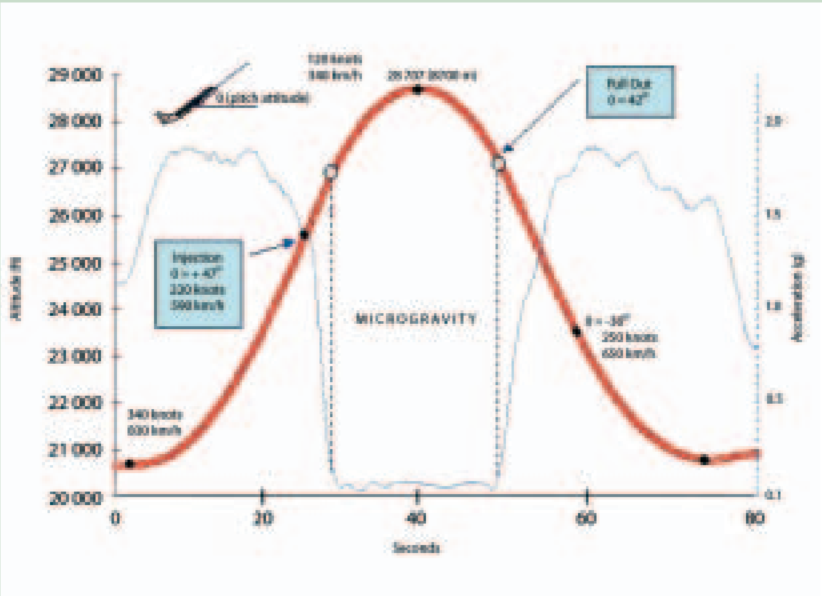
Introduction

ESA has organised thirty-seven aircraft parabolic-flight campaigns for microgravity research experiments since 1984, and seven purely for student-proposed experiments. During these flights, 446 experiments have been performed in the physical- and life-sciences, and technology domains. A total of 3462 parabolas have been flown, providing 19 hours 14 minutes of microgravity in 20 second 'slices', equivalent to making twelve and a half orbits of the Earth.

How Does the Airbus Generate 'Microgravity' ?

The microgravity environment is created by putting the aircraft through a series of carefully orchestrated flight manoeuvres (see figure):

- *From steady horizontal flight at 20 000 ft, the aircraft first climbs to an angle of 47° (pull-up) over a period of about 20 seconds, generating acceleration forces of between 1.8 and 2 g.*
- *At 25 000 ft, the engines are throttled back for about 20 to 25 seconds, generating ballistic free-fall, or 'microgravity' conditions inside the aircraft as it crests the parabola.*
- *The aircraft dives back down to an angle of 42° (pull-out), again generating accelerations of 1.8 to 2 g for approximately 20 seconds, before returning to steady horizontal flight at 20000 ft, and then repeating the whole manoeuvre.*



Flight profile of the Airbus A300 'Zero-G' during a parabola (in red) superposed on acceleration levels along the local vertical axis (Courtesy of Novespace)

The parabolas are flown over the Gulf of Biscay or the Mediterranean Sea. With a typical flight lasting about two and half hours, 30 parabolas are usually flown in sets of five, with two-minute intervals between parabolas and with four to five minutes between sets of parabolas. The intervals between parabolas can be arranged prior to the flight to give investigators sufficient time to change an experiment set-up.

Since 1997, the parabolas have been flown with the Airbus A300 'Zero-G', the largest aircraft being used for this type of research activity anywhere in the World. ESA has already organised 13 microgravity research campaigns on the Airbus, and 15 of the 160 experiments conducted have involved study of the human cardiovascular system.

Why Parabolic Flights?

The microgravity conditions that astronauts experience during space flight can pose severe challenges for the human physiology in general, and our cardiovascular system in particular. Extensive physiology experiments in space are needed to determine the long-term effects, but several practical considerations limit the possibilities, not least:

- the high experiment costs (approximately 20 kEuro per kilogram), including uploading the necessary equipment to the International Space Station (ISS);
- the limited access, especially now when the Space Shuttle fleet is still grounded and all manned travel to and from the ISS depends on just two annual Soyuz flights;
- the small number of available test subjects, with only two permanent crew members currently on the ISS;
- the limited crew time available, as they are also responsible for operational and maintenance tasks;
- no possibility of on-board intervention by the researchers themselves.

These limitations will persist as long as the number of flight opportunities does not increase, and until Europe's Columbus Laboratory, with its European Physiology Module, is launched and attached to the ISS.

There are only three sources of short-duration weightless conditions accessible on Earth: drop towers, providing about 5 seconds of free fall from a height of 110 m; sounding rockets, providing up to 13 minutes of microgravity; and aircraft parabolic flights, providing repetitive periods of 20 - 25 seconds of low-gravity conditions. The first two are not an option for life-science experiments on human subjects, leaving aircraft parabolic flights as the only realistic sub-orbital possibility.

Aircraft parabolic flights also have two major scientific advantages for physiology studies in that they make it possible both to investigate phenomena at different g-levels during successive repetitions of periods of 1, 2 and 0 g, and to study transient phenomena occurring during the changeover from high to low gravity and back again. On the technical side, they allow the early testing of equipment hardware in a microgravity environment, assessment of the safety aspects of an instrument's operation in microgravity, and the training of astronauts in instrument operation and experiment procedures.

Other key advantages of parabolic flights include: short turn-around times,

An early parabolic-flight cardiology experiment onboard NASA's KC-135 aircraft in which a free-floating bed was used to record a ballistocardiogram for the test subject and measure the expulsion of blood from the heart into the bodily circulation under different g-forces (photo NASA)

with typically just a few months between the experiment being proposed and performed; the low costs involved, as ESA provides the flight opportunity free of charge to investigators; the flexibility in experimental approach, as ground-laboratory instrumentation can often be used; the possibility of direct intervention by investigators onboard the aircraft during and between parabolas; and the possibility of modifying the experiment setup between flights.

Today, the Airbus A300 'Zero-G' parabolic flight programme is managed by the French company Novespace (commissioned to do so by CNES), with the technical maintenance and flight operations tasks being handled by the French company Sogerma and the 'Centre d'Essais en Vol' (French Test Flight Centre). Novespace is contracted by ESA to provide the aircraft for its parabolic flights, and to provide some support to the investigator teams and integrate their experiments at Novespace's facilities near Bordeaux-Mérignac airport.

Parabolic Flights and the Human Cardiovascular System

The human cardiovascular system consists of a dual pump: a right part consisting of an atrium and a ventricle whose purpose it is to circulate oxygen-depleted blood (venous blood) through the lungs to re-oxygenate it, and a left part consisting of an atrium and a ventricle to circulate that oxygen-enriched blood (arterial blood) around the body. Both ventricles have an entry valve (between atrium and ventricle) and an exit valve (between ventricle and circulatory blood vessels). From an engineering point of view, the heart can be likened to an electronically driven (by the brain) mechanical pump. It can be viewed as a closed-loop system, with a return loop providing information obtained from pressure sensors – so-called 'baro-receptors' – located at different points in the body, for instance in the carotid arteries that supply blood to the head and neck.

The human circulatory system is unique in that in the standing position the heart is located 130-160 cm above the ground, while the brain, which needs to be constantly 'irrigated' by blood, is 30-40 cm higher! Blood tends to accumulate in the organs that lie below the heart, and needs to be transported back to the heart against the force of gravity. A normal individual has five to six litres of blood, two thirds of which are below the heart. Should fluid leak out of the blood vessels located below the heart, it would accumulate within the tissues of the legs, producing oedema. The body has therefore had to develop oedema-preventing mechanisms, which in effect counteract gravity. Such considerations are of less importance when the human body is in the supine (lying down) position.

These physiological aspects have certain consequences for parabolic flights, during which the brief spell of microgravity is preceded by a period of hypergravity, and the body's orientation with respect to the direction of gravity will influence heart function and circulation. This is not the case during extended periods of microgravity, for instance during stays on the Space Station.

Hydrostatic effects also play a role. In a standing position, the carotid sinuses are 20-30 cm above the heart and therefore they measure a lower pressure than at heart level. At the onset of microgravity, this effect disappears and the baroreceptors will observe a higher pressure. In the absence of gravity, venous blood will rush to the right atrium when it is no longer pulled down by gravity into the compliant vessels of the legs and the abdomen, resulting in increased stroke volume. This in turn may lead to increased pressures in the right side of the heart and a distension of the right atrium (as shown by Norsk and collaborators). The return loop through the baroreceptors will lead to further autonomic nervous influences on the left heart, including the systemic blood pressure and heart rate.

The heart's pumping rate is adapted to prevailing physiological needs mostly through modulation by the body's autonomic nervous system (ANS). Many questions were originally asked about the role of the ANS on cardiovascular regulation during the short periods of microgravity on parabolic flights: Would there be any influence at all because of their short duration? What would be the influence of gravity transitions? Would body position matter? Would gravity transitions influence heart dimensions? Would equilibrium set in during such short time periods? What might be the optimal measuring techniques?

Speculative answers can be given to some of these questions, but others needed to be investigated experimentally. Cardiovascular variability can be expected during parabolic flights as the ANS can control the cardiovascular system within a few heart beats. However, since different phases of the parabolic flight profile last for no longer than 20-25 seconds, it is to be expected that ANS activity will also be influenced by conditions during previous phases, i.e. hypergravity. This activity will elicit changes directly in the cardiovascular system in terms of heart rate and blood pressure, and indirectly in the stroke volume (SV, volume of blood pumped with each heart beat) and cardiac output (CO, total blood volume pumped by the heart in 1 minute). The system can therefore be characterised by two easily measurable parameters: the electrocardiogram (ECG) to determine heart rate (HR), and blood pressure. Sometimes the breathing rate, or more general respiratory function, is also determined. Haemodynamic parameters (SV and CO) can be computed indirectly from the blood pressure, and the cardiac output is the product of the stroke volume

Cardiovascular Experiments Flown on the Airbus A300 'Zero-G' Aircraft

Investigation of cardiovascular haemodynamics during changing gravitational stresses and parabolic flight
J. Watkins, Univ. of Wales, UK; 24th ESA Campaign, October 1997

Arterial pressure in microgravity
B. Pump, DAMEC, Copenhagen, DK; 25th ESA Campaign, October 1998

Effect of Lower Body Negative Pressure (LBNP) on vectocardiography, electrocardiography, and haemodynamic parameters in humans
P. Vaïda, Univ. Bordeaux 2, F; G. Miserocchi, Univ. Milan, I; 26th ESA Campaign, June 1999

Advanced Respiratory Monitoring System (ARMS): does weightlessness induce peripheral vasodilatation?
P. Norsk & R. Videbaek, DAMEC, Copenhagen, DK, CNES Camp., part of 27th ESA Campaign, November 1999

Otolithic control of the cardiovascular system during parabolic flights
P. Denise & H. Normand, Fac. Médecine Caen, F; P. Arbeille, CHU Trousseau, Tours, F; 27th ESA Campaign, October 1999

An assessment of the feasibility and effectiveness of a method of performing cardiopulmonary resuscitation during microgravity
S. Evetts, School Biomedical Sciences, London, UK; T. Russomano, Univ. do Rio Grande do Sul, Porto Alegre, Brazil; 29th ESA Campaign, November 2000

Acute heart rate response to weightlessness conditions during parabolic flight
A. Aubert, F. Beckers & D. Ramaekers, Univ. Leuven, B; 29th ESA Campaign, November 2000

Pulse transit time for the non-invasive determination of arterial wall properties
T. Dominique & P.F. Migeotte, Univ. Bruxelles, B.; 29th ESA Campaign, November 2000

Effect of the Lower Body Negative Pressure (LBNP) on the cardiac electrical activity and the hemodynamical parameters
P. Vaïda , Univ. Bordeaux 2, F; 30th ESA Campaign, May 2001

Does weightlessness induce peripheral vasodilatation?
P. Norsk, DAMEC, Copenhagen, DK; 30th ESA Campaign, May 2001; 31st ESA Campaign, October 2001

Imaging autonomic regulation during parabolic flight
M. Moser & D.M. Voica, Univ. Graz, Austria; A. Noordergraaf, Univ. Pennsylvania, USA; 31st ESA Campaign, October 2001

Acute cardiovascular response to weightlessness conditions during parabolic flights: parallelism with long-term microgravity in space
A. Aubert, B. Verheyden, F. Beckers & D. Ramaekers, Univ. Leuven, B; 32nd ESA Campaign, March 2002 ; 34th ESA Campaign, March 2003

Cardiovascular autonomic responsiveness to hemodynamic changes during parabolic flight: influence of respiration
A.E. Aubert, F. Beckers & B. Verheyden, Univ. Leuven, B; 36th ESA Campaign, March 2004

Dr P. Norsk monitors Dr B. Pump acting as the test subject for the measurement of arterial blood pressure during the 25th ESA Parabolic-Flight Campaign in October 1998

and heart rate. As an alternative to these indirect determinations, Doppler echo-soundings can be used to measure heart dimensions and ventricular and circulatory flow.

The Cardiovascular and Cardiopulmonary Experiments Conducted

Some of the most interesting experiments conducted during the early campaigns on the Airbus A300 'Zero-G' were those using the Advanced Respiratory Monitoring System (ARMS) (see photo). It provides the subject's breathing gas concentration and respiratory flow, blood pressure and an electrocardiogram (ECG). ARMS was flown in space for the first time on the Spacehab/STS-107 mission in January 2003, and was therefore lost in the tragic Columbia accident. Preparatory experiments for this mission had been conducted during several parabolic-flight campaigns in 1999. They provided us with a better understanding of the mechanisms of respiratory gas exchange and the mechanics of human breathing on Earth by measuring specific parameters in weightlessness, as well as providing valuable data on cardiovascular adaptation to microgravity.

One of the ARMS experiments, from Denmark, titled *Does weightlessness produce peripheral vasodilatation?*, tested a hypothesis that dilatation of the heart and the peripheral vascular system could be caused by weightlessness. Several physiological parameters were measured, including arterial pressure by photo-plethysmography, and cardiac output by rebreathing tracer gases (Freon 22 and SF6). The same group also showed that mean arterial pressure decreases during short-term weightlessness to below that when lying down in normal gravity, simultaneously with an increase in left atrial diameter (as measured by echo-cardiography) and an increase in transmural central venous pressure (determined with a catheter with a pressure sensor at the tip). They concluded that distension of the heart and associated central vessels during 0-g might induce the hypotensive effects through peripheral vasodilatation. It was also concluded that the supine position mimics better the effects of weightlessness on mean arterial pressure, heart rate and left atrial diameter.

The Franco-Italian experiment *Respiratory mechanics under 0g* studied pulmonary mechanics. Respiratory volumes and pressures were measured for subjects sitting in a whole-body pressure-

Measurement of various psychological parameters on an instrumented test subject in a supine position for the experiment of P. Denise and P. Arbeille during the 27th ESA Parabolic-Flight Campaign in October 1999

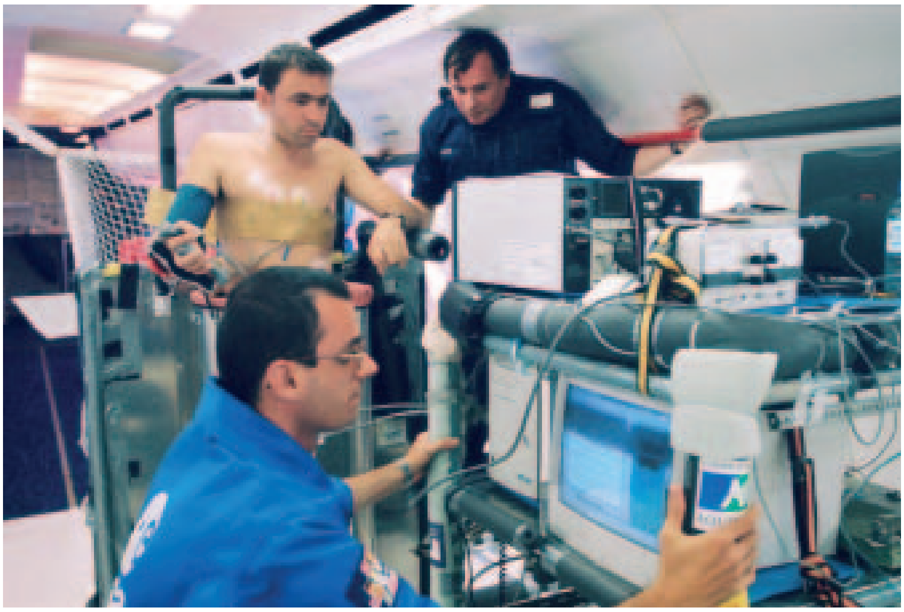
The ARMS equipment was used onboard the Airbus A300 'Zero-G' for several respiratory experiments in 1999. Here Prof. G.K. Prisk (Univ. California, San Diego, USA) is monitoring ESA astronaut Andre Kuipers acting as the test subject

tight caisson and breathing through a mouth-piece connected to external measuring equipment. Oesophageal pressures were also measured using a pressure balloon inserted through the nose into the subject's oesophagus. The data obtained complemented those from previous ground-based (anti-g suit, dry immersion, etc.) and space (ESA and CNES campaigns, and Spacelab D2 and EuroMir-95 missions) studies. It was shown that microgravity causes a decrease in lung and chest-wall recoil pressures as it removes most of the lung parenchyma and thorax distortion induced by gravity transitions and/or posture. Hypergravity does not greatly affect respiratory mechanics, suggesting that mechanical distortion of the organs involved is already close to a maximum in Earth's gravity.

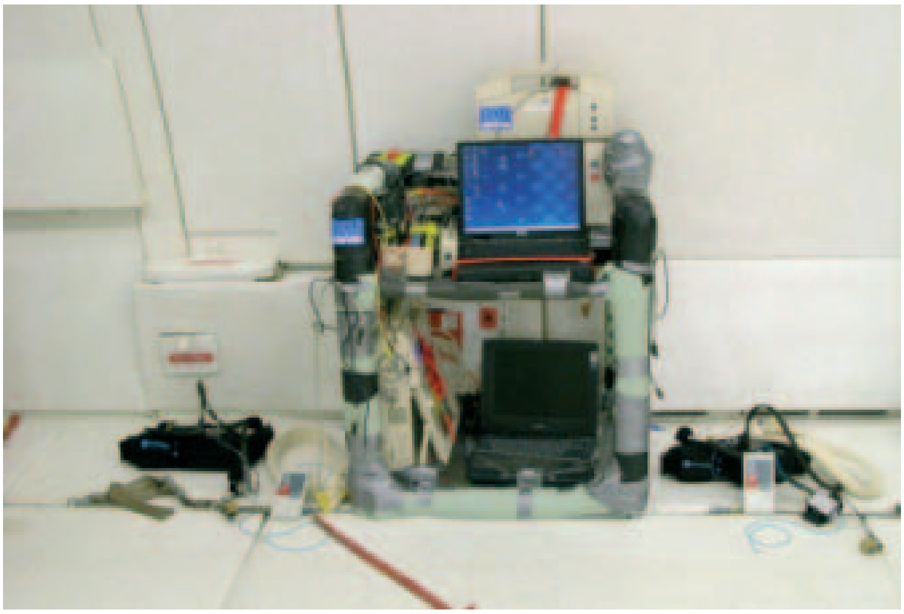
In an initial flight campaign, Aubert et al. studied the influence of position on heart-rate variability, determined from the ECG. They found a higher vagal modulation of the ANS in microgravity compared to 1g and hypergravity, for subjects in a standing position, and no significant differences in supine subjects, between different g-phases. These results were also confirmed by time-frequency analysis, which showed a higher vagal (high-frequency) component in a standing subject compared with a supine one. In later campaigns, they added blood-pressure and breathing measurements and also tested ISS astronauts during parabolic flights to compare results from ultra-short periods of weightlessness with those from a longer duration mission to the ISS. The high-frequency component (corresponding to vagal activity) and the low-frequency component (corresponding mostly to sympathetic activity) during microgravity on parabolic flights are comparable to the values seen during a ten-day mission to the ISS.

In order to stimulate cardiovascular responses, the test subjects often have to perform special exercises. One of the easiest consists of a voluntary elevation of intra-thoracic and intra-abdominal pressures provoked by blowing against pneumatic resistance (i.e. trying to blow with the mouth closed and nose pinched). During the manoeuvre, venous blood return to the heart is impeded, setting off a well-characterised sequence of positive and negative arterial pressure changes heavily influenced by the autonomic nervous system. As the duration of sustained pressure can be as short as 10 s, it is well-suited for use during weightlessness on parabolic flights.

Neck flexion (an anterior flexion of the neck by 70º, maintained by a solid support)



A test subject standing in the LBNP caisson while his heart rate and blood pressure are monitored for the experiment of Prof. P. Vaida during the 30th ESA Parabolic-Flight Campaign in May 2001



A typical instrumented rack for cardiovascular measurements as used by A.E. Aubert et al. during the 36th ESA Parabolic-Flight Campaign in March 2004 (photo A.E. Aubert)

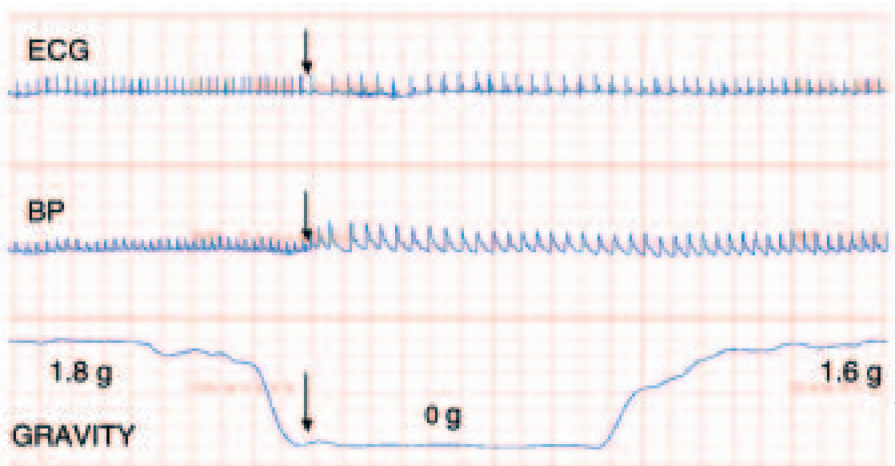
was used in the French experiment *Otolithic control of the cardiovascular system during parabolic flights,* to test the hypothesis that the otolithic receptors (part of the inner-ear balance system) affect the cardiovascular system during parabolic flights. Several physiological parameters - cerebral and femoral blood flow, vascular resistance, mean arterial pressure and heart rate - were measured for several subjects in a supine position and for two head positions (flexion and in line with the trunk). This could lead to a better understanding of the orthostatic intolerance and modifications of the peripheral blood flow and resistance response suffered by astronauts on their return to Earth. The experimenters concluded that in microgravity neck flexion, which stimulates only the neck muscle, induces larger vasoconstriction of the lower limbs and flow changes than in 1 g, where both the neck muscle and the otholiths are stimulated by the flexion. The peripheral vascular response associated with neck flexion could be mediated by the sympathetic nervous system.

Prof. Watkins' experiment used colour-Doppler echocardiography for direct imaging of the heart and major blood vessels in the seated, standing, and supine positions, in order to determine cardiac output and measure lower limb perfusion.

Lower Body Negative Pressure (LBNP) was exploited by Prof. P. Vaïda and his team, using tight-fitting 'trousers' around the lower body to create a negative pressure (compared to the surrounding pressure). In these experiments, LBNP was regulated at a pressure of -50 mmHg during the period of weightlessness. It was found that parasympathetic modulation of the heart by the ANS increased during microgravity, but was reversed while applying LBNP.

A Belgian team (T. Dominique and P.F. Migeotte) measured ECG, continuous finger blood pressure and respiration with an imposed breathing rate. During microgravity they found a slower heart rate, an increase in left ventricular ejection time (time between opening and closing of the aortic valve), a decrease in pre-ejection time (time delay between the contraction of the heart and the opening of the aortic valve), and a similar pulse transit time (time delay between the opening of the aortic valve and arrival of the pulse at the finger tip) compared to 1 g. They concluded that the heart's pre-load volume is increased in microgravity.

The likelihood of cardiopulmonary resuscitation (CPR) being performed successfully in space is seemingly very low, but not non-existent, as one reported incident has shown. During the second month of a four-month tour of duty on the Mir station, a cosmonaut was shown during Holter monitoring to have experienced an episode, lasting 14 beats, of non-sustained ventricular tachycardia. An ergonomic investigation was performed by Evetts et al. on the 29th ESA Parabolic Flight Campaign in November 2000 to study the effectiveness of different



From top to bottom: ECG, blood pressure and gravity level as recorded during a complete parabolic flight manoeuvre: hypergravity at 1.8 g. transition to microgravity and hypergravity at 1.6 g. A decrease in heart rate is apparent almost at the onset of microgravity (lengthening in distance between the successive peaks). This corresponds to increased vagal modulation of the heart rate. In the blood-pressure signal, there is a sudden increase in pulse pressure (difference between maximum and minimum pressure) at the onset of microgravity, indicating an immediate increase in stroke volume

A team from the School of Biomedical Services (London, UK) and the University do Rio Grande do Sul (Porto Alegre, Brazil) assess the best method of performing cardiopulmonary resuscitation (CPR) in weightlessness during the 29th ESA Parabolic-Flight Campaign in November 2000

resuscitation methods in microgravity, and two-rescuer CPR was deemed the most effective.

The Lessons Learned

The ESA parabolic-flight campaigns have provided a wealth of valuable results regarding the human cardiovascular response to space flight, including many that were totally unexpected beforehand. It has been shown, for example, that variations in heart size occur even during short periods of microgravity, and some results concerning heart rate and certain aspects of ANS modulation of the cardiovascular function are comparable to those seen during longer duration space flights.

The accompanying table, which is a compilation of results from several experiments, shows how the human heart behaves when it experiences changes in the gravitational conditions under which it is called upon to function. The results shown are a mean for 36 standing subjects, with an average control heart rate of 83 beats/minute, in five different experiments.

A general finding was that there was an initial increase in the heart rate of a standing subject at the beginning of the parabola, and decrease at the top. The differences were much less pronounced in supine subjects. Gender- and age-related studies have not been performed so far.

Conclusion

The unique and valuable experience acquired by ESA with the Airbus A300 ‘Zero-G’ flights and the many earlier ones on NASA’s KC-135, the Russian Ilyushin, and CNES’s Caravelle aircraft, is reflected in the large number of physical- and life-sciences experiments successfully conducted in space since their inception, and the many peer-reviewed articles that have been published as result of these studies. ESA will continue to organise parabolic-flight campaigns for the European scientific and technical microgravity communities at a rate of two to three per year, with mixed payloads of physical- and life-sciences and technology experiments. Their frequency has recently been increased to compensate somewhat for the further reduced space-based possibilities since the grounding of the Shuttle.

ESA maintains a permanently open invitation to investigators to submit microgravity experiment proposals for its future parabolic-flight campaigns. In July, within the framework of its Outreach Programme, the Agency conducted its seventh parabolic-flight campaign for experiments proposed by students from European universities and research institutions, to promote awareness among ‘tomorrow's scientists’ of the attractions and benefits of conducting scientific research in a reduced-gravity environment. In addition, ESA has also decided to fly one to two experiments proposed by students as part of its regular parabolic-flight campaigns.

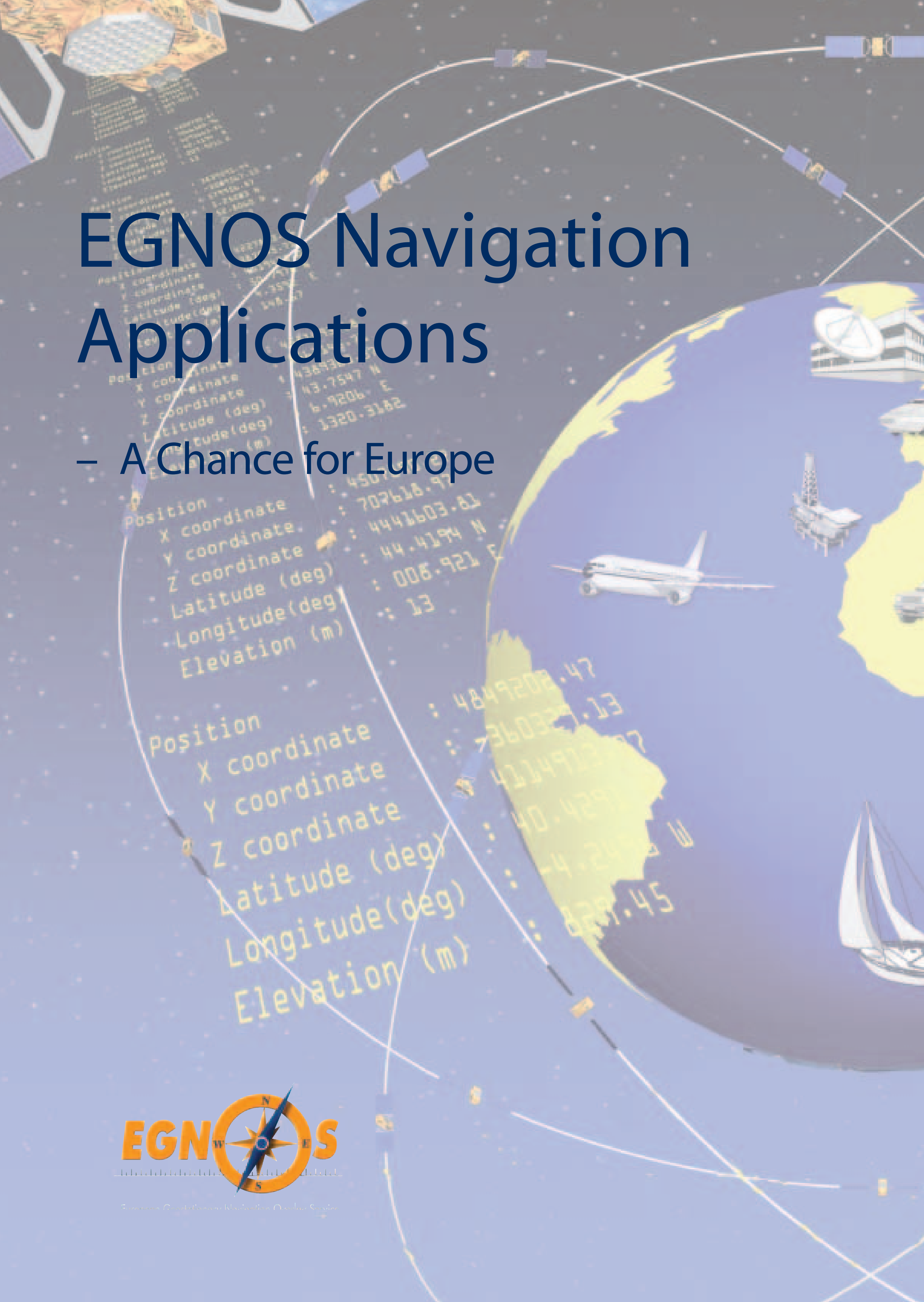
The flexibility of the experiment programming for the five to six campaigns that are flown with the Airbus A300 ‘Zero-G’ aircraft every year is enhanced by an experiment-exchange agreement between ESA, CNES and DLR. The wide experience of Novespace, the company providing the preparation and logistics support for the Airbus campaigns, is another positive factor in the high success rate in terms of the technical preparation of the experiments proposed and flown. esa

Behaviour of the Human Heart Rate for Different Gravity Transitions

Gravitational transition (g)	Change in heart rate (beats/minute)
1 → 1.8	+13
1.8 → 0	-23
0 → 1.6	+19

EGNOS Navigation Applications

– A Chance for Europe

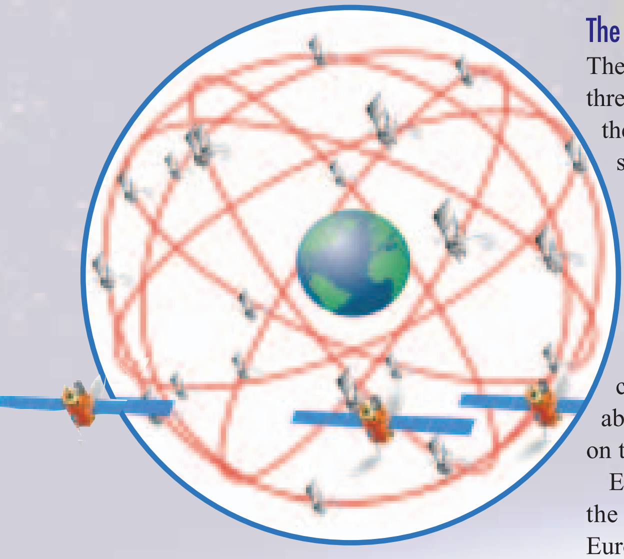


EGNOS

Alberto Garcia, Michel Tossaint, Jaron Samson,
Gonzalo Seco, Juan De Mateo & Jean-Luc Gerner
ESA Directorate of Technical and Quality Management,
ESTEC, Noordwijk, The Netherlands

When the Global Positioning System (GPS) was first conceived in the United States in the late 1970s, it was intended for institutional use only. The US Navy needed a system that could provide it with accurate positioning information anywhere in the World. Nobody at that time could have imagined the huge growth in civil applications of global positioning that has occurred since then. The same was true when Europe embarked on the development of the European Global Navigation Overlay System (EGNOS) in the early 1990s with the primary objective of providing Civil Aviation Authorities with the accuracy and integrity needed for safe air-traffic control over European countries. It eventually transpired that in the improved performances brought by EGNOS lay the foundations for a wide range of new navigation applications in Europe for its roads, railways, inland and coastal waterways, and even its pedestrians. In 2008, when the Galileo system is fully deployed and offers an even higher level of service, yet another raft of as yet unforeseen applications for both professionals and the public can be expected to be triggered, based to a large extent on the precursor activities initiated with EGNOS.

* The development of navigation applications is managed within ESA by the Navigation Applications Office in the Navigation Department. The technical support is provided by the Radio Navigation Section in the Technical Directorate. In recent years, the latter has developed numerous innovative EGNOS navigation applications in order to stimulate European industry and help the EGNOS system penetrate the navigation market.



The EGNOS concept, with three geostationary satellites

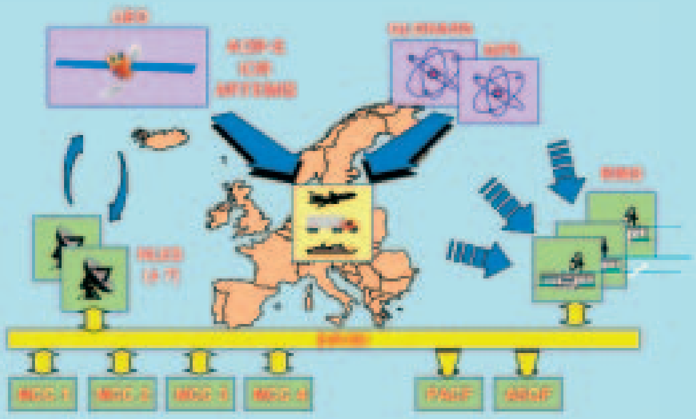
The GPS and EGNOS Systems

The original GPS system is made up of three distinct elements, namely the space, the control and the user segments. The space segment consists of 24 satellites orbiting the Earth at approximately 20 200 km altitude every 12 hours. The constellation is designed in such a way that at any given time there will be at least four satellites visible (the minimum required for positional computation for most applications) above a 15° cut-off angle from any point on the Earth's surface.

EGNOS is a joint undertaking by ESA, the European Commission and the European Organization for the Safety of Air Navigation. It has been designed to provide a civil and safe complement to the GPS system over the European continent by transmitting, via geostationary satellites, GPS-like ranging signals containing differential corrections and integrity information that supplements the basic GPS positioning solution. At the same time, the ranging signals from the geostationary satellites themselves can also be used in the position determination.

How EGNOS Works

The data-processing cycle starts at the Receiver Integrity Monitoring Stations (RIMS) which make pseudo-range measurements to the American GPS - and in future possibly also Russian GLONASS - satellites. These measurements are sent through the European Wide Area Network (EWAN) to the active Master Control Centres (MCC), where the corrections and integrity information are computed and uploaded to the geostationary (GEO) satellites by the Navigation Land Earth Stations (NLES). These GEO satellites broadcast GPS-like signals on which this information is modulated. The user can then combine the GPS pseudo-ranges with the EGNOS corrections, and compute the integrity of the computed positions. The differential corrections for the GPS signals consist of orbit and clock corrections and precise ionospheric corrections. The integrity information consists of estimated variances in these corrections, including some integrity margin. The foreseen European constellation is shown in the figure above, with three geostationary satellites covering the European service area.



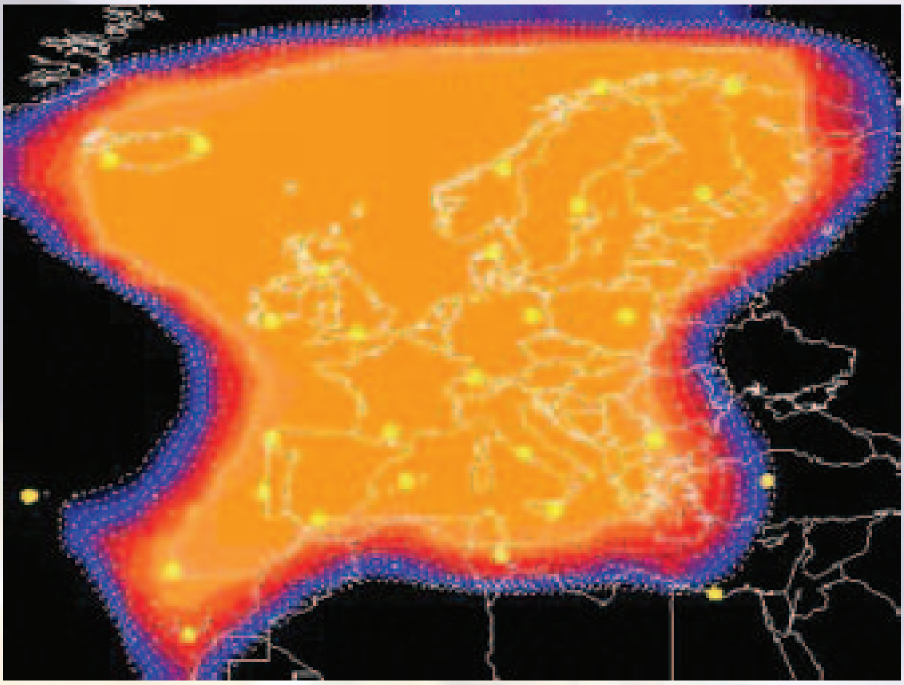
The EGNOS Enabling Technologies

The widespread application of EGNOS is facilitated by recent advances in technology in several key areas, including inertial sensors, receiver technology and communications systems.

The latest inertial sensors (odometers, gyroscopes, accelerometers, etc.) are the ideal complement to EGNOS for improving the availability, accuracy and safety of the overall hybrid system. The availability of EGNOS depends unavoidably on the operational environment, in that the signal transmitted by the satellite can be temporarily blocked out, especially at high latitudes, by trees, mountains, buildings, tunnels, etc., whereas the inertial-sensor information is always available and can easily fill-in for short-term outages in the satellite-based data. On the other hand, inertial sensors provide good relative accuracy over short periods of time, but can 'drift' over extended periods and thereby fail in providing an absolute reference. EGNOS, however, provides superb long-term stability, which can be used to calibrate the inertial sensors. An integral part of the development of the positioning terminals for some of the applications has therefore been the design of an appropriate 'fusion algorithm' that combines the best properties of both types of information.

The advance in inertial-sensor technology due, for example, to MEMS (Micro-Electro-Mechanical Systems), has made cheap, small, high-performance devices a reality, leading to competitive hybrid positioning systems. Other types of sensors, such as high-speed digital cameras, have also progressed significantly of late and are also useful in combination with EGNOS receivers. Thanks to the wider availability of accurate digital maps, more and more applications will combine satellite navigation with map-matching algorithms.

The continuous advance in ASIC (Application Specific Integrated Circuit)



Expected EGNOS coverage for a high-accuracy European service with 1 to 3 metres horizontal accuracy

technology directly translates into an improvement in GPS/EGNOS receiver technology. Nowadays, there are a large variety of receivers to meet all application needs, from the cost-sensitive and less-demanding solutions to dual-frequency high-performance implementations. For example, the reduction of power consumption and size are key aspects in applications using handhelds. Technology is also facilitating the integration of receiver components into a smaller number of chips, bringing further benefits in terms of cost, size, power and reliability. EGNOS receivers are present in the market in a variety of forms, including single chips, OEM boards and application-specific receivers, so that each assembler of positioning terminals can easily find the solution that best fits their needs.

For most service applications, the navigation terminal must include some communication functionality, in order to be able to:

- transmit or receive raw measurements so that it can support, for instance, real time kinematic positioning
- receive EGNOS corrections via alternative means other than the geostationary satellite
- transmit information (position, alarms, etc.) to a control centre and receive commands from it.

There are a variety of communication systems that may be used together with the navigation terminal, some of the most common being: GSM, GPRS, UMTS, LW/MW radio, FM RDS, FM Darc, IEEE 802.11x and satellite communications (Inmarsat, Orbcom, Globalstar, etc.). Others are application-specific systems, such as GSM-R for trains, AIS, Loran-C and IALA for maritime applications, and VDL-4 for aircraft. The communication and navigation functionalities can be integrated on the same board, and in some cases even on the same chip. It has been estimated that, for mass-market applications, adding mobile-phone functionality (GSM) to a GPS receiver would increase the cost of the unit by less than 10 Euros. It is just this combination of communications and positioning that is leading to a host of new applications for EGNOS.

Categories of EGNOS Service

EGNOS will benefit Europe's citizens by providing four particular categories of service:

The first driver for developing EGNOS was 'Safety-of-life applications'. EGNOS has been designed to comply with the strict requirements of civil aviation, but will also reduce the need for expensive ground-based equipment. EGNOS will also offer the possibility of performing curved rather than straight landing approaches at airports, which should result in both increased landing capacity and reduced noise pollution. Other examples of 'safety-of-life applications' are railways and particular maritime operations, where EGNOS can also lead to greater safety margins and reduced costs.

'Law-enforcement applications' are a second category of EGNOS services, whereby vehicle-position information can be used by authorities to monitor the compliance of vehicles with legal restrictions on their locations and speeds. By knowing a car's position, for example, an authority could charge the driver according to the type of road being used and the period spent on it ('road tolling'). Another example of 'law enforcement applications' could be an authority checking that fishing boats do not enter pre-defined exclusion zones at sea. Because GPS anomalies, which occur from time to time (e.g. satellite clock jumps), may not be detected by the user, a GPS-only solution is not sufficiently reliable for such applications. Since basic GPS does not provide integrity information, an anomaly could result, for instance, in a large number of road users being incorrectly billed. With the real-time integrity information broadcast by EGNOS, such anomalies cannot occur.

'Commercial services' are the third category. For the majority of commercial services, availability and accuracy are the most important navigation parameters. The use of EGNOS instead of GPS-only will improve both accuracy and availability, thereby creating the potential for new commercial services. For example, ESA has recently been contacted about using EGNOS for the 'Tour de France' cycle race, to provide accurate real-time information on the positions and speeds of the individual riders, as well as their relative positions.

The fourth category are 'Special services'. Some applications require a

EGNOS application developments will significantly improve operational safety and efficiency for many types of vehicles, including airport service units like snowploughs (Photo courtesy of Flughafen München GmbH)

certain level of integrity, but cannot be classified under the first three categories. One such example is the use of EGNOS for guiding blind people, where the improved accuracy and integrity of the system compared with a GPS-only solution can dramatically improve the quality of the service being offered.

Selected Applications

The following are just a small selection of the twenty or more satellite-navigation applications that the Radio Navigation Section at ESTEC has helped to investigate and develop over the last few years, ranging from individual-user to system-level (EGNOS, Galileo) applications:

Winter road services

A major concern for public-service providers is the growing demand for legally sound documentation of their operations, to protect themselves against lawsuits after accidents caused by icy or otherwise treacherous winter road conditions. The integrity protection inherent in the EGNOS system allows this goal to be achieved without the need for expensive local augmentation systems.

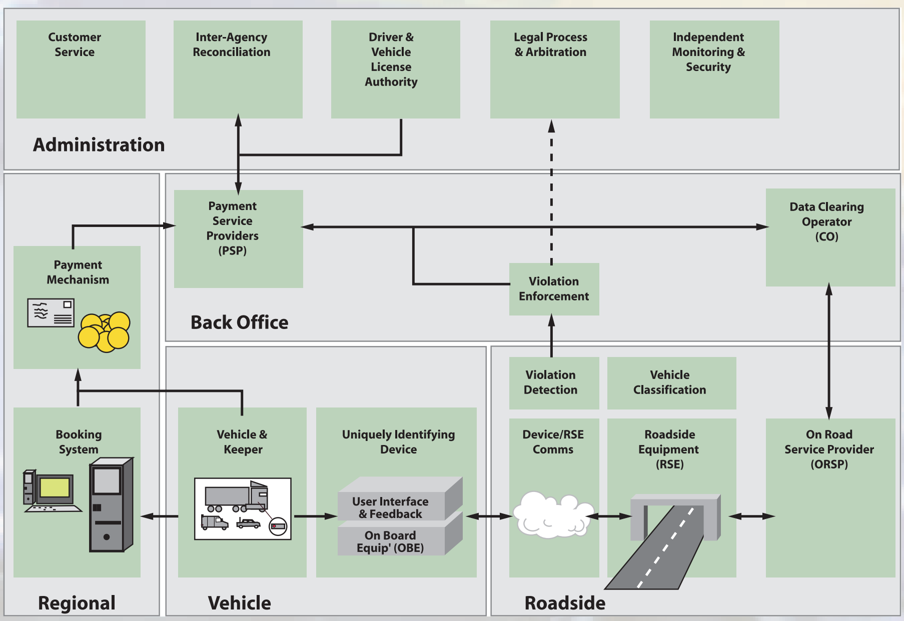
Another concern is the operation of snowplough services under poor-visibility conditions, be they caused by falling snow or fog, or simply because the limits of snow-covered roads are no longer visible. Thanks to the EGNOS system's superior precision, accurate driver guidance can be offered by equipping the vehicle with a detailed moving-map display.

In most cases, local authorities convert their snowplough vehicles outside the winter season to provide other services like street cleaning or the mowing of grass verges. Here again, the integrity provided by EGNOS can provide reliable operating records for legal and billing purposes.

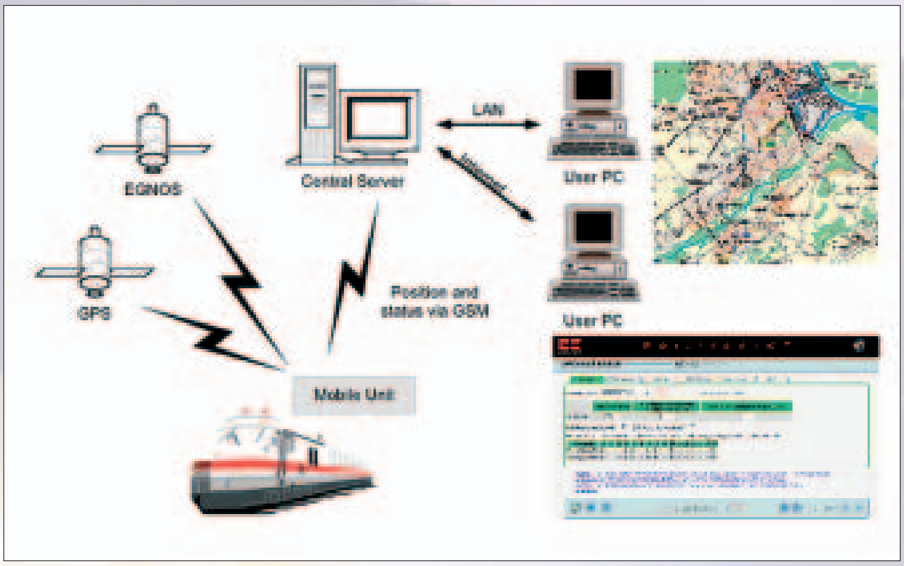
One example is the operational supervision and management of the winter service vehicles at Munich Airport in Southern Germany. As these services are operating on the entire airport premises – specifically on the taxiways and runways – an extension of the current system is being prepared with Euro Telematik (Germany) to provide a steering aid to the driver and to implement additional safety and warning functions.

Electronic road tolling

In the road sector, several Intelligent Transport Systems (ITS) are currently being designed, many of which will make use of satellite-navigation equipment. The latter will be used to provide new services that require particular levels of safety and reliability. EGNOS is ideal for that purpose and so ESA, together with the Portuguese firm SKYSOFT, initiated the 'Active Road Management Assisted by Satellite' (ARMAS) demonstration project. Its aim is to show how to transform the transport infrastructure (roads, bridges, urban roads) into a safer and more user-friendly environment, by improving safety, increasing dynamic traffic-management capabilities, and providing Electronic Fee-Collection (EFC) mechanisms through the



A generic Electronic Fee-Collection (EFC) system for road tolls



The INTEGRAIL system architecture (Courtesy of Kayser-Threde GmbH)

use of satellite positioning. Other functionalities foreseen include 'warning messages' and 'SOS requests'.

A recently approved Directive calls for the creation of a European Electronic Road Toll System based, in the longer term, primarily on the use of satellite-based systems. The proposal advocates the use of satellite positioning and mobile communications technologies, namely GPS/EGNOS and Galileo, for the deployment of the European toll service as well as for all new national systems, these technologies being more flexible and better suited to the new Community charging policies. Moreover, they are already a component of many of the active safety systems that manufacturers are starting to install in their vehicles.

The ARMAS architecture has been influenced by the existing Traffic Control Centres (TCCs). The Regional Navigation Control Centre (RNCC) is seen as an evolution of the TCC, with greater functionality. Existing Road-Side Equipment (RSE) does not need to be replaced, but can be integrated into ARMAS (see figure).

Low-density railway traffic

The train command and control systems in use today are too expensive for cost-effective application on lines with low traffic densities, for instance just one train per hour. Consequently, many such lines all over the World are still equipped with outdated or human-based safety systems. The new ERTMS/ETCS system (European Rail Traffic Management System/ European Train Control System) will provide a unified safety standard at European level, but it will be used mainly on high-speed and trans-European lines. Although this new common standard will provide clear safety benefits, the very high installation and maintenance costs are not viable for lines with low traffic densities.

There is therefore a clear need for an innovative and cost-effective system for low-density routes based on new available technologies, including satellite-based positioning. Just such a system, known as LOCOPROL/LOCOLOC, is currently being developed in cooperation with Alstom BSI (B). This GNSS-based system will provide the same level of safety as on high-density lines, whilst greatly reducing deployment, operating and maintenance costs. The LOCOPROL project, supported by the European Commission as part of the 5th Framework Programme, essentially addresses the location, control centre, and communications elements, while the complementary LOCOLOC project, supported by ESA, is focussing on the safe-speed measurement element and the service centre for future users.

The greater cost-effectiveness of the LOCOPROL/LOCOLOC solution is achieved mainly by relocating the safety functions from the ground (ERTMS standard) to the train, removing the need for such expensive elements as track points, balises, and many other sensors required today.

A successful live demonstration of the system has already been conducted using an SNCB train on 15 kilometres of track in Belgium.

The INTEGRAIL unit installed in a locomotive for test purposes (Courtesy of Bombardier GmbH)

Challenging navigation in narrow waters (Photo courtesy of Seatex-Konsberg)

Advanced rail-traffic management and safety

INTEGRAIL is a prototype demonstration system that uses EGNOS for the autonomous and reliable determination of a train's position, direction and speed under practically all weather conditions. It is an advanced train and signalling control application that imposes much more stringent safety requirements than the current fleet-management information applications. It also promises significant improvements for the rail-traffic operator in terms of cost, redundancy, and reliability by adding satellite-navigation information and, even more importantly, the integrity information provided by EGNOS.

INTEGRAIL has been developed by Kayser-Threde, Munich (D), as prime contractor, in partnership with Bombardier Transportation/Rail Control Solutions, Ulm (D) and ifEN (D). The complete system consists of mobile units to be mounted in the locomotives and a Control Centre.

A necessary prerequisite for the adoption by the rail operators of EGNOS-based systems for train control and management is to conduct extensive field trials and to characterise their performance under representative conditions. Two such demonstrations have been conducted over a period of 8 months; the first took place in Austria using trains from LogServ, and the second in Belgium with trains belonging to SNCB. The extensive data that were collected showed that the INTEGRAIL system delivers a mean accuracy of better than 5 metres.

Guiding and monitoring maritime vessels

The accuracy of the EGNOS system makes it extremely suitable for guiding shipping, including coastal navigation, dredging operations and manoeuvering within harbours. It is also very economical as it means that the expensive deployment of the local reference stations required for systems like Differential-GPS can be dispensed with.

For vessel-monitoring applications, it is EGNOS's integrity that is key. EEC Regulation 2847/93 requires, since 1 January 2000, that all Community fishing vessels more than 24 metres long carry a 'blue box' for a satellite-based Vessel Monitoring System (VMS). This box provides automatic reporting of the vessel's position at all times, as well as communication with the Fisheries Monitoring Centre (FMC) of the State in which the vessel is registered. EEC Regulation 489/97 stipulates that the tracking application must provide reliable position reporting for effective control by the authorities. EGNOS's integrity makes its positioning information usable in a court-of-law, which GPS-only-based VMS would not be.

VMS was developed in Portugal and is being upgraded by INOV under ESA contract.

Vessel monitoring in narrow waters

As a result of Regulation V/19, paragraph 2.4, of the International Convention for the Safety of Life at Sea (SOLAS), introduced in 1974, it is mandatory for all ships larger than 300 gross tonnage engaged in international voyages, all cargo ships of more than 500 tons, and all passenger ships irrespective of size, to be fitted with an Automatic Identification System (AIS). The EGNOS TRAN project has been exploring the benefits of integrating the EGNOS technology with a VHF link like AIS, which is normally used for communication between vessels and with the shore. A system was set up in the fjords of Trondheim (Norway). The AIS stations were equipped with EGNOS signal receivers and its differential corrections and integrity information were then specially formatted and transmitted through AIS to the vessel, in order to ensure compatibility with the local Differential-GPS equipment onboard. Field trials were conducted during the winter of 2002/3 with the EGNOS Test Bed signals using the coastal vessel MS Nordlys, which plies continuously between Bergen on the Norwegian west coast and Kirkeness close to the northern border with Russia. These trials based on the use of only two AIS stations demonstrated good complementarity in terms of EGNOS coverage and continuity of service, meeting the accuracy and integrity requirements laid down by International Maritime Organisation (IMO) regulations for coastal and harbour navigation.

Conclusion

European expertise in the development of satellite navigation systems has been initiated with EGNOS and is now being successfully applied to Galileo. Similarly, the applications being developed with EGNOS are the forerunners of Galileo applications. ESA has been complementing the efforts of the European Commission and the Galileo Joint Undertaking in this direction in order to stimulate institutional and commercial interest in a wide range of safety-related and other essential services that can be provided across a broad range of European business sectors. This has boosted interest in the development of navigation applications by companies throughout Europe, ranging in size from the large to the very small. It is ESA's intention to maintain its effort in this domain to ensure that European companies achieve a strong position in this new and very promising market.

The ESA History Project

Karl-Egon Reuter
Chairman of the ESA History Advisory Committee

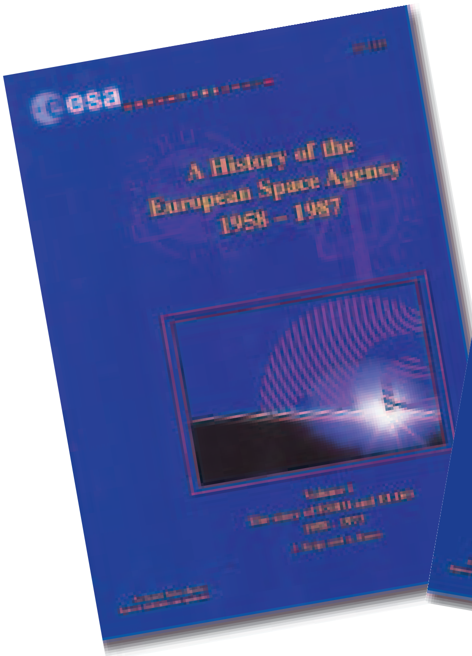
Johann Oberlechner
Director General's Cabinet, ESA, Paris

At the end of the eighties, the space age was still relatively young and had largely been ignored in terms of academic historical research. This was especially true in Europe, which was not a competitor in the high-profile space race that took place in the 1960s. The European Space Agency, and its Director General Prof. Reimar Lüst, therefore responded enthusiastically when, in 1989, three historians came forward with a proposal to write an independent authoritative history of ESA and its precursor organisations ESRO and ELDO, which have been coordinating Europe's space endeavours for more than forty years.

Following the initial contact made during a scientific symposium in Palermo, a feasibility study was undertaken in the first half of 1990. The positive outcome of that study prompted ESA to give its full support to the proposed History Project. After the ESA Council had formally given its approval for the Project, work got under way with the signing of a study contract on 27 November 1990.

The Approach

A preparatory task of decisive importance when assessing the feasibility of undertaking the ESA History Project was the transfer of the Agency's archives to the European University Institute in Florence (I). This had already started in 1989, which meant that professionally prepared document collections were available for consultation right from the outset. The catalogue for this collection of texts, which contains a complete set of internal ESA records up to the end of the 1980s, plus correspondence and some personal archives, can be consulted at the Institute's web site (http://www.arc.iue.it/).



To ensure a successful outcome to the Project, and in line with the proposals set out in the feasibility study, it was decided to base the project planning on the following three cornerstones:

- Firstly, the research was to be the work of three independent professional historians. Dr John Krige, who had already been the driving force behind the CERN history project over a number of years, agreed to lead the project. Professor Arturo Russo from the University of Palermo (I) and Professor Michelangelo de Maria from the University of Rome (I) were appointed project researchers and made a significant contribution to the work. Prof. De Maria later withdrew for personal reasons and was replaced in 1993 by Dr Lorenza Sebesta from the University of Bologna (I).
- Secondly, the Project was to be based at an independent academic institution. With ESA's archives having been sited since 1989 at the European University Institute in Florence, it seemed the most appropriate place at which to carry out the work, with Dr Krige being appointed to a research post there. The Rector of the Institute accepted this proposal and stated his willingness to oversee the Project in collaboration with ESA.
- Thirdly, an ESA History Advisory Committee was to be set up to oversee the progress of the research work and to advise ESA on administrative and academic questions. The membership included a number of ESA pioneers (Michel Bignier, Peter Creola, George van Reeth) and distinguished European historians (Prof. Paolo Galuzzi from Florence, Prof. Guido Gambetta from Bologna, Prof. Svante Lindqvist from Stockholm, Prof. Dominique Pestre from Paris, and Dr Walter Rathjen from Munich). Former ESA Director General Reimar Lüst, having been actively involved in European space activities from the very beginning and having been the initial driving force behind the Project, was appointed to chair the Advisory Committee.

The Results

The ambitious project to write up ESA's history was completed in 1999. The results, which are most visibly measurable in terms of the range and quality of the resulting publications, are impressive in their scope. Because of the very large amount of material available, from 1992 onwards ESA began publishing a series of History Study Reports, 24 of which have been issued in all (see accompanying panel). The complete history itself was published in two volumes (462 and 703 pages, resp.) as an ESA Special Publication (SP-1235). The first volume covers the history of ESRO and ELDO, and the second the history of ESA up to 1987. Supplementing this two-volume history, a smaller work has been published on the history of European space activities from 1960 to 1973 (ESA SP-1172), as well as numerous articles in the relevant specialist journals. A series of Symposia and Seminars on European space-history topics have also been organised as part of the History Project.

The culminating highlight of the Project was an International Symposium, jointly hosted by ESA and the Science Museum in London from 11 to 13 November 1998. This attracted leading figures from

ESA History Study Reports

HSR-#	Date	Title	Author
1	July 1992	The Prehistory of ESRO 1959/60	J. Krige
2	October 1992	ESRO's First Scientific Satellite Programme 1961-1966	A. Russo
3	November 1992	Choosing ESRO's First Scientific Satellites	A. Russo
4	January 1993	The Early Activities of COPERS and the Drafting of the ESRO Convention (1961/62)	J. Krige
5	March 1993	Europe in Space: Edoardo Amaldi and the Inception of ESRO	M. de Maria
6	March 1993	The Definition of a Scientific Policy: ESRO's Satellite Programme in 1969 - 1973	A. Russo
7	March 1993	The Launch of ELDO	J. Krige
8	May 1993	Europe into Space: The Auger Years (1959 - 1967)	J. Krige
9	May 1993	The Early Development of the Telecommunications Satellite Programme in ESRO (1965 - 1971)	A. Russo
10	September 1993	The History of ELDO Part 1: 1961 - 1964	M. de Maria
11	January 1994	Reflections on Europe in Space	J. Krige & A. Russo
12	January 1994	The Origins of the Federal Republic of Germany's Space Policy 1959 - 1965: European and National Dimensions	P. Fischer
13	February 1994	ESRO's Telecommunications Programme and the OTS Project (1970 - 1974)	A. Russo
14	July 1994	United States - European Cooperation in Space During the Sixties	L. Sebesta
15	February 1995	United States - European Cooperation in the Post-Apollo Programme	L. Sebesta
16	February 1995	The Scientific Programme Between ESRO and ESA: Choosing New Projects (1973 - 1977)	A. Russo
17	February 1996	The Aeronautical Satellite System: An Example of International Bargaining	L. Sebesta
18	September 1996	The Availability of European Launchers and Europe's Decision 'To Go It Alone'	L. Sebesta
19	August 1997	Big Technology, Little Science: The European Use of Spacelab	A. Russo
20	September 1997	The Definition of ESA's Scientific Programme for the 1980's	A. Russo
21	October 1997	Spacelab in Context	L. Sebesta
22	March 1998	The European Meteorological Satellite Programme	J. Krige
23	September 1998	The Third Phase of the Telecommunications Programme: ECS, Marecs and Olympus	A. Russo
24	May 1999	ESA's Scientific Programme Towards the Turn of the Century	A. Russo

European government, industry and research, all of which have made important contributions to the development of European space activities. Speakers included the former Chairman of the ESA Council at Ministerial Level Lord Sainsbury (UK), and former Ministers such as Michael Heseltine (UK), Hubert Curien (France) and Antonio Ruberti (Italy). The Proceedings were also issued as an ESA Special Publication (SP-436).

Without this rich harvest of publications resulting from the painstaking scientific approach on the part of the team of professional historians, many key but often little-known facets of European space activities over the years would otherwise have remained part of a forgotten past.

Extension of the Project

The ESA History Project concentrated mainly on the intergovernmental collaborative effort in space made under the patronage of ESRO, ELDO and ESA. The national space programmes of the Member States were not included as topics for research. However, the success of the ESA Project and the resources that it had made available for further research aroused strong interest in several Member States. As a result, there are now a growing number of national-level archival and history projects, which should help safeguard this important part of the national heritage and promote wider appreciation of national space achievements.

At the London Symposium, the Director General had indicated the Agency's willingness to support such initiatives. The idea was subsequently put to the ESA Council that December (1998), and also received strong backing from the Advisory Committee, chaired by Prof. Lüst, at its final meeting in March 1999.

An informal gathering of Member State representatives on 20 April 1999 took stock of any ongoing projects for writing up national space histories. Also discussed was an extension of the History Project, with a view to covering national activities in a second phase. That meeting was attended by delegates from the United Kingdom, France, Germany and Italy, and strong interest was also expressed by four

"A sense of history is important for any organisation: it both binds members together and helps to identify where we are heading…….. The key role that ESA has played since its inception in 1975, and above all its ability to adapt to changing circumstances, stand the Agency in good stead to play a key role in this future".
Lord Sainsbury, UK Science Minister, speaking at the London Symposium

ESA HISTORY COMMITTEE

Status: July 2004

Chairman:	Karl-Egon Reuter
Austria	Johannes Ortner Bruno Besser
Belgium	George van Reeth Dawinka Laureys Rober Halleux
Canada	Florian Guertin
Denmark	Preben Gudmandsen
Finland	Risto Pellinen Hanna Lappalainen
France	Louis Laidet Michel Bignier Hervé Moulin
Germany	Helmut Trischler
Italy	Lorenza Sebesta Michelangelo de Maria
Netherlands	Daniel de Hoop
Norway	Per Torbo
Spain	Manuel Serrano
Sweden	Jan Stiernstedt
Switzerland	Peter Creola
United Kingdom	Douglas Millard
Consulting Scientist	John Krige
ESA	Bruce Battrick Roger Elaerts Johann Oberlechner Nathalie Tinjod

other countries whose delegates were unable to attend that day (Belgium, Finland, Norway and Sweden).

Those present discussed a variety of documentation and research projects, some planned and some already under way, designed to place on record and highlight the histories of national space programmes. They were insistent that ESA should play a key role in coordinating the various activities, so as to capitalise on the results of the original History Project, make the most effective use of the limited resources available, and foster synergy between individual projects.

With this prior clarification, the ESA Executive was able to put to Council a proposal for continuing the History Project into a second phase, to be devoted exclusively to the history of national space activities. Council unanimously approved this proposal at its 23/24 June 1999 meeting. Since then, of course, Portugal has joined the ESA family, and the accession of Greece and Luxembourg was given the go-ahead at the March 2004 Council meeting. Their space histories are therefore now just beginning!

Even before the Project extension was approved, it was already clear that work in such a second phase needed to be organised differently from the writing up of the purely ESA history. It is, therefore, headed by an ESA project leader, who announces opportunities for national history projects and acts as interlocutor within ESA. In support, an academic project scientist was appointed – and here we were able to persuade Dr John Krige, who led the original Project, to come back and supervise the scientific progress of national projects and be responsible for their coordination. ESA is providing the necessary administrative support.

As decided by Council, an ESA History Advisory Committee was again set up to serve as a consultative body, its membership being drawn from the Member States participating in the Project (see accompanying panel). This Committee has examined all project proposals submitted by the Member States, assessed their quality, and estimated the financial support required, having regard first to available resources and competing proposals. Dr John Krige also sits in an advisory capacity on this Committee, which usually meets twice per year, with ESA providing the Secretariat.

The Results of Phase 2

In contrast to the original History Project, which was only concerned with ESA's multinational space activities, the second phase, which is still ongoing, is progressing much more slowly. This is due firstly to the very different structures of the groups concerned with space history in the various Member States. In many countries it was necessary first to apply to appropriate academic groups or institutes before the actual historical research could be started. A second obstacle to a prompt start was the increasingly apparent lack of suitable archives for the historians to draw upon. It was not therefore uncommon for the start of work to involve laborious searching and recording of the necessary documents prior to beginning the actual writing-up process.

When it transpired that the preparatory activities in most Member States would require more time than had originally been allowed, the Advisory Committee recommended applying a step-by-step approach. Before a complete national space history was drafted, each ESA Member State was first to produce a concise overview of the historical development of its space policy, describing the milestones and turning points in that history. This was supplemented by some smaller project tasks, which either served to identify and compile archive material or to describe specific areas of national space programmes.

Despite the initial difficulties, Phase 2 of the ESA History Project has already yielded a rich harvest, with the overview reports on the national space activities of ten Member States and Canada. These have also been published in the ESA History Study Reports series (see accompanying panel). The reports from five other Member States are nearing completion, with publication expected in the second half of 2004.

The state of preparation of the longer space histories of each of the ESA Member States still varies greatly from country to country, and will place a considerable strain on the Project as it moves towards its conclusion, given that Phase 2 has to be completed no later than the end of 2005. The accompanying panel summarizing the progress of the individual national projects shows what still remains to be done to bring the project to a successful conclusion. While the work in Germany and Finland in the respective national languages has been completed, the final versions are not expected until some time in 2005 or 2006. Five countries are missing from the table. For Denmark, Ireland and the Netherlands, the Advisory Committee has agreed that the ‘shorter’ space histories already completed provide an extensive overview of these countries' space activities, making a second longer work unnecessary. The same applies to the report on ESA's cooperation with Canada. Of all the ESA Member States, France has by far the most extensive national space programme, dating back beyond the founding of ESRO and ELDO, and often involving a military component. This means that the existing archives may well be scattered or even inaccessible. Our French colleagues, who have teamed up at the Institut Français d'histoire de l'espace, are therefore faced with a Herculean task of archive searching, verification and processing, ruling out any hope of producing a national space history within the time frame of Phase 2 of the ESA History Project.

Conclusion

The Latin American philosopher George Santayana urged his readers to bear in mind that *“those who do not learn the lessons of history will be forced to repeat them"*. This maxim is particularly relevant to the fast-changing space domain, in which experience already gained can all too often be quickly forgotten. We certainly cannot afford to reinvent the wheel every few years in such high-cost multinational projects. Writing up of the academic histories of cooperation on technology – especially for endeavours in space – is therefore especially important for Europe and should definitely be seen as an ongoing task.

SHORT HISTORIES

Status: 7 July 2004

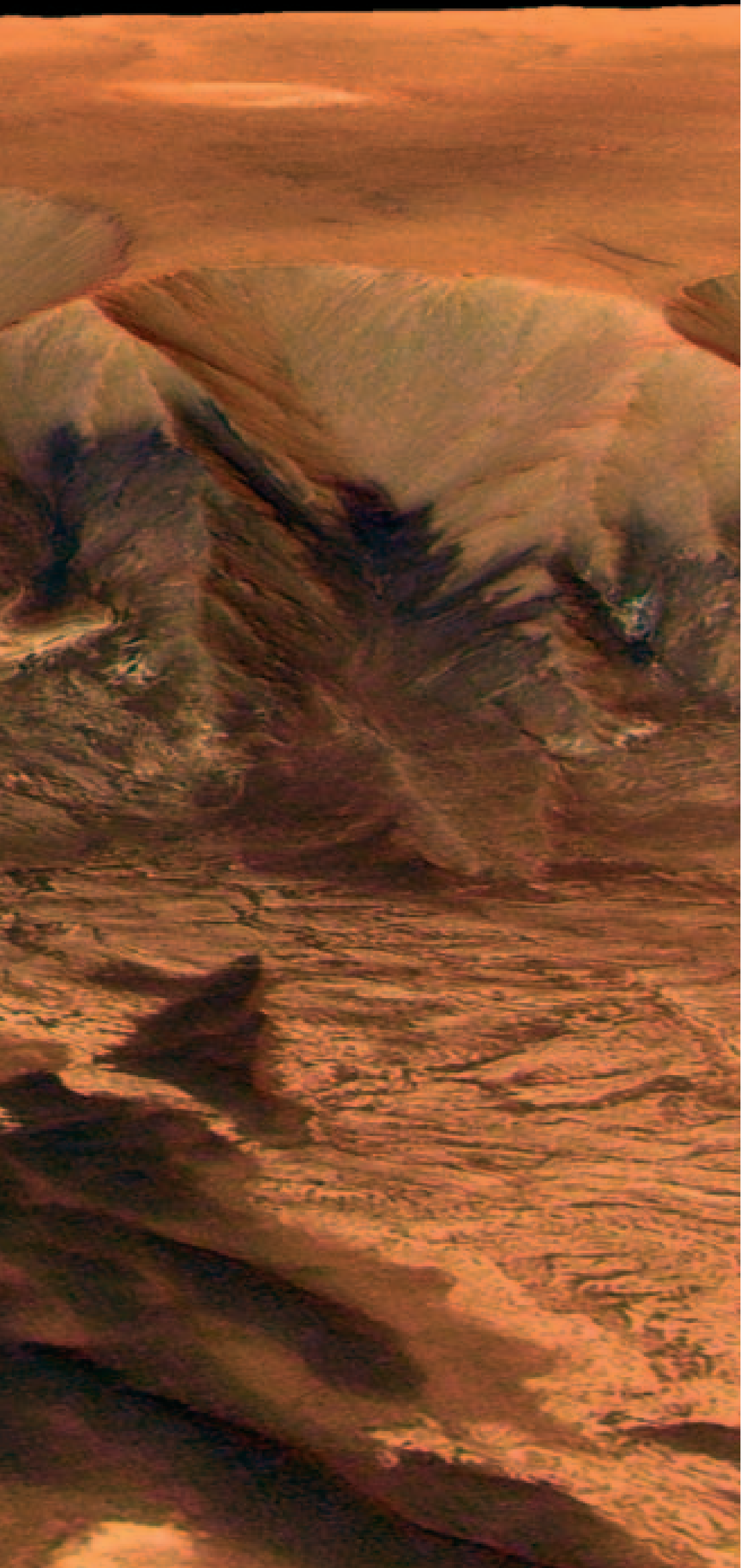
Country	Title	Author	Status
PUBLISHED:			
Austria	Austria's History in Space	Bruno Besser	HSR-34, January 2004
Belgium	Belgium's Participation in the European Space Adventure	Dawinka Laureys	HSR-29, February 2003
Canada	Canada and ESA - Three Decades of Cooperation	Lydia Dotto	HSR-25, May 2002
Denmark	ESRO/ESA and Denmark - Participation by Research and Industry	Preben Gudmandsen	HSR-33, September 2003
Finland	Finland and the Space Era	Ilkka Seppinen	HSR-32, April 2003
Germany	The 'Triple Helix' of Space - German Space Activities in a European Perspective	Helmuth Trischler	HSR-28, December 2002
Italy	Italy in Space	Michelangelo de Maria Luca Orlando Filippo Pigliacelli	HSR-30, February 2003
Netherlands	An Overview of Space Activities in the Netherlands	Joost van Kasteren	HSR-27, November 2002
Norway	Norwegian Space Activities 1958-2003 - An Historical Overview	Ole Anders Røberg John Peter Collett	HSR-35 (in preparation)
Spain	Spain in Space	José M. Dorado et al.	HSR-26, August 2002
Switzerland	Switzerland in Space - A Brief History	Peter Creola	HSR-31, March 2003
TO BE COMPLETED:			
Ireland	TBC	Leo Enright	Expected delivery: October 2004
United Kingdom	UK and Space	Doug Millard	Expected delivery: September 2004
Sweden	Sweden in Space	Jan Stiernstedt	Expected delivery Second half 2004
France	La France dans l'Europe spatiale	TBC	First draft expected: Autumn 2004

LONGER HISTORIES

Status: 7 July 2004

Country	Project	Historian(s)/Author(s)	Due for completion
Austria	The Austrian History in Space	Bruno Besser	December 2004
Belgium	La Belgique et l'Espace	Dawinka Laureys	December 2004
Finland	The History of Finnish Space Activities	Ilkka Seppinen	Finnish version published May 2004 English version October 2004
Germany	Deutsche Raumfahrtpolitik 1923-2002	Niklas Reinke	German version published by Oldenbourg May 2004 English translation to be completed by May 2005
Italy	Italy in Space, 1957-1975	Michelangelo de Maria (leader) Maria Pia Bumbaca Giovanni Paoloni Filippo Pigliacelli Lucia Orlando Lorenza Sebesta Alberto Traballesi	end July 2004
Norway	Participation in the Joint Swedish-Norwegian Project on Nordic Space Cooperation	John Peter Collett Ole Anders Røberg	See under Sweden
Spain	Spain in Space Five essays for Phase 2 Five essays for Phase 3	José Manuel Sànches-Ron José M. Dorado Pedro Sanz-Arànguez José Rivacoba Miguel Angel Sabadell	Phase 2 completed Phase 3 to be completed December 2004
Sweden	The Nordic Dimension of Space Cooperation Four essays	Nina Wormbs Jan Stiernstedt	2nd quarter 2004?
Switzerland	A Place in Space – The History of Swiss Participation in European Space Programmes 1960-2000	Stephan Zellmeyer	September 2006
United Kingdom	British Sounding Rocketry: Skylark and ESRO 1957-71	Matthew Godwin	September 2004

ESA Portal Brings Europe's Mars Adventure to Millions



Fulvio Drigani
Communication Department, ESA Directorate of External Relations, ESRIN, Frascati, Italy

Jurgen Scholz
Information Systems Department, ESA Operations and Infrastructure Directorate, ESRIN, Frascati, Italy

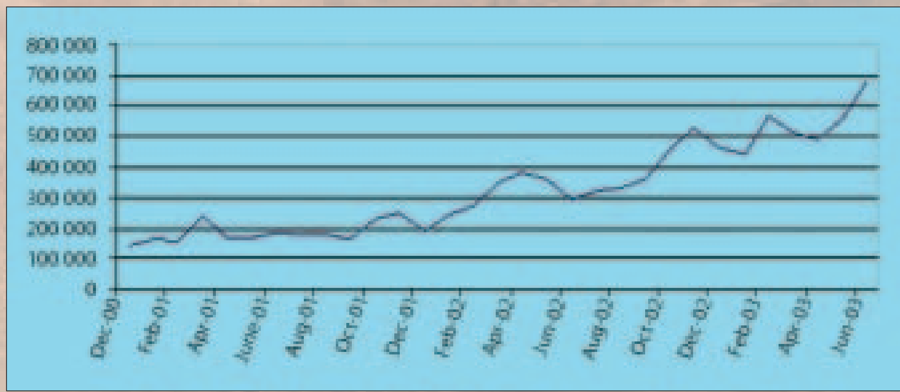
Currently read by more than 1.5 million external visitors a month, the ESA Portal is now the leading source of European space news and information. Mars Express, Europe's first mission to Mars, brought unprecedented traffic to the ESA Portal, presenting the team that run it with the challenge of dealing with a fourfold increase in visitors. A new system put in place in time for the great Mars adventure guarantees fast round-the-clock access to the Portal from around the World.

About the Portal

An independent marketing study carried out in 1999 showed that the public image of ESA was weak and fragmented. At that time NASA was better known among the European public than ESA. The Internet was a logical choice as one of the key elements to boost ESA's visibility and strengthen the Agency's image. Although ESA had already had a web presence since November 1993, a new project was started to create a European online space magazine. The new ESA Communication Portal, www.esa.int, was launched on 18 October 2000. In line with the recommendations of the study, its main objective is to increase awareness of the importance of space for Europe and its citizens among the general public and the media.

With a coherent graphical 'look and feel', the Portal conveys a consistent image of ESA. The site is a dynamic online magazine, with a news desk model, publishing at

The ESA Communication Portal



ESA Portal access statistics, December 2000 to June 2003 – External visitors

least one new article every day, with more and more emphasis on multimedia elements such as graphics, video clips and animations. The backbone of the ESA Portal is its ContentServer publishing system, allowing editors to concentrate on news, content, and images, while guaranteeing a consistent graphical house style.

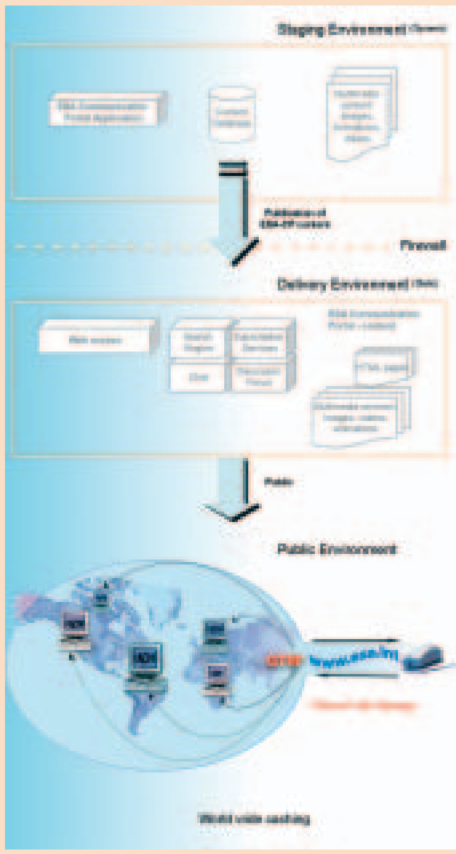
In the three years since its launch, the number of visitors to the Portal has grown steadily. From 140 000 visitors in December 2000, by the end of 2001 the Portal

What is Caching?

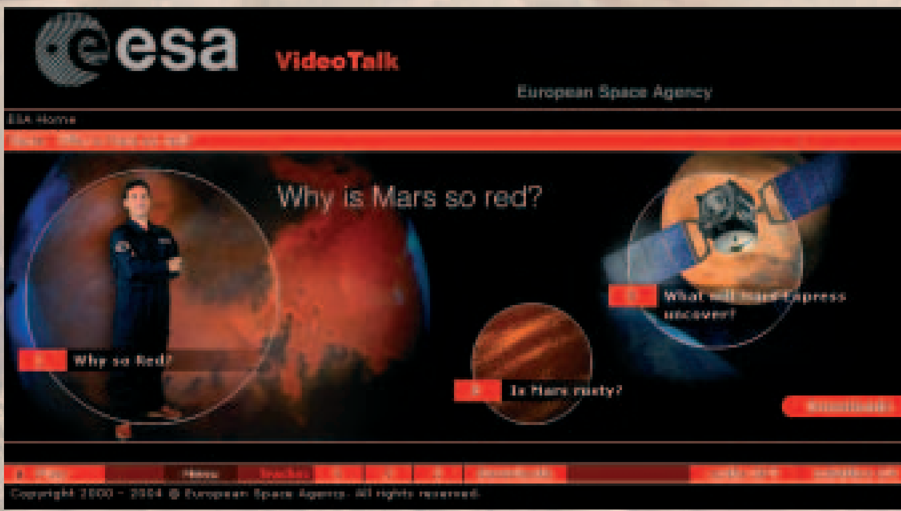
'Caching' basically means that a copy of the ESA Portal's content is stored on thousands of other servers worldwide. These servers are close to the 'edge of the Internet', i.e. very well connected to the backbone network infrastructure. A user requesting to see an ESA web page thereby no longer downloads this from the Portal's server at ESRIN in Frascati (I), but from the closest and best available server. This is made possible with the support of a commercially available Content Delivery Network and sophisticated worldwide Internet traffic monitoring and management applications. As soon as any change is made on any page of the Portal, it is almost instantly replicated on the network of servers.

This 'whole-site-delivery' technology relieves the load on the Agency infrastructure, helps to bypass common Internet bottlenecks, and at the same time boosts the performance of the Portal experienced by the visitor in terms of availability and responsiveness.

As well as supporting peaks in traffic due to special events, this service solution offers a number of distinct advantages for the Agency's website year round:
- *guaranteed worldwide fast delivery of the web pages even during peaks in traffic, 24 hours a day, seven days a week*
- *reduced infrastructure costs, since there is no need to upgrade servers, hardware or the network*
- *increased resilience against security threats*
- *real-time on-demand reporting on network utilisation, total bandwidth, and server response times*
- *24/7 availability of technical support staff at a network operations centre.*



The network infrastructure



VideoTalk, an exciting new multimedia feature that discusses the questions that we hope will be answered by ESA's pioneering space exploration

was already attracting about 250 000 visitors per month. This figure doubled again in 2002, reaching 600 000 visitor sessions a month by summer 2003.

An active news promotion policy, as well as partnerships with other media or web players, has played an important role in the steady increase. Visitors are attracted by the reliable flow of news and accurate background information, presented in an easily understandable and coherent way.

The Launch of Mars Express

One of the biggest challenges that the ESA Portal team faces are the 'special events' – launches of spacecraft or astronauts or other high-profile events resulting in peak traffic on the site. With the web being increasingly perceived as the ideal medium for communicating 'space' to the public, the launch of Mars Express in June 2003 boosted the visitor sessions to a then-record of 70 000 visitors on a single day.

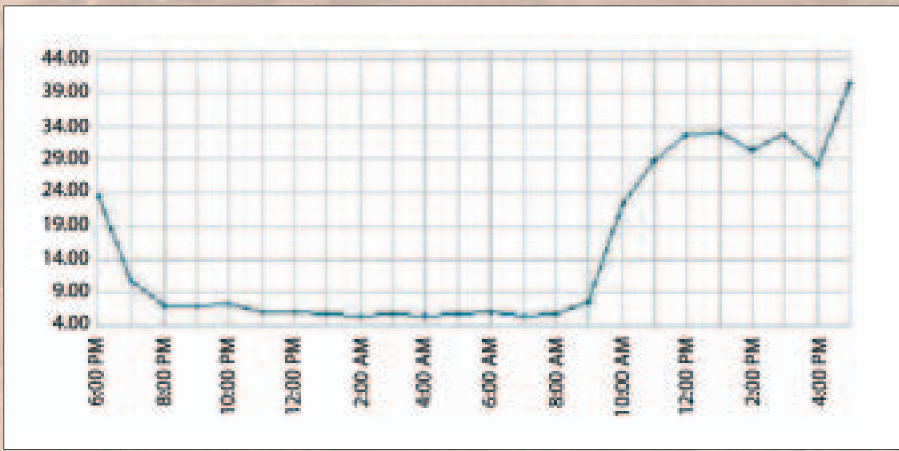
The web-cam image from ESOC was downloaded more than 1.6 million times in December 2003

Monitoring the statistics, it was obvious that contingency plans to handle such peaks in traffic were needed. On the day of the launch of Mars Express, the interest from the general public was so enormous that the infrastructure hosting and serving the web pages became overloaded and users began to report problems downloading material from the Mars pages. The available Internet bandwidth was simply not sufficient to deal with this massive interest.

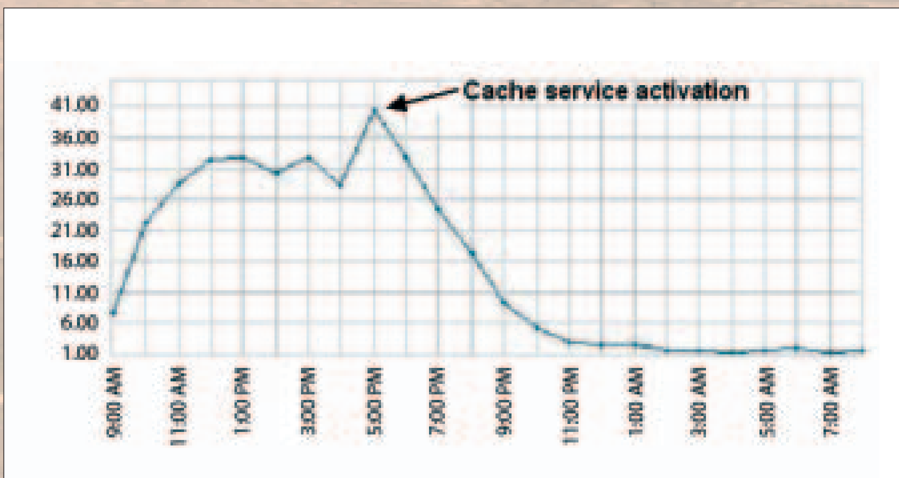
It was clear that with the arrival of Mars Express at the Red Planet, together with the landings of the NASA rovers, worldwide interest in Mars was going to reach unprecedented levels. An immediate solution was necessary. A straightforward increase in network bandwidth had to be discarded for technical and cost reasons, because the real need was neither precisely known nor possible to estimate. Was it 10 Mbit/s, 100 Mbit/s, or even more? By working closely together, the Agency's Online Communication Section and Information Systems Department identified 'caching' of the content of the Portal worldwide as the best solution (see accompanying panel). After evaluation of the vendors available, one of the market leaders was selected to provide this service under contract to ESA.

Arriving at Mars!

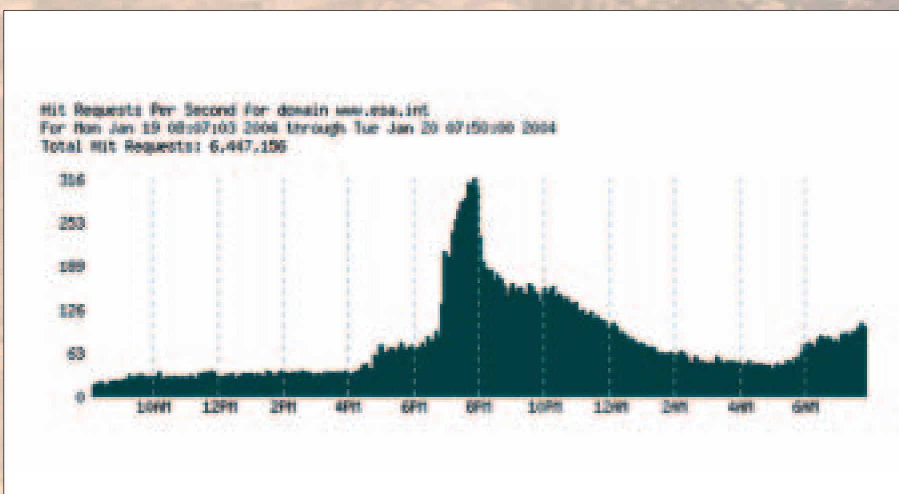
An additional challenge for the Portal team was that while there would not be hard news every single day, this huge new audience had to be kept 'online'. To this end, special Mars Express pages were created in close cooperation with the ESA Science Communication Service. The goal was to have one 'new(s) item' every day, from 1 December until the arrival at Mars on 25 December. These included images, graphics, animations, video clips, background information, news and press releases, interviews with lead scientists, a web-cam image from the Control Room in ESOC refreshed once per minute and, for



Average time in seconds taken to download the ESA Communication Portal Home Page between 6 pm on 3 December and 5 pm on 4 December 2003, prior to activation of the caching service



Average time in seconds taken to download the ESA Communication Portal Home Page between 9 am on 4 December and 8 am on 5 December 2003. Note the drop in download time after 5 pm when the caching service was activated



The traffic surge after the publication of the first Mars Express images

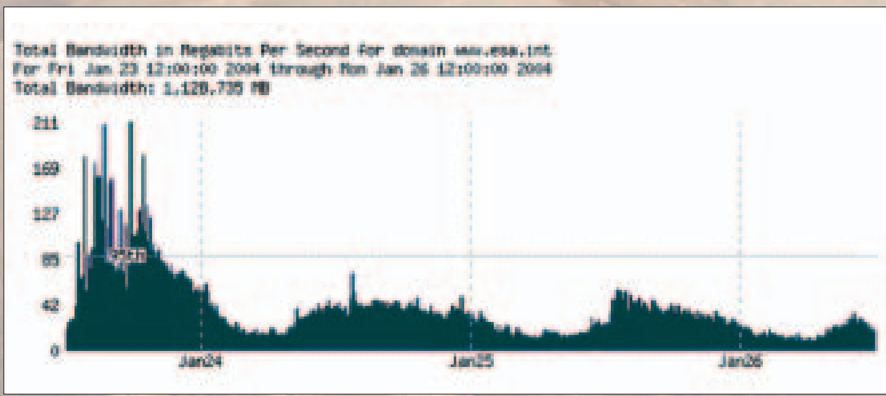
the first time, an exciting new multimedia feature called 'VideoTalk'. For the countdown to Christmas, these elements were presented in the form of an advent calendar – something new each day behind every window.

The first peak in traffic was expected on 19 December, with the separation of the British Beagle 2 lander from the mother spacecraft Mars Express, and so the intention was to activate the new caching service before that date. However, the first blurry image of Mars taken by Mars Express while still 5 million kilometres from its target, published late on 3 December, brought such a big surge in traffic that activation of the caching service had to be brought forward by a week.

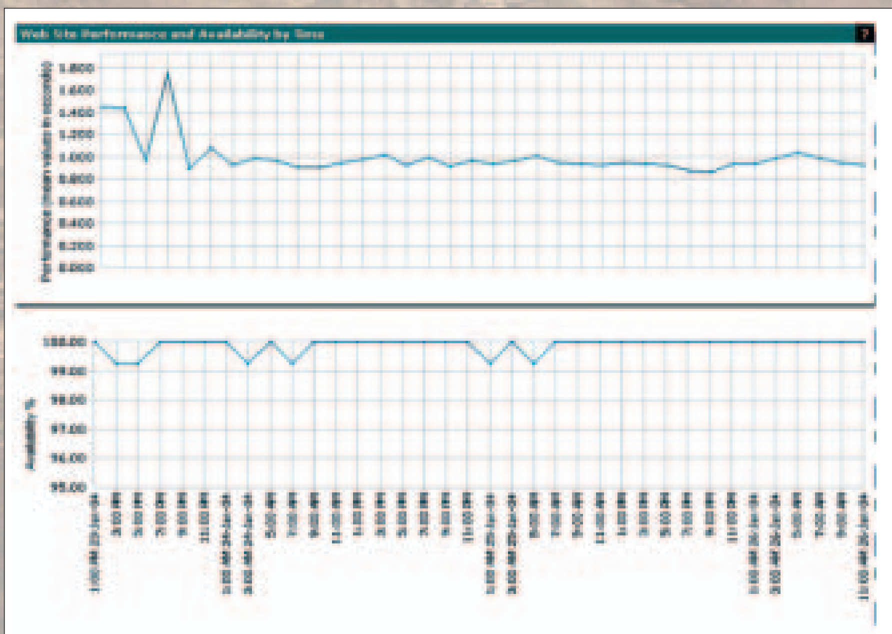
To verify the efficiency of the new caching service an independent monitoring system was set up. The results were startling – while on 4 December from early morning on, the average time required to download the ESA Portal's home page increased steadily from some 20 seconds to more than 40 seconds (against a benchmark value of not more than 8 seconds), in the late afternoon, once the cache servers had taken over at 5 pm, the download time dropped to a 'dream value' of very close to 1 second. At the same time, the website's availability (measured for 35 cities worldwide) increased from a low of 45% in, for example, Shanghai, Hong Kong, San Diego and Kansas City, to 100% everywhere.

Coverage of the separation of Beagle from Mars Express on 19 December, including a live webcast from the ESOC Control Room, attracted another record number for a single day with some 118 000 external visitors. This record was soon to be broken again by the arrival of Mars Express at Mars on Christmas morning 2003, with the added drama of waiting for news about the Beagle lander. In all, 280 000 external visitors participated in live web events and streaming – four times the number that had looked at the site on launch day! Traffic remained very high during the period up to New Year's Eve.

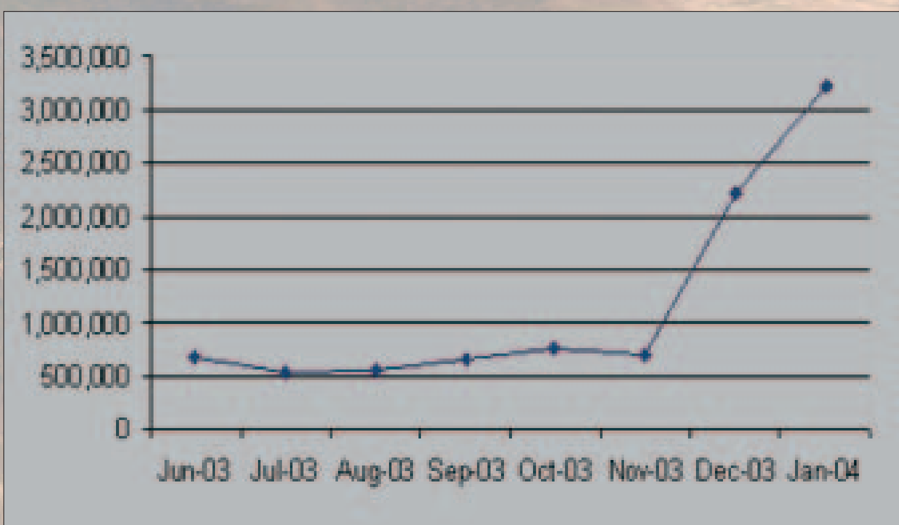
In total, the ESA Communication Portal had served almost 3.4 million visitors during the month of December – almost



Network bandwidth utilisation after the discovery of water on Mars



Average worldwide site performance and availability during the weekend of 23/26 January 2004



ESA Portal access statistics, June 2003 to January 2004 – External visitors

ten times more than during the same period the year before.

Let the Flash Crowds In!

In 'Flash Crowd', a science fiction story of the 1970s, the author describes the consequences of instantaneous (and free) teleportation, which allowed tens of thousands of people worldwide to flock almost instantaneously to the scene of anything interesting that was happening. In web terms, a similar phenomenon occurs when a site catches the attention of many 'surfers' and attracts sudden surges of traffic, often leading to an overload of the site's Internet bandwidth or servers.

Several such 'flash crowds' hit the Agency's Communication Portal at the end of January 2004. The first came with the publication of the first image of Mars taken by Mars Express on 19 January – an all-time high of 310 000 visitor sessions on a single day, on 20 January.

The discovery of water on Mars, officially announced during a Press Conference at ESOC on 23 January, also attracted some 240 000 visitors, with peak traffic continuing all weekend. This event was particularly 'bandwidth heavy', due to the availability of multimedia material, which led to traffic peaks exceeding 200 Mbit/s immediately following the announcement, almost a hundred times the consumption only a few weeks earlier. Although more than 1.1 Terabytes of data were provided to users during this 'hot' weekend, no service interruptions or decreases in performance were reported.

'Brilliant!'

Today the ESA Communication Portal, as an online magazine for the general public and media, has become the leading source of European space information. In the past years, both the number and the variety of sites picking up ESA's news have steadily increased. While in the early years only specialist sites such as Space.com referred to the ESA Portal, today the BBC, CNN, Yahoo, Reuters, USA Today, National Geographic, and the Discovery Channel regularly pick up stories from the ESA Portal.

CNN, Heute Journal, Le Monde and La Repubblica are regular customers of the ESA Portal

The Sunday Times (UK) on 4 January 2004 *"reached out to the brilliant Mars Express website"*, calling it *"enthralling…, rich in contributions from many sources, … and an object lesson in how scientists can harness the web to involve the general public, while also reaching those whose interest is more serious."*

Even after the Mars storm died down, traffic to the ESA Portal has consistently remained above 1.5 million external visitors a month, with smooth delivery of web pages continuing to be guaranteed by the new caching system. Next Christmas promises to be no less exciting, with the arrival at Saturn of Cassini/Huygens, and the release of ESA's Huygens probe to parachute down to explore the surface of the planet's mysterious moon Titan.

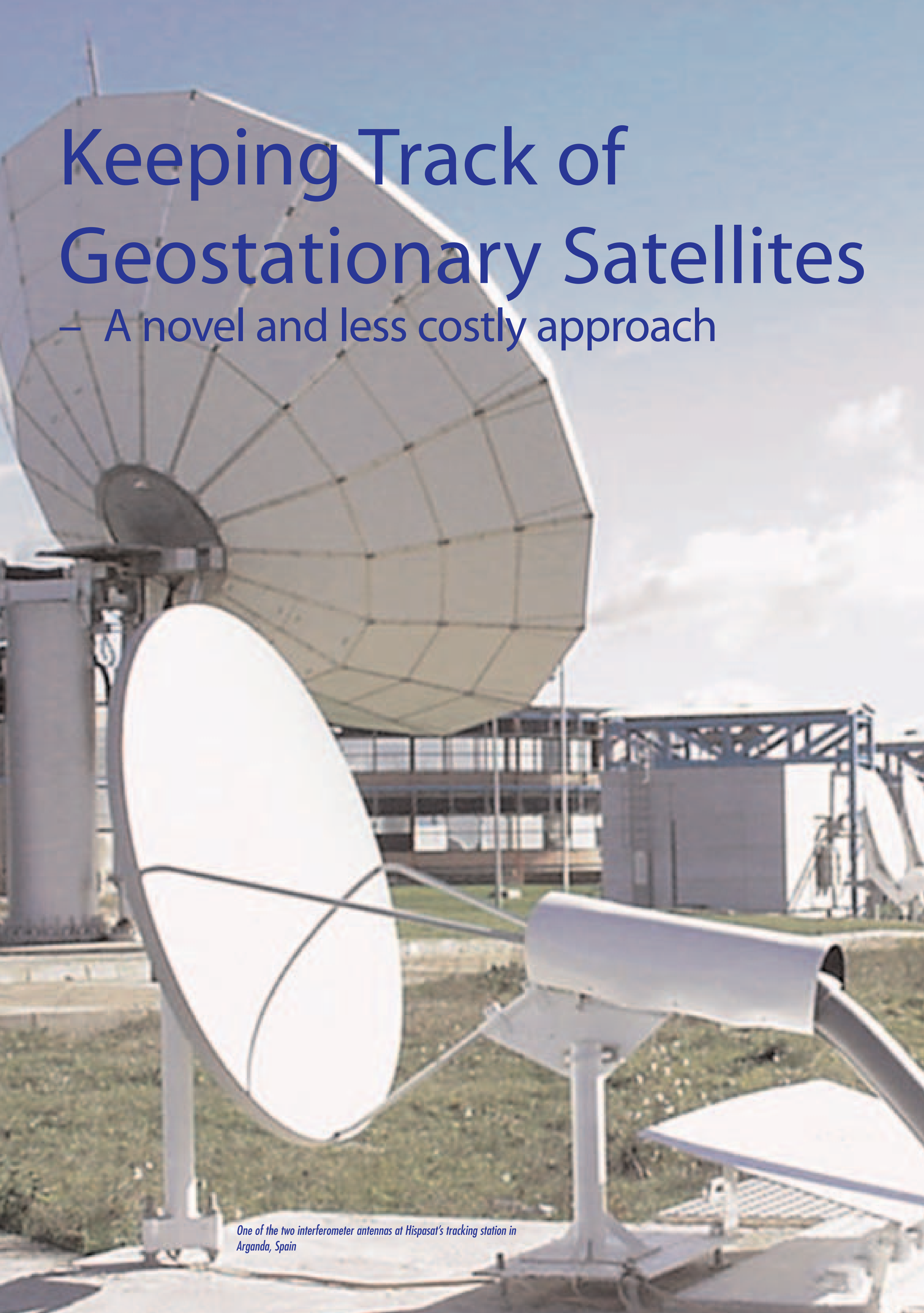
esa

Useful Internet links:

ESA Communication Portal	http://www.esa.int
Mars Express pages	http://www.esa.int/marsexpress
Cassini-Huygens pages	http://saturn.esa.int

Keeping Track of Geostationary Satellites

– A novel and less costly approach



One of the two interferometer antennas at Hispasat's tracking station in Arganda, Spain

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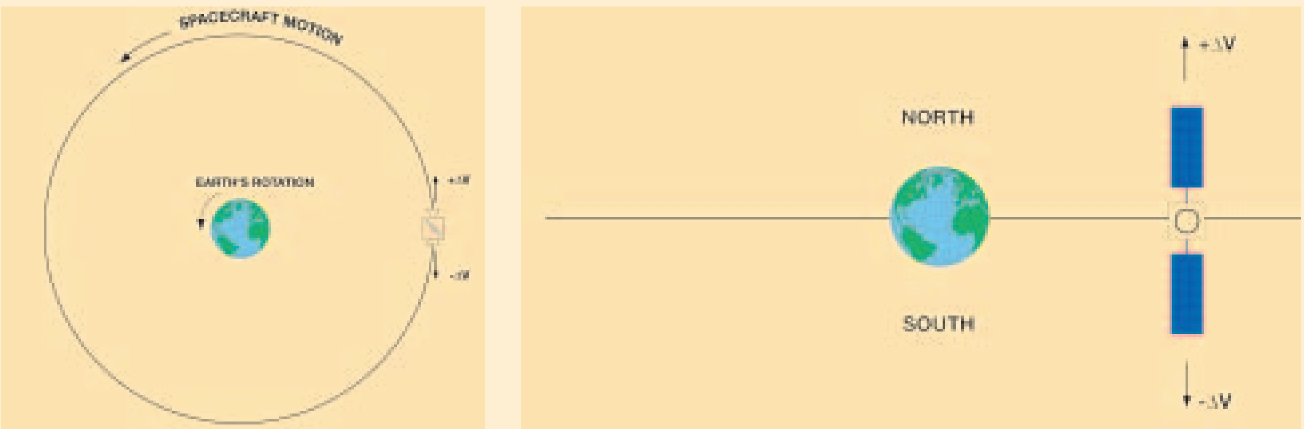
The Nature of the Problem

The usual way to establish a satellite's orbit is based on measuring the distances between it and so-called 'ranging antennas' on the Earth at different times. These distances are determined by measuring the time needed for a radio signal to make the round trip between the ranging antenna and the spacecraft. If this distance is measured at several different times, and possibly also using several antennas at different geographical locations on the Earth's surface, the spacecraft's orbit can be uniquely identified. Parameters affecting the spacecraft's motion, such as the solar radiation pressure or imperfectly known equipment parameters like delays in the spacecraft's transponders and/or in the ranging equipment on the ground, can be identified/determined as part of this process. Determining these additional parameters makes the mathematical modelling more precise and therefore also increases the accuracy with which the spacecraft's true orbit can be established.

The Geostationary Orbit

Most telecommunications and many weather satellites are operated in what is known as a ‘geostationary orbit’. This is a circular orbit high above the Earth’s equator with a radius of 42 164 km (about 6.6 Earth radii). This is the radius for which the time taken by the satellite to complete one orbit is the same as that taken by the Earth to rotate once around its axis, namely one day. This is consequently the altitude at which the ‘centrifugal force’ caused by the rotation of the Earth is equal to its gravitational attraction. As the satellite in geostationary orbit always appears to be at the same point in the sky when viewed from a given point on the Earth’s surface, it means that a fixed antenna on the ground can be used to communicate with it. Millions of private households all over the World use such a fixed (dish) antenna to receive TV and radio programmes broadcast via satellite.

In practice, the gravitational attractions of Sun and Moon, the solar radiation pressure and the slight misalignment between the centrifugal force and the Earth’s gravitational force disturb the sought-after ‘equilibrium’. To compensate for these disturbing effects, an orbit-maintenance strategy has to be worked out, consisting of ‘tangential burns’ and ‘out-of-plane burns’ of the satellite’s onboard thrusters to continuously adjust the actual orbit and keep it as ideal as possible. In order to design the necessary correction burns optimally, the satellite’s real orbit has to be determined very accurately.



The geostationary orbit and the concept of tangential and out-of-plane burns

Accurate orbit determination for geostationary spacecraft poses particular problems for the very same reason that these orbits are used, namely the geometry of the spacecraft relative to Earth-fixed objects does not change and so the orbit cannot be determined by making ranging measurements from a single ground station at different times. The most common way to overcome this conundrum is to combine the ranging measurements with pointing data from a high-gain antenna. This antenna must then be controlled such that it automatically finds the pointing direction for which the strength of the signal from the satellite is a maximum (this is known as the ‘auto track’ mode). This ‘best’ pointing direction (azimuth and elevation) is then used as additional data for the orbit determination.

However, the pointing data obtained in this way only has an accuracy in the order of ± 0.01 deg – the larger the antenna, the narrower the beam and the better the accuracy. This accuracy is certainly good enough for the basic orbit-maintenance strategy for a single spacecraft, but with many ‘co-located’ spacecraft occupying the same nominal position on the geostationary ring, more accurate orbit determination is needed for the implementation of an additional ‘collision-avoidance’ strategy. Most operators with several spacecraft at the same geostationary position therefore have a second ranging antenna at a remote location. Hispasat, for example, which is a Spanish commercial satellite operator, has its control centre in Arganda close to Madrid and an additional ranging station on the Canary Islands.

The Novel ESA Solution

The problem of orbit determination for geostationary spacecraft was analysed at ESOC in considerable detail about 10 years ago by the late Mattias Soop. He found that, provided that the longitudes of the spacecraft and the ground station were significantly different, it is not necessary to have both azimuth and elevation data from an antenna to be able to determine the satellite’s orbit accurately; it is sufficient to have only one of these parameters determined as a function of time. He called this a 'One-and-a-Half Tracking System' (presented at the Conference on Space Flight Dynamics in Toulouse in June 1995). Furthermore, it is not even necessary to ascertain the parameter directly, but it is enough to know the variation in the parameter over a sufficiently long time interval. This led him to propose the novel solution of using an interferometer for the orbit determination of geostationary spacecraft.

The interferometer technique relies on measuring the interference between the radio signals from the spacecraft as received by two antennas (see figure). The direct output of such an interferometer would only be the phase difference as a fraction of a wavelength. If, for example, this difference were 0.3 of a wavelength, one cannot know a priori if the difference in distance to the spacecraft for the two antennas is -1.7, -0.7, 0.3, 1.3, 2.3, etc. It is therefore not possible to determine the azimuth directly. But as this shift changes only slowly (the basic cycle has a period of one day), and as this shift can be monitored continuously, the change in azimuth can be determined unambiguously and with a very high accuracy – in fact orders of magnitude better than the pointing accuracy obtained from an antenna in 'auto-track mode'. The resulting orbit determination is even accurate enough for co-located clusters of spacecraft that require a collision-avoidance orbit-control strategy, making a second, costly, and remotely located ranging terminal unnecessary.

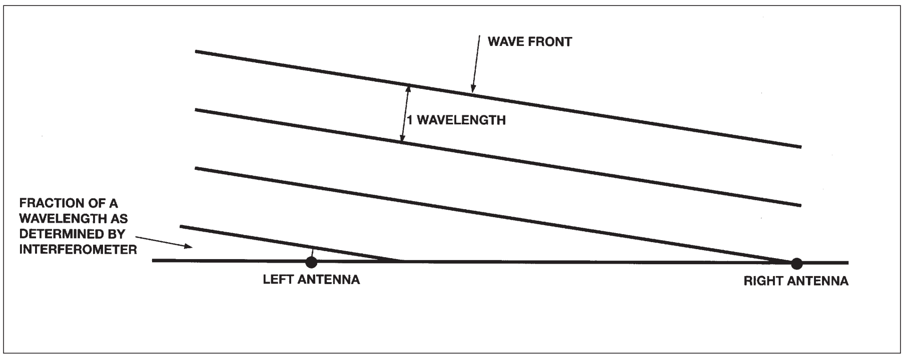
Now, 10 years later, such an interferometer has been built and tested at Hispasat's tracking station in Arganda, Spain. Developed by the Spanish company CRISA under an ESA contract, it consists of two identical parabolic antennas sited just 250 metres apart. Signals received at both antennas are transmitted to a central electronics rack by means of wide-band phase-stable optical fibres that can handle frequencies of up to 20 GHz (see accompanying panel).

The accompanying figure illustrates the basic output of the interferometer. It shows the difference in 'linear phase', which is

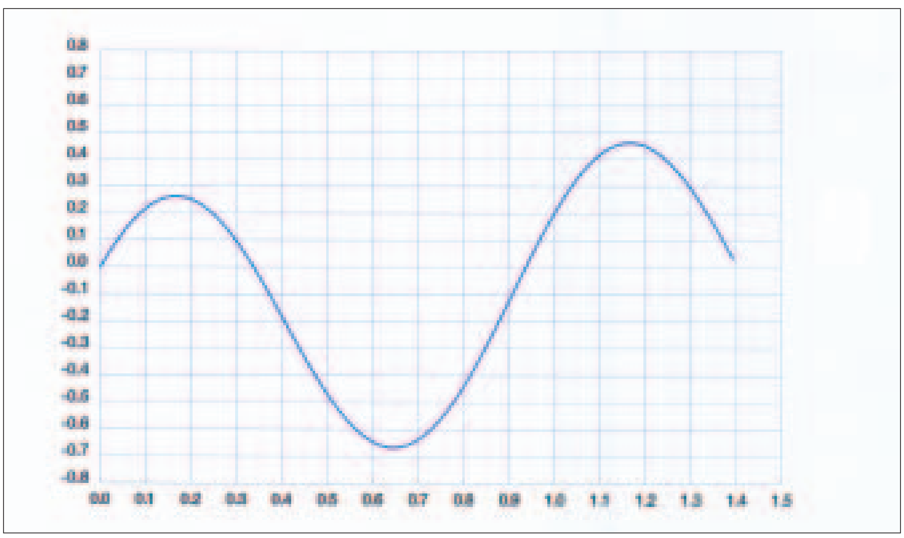
Why Use Optical Fibres?

The use of these fibres is a key element in the interferometer's performance for two reasons. Firstly, the excellent stability of the fibres as a function of temperature keeps the relative phase error between both antenna chains and the central rack within acceptable limits. Secondly, the wide-band characteristic of the fibres allows the signal transmission to the central rack to be made at spacecraft received frequencies. This removes the need for distributed down-conversion equipment, which would otherwise be a major source of phase errors in the system, and enables a centralised dual down-converter design, in which intermediate frequencies are generated directly at the central rack, thereby minimising phase errors due to local oscillator frequencies and their transmission to remote equipment.

Following the dual down-converter, both intermediate frequencies are digitised, such that their Fourier transform can be computed. This allows the relative phase difference between the two signal chains to be measured accurately over time and stored for further processing. This process is not limited to a single spacecraft and can be simultaneously performed for all satellites within view and within the receiver's frequency band.



The principle of the interferometer technique



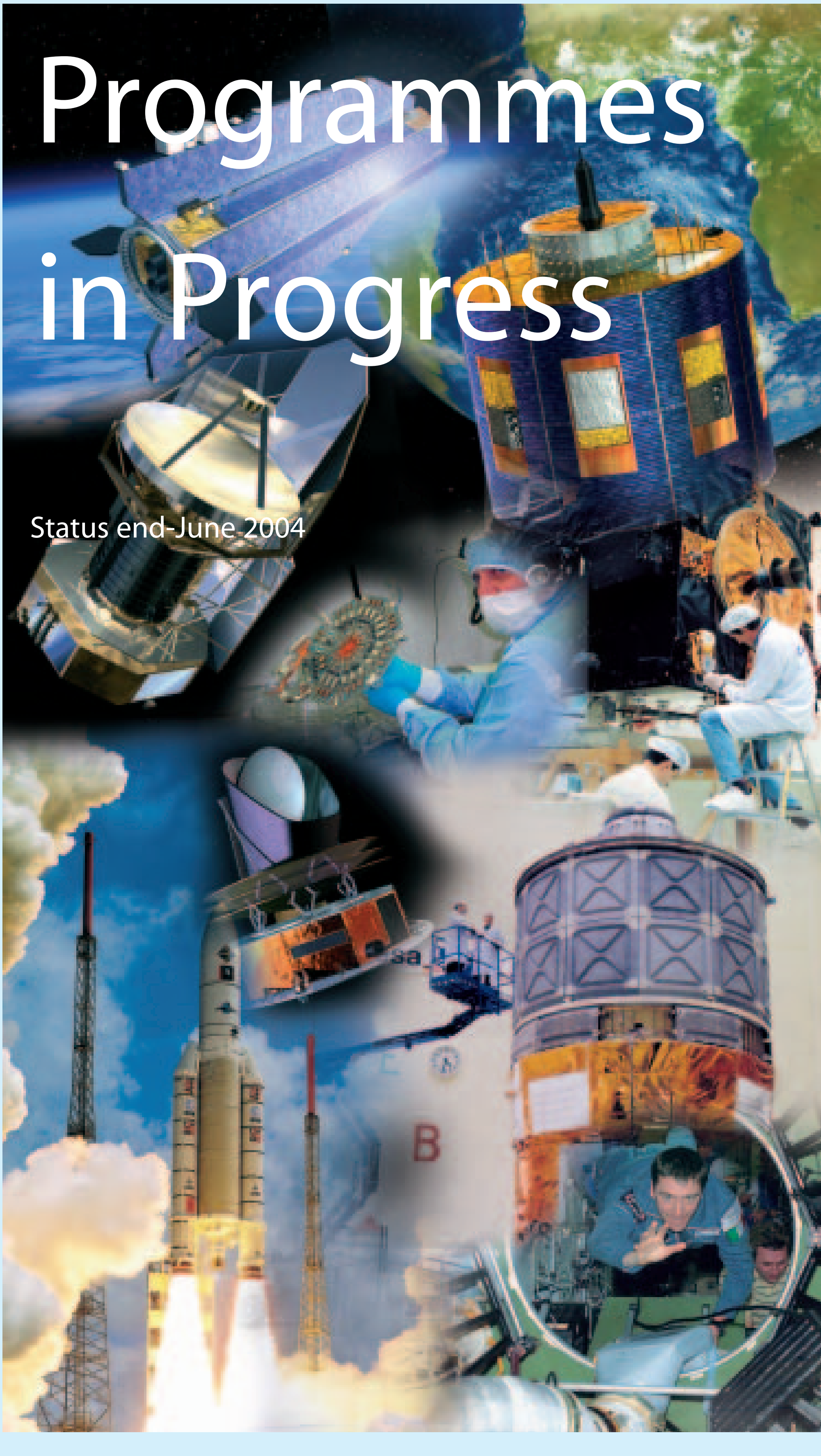
Typical output from the interferometer essentially the difference in distance to the spacecraft from the left and right antennas. Because this phase shift is permanently monitored and its rate of change is slow compared with the sampling frequency, the change in this 'linear phase' can be computed without ambiguity (positive/negative and number of wavelengths). In the example shown, the daily variation has an amplitude of 513 mm, which corresponds to about 22 wavelengths. This variation is due to the fact that the spacecraft's orbit is neither perfectly circular nor perfectly equatorial.

The basic accuracy obtained with one set of measurements used for one Fourier Transform is about 5% of a wavelength. With a frequency of 13 GHz this is about 1.2 mm. The corresponding directional accuracy with 250 m between the antennas is then 1.2/250000 radians, or about 0.0003 deg. This compares with the approximately 0.01 deg pointing accuracy of an auto-track-mode antenna. It must, of course, be remembered that the interferometer does not directly measure azimuth direction, but only the change of this azimuth with time. However, provided the longitude of the spacecraft is significantly different from the longitude of the tracking station, the high accuracy of the interferometer more than compensates for any accuracy dilution due to having to determine this additional parameter.

The Software

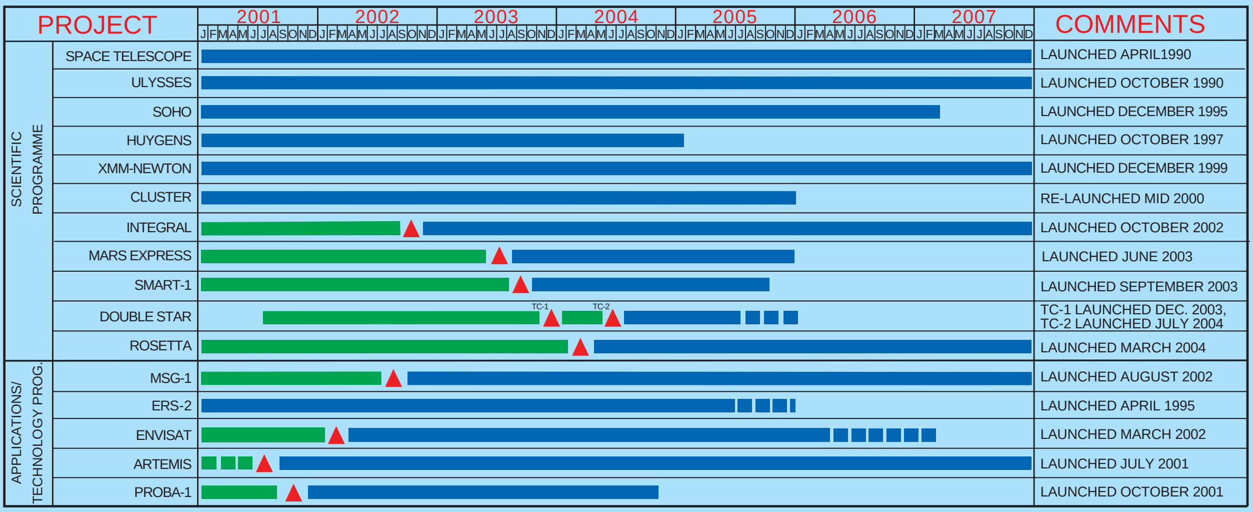
The orbit-determination programs that make up the ESOC 'export package' for geostationary orbit control have been extended to accept the interferometer data. This upgraded software package has already been applied to accurately determine the orbit of the Hispasat-1A satellite, using data from a ranging antenna in Arganda (close to Madrid) provided by the Hispasat organisation, and from the CRISA interferometer also installed on this site. Used in combination with interferometer ranging, this ESOC software package (PEPSOC - Portable ESOC Package for Synchronous Orbit Control) is the ideal system for optimal and cost-efficient orbit control for either a single spacecraft, or a cluster of several spacecraft sharing a common position in the geostationary ring. esa

Programmes in Progress

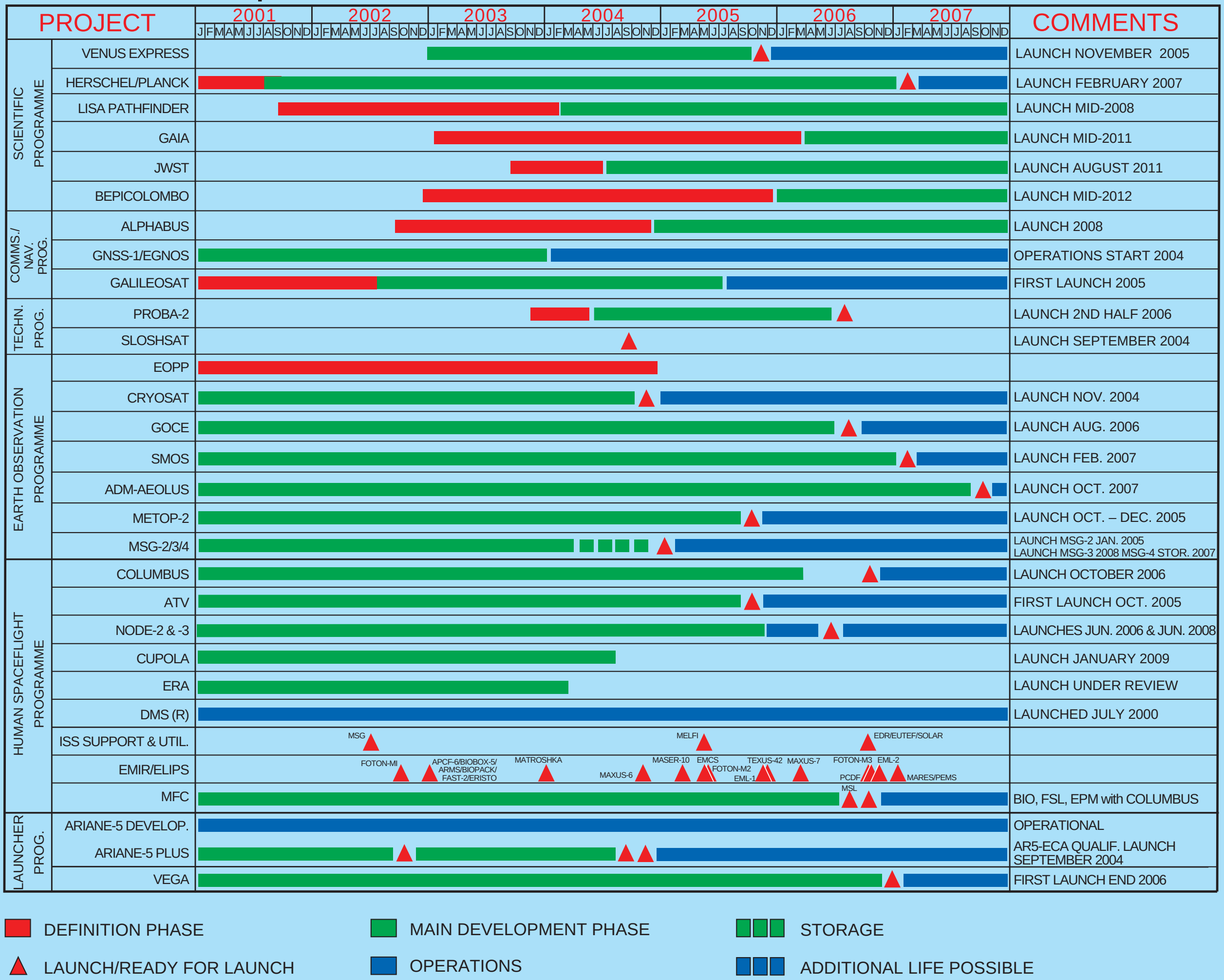


Status end-June 2004

In Orbit



Under Development



ISO

The ISO Active Archive Phase Mid-Term Review was held on 14-15 June at the European Space Astronomy Centre (ESAC) in Villafranca (E). The Board, composed of external data providers and users, was impressed with the achievements of the past two and a half years. Their recommendations focused on making ISO data and results as widely available as possible, by (i) concentrating the activities during the remaining 30 months on maximising the content and visibility of the Highly Processed Data Products (HPDP), the result of dedicated projects focused on cleaning the pipeline products of residual instrument artifacts, (ii) continuing with the integration of the ISO Archive into the Virtual Observatories, (iii) ensuring prompt publication of the planned special issue of ISO Space Science Reviews, a 400 pages book reviewing the results of ISO, based on the 1120 refereed papers published to date and embracing all areas of astronomy.

A new, major version of the ISO Data Archive (Version 7) was released on 8 June. This release includes enhanced quality information (important in the Virtual Observatory context), a link to ISO catalogues based at the Centre de Données Astronomique, Strasbourg (F), and an improved postcard server. Additionally, ISOPHOT catalogues and an atlas of combined SWS and LWS observations of galactic HII regions have been added as HPDPs.

Ulysses

Ulysses operations continue to run smoothly. Experiment power sharing has resumed following the end of the Jupiter Distant Encounter (JDE) campaign earlier this year. On 1 September, the position of the spacecraft will be such that Ulysses will be almost directly behind the Sun as seen from the Earth. This line-up is known as a 'conjunction'. During periods of close conjunction, the radio path between the spacecraft and Earth travels through the solar corona, introducing noise into both the uplink and downlink that can potentially disrupt commanding and degrade data. In addition, the angle between the Sun, the spacecraft, and Earth decreases almost to zero, making it necessary to perform so-called 'Sun avoidance manoeuvres' in order to maintain the functionality of the onboard Sun sensors. These manoeuvres in turn increase the off-pointing of the high-gain antenna from the Earth, further degrading the telemetry reception. All in all, this will be the most operationally challenging conjunction for the Ulysses team since August 1991.

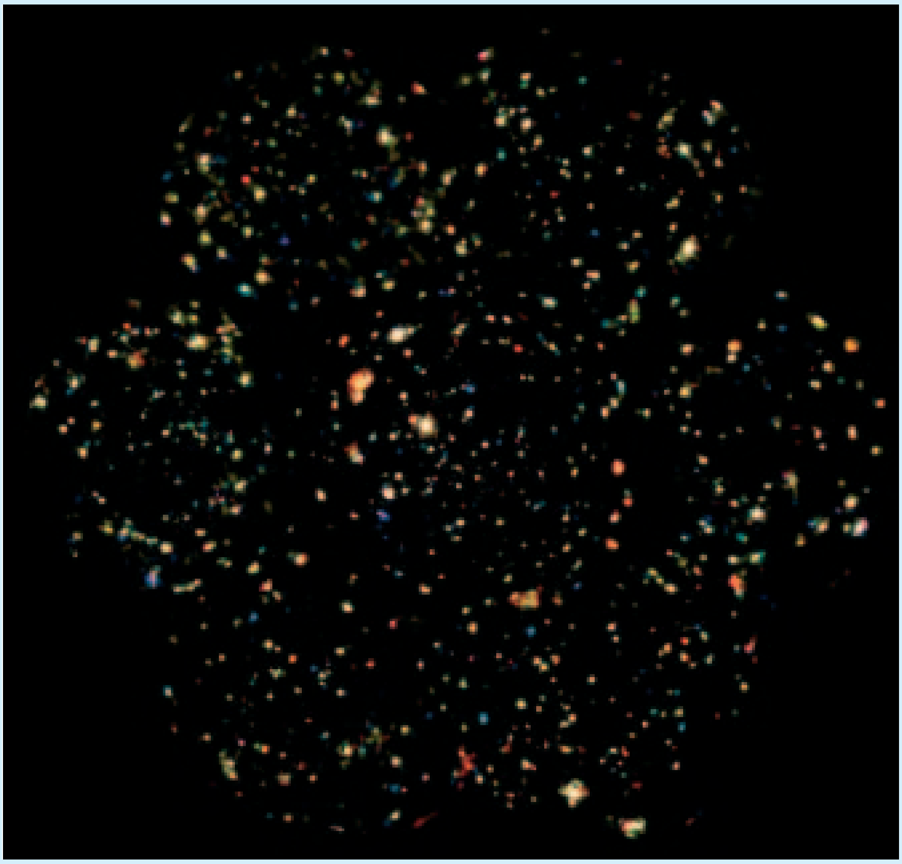
After the excitement of last year's upsurge in solar activity and the recent Jupiter campaign, the science teams are turning their attention once again to studying the evolution of the global structure of the heliosphere. The Sun is apparently settling down as solar minimum approaches, and this is reflected in the relatively stable recurrent solar-wind patterns that are observed at Ulysses as the Sun rotates beneath it.

XMM-Newton

XMM-Newton operations are continuing smoothly. Radiation levels around the belts and during the remainder of the orbit have started to decrease again, which is a well-known seasonal effect. Data processing and data shipment is proceeding according to plan; over 3400 observation sequences have been executed, and the data for over 3250 have been shipped.

The work on upgrading the overall ground segment (to SCOS-2000) is progressing according to plan, and should see initial operations towards the end of 2004 and full operations by early 2005.

The programme-completion status is currently as follows:
- AO-2 programme: 99.0%
- AO-3 programme: 50.2%.



XMM-Newton X-ray spectral-colour-composite image of the Subaru/XMM-Newton Deep Field. It covers a roughly square patch in the sky, measuring about 1.3 degrees on a side, or about seven times the area of the full Moon. This view gives an X-ray pseudo-colour representation of all of the sources, coded according to their X-ray energies

The National Astronomical Observatory of Japan (NAOJ) has made the X-ray, optical and radio data of the XMM-Newton/Subaru Deep Survey available to researchers worldwide. Over a thousand X-ray sources are found in the XMM-Newton images. The first results concerning the history and evolution of galaxies based on this multi-wavelength view have been published in MNRAS (350, p.1005). The data show an apparent age gradient, which provides an interesting challenge for modern galaxy-formation theories.

By the end of June 2004, some 580 papers based on XMM-Newton data had been published in, or submitted to the refereed literature.

Integral

Integral continues to operate smoothly, with the spacecraft, instruments and science ground segment all performing nominally. The fourth in-flight annealing of the Spectrometer's (SPI) Ge detectors was completed on 30 June. This baking is necessary to maintain their outstanding spectral resolution, which is degraded by the intense cosmic particle background. Recently performed observations include deep looks at the Carina and Cygnus-X star-formation regions, designed to search for gamma-ray line emission from radioactive aluminum, iron and titanium. Taking advantage of the large fields of view of the high-energy instruments, observations of the Sagittarius-arm tangent region were performed to further investigate it and its numerous high-energy sources. The extragalactic sky had good visibility conditions during the last quarter and Integral observed the Seyfert galaxies NGC 5548 and Mkn 590 (together with XMM-Newton), as well as making a Target of Opportunity observation of the Blazar 3C 273 when it entered an unusual state. In addition, the distant cluster of galaxies Abell 2256 was studied to investigate where in the cluster the intense hard X-ray emission, discovered by the non-imaging BeppoSAX high-energy detector, originates.

Preparations are under way at the Integral Science Operations Centre (ISOC) for release of the 3rd Announcement of Opportunity (AO), covering observations between 18 February 2005 and 17 August 2006. The AO is expected to open on 13 September, with proposals due by 29 October 2004. The planning for the move of the ISOC from ESTEC to ESAC in Villafranca (E) is continuing. Full ISOC operations at ESAC will start with the AO-3 observations. During the transfer, the ISOC will continue to fully support Integral operations and ensure that the 8-hour Target of Opportunity response time is met.

Hubble Space Telescope

On 1 June, at the meeting of the American Astronomical Society, Administrator Shawn O'Keefe announced NASA's decision to pursue the feasibility of a robotic servicing mission to HST. Although the primary goal of such a robotic mission is to install a de-orbit module on HST, NASA is studying the feasibility of also performing other tasks. These could include installing new batteries, gyroscopes and possibly science instruments that would enhance the observatory's science capabilities as originally planned.

On 13 July, the Lanzerotti Committee published its Interim Report. It states that HST is *"arguably the most important telescope in history"*, and recommends that *"NASA commit to a servicing mission that accomplishes the objectives of the originally planned SM4 mission"*, including the new instruments and the life-extending engineering components. It also urges NASA to *"take no actions that would preclude a Space Shuttle servicing mission"* to HST while vigorously pursuing the development of a robotic servicing capability.

These developments may pave the way for a servicing mission to HST, either by Shuttle or robotically, in late 2007 or early 2008, which could accomplish virtually all of the goals of the original SM4, including the installation of both new instruments. In this case, Hubble operations until 2012 or later should still be possible, providing overlap with JWST operations.

In the meantime, Hubble scientists and engineers have begun to study every option to prolong Hubble's life. An operational mode using only two gyroscopes instead of the normally required three is in development and will be tested on the spacecraft later this year. All of HST's science instruments and the observatory itself continue to operate nominally, delivering data that will continue to advance our knowledge of the Universe.

SMART-1

During the second quarter of 2004, SMART-1 has continued to make great progress on its journey towards the Moon.

The new thrusting strategy is working well, with thrusting taking place around perigee for about one third of every revolution, presently representing about 27 hours of operation per 81 hour orbit. The thrust duration will progressively increase to a maximum of 41.5 hours starting on 10 August, when the orbital period will be about 120 hours (5 days). The electric-propulsion system has accumulated some 2700 hours of operation, has imparted to the spacecraft a velocity increment of about 2000 m/s (equivalent to 7200 km per hour), but has consumed a mere 42 kg of xenon. A series of lunar-resonance gravity assists will take place on 20 August, 16 September and 14 October.

In the meantime, all of the scientific instruments have been commissioned and are performing above expectations.

The ground-control teams at ESTEC (NL) and ESOC (D) are conducting 'routine spacecraft operations', as well as actively preparing for the lunar resonance, lunar capture and lunar-science phases.

Detailed trajectory optimisation based on actual electric-propulsion performance has been pursued and SMART-1's arrival at and capture by the Moon is now expected on 19 November. The lunar orbit itself will then be optimised to match scientific observational needs. The main lunar-science phase will begin in January 2005.

Double Star

The launch campaign for the second Double Star satellite (TC-2) began on 28 June. All functional tests and preparation activities were

Launch of the Double Star TC-2 satellite on 25 July from China's Taiyuan launch site

completed with the support of a small ESA and Astrium team. The satellite was launched successfully on 25 July at 07:05 UTC by an LM-2C/SM from the Taiyuan launch site, located in Shanxi Province, west of Beijing.

The launch took place a day earlier than originally scheduled in order to avoid adverse weather conditions predicted for the following days. About 31 minutes after lift-off, TC-2 was released into its nominal polar orbit, with perigee at 682 km, apogee at 38 280 km and an inclination of 90.1 degrees. This success marks the latest important milestone in the scientific collaboration between China and ESA.

Following the release of both rigid booms on the spacecraft, the commissioning of the Chinese and European scientific instruments has started and is expected to be completed by mid-September.

Meanwhile operations with the first Double Star satellite (TC-1) coordinated by the DSP/Cluster scientific community are proceeding smoothly, as too is the routine data analysis. TC-2 is expected to enter its routine operational phase after the Commissioning Review planned for early October, and one month later the first results of the DSP mission will be discussed at a Joint DSP/ Cluster Scientific Workshop in Beijing.

Rosetta

The first part of Rosetta's commissioning was successfully completed at the beginning of June. A preliminary Mission Commissioning Results Review found no major problems with the spacecraft or payload. Due to the sharing of the New Norcia ground station with the Mars Express mission, the Rosetta commissioning is taking place in two phases, with the second part scheduled for September/October. All elements of the ground segment have so far worked according to plan.

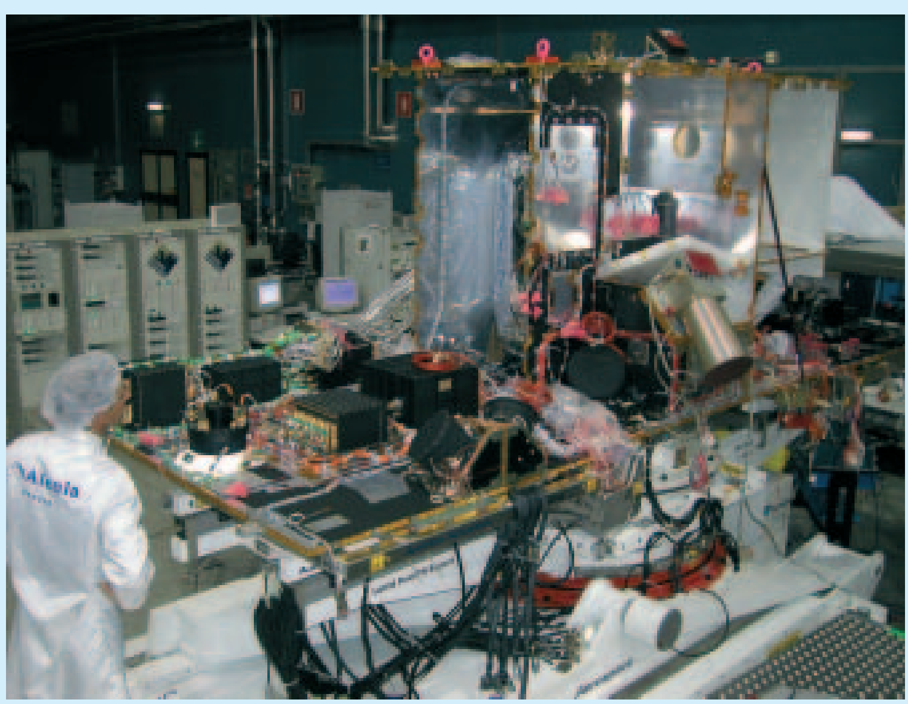
During the commissioning, some of the imaging instruments took the opportunity to observe Comet Linear, which is close to its perihelion. This was a good opportunity for the 'comet chaser' to fine-tune its instruments using a real comet! The latest version of the software was successfully uploaded to the spacecraft at the end of July.

Having made its first deep-space manoeuvre at the end of May, the spacecraft is now on course to return to Earth for its first gravity-assist in March 2005, which will complete the first part of the 'grand tour' designed to allow Rosetta to rendezvous with Comet Churyumov-Gerasimenko in 2014.

Venus Express

The project continues to progress according to plan, with the spacecraft taking shape in the integration facilities at Alenia Spazio in Turin (I). A successful Critical Design Review process, which began in March, was completed at the prime contractor's site during an intensive week-long meeting at Astrium in Toulouse (F) in the first week of April. Deliveries of flight-model experiments are in progress, and the first experiment to be delivered – the Magnetometer (MAG) from the Institute for Space Research in Graz (A) – has already been successfully integrated and tested with the flight spacecraft.

The environmental test campaign for Venus Express is following the normal pattern for any spacecraft, except for the need to simulate the substantially stronger solar flux it will experience when orbiting Venus. For this, the solar-simulation facility at Intespace (F) will be



Venus Express spacecraft integration nearing completion at Alenia Spazio (I) modified to concentrate the solar beam. The necessary design studies have been completed and a new lens for the facility has been manufactured.

The Venus Express ground segment is progressing well due to its effective heritage from the Mars Express mission control system. A basic command and telemetry compatibility test has already been successfully performed between the mission control system and the satellite. The primary ground station for Venus Express will be the new ESA station at Cebreros in Spain, which has a 35 metre antenna with X-band transmission and reception.

Negotiations with Starsem (F), the launch-service provider, are proceeding well and agreement on the details of the final launch-window opportunities is imminent. Venus Express will be launched on 26 October 2005 from the Baikonur Cosmodrome in Kazakhstan.

Herschel/Planck/ Eddington

Several engineering models of electronic units for the Service Module have been delivered and are being integrated into the avionics model. The manufacturing of structural-thermal/qualification model structural and cryostat hardware is nearly complete, with most of the units having already been delivered. The two main subassemblies of the qualification model of the Planck Payload Module have completed all of their qualification tests (mechanical and optical) and have been formally delivered to Alcatel. Manufacture of the flight-model hardware for the Herschel cryostat, including the helium tanks and the cryostat vacuum vessel, is now fully complete. Assembly and early testing of these items is underway. In preparation for the System and Service Module Critical Design Review (CDR) that will start in mid-August, the Payload Module CDRs for Herschel and Planck have already successfully concluded.

The Preliminary Design Review process for the launcher with Arianespace has also been completed successfully. The details of the injection strategy and the mission analyses

Flight model of the giant 3.5 metre silicon-carbide telescope for the Herschel spacecraft. When launched in 2007, it will be the largest telescope ever placed in space

have been finalised as part of the review process and have been passed to industry for the preparation of the CDR.

The qualification models of the scientific instruments have completed a good part of their test sequence and are due for delivery to industry in early autumn.

The grinding of the Herschel telescope primary mirror has been successfully completed, as well as the mechanical proof test. The mirror has been shipped to Finland for the final surface polishing. The cryogenic optical testing of the complete Planck telescope secondary-reflector qualification model proved to be extremely difficult; however, the central part could be measured down to the operational orbital temperature of about 40 K. The primary reflector of the qualification-model telescope has successfully passed the mechanical test phase and is awaiting cryogenic optical testing.

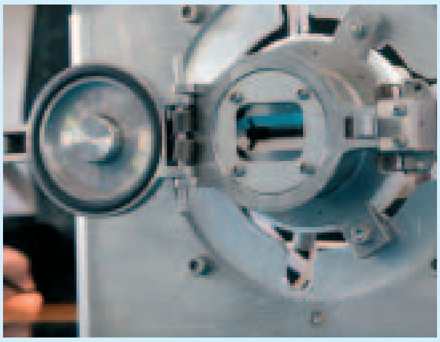
The parallel Eddington system-definition studies have been completed with a well-defined technical baseline. The first CCDs for the Eddington cameras have been tested and work according to the requirements. The second hardware set is in the final stages of completion.

SMART-2/LISA Pathfinder

LISA Pathfinder implementation-phase activities have started for the spacecraft, with Astrium UK as industrial prime contractor. The first major event has been the System Requirements Review (SRR), which took place from 24 May to 25 June. The Board requested that the scientific and mission requirements be fully incorporated into the System Requirements Document before the Review could be successfully closed. The mass and power budgets also need to be consolidated. A delta SRR close-out review will therefore address these and other spacecraft architectural-level requirements, including the European instrument LISA Technology Package (LTP) and the US instrument Disturbance Reduction System (DRS), and is due to be completed at the beginning of November.

For the European instrument development, following the positive recommendation for Council approval of the LTP Multi-Lateral Agreement, the LTP procurement action at national level has started.

Signature of the Technical Assistance Agreements between ESA and the US authorities is imminent. This is essential to permit the flow of technical-interface data between Jet Propulsion Laboratory (JPL) and



FEEP-8, an 8mm slit field-emission thruster for the LISA Pathfinder mission

ESA, and to allow European participation in the Critical Design Review for the American instrument, which will take place in October at JPL.

The technological development of the micro-propulsion technology, which is essential for the LISA Pathfinder mission, is in a decisive phase. Long-duration testing of one the field-emission electrical propulsion (FEEP) micro-thrusters has started, as well as direct thrust and thrust noise measurements. Performance verification for the cold-gas micro-thrusters is proceeding in parallel.

James Webb Space Telescope (JWST)

The JWST project has successfully passed several NASA lower-level System Requirement Reviews (SRR), including those for the Optical Telescope, the Integrated Science Instrument Module (ISIM) and NIRCam, as well as the delta-SRR for MIRI.

ESA's participation in JWST includes provision of the Near-Infrared Spectrograph (NIRSpec), a major part of the Mid Infra-Red Instrument (MIRI), consisting of an imager and a spectrograph developed by a consortium of European Institutes, and an Ariane-5 launch vehicle to put JWST into orbit in 2011.

NIRSpec
Following approval by ESA's Industrial Policy Committee (IPC), the NIRSpec Implementation-Phase Contract was successfully negotiated on 2 July with EADS Astrium GmbH (D). Subcontractors for all 'complementary activities' will be selected via open competitive tenders in the period between September 2004 and July 2005. In parallel, agreements with NASA on interfaces and delivery dates are being finalised. NIRSpec activities will now focus on preparations for the forthcoming SRR, with a final Board meeting currently scheduled for the beginning of November.

Work on the NASA-provided Detector and Micro Shutter Systems is ongoing, with new test results expected in the September timeframe. The SRRs for both systems are currently planned for the second week of September.

At its June session, the ESA Science Programme Committee (SPC) approved the composition of the NIRSpec Instrument Science Team.

MIRI
First units for the MIRI structural-thermal model (STM) programme are being delivered for system integration. A successful Test-Facility Critical Design Review was recently held at RAL (UK), paving the way for the STM test campaign. The MIRI European Consortium is now preparing for the Optical Bench Assembly (OBA) Preliminary Design Review, with the final Board meeting currently planned for end-November.

On the US side, JPL has ultimately selected Lockheed Martin (US) as prime contractor for the MIRI dewar cryostat. This should enable a MIRI System Preliminary Design Review to take place in January 2005.

Gaia

The demonstrator model for the Gaia primary mirror was successfully sintered at the Boostec facilities in France in May. The Gaia Large Size SiC Mirror study, led by EADS Astrium, aims to demonstrate the feasibility of the current primary mirror design by building and testing a replica mirror (including polishing and coating). The study is expected to be completed by mid-2005.

Under contract to ESA, EADS Astrium in Toulouse (F) is designing, building and testing two engineering models of the Gaia astrometric focal plane. The Thermal Mechanical Demonstrator Model (TMDM) is a mock-up of the focal-plane structure that will be used for integration and alignment verification, and thermal-vacuum testing. The Electro-Optical Demonstrator Model (EODM) is designed to be electronically representative of the flight focal plane. It contains four fully-functional CCDs and will be used to assess their performance under nominal operating conditions in the various Gaia TDI modes and for a variety of simulated star magnitudes. The Critical Design Review (CDR), held in June, marked the end of the design phase for both of these demonstrator units. Astrium now has formal approval for its designs from ESA and will proceed to integrate the focal-plane demonstrators.

A core project team has been established at ESTEC in Noordwijk (NL) with the immediate priority of reviewing the status of all of the critical technologies needed, before issuing the industrial Invitation to Tender (ITT) in 2005.

A major Symposium devoted to Gaia, 'The Three-Dimensional Universe', will be held at the Observatoire de Paris-Meudon on 4-7 October and more than 200 participants have already registered. This Symposium will be a focus for the presentation of the scientific and technical progress made by the project over the past two years, in advance of entering Phase-B2. Details are available on the Gaia web site.

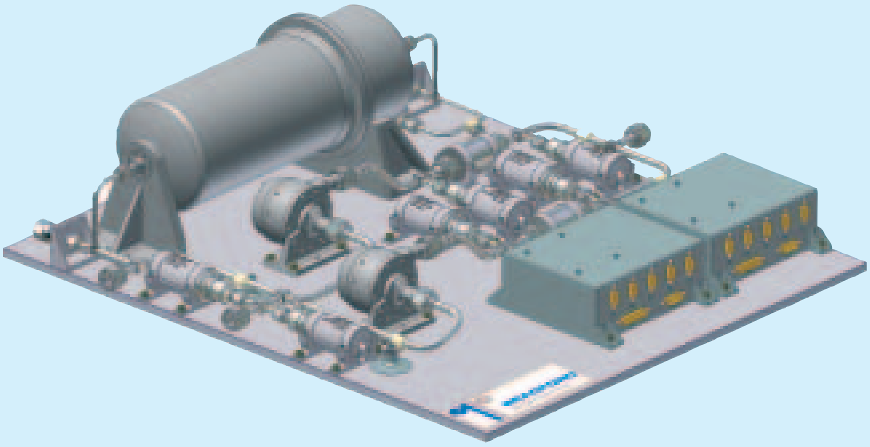
AlphaBus

AlphaBus is a cooperative undertaking by ESA and CNES for the development of a new multi-mission platform for satellite telecom-munications. Both Agencies have agreed to proceed with the preparation of a common Request for Quotation (RFQ) for the AlphaBus main development phase (Phase-C/D) with the prime contractors Alcatel Space (F) and EADS Astrium (F). The AlphaBus Phase-C/D RFQ anticipates the development of the Alphabus product line and the procurement of the proto-flight model.

AlphaBus is a unique product to complement the upper range of existing Eurostar and Spacebus lines, both of which accommodate payloads requiring up to 12 kW of power. AlphaBus targets payloads with power needs from 12 to 18 kW, and the design is flexible enough to handle a very wide range of future multi-band telecommunication missions.

AlphaBus benefits from several novel technologies being developed as part of the preparatory programme running under the ESA ARTES-8 element. To date more than twenty contracts have been awarded by the Agency to support equipment providers in pre-developing the necessary enabling technologies.

The overall tendering and selection process for building up the Phase-C/D industrial consortium is also part of ESA's preparatory programme and the evaluation of first bids is now well underway.



3D model of the Mechanically Pumped Fluid-Loop Pump package developed by Bradford Engineering (NL), NLR (NL) and Realtechnologie AG (CH) for the high-power AlphaBus satellites

Finally the first part of the pre-validation campaign (CryoVex 2004) has been successfully conducted in-situ with the support of scientific experts stationed in Greenland.

Due to the various delays encountered, the CryoSat launch is now planned to take place from Plesetsk in March 2005.

In parallel, the core Phase-B system activities at prime-contractor level funded by CNES are almost completed and will be finalised with the Preliminary Design Review starting in October.

CryoSat

Significant progress has been made in the assembly and integration of the proto-flight model of CryoSat: the nadir plate has been populated with the electronic equipment previously tested on the 'Satellite Test Bed', and the three star trackers are now installed close to the large double antenna of the SIRAL radar altimeter. With the integration of the Sun-Earth sensors, the Attitude Orbit Control System (AOCS) is now fully operational. Finally, in early July, the two large solar panels have been put into position. Before shipment to IABG (D) for environmental tests, the CryoSat spacecraft has successfully undergone a large number of electrical and software tests.

On the payload side, the start of the final tests on the SIRAL altimeter has been postponed due to unexpected activities on the Digital Processing Unit: a critical electronic module has been exchanged, as a precautionary measure, to avoid potential problems in orbit.

A Critical Design Review of the space segment has also been performed and it positively concluded that the performance predictions for both the spacecraft and its payload are well within the specified requirements. This gives good confidence that the scientific objectives of the CryoSat mission will be met.

The activities related to the CryoSat ground segment are progressing according to plan. A new Satellite Validation Test (SVT 1-a) was successfully performed by ESOC in mid-July, to check the overall operability of the satellite. An internal workshop has also taken place to consolidate the consistency of the algorithms developed within the Instrument Processing Facility to generate the Level-1b and Level-2 products.

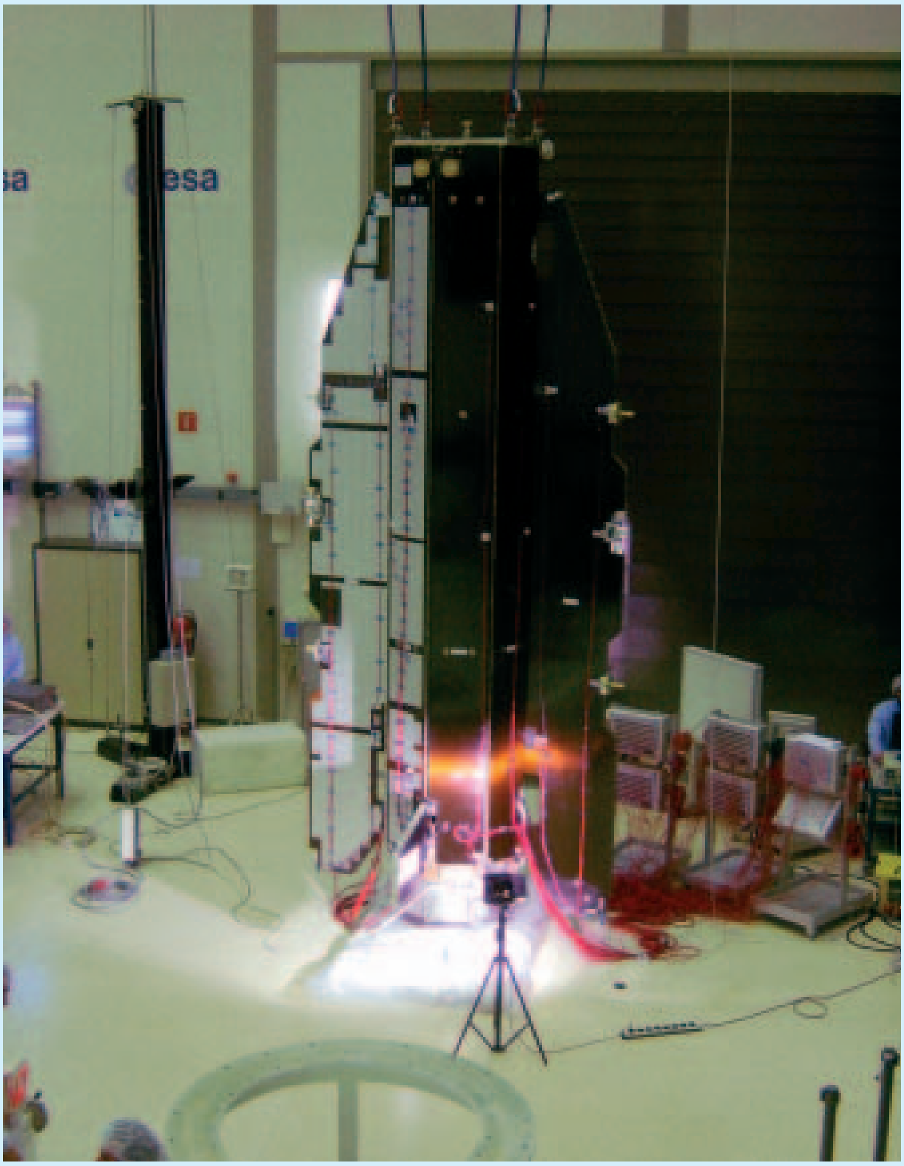
On the launcher side, a visit to the Plesetsk cosmodrome has been organised to finalise the preparatory activities for the launch campaign.

GOCE

The main emphasis in the space-segment development activities continues to be on the unit-level testing and on the execution of the equipment-level Critical Design Reviews. The satellite structural-model (SM) mechanical qualification test programme has been successfully completed. Sine, acoustic-noise, and clamp-band release shock tests and the related alignment checks have all been performed according to schedule in the ESTEC test facilities in Noordwijk (NL). The next activity will be the transportation of the SM primary structure back to CASA (E) for its refurbishment to become the flight model.

Good progress has also been made in the development of the satellite's main instrument.

The CryoSat spacecraft at EADS-Astrium's premises, prior to shipment to IABG for further testing



GOCE structural-model separation shock test, simulating the firing of the pyrotechnic devices that will release the satellite from the launcher adapter

Alcatel Space has started the electrical integration of the engineering model of the Gradiometer, while ONERA has completed the mechanical integration of the first Accelerometer Sensor Head flight model.

In the platform area, Astrium GmbH has begun the integration of the Engineering Model Test Bench that will be used to verify the functional and electrical performance of the platform, including real-time closed-loop tests with the pre-validated flight software.

The Eurockot launch-services procurement activities are proceeding according to plan, with the related preliminary mission analysis consolidation phase having been successfully completed.

Concerning the ground segment, the European GOCE Gravity Consortium proposal for the Level-1 to Level-2 data-processing facility has been successfully negotiated and the related work kick-off has been sanctioned. The Invitation to Tender (ITT) for the procurement of the Calibration Monitoring Facility and the Reference Planning Facility has been finalised and released.

The European Geophysical Union Congress and Exhibition in Nice at the end of April provided an excellent opportunity to promote the GOCE mission during specific Geodesy sessions, in which GOCE was the focus of a number of scientific presentations.

SMOS

The payload Phase-C/D contract with EADS CASA (E) was signed on 11 June, and work is under way at all subcontractors. Manufacturing Design Reviews have been completed for most subsystems and engineering-model production is also under way. The first (and most schedule-critical) subsystem, the LICEF receivers, have already been completed and are undergoing environmental testing.

The Implementation Agreement with CNES was endorsed at the June meeting of the ESA Council and is now ready for signature by the Director Generals of ESA and CNES.

The satellite Phase-B/C/D contract with Alcatel is in preparation, with the Phase-B start scheduled for October.

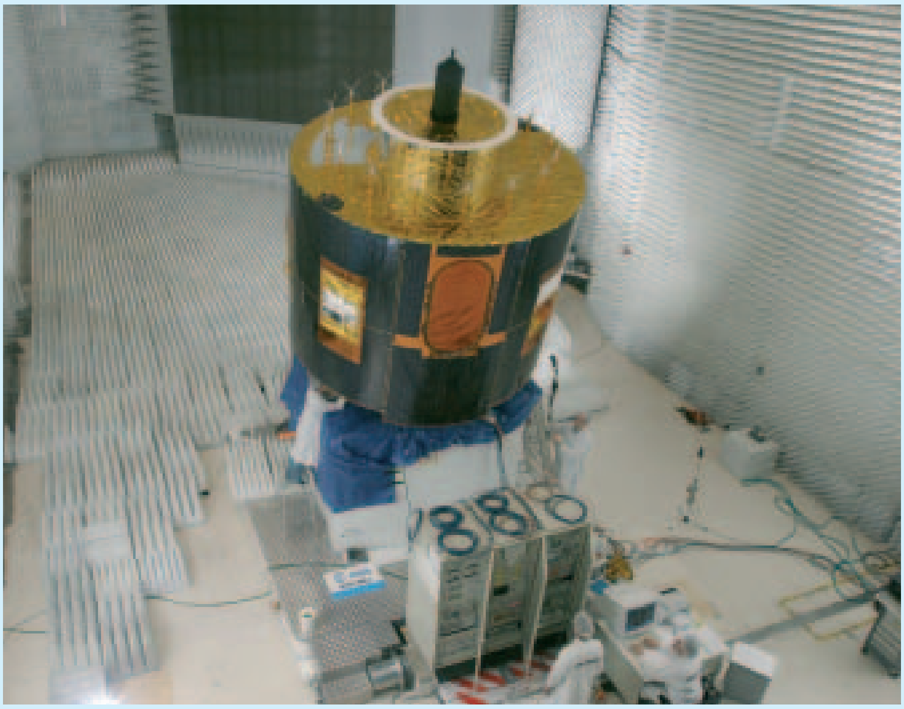
The Mission Preliminary Design Review (PDR) was held in May/June, and emphasised the schedule criticality of the Data Processing Ground Segment. Its Phase-B was released in July, with the aim of starting Phase-C/D in January 2005.

ADM-Aeolus

Design and manufacture of all the spacecraft and instrument subsystems is well underway. Almost all subsystem Preliminary Design Reviews have been held. Several subsystem Critical Design Reviews have also been completed.

All parts of the optical structural/thermal model (OSTM) of the instrument are being manufactured. A large crack in the primary silicon-carbide mirror of the OSTM has been successfully repaired. The structural model of the optical bench, which forms the heart of the instrument, has been successsfully mechanically tested. Assembly and testing of the OSTM, which includes critical alignment of

The MetOp-2 satellite during coupling of the Payload and Service Modules at EADS Astrium in Toulouse (F)



MSG-3 on the Compact Antenna Test Range (CATR) at Alcatel Space in Cannes (F) (Courtesy of Alcatel Space)

the telescope, will take place towards the end of the year. The structural model (STM) of the spacecraft platform will be delivered in August. Mating of the OSTM and the platform to form the satellte STM will take place in early 2005, to be followed by a satellite mechanical testing campaign.

The flight models of the primary and secondary mirrors have been accepted, and the primary mirror has been sent for polishing. A flight-spare primary mirror has also been accepted. Elsewhere in the instrument, small changes have been made to reflect lessons learnt from the instrument pre-development model test programme.

There have been difficulties with the delivery of an adequate number of pump diode stacks for the laser. The main problem has been traced to a small change in the manufacturing processs for the semiconductor wafers used to fabricate the stacks. The original process has been reverted to and the problem solved. Changes to the model philosophy for the laser are being studied in order to minimise the schedule impact of this problem.

There is no engineering model of the satellite, but rather a test configuration based around onboard software, EGSE and simulations, known as the Model-based Development and Verification Environment (MDVE). The basic EGSE has been delivered, as has a breadboard onboard computer and its basic software. The software models needed for the configuration are also nearing completion. Work on building the MDVE itself is now starting.

The flight-model satellite is due to be launched in October 2007.

MetOp

A major milestone has been achieved with the completion of the MetOp-1 satellite integration programme and the successful execution of the MetOp-1 Flight Acceptance Review (Part 1) (FAR-1). The latter marks the completion of the design and qualification phase. Due to the restructured programme, MetOp-1 does not yet have a full flightworthy set of instruments and will now be stored during the preparation of MetOp-2, the first MetOp to be launched at the end of 2005. The final instrument complement will be integrated on MetOp-1 before its launch, planned in the 2010 time, and Part-2 of the FAR-1 will be held at that time.

Following the post-environmental-test checks, which confirmed the excellent health of the satellite, the final MetOp-1 assembly, integration and test (AIT) activities concentrated on the execution of the satellite onboard software testing, the AOCS sign tests and the second Satellite System Verification Test (SSVT) with the Eumetsat mission-control system.

The MetOp-1 satellite will be now de-integrated into its three constituent modules: Service Module (SVM), Payload Module (PLM) and Solar Array (SA). A number of open tasks mainly related to the retrofitting of units/instruments following the correction of anomalies will be performed before their entry into storage, which is now predicted for the late autumn.

On MetOp-2, the Payload Module (PLM-2) completed the standalone preparatory activities following the thermal-vacuum test in February. These included the updating of some software at instrument (A-DCS) and PLM level, and the re-integration of a new AMSU-A1 instrument, following the failure that occurred on the previous instrument model during thermal-vacuum testing. The final mission timeline test (SFT-3) including some modified operations has also been successfully completed. Following an antenna-deployment check and the completion of the alignment and dimensional measurements, PLM 2 was shipped to Toulouse (F) for the start of the satellite activities.

With respect to the Service Module (SVM-2), a number of open work items resulting from previous AIT activities have been completed in the past months, including repair of the EPRM, EDR and EIU and replacement of a few defective thermostats. The only critical, still-ongoing issue at the moment is the investigation of a leak in the Reaction Control Subsystem (RCS) which occurred during the thermal-vacuum test at low temperature. An investigation plan has been agreed with industry and a dedicated test set-up is being prepared to identify the leaking element before the start of the FM2 satellite integration activities.

The MetOp-2 satellite is well on track for a launch in the fourth quarter of 2005, within the launch period agreed between Eumetsat and the launch service provider Starsem.

Meteosat Second Generation (MSG)

MSG-1
The Routine Operations of the first of the Meteosat Second Generation satellites, now designated Meteosat-8 by Eumetsat, which started on 29 January, are nominal.

MSG-2
MSG-2 was taken out of storage in the second week of April for the completion of open work items and de-storage health tests. Some MSG-2 units have been be replaced by MSG-3 units. After the System Validation Test (SVT) and fine balancing, the spacecraft will be ready for shipment to the Ariane-5 launch site in Kourou, French Guiana, in early November, for a planned launch on 15 February 2005.

MSG-3
All nominal assembly, integration and test activities have been completed. Some units had to be dismounted for retrofitting or mounting on MSG-2. The Pre-Storage Review, which started at the end of April, was completed by the beginning of July. The spacecraft remains stored in the clean room at Alcatel Space in Cannes (F).

MSG-4
The MSG-4 System Baseline Status Review was successfully completed on 11 May. The parts procurement schedule, mainly for the MCP units, remains critical.

Vega

The Vega System Design Review took place during April and May and also involved independent reviewers from ASI, CNES, DGA and EADS, as well as ESA. The conclusions were submitted on 8 June to a Board of senior representatives of ESA and the other agencies involved in Vega. A number of technical and programmatic difficulties that need timely resolution have been identified and an action plan has been agreed with industry for the completion of critical actions.

Live acoustic tests with a scaled model of Vega and its launch pad have been completed at the Avio plant in Colleferro (I).

The mechanical tests on the first model of the Zefiro-9 motor case have been successfully completed. Manufacture of the next model (DM 0) is in progress. The first Zefiro-23 motor case has undergone its hydroproof test.

In April, a working group involving ESA, Arianespace and ELV staff analysed a number of organisational and programmatic elements that need to be defined before the start of the Vega production and exploitation phase. The results of these analyses will serve as input for an overall approach to the organisation of launcher production and exploitation (Ariane, Vega and Soyuz).

The P80 Inert Loading Model activities have been successfully concluded in Kourou (Fr. Guiana) with the validation of the casting process and its tooling, which differ substantially from Ariane. Manufacture of the first model of the P80 motor case (shortened TM) is in progress at the dedicated Avio facility in Colleferro (I). The Ariane and P80-induced modifications to the BEAP firing test range in Kourou have been completed as planned, ready for the ARTA tests this autumn.

In its June session, the Industrial Policy Committee (IPC) endorsed the Agency's proposal to allocate overall industrial responsibility for the Vega Ground Segment to Vitrociset (I) as Prime Contractor, leading a consortium of European companies. This proposal offered an optimised solution to several programmatic issues and its endorsement by the IPC allows work to start on the launch facilities for Vega in French Guiana.

International Space Station

Highlights
The very successful Dutch Soyuz mission, DELTA, with André Kuipers took place from 19 to 30 April. Most of the experiments conducted produced good scientific results (more than an 80% success rate) and some are being continued into Increment 9. This Soyuz mission (flight 8S) marked the 40th successful flight to the ISS. Progress flight 14P has since flown successfully to the Station, arriving on 27 May.

Planning for an Italian Soyuz flight to the ISS in April 2005 with ESA astronaut Roberto Vittori is underway, and negotiations have also been initiated with the Russian parties for a possible long-duration flight to the ISS in October 2005 with an ESA astronaut.

Negotiations on the ISS Initial Exploitation contract have been completed and signature of the contract, which involves a total of 1.046 BEuro and includes the production of six ATVs, logistics and sustaining engineering, ATV crew training and operations-preparation activities, took place on 13 July.

Space infrastructure development
All Columbus payload facility racks (Biolab, European Physiology Module, Fluid Science Laboratory, and European Drawer Rack) have been integrated into the Columbus proto-flight model, and the first round of individual-payload integrated functional testing has been successfully completed. The External Payload Facility has been attached to the end-cone of

the module. The first end-to-end test involving the Electrical Test Model and ground segment (the so-called System Validation Test 10) has started, and preparation for the Qualification Review Part 2, due to start in September, is well underway.

The ATV 'Jules Verne' Spacecraft Structure Qualification Review has been successfully completed and System Validation Tests, including end-to-end tests with the Tracking and Data-Relay Satellite System (TDRSS), also involving the ATV Control Centre, have been completed successfully. Integration in Bremen (D) has been completed and delivery to ESTEC in Noordwijk (NL) for environmental testing has been brought forward to mid-July. The integrated launch-readiness date has been agreed by all parties to be mid-October 2005; both NASA and the Russian Space Agency have been informed in order to plan for the launch and mission scheduling.

Discussions are ongoing with NASA on the technical and programmatic baseline for the Nodes programme.

The Preliminary Design Review for the Cryogenic Freezer (CryoSystem) has been completed and negotiations with NASA on some rack-configuration changes have been concluded.

The Cupola harness and secondary structure have been installed and crew inspection, including crew fit checks, performed. The Qualification and Acceptance Review has started in readiness for the Cupola's delivery to NASA in September 2004 and the process for transfer of ownership has been initiated.

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

The Acceptance Review closeout data package for the European Robotic Arm (ERA) is under review.

Operations and related ground segments

The Columbus Control Centre System Design Review was successfully completed. The Qualification and Acceptance Review has been postponed to Spring 2005, but will now cover the entire scope of the qualification.

Work is continuing to prepare for the first System Validation Tests, currently planned for end-July, of Columbus with the Columbus Control Centre (COL-CC) and the User Support and Operations Centres (USOCs).

Utilisation planning, payload development and preparatory missions

A new Announcement of Opportunity (AO) in Life and Physical Sciences, including a part for new Microgravity Application Promotion (MAP) proposals, was approved and has been released on 2 July.

As a result of the International Life Science Research Announcement (ILSRA 2004), there are 80 ESA proposals, 70 of which are being reviewed by international Peer Boards in Washington DC, to which ESA has contributed 50% of the members.

Instrument acceptance for the external payloads EuTEF (an infrastructure to provide accommodation for up to seven experiments) and SOLAR (for investigating solar phenomena) is in progress and interface testing on the Columbus Rack Level Test Facility is planned to take place in October 2004.

Issues relating to the operability of the Atomic Clock external payload (ACES) on the ISS have now been clarified.

Delivery of the European Drawer Rack (EDR) training model to the European Astronaut Centre (EAC) in Cologne (D) has taken place, thereby completing the deliveries of training models of all Columbus payloads.

Interim Utilisation activities, covering the period 2004-2006, have been approved and include a European Soyuz Mission. The substantial experiment package includes:

- increased parabolic flights and drop-tower experiments
- an Electromagnetic Levitator precursor for material science on a MiniTexus sounding rocket
- EXPOSE-R for exobiology research on the Russian Module of the ISS
- biology experiments with KUBIK on Soyuz Taxi Flights
- various human-physiology experiments on the ISS (FlyWheel, Respiratory, Cardio/ Neuro), and
- various physical-science experiments in the Microgravity Science Glovebox (MSG) on the ISS.

The Pulmonary Function System Flight Model-2 has been delivered to JSC for integration into NASA's Human Research Facility, for launch in March 2005.

The first flight model of the –80 degC Freezer (MELFI) is being prepared at Kennedy Space Center (KSC) for launch in May 2005 and the second flight model has been delivered to KSC for ISS interface testing.

The European Modular Cultivation System (EMCS) flight-model system integration/ verification is in its final stage before delivery to KSC for EXPRESS rack integration and launch in May 2005.

ISS education

Education Kits have been completed in other languages and distributed, and two video lessons (DVDs) are being prepared. Three university student experiments were performed during the Dutch Soyuz Mission, DELTA, and further student experiments are being planned for FOTON and future Soyuz missions.

Commercial activities

A commercial agent for Biotechnology has been selected and an independent review of the commercialisation programme is close to completion.

Astronaut activities

From 10 to14 May, the European Astronaut Centre (EAC) in Cologne (D) hosted a meeting of the International Training Control Board (ITCB).

The Multilateral Medical Operations Panel, meeting at Johnson Space Center in June, has updated the Crew Scheduling Constraints for Short Duration Missions on the ISS (Soyuz and Shuttle) in order to maintain the balance between crew operations and scientific return.

At the Multilateral Crew Operations Panel meeting held at EAC on 28-30 June, the main points of discussion were the Space Shuttle's return-to-flight in 2005 and crew-rotation options with two crew members on Soyuz and one on the Shuttle.

The third one-week session of Columbus System User Level Training has been performed for payload engineers, Facility-Responsible Centre personnel, and Columbus flight controllers.

In Brief

Snapshots from a planetary holiday – international interplanetary networking works!

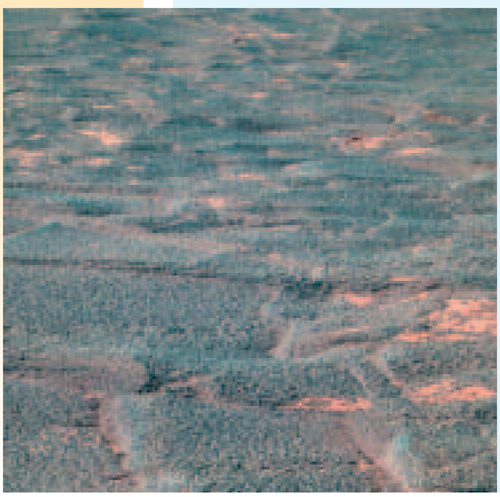
ESA's Mars Express has relayed pictures from one of NASA's Mars rovers for the first time, as part of a set of interplanetary networking demonstrations. These demonstrations pave the way for future Mars missions to draw on joint interplanetary networking capabilities. ESA and NASA planned these demonstrations as part of continuing efforts to cooperate in space exploration.

On 4 August, as Mars Express flew over NASA's Mars exploration rover Opportunity, it successfully received data previously collected and stored by the rover. The data, including 15 science images from the rover's nine cameras, were then downlinked to ESA's European Space Operations Centre (ESOC) in Darmstadt (Germany) and immediately relayed to the Mars Exploration Rovers team based at the Jet Propulsion Laboratory in Pasadena, USA.

NASA's Mars Odyssey and Mars Global Surveyor orbiters have so far relayed most of the data produced by the rovers since they landed in January. Communication compatibility between Mars Express and the rovers had already been demonstrated in February, although at a low data rate. The 4 August session, at a transmit rate of 42.6 megabits in about six minutes, set a new mark for international networking around another planet.

"We're delighted how well this has been working, and thankful to have Mars Express in orbit," said Richard Horttor of NASA's Jet Propulsion Laboratory, Pasadena, California, project manager for NASA's role in Mars Express. JPL engineer Gary Noreen of the Mars Network Office said: *"the capabilities that our international teamwork is advancing this month could be important in the future exploration of Mars."*

"Establishing a reliable communication network around Mars or other planets is crucial for future exploration missions, as it will allow improved coverage and also an increase in the amount of data that can be brought back to Earth," said Con McCarthy, from ESA's Mars Express project, *"the tracking mode will enable ESA and NASA to pinpoint a spacecraft's position more accurately during critical mission phases."*



This false-colour image of the interior of 'Endurance Crater' on Mars was collected on 4 August 2004 by NASA's Mars Exploration Rover Opportunity and relayed to Earth by ESA's Mars Express together with other scientific data. Three separate frames, taken through red, green and blue filters, were combined to produce this colour image. (NASA/JPL/Cornell)

This view of the interior slope and rim of 'Endurance Crater' comes from the navigation camera on NASA's Mars Exploration Rover Opportunity with an assist from the ESA's Mars Express. Rover wheel tracks are visible in the foreground. (NASA/JPL)

Huygens probe in perfect health

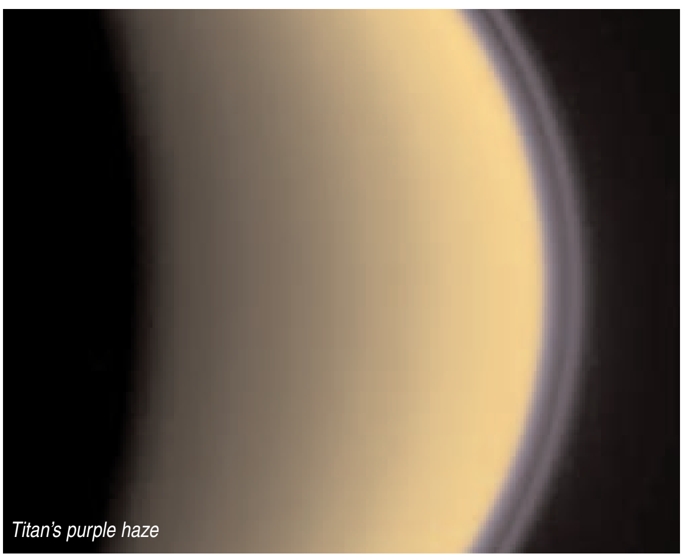
On the way to its final destination Titan, ESA's Huygens atmospheric probe has undergone an important health check-up.

The NASA/ESA/ASI Cassini-Huygens spacecraft entered orbit around Saturn on 1 July, crossing the planet's rings. The data collected at ESA's European Space Operations Centre (ESOC) in Darmstadt (D) show that this delicate and risky manoeuvre proved harmless for all instruments on board and mission-control specialists gave Huygens a perfect bill of health.

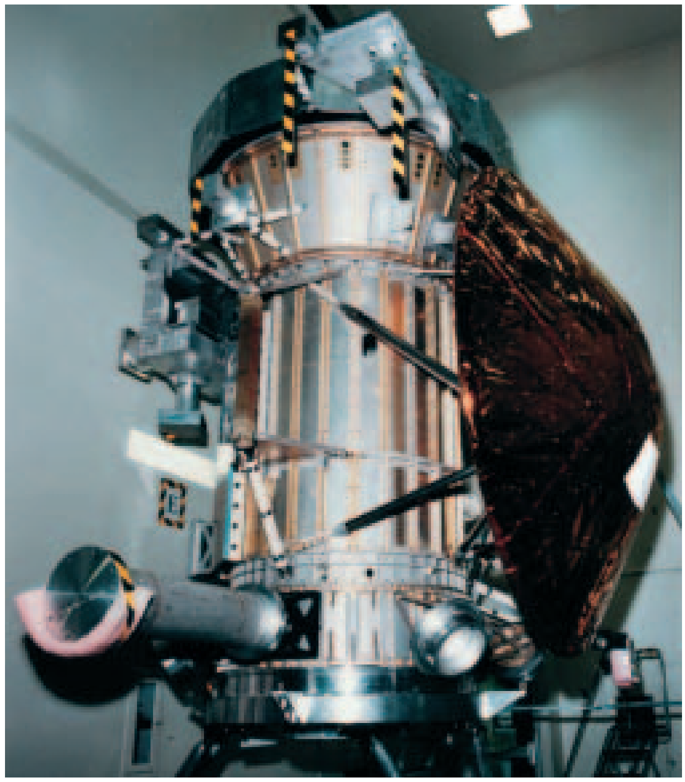
During its long journey with Cassini, starting on 15 October 1997, the proper working of the Huygens probe and of its scientific instruments has been regularly verified. This check-out, however, was special, since it took place after Cassini-Huygens transited twice through the rings of Saturn. Although the rings appear solid from a distance, they are formed by millions of tiny frozen dust particles and ice blocks, some the size of a grain of sand and others as big as a house.

To minimise any risk that some of these fragments would hit critical subsystems or on-board instruments, mission specialists sent Cassini-Huygens through a 'gap' in the rings. The gap was known to be safe as other earlier deep-space probes, such as NASA's Pioneer 11, had already passed through it unharmed.

The excellent performances of Cassini and its instruments immediately after the ring-plane crossings already indicated that the spacecraft had survived this extreme environment. The next probe check-outs, scheduled for 14 September and 23 November, are two major steps in preparation for the release from Cassini on 25 December this year. The cruising phase to Titan will then last 21 days, followed on 14 January 2005 by the descent through its dense atmosphere.



Titan's purple haze



The Huygens probe (right) mounted on Cassini

In the meantime, Cassini-Huygens has taken its first pictures of Saturn's moon Titan, which can be seen encircled in a purple stratospheric haze. The image shows two thin haze layers. The outer haze layer is detached and appears to float high in the atmosphere. Because of its thinness, the high haze layer is best seen at the moon's limb.

Images like this one reveal some of the key steps in the formation and evolution of Titan's haze. The process is thought to begin in the high atmosphere, at altitudes above 400 kilometres, where ultraviolet light breaks down methane and nitrogen molecules. The products are believed to react to form more complex organic molecules containing carbon, hydrogen and nitrogen that can combine to form the very small particles seen as haze. The bottom of the detached haze layer is a few hundred kilometres above the surface and is about 120 kilometres thick.

The image has been falsely coloured, the globe of Titan retains the pale orange hue our eyes would usually see, but both the main atmospheric haze and the thin detached layer have been brightened and given a purple colour to enhance their visibility.

A full article on the scientific discoveries of the mission so far will appear in the next issue of ESA Bulletin.

Contract signed with EADS Space Transportation for European ISS elements

On 13 July ESA and EADS Space Transportation signed a 1-billion-Euro contract that will allow Europe to start the initial exploitation of the International Space Station.

The contract covers preparations for the operation of Columbus, ESA's laboratory on the International Space Station, and the production of six European multifunctional cargo ships, called Automated Transfer Vehicles (ATVs). On behalf of the ESA Director General, the Director of Human Spaceflight, Jörg Feustel-Büechl, signed this 'Initial Exploitation Contract'; on the industrial side the signatures were Josef Kind and Hervé Guillou, President and CEO of EADS Space Transportation, respectively.

The ATVs are essential in the supply of the ISS with spare parts, food, air and water for its permanent crew. They will also carry experiment equipment to the Station and remove waste and material that is no longer needed onboard. Their flights represent Europe's contribution in kind to the operating cost of the ISS and help make ESA a key partner in the ISS programme. The procurement of the six new ATVs, via a new phased contract, starts with the purchase of equipment for the second ATV flight model in 2004, followed by purchase of equipment for the third ATV and the integration of the second ATV. The first vehicle, named after Jules Verne, has been developed and produced under a previous contract and is due for launch on an Ariane-5 from Kourou in the second half of 2005. The purchase of equipment for the next ATV flight models and their assembly will follow in 2006.

The new contract allows for a flexible approach that takes into account the evolving needs of the ISS programme. The activities covered by the contract deal with the European experiment facilities for the International Space Station and the experiment programme. The contract also covers activities in the fields of the European flight control team and crew training, ground facility maintenance and engineering support for Columbus.

"This contract is a big step forward for Europe in the exploitation of the International Space Station", said ESA Director Jörg Feustel-Büechl. *"I am very pleased to see this happen, because it demonstrates that Europe is an important and reliable partner in the ISS programme and is able to deliver state-of-the-art space technology, in this case for rendezvous and docking – which is a European first."* esa

'Project: Zero Gravity' – Free ISS DVD lesson for teachers

We all know that space is a subject that fascinates children of all ages. To help capture the interest of youngsters in science, and to support teachers looking for ways to teach the basics of physics, ESA has produced a comprehensive ISS DVD Lesson (the first in a series entitled 'Project: Zero Gravity') about Newton's three Laws of Motion. Experts, teachers and their pupils from across Europe gave their input and support during the production.

Pupils from schools in Germany, Spain and Ireland joined with ESA astronauts to create a series of filmed space and comparable Earth-based science experiments that take science out of the classroom and into real life. The space footage was shot on board the ISS – a novel classroom environment – during the 'Cervantes' Soyuz Mission last October by Spanish ESA astronaut Pedro Duque and Russian Commander Alexander Kaleri. The ground-based experiments show how Newton's Laws of Motion affect everyday objects and even the pupils themselves.


Pedro Duque tests Newton's Laws on the ISS

Of relevance to pupils aged 12-18 years, the DVD has been designed for use in the classroom and to encourage group exercises. It includes 11 European languages and comes in a handy DVD case that contains a Teacher's Guide with an explanation of how to use the DVD, a brief introduction to the ISS, inter-disciplinary classroom activities related to European curricula, a glossary, further web and reading references and an evaluation form. Chapters from the Teacher's Guide (classroom exercises, glossary, etc.) can also be copied and distributed to pupils.

Over 10,000 copies will be distributed to secondary schools across ESA Member States. So we're calling all secondary-school teachers: get your free copy of the DVD by signing up at "http://www.esa.int/spaceflight/education"

Filming the DVD on the Space Station

Jules Verne at ESTEC

After a long and complicated journey by air, land and sea, the first Automated Transfer Vehicle (ATV) called 'Jules Verne' arrived at ESA's European Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands, on 15 July. Jules Verne is the first of seven European supply ships for the International Space Station. It will undergo extensive testing at ESTEC over the next six months.

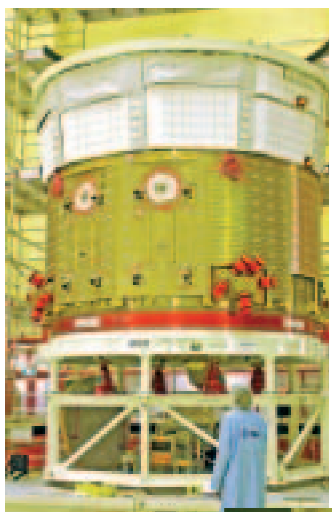
The ATV's instrumentation and payload bay were flown in two Airbus Transporters from Bremen in Germany to Amsterdam's Schiphol airport. The two shipments continued their journey by boat to Katwijk, finally arriving at the gates of ESTEC on 15 July.

The first tests in ESTEC's new Maxwell electromagnetic radiation chamber will take place in September, followed in October by acoustic testing in the Large European Acoustic Facility (LEAF). The ATV will be subjected to a noise level of 145 decibels (several hundred times louder than a pop concert) in order to see whether the vibration resulting from the massive noise of the Ariane-5 rockets could cause any damage during the launch.

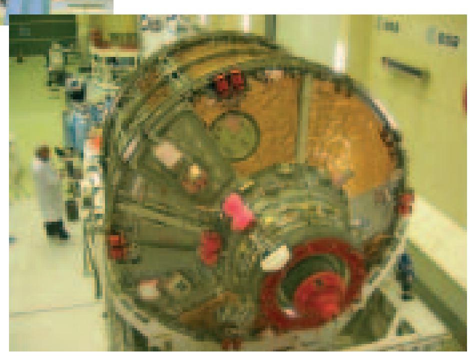
After the tank leakage tests and extending the solar panels, temperature testing will take place in the new year in the Large Space Simulator. This simulator will give Jules Verne a taste of what it will be like outside the Earth's atmosphere by providing extremely high and extremely low temperatures in a vacuum.

If the ATV comes through all these tests unscathed, the space carrier will be shipped to French Guiana and launched a few months later. This launch will be the first independent delivery by Europe of food, water, oxygen and scientific experiments to the ISS. New provisions will be carried into space at least six times over the next 10 years in the new fleet of ATVs. Each of these craft can transport as much as 7500 kilogrammes, three times more than the capacity of today's supply ship, the Russian Progress.

Once the ATV has made the three-day journey to the International Space Station, it can remain there for up to six months and serve as extra work space for the permanent crew. Its motors can also be used to boost the Space Station to a higher orbit. But there's one more job for Jules Verne: it will bring waste material from the ISS back towards Earth to be completely and harmlessly incinerated high up in the atmosphere.



Jules Verne's avionics/propulsion module at the test centre in ESTEC



Jules Verne's integrated cargo carrier

International Space Station Heads of Agency Meeting

The heads of space agencies from the United States, Russia, Japan, Europe and Canada met on 23 July at ESTEC in Noordwijk, the Netherlands, to discuss International Space Station (ISS) cooperation activities.

At this meeting, the ISS Partnership unanimously endorsed the ISS technical configuration and reviewed the status of ISS in-orbit operations and plans. The new ISS configuration is planned for completion by the end of the decade and will accommodate in-orbit elements from each of the ISS Partners. The configuration will enable increased utilisation and will provide early opportunities for an enhanced crew of more than three people.

The ISS Partnership's endorsement of this configuration provides a clear basis for the completion of programmatic and financial evaluation and subsequent agreement on a transportation and logistics framework that will support assembly and operation of the ISS.

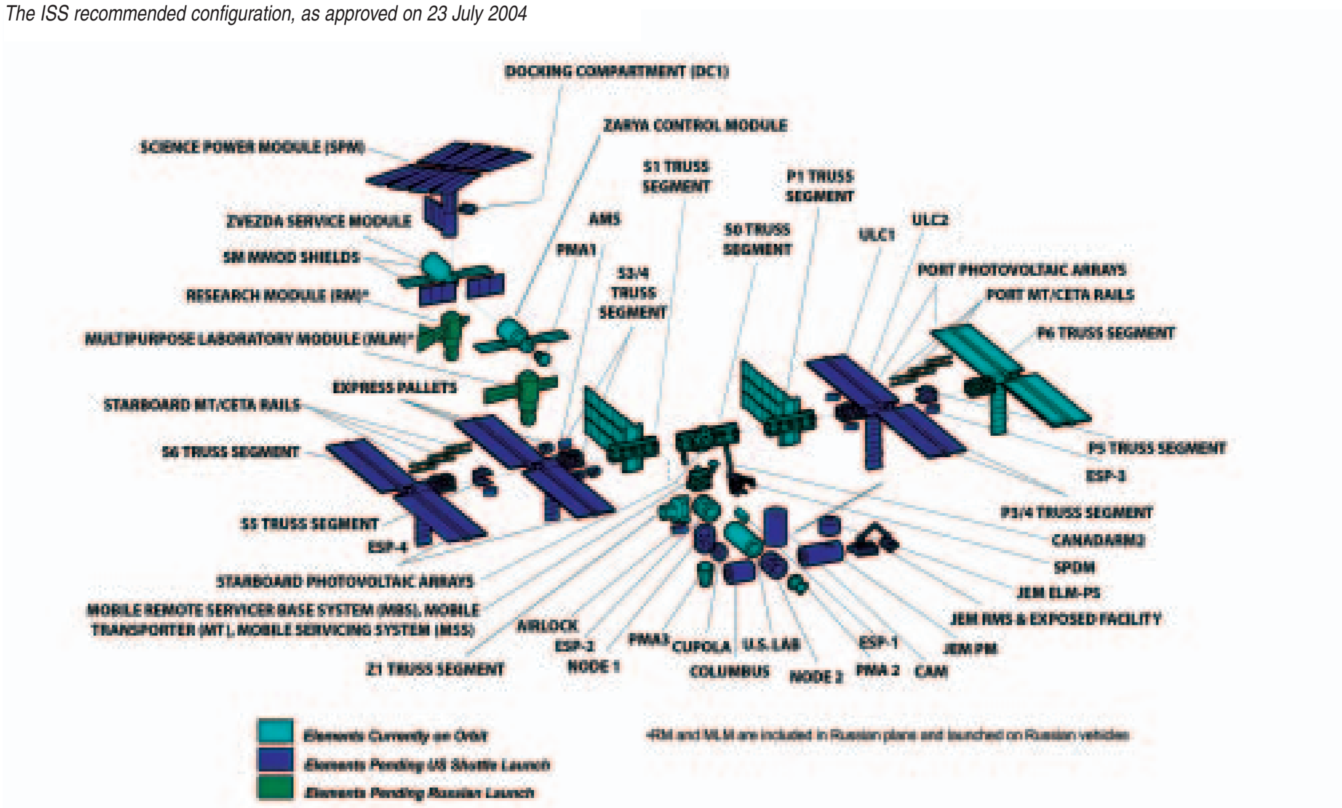
This framework will be supported by Russian Soyuz vehicles, the US Space Shuttle, the automated logistics re-supply and re-boost capabilities provided by Russian Progress vehicles, and the ATV and HTV transfer vehicles to be provided by Europe and Japan.

The Partnership also agreed that additional assessments would be conducted to confirm the ISS flight programme in a nominal mode and to evaluate further opportunities to accelerate the launch of the Japanese and European research modules JEM (Kibo) and Columbus, as well as establishing a specific schedule to enhance the permanent crew.

NASA and ESA once again reconfirmed their commitment to support individually and cooperatively, in 2005, uninterrupted human presence on the ISS of the integrated crew, and provide for its rotation and rescue on a parity basis. For that they agree to complete agreements on mutual responsibilities for the ISS as soon as possible. The results of these assessments will be reviewed at the next ISS Heads of Agency meeting in early 2005, leading to the Partnership's final endorsement of the ISS configuration.

During their discussions, the space agency leaders reaffirmed their enduring commitment to the unprecedented international cooperation that has characterised the ISS Programme. They also expressed their appreciation for NASA's continuing efforts to safely return the Space Shuttle to flight in the March 2005 timeframe as a significant step for continuing ISS assembly and operations. esa

The ISS recommended configuration, as approved on 23 July 2004



Envisat marks two and a half years of operations

From 6 to 10 September 2004, more than 700 scientists from 50 countries will meet in Salzburg, Austria, to review the impressive results already obtained from ESA's Envisat environmental satellite mission. Launched in March 2002, Envisat is the most powerful means ever created for monitoring the state of our planet and the impact that human activities are having on it. It carries ten sophisticated optical and radar instruments to observe and monitor the Earth's land surfaces, atmosphere, oceans and ice caps, maintaining continuity with the Agency's ERS remote-sensing missions which began in 1991.

The main objective of the Symposium is to provide a forum for investigators to present the results from their ongoing research-project activities and to discuss and assess the development of added-value applications and services. Scientists and operational users of Envisat data working in the framework of international, ESA and national projects will present the early results from the Envisat mission and also the scientific benefits of the 13 years of ESA's two predecessor ERS missions. Envisat data contains a wealth of information on the workings of the Earth system, including insights into factors contributing to climate change. The satellite is supporting research activities and government programmes in the fields of global change, pollution and disaster monitoring, and commercial applications.

The Salzburg Symposium will address almost all fields of Earth science, including the Earth's atmosphere, coastal studies, radar and interferometry, winds and waves, vegetation and agriculture, natural disasters, gas mapping, ocean colour, oil spills and ice. Over 650 papers, selected by peer review, will be presented. The presentations will include Envisat data on: the 'Prestige' oil spill, the major fires in Portugal in 2003, the Elbe flooding in 2002, the evolution of the Antarctic ozone hole since the launch of Envisat, the Bam earthquake, and pollution in Europe. There will also be numerous demonstrations during the week in the ESA Exhibition area. An industrial consortium exhibit on GMES (Global Monitoring for Environment and Security) is also planned.

The event will be opened by Mr Eduard Mainoni, Secretary of State at the Austrian Federal Ministry of Transport, Innovation and Technology. The complete Proceedings of the Symposium will be available on CD-ROM (as ESA SP- 572) from ESA Publications Division before the end of the year.

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 Annual Report

ANNUAL REPORT 2002 (JULY 2003)
BATTRICK B. (ED.)
ESA ANNUAL REPORT // 116 PAGES
NO CHARGE

ESA Newsletters

ECSL NEWS NO. 27 (JUNE 2004)
BULLETIN OF THE EUROPEAN CENTRE FOR SPACE LAW
MARCHINI A. & DANESY D. (EDS.)
NO CHARGE

EDU NEWS NO. 6 (JULY 2004)
NEWSLETTER OF ESA'S EDUCATION OFFICE
WARMBEIN B. (ED.)
NO CHARGE

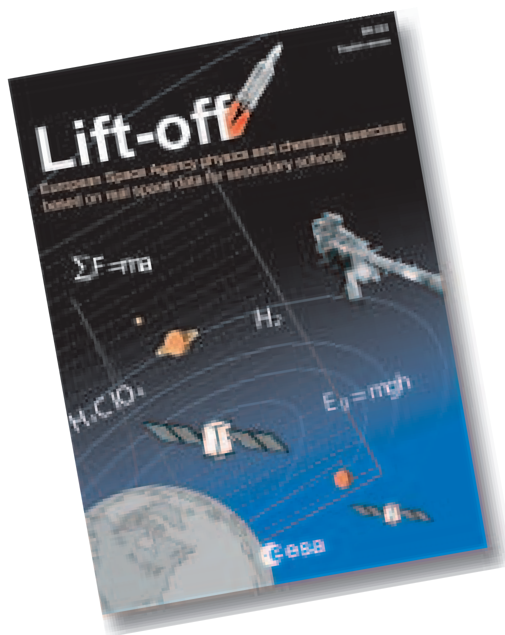
ON STATION NO. 17 (AUGUST 2004)
NEWSLETTER OF THE DIRECTORATE OF HUMAN SPACEFLIGHT
WILSON A. (ED.)
NO CHARGE

ESA Brochures

THE EUROPEAN ASTRONAUTS – A CASE FOR HUMANS IN SPACE (JULY 2004)
EUROPEAN ASTRONAUTS (ED. B. WARMBEIN)
ESA BR-221 // 36 PAGES
PRICE: 10 EURO

LIFT-OFF – EUROPEAN SPACE AGENCY PHYSICS AND CHEMISTRY EXERCISES FOR SECONDARY SCHOOLS BASED ON REAL SPACE DATA (MAY 2004)
BUISÁN S.T. (ED. B. WARMBEIN)
ESA BR-223 // 66 PAGES
PRICE: 10 EURO

SMOS – ESA'S WATER MISSION (JUNE 2004)
BERGER M., BOCK R., DRINKWATER M. & REBHAN H.
(EDS. H. RIDER, M. RAST & B. BATTRICK)
ESA BR-224 // 18 PAGES
PRICE: 10 EURO



CASSINI-HUYGENS – UNIQUE INSIGHTS INTO A RINGED WORLD (JUNE 2004)
ESA SCIENCE PROGRAMME COMMUNICATION SERVICE (EDS. B. BATTRICK & M. TALEVI)
ESA BR-225 // 24 PAGES
PRICE: 7 EURO

AMERHIS – A NEW GENERATION OF SATELLITE COMMUNICATIONS SYSTEMS (JUNE 2004)
AMERHIS TEAM & N. MENNING
(ED. B. BATTRICK)
ESA BR-226 // 26 PAGES
PRICE: 7 EURO

EGNOS – THE EUROPEAN GEOSTATIONARY NAVIGATION OVERLAY SERVICE (JUNE 2004)
EGNOS TEAM (ED. B. BATTRICK)
ESA BR-227 // 8 PAGES
NO CHARGE

TELEMEDICINE 2010: VISIONS FOR A PERSONAL MEDICAL NETWORK (AUGUST 2004)
TELEMEDICINE ALLIANCE TEAM
(ED. B. BATTRICK)
ESA BR-229 // 42 PAGES
PRICE: 7 EURO

ESA Special Publications

MARS EXPRESS: THE SCIENTIFIC PAYLOAD (AUGUST 2004)
WILSON A. & CHICARRO A. (EDS.)
ESA SP-1240 // 230 PAGES
PRICE: 50 EURO

PROCEEDINGS OF THE 37TH ESLAB SYMPOSIUM – TOOLS AND TECHNOLOGIES FOR FUTURE PLANETARY EXPLORATION,

2-4 DECEMBER 2004, ESTEC, NOORDWIJK, THE NETHERLANDS (APRIL 2004)
BATTRICK B. (ED.)
ESA SP-543 // CD-ROM
PRICE: 30 EURO

PROCEEDINGS OF THE MERIS USER WORKSHOP, 10-13 NOVEMBER 2003, ESA/ESRIN, FRASCATI, ITALY (MAY 2004)
LACOSTE H. (ED.)
ESA SP-549 // CD-ROM
PRICE: 40 EURO

PROCEEDINGS OF THE FRINGE 2003 WORKSHOP, 1-5 DECEMBER 2003, ESA/ESRIN, FRASCATI, ITALY (JUNE 2004)
LACOSTE H. (ED.)
ESA SP-550 // CD-ROM
PRICE: 40 EURO

PROCEEDINGS OF THE 22ND INTERNATIONAL LASER RADAR CONFERENCE (ILRC 2004), 12-16 JULY 2004, MATERA, ITALY (JUNE 2004)
PAPPALARDO G., AMODEO A. & WARMBEIN B. (EDS.)
ESA SP-561 // 552 PAGES (VOL. 1), 492 PAGES (VOL. 2) & CD-ROM
PRICE: 70 EURO

PROCEEDINGS OF THE SECOND WORKSHOP ON COASTAL AND MARINE APPLICATIONS OF SAR, 8-12 SEPTEMBER 2003, SVALBARD, NORWAY (JUNE 2004)
LACOSTE H. (ED.)
ESA SP-565 // CD-ROM
PRICE: 40 EURO

PROCEEDINGS OF THE SECOND WORKSHOP ON THE ATMOSPHERIC CHEMISTRY VALIDATION OF ENVISAT (ACVE-2), 3-7 MAY 2004, ESA/ESRIN, FRASCATI, ITALY (AUGUST 2004)
DANESY D. (ED.)
ESA SP-562 // CD-ROM
PRICE: 50 EURO

PROCEEDINGS OF THE SECOND INTERNATIONAL GOCE USER WORKSHOP – GOCE, THE GEOID AND OCEANOGRAPHY, 8-10 MARCH 2004, FRASCATI, ITALY (JUNE 2004)
LACOSTE H. (ED.)
ESA SP-569 // CD-ROM
PRICE: 40 EURO

ESA Procedures, Standards & Specifications

SPACE PRODUCT ASSURANCE: REQUIREMENTS FOR MANUFACTURING AND PROCUREMENT OF THREADED FASTENERS (FEBRUARY 2004)
ECSS SECRETARIAT
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