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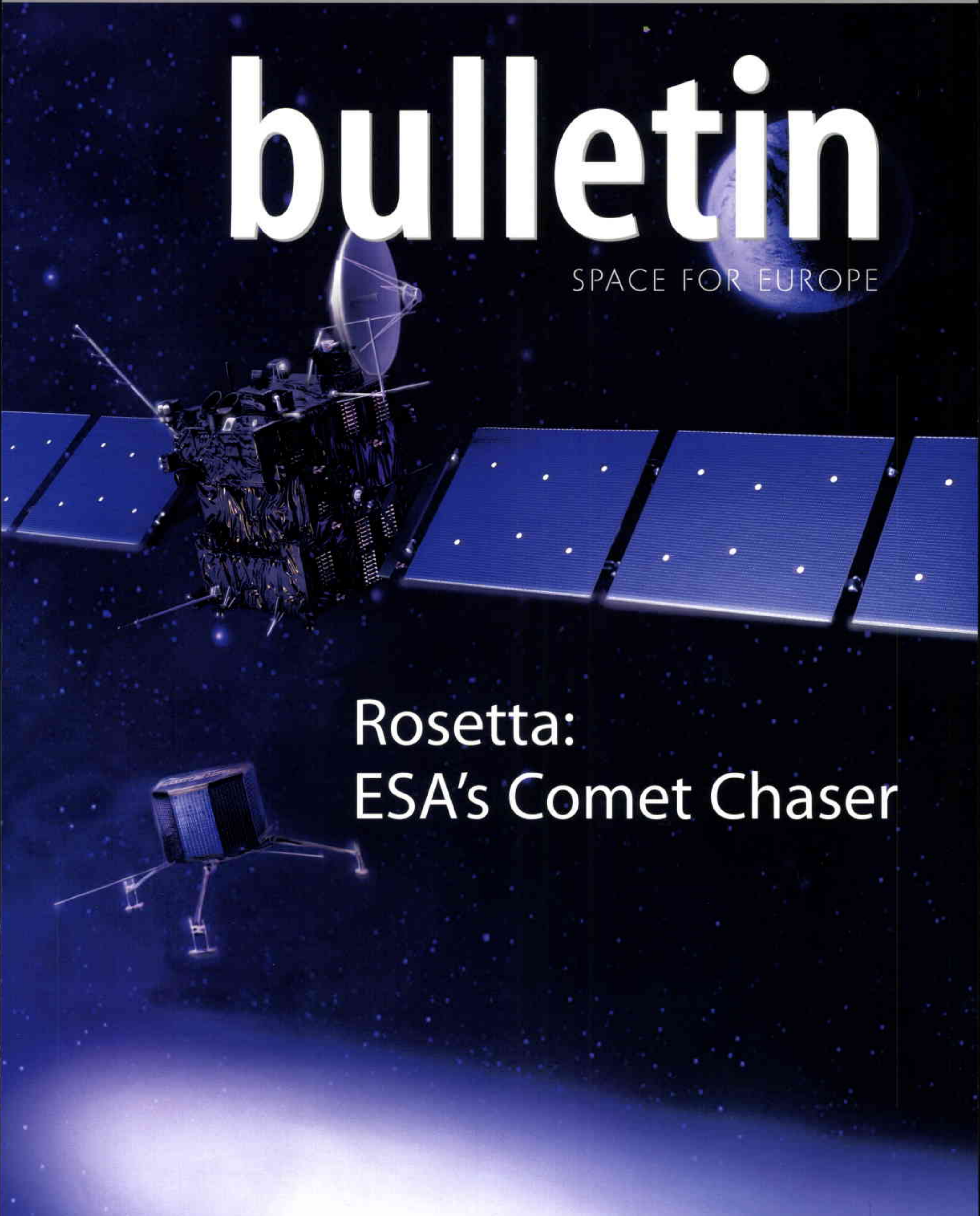
bulletin

SPACE FOR EUROPE



Rosetta: ESA's Comet Chaser

European Space Agency
Agence spatiale européenne

european space agency

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

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

(a) by elaborating and implementing a long-term European space policy, by recommending space objectives to the Member States, and by concerting the policies of the Member States with respect to other national and international organisations and institutions;
(b) by elaborating and implementing activities and programmes in the space field;
(c) by co-ordinating the European space programme and national programmes, and by integrating the latter progressively and as completely as possible into the European space programme, in particular as regards the development of applications satellites;
(d) by elaborating and implementing the industrial policy appropriate to its programme and by recommending a coherent industrial policy to the Member States.

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

The ESA HEADQUARTERS are in Paris.

The major establishments of ESA are:

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THE EUROPEAN SPACE OPERATIONS CENTRE (ESOC), Darmstadt, Germany

ESRIN, Frascati, Italy.

Chairman of the Council: P. Tegnér

Director General: A. Rodotà

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agence spatiale européenne

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

Selon les termes de la Convention: l'Agence a pour mission d'assurer et de développer, à des fins exclusivement pacifiques, la coopération entre Etats européens dans les domaines de la recherche et de la technologie spatiales et de leurs applications spatiales, en vue de leur utilisation à des fins scientifiques et pour des systèmes spatiaux opérationnels d'applications:

(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications;
(d) en élaborant et en mettant en oeuvre la politique industrielle appropriée à son programme et en recommandant aux Etats membres une politique industrielle cohérente.

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Editorial/Circulation Office
ESA Publications Division
ESTEC, PO Box 299, Noordwijk
2200 AG The Netherlands
Tel.: (31) 71.5653400

Editors
Bruce Battrick
Barbara Warmbein

Layout
Carel Haakman

Montage
Paul Berkhout
Isabel Kenny

Advertising
Barbara Warmbein

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Cover: ESA's Rosetta mission, due for launch in January 2003 (see page 10)

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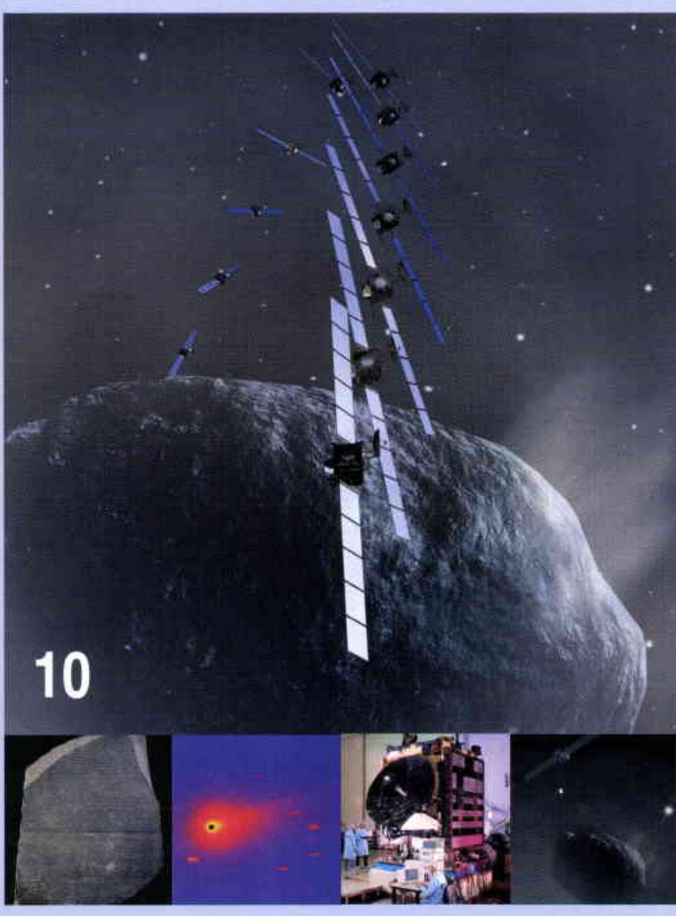
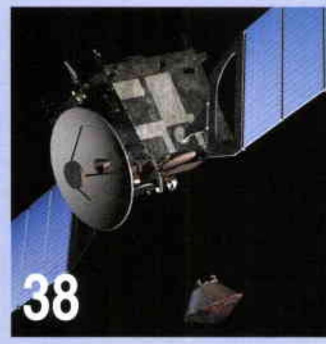


Cover Story: **Rosetta: ESA's Comet Chaser**



Payloads for Mars in Partnership with Industry

EAC Trains its First International Astronaut Class

News from Europe's Spaceport

esa bulletin 112 - november 2002

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Contraves | Space

Standard Space Radiation Monitoring

Under a contract with the European Space Agency (ESA) **SREM** (Standard Radiation Environmental Monitor) has been developed and manufactured by Contraves Space in co-operation with the Paul Scherrer Institute (PSI) in Switzerland.

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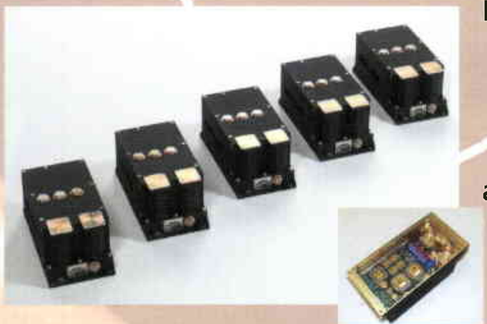

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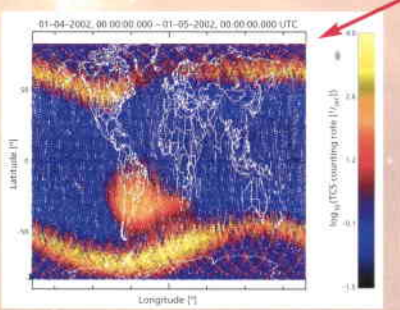
- PROBA Now flying
- Integral Now flying

and are selected for upcoming missions:

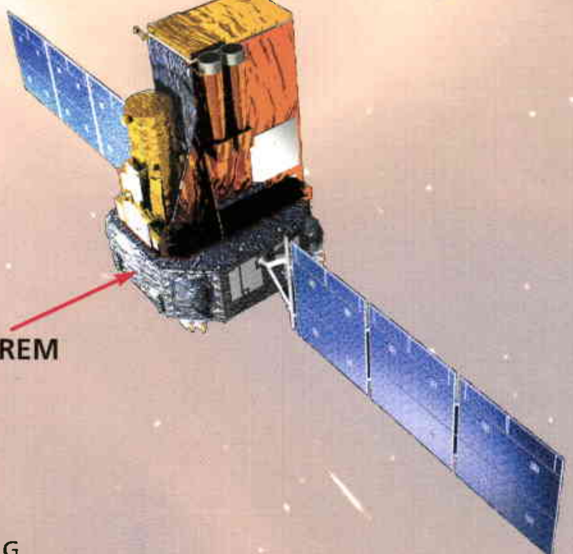
- Rosetta, Mars Express, GSTB, PROBA 2, Herschel, Planck.

SREM on PROBA

SREM in orbit data



SREM on INTEGRAL



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Contraves Space AG
Marketing and Sales
Schaffhauserstrasse 580
CH-8052 Zurich, Switzerland
www.contravesspace.com

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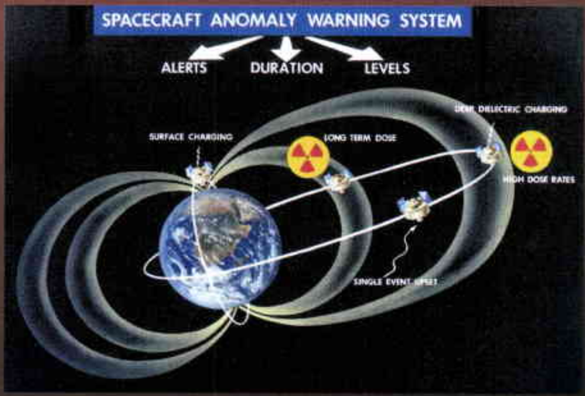

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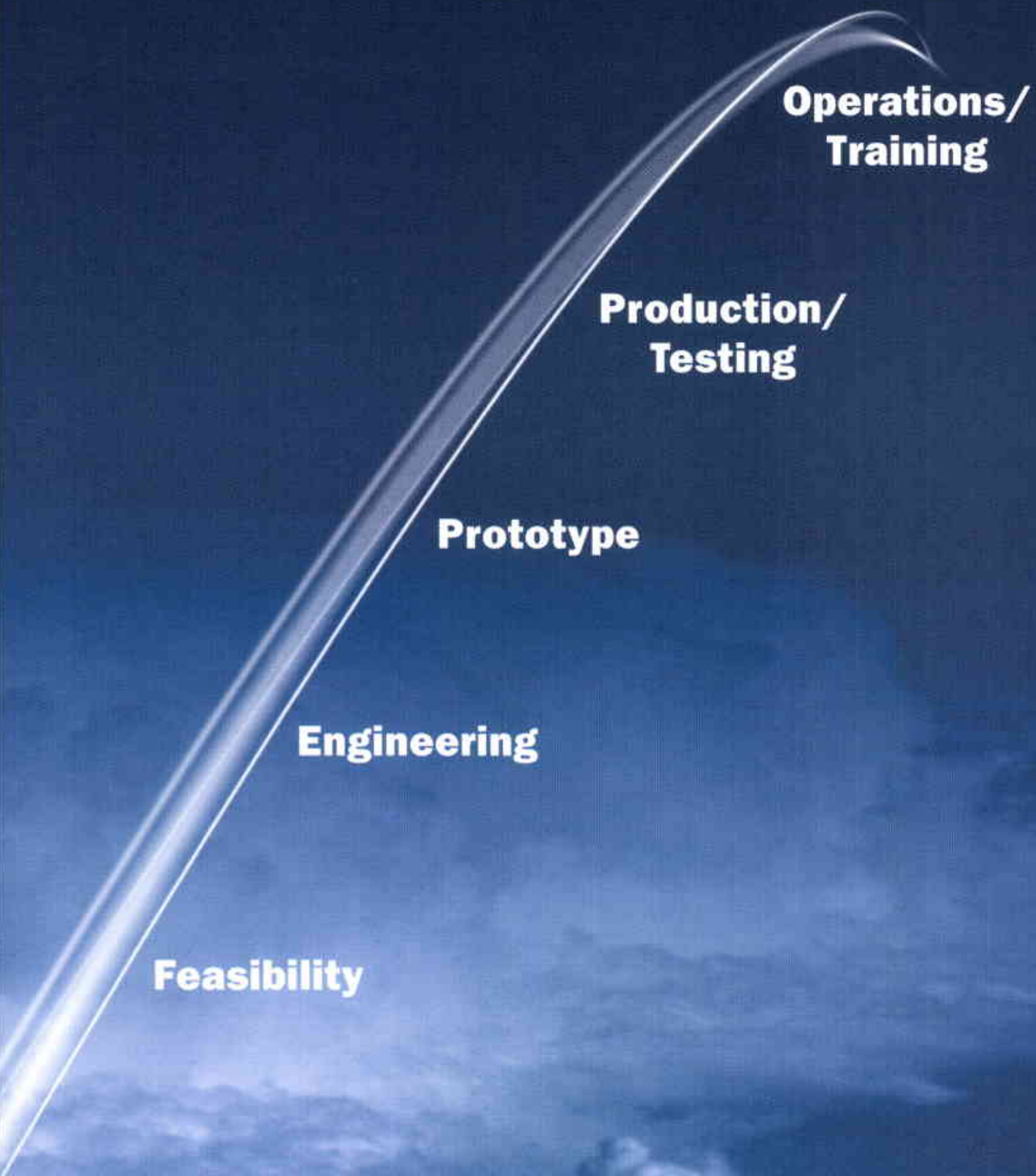

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EuroSim Consortium

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Information

Find out more about EuroSim at **www.eurosim.nl**

or contact EuroSim Marketing & Sales at:

Dutch Space	+31 71 5245455
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Dear Reader,

I would like to welcome you to this issue of the ESA Bulletin, in its new format, with a more pictorial and less technical content. It is my hope that this change in presentation will help to put the excellent work that the Agency is doing in the different facets of the space business into a broader context, and more clearly highlight its value for the citizens of Europe, both now and in the future.

The leading-edge research and applications work that ESA is doing at the very challenging frontiers of space – in science, earth observation, telecommunications, satellite navigation, space transportation, human spaceflight and microgravity – is already producing many spin-offs that are having far-reaching benefits for our everyday lives. The new-look Bulletin will endeavour to keep you, as a European taxpayer and hence a contributor to this exciting effort, fully informed in that regard.

This issue features the Rosetta scientific mission, which will be launched in January 2003. Some ten years in development with European industry, and after an eight-year trek through the inner Solar system, Rosetta will complete the most comprehensive examination ever made of a comet, orbiting and sending a Lander to the surface of this piece of primordial cosmic debris.

I hope that you will enjoy reading this and future issues of the new Bulletin and that it will stimulate your interest in our exciting European space missions and programmes.

Antonio Rodotà
Director General, ESA

Rosetta:

Claude Berner, Loic Bourillet, Jan van Casteren, John Ellwood, Michael Kasper, Philippe Kletzkine, Rita Schulz & Gerhard Schwehm
ESA Directorate of Scientific Programmes, ESTEC, Noordwijk, The Netherlands

Manfred Warhaut
ESA Directorate of Technical and Operational Support, ESOC, Darmstadt, Germany

Peter Bond
Space Consultant, Cranleigh, United Kingdom

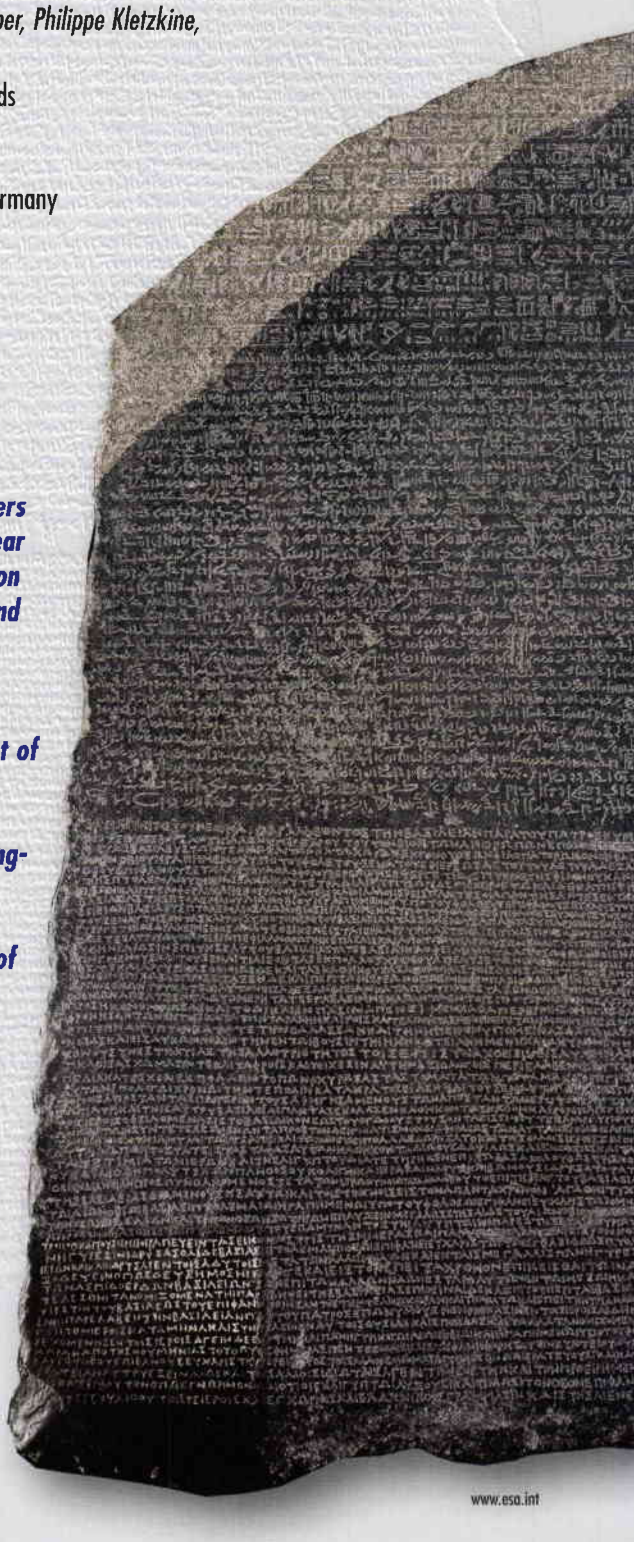
Why 'Rosetta'?

The Rosetta spacecraft is named after the famous Rosetta Stone, a slab of volcanic basalt now on display in the British Museum in London. French soldiers discovered the unique Stone in 1799, as they prepared to demolish a wall near the village of Rashid (Rosetta) in Egypt's Nile delta. The carved inscriptions on the Stone included hieroglyphics – the written language of ancient Egypt – and Greek, which was readily understood.

By comparing the inscriptions, it eventually became possible to decipher the mysterious figures that had been carved several thousand years earlier. Most of the pioneering work was carried out by the English physician and physicist, Thomas Young, and French scholar Jean François Champollion. As a result of their breakthroughs, scholars were able to piece together the history of a long-lost culture for the first time.

Just as the discovery of the Rosetta Stone eventually led to the unravelling of the mysterious hieroglyphics, so Rosetta will help scientists to unravel the mysteries of comets. Whereas hieroglyphics were the building blocks of the Egyptian language, comets are considered to be the most primitive objects in the Solar System, the building blocks from which the planets formed.

Billions of these giant chunks of ice still linger in the depths of space, the remnants of a vast swarm of objects that once surrounded our Sun and eventually came together to form planets. Virtually unchanged after 5 billion years in the deep freeze of the outer Solar System, they still contain ices and dust from the original solar nebula. They also contain complex organic compounds which some scientists believe may have provided the raw material from which life on Earth evolved.



ESA's Comet Chaser

On the night of 12-13 January 2003, one of the most powerful rockets in the world will blast off from Kourou spaceport in French Guiana. On top of the giant Ariane-5, cocooned inside a protective fairing, will be the Rosetta comet chaser, the most ambitious scientific spacecraft ever built in Europe.

Rosetta's mission is to complete the most comprehensive examination ever made of a piece of primordial cosmic debris – a comet. After an eight-year trek around the inner Solar System, the spacecraft will home in on its fast-moving target, eventually edging to within just a few kilometres of the solid nucleus, the icy heart of Comet Wirtanen.

By the summer of 2012, the Rosetta Orbiter will be close enough to map and characterise the nature of the dormant nucleus in unprecedented detail. Once a suitable touchdown site is identified, a small Lander will descend to the pristine surface, the first object from planet Earth to soft-land on one of these primitive worlds. Meanwhile, as the comet inexorably continues on its headlong rush towards the inner Solar System, the Rosetta Orbiter will catalogue every eruption of gas and dust as Wirtanen's volatiles vaporise in the warmth of the Sun.

The final chapter in Rosetta's decade-long tale of exploration will take place in July 2013, when the roving explorer returns once again to the vicinity of Earth's orbit. However, as with any complex, exciting adventure, it is worth delving into the historical background in order to understand how it all began. In the case of Rosetta, the tale began 17 years ago in a conference room in Rome.

The Rosetta Lander is released from its 'mother craft' as it orbits the nucleus of Comet Wirtanen

Comet Nucleus Sample Return

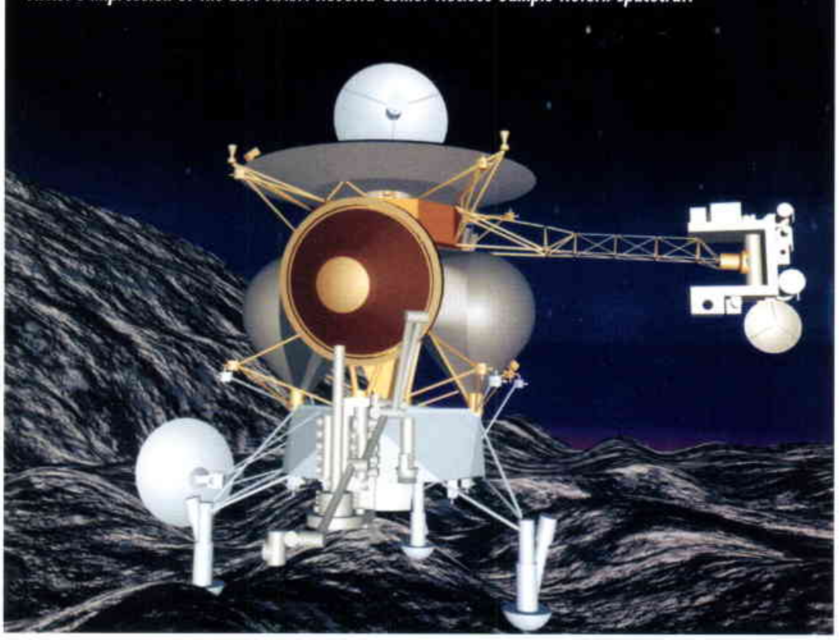
In January 1985, Ministers responsible for space matters in ESA's Member States came together to approve an ambitious and far-seeing programme of scientific and technological research. One of their most significant decisions involved approval of a long-term science plan, which was then named 'Horizon 2000'. A Resolution drafted by the Ministers stated, "The Council agrees to reinforce space-science activities in Europe during the next decade with a view to enabling the scientific community to remain in the vanguard of space research."

Based on inputs from the European space-science community, the revolutionary plan included ground-breaking missions that would be launched between the mid-1990s and the early years of the 21st century. The proposed programme was founded on four major Cornerstones, one of which was described as "a mission to primordial bodies including return of pristine materials". Even before its Giotto spacecraft reached Comet Halley, ESA was looking forward to establishing a leading role in the exploration of the smaller bodies of the Solar System by bringing back samples of material from either a comet or an asteroid.

After Giotto's remarkably successful Halley flyby in March 1986, the emphasis switched to comet sample return, but it soon became clear that the cost of such a mission would be too prohibitive for Europe to carry out alone. As a result, the ESA Science Executive began to investigate the possibility of conducting the Planetary Cornerstone as a collaborative venture with NASA, which was already pursuing its own Comet Rendezvous and Asteroid Flyby (CRAF) mission.

At this stage, scientists on both sides of the Atlantic were excitedly anticipating sending a mission to land on a relatively active, 'fresh' comet that did not approach too closely to the Sun. Apart from characterising the surface of the nucleus and obtaining high resolution imagery of the landing site, it was hoped to obtain three types of sample: a 'core' drilled to a depth of at least one metre; a sealed sample of volatile, icy material; and a sample of non-volatile surface material. Stored at the same frigid temperatures experienced on the comet, the samples would be returned for comprehensive analysis in laboratories on Earth.

Artist's impression of the ESA-NASA Rosetta Comet Nucleus Sample Return spacecraft



By 1991, a joint ESA-NASA Rosetta Comet Nucleus Sample Return mission had been defined, with launch anticipated in December 2002. The spacecraft was to comprise three modules. A large NASA Mariner Mark II Cruiser would provide attitude control, navigation, power, propulsion and communications. Attached to the main bus would be a Lander, which was to carry a drill and surface sampling tool, and an Earth-Return Capsule. Once the samples were safely transferred to a container in the Capsule, the spacecraft would lift off, leaving the Lander behind on the comet. Two and a half years later, the Capsule would parachute into the ocean with its precious cargo, ready for collection by helicopter and ship.

A Revised Rosetta

Within two years, NASA's financial difficulties and resultant cutbacks in its space-science programme (notably the cancellation of the CRAF mission) forced ESA to reconsider its options for Rosetta. The prime consideration was to define a core mission that could be performed by ESA alone, using European technology – although the door was left open for other agencies to participate. The revised baseline mission that emerged involved a rendezvous with a comet and at least one asteroid flyby. It was hoped that a small Lander would be added as an additional experiment provided by one or more scientific institutions.

To all intents and purposes, that is the mission that has survived to the present. The Rosetta that will be launched towards Comet Wirtanen in January 2003 comprises two spacecraft: a 3 ton Orbiter, including 165 kg of scientific instruments, and a 100 kg Lander provided by a consortium including ESA and institutes from Austria, Finland, France, Germany, Hungary, Ireland, Italy and the United Kingdom, under the leadership of the German Space Agency (DLR).

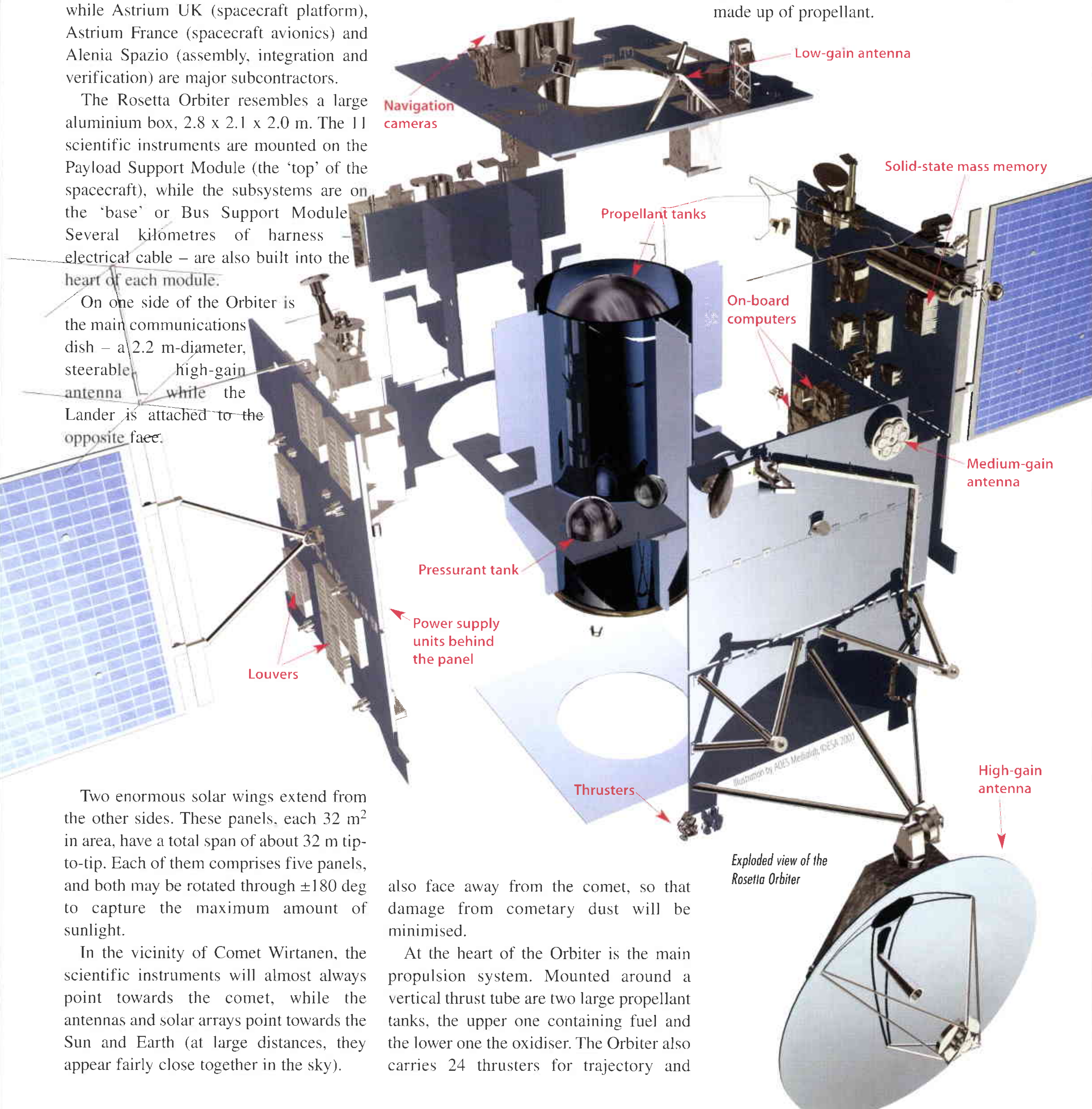
"That such a complex mission can be built in partnership and delivered on time is a great tribute to the management and cooperative spirit of industry, the scientists and the many agencies involved, as well as ESA's staff," says John Ellwood, Rosetta Project Manager.

Anatomy of a Spacecraft

Rosetta is truly an international enterprise, involving more than 50 industrial contractors from 14 European countries and the United States. The prime spacecraft contractor is Astrium Germany, while Astrium UK (spacecraft platform), Astrium France (spacecraft avionics) and Alenia Spazio (assembly, integration and verification) are major subcontractors.

The Rosetta Orbiter resembles a large aluminium box, 2.8 x 2.1 x 2.0 m. The 11 scientific instruments are mounted on the Payload Support Module (the 'top' of the spacecraft), while the subsystems are on the 'base' or Bus Support Module. Several kilometres of harness – electrical cable – are also built into the heart of each module.

On one side of the Orbiter is the main communications dish – a 2.2 m-diameter, steerable, high-gain antenna – while the Lander is attached to the opposite face.



Exploded view of the Rosetta Orbiter

Two enormous solar wings extend from the other sides. These panels, each 32 m^2 in area, have a total span of about 32 m tip-to-tip. Each of them comprises five panels, and both may be rotated through ±180 deg to capture the maximum amount of sunlight.

In the vicinity of Comet Wirtanen, the scientific instruments will almost always point towards the comet, while the antennas and solar arrays point towards the Sun and Earth (at large distances, they appear fairly close together in the sky).

By contrast, the Orbiter's side and back panels are in shade for most of the mission. Since these panels receive little sunlight, they are an ideal location for the spacecraft's radiators and louvers which regulate its internal temperature. They will also face away from the comet, so that damage from cometary dust will be minimised.

At the heart of the Orbiter is the main propulsion system. Mounted around a vertical thrust tube are two large propellant tanks, the upper one containing fuel and the lower one the oxidiser. The Orbiter also carries 24 thrusters for trajectory and attitude control. Each of these thrusters pushes the spacecraft with a force of 10 Newton, equivalent to that experienced by someone holding a bag of 10 apples. Over half the launch weight of the entire spacecraft – more than 1.7 tonnes – is made up of propellant.

1

OSIRIS (Optical, Spectroscopic, and Infrared Remote Imaging System): A Wide Angle Camera and a Narrow Angle Camera to obtain high-resolution images of the comet's nucleus and asteroids Siwa and Otawara.

2

ALICE (Ultraviolet Imaging Spectrometer): Analyses gases in the coma and tail and measures the comet's production rates of water and carbon monoxide/dioxide. Also provides information on the surface composition of the nucleus.

3

VIRTIS (Visible and Infrared Thermal Imaging Spectrometer): Maps and studies the nature of the solids and the temperature on the surface of the nucleus. Also identifies comet gases, characterises the physical conditions of the coma and helps to identify the best landing sites.

4

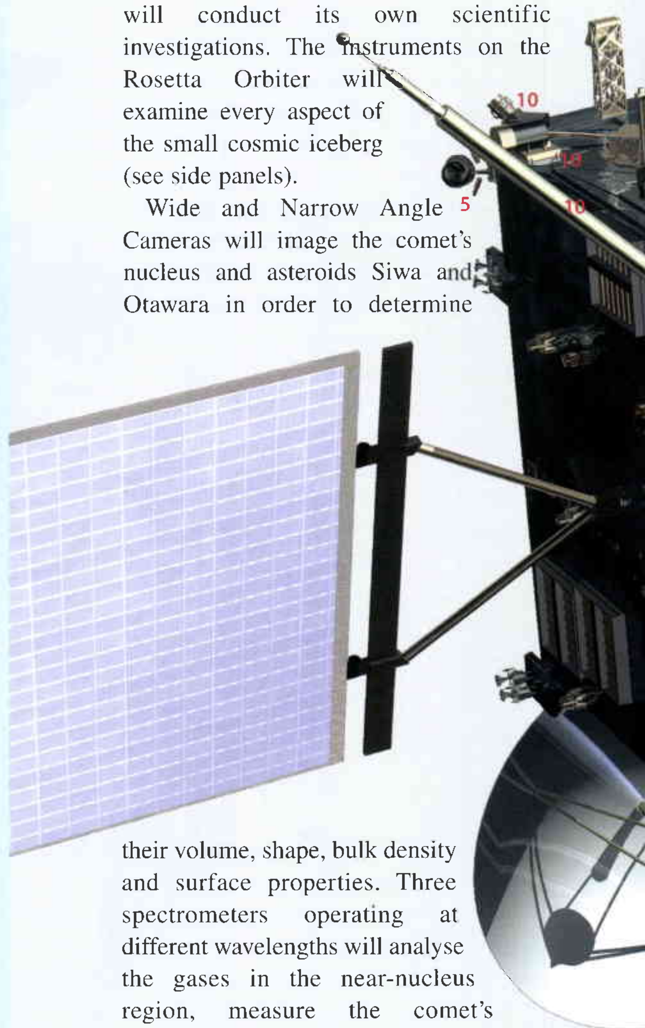
MIRO (Microwave Instrument for the Rosetta Orbiter): Used to determine the abundances of major gases, the surface outgassing rate and the nucleus subsurface temperature. It will also measure the sub-surface temperatures of Siwa and Otawara, and search for gas around them.

5

ROSINA (Rosetta Orbiter Spectrometer for Ion and Neutral Analysis): Two sensors will determine the composition of the comet's atmosphere and ionosphere, the velocities of electrified gas particles, and reactions in which they take part. It will also investigate possible asteroid outgassing.

The Rosetta Payload

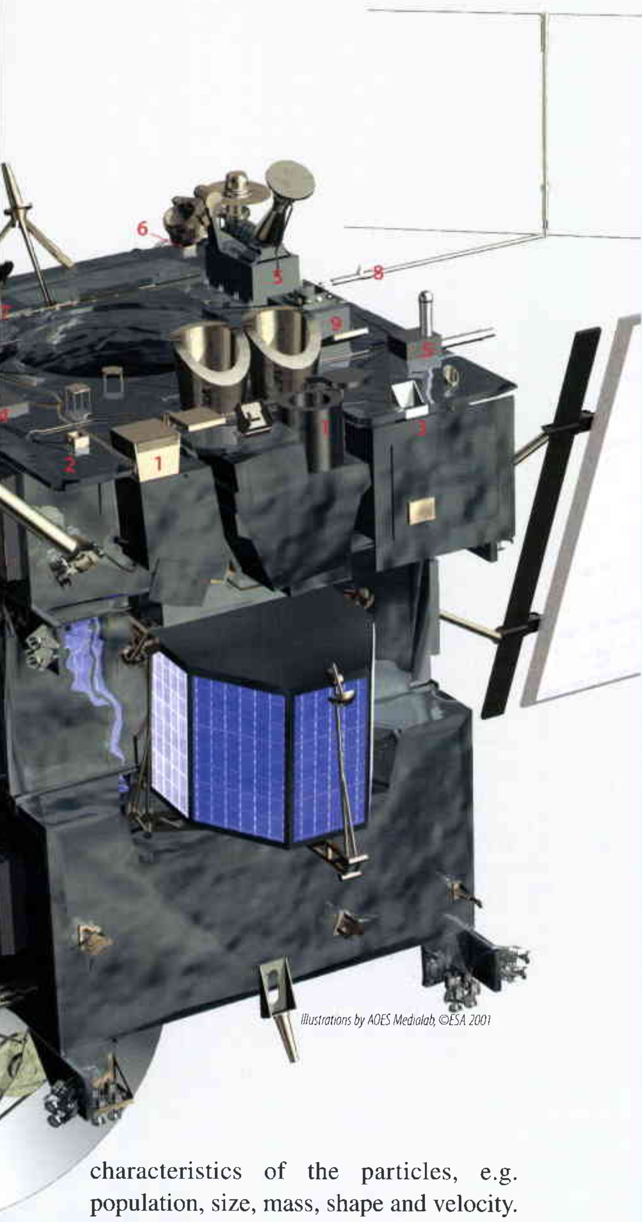
The Orbiter's scientific payload includes 11 experiments and a small Lander, which will conduct its own scientific investigations. The instruments on the Rosetta Orbiter will examine every aspect of the small cosmic iceberg (see side panels).



Wide and Narrow Angle Cameras will image the comet's nucleus and asteroids Siwa and Otawara in order to determine their volume, shape, bulk density and surface properties. Three spectrometers operating at different wavelengths will analyse the gases in the near-nucleus region, measure the comet's production rates of water and carbon monoxide/dioxide, and map the temperature and composition of the nucleus.

Our knowledge of the nucleus should be revolutionised by the CONSERT experiment, which will probe the comet's interior by transmitting and receiving radio waves that are reflected and scattered as they pass through the nucleus.

Four more instruments will examine the comet's dust and gas environment, measuring the composition and physical



Illustrations by AOES Medialab, ©ESA 2001

characteristics of the particles, e.g. population, size, mass, shape and velocity.

The comet's plasma environment and interaction with the electrically charged particles of the solar wind will be studied by the Rosetta Plasma Consortium and the Radio Science Investigation.

The 100 kg Rosetta Lander carries a further nine experiments, as well as a drilling system to take samples of sub-surface material. The Lander instruments are designed to study in situ for the first time the composition and structure of the surface and subsurface material on the nucleus.

COSIMA (Cometary Secondary Ion Mass Analyser): Will analyse the characteristics of dust grains emitted by the comet, including their composition and whether they are organic or inorganic.

MIDAS (Micro-Imaging Dust Analysis System): Studies the dust environment around the asteroids and comet. It provides information on particle population, size, volume and shape.

CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission): Probes the comet's interior by studying radio waves that are reflected and scattered by the nucleus.

GIADA (Grain Impact Analyser and Dust Accumulator): Measures the number, mass, momentum and velocity distribution of dust grains coming from the nucleus and from other directions (reflected by solar radiation pressure).

RPC (Rosetta Plasma Consortium): Five sensors measure the physical properties of the nucleus; examine the structure of the inner coma; monitor cometary activity; and study the comet's interaction with the solar wind.

RSI (Radio Science Investigation): Shifts in the spacecraft's radio signals are used to measure the mass, density and gravity of the nucleu; define the comet's orbit; and study the inner coma. Also be used to measure the mass and density of Siwa, and to study the solar corona during the periods when the spacecraft, as seen from Earth, is passing behind the Sun.

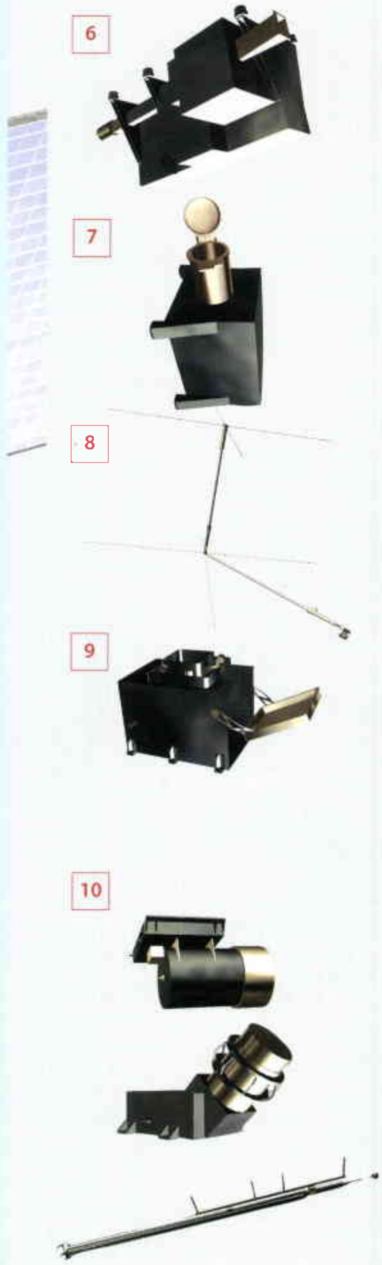


Illustration by AOES Medialab, ©ESA 2001

The Rosetta Lander

The box-shaped Lander piggybacks on the Orbiter until it arrives in close orbit around Comet Wirtanen. Once the 'mother craft' is aligned correctly, the ground commands the Lander to push off and unfold its three legs, ready for a gentle touch down at the end of the slow descent. On landing, the legs damp out most of the kinetic energy to reduce the chance of bouncing, and they can rotate, lift or tilt to return the Lander to an upright position.

Immediately after touchdown, a harpoon is fired to anchor the Lander to the ground and prevent it escaping from the comet's extremely weak gravity. The minimum mission target is 65 hours, but surface operations may continue for many months.

The Lander structure consists of a baseplate, an instrument platform, and a polygonal sandwich construction, all made of carbon fibre. Some of the instruments and subsystems are beneath a hood, which is covered with solar cells for power generation. An antenna transmits data from the surface to Earth via the Orbiter.

A Space Odyssey

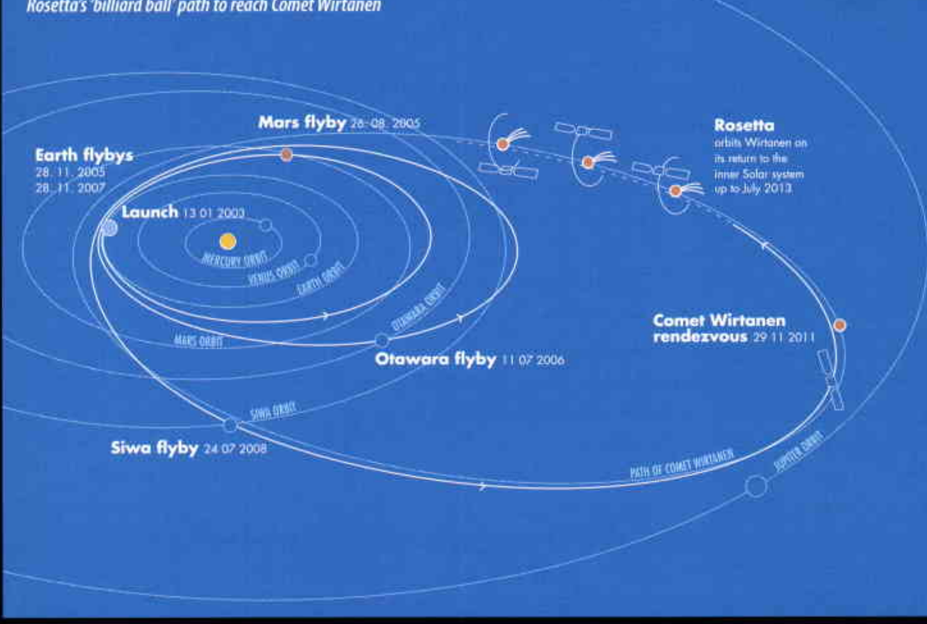
Although its cometary target has changed since Rosetta was first envisaged, the launch date has altered very little. Rosetta's 10-year odyssey will begin in January 2003, when an Ariane-5 launcher boosts the spacecraft into an elliptical (4000 km x 200 km) trajectory around the Earth. After about two hours, Ariane's upper stage re-ignites to send Rosetta on its way towards the asteroid belt.

The hardy spacecraft will then bounce around the inner Solar System like a cosmic billiard ball, circling the Sun almost four times during its eight-year trek to Comet Wirtanen. Along this roundabout route, Rosetta will enter the asteroid belt twice, enabling it to glimpse the ancient, battered surfaces of two contrasting rocky objects, Siwa and Otawara. It will also receive a boost in speed from gravitational 'kicks' provided by close flybys of Mars in 2005 and Earth in 2005 and 2007.

After a large deep-space manoeuvre, Rosetta will break the record for a solar cell-powered spacecraft as its elongated path carries it some 800 million km from the Sun. It will then be re-activated for the most difficult phase of the mission – the final rendezvous with the fast-moving comet.

Arriving in the comet's vicinity in November 2011, Rosetta's thrusters will brake the spacecraft so that it can match Comet Wirtanen's orbit. Over the next six months, it will edge closer to the black,

Rosetta's 'billiard ball' path to reach Comet Wirtanen



Rosetta Lander Scientific Experiments

COSAC (Cometary Sampling and Composition experiment): One of two evolved gas analysers, it detects and identifies complex organic molecules from their elemental and molecular composition.

MODULUS PTOLEMY: Another evolved gas analyser, which obtains accurate measurements of isotopic ratios of light elements.

MUPUS (Multi-Purpose Sensors for Surface and Subsurface Science): Uses sensors on the Lander's anchor, probe and exterior to measure the thermal and mechanical properties of the surface.

ROMAP (Rosetta Lander Magnetometer and Plasma Monitor): A magnetometer and plasma monitor study the local magnetic field and the comet/solar-wind interaction.

SESAME (Surface Electrical, Seismic and Acoustic Monitoring Experiments): Three instruments measure properties of the comet's outer layers. The Cometary Acoustic Sounding Surface Experiment measures the way in which sound travels through the surface. The Permittivity Probe investigates its electrical characteristics, and the Dust Impact Monitor measures the dust environment to the surface.

APXS (Alpha X-ray Spectrometer): Lowered to within 4 cm of the ground, it detects back-scattered alpha particles and alpha-induced X-rays, which provide information on the elemental composition of the comet's surface.

CONSERT (Comet Nucleus Sounding Experiment by Radiowave Transmission): Probes the internal structure of the nucleus. Radio waves from the CONSERT experiment on the Orbiter travel through the nucleus and are returned by a transponder on the Lander.

ÇIVA: Seven micro-cameras - six mono and one stereo pair - take panoramic pictures of the surface. A visible-light microscope and coupled infrared spectrometer studies the composition, texture and albedo (reflectivity) of samples collected from the surface.

ROLIS (Rosetta Lander Imaging System): A CCD camera to obtain high-resolution images during descent and of the nucleus surface below the Lander and of the areas sampled by other instruments.

SD2 (Sample and Distribution Device): Drills more than 20 cm into the surface, collects samples and delivers them to different ovens or for microscope inspection.

dormant nucleus until it is only a few dozen kilometres away. The first camera images will dramatically improve calculations of the comet's position and orbit, as well as its size, shape and rotation.

By the summer of 2012, Rosetta will enter orbit around the comet, sweeping to within a few kilometres of the coal-black surface. However, the almost imperceptible gravitational pull of the 'dirty snowball' will mean that Rosetta need only circle Wirtanen at a snail's pace – a few centimetres per second. With the alien landscape now looming large, the Orbiter's cameras will start to map the nucleus in great detail. Eventually, a number of potential landing sites will be selected for close observation.

Once a suitable site is chosen, the Lander will be released from a height of about 1 km. Touching down gently at walking speed – less than 1 metre per second – the ambassador from Earth will anchor itself to the nucleus before sending back high-resolution pictures and other information on the nature of the comet's ices and organic crust. Scientists back on the distant Earth will eagerly await the treasure trove of data from the pristine surface as it is relayed to ground stations via the Orbiter.

The way will then be clear for the exciting comet chase towards the Sun. Over a period of 12 months, the Orbiter will continue to orbit Wirtanen, observing the dramatic changes that take place as the icy nucleus begins to warm and vaporise during the headlong rush towards the Sun. The escort mission will end in July 2013, at the time of the comet's closest approach to the Sun (perihelion). More than 3800 days will have elapsed since Rosetta's dramatic space odyssey began.

"The Rosetta mission is something that we could only dream about 17 years ago, and now it is becoming an exciting reality", says Gerhard Schwehm, Rosetta Project Scientist.

Exploring A Cosmic Iceberg

"When beggars die, there are no comets seen:
The heavens themselves blaze forth the death of princes."

Shakespeare's Julius Caesar

For centuries, comets have inspired awe and wonder. Many ancient civilisations saw them as portents of death and disaster, omens of great social and political upheavals. Shrouded in thin, luminous veils with tails streaming behind them, these 'long-haired stars' were given the name 'comets' by the ancient Greeks (from the Greek word kome meaning 'hair').

Apart from their links to soothsaying and astrology, comets – particularly the very bright objects visible to the naked eye – have always been popular targets for all kinds of observations and speculation. Their sudden appearance and spectacular shape make them very appealing for amateur astronomers and photographers everywhere, and the 1997 apparition of Comet Hale-Bopp made headlines around

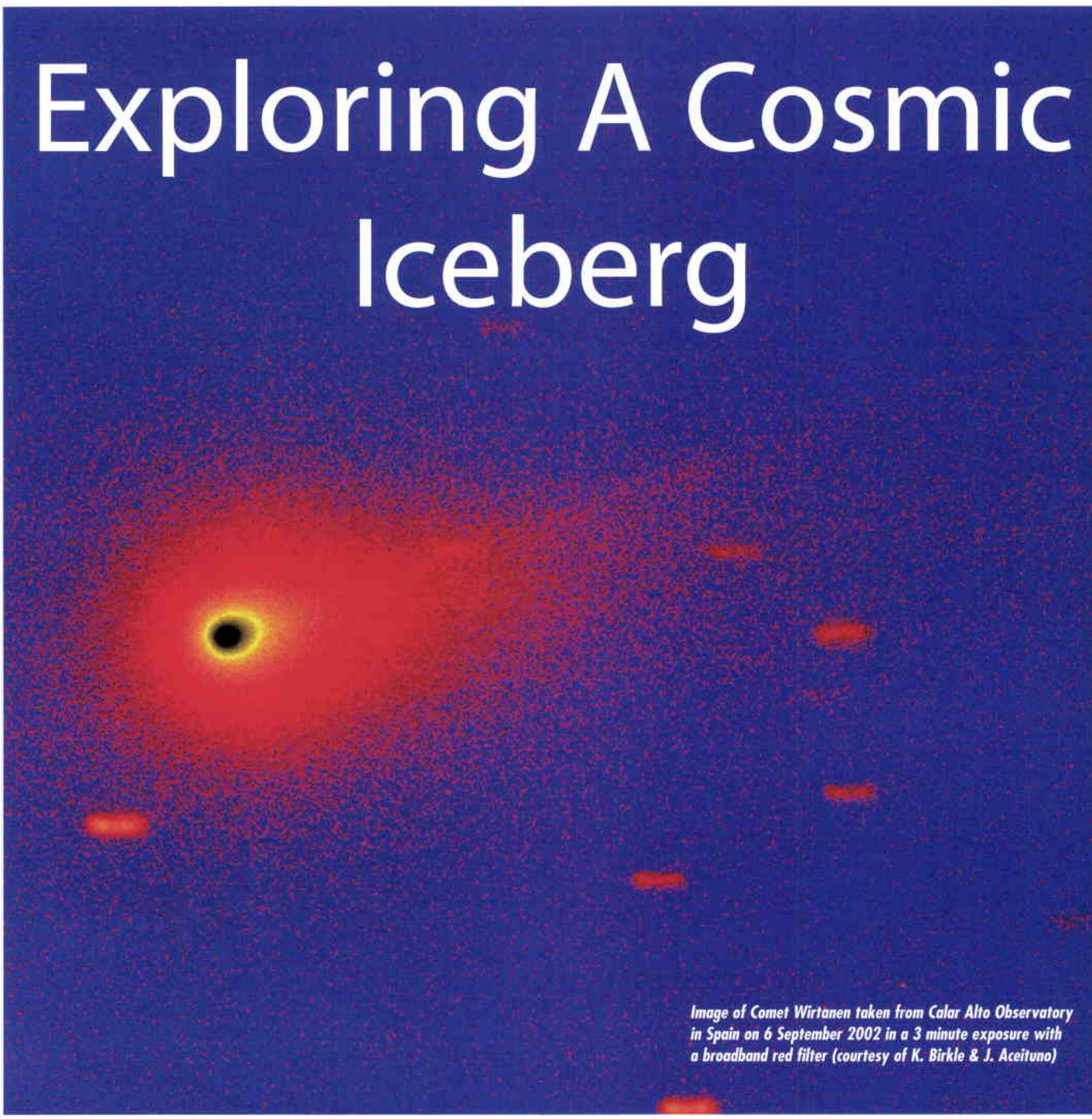


Image of Comet Wirtanen taken from Calar Alto Observatory in Spain on 6 September 2002 in a 3 minute exposure with a broadband red filter (courtesy of K. Birkle & J. Aceituno) the world. But why are scientists so keen to study these beautiful intruders into the inner Solar System?

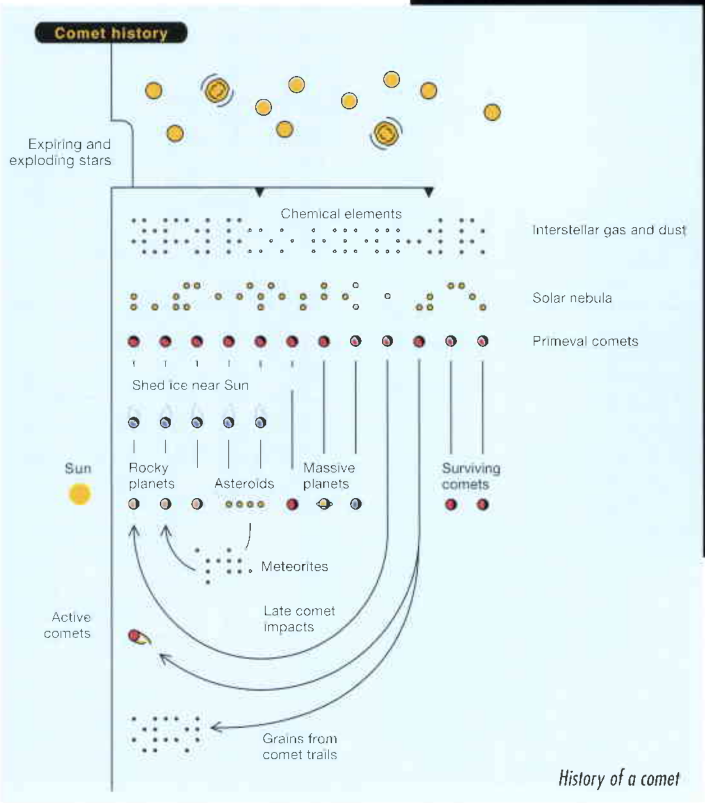
Planetary Building Blocks

Comets are small icy bodies, usually only a few kilometres across. Their basic ingredients are dust and frozen gases that were formed and preserved at very low temperatures in the vast, rotating cloud of material which surrounded the young Sun. Since they have not been altered by internal heating and spend most of their lives far from the Sun, these primitive bodies have changed little since their creation. Today we believe that comets represent the oldest building blocks of our Solar System, cosmic icebergs from which the planets were assembled some 4.6 billion (4 600 000 000) years ago.

In those violent times, many comets crashed into the infant planets. Craters caused by ancient comet and asteroid impacts can still be seen on the surfaces of the Moon, Mercury and many planetary satellites. Comets may also have provided much of the water that now forms Earth's oceans, and may even have delivered the complex organic chemicals that led to the first primitive life forms.

By learning more about individual comets, scientists also hope to get a broader understanding of the formation and evolution of our Solar System as a

Hubble Space Telescope time-lapse composite image of Comet Shoemaker-Levy approaching the planet Jupiter in 1994



History of a comet

whole. Like detectives trying to gather clues about a case, they need to obtain detailed information about the physical and chemical properties of comets in order to discover what the interplanetary environment was like when the planets were born. Unfortunately, this is far from easy since most of the comets have been hurled into the outer parts of the Solar System by gravitational interactions with the giant outer planets. As a result, only the modest number of comets deflected towards the Sun become accessible to our scrutiny.

Dirty Snowballs

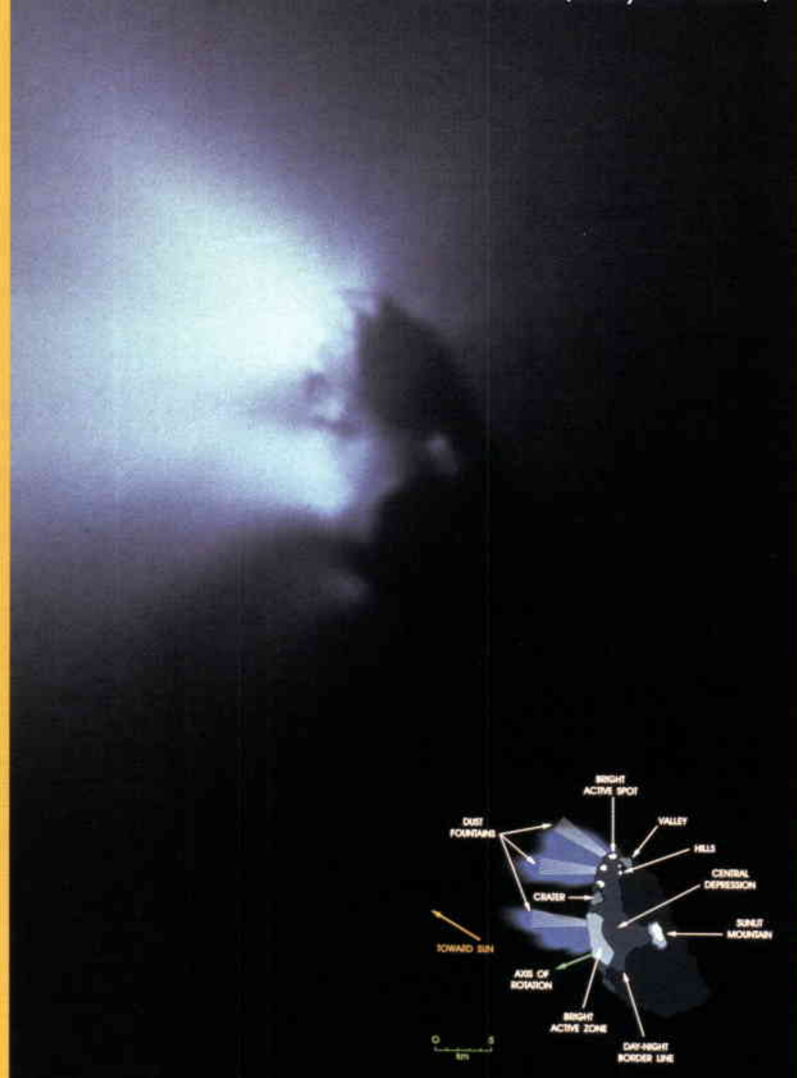
Until the 1986 flyby missions to Comet Halley, no one knew what a comet nucleus was really like. The icy heart of a comet is so small that it is almost impossible to see and analyse from Earth. As soon as the nucleus moves close enough to us for detailed observation, it is obscured from view by the coma, an all-enveloping shroud of gas and dust. When it is inactive, and not hidden by the coma, it is too far away to be resolved by even the best telescopes and too faint to allow detailed spectroscopic analysis of its surface material.

The most popular theory about the nature of comets was put forward by American astronomer Fred Whipple, often known as the 'grandfather' of modern cometary science. Whipple believed they were like dirty snowballs – large chunks of water ice and dust mixed with ammonia, methane and carbon dioxide. As the snowball approached the Sun, its outer ices began to vaporise, releasing large amounts of dust and gas, which spread through space to form the characteristic tails.

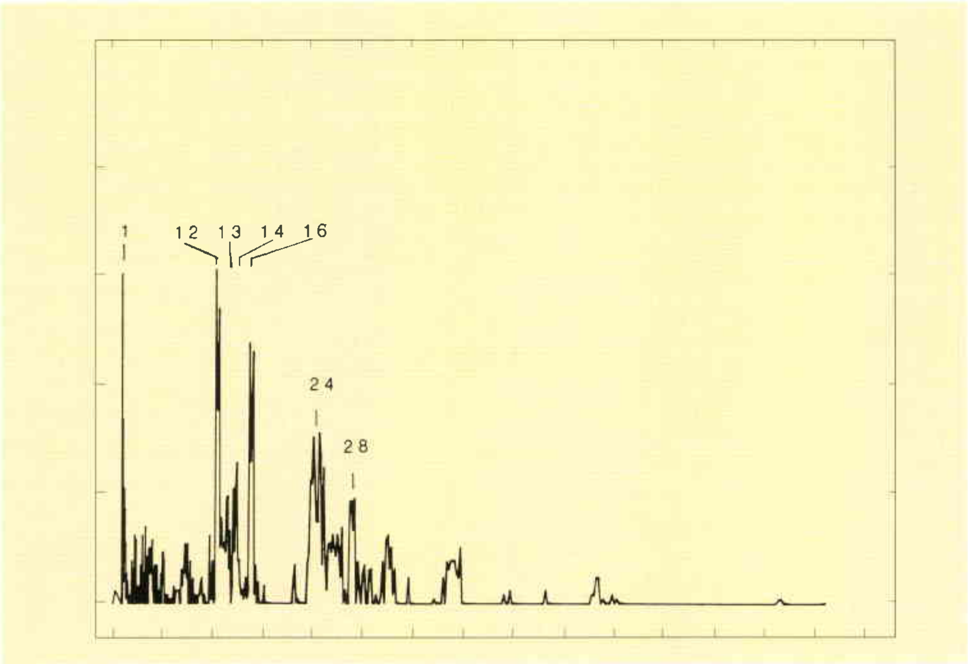
Today, largely thanks to data from ESA's Giotto and two Russian Vega spacecraft, along with the recent encounter by NASA's Deep Space 1, we now know that Whipple's model was fairly accurate. Giotto's pictures provided the final proof that Comet Halley resembles a lumpy, peanut-shaped body, about 15 km long and 7–10 km wide. The 'dirty snowball' was indeed very dark in appearance – blacker than coal. The images also showed at least seven jets of vaporised ice and dust spurting through vents in the surface material that coated the nucleus – convincing evidence to support the concept that cometary activity is confined to a small number of localised active areas on the rotating nucleus.

Analysis of the material released when Halley's nucleus was exposed to the Sun led to major progress in the understanding of the comet's composition. New insights were provided into the physical and chemical processes taking place in the inner coma, and the way in which the comet interacted with the electrified particles of the solar wind.

Simple organic (carbon-rich) molecules, such as formaldehyde and methanol, were also detected for the first time. A major surprise was the discovery of a new class of minuscule particles, each less than a millionth of a metre across – too small to be detectable by remote-sensing techniques. These were dubbed 'CHON' particles because they were rich in the light elements carbon, hydrogen, oxygen and nitrogen.



Giotto Halley Multicolour Camera (HMC) image of Comet Halley with, inset, a sketch of its main features (courtesy of MPAe Lindau)



Mass spectrum of a cometary 'CHON' particle recorded in 1986 by the Soviet Vega-1 spacecraft's dust-impact analyzer. The numbers are Atomic Mass Units (AMU)

Breakthroughs with Rosetta

The images and other data returned during these short-lived flybys have improved our knowledge of comets tremendously. However, despite such significant advances, scientists want to learn more about these fleeting visitors to the inner Solar System. Further studies are important in order to answer these key questions. What role, if any, did comets play in the evolution of life? How and why does a comet change during repeated approaches to the Sun? What lies at the heart of the nucleus, beneath its mysterious black blanket? Questions such as these can only be answered by Rosetta, the most sophisticated spacecraft ever to investigate a 'long-haired star'.

Rosetta will not just cast a cursory glance at its target, Comet Wirtanen, but it will provide the first intimate look at one of these intriguing objects. The investigation will begin while the intruder is still in deep space, 650 million km from the Sun. As it accompanies the comet on its headlong charge towards the Sun at speeds of up to 135 000 km/h, instruments on the Orbiter will determine the basic properties of the frozen, inactive nucleus, measuring its size, shape, mass and density.

After the Rosetta Orbiter has moved to within a few kilometres of the pristine surface, the entire nucleus will be surveyed at wavelengths covering almost the entire electromagnetic spectrum. Close-range images taken in visible light will be combined to map every bump and surface crack in the alien landscape down to a resolution of just a few centimetres. Parallel mapping from infrared to millimetre wavelengths will measure the corresponding surface temperatures, identify individual icy and mineralogical components and determine their distribution on the surface.

This will only be the beginning. As the nucleus is heated, the frozen volatiles (gases) start to vaporise and the dust is released, Rosetta will become the first spacecraft to witness how a dormant nucleus begins to stir into activity and evolve.

Over a full year, the Orbiter will observe from close range the extraordinary metamorphosis that takes place in the nucleus and its surrounding coma, providing the long-awaited information needed to understand the physical and chemical processes causing this phenomenon. Will the material be smoothly released from the entire heated area through micropores, or will the surface be cracked open at certain areas to release the material underneath? Nobody yet knows, but Rosetta will be on station to solve the mystery.

As soon as the nucleus becomes active, the Rosetta Orbiter will start to analyse the material that is released. The comet watch will continue as Wirtanen accelerates towards the inner Solar System and activity on the nucleus becomes ever more frenetic. Instruments will measure the elemental, molecular and isotopic composition of the gas and dust, along with the dust size distribution. Individual dust particles will also be collected and scanned by an atomic force microscope with an imaging resolution of a millionth of a millimetre.

From all of these studies, scientists will discover how the level of comet activity influences the properties of the material it spews into space. The interaction of the comet with the interplanetary magnetic field and the particles of the solar wind will complete the monitoring of the comet's evolution. Only when Wirtanen reaches perihelion, the closest point in its orbit to the Sun, will Rosetta's remarkable mission be terminated.

Rosetta Lander Science

By making the first soft landing on a comet, the Rosetta Lander will be able to conduct unique investigations into what the nucleus of Comet Wirtanen is made of. Equipped with 9 scientific experiments, the box-shaped spacecraft is dedicated to studies of the physical properties and the composition of the nucleus. All of the instruments will take at least one contingency measurement immediately after landing, and then continue to follow the evolution of the nucleus at it approaches the Sun. These in situ investigations will provide unprecedented knowledge of the comet's icy heart.

Samples of material will be obtained, not only from the surface but also to a depth of 20 cm, using a special sample drilling and handling device. The samples will then be imaged in visible and near-infrared light, and analysed in detail to discover their elemental, isotopic, molecular and mineralogical composition.

Panoramic and close-up images of the surface around and beneath the Lander will give Earthlings their first views of the alien, hostile landscape. The physical properties of the strange, black surface material, the local magnetic field and the comet/solar wind interaction will also be studied. Meanwhile, the CONSERT instrument (half of which is on the Lander and half on the Orbiter) will sound the interior of the 1.1 km-wide nucleus, rather like a physician using ultrasound to study an unborn child in its mother's womb.

Asteroid Science

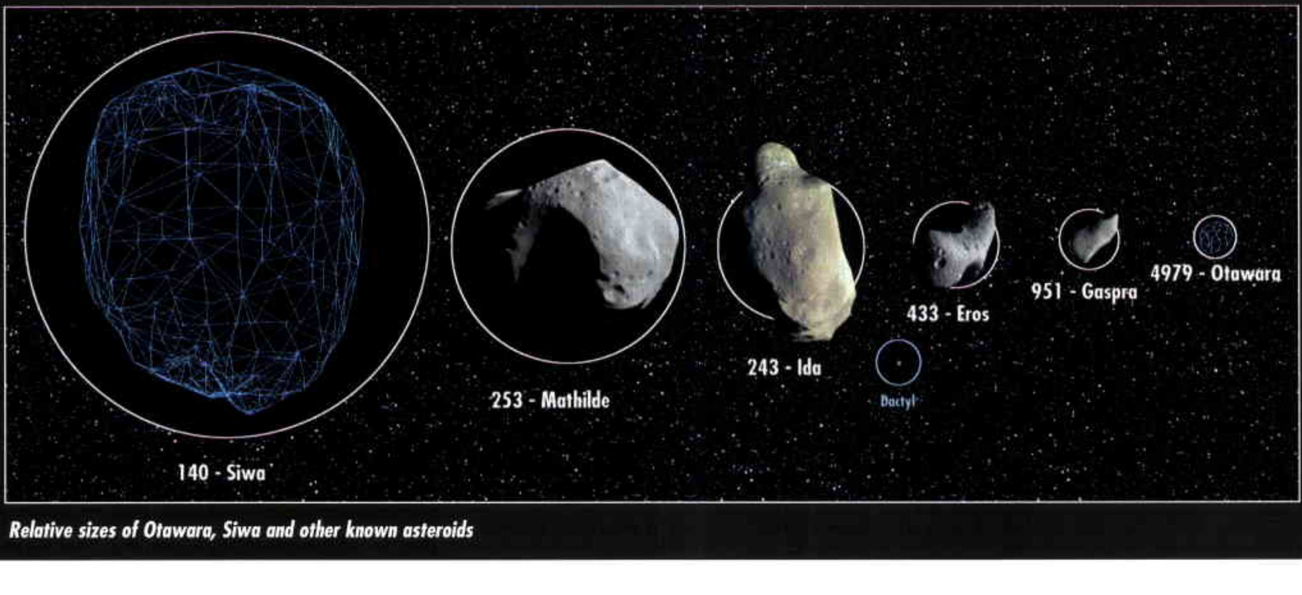

Comet 140 Siwa

On the outward leg of its eight-year trek to Comet Wirtanen, Rosetta will make two excursions into the main asteroid belt between the orbits of Mars and Jupiter. This will enable the spacecraft to encounter two contrasting asteroids, 4979 Otawara in July 2006 and 140 Siwa in July 2008. These primordial, rocky worlds – leftovers from the formation of the planets – have been selected after careful evaluation of the scientific significance of the reachable targets combined with an assessment of the spacecraft's fuel budget.

Siwa, a C-type (carbon-rich) asteroid, is particularly interesting. Unlike the more common S-type, the C-type asteroids are believed to have undergone little or no heating, so they are considered to be unaltered, volatile-rich bodies, darkened by opaque organic material. The meteorite analogues of these primitive asteroids are carbonaceous chondrites. Approximately 110 km in diameter, Siwa will be the largest asteroid ever studied during a spacecraft flyby.

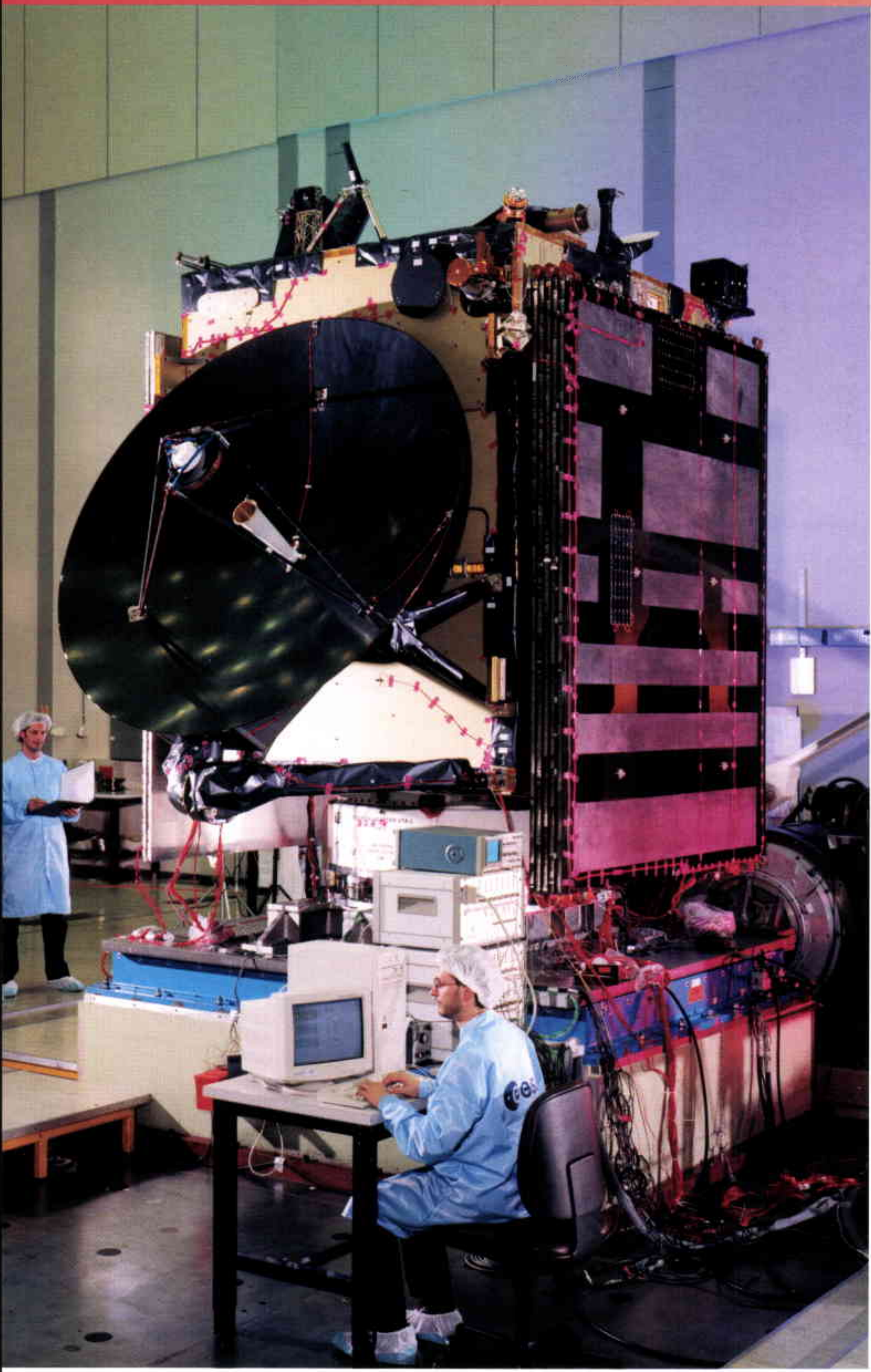
Once Siwa was identified as the prime target, subsequent mission analysis showed that Rosetta's fuel budget would also allow a visit to Otawara, a 4-km-wide S-type asteroid. Otawara rotates faster (about once every three hours) than any asteroid so far visited by a spacecraft and so Rosetta should be able to image most of its surface during the fly past.

A multi-wavelength study will be performed of both asteroid targets. Apart from their basic characteristics such as size, shape and mass, the measurements will allow scientists to discover the mineralogical composition of their surfaces and to search for frozen volatiles, particularly water ice. Very sensitive sensors, designed to analyse the gas and dust in the coma of Comet Wirtanen, will also be switched on to search for evidence of any very sparse comas surrounding the asteroids, particularly the much larger Siwa.



Relative sizes of Otawara, Siwa and other known asteroids

A Race Against Time



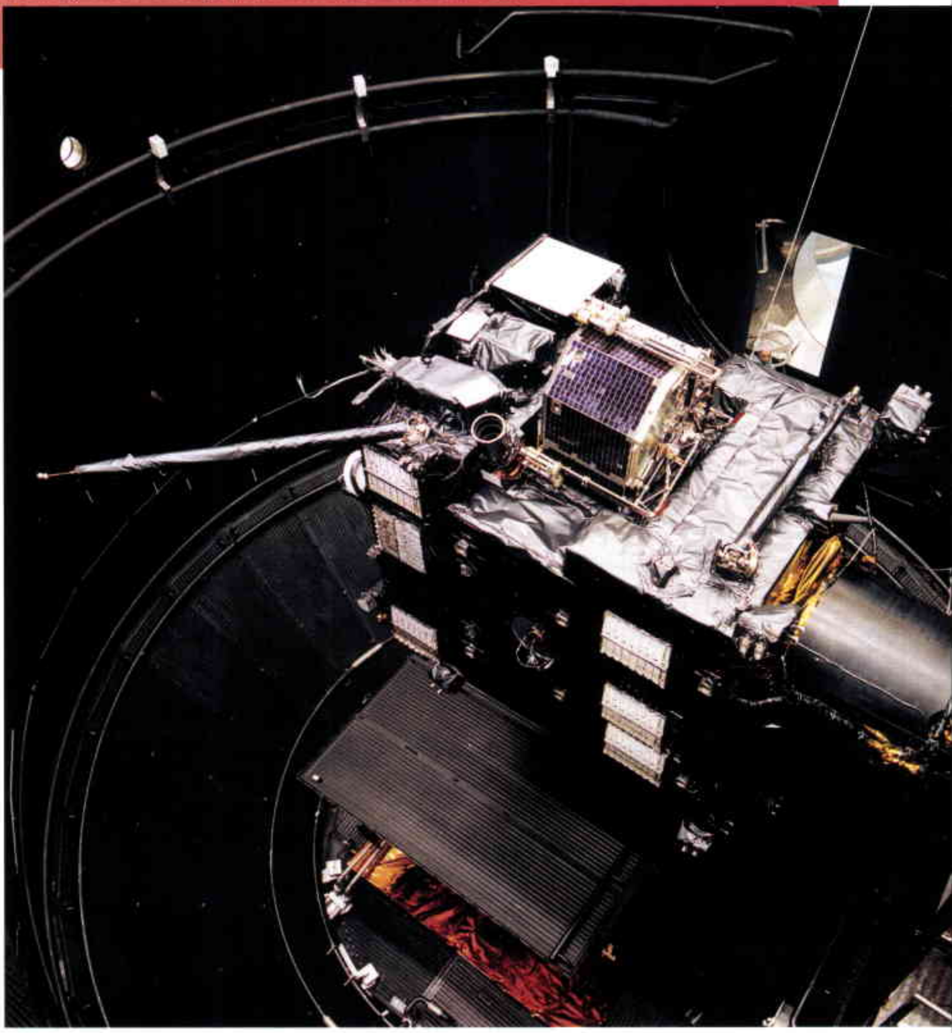
The International Rosetta Mission was approved as a Cornerstone mission within ESA's Horizon 2000 Science Programme in November 1993. Even at this early stage, it was envisaged that the ambitious mission would be scheduled for launch in the 2003 timeframe and a number of comet-rendezvous opportunities were identified. Although the original target, Comet Schwassman Wachmann 3, has since been superseded by another periodic intruder into the inner Solar System, Comet Wirtanen, there has been little shift in the original launch schedule. Rosetta is now set for lift-off from Kourou on the night of 12-13 January 2003.

Ever since the mission was accepted and given a slot in the long-term Horizons 2000 programme, the teams of ESA engineers and scientists have been engaged in a race against time. Once the design and specifications of the spacecraft and its payload were fixed in 1998, just four years remained for the Assembly, Integration and Verification phase.

Following the conventional spacecraft development philosophy, the Rosetta project team and its industrial partners were first required to build a Structural and Thermal Model in order to evaluate the design and thermal characteristics of the satellite. This was to be followed about seven months later by the delivery of an Engineering and Qualification Model that would be used to demonstrate that Rosetta's electrical and other subsystems would operate correctly in the extreme environment of deep space. Only then would the Flight Model be assembled and put through a final series of exhaustive tests that would check out overall performance and flight readiness.

Rosetta Structural and Thermal Model undergoing vibration testing at ESTEC in January 2001

Rosetta Flight Model in the Large Space Simulator (LSS) at ESTEC in March 2002



Meanwhile, teams from many countries were also required to deliver a Structural and Thermal Model, an Engineering and Qualification Model and a Flight Model of each of their instruments that would be used to survey the comet. With a three-month launch campaign scheduled to begin in early September, there was no time to pause for breath and 24-hour shifts became commonplace for the engineers and scientists who endeavoured to ensure that Rosetta would leave the pad on time.

"The heavens have their own timetable and the comet won't wait for us if we're late," said John Ellwood, Rosetta Project Manager.

The Flying Italian

Preparing a 3 tonne spacecraft for a series of endurance tests is far from easy. Before the thermal vacuum checks could take place, intrepid Alenia Spazio engineer Natalino Zampirolo was required to imitate an acrobat on a high wire. Suspended from an electric hoist, the engineer was required to 'fly' alongside the spacecraft at a height of 5 metres above the floor of the giant test chamber.

Dangling next to the Rosetta orbiter, Zampirolo gingerly removed the 'red tag' items – protective covers, arming plugs on the explosive connectors etc. – that were fitted as a safety precaution during normal work on the spacecraft. With his task successfully accomplished, the flying Italian was relieved to retreat to safety, leaving the spacecraft armed and ready to start its thermal trial.

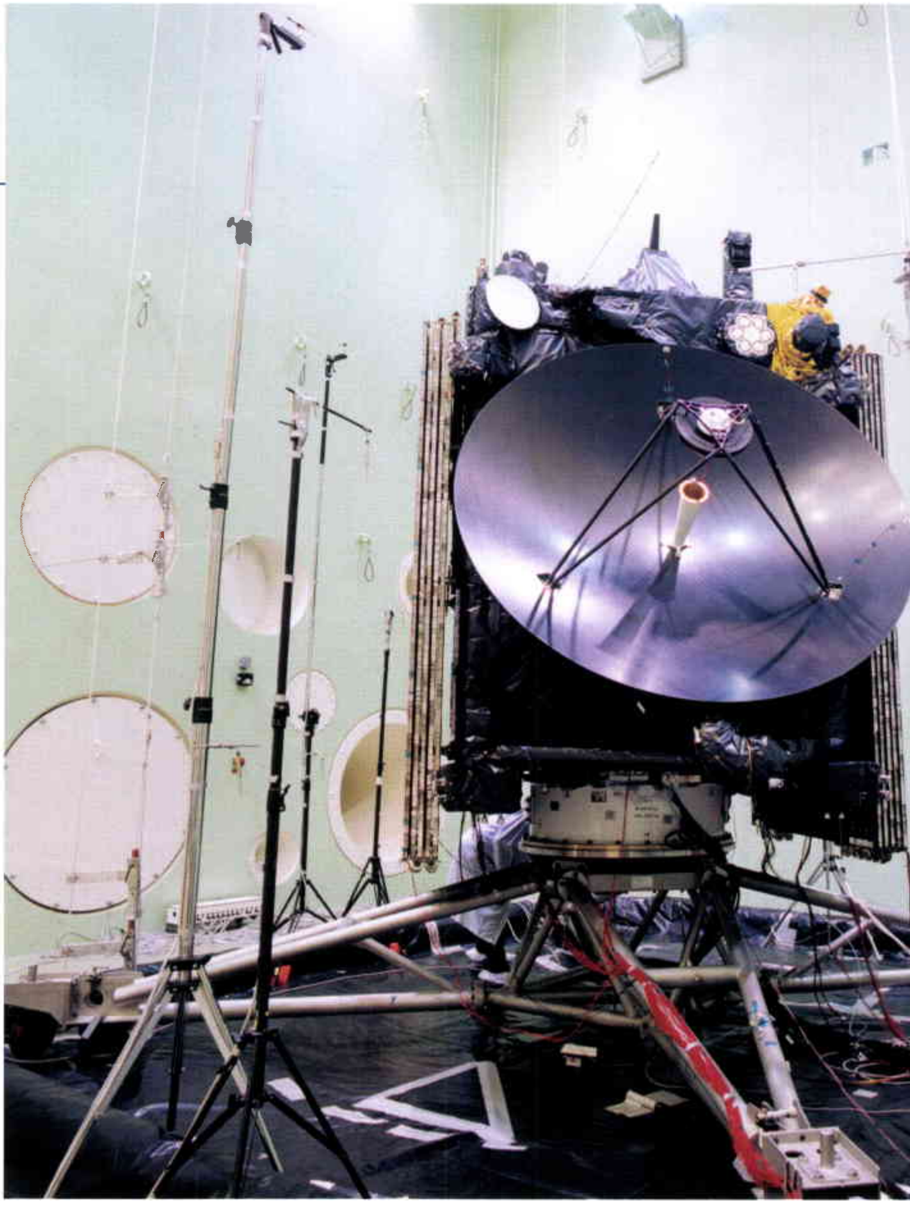
Rosetta Runs Hot and Cold

One of the key stages in the test programme was to establish whether Rosetta could maintain reasonable working temperatures throughout its circuitous trek to the orbit of Jupiter and back. In order to check the efficiency of Rosetta's thermal-control system, engineers at the European Space Research and Technology Centre (ESTEC) in the Netherlands placed the spacecraft in a thermal-vacuum chamber where the wildly fluctuating temperatures that Rosetta will experience could be replicated.

Imprisoned in the giant airless chamber, the Rosetta Orbiter, the Lander and their complement of 20 scientific instruments were alternately baked and frozen. In order to simulate the warmth of the inner Solar System, the exterior of the spacecraft was heated to a sizzling 150°C by a solar simulator comprised of 12 lamps each radiating 25 kW. During subsequent tests, liquid nitrogen was pumped through pipes in the chamber, causing the temperature inside to plummet to -180°C.

Sensors indicated that the spacecraft's insulation and heat control systems enabled Rosetta to survive these thermal tortures in fine shape, with internal temperatures restricted to between 40°C and -10°C. ESTEC engineers confidently predicted that, with the aid of its radiators and reflective louvers, Rosetta will be the 'coolest spacecraft' around.

"These tests show that Rosetta can survive the tremendous temperature contrasts it will endure as it flies from the vicinity of the Sun to the orbit of Jupiter," says Claude Berner, Payload and Operations Manager. "This gives us great confidence that the spacecraft will be able to survive its long exposure to the harsh environment of space."



Rosetta Breaks the Sound Barrier

Even before Rosetta has left the planet, the spacecraft has managed to break the sound barrier. In April 2002, the Flight Model was removed from the thermal vacuum chamber and prepared for the next stage of its pre-launch punishment. Once the high-gain antenna and huge solar arrays were mounted, the Orbiter was subjected to a series of deafening vibration tests in order to check whether it can survive the stresses it will experience during launch.

"The spacecraft was powered on, while the Lander, the high-gain antenna and the solar arrays were all in launch configuration," explained Claude Berner. "Even the propellant tanks were filled with 'dummy fuel'."

Placed in a giant acoustic/vibration chamber, a barrage of sound was directed at Rosetta from a huge amplifier in order to simulate the noise expected during lift-off. Soaring to a maximum of 135 decibels – ten times louder than Concorde at take-off – the sound levels were so severe that anyone straying into the chamber would have been killed within seconds.

Following these not-so-good vibrations, Rosetta returned to the clean room to complete a rock-and-roll ride on a giant shaker in order to simulate its ride into orbit aboard an Ariane-5 rocket. Attached to a table capable of moving the 3 tonne spacecraft from side to side like a metallic toy being mauled by a mastiff, Rosetta was severely shaken, first horizontally and then vertically, over a wide range of frequencies. Several hundred accelerometers on the structure were used to monitor the spacecraft's performance during each three-minute simulation. The results confirmed that the launch by the powerful Ariane-5 would leave Rosetta shaken but not stirred.

Solar Wings

Once the engineers at ESTEC had verified that all of the spacecraft's electronics had survived intact, it was time to check whether the pair of 14 m-long solar arrays and the delicate instrument booms had survived their potentially shattering ordeal.

Most critical of all were the deployment tests on the two giant 'wings' that will power Rosetta throughout its 10-year mission to deep space and back. These arrays, stretching one and a half times the length of a tennis court, must gently unfold to expose the special silicon cells that will generate electricity for the spacecraft to sunlight.

The 'minus-y' array, located to the left of the dish-shaped high-gain antenna, was the first to be unfolded. This was followed a day later by deployment of the 'plus-y' array on the opposite side of the spacecraft. Held in place by six Kevlar cables that will embrace the arrays during launch, each solar array was released after commands sent via the spacecraft activated the deployment sequence. 'Thermal knives' then severed each cable in turn by heating it to a temperature of several hundred degrees Celsius.

After the sixth cable was cut, the array began to unfold like a giant accordion. Attached to a huge, specially developed, deployment rig, the five panels in each array were gradually extended to their full

Rosetta Flight Model in the Acoustic Chamber at ESTEC

length across the clean room. To simulate the zero-gravity conditions of outer space, the weight of the arrays was counterbalanced by a mass-compensation device equipped with dozens of springs.

"Both tests went very well and there was a big round of applause when they were successfully completed," said Walter Pinter-Krainer, Principal AIV Systems Engineer for Rosetta.

Checking the Booms

Confident that their spacecraft's powerhouse would deploy properly after launch, the engineers went on to check out Rosetta's other movable parts. First came a partial deployment of the orbiter's 2.2 m-diameter high-gain antenna, when three pyros (explosive charges) were fired to release the dish from its stowed launch position.

The engineers also had to retreat to the safety of an observation area in the clean room for the firing of more pyros during the deployment of the upper and lower experiment booms on the Orbiter. Each 2 m-long boom carries probes and other equipment that will investigate the magnetic field and particle environment around Comet Wirtanen.

The fifth and final deployment test involved the release of a wire antenna to be used by the CONSERT experiment. After another explosive charge was fired, this unusual, H-shaped aerial was gently unfolded, suspended beneath five helium balloons to simulate the weightlessness of space.

The CONSERT experiment unfolded

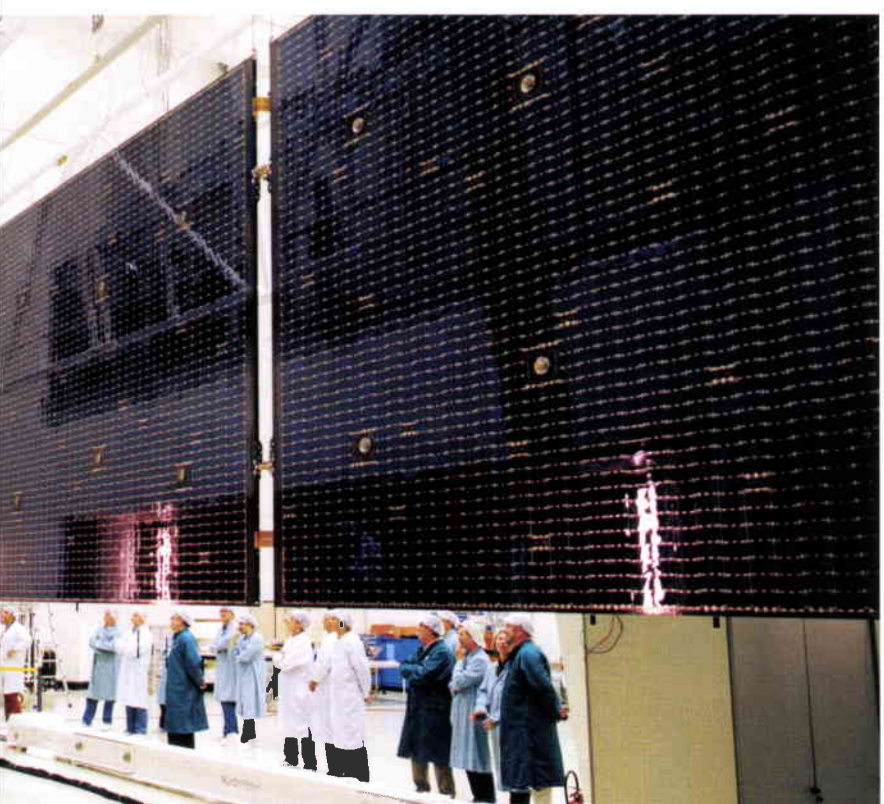
"Once again, the trial was completed without a hitch," announced a proud Marc Schwetterle, one of the payload engineers responsible for the tests.

"All of the deployment tests were very successful," commented Walter Pinter-Krainer. "These were crucial moments in our test programme and we were very happy to see everything working so well."

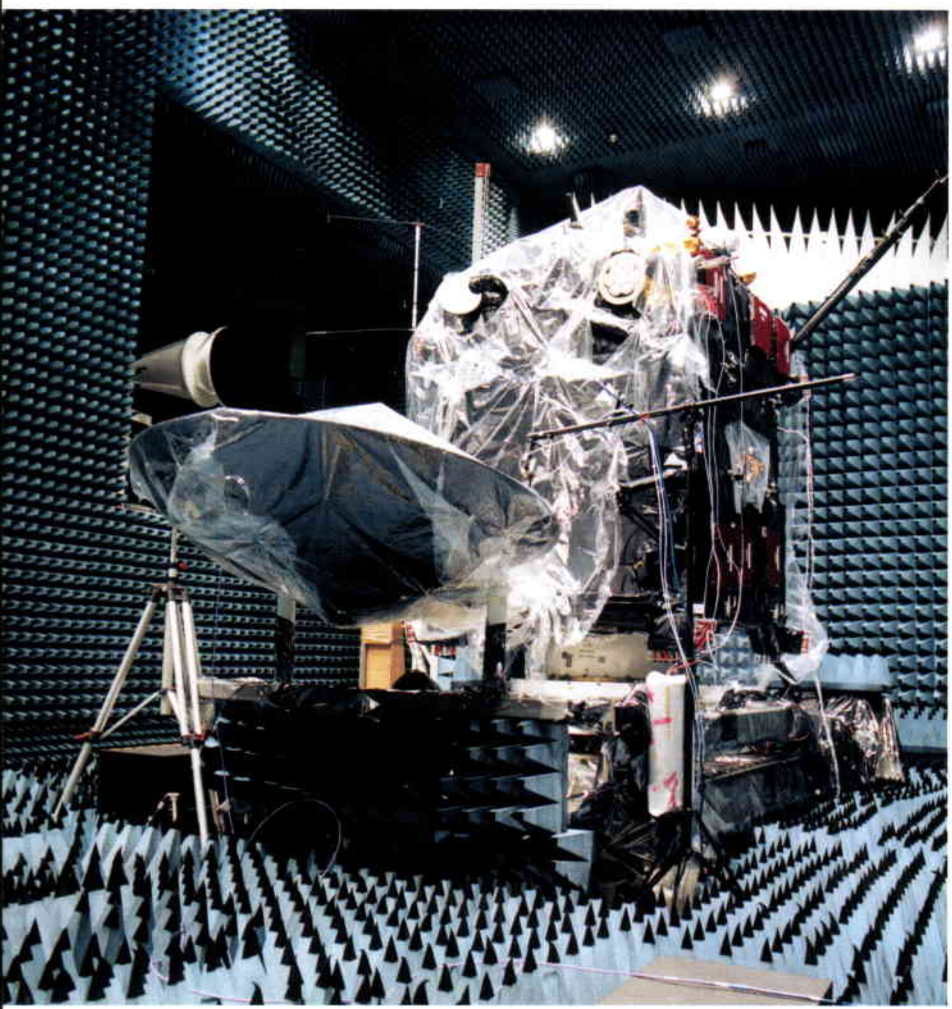
Rosetta Cleared of Interference

The hectic schedule continued in June when Rosetta was moved into another large test chamber at ESTEC, known as the Compact Test Range, where it was subjected to an extensive electromagnetic-compatibility (EMC) check.

In order to simulate the EMC environment during its long trek through deep space, Rosetta was placed inside a



Unfurling of the spacecraft's solar array



A 'cocooned' Rosetta Flight Model in the Compact Test Range facility at ESTEC

chamber lined with cones that absorb radio signals and prevent reflections. To avoid TV or radio interference, the chamber walls form a steel 'Faraday cage', impenetrable to electromagnetic signals from the outside world. In this radiation-free environment, the ESTEC team was able to study the radio signals and electrical noise coming from the various systems on the spacecraft and to check whether they caused any electromagnetic interference with each other.

"Before a satellite is launched it is essential to ensure that the electrical and electronic equipment within a spacecraft functions correctly," explains Flemming Pedersen, a senior AIV engineer for Rosetta. "For example, it could be fatal if, when switching on one unit, other instruments or systems such as the telecommunication link, were disturbed or even disrupted."

Like some alien creation, the spacecraft was cocooned in protective plastic foil while the engineers and scientists painstakingly prepared to switch on Rosetta's systems and payloads. At first, the see-through wrapping proved to be too tight, causing the spacecraft's temperature to rise. Once this was remedied and the staff vacated the chamber, all was set to simulate the various phases of Rosetta's 10-year mission.

"For some of the time we were measuring the energy emitted by the spacecraft's high-gain antenna, and this is hazardous, so the chamber was completely closed and everyone had to remain outside it whilst the measurements were made," said Flemming Pedersen. "It would be like exposing the engineers to the radiation from thousands of mobile phones simultaneously."

The first series of tests studied how the spacecraft behaved in 'launch mode'. At this time Rosetta was in its launch configuration, with a minimum of systems active while awaiting the lift-off of the Ariane-5 rocket. This was to ensure that signals from the spacecraft would not interfere with communications between the rocket and ground control during the launch phase.

Subsequent EMC tests took place when the spacecraft was at various levels of activity – from quiet periods when no science payloads were operating, to spells of hectic scientific investigation.

"We could switch on each instrument individually and measure the electromagnetic waves coming from it," explains Bodo Gramkow, Principal Payload engineer and EMC expert. "The rest of the instruments were put into listening mode to see if any of them detected any disturbance."

"On other occasions we switched on all of the instruments, including those on the Lander, in order to see whether we got any unexpected 'noise' or interference," he says. "From this we could determine whether we will need to switch a particular instrument off when we are making a very sensitive measurement with another one."

"All of the EMC tests proved to be very successful," says Bodo Gramkow. "This was the last of the three big system-validation tests and Rosetta passed with flying colours."

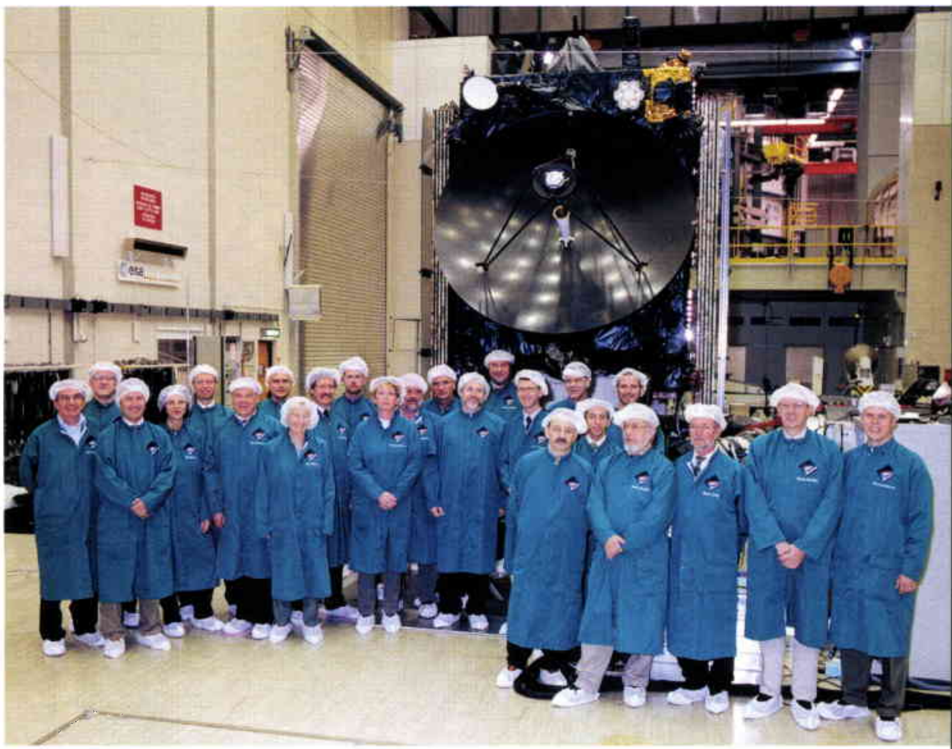
Ironing-out the 'Bugs' (from the Pilot's Seat)

One key question that needs answering with confidence is: "Will Rosetta fly?" If the onboard computers are receiving all the right signals to convince them that the spacecraft is flying, will they react correctly? That question was asked and answered several times throughout 2002 in the form of an extensive set of Mission Simulation Tests.

It's 6 a.m. and a new shift starts. Into the control room come the software experts and they take up their positions in front of large, crowded, computer screens. Two sets of computers are synchronised: one set, on the ground, simulating a 'real-space' environment for their counterparts onboard. The ground equipment feeds the Spacecraft Star Tracker with a simulated star-field image, and the onboard computers react and command a small attitude change for the spacecraft body.

Standing in the clean room and watching from the outside, nothing changes, but on the inside, from the perspective of the many onboard computers .... Yes! Rosetta is flying! So it goes on. For each mission phase the spacecraft computers are put through their paces.

"The functional testing of such a complex spacecraft as Rosetta should not be underestimated," says Mark Nesbit, the ESA engineer responsible for defining much of the functional test programme. "We test the spacecraft system in many closed-loop simulations, with the full scientific payload on-line, performing comet observations just as it will during the actual mission."



The Rosetta Team, with the Flight Model spacecraft in the background

"But for Rosetta," Mark continues, "we have to go a few steps further and we give the onboard computers a hard time. We feed them with unexpected situations, where the onboard autonomy has to take over and automatically recover the spacecraft into a safe mode. The variety in the mission profile and the long periods without ground contact mean that Rosetta has to be able to take care of itself, and on the ground we have to convince ourselves that it can."

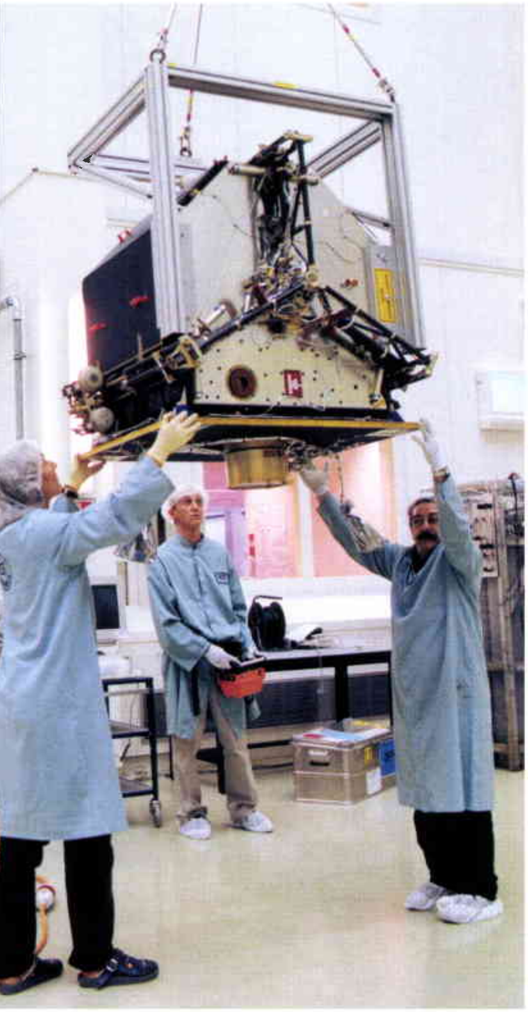
The Trip to the Tropics

With the completion of the AIV programme, the final leg of Rosetta's race to the launch pad could get under way. It was time to transport ESA's comet chaser to the Kourou spaceport on the other side of the world. First to be packed was the ground-support equipment, which was loaded onto transporters for the short road journey to Rotterdam. There, the containers were transferred onto a regular Arianespace supply ship for the two-week voyage to French Guiana.

This was followed in early September by the Rosetta spacecraft itself, minus the large high-gain antenna and the twin solar arrays. Cocooned inside a protective container and purged with nitrogen to prevent contamination, the Orbiter and the attached Lander were loaded onto a Russian Antonov-124 air freighter at Amsterdam airport for the flight to Cayenne.

Over the next four months, the spacecraft would be prepared for launch in the specialist facilities at Kourou. After installation of the high-gain antenna, the folded solar wings, the explosive pyros and the spacecraft batteries, Rosetta is to be moved to another building for hazardous operations where its propellant tanks will be filled and pressurised. By early January 2003, it is scheduled for mating with the upper stage of the Ariane-5 launch vehicle. Five days after the fairing installation on 6 January, the huge rocket and its precious payload will inch along the causeway to the launch pad.

If all goes well, Rosetta's long, hard road from initial acceptance to successful launch will take place on the night of 12-13 January. Eight years later, the odyssey will be completed when Comet Wirtanen sails into view and the expedition to explore this small, primordial world begins in earnest.



The Rosetta Lander undergoing testing at ESTEC

Rosetta Rises to the Challenge

Few enterprises are more difficult or hazardous than space travel. Yet, even when compared with the achievements of its illustrious predecessors, ESA's Rosetta mission to orbit Comet Wirtanen and deploy a lander on its pristine surface must be regarded as one of the most challenging ventures ever undertaken in more than four decades of space exploration.

The first of the challenges faced by the Rosetta project team, the scientific collaborators and industrial partners was to design, build and test the complex comet chaser in time to meet the scheduled launch date in January 2003. With less than four years from the beginning of the development phase to launch, it was only possible to meet the series of tight deadlines through highly efficient and motivated team work, long shifts and remarkable dedication by all involved.

Having overcome the time constraints associated with the launch, the hundreds of engineers and scientists involved in Rosetta are now about to face the ultimate assessment of their endeavour – the ability of their creation to not only survive in deep space for more than a decade, but to successfully operate in the close vicinity of a comet and return a treasure trove of data that will revolutionise our knowledge of these mysterious worlds.

The Launch Window

As history has frequently shown, the first hours of a spacecraft's journey to the depths of the Solar System can be among the most critical. In the case of Rosetta, the odyssey will begin with launch from Kourou spaceport aboard an enhanced version (P1 Plus) of Ariane-5.

The first obstacle to be overcome is the limited launch window. In order to meet up with Comet Wirtanen, Rosetta must be launched within a period of 19 days, starting on 13 January 2003. On six of those days there will be a launch window of just 20-30 minutes. The remaining days account for a roll back of the rocket for replenishing of the cryogenic fuel. If this opportunity is missed, the mission will have to be postponed while another target is selected.

Fortunately, the Ariane-5 operator, Arianespace, has an excellent record in launching payloads within such a restricted time frame and has expressed its willingness to do everything possible to ensure that the launch will take place within the three-week window.

Meanwhile, the project team is also taking precautions to ensure that Rosetta launches on time:

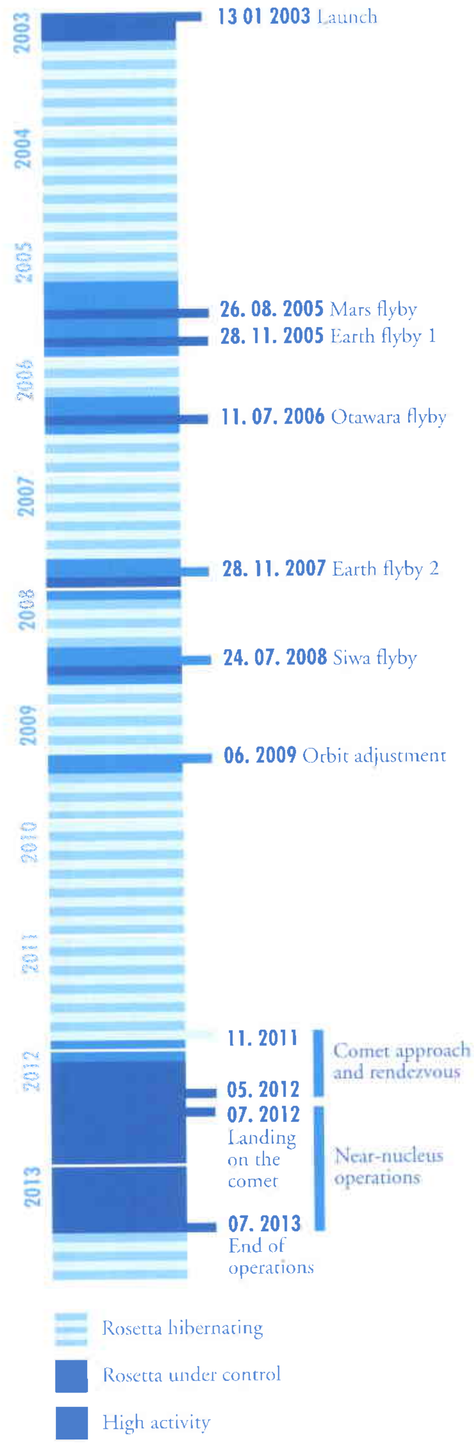
"We do not anticipate any drastic launch postponement," says John Ellwood, Rosetta project manager, "However, it is always prudent to have contingency plans. For example, we are able to work three shifts a day if the spacecraft testing or preparation fall behind schedule. There will be a spare upper stage at the Kourou launch centre if there are problems with Ariane-5 close to launch. A spare Ariane-5 main engine will also be on hand in France ready for shipment within 24 hours."

After the EPS upper stage and its Rosetta payload have been safely placed into a trajectory around the Earth, the next challenge will be to send the spacecraft on its way towards Comet Wirtanen, just two hours after lift-off from Kourou. Prior to reaching perigee (the closest point to the Earth), the upper stage will be re-ignited to inject Rosetta into the required Earth-escape trajectory towards Mars and the asteroid belt. This will be the first time that an Ariane-5 has boosted a spacecraft beyond Earth orbit.

Survival in Deep Space

Ensuring that the spacecraft survives the hazards of travelling through deep space for more than 10 years is one of the great challenges of the Rosetta mission. This prolonged journey will provide the ultimate test of the spacecraft's long-term reliability, robustness and ability to cope with unexpected problems.

Once the spacecraft is safely on its way,



its solar arrays and booms have been deployed and its systems checkout has been completed, Rosetta will have to survive lengthy periods of inactivity, punctuated by relatively short spells of intense action – the encounters with Mars, Earth and two asteroids.

Apart from the hazards posed by the hostile space environment – dust impacts, energetic solar particles, cosmic rays and extremes of temperature – the spacecraft will spend roughly two years in hibernation. To limit consumption of power and fuel, almost all of Rosetta's electrical systems will be switched off, with the exception of the radio receivers, command decoders and power supply. At such times, the spacecraft will spin once per minute while it faces the Sun, so that its solar panels can receive as much sunlight as possible.

Onboard Autonomy

Apart from the necessity to place Rosetta in hibernation for half of its interplanetary trek, the operational situation is further complicated by occasional communication blackouts (up to four weeks long) due to solar occultations, when the spacecraft passes behind the Sun. Even under optimum conditions, daily communication opportunities from the Australian ground station will last a maximum of about 12 hours.

So what happens if some unexpected malfunction or damage occurs during the prolonged interplanetary voyage? There were two options: (i) to provide Rosetta with enough 'artificial intelligence' to solve the problem without human intervention; or (ii) to analyse the problem on the ground and transmit remedial instructions to the spacecraft.

Unfortunately, although the second of these is usually preferable, the laws of physics and the vast distances involved mean that it is rarely feasible. For venturing all the way out to the orbit of Jupiter, 780 million kilometres from the Sun. Even travelling at the speed of light (300 000 km/s), radio signals will take up to 45 minutes to cross the vast gulf between the distant spacecraft and the Earth. By the time Rosetta receives a response, at least one and a half hours will have elapsed.

Since real time command and monitoring from the ground are out of the question, Rosetta has been designed with a considerable degree of autonomy. Although four onboard computers are programmed to deal with tasks such as data management and attitude and orbit control, only two are required to be operational at any one time. If the onboard monitoring system detects a problem that threatens the health of the spacecraft, the computers will take immediate corrective action, switching to a backup system if necessary.

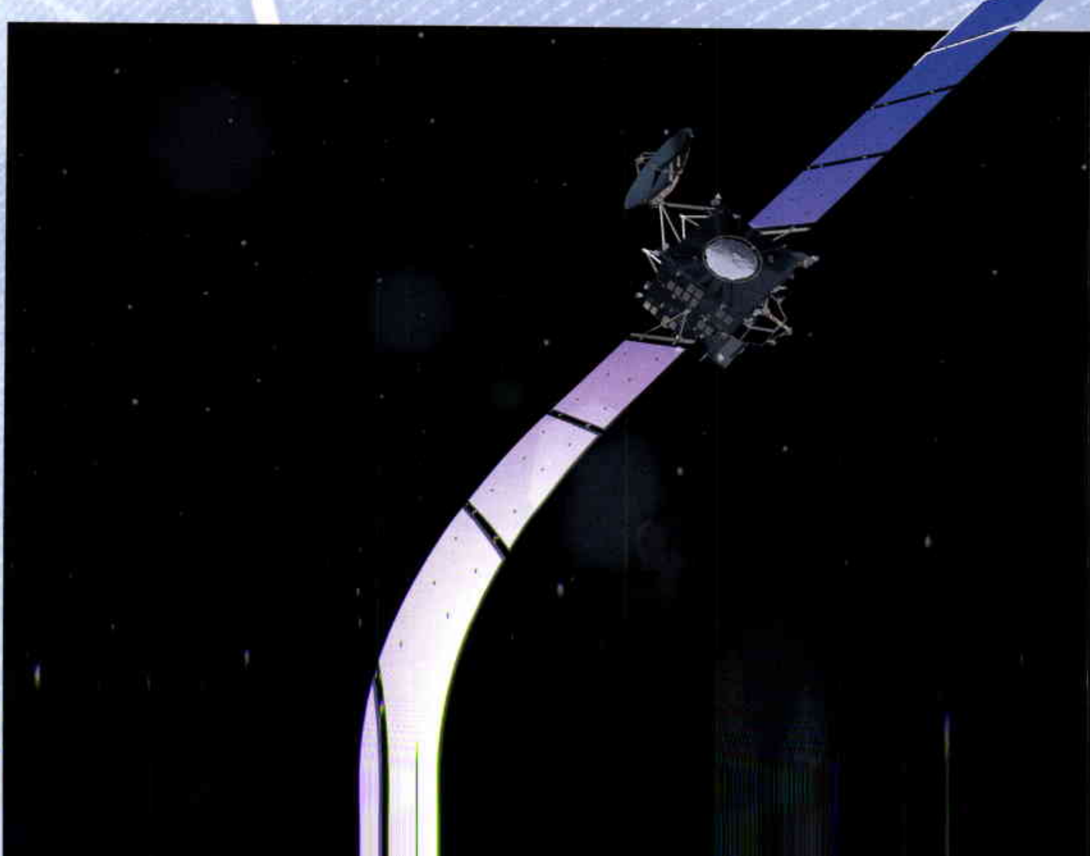
"Rosetta has been designed to carry multiple computers that provide it with a sophisticated failure recognition and recovery capability," explains Jan van Casteren, Spacecraft System Manager. "It's a highly autonomous system based on two computers, each with two separate parts that can be interchanged. We always have the option to upload new, enhanced software over the 10-year mission. The software for each computer can also be interchanged. This means that both the Data Management System and the Attitude and Orbit Control subsystem can be run on all processors. If the spacecraft is in serious trouble, it automatically goes into safe mode – in other words, it goes into hibernation with its solar arrays pointing at the Sun. These backup systems should ensure that the spacecraft will remain operational during critical mission phases, including the highly complex scientific observations when Rosetta is orbiting close to the comet's nucleus."

Solar Power

Venturing far from the Sun puts other serious constraints on Rosetta's design and performance, particularly its electricity supply and temperature.

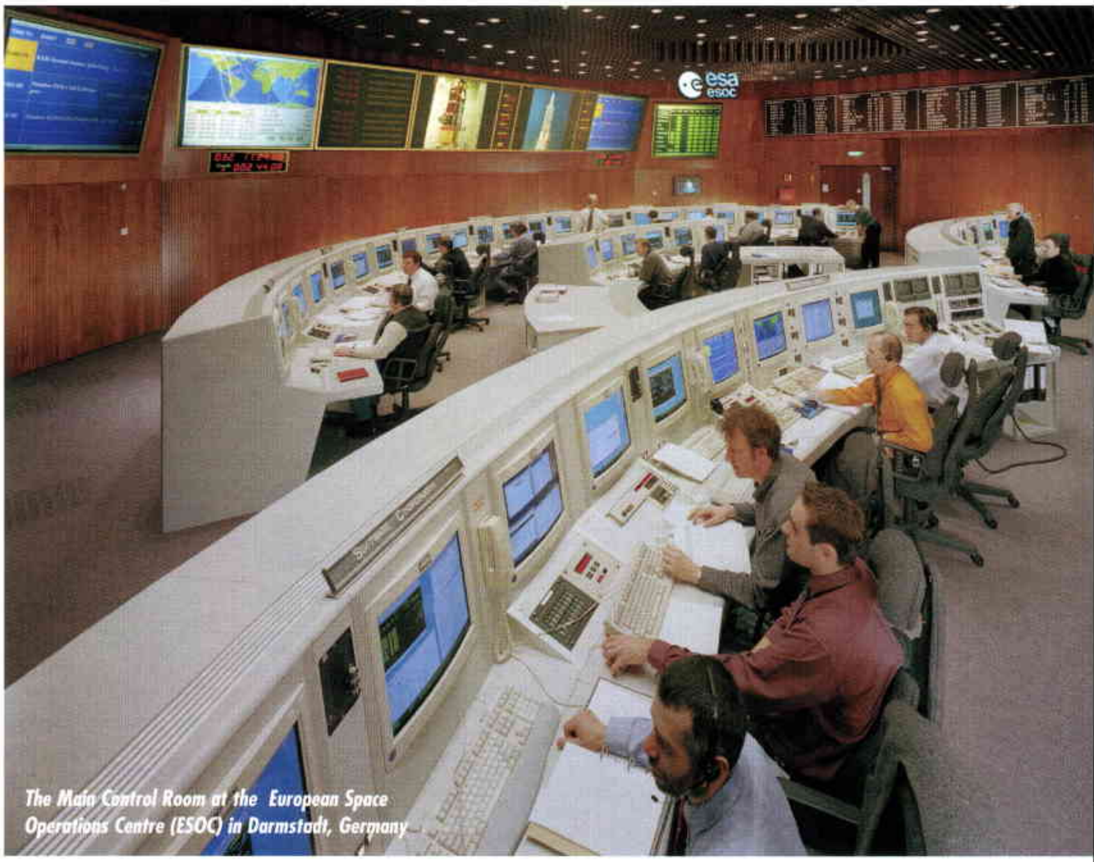
Rosetta will set a record as the first space mission to journey far beyond the main asteroid belt while relying solely on solar cells for power generation. Unfortunately, there is a price to pay. When Rosetta reaches the orbit of Jupiter, where levels of sunlight are only 4% those on Earth, the spacecraft will be generating only 1/25th of the electricity that it can produce when in the inner Solar System.

In order to compensate for this drop in power, Rosetta is equipped with two enormous, steerable solar arrays that span 32 m tip-to-tip (longer than a tennis court) and cover an area of 62 square metres. Each of the 'wings' comprises 5 panels and



is fitted to the spacecraft body with a yoke and drive mechanism, allowing 180° rotation in order to capture the maximum amount of sunlight. Both sides of the arrays are electrically conductive, to avoid a buildup of electrostatic charge.

More than 22 000 non-reflective silicon cells have been specially developed for the Rosetta mission. The main challenge was to achieve maximum efficiency by designing a pyramid-shaped, non-reflective upper cell surface. Optimised for low-sunlight (40 W/m^2), low-temperature (-130°C) operation, these cells should provide an end-of-life conversion efficiency of 15%. They will generate up to 8700 W in the vicinity of the Earth and around 400 W (equivalent to the power consumed by four normal light bulbs) during the deep-space comet encounter.



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

Hot and Cold

Imagine leaving home for 11 years, to embark on a trek that will take you from the frozen wastes of Antarctica to the scorching deserts of Arabia. Working out how to survive such extremes of hot and cold would be a major headache.

In the same way, dramatic temperature variations were a major cause of concern for Rosetta's designers. When the spacecraft is cruising around the inner Solar System, bathed in the warmth of the Sun, its surface temperature may soar to 130°C, and even internal equipment may reach 50°C. However, in order to rendezvous with Comet Wirtanen, Rosetta will have to probe the frigid regions beyond the asteroid belt, where temperatures plummet to -150°C.

Since it is not feasible to wrap a spacecraft in multiple layers of warm clothing for periods of deep freeze, then strip these away when sunbathing is the order of the day, Rosetta has been provided with alternative ways of regulating its temperature.

Near the Sun, overheating will be prevented by using radiators to dissipate surplus heat into space. 14 louvers – high-tech Venetian blinds that control heat loss from the spacecraft – are fitted over the radiators on two sides of the spacecraft. Lovingly polished by hand, these assemblies of thin metal blades must be handled like precious antiques, since any scratching, contamination or fingerprints will degrade their heat-reflecting qualities.

The principle behind the louvers is quite simple. In the balmy regions between Earth and Mars, they are left fully open, allowing as much heat as possible to escape into space from Rosetta's radiators. During the prolonged periods of hibernation and comet rendezvous, however, heat conservation is the order of the day. Since the spacecraft's limited internal power supply – equivalent to the output from a few light bulbs – then becomes the main source of warmth, it is essential to retain as much heat as possible. This means completely closing the louvers to prevent any heat from escaping. Heaters located at strategic points (e.g. fuel tanks, pipework and thrusters) will also be turned on and the multi-layered blankets of insulating material come into their own.

Communications

Communications play an even more important role in space missions than they do in our everyday lives. Whereas it is reasonable to believe that a good friend is safe and sound after several weeks without speaking to them, the same cannot be assumed for a spacecraft millions of kilometres from home.

The task of keeping in touch with the far-roaming Rosetta falls on the operations team in the Mission Control Centre at the European Space Operations Centre (ESOC) in Darmstadt, Germany. They are responsible for mission planning, monitoring and controlling the spacecraft throughout its circuitous voyage to Comet Wirtanen. The flight-dynamics team at ESOC will calculate and predict its attitude and orbit, prepare orbit manoeuvres, and evaluate spacecraft dynamics and navigation. Ground controllers will also evaluate Rosetta's performance, preparing and validating modifications to onboard software when necessary.

Planning of the scientific mission and generation of commands to experiments will be conducted either from the Science

Operations Centre at ESOC or from ESTEC. During the climax of the mission, ESOC will be responsible for pre-processing, archiving and distributing the unique cometary data to the scientific community. Lander operations will be undertaken from the DLR Lander Control Centre in Cologne, Germany, with support from the CNES Lander Science Centre in Toulouse, France.

In order to keep in touch with their itinerant explorer, ground control will be able to use radio communications at both S-band (2 GHz) and X-band (8 GHz) frequencies. Rosetta itself has the capability to 'speak' and 'listen' to Earth via several antennas. Two low-gain antennas with wide-angle coverage will support emergency operations in S-band. There are also two medium-gain antennas, one for S-band and one for X-band. However, the primary communications link will be the 2.2 m-diameter high-gain antenna, which will be able to send and receive large amounts of data at both frequencies. This lightweight steerable dish is largely made of carbon fibre and tips the scales at just 45 kg, including the electronics.

The rate at which information can be transmitted from the spacecraft will vary considerably with its distance from Earth (up to 930 million km) and its level of activity, ranging between 8 bit/s and 64 kbit/s. However, during the comet-exploration phase, the minimum telemetry data rate will be 5 kbit/s. New computer software will be used to compress the data, so compensating for the limited downlink bandwidth and ensuring that as much information as possible will be returned. The unique results from Rosetta's experiments can be stored temporarily in the spacecraft's 25 Gbit mass memory for relay to Earth at a convenient time.

To ensure that optimal contact is maintained with the wandering spacecraft, ESA's network of ground stations has been augmented with a specially-built ground station at New Norcia (Western Australia). Equipped with a newly constructed 35 m dish and cryogenically cooled, low-noise amplifiers to receive Rosetta's weak radio signal, the state-of-the-art antenna will be remotely controlled from ESOC. NASA's Deep Space Network will offer back up for telemetry, telecommand and tracking operations during critical mission phases, while the Kourou station in French Guiana will provide additional support during the launch, early-orbit and near-Earth phases of the mission.

The New Norcia ground station in Western Australia

Longevity

One of the most significant but least-tangible challenges to Rosetta's success is the insidious passage of time. Not only must the hardware survive for more than 10 years in the hostile environment of space, but the mission teams must continue to function efficiently throughout the entire voyage.

At the time of the critical near-comet operations, it is very likely that many of the engineers who designed and tested the spacecraft 10 or 15 years earlier will no longer be available to offer support if unforeseen circumstances arise. In fact, a fair number of them may well have retired. In preparation for this inevitable turnover of personnel, a number of younger people are being drafted into the instrument teams, including several principal scientific investigators. In order to ensure that the replacements can slot into the programme as easily as possible, the Rosetta project is creating a database that contains complete information about the spacecraft and its complex mission.

The unusual duration of the mission means that considerable attention must be paid to proficiency and cross training of staff to guarantee backup support, while refreshing skills and motivation. Facilities available at ESOC to support tests and simulations will include a spacecraft simulator, an onboard-software maintenance facility, and the spacecraft electrical model. If spacecraft anomalies arise, these items at ESOC will be indispensable for reproducing the problems, developing and testing solutions prior to implementing corrective actions on the spacecraft itself.

"The first eight months of the mission will involve intensive activity that will enable everyone to become familiar with the spacecraft's behaviour," explains Manfred Warhaut, Rosetta Ground Segment Manager.

"There will then be periodic training and communication activities – once every 6-12 months – to keep the team on the ball, as well as for the operations during the Earth and Mars flybys. We will take care to have adequate training before each manoeuvre."

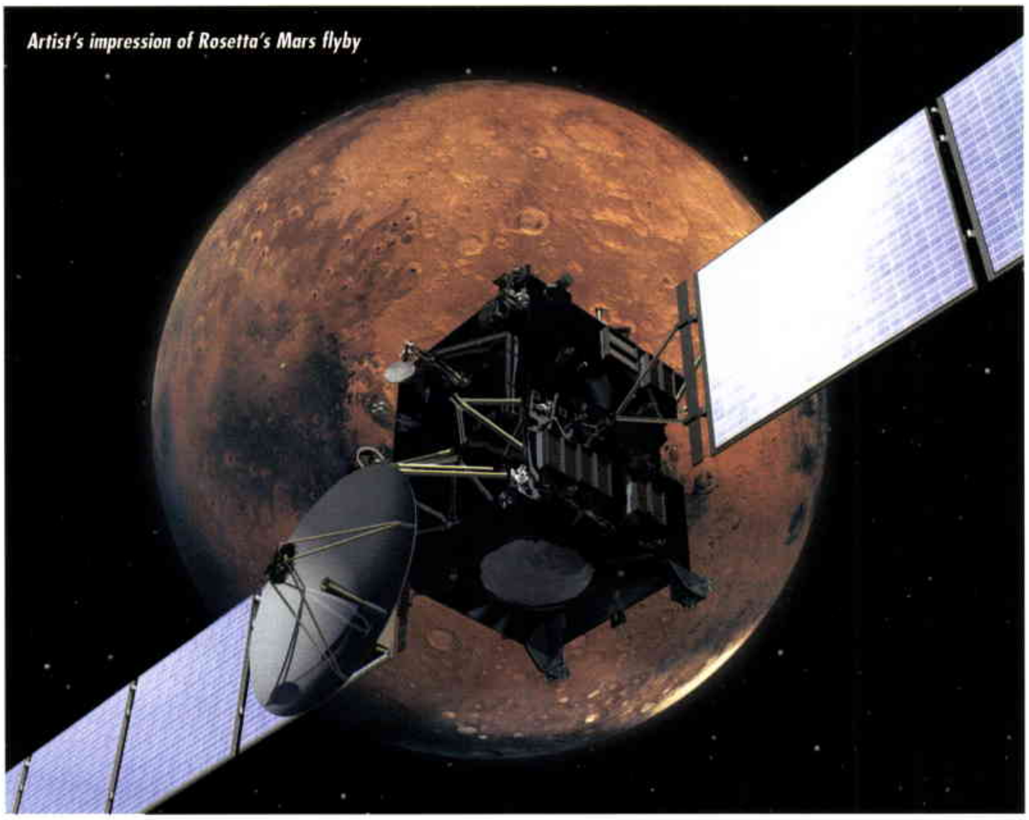
Navigation

Rosetta's mission resembles a multi-million-kilometre, high-speed chase, hopefully culminating with the spacecraft and comet travelling alongside each other on parallel paths. Unfortunately, if Rosetta arrives too early or too late, the comet will not be there to meet it!

Achieving a long-distance rendezvous and matching orbits requires some highly complicated navigational calculations, particularly since not even the powerful Ariane-5 has the capability to send a three tonne spacecraft directly to Comet Wirtanen. To match the comet's velocity, Rosetta will have to be accelerated by 7.8 km/s after leaving Earth orbit. To achieve this, the spacecraft will bounce around the inner Solar System like a cosmic billiard ball, gaining speed from three planetary flybys. After an initial boost of 3.4 km/s from Ariane-5's upper stage, the spacecraft must take advantage of gravity assists from Mars (in 2005) and Earth (in 2005 and 2007).

In order to ensure that Rosetta stays on course throughout this circuitous passage, ground controllers will have to carefully monitor the spacecraft's velocity and position. This will be done by monitoring the telemetry and navigation images from the spacecraft, and by visual and radar tracking during the Earth encounters. Studies of the shift in frequency of the radio signals coming from Rosetta – the Doppler shift – will reveal how fast the robotic ambassador is travelling towards or away from us.

However, this is not sufficient to tie down Rosetta's motion. Like a Space Shuttle pilot trying to rendezvous with the fast-moving International Space Station, it is essential to know the quarry's position, speed and direction of movement. Unfortunately, comet orbits can be severely influenced by the gravitational pull of nearby planets. In the case of Comet Wirtanen, the orbit was significantly altered by close encounters with Jupiter in 1972 and 1984. As a result, the comet's orbital period was shortened from 6.7 years to 5.5 years. Outgassing from the nucleus may also modify a comet's trajectory, so a continuous observational programme using ground-based observatories has been put into place to accurately pin down Wirtanen's path.



Artist's impression of Rosetta's Mars flyby

Even if Rosetta follows the optimum route to its target, the final rendezvous is complicated by the fact that the comet's and the spacecraft's orbital planes do not coincide. Thus, about 8.5 years into the mission, the spacecraft's bi-propellant reaction-control system will have to be fired to make the largest manoeuvres of the mission in order to phase Rosetta's orbital plane with that of the comet. Once the onboard navigation cameras have detected the dark, inactive comet from a distance of some 300 000 km, the task of closing on the nucleus will become more straightforward.

Remote Science

Rosetta exists for one purpose – to complete humankind's first extended exploration of a comet. Although it has been equipped with a suite of state-of-the-art instruments, this alone is insufficient to ensure a successful outcome. Different experiments need different conditions to work properly and optimally. A particular environment, spacecraft orientation or orbit that is perfect for one instrument might fatally compromise the performance of another. For instance, Rosetta's dust-collecting instruments must pass through a dust jet from time to time to gather the ejected pristine material, but care must be taken to ensure that too much dust does not collect on optical instruments and other sensitive surfaces.

Clearly, proper coordination of the science operations is very important and every effort has to be made to coordinate these operations in order to maximize the outcome of the mission. This has been done by defining different 'mission scenarios' to meet the needs of the different instruments. In the above example, one mission scenario will be dedicated to the collection of dust (and gas) in a very active part of the coma (a jet), during which the cameras will be protected by leaving their covers on.

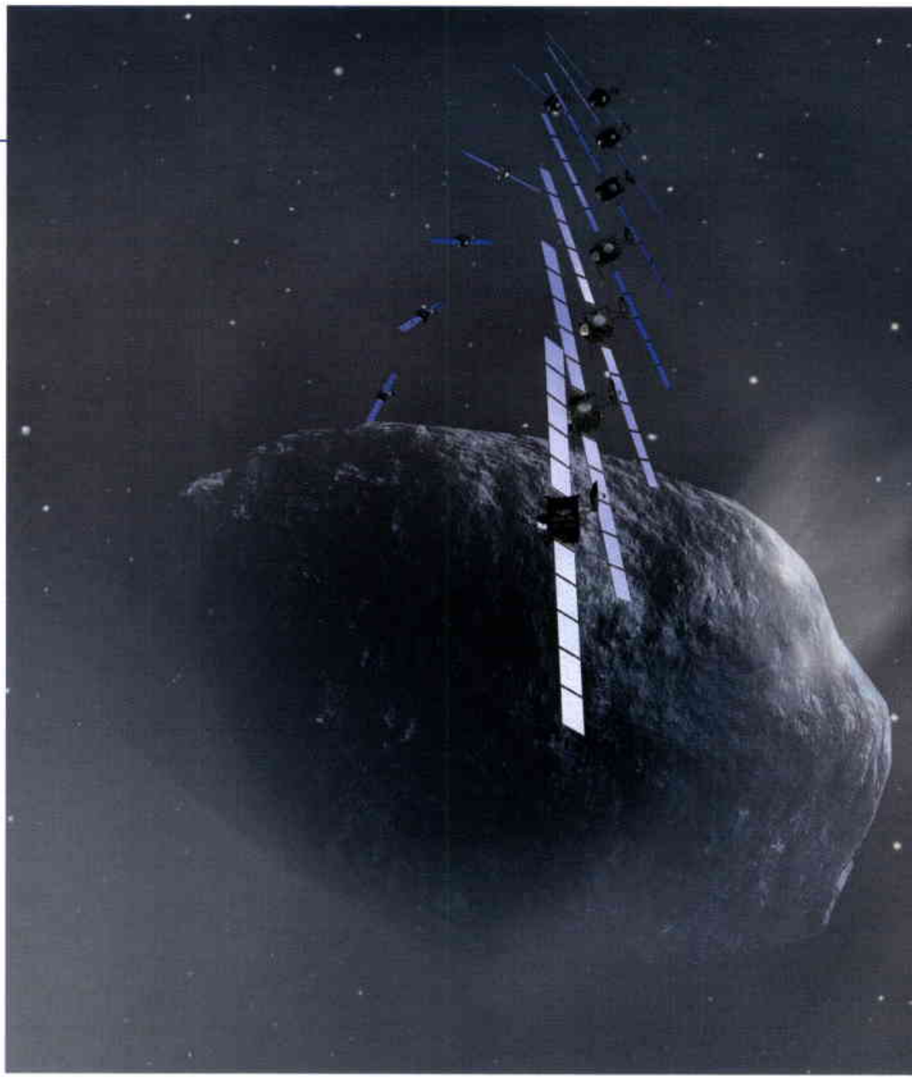
Each investigation also presents its own challenges. One of the most revolutionary experiments is CONSERT, which will send short pulses of radio waves through the cometary nucleus. By transmitting and receiving the pulses on the Orbiter and the Lander, the attenuation and the time delay of the radio signal propagating through the comet are determined. From this sounding data, information on the interior of the nucleus can be retrieved.

Since the time taken for wave propagation through different nucleus materials varies by tiny amounts, it is crucial to ensure that the clocks on the Orbiter and Lander are offset by no more than 5 to 100 nanoseconds (a nanosecond is a billionth of a second).

Imaging with instruments such as OSIRIS presents a different type of challenge. During the fast flybys at two asteroids, scientists want to take as many images as possible of the illuminated areas, as well as numerous high-resolution images when Rosetta is at its closest to the surfaces.

A number of constraints have to be considered here. Due to the rotation required to follow the asteroid, the spacecraft has times where it is not stable enough to take images. Between images, it may be necessary to turn the filter wheel very rapidly. Furthermore, the precise flyby time is uncertain until a few hours beforehand and the number of images has to be restricted because of the limited memory onboard the spacecraft.

Simultaneous imaging of very luminous and very dim objects is a particular headache close to the comet. One of Rosetta's main objectives is to image the faint dust jets emanating from the nucleus whilst the brightly illuminated nucleus is also in the field of view. Such requirements were a major design driver for OSIRIS and could only be achieved by a combination of extremely flat mirror optics, complex high-resolution readout electronics and considerable work by the developers to remove any 'noise' from the system.



Rosetta orbiting Comet Wirtanen (artist's impression)

Landing on a Dirty Snowball

Landings on other worlds are remarkably difficult to achieve. During the last 40 years, the only objects in the Solar System on which robotic spacecraft have soft-landed have been the Moon, Venus, Mars and the near-Earth asteroid Eros. A decade from now, it will be the turn of Rosetta to make history with the first touch down on a comet.

By the summer of 2012, instruments on the Rosetta Orbiter will have mapped every square centimetre of the Comet Wirtanen's surface, enabling scientists to select a suitable landing site. The Orbiter's position and speed must by that stage have been precisely determined to within 10 cm and 1 mm/s, respectively, to ensure that Lander ejection takes place at the correct time for arrival at the selected site.

Following instructions uploaded from mission control, the 100 kg Lander will be released from the Rosetta Orbiter about one kilometre above the comet's nucleus. After a gentle push away from the 'mother ship', the box-shaped craft will deploy its landing gear and edge towards its target, prevented from tumbling by an internal flywheel that provides stability as its spins. A single cold-gas thruster will be able to provide a gradual upward push to improve the accuracy of the descent.

After a nail-biting 30 minute descent, sensors onboard the Lander will record the historic moment of touchdown for the helpless mission team back on Earth. Since the nucleus is so small, its gravitational pull will be extremely weak – 100 000 to 200 000 times lower than on the Earth's

surface – causing the Lander to touch down at no more than walking pace. Nevertheless, a damping system in the landing gear will be available to reduce the shock of impact and prevent a rebound.

The Lander also carries two harpoons. One of these will be fired at the moment of touchdown to anchor the spacecraft to the surface and prevent it from bouncing. Ice screws on each leg will also be rotated to bite into the nucleus and secure the Lander in place. The second harpoon will be held in reserve for use later in the mission if the first one becomes loose.

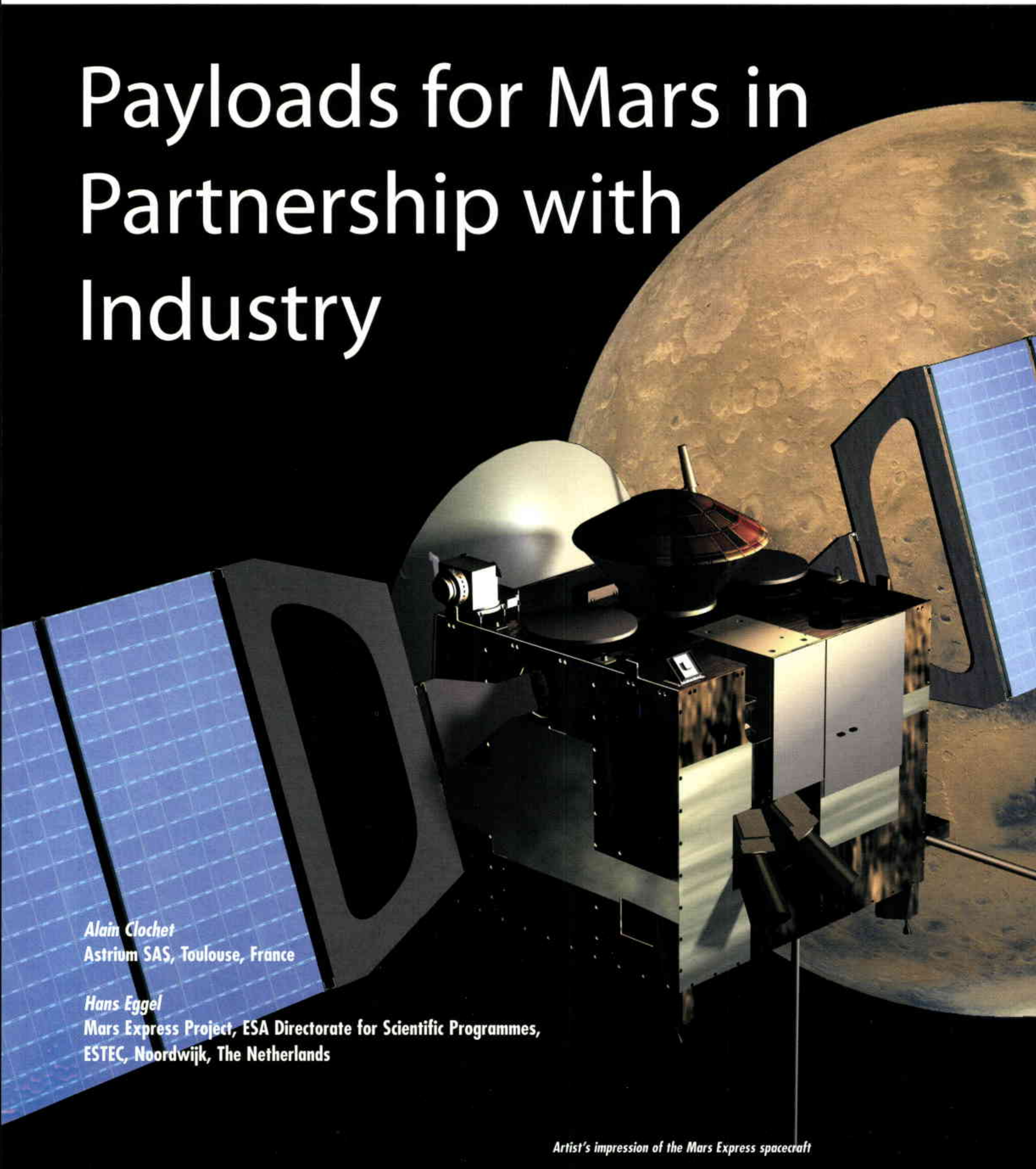
"Hopefully, gradient will not be a problem, since the spacecraft is designed to stay upright on a slope of up to about 30 degrees," says Philippe Kletzkine, Rosetta Lander Manager.

The operational lifetime of the Lander is highly uncertain. Its survival will depend on a number of factors such as power supply, temperature or surface activity on the comet. In order to ensure a significant science return, the most important images and measurements will be obtained within 60 hours of arrival. The remaining, more detailed investigations will be conducted as long as the Lander continues to function, relying on the remaining battery power and energy from the solar cells on the exterior of the Lander.

No one knows what this first soft landing on a cosmic iceberg will reveal. What we can be sure of is that the Orbiter and its little Lander will revolutionise our knowledge of comets, providing new insights into the nature and origins of these primordial objects.

The Rosetta Lander on Comet Wirtanen's surface (artist's impression)

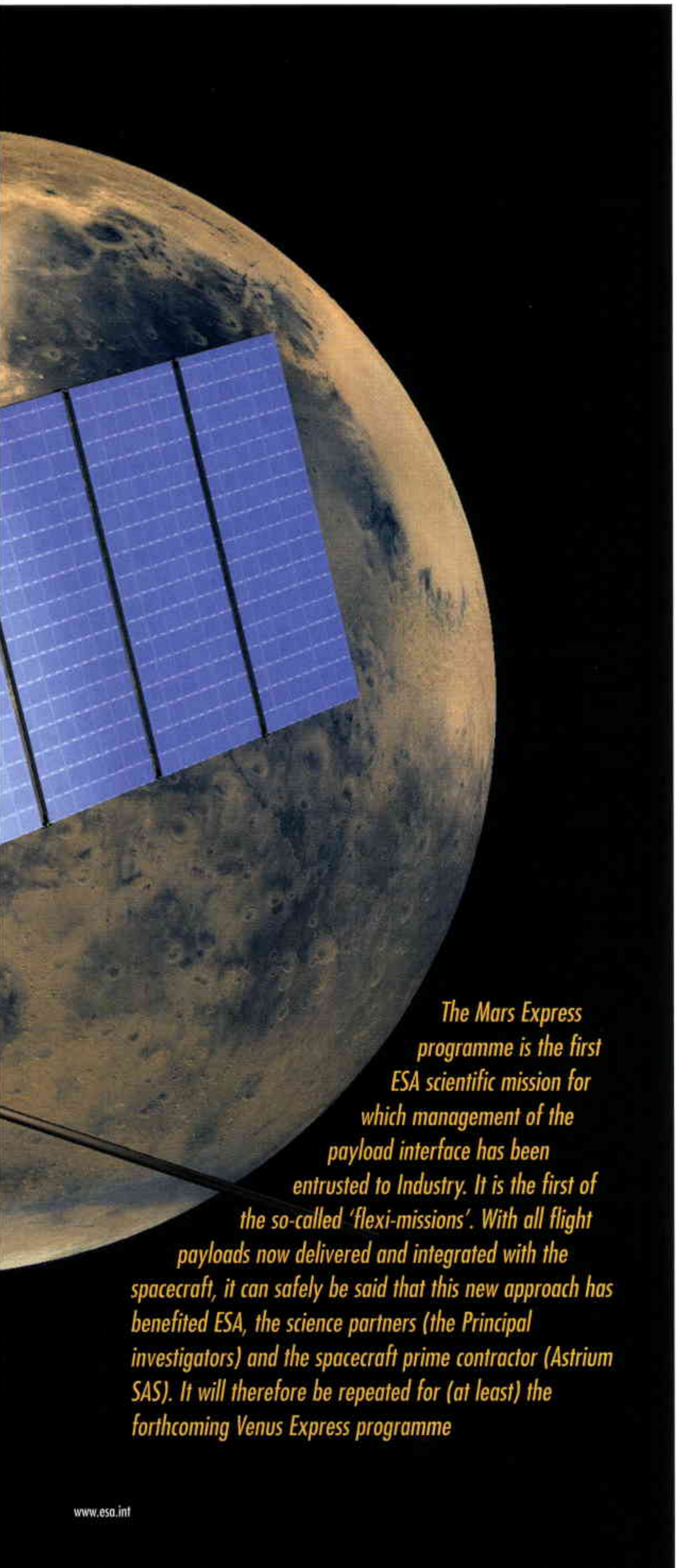
Payloads for Mars in Partnership with Industry



Alain Clochet
Astrium SAS, Toulouse, France

Hans Eggel
Mars Express Project, ESA Directorate for Scientific Programmes, ESTEC, Noordwijk, The Netherlands

Artist's impression of the Mars Express spacecraft



The decreasing frequency of scientific-satellite launches, together with the need to maintain a balance in the future missions between the different scientific communities, has led the ESA Scientific Programmes Directorate to revise its Long-Term Programme. One of the new elements in that revised programme, known as 'Cosmic Vision', are so-called 'flexi- (or 'F') missions', which are designed to cost half as much as the previous 'medium-sized (or 'M') missions'. This revised plan will allow ESA to launch missions more often than the shrinking Science budget would have otherwise allowed. Mars Express was selected as the first 'flexi-mission'.

In parallel with this programmatic re-direction, a new management approach has been introduced for this type of mission, with an ESA team half the size of those for the traditional missions. As a consequence, key tasks such as the management of the interface with the scientific instrument teams, of the technical interface to the launch authorities, and of the test-facility procurement has been delegated to the Mars Express prime contractor.

Selecting Payload and Prime Contractor

After the Mars Express mission's initial approval by the Agency's Science Programme Committee (SPC) in June 1997, an intensive phase of preparatory work for the Announcement of Opportunity (AO) for the scientific investigations and for the industrial study activities was undertaken at ESA, during which the feasibility of the project also had to be ascertained.

The industrial 'study phase' effectively began in October 1997 with a competitive study contract. The AO for the scientific instruments was issued in December, with replies due at the end of February 1998. The Invitation to Tender (ITT) contained only the top-level requirements and it was intentionally left to industry to elaborate the detailed mission design.

The industrial study phase was divided into two parts. During the first six weeks, the contractors had to develop a conceptual design for the spacecraft based on the model payload as recommended by the SPC. Their designs were then further refined during the second, four-month period. The scientific community's responses to the AO were received at the start of that second phase. A formal science-payload-proposal review cycle was then initiated, in which the industrial competitors were fully involved where appropriate. A procedure for information and data exchange was applied whereby interactions between the payload selection committee, the competing industrial contractors and the scientific community were facilitated without breaching the confidentiality requirement.

To minimise the time and resources required to freeze the payload configuration, the PI teams had to be kept fully informed about the capabilities and limitations of the spacecraft platform selected. Close liaison between the project personnel and the PI institutes was essential to achieve this early in the project.

There were three iteration loops during which the Peer Review Committee identified either specific questions to industry or preferred sets of payload elements. In parallel, industry assessed the feasibility of these preferred sets against their spacecraft concept. For a better understanding of the instruments, industry could also raise questions, via ESA, to the respective instrument teams. The instrument teams' answers were also channelled through ESA. More than 700 questions were satisfactorily processed during this phase. Only after the confirmation by ESA's Solar System Working Group of the recommended payload composition did ESA allow industry to enter into direct contact with the instrument teams.

Acronym	Measurement Type	Principal Investigator
ASPERA	Energetic Neutral Atom Analyser	R. Lundin, Sweden
BEAGLE-2	Mars Lander	C. Pillinger, UK
HRSC	High-Resolution Stereo Camera	G. Neukum, Germany
MaRS	Mars Radio-Science Experiment	M. Pätzold, Germany
MARSIS	Sub-surface Sounding Radar Altimete	G. Picardi, Italy
OMEGA	Visible and Infrared Mineralogical Mapping Spectrometer	J.P. Bibring, France
PFS	Planetary Fourier Spectrometer	V. Formisano, Italy
SPICAM	Ultraviolet and Infrared Atmospheric Spectrometer	J.L. Bertaux, France

Mars Express payload elements and their Principal Investigators (PIs)

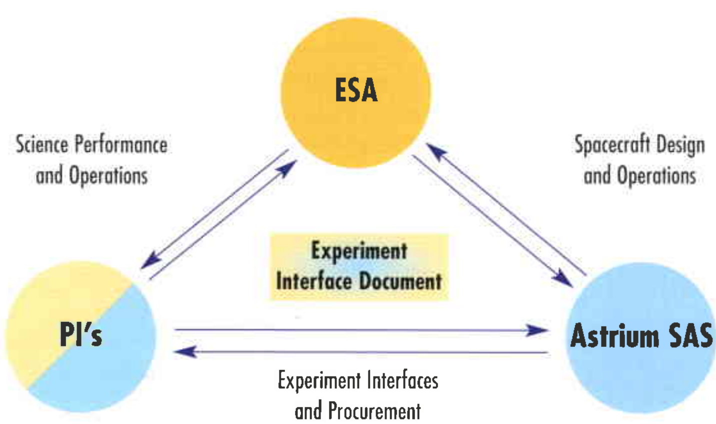
The competitive study phase was completed by May 1998. The formal ITT for industry proposals was issued by ESA in June, and the responses were received and evaluated in the autumn. Astrium was subsequently chosen as the prime contractor, and the spacecraft development programme began in early February 1999.

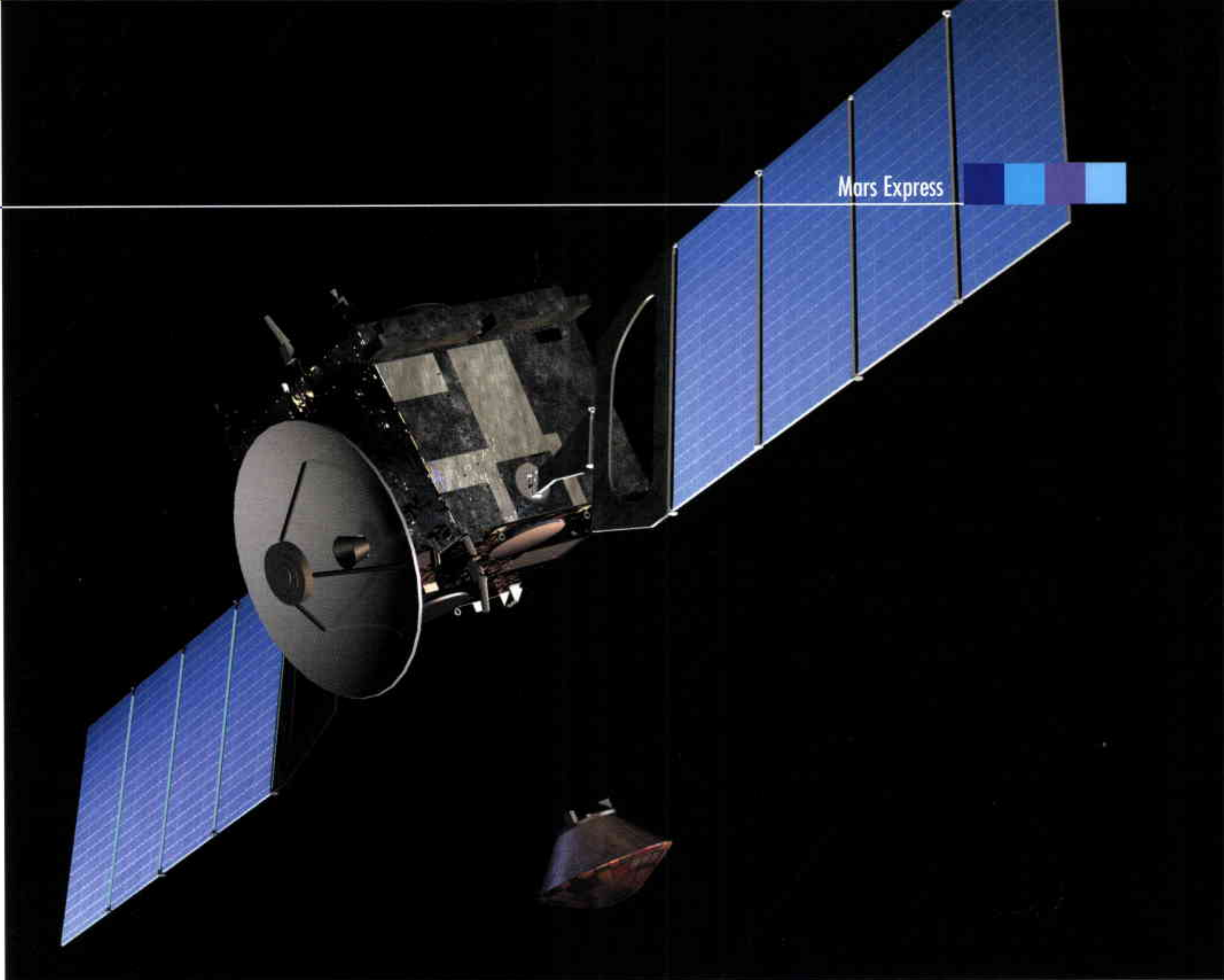
The Partnership Agreements

Initiated during the proposal work, and effective from the time of their selection as prime contractor, Astrium (formerly MMS) have applied a novel working scheme with respect to all instrument matters for Mars Express:

- The Principal Investigators, together with ESA, remain responsible for the scientific performances of the instruments and related in-flight operations.
- The spacecraft contractor is responsible for instrument technical-interface management, provision of an acceptable payload environment, progress monitoring for the timely delivery of the instrument models, and administration of any changes or non-conformances.

To institute this new approach, formal partnership agreements between the Principal Investigators and Astrium, precisely defining the way of collaboration between the PIs and the prime contractor, were established and signed. In particular, as part of these agreements the PIs were to support the industrial team in drafting the various interface control documents. In addition, for programme-monitoring purposes, a regular cycle of progress meetings and formal instrument reviews was implemented, together with active participation of the science teams in the instrument verification process at spacecraft level. This ensured a phased and consistent approach in the overall Mars Express spacecraft preparation activities.





The Experiment Interface Documents

A set of Mars Express Payload Interface Documents (or PIDs), co-written by ESA and Astrium, define the project-requirement links between ESA, Astrium and the PIs. PID-A is intended to ensure that:

- The payloads are designed, built and verified within the scope defined by the ESA mission and science objectives, as constrained by the capabilities of the spacecraft, the launch vehicle and the ground segment.
- The spacecraft contractor is able to design, build and verify the satellite in such a way that the science payload is properly integrated into the system.
- The spacecraft can be successfully launched and operated to achieve the complete set of ESA mission and science objectives.
- The overall programme management follows clear, efficient and approved rules.

As mandatory complements, the PID-B's, issued by the various PIs, have recorded the technical and programmatic status of each payload with respect to the Mars Express PID-A requirements.

Meetings and Reviews

Programme phases and reviews

Starting with the payload and spacecraft contractor selections, the overall Mars Express spacecraft procurement period (Phases-B/C/D), initiated in early February 1999, was split into the three classical phases:

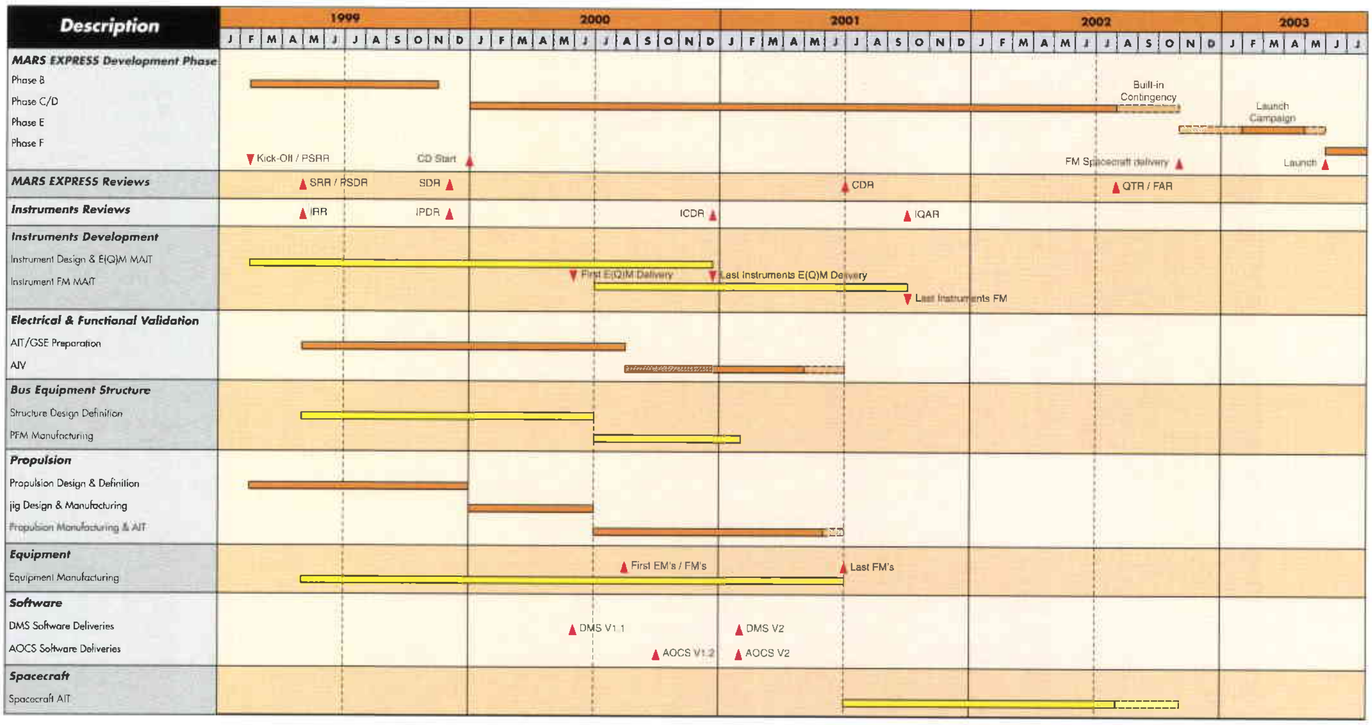
- The Preliminary Definition Phase (Phase-B), lasting from project kick-off until the spacecraft Preliminary Design Review (PDR) at the end of 1999: this phase was intended to freeze the system requirements, finalise the spacecraft's design (including the lower level elements), and select the spacecraft unit suppliers.
- The Detailed Design and Validation Phase, lasting from the PDR until the spacecraft Critical Design Review (CDR) at the end of 2001: this detailed design phase – again down to unit level – was conducted to authorise the development and major validation steps for the spacecraft items.
- The spacecraft flight-model integration and qualification from the CDR until the Qualification Review (QR) at the end of 2002: this phase will last until spacecraft qualification.

These three development phases will be followed by the launch preparations and launch campaign (Phase-E/F), leading up to the launch itself in early June 2003.

The Mars Express payload-development process has followed the same logic and review philosophy, but performed in advance of the spacecraft-level cycle. This has allowed all interface aspects of each instrument programme to be reviewed by ESA and Astrium, prior to the general system assessments, usually at the PI's premises. The objective was to ensure that all instruments:

- meet the anticipated science objectives accepted at selection (ESA the only reviewer)
- comply with the interface requirements of the PID
- provide a consistent development and verification approach in meeting the schedule delivery-date requirements.

The formal Review Board was made up of both ESA and Astrium personnel, and was co-chaired by the spacecraft contractor's representative and the ESA Project Scientist.



The Master Development Schedule for Mars Express

The Mars Express electrical, functional and validation test bench

Instrument progress meetings

Regular – typically monthly – progress meetings were held at the PIs' premises during the instrument early design, development and verification programme. Involving ESA, Astrium and the payload teams, they were intended to ensure that the technical-design (particularly spacecraft interfaces) and instrument-programmatics aspects were progressing according to plan at the various institutes.

Model philosophy and deliverable hardware

For each payload, two intermediate instrument models have been developed – structural dummies for spacecraft mechanical qualification and an engineering model (or at least an electrical simulator) for anticipated system electrical and functional bench validation – to allow exhaustive system-level validation. These models are in addition to a flight model and have been fully acceptance tested before further integration and testing on the flight spacecraft.

The science teams were given the flexibility to define their own development approach and associated model philosophy. In some cases, this led to their developing a specific qualification model, either complete or partial.

Conclusion

This new ESA scheme for developing payloads under direct prime contractor control, based on a full and explicit partnership agreement, has proved to be both viable and highly successful for Mars Express. With this new approach, ESA and Astrium have paved the way for closer contacts between science institutes and industry. Other science-driven programmes in ESA could follow the same route, and the Mars Express experience should help in fostering and developing new relationships.

The ESA Science Directorate's new 'Cosmic Vision' programme will endeavour to build on the Mars Express experience in conducting the Agency's future missions in astronomy, fundamental physics and solar-system science. esa

Casting Your Vote in ESA

– Now and in the Future

Ersilia Vaudo, Lucia Linares-Calduch & Florent Mazurelle
Directorate of Administration, ESA, Paris

Andreas Diekmann
ESA Directorate of Manned Spaceflight and Microgravity, ESTEC, Noordwijk, The Netherlands

The voting rules applied in ESA's delegate bodies are defined in its Convention. Article XI.6(d) states that, unless otherwise provided for under the Convention, the majority rule is a simple majority of Member States represented and voting. The Convention provides for numerous derogations to this principle: unanimity, two-thirds majority, simple majority of all ESA Member States, and two-thirds majority of the Participating States representing two-thirds of the contributions (so-called 'double two-thirds majority'). The latter, applied within ESA in only a very limited number of cases, represents an element of weighted voting, which means a deviation from the pure one-country one-vote principle.

Weighted voting is also applied in other international organisations, such as the UN Security Council, the International Monetary Fund, the World Bank and the European Bank for Reconstruction and Development. In the space sector, in Intelsat, Eutelsat and Inmarsat, which were formed as intergovernmental organisations and are currently in the final phases of privatisation, the investment shares of its members constitute a voting weighting factor. In the Council of the European Union, the Qualified Majority Vote (QMV), which is the most frequent modality, implies a weighted system in which votes are attributed to each Member State roughly according to its population.

A discussion within ESA on its voting rules, and in particular on strengthening elements of weighted voting, was last held in 1998 in the framework of reflections on how to improve the Agency's efficiency and decision-making process. No firm conclusions were reached at that time, but the discussion might attract new attention when concrete steps towards enlargement of the Agency – perhaps to more than 20 Member States – are undertaken. Such a discussion, which would be driven by political considerations, could however profit from a better understanding of the statistical properties and implications of potential alternative voting rules.

In order to provide some 'technical' insight in this respect, here we assess current and alternative voting rules for ESA in terms of their 'efficiency', defined as the probability that a vote has a positive outcome, and the voting power of Member States, defined as the statistical significance of a Member State's voting behaviour for the outcome of the vote. Particular attention is paid to the influence of an increasing number of Member States on these parameters. The statistical approach applied is based on the theoretical foundation of voting-power analysis and follows the methodology pursued when analysing the proposed voting reforms that were discussed at the EU Summit in Nice (F) in December 2000. The conclusions reached have been complemented by an analysis of the practical voting behaviour of ESA's Council from 1999 to 2001.

Current and Potential Alternative Voting Rules: What Lies behind Weights

The choice of alternative voting systems explored here has been driven by the concern to preserve the element of equitability represented by the one-State, one-vote rule. Thus, voting systems based exclusively on proportional – weighted – representation have only been investigated for comparative purposes.

A weighted voting system is one where different participants have different numbers of votes. A country's weight might depend on its population (as in the EU's voting system), its GNP, or other parameters (e.g. financial contributions), justifying giving each country a different influence over the outcome of a vote.

The weighted voting systems considered here include the EU current and potential (Nice Treaty) systems adapted to ESA specificities, as well as voting systems based on combinations of simple and two-thirds majority rules applied to a two-tier voting configuration (one-country, one-vote + weighted vote). They have been analysed for the current 15 Member States, for 17 Member States (present Members plus Greece and Luxembourg) and for 21 Member States (present Members plus Greece, Luxembourg, Poland, Romania, the Czech Republic and Hungary).

The nine different scenarios assessed, including for comparative purposes the current ESA voting systems, are:

– *Current ESA voting systems*

1. Simple majority of Member States

The European Union's current voting system and the one provided for in the Treaty of Nice have been adapted to ESA specificities by considering contributions instead of populations as the most appropriate basis for determining the allocation of weights. In the EU's Council, weighted votes are attributed to each Member State roughly according to their populations: more populous states have greater weights. But there is no strict proportionality: the ratio of weight to population is higher for the smaller Member States and lower for the most populous ones. A proposed resolution is approved if the total weight of those voting for it equals or exceeds a certain threshold. Following the same criteria, the Treaty of Nice is intended to readjust institutional equilibrium by fixing afresh the weights and the threshold in view of progressive enlargement from 15 to 27 Members.*

Keeping the present weighted voting formula in the EU's Council as new Members join would make it harder to pass a motion because the number of possible majorities capable of blocking a given proposal increases faster than the number capable of approving it. Therefore, dealing with this problem was considered a priority during the Nice Intergovernmental Conference in December 2000. The Treaty of Nice, which foresees the new weighting distribution in the accompanying table, is not yet in force as it still needs to be ratified by referendum in Ireland. If ratified, this modified voting system will replace the current one from 1 January 2005.

The weights for ESA Member States as derived from adapting to ESA the weighting methodology applied in the EU are shown in the accompanying table. The minimum and maximum weights are the same as in the EU voting systems, in order to facilitate comparison.

* The projected contributions from potential new Member States are based on Gross National Product (GNP), applying the ratio of average GNP to the average contributions of the present 15 ESA Member States.

Countries	Weights			
	EU current	EU adapted to ESA	EU Nice T	EU Nice T adapted to ESA
D	10	10	29	29
UK	10	5	29	15
F	10	10	29	29
I	10	8	29	27
E	8	5	27	13
NL	8	4	13	9
GR	5	3	12	7
B	5	5	12	14
P	5	2	12	5
S	5	3	10	7
A	4	3	10	6
DK	3	3	7	6
FIN	3	3	7	5
IRL	3	2	7	4
L	2	4	4	4
CH		4		10
N		3		6
PL			27	12
RO			14	7
CZ			12	7
H			12	6

2. Two-thirds majority of Member States
3. Two-thirds of the contributions representing two-thirds of Member States.

– *Combinations of contributions* and number of Member States:*
4. Simple majority of contributions representing a simple majority of Member States
5. Two-thirds of contributions representing a simple majority of Member States
6. Simple majority of the contributions representing two-thirds of Member States.

– *The EU's weighted voting system adapted to ESA (see accompanying panel):*
7. The EU's current weighted voting system
8. The one provided for in the Treaty of Nice.

– *Voting systems based exclusively on proportional representation:*
9. Simple majority of contributions.

* The contributions considered for the calculations are the 2001 totals. They reflect the distribution of contributions over the last 5 years, as the shares indicated in the annual budgets have remained relatively stable.

Evaluating the Efficiency of a Voting Rule

Assuming that N Member States vote either 'yes' or 'no' (no abstentions), there are 2^N different combinations of voting results. For 15 Member States, therefore, there are 32 768 possible combinations. The choice of voting rules applied determines how many of the combinations are 'winning combinations', i.e. those that result in a positive outcome to the vote. On this basis, the 'efficiency' of a voting rule, i.e. the chance that the vote has a positive outcome, can be measured as the *ratio of winning combinations to the total number of combinations.*

Such a voting-rule efficiency is obviously not a quality criterion, which justifies per se the preference of one voting rule to another. Although it is theoretically easier to achieve a simple majority than a two-thirds majority, since the efficiency with the simple-majority rule is higher than with the two-thirds-majority rule, there is good reason to prefer the two-thirds-majority rule in cases where a wider consensus between Member States is regarded as necessary to pass a decision. The extreme case is the requirement for unanimity. Although the statistical probability of unanimity is close to zero – as there is only one winning combination out of all the possible combinations of votes – unanimity is a widely established voting rule.

The voting-rule efficiency defined above does, however, allow the comparison of voting rules in terms of the statistical probability of producing positive voting results, as well as the study of the influence of an increasing number of voters.

As shown in graph 1**, the efficiency of the simple majority of all Member States rule is always 50% for an odd number of countries, but is lower for an even number. In the latter case, the existence of 'neutral' coalitions – where half of the countries vote 'yes' and half 'no' – lowers the number of winning coalitions and therefore the efficiency. It might be surprising at first sight that for an even number, the actual efficiency depends on the number of Member States. This is due, however, to the fact that the share of neutral coalitions in the overall number decreases as the number of Member States increases.

The influence of the number of Member States on the efficiency of a voting rule is even more striking for the two-thirds-majority rule, as is apparent in graph 2. The overall trend of decreasing efficiency with increasing number of Member States can be illustrated with the example of flipping a coin: for 3 coins, in 50% of the cases either 2 or all 3 coins show heads. For 15 coins, the likelihood of finding at least 10 coins showing heads is obviously much less than 50%. Also, under the two-thirds-majority voting rule, the evolution of efficiency is not linear with the number of

Graph 1

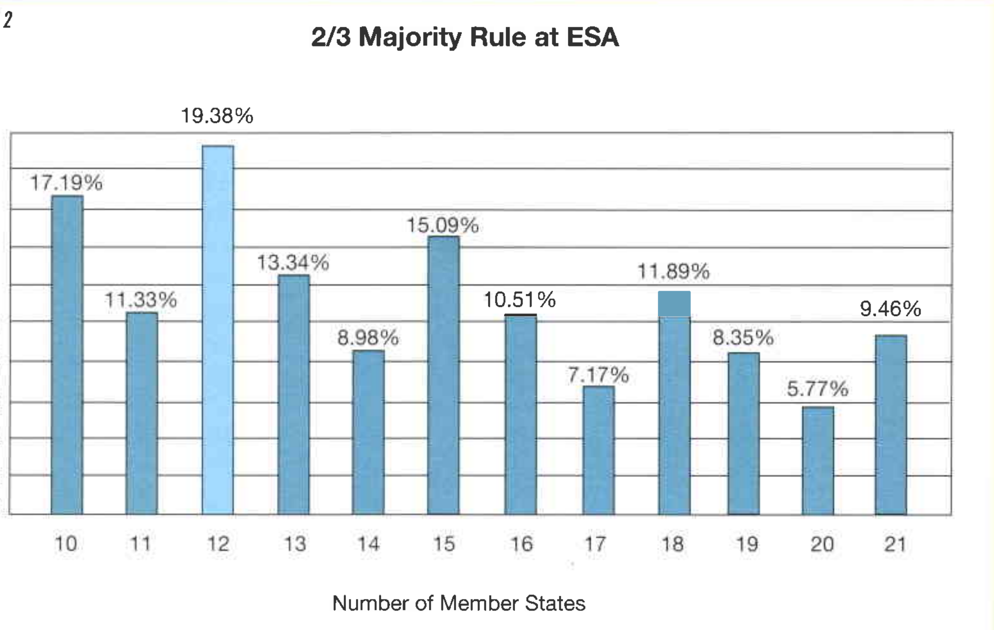
** ESA moved directly from 11 to 13 Member States because Austria and Norway entered the Agency as full members at the same time.

countries, i.e. it is higher with 21 voters than with 14, but varies monotonically by groups of three.

The probability of the ESA Council passing a randomly selected decision under the current and the alternative voting schemes is shown in graph 3.

It is also surprising that the simple-majority rule applied to a one-country, one-vote system (scenario 1) or to a purely weighted system (scenario 9) results in the same 50% efficiency level. In other words, *the efficiency of the simple-majority rule is independent of the distribution of weights per country.*

Graph 2



As is to be expected, the 'dual-simple-majority' decision rule, i.e. a simple majority of Member States representing a simple majority of contributions (scenario 4), is clearly superior in efficiency terms to voting rules that include a two-thirds majority (scenarios 2,3, 5 and 6). It also exhibits very little sensitivity to an increase in the number of Member States, which means it could constitute a long-lasting voting system by being able to accommodate potential future enlargements.

Compared to the 'dual-simple-majority' rule, the increase in the threshold on contributions from simple-majority to two-thirds-majority – while requiring a simple majority of Member States (scenario 5) – almost halves the likelihood of passing a randomly selected proposal. However, this decision rule still maintains a stable efficiency level in an ESA with 21 Member States.

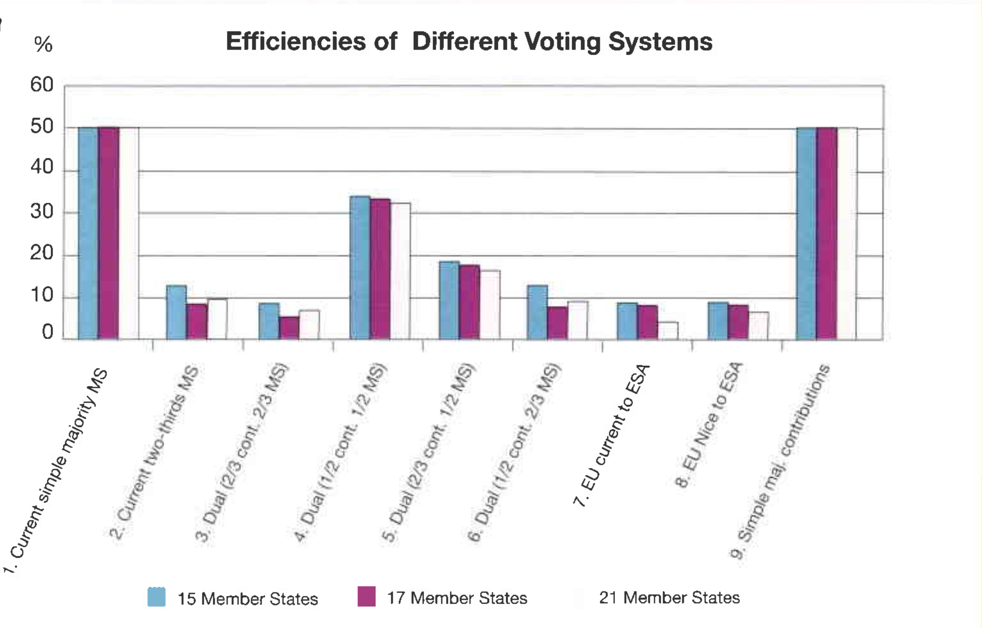
The decision rules including a two-thirds majority of Member States (scenarios 3 and 6) show a high dependency of efficiency on the number of Member States. An increase from 15 to 17 almost halves the efficiency !

The European Union's actual and potential weighted voting systems, when adapted to ESA, display efficiencies that are comparable to those of the existing ESA voting systems (scenarios 2 and 3), the adaptation of the 'Nice Treaty' system providing slightly better efficiencies than the adapted 'current EU system'.

Evaluating the Voting Power of Member States

A voter's power under a given decision rule is defined as the amount of influence that the voter has over the outcome of the vote. It is a measure of *the probability that the given voter can be critical to the final outcome of the vote* or, in other words, that the voter can reverse the outcome by reversing his/her vote. Hence, the more powerful a voter is, the more often the outcome goes the way he/she votes. Such

Graph 3

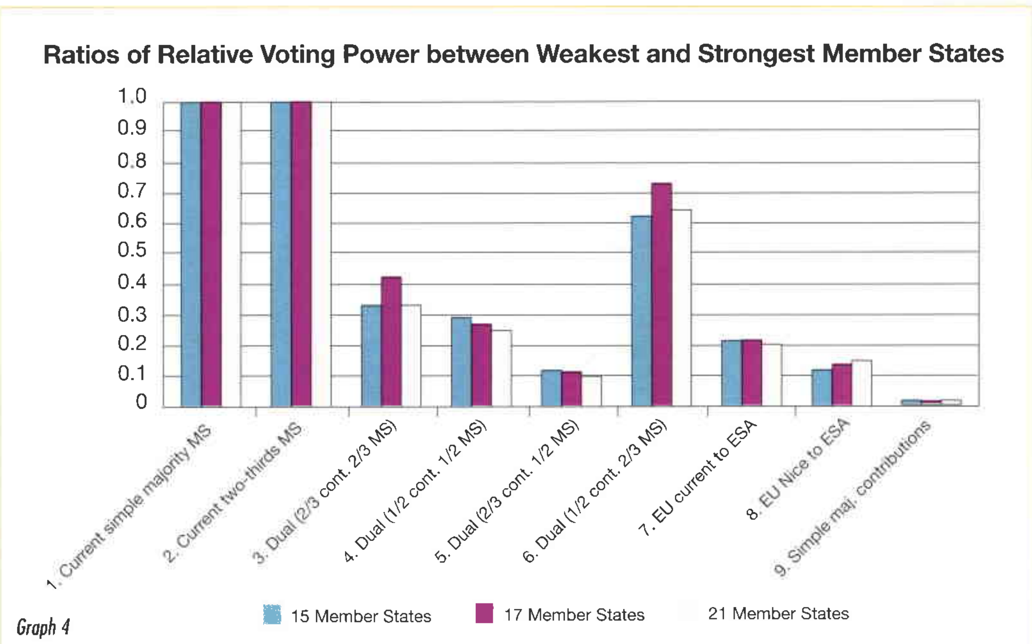


voting power is a purely mathematical parameter, independent of real-life factors like the ability to persuade or to convince other voters. Such factors might result in a much higher 'de facto' influence over the outcome of the vote than the statistical voting power alone indicates.

Of the voting schemes investigated, the one under which all Member States have the highest probability of being crucial to the final outcome is the dual-simple-majority rule, whereas under the double two-thirds-majority rule this probability decreases sharply*.

ratio of relative voting powers is 1 because the voting weights of all Member States are equal. Of the dual-majority schemes, the voting rule based on two-thirds of Member States and a simple majority of contributions (scenario 6) is the one displaying the least disparity in terms of voting power, while under the voting rule requiring two-thirds of contributions and a simple majority of Member States (scenario 5), the amount of influence exerted by the 'weakest' Member State over the outcome is low, amounting to about only 10% of that of the 'strongest' voter.

on an equal footing, while the second introduces a correspondence between the voting power and contribution level of a Member State, thus favouring the big contributors, avoiding their being out-voted by the smaller ones. Achieving the right balance between these elements is essential to arrive at a scheme acceptable to all Member States. However, even a purely weighted voting rule (as scenario 9) attains such a balance if the weights are chosen satisfactorily for all Member States. This could be achieved by applying weights that are not strictly proportional to contribution levels, in the same way that the weights in the EU system are not strictly proportional to the actual population levels.



Graph 4

Voting Practice in ESA: Majorities Required and Obtained

In order to determine the empirical efficiency of the ESA voting system, regarded as the Council's actual ability to act, decision items proposed to the ESA Council – excluding ministerial Councils – over a three-year period (1999-2001) were analysed. The results were compared with the theoretical efficiencies of each of the required majorities as defined above.

The analysis shows that the most commonly applied voting rule in the ESA Council is a two-thirds majority, applying to 44.4% of the decision items during the period, compared with 34.1% requiring a simple majority and 21.5% unanimity.

In term of the final outcome of decisions taken from 1999 to 2001, 89.6% of Council decision items were approved, 8.2% were rejected and 2.2% were withdrawn from the agenda. Of the items rejected, about half were required to be approved by a simple majority.

It should be underlined that, in practice, disregarding the majority required, Member States tend to seek unanimity. In fact, 60.7% of all decision items were

A picture of the relative voting power distribution of Member States for each of the assessed voting systems is given in graph 4 by comparing the ratios of power between the least and most influential Member States: the lower that ratio is, the larger is the difference between their relative voting powers.

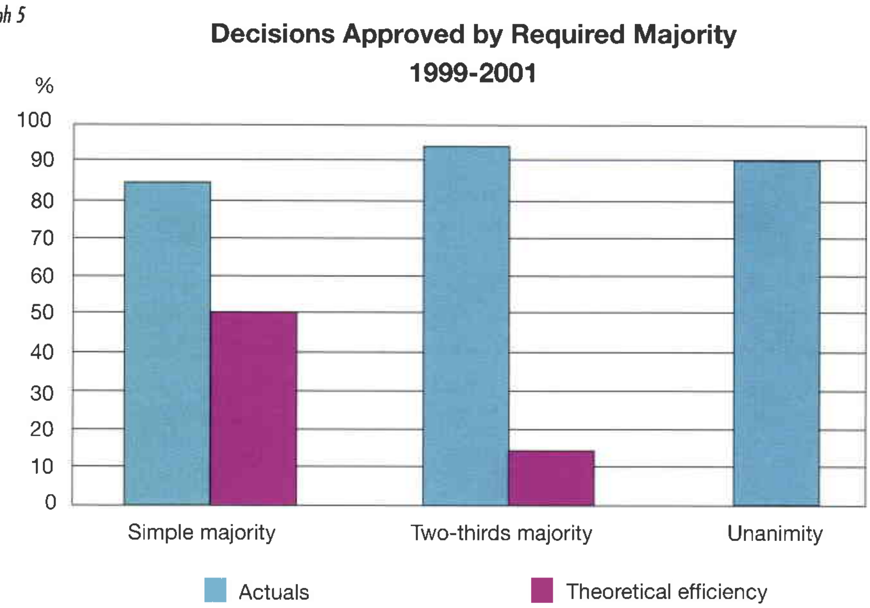
As is to be expected, under (non-weighted) one-country one-vote rules, the

From the graphs 3 and 4 above, it transpires that the combination of the different yardsticks – efficiency of voting systems and their sensitivity to enlargement trends together with the voting power of Member States – points to the dual simple majority as the most acceptable scheme for ESA on both efficiency and political-acceptability grounds. It also represents a long-term solution in that it could accommodate further ESA enlargement.

All dual schemes combine the element of 'one-country, one-vote' with the element of weighted voting. The first element puts small and large contributors

* As an example, under the dual-simple-majority scheme, France could reverse the outcome by reversing its vote in 38% of the cases, but only in 16% of the cases under the double two-thirds majority rule.

Graph 5



finally approved with unanimity, whereas only one-third actually required unanimous approval.

Based on the results obtained for each of the required majorities in the Council during the period 1999-2001, we can compare the actual percentage of proposals approved by the required majority and the theoretical efficiency of the voting rule (see graph 5).

It must, of course, be remembered that the theoretical efficiency is a mathematical parameter, which does not take into account the fact that the Executive does not propose random measures, or that coalitions of Member States do not form randomly around any proposal. In practice, therefore, the likelihood of a positive outcome under the three voting rules applied – simple majority, two-thirds majority, and unanimity – is considerably higher than the statistics predict.

Conclusion and Prospects

This analysis of the decision-making efficiency of the current ESA voting system has shown that – from a statistical point of view – the Agency's projected enlargement would not significantly affect the ability of Member States to approve a given measure. For the two-thirds-majority rule in particular, future enlargements would only moderately lower decision-making efficiency. Moreover, voting practice in Council shows that the empirical efficiency of the system is high and the agreement of all Member States to a given proposal is generally pursued and achieved.

Based on the results of our statistical analysis, ESA's potential enlargement would not require the introduction of alternative voting rules to maintain the Council's efficiency to act. The main concern is to construct a decision-making system that remains efficient and democratically legitimate for an enlarged Agency with up to 21 members. At the same time, the distribution of power, which represents the key to political acceptability, should be satisfactory for each incumbent Member State.

Our analysis of combinations of simple and two-thirds majority rules applied to a two-tier vote configuration (number of Member States + votes weighted on contributions) shows that the dual-simple-majority rule (simple majority of the contributions representing a simple majority of Member States) best combines high efficiency and a 'fair' distribution of voting power. This voting system would also represent a long-lasting reform as its efficiency and voting power distribution is rather insensitive to future ESA enlargements.

Examination of the recent voting behaviour of Council shows that its efficiency to act is significantly higher than statistical analysis predicts. In practice, the ESA Executive seeks to make proposals that are likely to be accepted by Council. The existence of subordinate bodies providing for a process not only of refining proposals, but also of consensus-building before an actual decision is sought, also explains the high level of voting efficiency in Council. The impact of future enlargement on voting efficiency is therefore expected to materialize not so much in statistical effects due to the larger number of voters, but rather in the increased complexity of reaching consensus, which is fundamental to the practical voting efficiency. esa

EAC Trains its First International Astronaut Class

Hans Bolender, Loredana Bessone, Andreas Schoen & Hervé Stevenin
Astronaut Training Division,
European Astronaut Centre (EAC), Cologne, Germany

EAC's first international astronaut ISS advanced training class, photographed in front of the Columbus module. From left to right: S. Furukawa (NASDA), S. Wilson (NASA), P. Nespoli (ESA), T. Reiter (ESA), P. Duque (ESA), K. Wakata (NASDA), L. Eyharts (ESA), T. Doi (NASDA), N. Stott (NASA) and A. Hoshide (NASDA)

After several years of planning and preparation, ESA's ISS training programme has become operational. Between 26 August and 6 September, the European Astronaut Centre (EAC) near Cologne gave the first ESA advanced training course for an international ISS astronaut class. The ten astronauts who took part – two from NASA, four from Japan and four from ESA – had begun their advanced training programme back in 2001 with sessions at the Johnson Space Center (JSC) in Houston and at the Japanese Training Centre in Tsukuba.

During their stay in Cologne, the ten astronauts participated in a total of 33 classroom lessons and hands-on training sessions, which gave them a detailed overview of the systems and subsystems of the Columbus module, the Automated Transfer Vehicle (ATV), and the related crew operations tasks. They were also introduced to the four ESA experiment facilities to be operated inside the Columbus module. After their first week of training at EAC, the astronauts were given the opportunity to see the flight model of the Columbus module being integrated at the site of ESA's ISS prime contractor, Astrium in Bremen. The second week of training at EAC included hands-on instruction on the Columbus Data Management System (DMS) using the recently installed Columbus Crew Training Facility.

In preparation for the first advanced crew training session at EAC, two Training Readiness Reviews (TRR) were conducted there in June and August. These reviews were supported by training experts and astronauts from NASA, NASDA and CSA (Canada), who were introduced to ESA's advanced training concept and the development process, and then analysed and evaluated the training flow, content and instructional soundness of lessons and courses, as well as the fidelity of the training facilities and the skills of the ESA training instructors. The International Training Control Board (ITCB), made up of representatives from all of the ISS International Partners and mandated to control and coordinate all multilateral training for ISS crew and ground-support personnel, testified to ESA's readiness to provide Advanced Training by declaring the EAC TRR successful.

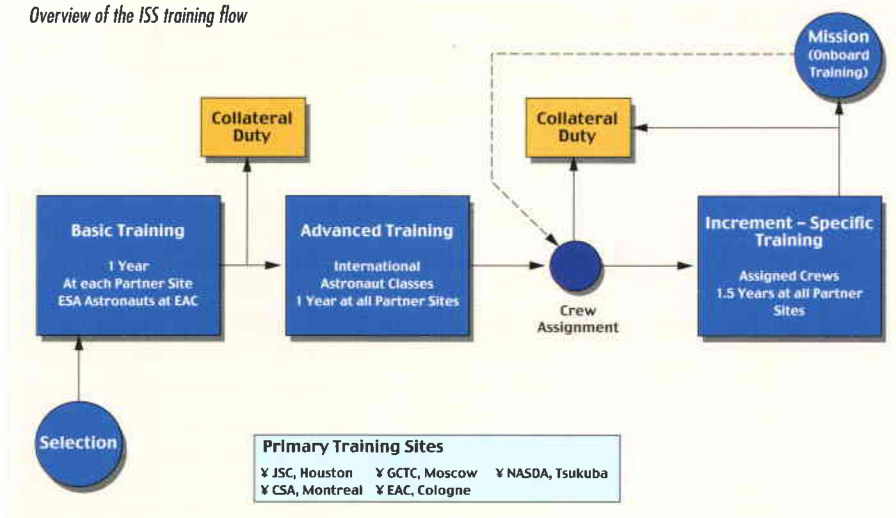
The completion of this first training course was therefore a good opportunity for the Astronaut Training Division to assess the status of its training programme. The comments and recommendations of the training experts and the astronauts who took part have been carefully evaluated and the results are being fed back into the on-going training development process.

The ISS Training Flow

The multilaterally agreed ISS training approach consists of three consecutive phases: Basic Training, Advanced Training and Increment-Specific Training.

The Basic Training, which takes a year, is provided independently by each ISS International Partner for its own astronauts. The next two phases of training are designed for international astronaut classes and are implemented at all International Partner training sites. During these so-called 'multilateral training phases', each Partner is responsible for providing training to all ISS astronauts for those elements that it is contributing to the Space Station Programme.

Overview of the ISS training flow



ESA's main contributions to the ISS, for which EAC therefore provides crew training, are the Columbus module, including the four ESA payload racks (EDR: European Drawer Rack, FSL: Fluid Science Laboratory, EPM: European Physiology Module and Biolab: Biological Laboratory), and the Automated Transfer Vehicle (ATV).

Basic training

This first training phase for newly recruited astronauts focuses on providing the fundamental knowledge, attitudes and skills needed by a professional astronaut. It includes an introduction to space activities (organisations and current programmes), spaceflight fundamentals (e.g. engineering, and life and biomedical sciences) and space systems and operations (e.g. US Space Shuttle, Soyuz and ISS, incl. ESA contributions). It also fosters the development of the basic skills considered necessary for future astronauts, such as scuba-diving training in preparation for Extra Vehicular Activities (EVAs), media skills for pubic-relations purposes, and Russian language training.

Advanced training

This also lasts a year and provides a more in-depth understanding of ISS systems and subsystems, payloads and payload support systems, transport vehicles and related operations. It focuses on generic ISS onboard tasks and the interactions with the ground control centres, and thoroughly prepares crew members for their first flight assignment. As new elements, payloads and capabilities are added to the ISS, the content of the Advanced Training curriculum is augmented to reflect the current Station configuration. It is organised around generic crew jobs and thus includes some specialisation in terms of robotics skills, EVAs or other foreseen tasks. A crew member completing the Advanced Training is immediately eligible for assignment to a range of missions.

Increment-specific training

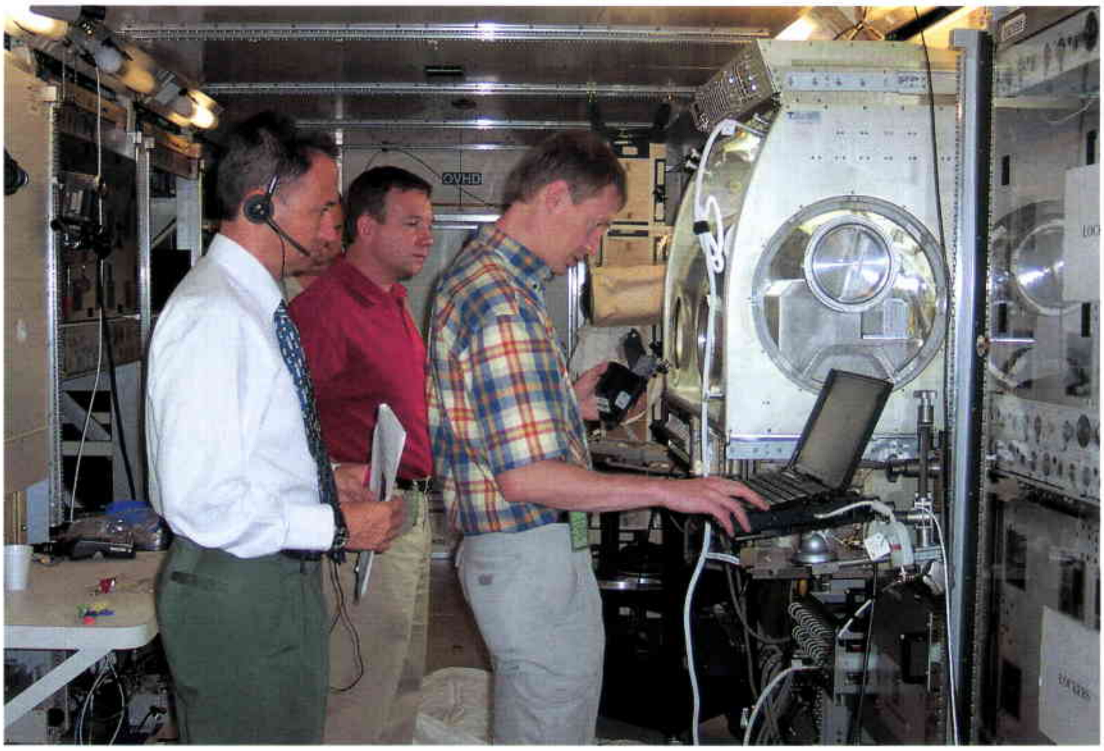
This final training phase lasts 18 months and its primary objective is to prepare the prime and backup crews assigned to a specific ISS flight for performing all of the activities planned for that particular flight Increment. This includes standard operations and maintenance tasks for systems and payloads, as well as such preventive maintenance as exchanges of Orbital Replaceable Units (ORUs) or particular assembly tasks like the activation and checkout of new ISS elements.

The training conducted at the International Partner's sites focusses mainly on single ISS elements or modules. Other so-called 'Multi-Segment Training' is performed at the Space Station Training Facility (SSTF) in Houston. As well as addressing on-board activities like emergency procedures, it also provides interface training for the on-board crew and the mission controllers at the various control centres. The training of individual crew members is tailored to the tasks assigned to each of them in the Crew Qualification and Responsibility Matrix (CQRM) for each ISS Increment.

The Training Challenges

Several factors combine to make the ISS crew training activities more complex and hence more challenging than any training programme that EAC has previously undertaken:

- The multinational nature of the ISS programme results in a large number of interfaces, calling for extensive and intensive consultation and coordination between the Partners.
- The decentralised training at sites around the World calls for carefully harmonised training concepts to avoid omissions or repetitions.

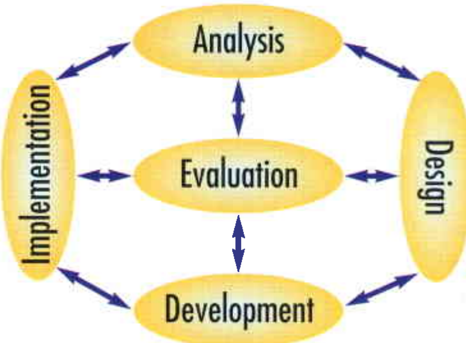


The ODISSEA crew, who visited the ISS on a Soyuz taxi flight in October 2002, receiving ISS training at the SSTF facility in Houston. ESA astronaut Frank De Winne (right) and his Russian crew mate, Yuri Lonchakov (centre) during their experiment training on the ESA Microgravity Science Glovebox (MSG), supervised by the EAC Training Coordinator, Hervé Stevenin

- The limited crew training time available dictates the use of the most effective training concepts in order to achieve the training objectives as quickly and as straightforwardly as possible, especially when dealing with astronaut classes consisting of crew members with diverse cultural and professional backgrounds.
- The different crew task and qualification level assignments require the training programme to be tailored to the actual tasks and responsibilities of each crew member.
- Last but not least, the training programmes for Increment crews have to be harmonised with those for the Shuttle and Soyuz crews who visit the ISS, to ensure that all of them can work together safely and effectively onboard the Space Station.

ESA and its International Partners have taken up these challenges, implementing a variety of measures and initiatives in order to provide highly skilled crew members capable of working safely and efficiently in the ISS environment.

The ISS Partners have agreed on using the same approach to training development, resulting in a harmonised training concept and structure. The underlying philosophy of the approach, relying on an Instructional System Design (ISD) based on research in learning psychology and addressing the shortfall between current and required knowledge and skills, is shown in the accompanying figure.



Phases of the Instructional System Design (ISD) approach used for astronaut training development

Payload Crew Training

The payload training is one of three main elements of the ESA-provided ISS training, together with the Columbus and ATV system training, and is a good example of the ISD development principles being applied.

Payload training is being developed for all four ESA microgravity research facilities: the Fluid Science Laboratory (FSL), the European Physiology Module (EPM), a biological research facility called Biolab, and the European Drawer Rack (EDR). EAC is also supporting NASA for the development and implementation of training for the Material Science Laboratory (MSL).

Payload training is founded on three closely interrelated building blocks:
- the payload courseware
- the payload training facilities and training tools
- the payload instructors.

Development of the training courseware has been contracted to an industrial consortium led by Lufthansa Flight Training (LFT), and including SAS (Brussels) and the companies developing the payload flight models for ESA (Astrium, Alenia and OHB). The payload developers are responsible for the on-board task analysis, for defining the training requirements and training manuals, and for developing lessons in close interaction with the payload training model developers. A Curriculum Board headed by LFT elaborates guidelines and standards and co-ordinates the courseware development. The course materials – training manuals, handouts, technical documentation, photos, videos and computer-based training aids – for all payloads are being produced by SAS. A

Steering Board, headed by the ESA Astronaut Division and consisting of representatives from each company involved, oversees the Curriculum Board and the courseware production.

The payload instructors have already undergone an introductory training phase at EAC and have participated in Instructor Training Courses at NASA-JSC and at EAC, familiarizing them with the methods and techniques of Instructional System Design. The development of training lessons and materials forms part of their on-the-job training and counts towards their instructor certification.

Hands-on training on the Data Management System (DMS) in the Columbus Trainer at EAC during the Advanced Training in August 2002

Columbus Crew Training

This training prepares the crew to monitor, operate and maintain the Columbus module's systems and subsystems.

During the *Advanced Training*, the astronauts are familiarised with the technical layout of the module, its characteristics and capabilities, and the operational concepts and modes. They receive knowledge-based training on the different systems and subsystems, their components, functions and redundancies. Special attention is paid to the Data Management System (DMS) – as seen from a crew operations perspective – which is a central element of the Columbus module. Working with crew displays, navigation within those displays, and the monitoring and commanding are other key elements in this training phase. The concept, locations, functions and maintenance of the Orbital Replaceable Units for Columbus are also covered. This knowledge-oriented part of the training is concluded with instruction in the Columbus operational modes. After completing this course, the crew begin hands-on training in the Columbus Crew Trainer.

The content of the *Increment-Specific Training* for the Columbus systems is driven by the overall activity plan for the particular ISS Increment and the tasks assigned to the various crew members. Major topics in this training phase are the preventive/corrective maintenance planned during the Increment, the day-to-day onboard activities to be performed using the various onboard tools, and understanding how the different ISS elements function together. During the Multi-Segment Training in Houston, the crew train to operate the Station as an integrated system. This includes the emergency training that the crews need to handle such emergencies as fire, rapid depressurisation or toxic spills.

Aside from the technical and operational content, team-building is an important element of the Increment-Specific Training.

ATV Crew Training

The ATV training focuses on three major areas: rendezvous and docking, cargo operations, and emergencies.

As the ATV docks automatically with the Station – monitored by the ground controllers and the crew – intervention possibilities during rendezvous and docking are rather limited. The crew can, however, monitor the approaching vehicle on video and via the data on their onboard displays to check that it is on a safe trajectory. If not, they can intervene to halt the approach and command the vehicle to a safe and collision-free orbit. This training is therefore very important for overall Station safety. The close interaction between the onboard crew and the ATV ground controllers in such situations is fostered during integrated simulations involving the ATV Control Centre and the ATV Crew Trainer (ACT), located at EAC.

The ATV will re-supply the ISS with a wide range of dry cargo, water, gases and fuel. Experience with the MIR space station and the first ISS Increments has shown that the complexity of cargo operations/handling can often be underestimated. After familiarisation with the basic ATV cargo operations, crews will therefore be trained to handle the actual cargo complement to be flown on the particular ISS Increment. When unloading cargo from the ATV and re-loading it with trash, for example, care has to be taken to keep the vehicle's centre of mass within a certain range to allow safe un-docking and departure from the Station.

The ATV emergency training covers all types of events, including potential emergencies specific to the ATV and ISS 'generic' emergencies that could have an impact on the ATV. The overall ATV training programme being conducted at EAC will therefore ensure safe and efficient operation of the ATV by the ISS crews.

Evolution of ISS Crew Training

A major issue for the ISS training community is the constant evolution of the ISS Programme, reflecting changing boundary conditions as well as learning from in-flight operational observations and post-flight crew feedback. As the Station grows and more International Partners have to provide their training, the requirements become more stringent and crew training time becomes an ever more critical resource. This makes careful harmonisation and integration of training flows to achieve greater efficiency and

ESA Training Facilities

In order to carry out the ISS training programme, training facilities had to be developed that represent the Station's flight equipment and systems both mechanically and functionally, and which provide the fidelity required by the complexity, specialized nature and safety implications of the tasks to be trained for. The choice of site for those facilities – EAC, Johnson Space Center or the Gagarin Cosmonaut Training Centre – is driven by the need to provide representative training for integrated payload-system and multi-segment operations whilst minimizing travel requirements for the astronauts.

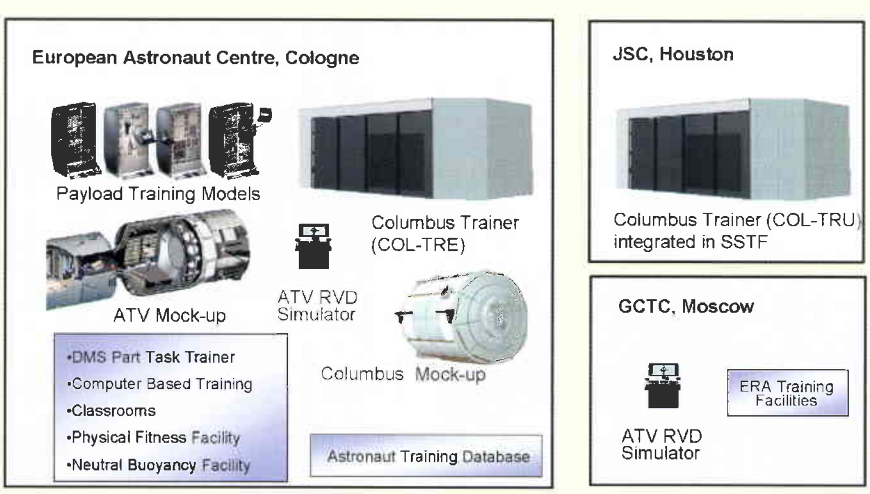
The two almost identical Columbus trainers located at EAC in Cologne and at Johnson Space Center in Houston provide high-fidelity simulation of the Columbus Data Management System (DMS) and its other systems and subsystems, but differ in terms of their simulation of payload/system interaction and of the interface between Columbus and the American in-orbit systems of the ISS.

The Columbus Trainer will soon be supplemented with a Columbus mock-up for crew familiarisation with the module's topology and equipment locations, and training for mechanical tasks, especially preventive and corrective maintenance. It is planned to partially integrate the mechanical and functional simulation to provide realistic training for such complex maintenance tasks as the deactivation, exchange, re-activation and checkout of failed Orbital Replaceable Units.

Interaction with the DMS lies at the heart of Columbus operations. To provide the crews with a clear understanding of its internal architecture, processes, functions and redundancies, a special task trainer is being developed, providing visual animations of DMS components and functionalities, and functional simulations of some dedicated DMS processes.

The automated docking of the ATV to the Russian Service Module is a safety-critical manoeuvre in terms of overall ISS safety. The ATV Crew Trainer at EAC therefore includes a high-fidelity rendezvous and docking simulator which will be used to train crew members for monitoring that critical event. A combined mockup of the ATV and the Russian Service Module is under development and will be delivered to EAC in early 2003. It will be used to train for cargo operations like the unloading of dry cargo, water and gas transfer to the Station, and the loading of trash into the ATV.

The Payload Training Facilities at EAC will be of two different types. The stand-alone Payload Training Models are full-scale mechanical and functional representations of the payload racks, with high-fidelity crew interfaces and maintenance-training capabilities. The Columbus Trainer will be supplemented with simulators for the ESA payloads, fully integrated into their rack positions. These simulators include full-scale representations of the payload front panels, activated by a software simulation model running on a dedicated work station.



The ESA Training Facilities

effectiveness of the overall training programme, exploiting synergies and reducing redundancies, an absolute necessity.

One of the training team's future tasks is therefore to develop a process for the distribution of training time to the Partners based on exact Increment training requirements. Crew feedback after flights also indicates a need to redefine the operational relevance of different areas of the training, which also implies a higher degree of fidelity for the training facilities.

Conclusion

As a result of the decision to delay the launch of the Japanese Experiment Module for the ISS to 2006, ESA will be the next International Partner to launch its ISS module. Changes being made to the Assembly Sequence also indicate that the Columbus launch, planned for October 2004, will no longer be a crew-exchange flight, but most likely a visiting-Shuttle flight. The Increment crew onboard the ISS when Columbus arrives will have already arrived in July 2004.

Under this scenario, preparation and implementation of the training for the 1E Shuttle flight and the respective Increment will be a special challenge, not only because it is the first flight-specific training to be provided by ESA, but also because it requires training for one Shuttle crew and one prime and one back-up Increment crew. Moreover, the training for the Increment crews needs to be advanced by three months compared with the original schedule. According to the draft assembly sequence, the first ATV launch is scheduled for the same Increment. In this case, the Increment crews will also have to be prepared for ATV crew operations.

The latest training schedule updates are currently being prepared, and Shuttle and Increment training coordination with the NASA training counterparts has been initiated. The first Increment-specific crew training at EAC can be expected in the last quarter of 2003. Preparations have therefore already started and we are confident that we are on the right track to meet the challenge ! esa

European Space Technology

Stephane Lascar, Marco Guglielmi, Antonio Martinez de Aragon, Maurizio Nati, Edmund Williams & Luca Maresi
ESA Directorate for Industrial Matters and Technology Programmes, ESTEC, Noordwijk, The Netherlands

Harmonisation and Strategy

– From Concept to Master Plan

The process of harmonizing and developing a future strategy for European space technology was initiated in 2000 in response to the adoption of a Resolution titled 'Shaping the Future of Europe in Space' at the ESA Ministerial Council in May 1999. This Resolution notes that

"...the new and demanding challenges of the 21st Century call for a concerted European effort, so that Europe achieves its fullest potential international cooperation and world competition".

The Technology Harmonisation and Strategy Initiative has therefore been developed to achieve better coordinated Research and Development (R&D) activities among all European space sector players, and to establish a strong technology base as a key to the worldwide competitiveness of European Industry and the success of future space missions. The strategy involves establishing a coordinated *European Space Technology Policy* and preparing a *Technology Master Plan* through a process of concertation, coordination, harmonisation and agreement between ESA's Member States, the European Commission, European Industry and ESA itself.

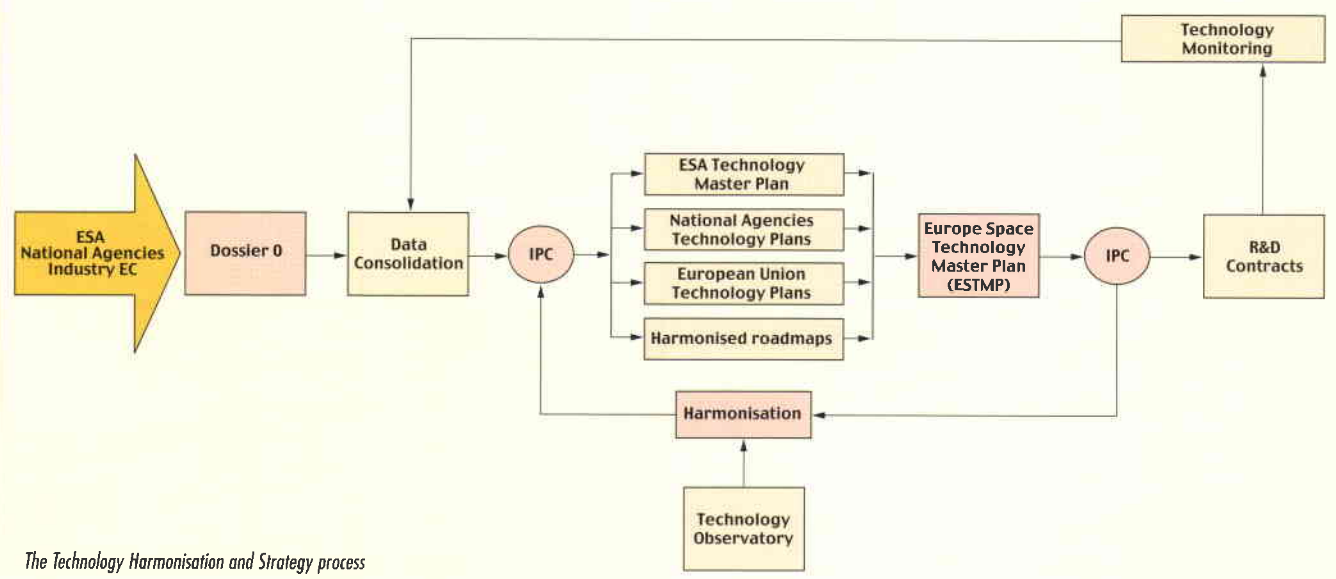
The 'European Strategy for Space Technology Workshop' in Seville, Spain, in May 2000

A Workshop was organized in Spain in May 2000, by ESA's Technology Programmes Department in cooperation with the European Commission (EC), Spain's 'Centro para el Desarrollo Tecnològico e Industrial' (CDTI) and Eurospace (representing the European space industry), to present to Delegations and Industry ESA's approach to the implementation of the May 1999 Council mandate on technology and to solicit their opinions. The participants at this Seville Workshop agreed that Europe had indeed to unify and coordinate its space-technology activities via a coherent European policy.

The necessity to identify needs, to map European capabilities and to define common European roadmaps for future developments was outlined and an overall process was established based on:

- Identification of technology needs for European programmes, strategic areas for European independent capabilities and leadership, and the competitiveness of European industry in both the short and long term.
- Acquisition of a complete overview of all relevant technology-development activities in Europe and the relevant skills, specifically at European and national level, including industry and academia.
- Definition of implementation guidelines and funding for the necessary technology R&D activities, harmonised in a coherent and co-coordinated Master Plan.

Under the overall co-ordination of ESA, the European space sector is elaborating a technology strategy based on top-level needs (Dossier 0), on the mapping and harmonisation of European development and competences, and on a co-ordinated European Space Technology Master Plan (ESTMP). This plan embraces today's technology needs, current and future European developments, industry capabilities and budgets to enhance the complementary role of the various partners in meeting common objectives. The whole effort is based on a voluntary process, transparency and the free exchange of information.



The Technology Harmonisation and Strategy process

The process starts with the elaboration of a 'European Space Technology Requirements Document' (Dossier 0) in which all European missions and technology requirements are gathered from all ESA Directorates, National Delegations, Industry and Operators. These requirements are then analysed, and synthesized.

The second cornerstone of the process is the 'European Space Technology Master Plan' (ESTMP), which constitutes a complete overview of planned institutional space-technology programmes in Europe and includes harmonised roadmaps. The analysis of these planned European R&D activities with regard to technology requirements forms the basis for conducting the technology-harmonisation activities with the European stakeholders.

A further strategic element is the 'Technology Observatory'. Its function is to support the harmonisation process with specialized inputs at critical points along the way.

The Technology Monitoring activities close the process loop by providing the feedback needed to measure the performance of the process, and to support continuous improvement.

The actual implementation of the R&D contracts is carried out through the various existing ESA or national programmes.

These principles and guidelines agreed in Seville were endorsed by ESA's Industrial Policy Committee (IPC) in May 2000. The ESA Ministerial Council, at its meeting in Edinburgh in November 2001, reaffirmed ESA's central role in the coordination and harmonisation of the European strategy and policy for space technology and invited the Agency and its Member States to pursue, together with the other players in the space sector, the programmatic coordination and harmonisation of technology programmes in Europe. The accompanying Ministerial Council Resolution confirmed the vision embodied in the joint ESA-EC Strategy for Space for strengthening the foundations of Europe's space activities.

The Edinburgh Ministerial Council:

1. REAFFIRMS the need for a strong technology base as the key to the worldwide competitiveness of European industry and the success of future space missions.
2. REAFFIRMS the central role of the Agency in the coordination and harmonisation of European strategy and policy for space technology and WELCOMES the good progress demonstrated in pilot cases.
3. INVITES the Director General and Member States, together with other players in the space sector, to:
   a) pursue the programmatic coordination and harmonisation of technology programmes in Europe and prepare the European Space Technology Master Plan as a further step to the recently developed ESA Technology Master Plan;
   b) define road-maps and harmonised implementation schemes for the development of critical technologies, involving industrial funding as appropriate; and
   c) define appropriate measures to ensure consistency between the European Space Technology Master Plan and ESA's industrial policy.

The European Space Technology Requirements Document

Dossier 0

The European Space Technology Requirements Document is intended to collect in a single text, and provide a complete overview at European level of, all the envisaged future missions and their associated technology requirements, including those related to 'technology push'. This document is the starting point for and a key element of the global technology strategy developed by ESA, which extends from the collection of the technology requirements, through to the implementation of the actual technology-development activities. Moreover, Dossier 0 is an important tool for the generation of the individual ESA, European Commission and national space-technology plans. Inputs are provided by all ESA Technical and Programme Directorates, by the national Delegations, the European Commission, and by European Industry through Eurospace and European Prime Contractors and by other interested parties.

The first version of the Dossier 0, issued in 1999 and widely circulated to Industry and Member State Delegations, was well received, confirming its importance within the overall European technology strategy. With the March 2002 issue, an effort has been made to improve the traceability of the inputs, the structure and the content of document, and its coverage.

The 2002 update of Dossier 0 on CD-ROM

The consolidation process

The data collected in Dossier 0 have been further processed in the Consolidated Dossier 0 (Dossier 0-C) with the aims of improving the document's overall legibility and completeness, and of providing a consolidated view of the technology requirements in order to better identify synergies and commonalities.

The consolidation process was strongly supported by all ESA Directorates, in particular the Directorate of Technical and Operational Support and, when needed, by Industry, Eurospace and the national Delegations. The Dossier 0 data was reviewed by 25 panels of ESA experts to:

(i) establish the 'Technology Tree' (which provides a detailed classification in terms of technology domains, sub-domains and groups of technological know-how required in space activities; and

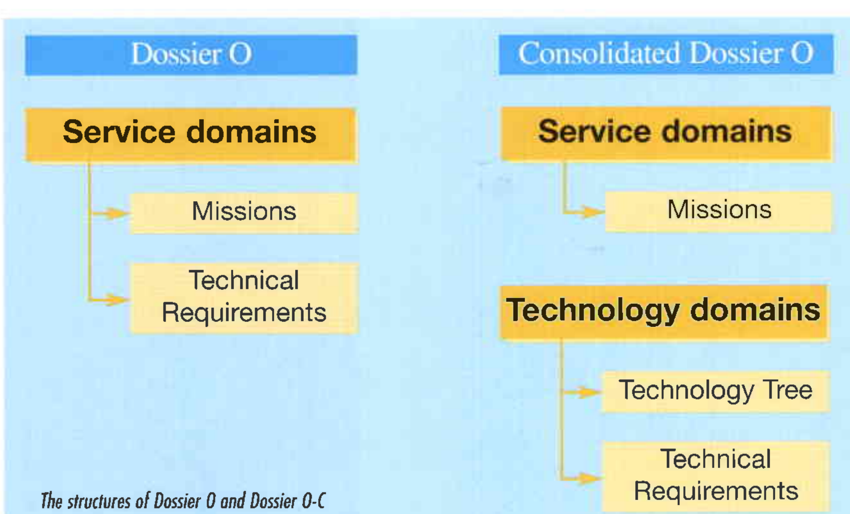
(ii) carry out a thorough analysis to ensure the coherence, completeness and correct classification of the various requirements within the Technology Tree.

Although the contents of the Dossier 0 and Dossier 0-C are similar, the document structures differ significantly.

The Dossier 0 data are organised into service and application domains, while in the consolidated document all missions are grouped together and the technology requirements are organised into technology domains. In practical terms, this allows a technology expert to find all of the technology requirements pertaining to his/her field of technical expertise grouped independently of the application. This helps considerably in identifying synergies and commonalities across various applications.

The evolution process

Dossiers 0 and 0-C are already playing a valuable role in European space-technology strategy. As they evolve further, more contributors will be included, thereby providing ever-growing benefits to the European space community. Subsequent yearly updates will increase both their validity and completeness. Web-based informatics tools are being developed to facilitate participation in the voluntary contribution process and to speed up the updating process.



The structures of Dossier 0 and Dossier 0-C

The Space Technology Harmonisation

The harmonisation initiative is based on two assumptions: firstly that the resources for basic space R&D need to be better coordinated and prioritized; and secondly that dedicated public budgets for space-technology developments in Europe will continue to be constrained, and consequently R&D should be increasingly financed through co-funding, partnership, cooperation and concertation schemes, and space agency / EC / industry agreements.

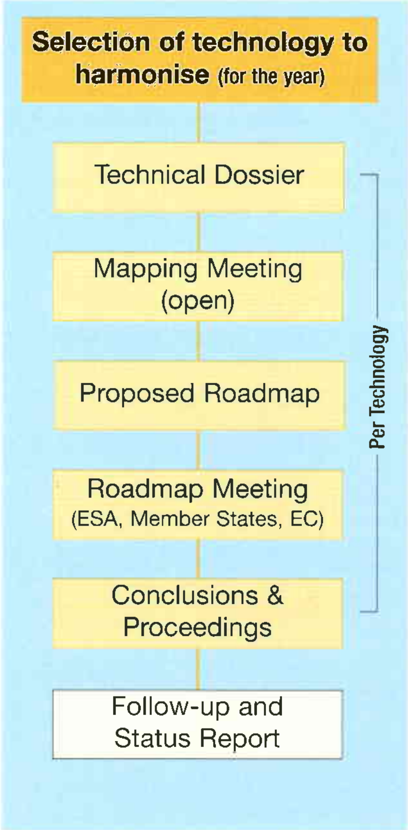
The technology-harmonisation process takes into account the various European developments, capabilities and budgets to enhance the complementary roles of the various partners in meeting common objectives. Success relies first and foremost on exchanging information on future plans and on results from on-going developments between participating stakeholders, and on the interest and willingness of these stakeholders to discuss and agree on a common and concerted approach for the benefit of both Europe's industry and its space programmes. ESA is playing a central role in this process, facilitating – through coordination, documentation, recommendation and synthesis – a fruitful dialogue between the ESA Directorates, the national Delegations, the European Commission and Industry.

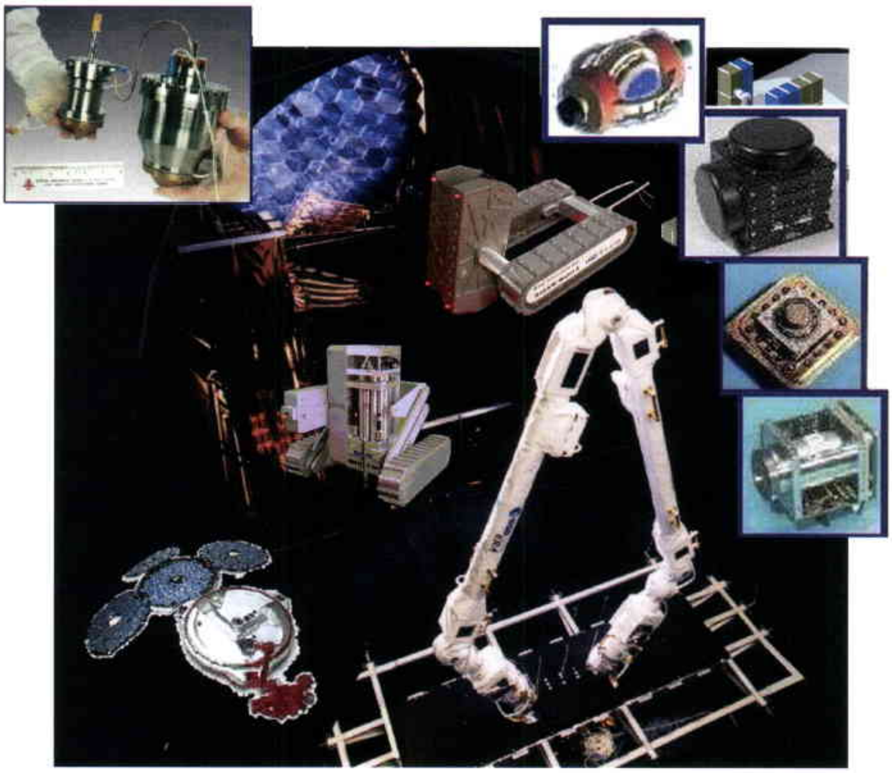
Given the novelty and wide-ranging scope of the harmonisation process, a methodology was tested on pilot cases in 2000 and 2001, covering different situations in terms of technology maturity, industrial competitiveness, funding needs and political interest. The pilot cases selected were: solar arrays, electric propulsion, and synthetic-aperture radars in 2000; and cryogenics, attitude and orbit control system sensors and robotics in 2001.

The methodology followed is based on two meetings per technology. The first is open to all players (Industry, National Agencies and Delegations, Operators, EC and ESA's Programme and Support Directorates). Its objective is to achieve as complete a mapping as possible of the technology in question. ESA introduces

Technology Harmonisation

The major objectives of the harmonisation process are to:
- optimise public investments in space-technology R&D
- fill strategic gaps and reduce unnecessary duplication
- ensure a fair role for each player
- specialise skills and strengthen industrial cooperation
- determine the R&D priorities to satisfy European space ambitions, commensurate with the available resources
- arrive at a coordinated and committed European Space Technology Policy and R&D programme.





the future mission and market needs, the worldwide technology trends, the European state of the art, competitiveness and strategic interest. National Delegations present their on-going activities, industrial expertise and plans. Eurospace presents the space-industry-coordinated capabilities, needs, and recommendations.

The second meeting is restricted to the funding parties (Delegations, EC, ESA). Its purpose is to discuss and agree on road-maps for future R&D activities, covering all programmatic aspects. Items for discussion and decision include what needs to be developed and by when, and the identification of sources of finance and possibilities for sharing skills, expertise, capacities and resources with potential partners. Issues such as maturity, target readiness, and competitive impact and position are also assessed.

Feedback on the pilot phase from all participants has been very positive. The mapping meetings and the supporting documentation have provided increased visibility of the opportunities and challenges related to specific technologies and market segments. The agreed road-maps have guided the various players in planning their R&D efforts in the corresponding technology areas.

The benefits obtained from harmonisation can therefore be summarised as:
- Increased visibility of the European situation for the technologies covered.
- Identification of inefficiencies.
- Contributions to skills specialisation and the strengthening of cooperation between companies across Europe.
- Helping in establishing and improving contacts and developing partnerships.
- Facilitating the adoption of strategic decisions by Delegations, which may reorient their national plans and help their industry to improve its competitive position.
- Constituting an essential step towards the optimisation of public investments and the achievement of a European Space Technology Master Plan.

The November 2001 harmonisation meeting concluded the pilot phase, and included a discussion with Delegations about lessons learnt and the way forward.

Harmonised Technologies

2000	2001	2002
• Solar Arrays • Electric Propulsion • Synthetic-Aperture Radar	• Cryogenics • AOCS sensors • Robotics	• Aerothermodynamics • On-board Radio Navigation Receivers • Thermal and Space Environment Software Tools and Interfaces • Energy Storage (Batteries) • Onboard Computers and Data Systems • Mechanisms and Motors • Chemical Propulsion • Ground-System Software

It was agreed to:
- Conduct technology harmonisation on a routine basis.
- Identify and plan harmonisation meetings well in advance.
- Retain the two-meeting approach.
- Increase the number of cases handled every year, with a target of two cycles/year (4 meetings and 8 cases per year).
- Revisit each case on a regular basis (every 2 to 3 years), to assess results and update the road-map.
- Prepare and distribute relevant documents (technical dossier, tentative road-map) to participants before each meeting.
- Provide annual feedback to Delegations and Industry regarding progress in harmonisation.

The harmonisation process proper started in January 2002 with the discussion and approval by ESA's Industrial Policy Committee (IPC) of the cases to be handled this year. The first four technologies were harmonised during the first quarter, and harmonisation of the second set will be completed by December.

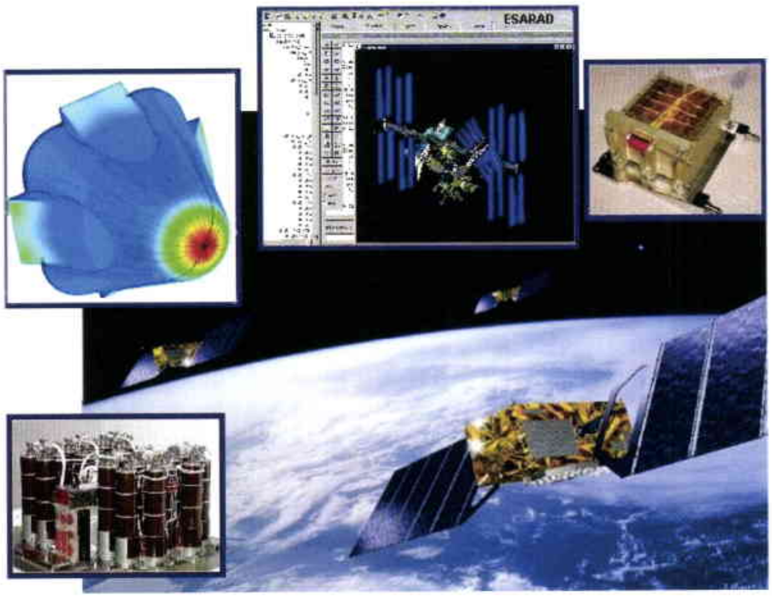
The European Space Technology Master Plan (ESTMP)

The ESTMP has its roots in the Technology Plans of the Member States of the EC and of ESA, which are synthesised in a manner comparable with the high-level requirements retained in ESA Dossier 0. It supports the on-going harmonisation process by identifying any gaps and overlaps. The ESTMP will increasingly be established based on technology road-maps agreed at European level, giving the European stakeholders an overall view of planned European institutional technology activities. It will provide a reference for the next iteration of Technology Work Plans for ESA as well as its European partners, thus becoming a common tool to define technology strategy and policy at both national and European level.

In addition to providing an overview of how the contributing national, ESA and EC technology authorities are structured and their programmes are funded, the ESTMP describes the various technology programmes and lists the key contact persons for the technology development activities in ESA, National Delegations, EC, and Industry within the Member States and sometimes beyond.

Generation of the ESTMP was initiated back in March 2002 with a letter to the Delegations and to the key ESA players, announcing the ESTMP activities and describing the process milestones. Most Member State Delegations have subsequently been briefed by key ESA Technology Programme staff regarding the Agency's approach to the ESTMP, to facilitate their participation. Similar contacts with EC representatives have become part of the ESA/EC Joint Task Force technology Working Group.

Strong support and interest was expressed by both ESA Delegations and ESA Programme Directorates for this common tool.



The first issue of the ESTMP (1.0) was presented to the Agency's Industrial Policy Committee (IPC) on 27 November. The IPC warmly welcomed the document and its associated database and recommended its extensive use at national and European level. The ESTMP will be presented to the ESA Council in December 2002.

Technology Monitoring

One of the essential components in formulating and implementing an effective technology strategy is knowledge of the results of past activities and their overall coherence with the strategies and policies of ESA and its Member States. ESA has therefore initiated a Technology Monitoring Study to develop a framework for assessing the impact of ESA R&D activities on European Industry.

As a validation exercise, a pilot study has already been run, selecting a limited set of past technology-development activities. A detailed questionnaire identifying the outputs of the R&D activities in terms of generation of patent applications, publications, etc. has been compiled with the help of the industries involved. The study is now in its final phase and the preliminary results are promising.

The Technology Observatory

The watch on key activities related to technology developments both inside and outside Europe is a further element of the technology strategy being developed by ESA. Within the remit of the 'Technology Observatory', therefore, information is being gathered concerning:

- European Industrial R&D capability mapping, including the identification of best practices.
- Identification of technology-dependence issues.
- Space-technology watch outside Europe.
- Non-space-technology watch within Europe.

The envisaged output from these Technology Observatory activities is a series of reports, which ESA will be making available to the National Delegations and the technology strategy units of European Industry. The first issues are planned by end of 2002.

Conclusions

ESA's central role in defining a European strategy and policy for space-technology R&D, coordinating the corresponding programmes and harmonising the activities resulting from their implementation, was reaffirmed at the Ministerial Council in November 2001. Space-technology research, development and demonstration must ensure effective technological preparation for future space programmes, leadership in some selected areas, and support the worldwide competitiveness of European space industry. ESA has therefore developed a comprehensive process for ensuring the implementation of these challenging strategic goals:

- Dossier 0 (now in its second edition) compiles at European level future missions and the technologies they require along with technology 'push'.
- The European space-technology harmonisation process, which is voluntary and transparent, is very strongly supported by Delegations and Industry, and this is key to its success. After the pilot phase in 2000 – 2001, the process is now in a 'running' phase that will result in 14 technology areas being harmonised by the end of 2002, with better-coordinated R&D plans and well-targeted industrial activities.
- The European Space Technology Master Plan documents the European R&D activity and guides its implementation. The ESTMP is a frame document that identifies, incorporates and analyses the European technology developments that are institutionally funded. As they are established, discussed and agreed, the harmonised road-maps will constitute the core of this Master Plan.

The process of defining a European strategy and policy for space-technology research, development and demonstration is highly dynamic, with active feedback throughout its various phases and frequent interactions with all parties involved. Dossier 0 and the ESTMP will be updated on a yearly basis, the harmonisation being a more continuous process with the objective of revisiting the technology road-maps on a 2 to 3 year basis.

Acknowledgement

The authors would like to thank the National Delegates, Industry and Eurospace for their strong and continuous support, to highlight the substantial contributions of the ESA Directorates and in particular the Directorate of Technical and Operational Support, and to acknowledge the work performed by A. Atzei, M. Novara and P. Cordero-Perez who initiated this whole effort. Special thanks also go to Dr. H. Kappler and N. Jensen for their encouragement and leadership.

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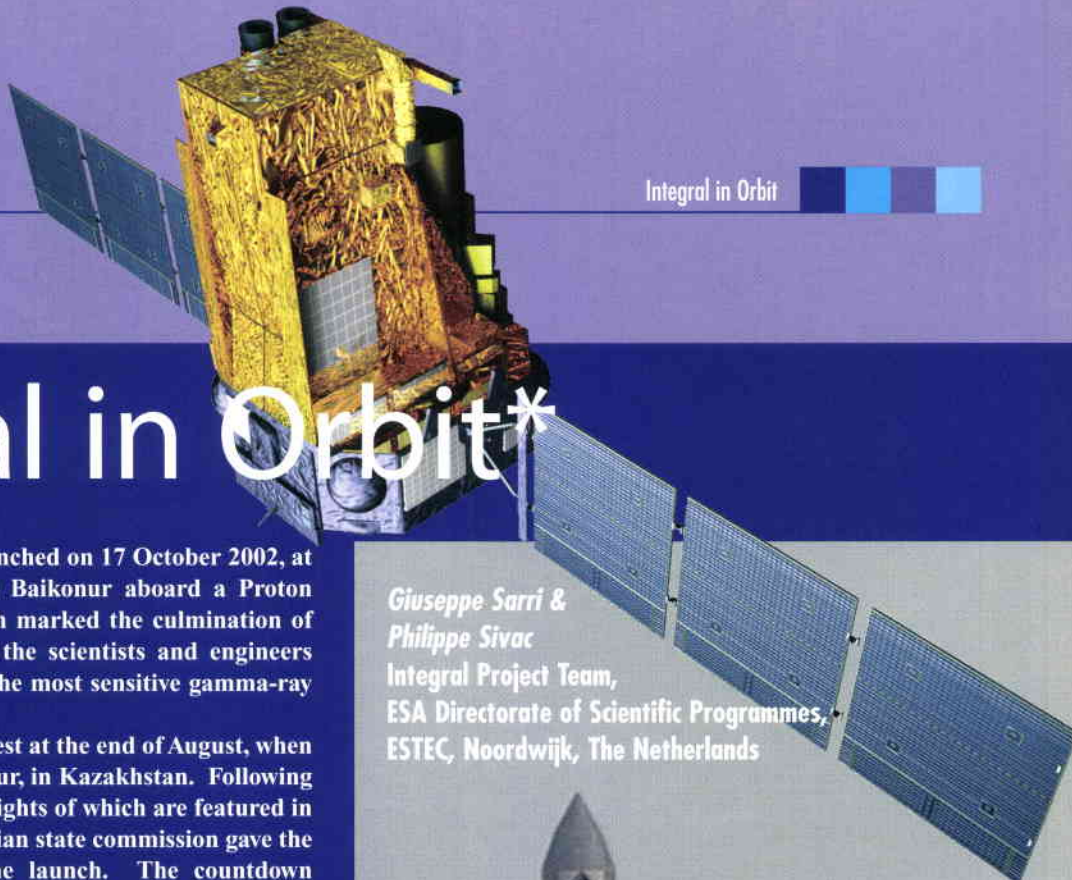

Integral in Orbit*

Giuseppe Sarri &
Philippe Sivac
Integral Project Team,
ESA Directorate of Scientific Programmes,
ESTEC, Noordwijk, The Netherlands

The Integral satellite was launched on 17 October 2002, at 4:41 Universal Time, from Baikonur aboard a Proton rocket. The flawless launch marked the culmination of more than a decade of work for the scientists and engineers dedicated to making this mission the most sensitive gamma-ray observatory in orbit.

Launch activities started in earnest at the end of August, when the satellite was shipped to Baikonur, in Kazakhstan. Following a short launch campaign, the highlights of which are featured in the accompanying panels, the Russian state commission gave the final go-ahead on the day of the launch. The countdown proceeded according to plan, with the following key events taking place exactly on time (all in Universal Time):

01:27 Completion of Proton propellant loading
01:49 Integral satellite powered up
03:55 Service tower rolled back
04:22 Integral satellite in launch configuration
04:30 Integral ground segment confirmed as ready for launch
04:36 Proton ignition key activated
04:41 Launch.

The flight sequence also proceeded precisely as planned. The upper stage separated 10 minutes after launch. It then coasted for 50 minutes until the upper stage engine fired for a 10 minute burn. An hour and a half after launch, the Integral satellite separated from the upper stage and its automatic activation procedure started, with the deployment of the solar arrays. Under the watchful eye of ESA's European Space Operations Centre (ESOC) in Darmstadt, Germany, the first few hours of the orbit were carefully monitored and controlled in order to start the commissioning of the spacecraft. By 1 November, the four perigee-raising manoeuvres had been executed, putting Integral safely into its operational orbit.

In parallel, instrument activation had already started, with the full participation of the teams from the Principal Investigator institutes, from Alenia and from ESA's Integral Project. On 21 October, the Optical Monitoring Camera (OMC) saw its first light (see panel). The Spectrometer (SPI) cool-down was achieved by turning on the onboard cryocoolers and by early November all of Integral's instruments were working well, in full scientific mode. They will now be carefully monitored until the formal completion of the Commissioning Phase, planned for mid-December 2002. At the same time, their fine tuning will continue, both at ESOC and at the Integral Science Data Center (ISDC) in Geneva.

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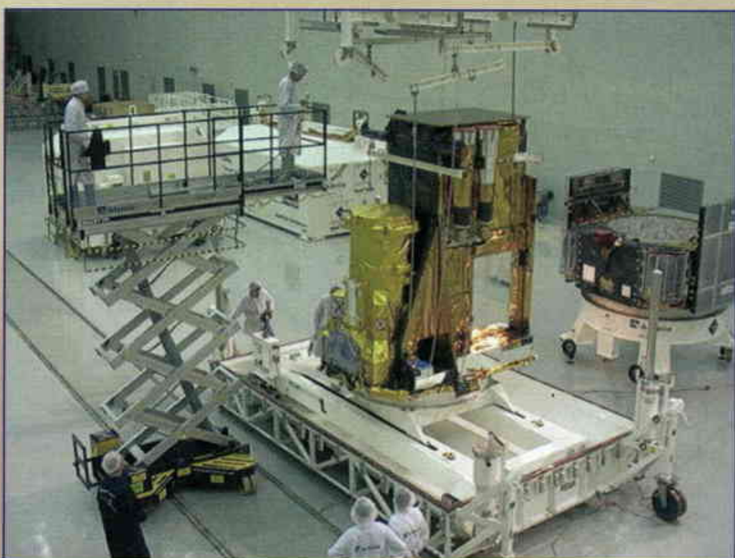
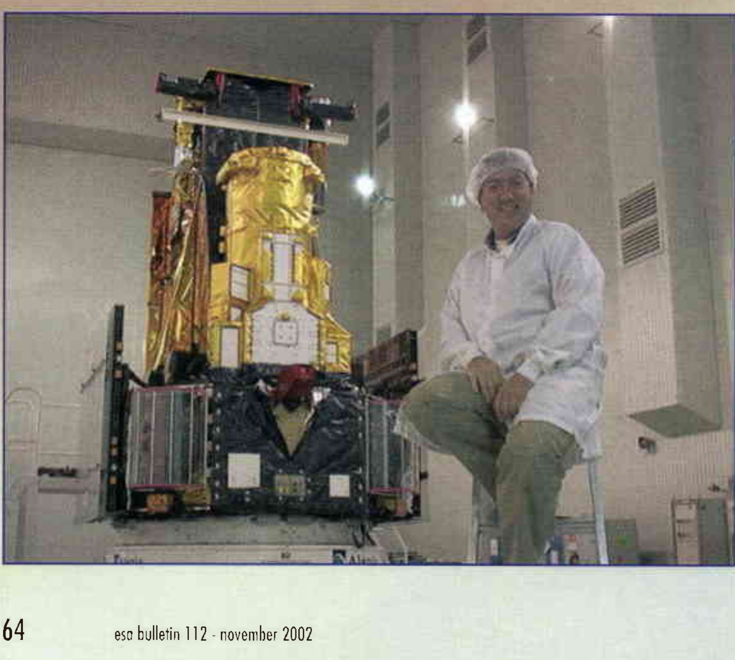
* The Integral spacecraft and its sophisticated payload of scientific instruments were described in detail in the August 2002 issue of the ESA Bulletin (No. 111).

The Integral

L-54 days: Arrival of satellite modules



L-46 days: Mating of the 2 modules



L-39 days: Satellite preparation and functional tests

Launch Campaign

L-26 days: Propellant loaded

L-14 days: Tilting and encapsulation

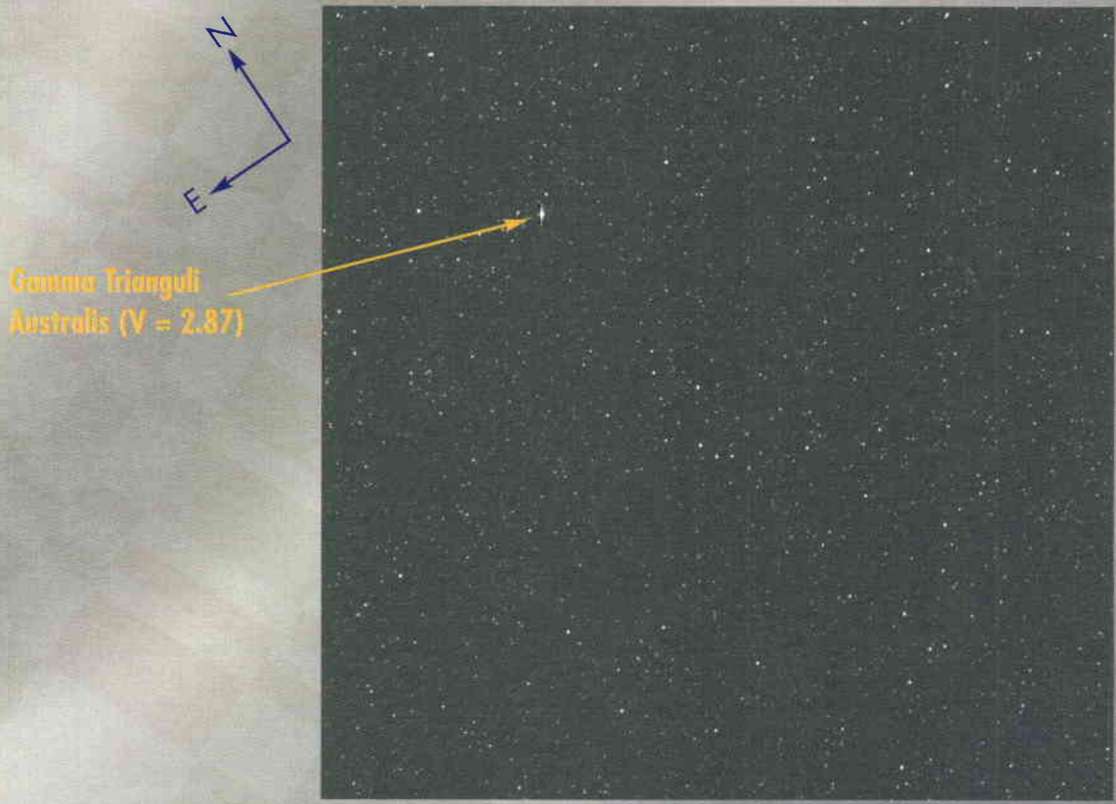
L-7 days: Mating of the upper-stage composite to Proton

L-5 days: Erection and final preparation

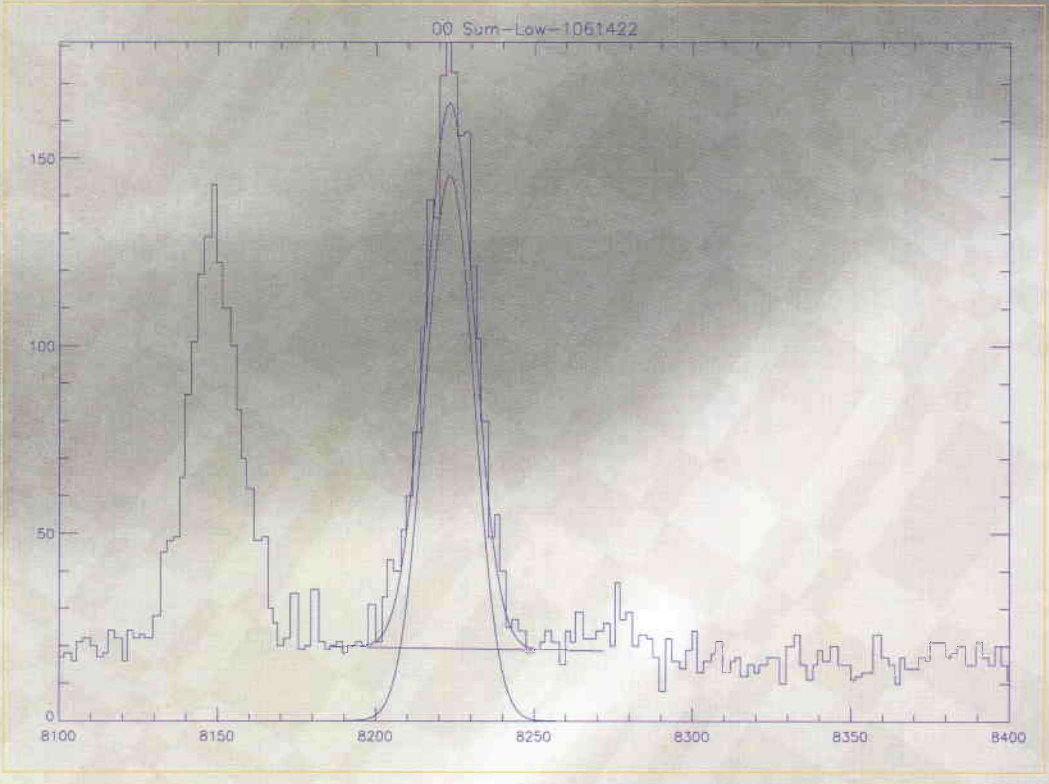
L-3 days: rehearsal with ESOC

First Images

OMC First Light Oct. 21st, 2002

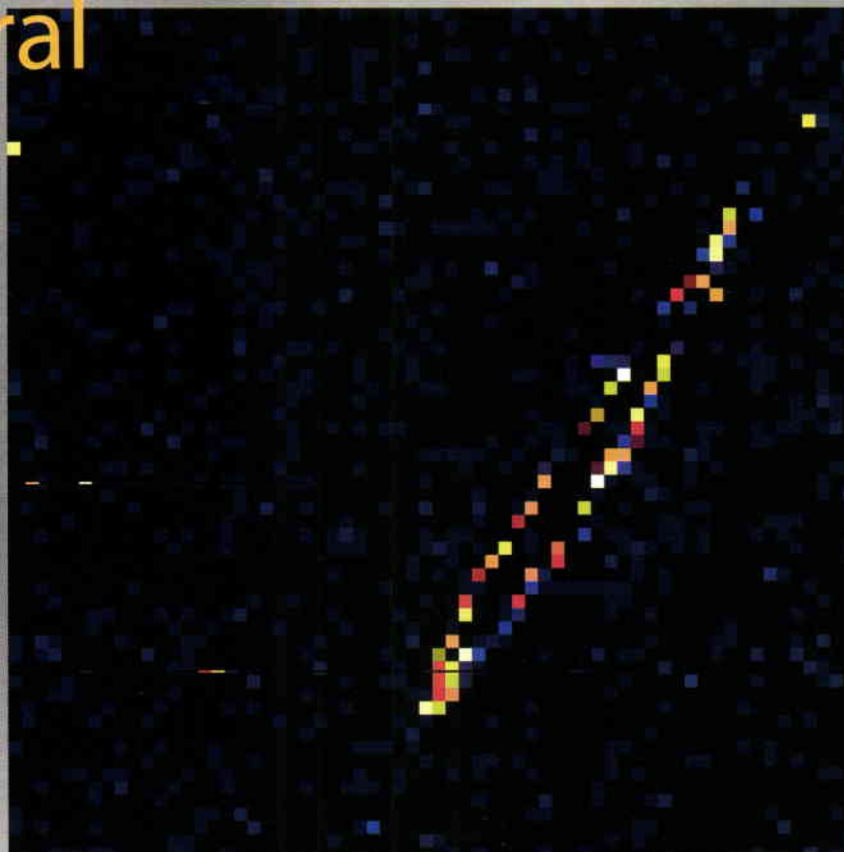


'First light' for Integral's Optical Monitoring Camera (OMC) just after the opening of its cover. The brightest star is Gamma Trianguli Australis. There is some saturation of the image pixels due to the combination of the brightness of the source and the relatively long integration time of ten seconds. (Courtesy OMC Team)

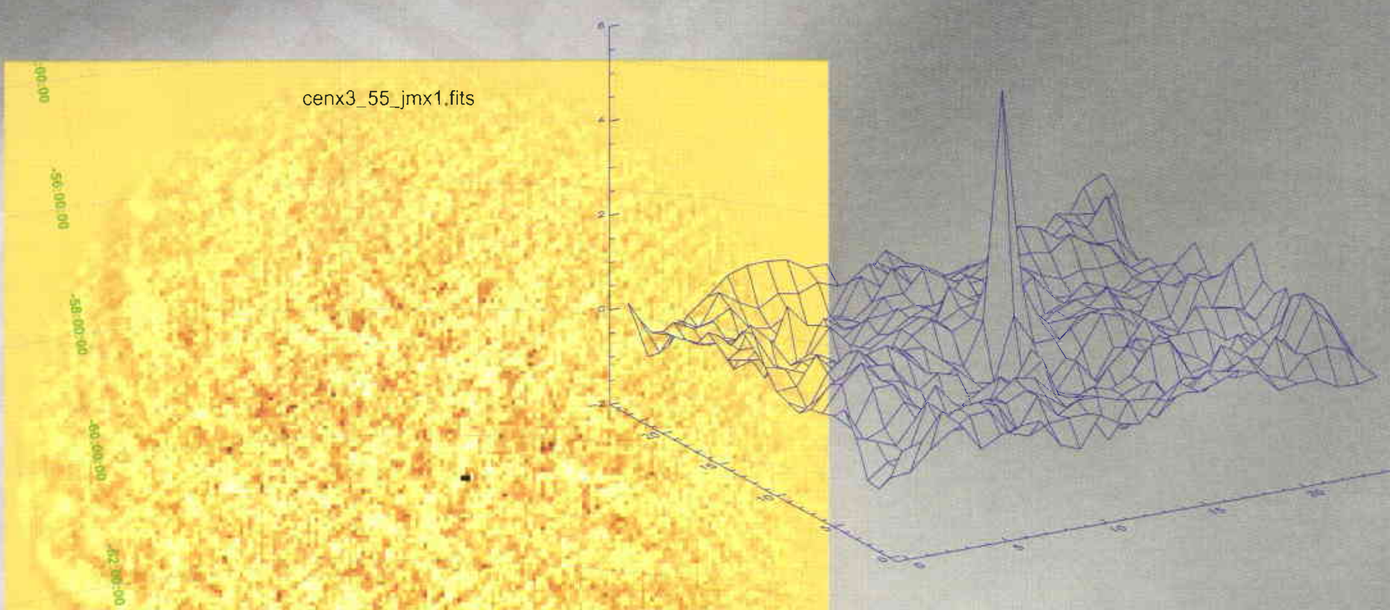


While looking to an empty space field, the Spectrometer sees spectral lines coming from its own germanium detectors (with the x-axis corresponding to the energy channels and the y-axis proportional to count rate). Here the two 69Ge lines at 1107 and 1117 keV can be clearly seen. The energy resolution around 2.5 keV indicates excellent instrument performance (Courtesy of SPI Team)

from Integral



A high-energy particle track seen by the Imager on-Board the Integral Satellite (IBIS). The image (integrated on 100 msec) shows a well-defined particle passage in terms of time and energy profile that can be easily discriminated. (Courtesy of IBIS Team)



The first image of an X-ray star, Cen X-3, obtained with the Joint European Monitor for X-rays (JEM-X1) instrument. The 'star' is the small black dot near the centre. Although maybe unimpressive, the image gives the scientists confidence that the instruments are capable of detecting and accurately pinpointing X-ray sources in the sky. The contour plot (above) is based on data from the JEM-X2 instrument. (Courtesy of JEM-X Team)

Meteosat Second Generation (MSG) : New Horizons for

Gerd Dieterle & Rob Oremus
Earth Observation Project Department,
ESA Directorate of Earth Observation,
ESTEC, Noordwijk, The Netherlands

Eva Oriol-Pibernat
MSG Mission Manager,
ESA Directorate of Earth Observation,
ESRIN, Frascati, Italy

MSG-1 in the Integration hall in Kourou, French Guiana

On the evening of 28 August 2002, Ariane-5 flight 155 lifted off from Europe's launch site in French Guiana carrying the MSG-1 satellite. Separation of satellite and launcher occurred 36 minutes later and ESA's European Space Operations Centre (ESOC), in Darmstadt, Germany, working on behalf of Eumetsat, began operations to move the spacecraft from the geostationary transfer orbit (GTO) that it had just entered, to its final geostationary operating orbit 36 000 km above the Earth's equator.

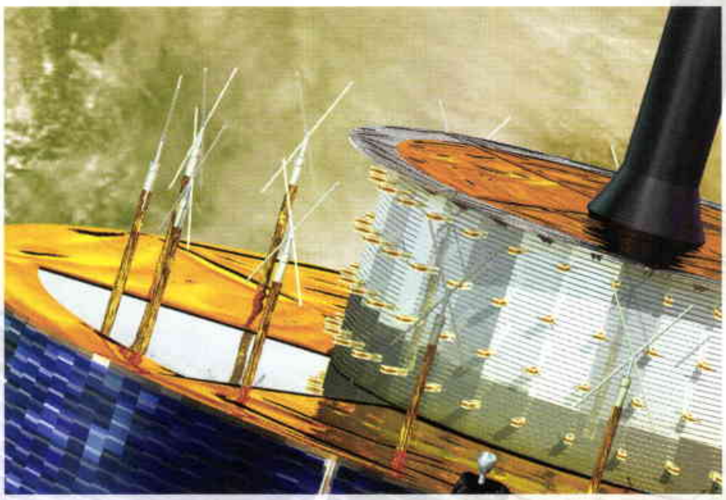
For Europe's citizens, few projects have made the benefits of space flight so obvious as the European Meteosat programme. Every TV channel shows daily sequences of Meteosat pictures taken from space and weather forecasters would not want to do without the information that Meteosat provides.

Twenty-five years ago, Meteosat-1 was ESA's very first Earth-observation satellite. From its geostationary orbit over the Gulf of Guinea, Meteosat-1 overlooked almost half of the globe, including more than 100 countries in Europe and Africa, as well as the Atlantic ocean and parts of the Indian ocean. To date, seven Meteosat satellites have been launched and, since 1981, at any given moment one is operational and one is in standby orbit in order to guarantee an uninterrupted flow of meteorological data.

ESA itself ran the Meteosat programme until 1987, a few months after the foundation of Eumetsat, which is an intergovernmental organisation with 18 member states at present. In December 1995, it took over the full operation of the Meteosat system.

In the early 1980s ESA, together with

Weather and Climate



The launch of MSG-1 from Kourou, in French Guiana, on 28 August at 22.45h GMT

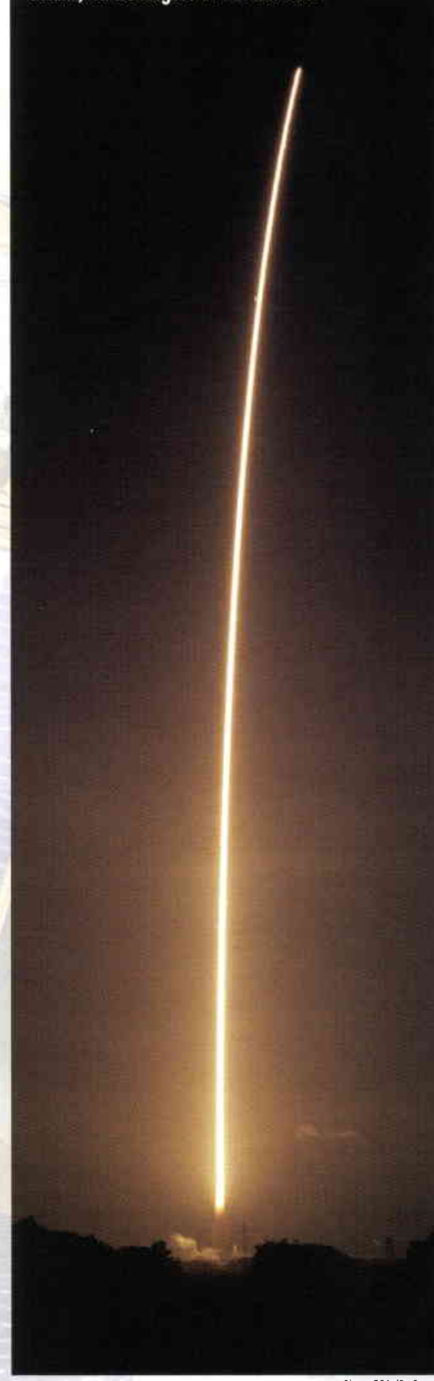


Photo ESA/S. Corvaja

European scientists and engineers, initiated the next step in the technological development of meteorological satellites. As a result and in co-operation with Eumetsat, in 1994 European industry, led by Alcatel-ESpace (F) under contract to ESA, began working on the Meteosat Second Generation, involving more than 50 European sub-contractors. MSG will soon begin to replace the previous Meteosat satellites.

MSG is equipped with a 12-channel imaging radiometer that delivers one complete picture in scanning mode every 15 minutes in high resolution (1 km in the visible band). It will provide meteorologists with new insights into the atmosphere (particularly clouds), land and ocean surfaces, contributing significantly to the accuracy of both now-casting and medium-range weather forecasts.

Its data-relay function has been upgraded from an analogue to a digital concept, providing a ten-fold increase in transmission capacity. MSG also carries a system to collect and transmit environmental data from remote platforms, a search–and–rescue transponder for humanitarian purposes, and the Geostationary Earth Radiation Budget instrument (GERB) for climate monitoring. GERB will measure the Earth's radiation budget at the top of the atmosphere for the first time from geostationary orbit.

With a seven-year design lifetime and at least three satellites to be launched, MSG will carry on Europe's meteorological space programme for the next decade. MSG is fully operated by Eumetsat, while ESA has developed the technology and is responsible for procuring the next 2 or 3 identical satellites.

With its ongoing and future space programmes to monitor the Earth, Europe is becoming a leader in climate science and weather data applications from space. It is the shared aim of ESA and Eumetsat to continue this success well into the future.

esa

News from Europe's Spaceport

Fernando Doblas
Head of the Kourou Office,
ESA Directorate of Launchers, French Guiana

Introduction

Since 1975, the availability of an operational launch base has been an essential component for Europe of its independent access to space. Since then, therefore, ESA's Member States have borne a significant part of the running costs and capital-investment expenditure for the Guiana Space Centre (CSG), Europe's spaceport. To this end, a series of agreements have been concluded between the French Government and ESA covering the utilisation and funding of the CNES/CSG facilities for ESA's launcher programmes – the so-called 'CSG Agreement' – and the installation at CSG of ESA's launch and associated facilities – the so-called 'ELA Agreement'.

The French Minister of Research and ESA's Director General signed the above two Agreements for the period 2002-2006 on 11 April 2002. These next five years will be very important for CSG because, during this period, Europe's spaceport will see construction of the launch facilities for the European small launcher, Vega. Moreover, if the ESA Council gives its approval at its December meeting, CSG will see also the construction of launch facilities for the Russian Soyuz launcher. It is therefore also conceivable that, one day, manned flights to the International Space Station might take place from CSG!

All of these new programmes will be developed and implemented in parallel with the current and future exploitation of the Ariane-5 launcher from CSG. Between now and 2006, more powerful versions of Ariane-5, Europe's highly successful workhorse in the commercial launch sector, will be developed and exploited. During the same period, a new type of relationship is being established on the site between ESA, CNES and Arianespace.

All in all, then, over the next years Europe's spaceport will become more utilised and more densely populated, and altogether a richer place in technological terms. The foundations for these important evolutions are already being laid.

The Main Facilities

Europe's spaceport in French Guiana covers a total of 850 km^2 and has a 50 km coastline. The two main building complexes are:

- The CNES/CSG establishment: This is a French national space agency (CNES) facility devoted to the general coordination and support of the launching activities, with radars, telemetry antennas, telecommunications and meteorological facilities, laboratories, etc. It is complemented by ESA-owned facilities put at CNES's disposal for supporting the launch activities, such as the payload-preparation complexes (EPCU) and the down-range tracking stations.
- The ELA Ariane launch complex: This complex contains all of the ESA-developed facilities devoted to launcher preparation and integration and to

specific launch operations. They are exploited by the European launcher operator Arianespace, supported by diverse European industries. There are also other ELA-associated facilities, again mainly belonging to ESA, devoted to the manufacture of such launcher elements as the solid-propellant boosters, and to the production of liquid oxygen, helium and hydrogen (the latter being the property of Air Liquide, France).

The total value of the ESA assets at CSG, which help to make Europe's spaceport one of the most modern and most efficient launch bases in the World, is more than 1.6 billion Euro.

The Main Ariane Programme Entities

Each of the three main players in the Ariane programme – ESA, CNES and Arianespace – has a major presence at CSG.

ESA assures the overall direction of the launcher development programmes. It also develops the Ariane production and launch facilities and contributes significantly to the launch base's fixed costs. The ESA Office at CSG is responsible for managing the contract through which CNES's part of the launch base's fixed costs are funded (the CSG contract).

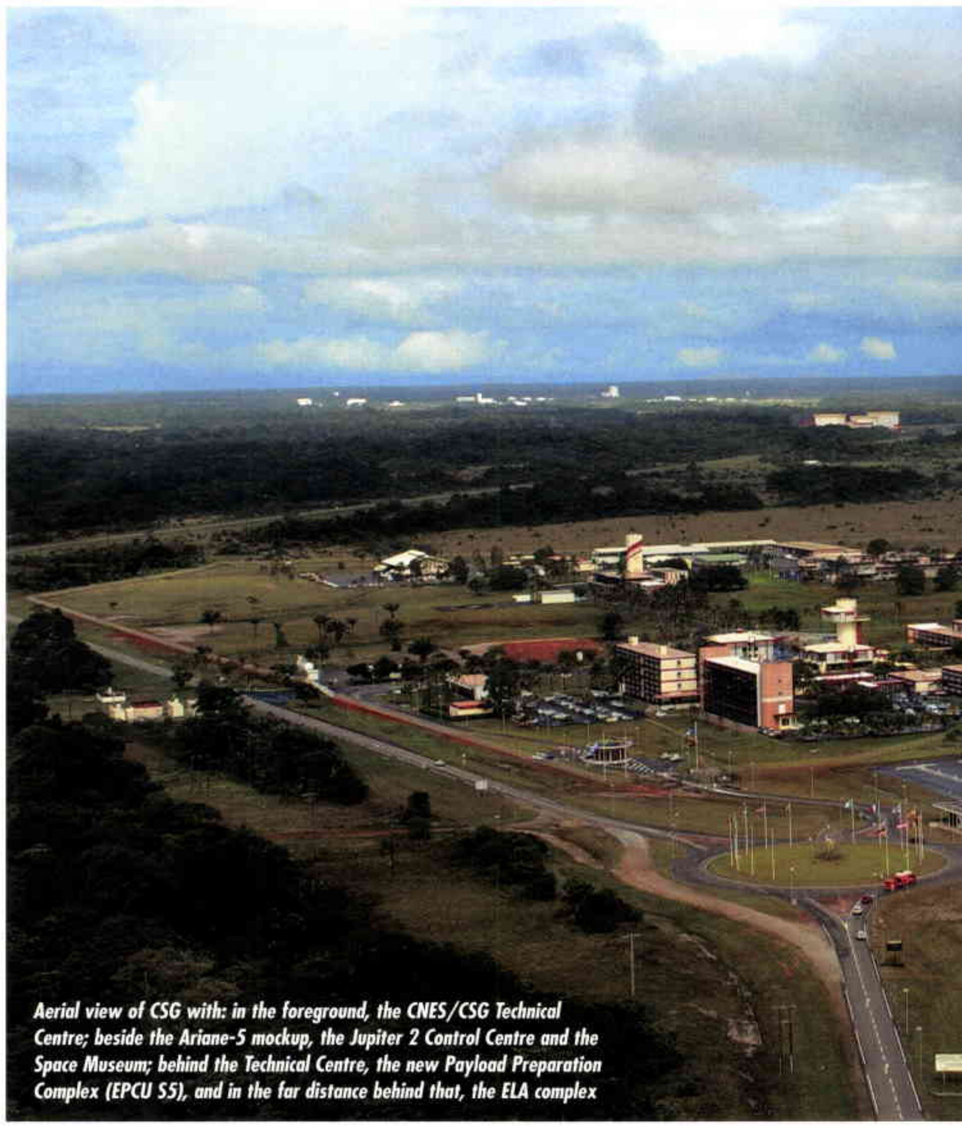
CNES, by delegation from ESA, is the prime contractor for the Ariane development programmes and for the construction of the facilities at CSG. It also co-ordinates the operations and the exploitation of the launch base and the payload preparation complexes, and is responsible for the safety and security of people and property at CSG.

When the development phases of its launcher programmes are completed, ESA makes available to Arianespace (or with the latter's agreement, to its suppliers), the production master files and facilities owned by the Agency, funded by the said development programmes, necessary for the commercial manufacture, marketing and launching of the operational launchers.

Arianespace fulfils three principal functions. Above all, it is responsible the commercialisation of European launcher services on the World market. It also manages the Ariane launcher production programme. In French Guiana, it is in charge of final launcher integration, as well as launch operations.

There is also a substantial European industrial presence at CSG, through the many companies participating in the launcher test and integration activities, in the launch-site construction activities, and in the maintenance and exploitation of the launch base. The companies with a permanent presence at CSG fall into two groups. The first group, the Guiana Industrial Space Community (CISG), which also includes CNES and Arianespace, consists of: Regulus (Ariane-5 solid-propellant production), Air Liquide Spatial Guyane (liquid oxygen, hydrogen and helium production), EuroPropulsion (Ariane-5 solid-propellant motor integration), and EADS-G (solid-booster stage integration). These CISG members, plus 28 other European industrial partners, from eight different European countries, form the UEBS (Launch Base Union of Employers).

One must add to this figure the many companies (mainly local) working as subcontractors to the CISG and UEBS members, and the European companies that visit CSG to undertake particular work packages (e.g. provision of telecommunication networks, software, fluid installations, civil works, etc), but who do not have permanent representation there.



Aerial view of CSG with: in the foreground, the CNES/CSG Technical Centre; beside the Ariane-5 mockup, the Jupiter 2 Control Centre and the Space Museum; behind the Technical Centre, the new Payload Preparation Complex (EPCU S5), and in the far distance behind that, the ELA complex

The participation of all of these companies means that almost all ESA Member States are represented at CSG, thereby helping to reinforce its European character.

ESA's Importance in Launcher Production

ESA's involvement in launcher activities does not end when the launchers that have been developed and qualified are transferred to Arianespace for exploitation. ESA continues to contribute to their production by, in particular, making sure that CSG is maintained in good operational order, by funding the CNES/CSG fixed costs and a part of the ELA fixed costs.

To ensure the operational availability of the CNES/CSG systems and the associated ESA facilities exploited by CNES at the launch base, ESA, through a contract placed with CNES/CSG (the CSG Contract), funds a significant part (two-thirds) of the fixed costs of these facilities. The remaining third of the fixed costs is borne by France. This represents a funding by ESA of 423.2 MEuro, out of a total of 617.4 MEuro for the period 2002-2006. All ESA Member States contribute to this funding according to a contribution key based on their Gross National Product and on their Ariane production activities return. In addition, ESA bears 56% of the fixed costs of the ELA (the launcher-specific complex), through the so-called 'Infrastructure Programme'. This involves 131 MEuro of ESA funding for the period 2002-2004. Although this programme is purely optional, most Member States are contributing to it, thereby underlining their awareness about the importance of placing European launcher industry on a level playing field with its competitors.

The above funding by the public sector (ESA and CNES) of a relevant part of the fixed costs of the launch base provides Arianespace, the European launcher operator, with conditions closer (although still not equal) to those enjoyed by their US competitors in launch operations activities.

The ESA Office in Kourou is responsible for the management of the CSG Contract, and is also the Agency's official representative in French Guiana.

Main Attributes of the CSG Contract

Signed in Kourou on 2 May 2002, this contract formalises the services to be provided by CNES/CSG to the ESA launcher programmes (with exploitation ensured by Arianespace), as well as the framework for the relations between ESA and CNES/CSG for the duration of the contract (2002-2006).

The new contract represents an important step forward compared to previous contracts in terms of greater visibility for Member States and improved efficiency, providing in particular:

- clarification and simplification: the funding envelope is clear and easy to trace
- cost reduction and improved efficiency: there will be a reduction of about 10% in the fixed costs for CNES activities at CSG from 2001 to 2006
- enhanced ESA control and involvement in the decision-making process: ESA will participate in all strategic CSG decisions, covering such areas as procurement policy, definition and implementation of the capital investment plan, industrial policy and the launch base's European image
- a guaranteed (by CNES/CSG) return coefficient of 0.9 to all ESA Member States: this means that industries in all ESA Member States should, by the end of 2006, have received contracts to the

Roll-out of an Ariane-5 from the Final Assembly Building (BAF) to the Launch Zone, at ELA-3

value of at least 90% of the 'ideal' entitlement based on their country's financial contribution to the CNES/CSG fixed costs.

Despite the short time that has elapsed since the placing of the new contract, major progress has already been achieved in most of the domains that it covers, and particularly in terms of:

– Europeanisation of personnel
A target of 20 non-French European staff at CSG has been established (in addition to the Europeans working for the various industrial companies present on-site). To this end, the job opportunities at CSG published on the CNES web site have been cross-linked to the 'Job Opportunities' page on the ESA web site at http://www.esa.int/hr/index.htm.

– Procurement policy
ESA is playing an active role in establishing with CNES/CSG the procurement policy for CSG activities, whereby ESA supports CNES in opening up the launch base to European companies, commensurate with the funding received from their different countries of origin. Concrete results have already been obtained, with industry in Member States previously absent from the launch base getting relevant contracts (most recently, Portugal and Norway)

Wider dissemination of CNES/CSG Calls for Tender has been achieved by the systematic use of ESA's EMITS system (http://emits.esa.int), which is already well known and widely used by European space industry. This gives the latter immediate access to the business opportunities on offer at CSG.

– Industrial policy
To fulfil the obligation of ensuring satisfactory returns for all Member States in an efficient way, it is foreseen, whenever possible, to actively solicit specific industrial participation (particularly from countries with low contributions) to avoid excessive fragmentation of the industrial involvement.

Measures are being taken to gain maximum advantage from the synergies between the industrial activities within the CNES/CSG and other areas of the launch base, particularly the ELAs, which are also financed by ESA through the Infrastructure programme.

Measures are also being implemented to improve the European image of CSG and to make it better known to the general public and, in particular, the decision-makers in Europe.

The ESA Team at CSG

The New Programmes

Over the next five years, the scale and scope of CSG will change considerably, with the arrival of ESA's Vega launcher and the possible arrival of Soyuz.

Vega is the small European launcher intended to complement Ariane-5 by putting payloads of up to 1.5 tons into polar orbit at 700 km altitude as cost-effectively as possible. The coherence of the overall European launcher effort is demonstrated by the reuse for Vega of the launch pad built for the first Ariane launchers (ELA-1). The civil-engineering work on the new launch pad and launcher preparation facilities will start in 2003. Operational Vega flights, conducted by Arianespace, will take place from 2006 onwards.

The well-proven Russian Soyuz-ST launcher could also be launched in the future from Europe's spaceport by Arianespace. Complementing both Ariane-5 and Vega, it would be able to put payloads of up to 2.8 tons into geostationary transfer orbit from CSG. If approved by the ESA Council in December this year, construction work on the Soyuz launch pad would also start in 2003, ready for its commercial exploitation by late-2005.

A Soyuz presence at CSG might lead, at a later stage, to the manned version (Soyuz-U) being launched from the European spaceport one day. This possibility is presently being thoroughly analysed by ESA and discussed with its Russian counterparts, in the context of Europe's interest in the International Space Station and its future evolution. A feasibility assessment is being made, which will be presented to Member States at the end of 2002.

With Vega and with the potential expansion plans using Soyuz still to be decided upon by Member States, Europe's spaceport could be, by 2006, an even more impressive and exciting launch base, with an array of launchers that would further increase its scope and volume of activities.

Conclusion

Since the start of the Ariane programmes, ESA has built many modern facilities at Europe's spaceport, involving financial investments totaling more than 1,6 billion Euros. CNES and Arianespace too have built a number of new facilities at CSG to support and coordinate the on-going launching activities. This fruitful cooperation between the two Agencies, as well as between ESA and Arianespace, has been the key to Europe's leading position today in the commercial launcher market. In CSG, Europe has developed and is maintaining one of the best-equipped and most efficient launch bases in the World, which is a key element of its independent access to space. The next five years will be extremely important for the base's long-term future, with the new programmes already decided (Vega) and to be decided (Soyuz) providing the prospect of an exciting new dimension. esa

Accord concernant la protection et l'échange d'informations classifiées

Elisabeth Sourgens
Conseiller pour la protection de l'Information, Direction de l'Administration, ESA, Paris

Introduction

Les informations relatives aux technologies développées et mises en œuvre dans le cadre des programmes spatiaux civils font, depuis les tout débuts de l'ère spatiale, l'objet de protections à divers niveaux de la part des Etats qui en ont permis la mise au point et qui en assurent le développement.

Soit ces technologies tirent leur origine de programmes de nature militaire, soit elles peuvent également être utilisées par le secteur de la défense, ou bien elles revêtent, d'une façon plus générale, un caractère «stratégique» pour l'Etat en question, y compris au plan de l'avance technologique par rapport à d'autres Etats, ou même sur le plan strictement commercial.

C'est la raison pour laquelle une partie des informations technologiques du secteur spatial est considérée par ses détenteurs, au plan national, comme relevant du secret défense, et est protégée comme 'information classifiée'. Si ce niveau de protection n'a pas été un obstacle au très considérable développement des applications civiles des activités spatiales au plan national en Europe ou aux Etats-Unis dans les trois dernières décennies, il soulève en revanche des difficultés particulières dans l'exécution de programmes spatiaux civils par des organisations intergouvernementales comme l'ESA, qui ont besoin d'accéder à, et parfois d'utiliser directement, des informations qui font l'objet d'une telle protection au plan national.

Par ailleurs, le souci d'une gestion plus efficace des ressources budgétaires conduit aujourd'hui les puissances spatiales européennes à une remise en cause des traditionnelles lignes de partage entre secteur civil et secteur de la défense: ainsi, la défense peut-elle désormais utiliser des répéteurs de communication sur des satellites 'commerciaux' ou bien acheter des images satellite sur le marché. Réciproquement, l'usager civil peut accéder à des mesures de positionnement très fiable issues du 'Global Positioning System' développé et mis en œuvre par le Département de la Défense aux Etats-Unis.

Cette évolution met une organisation de coopération intergouvernementale 'civile' comme l'ESA au défi de se doter des instruments lui permettant de poursuivre sa mission de maître d'ouvrage des grands programmes spatiaux européens, comme Galiléosat, dont les applications intéressent une très vaste gamme d'utilisateurs. Inversement, une organisation dotée de tels instruments fournit à ses Etats membres un cadre incitatif pour l'échange et la mise en commun d'informations et de technologies spatiales, ferment de futurs programmes à l'échelle européenne.

Jusqu'ici, l'accès - par l'Agence elle-même ou par ses personnels, ressortissants de ses Etats membres - à de l'information de nature classifiée impliquait, pour la réalisation des programmes, soit une 'déclassification' par l'Etat détenteur de l'information, soit une habilitation des personnes délivrée au cas par cas par les autorités nationales (exemple du programme d'avion spatial Hermès). Dans bien des cas, aucun accès n'était cependant possible, cette limitation découlant des dispositions suivantes de l'Article III, alinéa premier de la Convention portant création de l'Agence :

«Les Etats membres et l'Agence facilitent l'échange d'informations scientifiques et techniques relevant des domaines de la recherche et de la technologie spatiale et de leurs applications, *étant entendu qu'aucun Etat membre n'est tenu de communiquer une information obtenue en dehors du cadre de l'Agence s'il estime une telle communication incompatible avec les exigences de sa sécurité, les stipulations de ses accords avec des tiers ou les conditions dans lesquelles il a lui-même acquis cette information*».

Seule la mise en place d'un instrument juridique particulier, entre les Etats membres et l'organisation, suivie de la mise en place d'un système de protection effectif au sein de cette dernière, est de nature à permettre une meilleure mise en œuvre de cette disposition dont la philosophie est au cœur même de la possibilité d'une coopération spatiale européenne.

C'est ainsi que l'Agence vient de mettre au point les termes d'un *'Accord concernant la protection et l'échange d'informations classifiées'*, accord qui a fait l'objet d'une approbation unanime du Conseil réuni le 12 juin 2002 à Montréal, auquel l'Agence elle-même est Partie et qui est ouvert à la signature puis à la ratification ou l'approbation de chacun de ses Etats membres. Au cours de la même réunion, le Conseil de l'Agence décidait, par une résolution expresse, de créer un *Comité de sécurité*, composé de représentants de tous les Etats membres, aux fins de conseiller le Conseil et le Directeur général sur les questions de sécurité touchant aux intérêts de l'Agence, de veiller à la bonne mise en œuvre des dispositions de l'Accord, ainsi que de préparer les décisions internes qu'il implique, comme par exemple l'adoption d'un *Règlement de sécurité* spécifique.

Les mécanismes prévus par l'Accord du 12 juin 2002

Après avoir posé une définition très générale de ce qui constitue une 'information classifiée', et qui est compatible avec les définitions retenues au plan national et international par les Etats membres, l'Accord instaure un mécanisme d'engagement réciproque des Parties de protéger et de sauvegarder, dans le cadre des activités de l'Agence, les informations classifiées et identifiées comme telles en provenance de l'une d'entre elles. Il ajoute une obligation de mise en œuvre, à un niveau équivalent, des normes de sécurité émises par l'Agence pour la protection desdites informations.

Il comprend également des dispositions concernant l'habilitation des personnes amenées à connaître les informations ainsi protégées. Les informations classifiées étant des informations, documents ou matériels qui, produits ou échangés dans le cadre d'un programme ou d'une activité de l'Agence, font l'objet d'une identification spécifique par l'autorité émettrice ou détentrice, seules les personnes autorisées à les connaître peuvent y avoir accès.

Les critères d'autorisation sont le besoin d'en connaître, généralement déterminé par l'autorité émettrice de l'information classifiée, et l'habilitation. L'habilitation est une procédure strictement réservée au plan national, et qui est délivrée à l'issue d'une enquête conduite par une autorité nationale compétente permettant de déterminer si une personne peut, sans risques pour elle-même ou l'administration dont elle relève, prendre connaissance d'informations classifiées.

L'Accord prévoit également des mécanismes de coopération entre l'Agence et les autorités compétentes des Etats membres dans le cas d'enquêtes administratives ou judiciaires relatives à des divulgations non autorisées d'informations classifiées. Il convient de préciser à cet égard, qu'un membre du personnel de l'Agence reconnu responsable de la divulgation d'une information classifiée à une personne n'ayant pas à en connaître, ou non habilitée, verrait son immunité levée par le Directeur Général conformément à l'article XXI, alinéa 2 de la Convention de l'Agence.

Les clauses finales de l'Accord sont conformes aux usages des accords internationaux en la matière. Notons toutefois qu'elles ne prévoient pas de mécanisme de règlement des différends, la pratique en ce domaine voulant qu'en cas de conflit d'interprétation les parties s'efforcent de trouver une solution amiable entre elles.

L'Accord est déposé dans les archives du Gouvernement français qui assure également les fonctions de dépositaire de la Convention de l'Agence. Il entre en vigueur dès la notification par deux Etats membres de leurs instruments de ratification, d'acceptation ou d'approbation. Sa durée est illimitée. Les obligations de protection de l'information classifiée échangée s'étendent au-delà d'une possible dénonciation par un Etat membre ou en cas de dissolution de l'Agence.

La protection effective de l'information, l'élaboration d'une politique de la sécurité au sein de l'Agence

La mise en œuvre de l'Accord de sécurité au sein de l'Agence, s'appuiera sur un Règlement de sécurité qui sera élaboré, puis proposé à l'adoption du Conseil, par le Groupe de travail du Conseil sur la sécurité de l'information.

Au-delà de la stricte protection, par des mécanismes appropriés, de l'information classifiée définie par l'Accord, c'est à la mise en place d'une véritable politique de sécurité que l'Agence s'est attelée afin d'assurer à ses Etats membres le niveau de fiabilité nécessaire et suffisant pour la conduite des grands projets spatiaux européens.

Le Règlement de sécurité contiendra les directives nécessaires à la réalisation concrète des mesures de protection des informations classifiées au sein de l'Agence, ainsi que les modalités d'une protection de ces mêmes informations en provenance des Etats membres. Il conduira à la mise en place auprès du Directeur général d'un Bureau de sécurité chargé de mettre en œuvre la politique de sécurité de l'Agence en matière d'informations classifiées. Les domaines de protection de ces informations englobent la sécurité physique, la sécurité informatique, la sécurité industrielle ('contrats classés') et la sécurité des personnes, en particulier au niveau des procédures d'habilitation. Ce Bureau aura vocation à travailler en étroite collaboration avec les départements compétents de l'Agence, et à concrétiser les orientations données par le Comité de sécurité du Conseil.

Dès l'entrée en vigueur de l'Accord de sécurité, toutes les informations générées dans le cadre de l'exécution d'un contrat, ou de la gestion d'un programme, et devant circuler au sein de l'Agence ou entre celle-ci et ses Etats membres, et dont la nature exigera une diffusion restreinte, porteront un marquage ESA spécifique, affecté d'un niveau de classification déterminé en fonction de leur sensibilité. La sensibilité d'une information dépend d'une évaluation du plus ou moins grand préjudice qu'une divulgation non autorisée pourrait causer aux intérêts essentiels de l'organisation ou d'un ou plusieurs de ses Etats membres.

Ainsi que le prévoit l'Accord de sécurité, l'accès aux informations classifiées sera strictement limité aux personnes ayant le besoin d'en connaître et titulaires d'une habilitation de même niveau que la classification affectant les informations elles-mêmes. A titre d'illustration, pour connaître une information de niveau 'Secret', il faudra dans un premier temps être titulaire d'une habilitation 'Secret'. Cette habilitation permettra, exclusivement sur la base du besoin d'en connaître, d'être ensuite autorisé par l'autorité située à l'origine de l'information à accéder aux informations classifiées de ce niveau, ainsi qu'à celles de niveau inférieur. Ainsi, l'habilitation seule ne constitue pas un critère suffisant pour pouvoir prendre connaissance d'informations classifiées.

Il faut souligner que le besoin de connaître des informations classifiées est attaché à une fonction et non à une personne, impliquant ainsi une évaluation par les services compétents des différents postes concernés dans le cadre de l'élaboration d'un 'catalogue des emplois'.

La protection de l'information dans les relations avec l'Union européenne

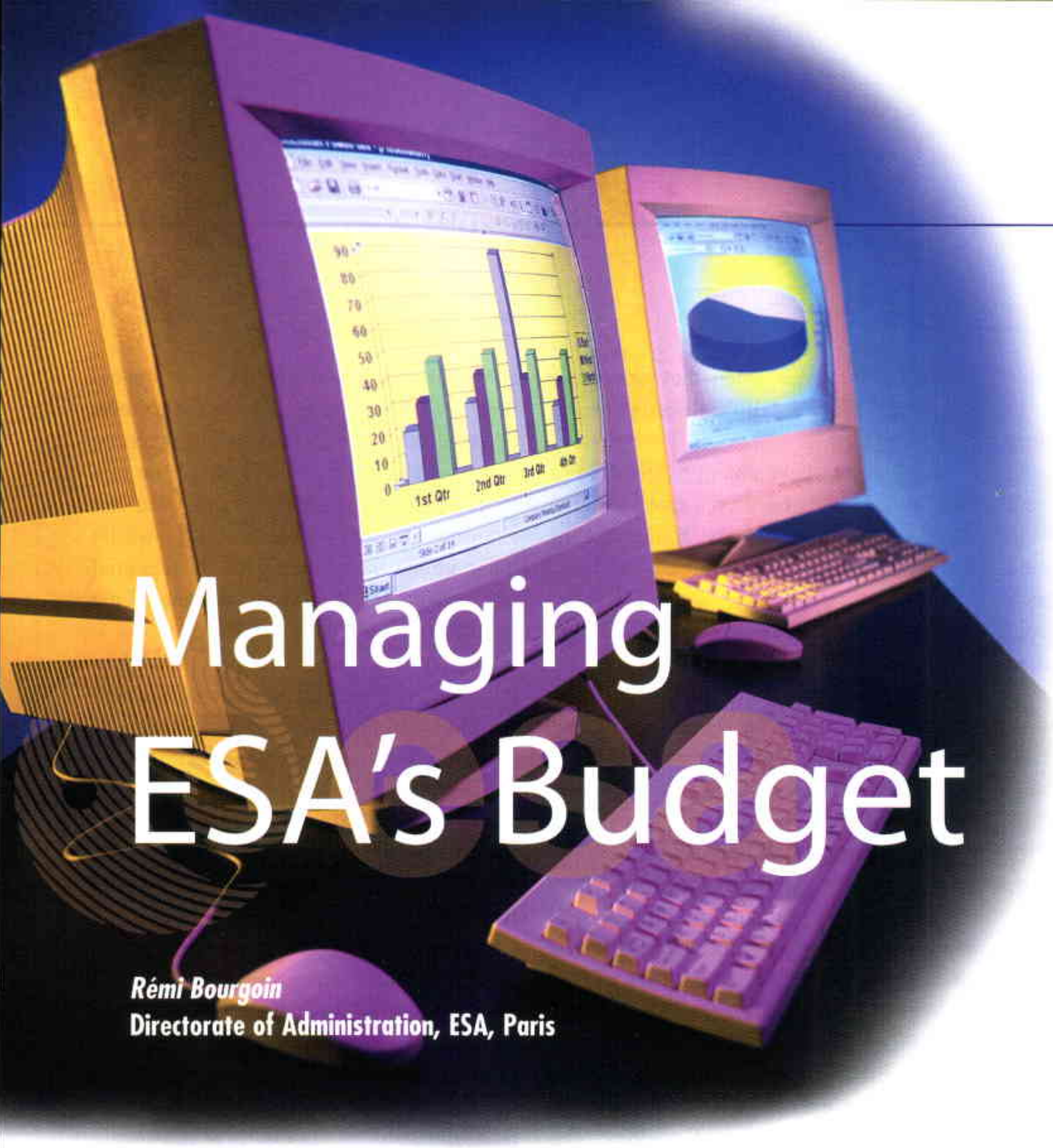
Les outils mis en place au sein de l'Agence dans le domaine de la sécurité de l'information seront de nature à faciliter les relations de travail avec l'Union européenne, et plus particulièrement avec la Commission européenne, dans le cadre dune coopération sur la réalisation de programmes spatiaux entrant dans le cadre des politiques inscrites dans le Traité sur l'Union européenne.

En effet, les institutions européennes se sont dotées récemment d'une architecture de sécurité qui leur permet non seulement de traiter des informations classifiées produites et échangées avec les Etats membres dans le cadre du deuxième et du troisième piliers ('PESD' et 'JAI') mais aussi de gérer des programmes multi-objectifs dans le cadre du premier pilier. Or, l'Agence a désormais vocation à tenir un rôle important dans des programmes spatiaux dont la Commission européenne aurait l'initiative. L'exemple le plus récent est Galileo, le programme européen de radionavigation par satellites, mais d'autres programmes devraient suivre dont GMES (système d'observation de la terre pour le développement durable). Bien que de nature 'civile', ces grands programmes drainent un volume important d'informations classifiées.

L'existence d'un Accord de sécurité de l'information au sein de l'Agence permet d'envisager la conclusion d'un accord de sécurité avec les institutions européennes dans la foulée de la mise au point de nouvelles relations inter-institutionnelles entre l'Agence et l'Union.

Conclusion

La mise en place d'une politique nouvelle de sécurité dans la gestion des programmes de l'Agence appellera de ses personnels une attention accrue, l'acquisition de nouveaux réflexes dans ses relations avec les tiers. Loin d'être un départ inattendu de la lettre et de l'esprit de la Convention créant l'Agence, elle doit au contraire en prolonger les effets et permettre à l'organisation d'être au cœur de l'élaboration et de la mise en œuvre de la politique spatiale européenne, à la hauteur des enjeux que lui assignent ses Etats membres. Elle se veut la meilleure réponse aux impératifs industriels et politiques d'aujourd'hui dans le secteur spatial. En effet, c'est paradoxalement l'existence d'un cadre réglementé de circulation de l'information qui constituera le meilleur stimulant à son échange, et ouvrira à l'Agence de nouvelles opportunités de démontrer son savoir-faire dans l'organisation et la gestion, à l'échelle européenne, de grands projets spatiaux conçus aujourd'hui au bénéfice de l'ensemble des communautés d'utilisateurs européens.



Managing ESA's Budget

Rémi Bourgoin
Directorate of Administration, ESA, Paris

Introduction

Over the past two decades, ESA has successfully funded and completed numerous research and development programmes. One of the keys to this success is that the Agency has been able to use what funding has been available both effectively and efficiently. One area, however, where it was felt that there was potential for additional progress was that of 'funding flexibility'. It was felt that better adjustment to the real programme needs of the Member States' contributions and their 'financing capacities' could benefit both the programmes and the Member States. In the past, ESA has had to face simultaneously a temporary lack of funds in certain programmes and an excess in others. Also, certain Member States have had temporary difficulties in contributing to new programmes, while their contributions to the on-going programmes were not being fully used.

As in other organisations that have to face the uncertainties inherent in managing leading-edge research and development programmes, ESA's budget is not always fully spent at the end of a given year. A certain amount of under-spending is imposed by the financial system itself: because ESA does not have a working capital fund and because the Member States' contributions are not due before 31 January at the earliest, most of the January/February expenditure can only be funded with the contributions arising from the previous year's underspending.

The underspendings result primarily from the difficulties that the programmes have in achieving a 100% accurate budget provision eighteen months in advance* due to the uncertainties introduced by:

- Deviation from the initial programme planning due to political or technical difficulties, unexpected delays in selecting contractors and negotiating contracts, and in industry.
- The fact that the Agency works with many different partners (other space agencies, industrial companies, etc.), whose decision-making might not be finalised when the budgets are being prepared.

* Budgets are prepared in July of year n and they forecast expenditure that will take place at the end of year n+1

The level of underspending varies considerably from one programme to another and from one year to another within each programme. Nevertheless, the total is significant and relatively constant year-on-year. An excess of contributions in one programme cannot, however, be used by another programme. Indeed, the Agency's ruling Convention lays down the legal principle of independence of the so-called 'Optional Programmes' – i.e. those in which not all Member States participate. This rule is designed to protect the interests of Participating States. Funds allocated to one programme by the Participating States cannot be used for another because the scale of contributions is different for each programme.

Even on a temporary basis, a loan between programmes is problematic because it can be viewed as a pre-financing between States. In the past, as an exceptional measure, ESA has managed to organise 'short-term' loans between programmes, but it was difficult due to the lengthy and heavy procedures involved, requiring the unanimous approval of Programme Boards.

It was decided that the best way forward would therefore be to find a mechanism that makes best use of the underspent portion of the contributions, whilst still keeping sufficient operating funds available for financing the development activities of the Directorates, on occasion reallocating the available funds to the most active programmes and thus rewarding managerial and industrial efficiency and rapidity. At the same time, adjusting contributions in this way to real needs should afford some flexibility to Participating States when they encounter temporary financial difficulties in joining new programmes.

The Budget Management System in use in ESA today has been conceived to solve these problems within the framework of the existing legal principles.

The Budget Management System

BMS principles

By definition, ESA budgets cover both expenditure that is certain to occur during the year, and expenditure that is 'uncertain' because it might occur during that year or somewhat later. The underlying principle of the BMS is to identify which expenditure is subject to uncertainty during the budget year and to centralise the contributions financing this expenditure outside the normal programme budgets. This allows for a lower level of financing whilst still covering the same level of Payment Appropriations (PA).

Car insurance is a good analogy. The premiums paid by car owners finance the expenditure incurred as a result of some subscribers being involved in accidents. The premiums are based on the likelihood of accidents occurring. Similarly, the Participating States finance contributions to the BMS in order to cover the uncertain expenditure. Depending on the likelihood of the 'uncertain' PA elements being used, these contributions may be higher or lower, but are in any case less than the financing of the total uncertain expenditure.

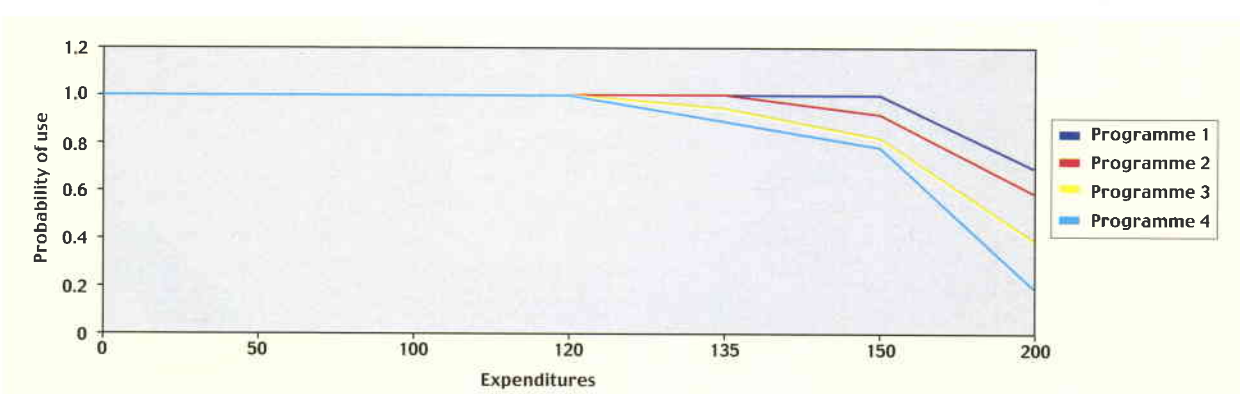
This difference between the contributions, as calculated with and without the BMS, provides some flexibility. This flexibility can be used to reduce the actual contributions whilst retaining the same level of potential expenditure. Alternatively, it can be used by keeping contributions constant to increase the rate of expenditure for programmes that are running ahead of schedule, whilst maintaining the same level of potential expenditure for the others. A mix of the two solutions is also possible.

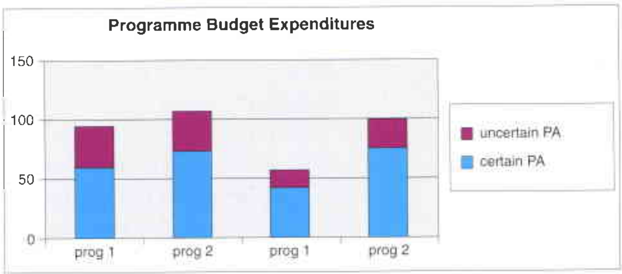
The system gives the programmes a guarantee that all of their expenditure will be financed when necessary. Because financing is always provided according to the contribution scales of the programmes, it guarantees that each contributor covers only his own risks and therefore the legal principles are respected. Moreover the BMS does not affect a programme's Cost at Completion, since it has no impact on the total actual expenditure or the total corresponding contributions of the Participating States. The system supposes, however, that the volume of activities and the level of participation by States in ESA programmes does not decrease drastically over a very short time period, which is very unlikely since the approved programmes are executed over several years.

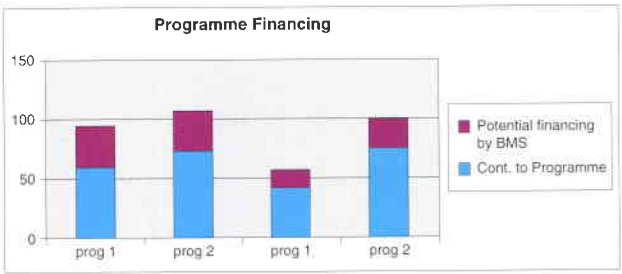
BMS preparation

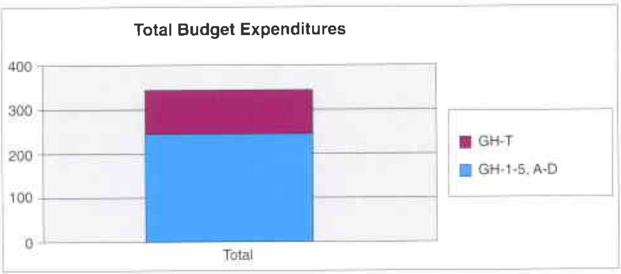
In each budget, the Payment Appropriations whose consumption during the year is uncertain are set aside under a specific General Heading* (GH-T). At the time of budget preparation, two sources of data are

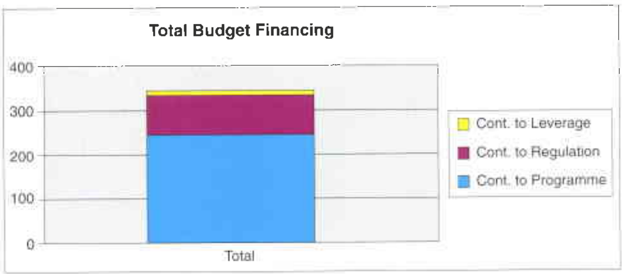
* Budgets are divided under General Headings each representing a particular type of expenditure: GH 1 = personnel expenditure, GH 4 = capital expenditure, etc.











available to identify that uncertain expenditure:

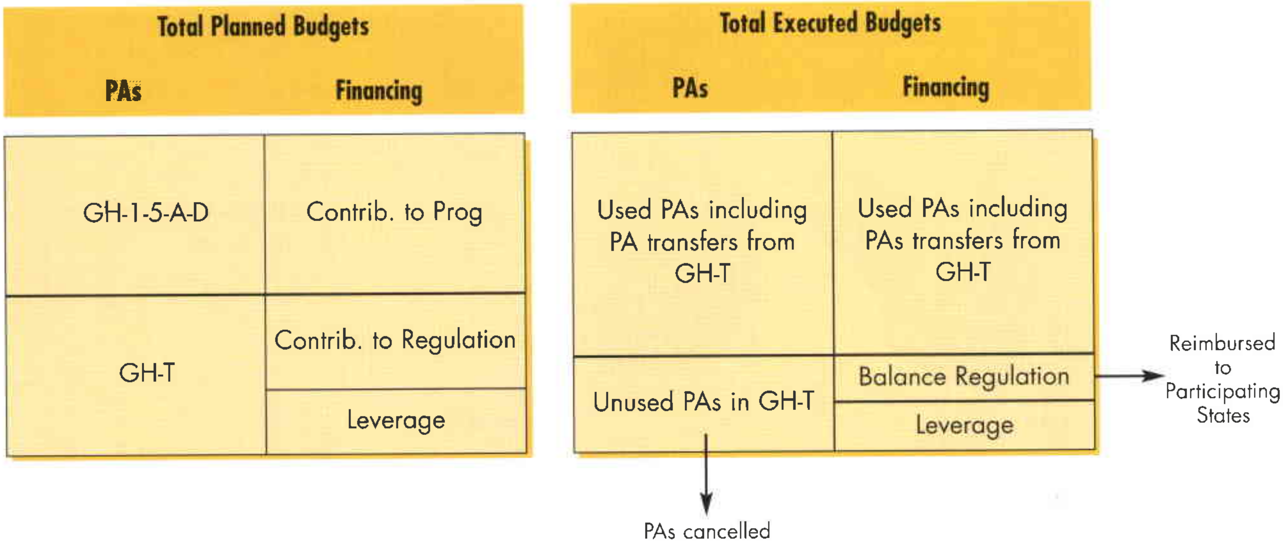
- Statistical tables that show the under-spending per programme over the years.
- Programme Controllers can highlight any expenditure forecasts that they consider involve a degree of uncertainty, which may be qualified as 'high', 'low' or 'unknown'.

From these data, the probabilities associated with uncertain expenditure are first assessed by programme and then ESA-wide. The total amount is then split into two: the part designed to cover the risks is termed the 'Regulation', and the other part not needed to cover the risks is the 'Leverage'. The Regulation and Leverage contributions from the different Participating States are calculated pro-rata based on their shares in the various programmes. In practice, the Regulation contributions are actually called-up, but the Leverage contributions are not.

BMS execution during the year

When a programme has used up its available Payment Appropriation under General Heading GH1-5-A-D (see accompanying diagram) and needs to call on funding from GH-T, PA is transferred via an internal procedure to the appropriate Heading. These transfers are limited to the amount of PA in the particular Budget GH-T, and consequently the total approved budget can never be exceeded.

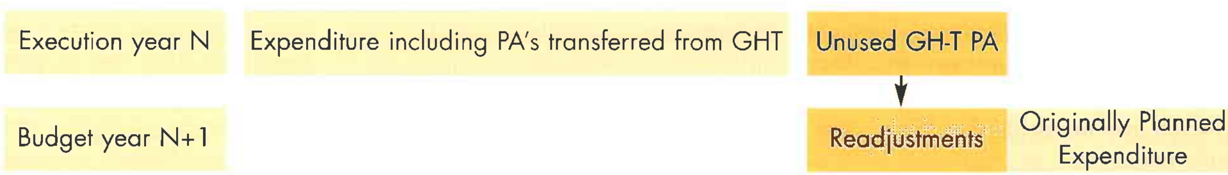
During the last months of the budgetary year, estimation of the transfers from GH-T becomes precise enough to forecast the balance of the Regulation per Participating State. If there are funds remaining in the Regulation, they can be used to finance supplementary budgets if needed. These supplementary budgets, which do not require additional contributions by Participating States, are subject to the normal budget approval procedure: recommendation by the Agency's Administration and Finance Committee (AFC) and approval by the appropriate Programme Board (PB). The BMS therefore allows redirection of the yearly financing to the most active programmes, without penalising others that are experiencing delays in their payments.



At the end of the year, all PAs in GH-T that have not been used because not all uncertain expenditure arose, are cancelled. The balance of the Regulation is reimbursed to the Participating States.

BMS execution over several years

Uncertain expenditure not occurring during year n will probably arise during year n+1. Hence, the corresponding PAs may be re-inscribed in year n+1, thus increasing the budgets. These are called 'Readjustments'. The budgets n+1 are also constructed with the BMS and therefore with Leverage; the system is designed so that the Leverage of budgets n+1 at least compensates the Readjustments. Consequently the BMS always has a positive or neutral effect on contributions, taking into account the reimbursed balance of the Regulation in the budgets of year n.



Conclusion

The new Budget Management System that has been outlined here was approved by the ESA Council in October 2000 and entered into force for the 2001 budgets of the Optional Programmes*.

In 2001 it led to a significant 11% reduction in contributions, thus solving some Participating States' difficulties in financing the budgets. At the same time, during the second semester of 2001 it allowed the financing of a supplementary budget without any increase in contributions. In practice, this facilitated the timely implementation of a programme that would have otherwise suffered delays, to the detriment of European industry. Last but not least, it reduced the underspending in the budgets of programmes participating in the BMS.

In 2002 it has led to a 7% decrease in contributions, thereby helping Participating States to participate in the new programmes that were approved by the Ministerial Council meeting in Edinburgh in November 2001. These first results are clearly very promising and should lead to further similar benefits in the future.

On a more general level, the introduction of the BMS has contributed to improving the financial system by introducing the management of planned expenditure according to statistical rules and by introducing the management of Participating States' contributions independently from the programmes to which they contribute, while still respecting the legal principles of the Agency.

These efficient and flexible management principles will also be the foundation for future reforms, in order to ensure that the Agency's financial system can always support its technical endeavours and achievements in the most effective manner.

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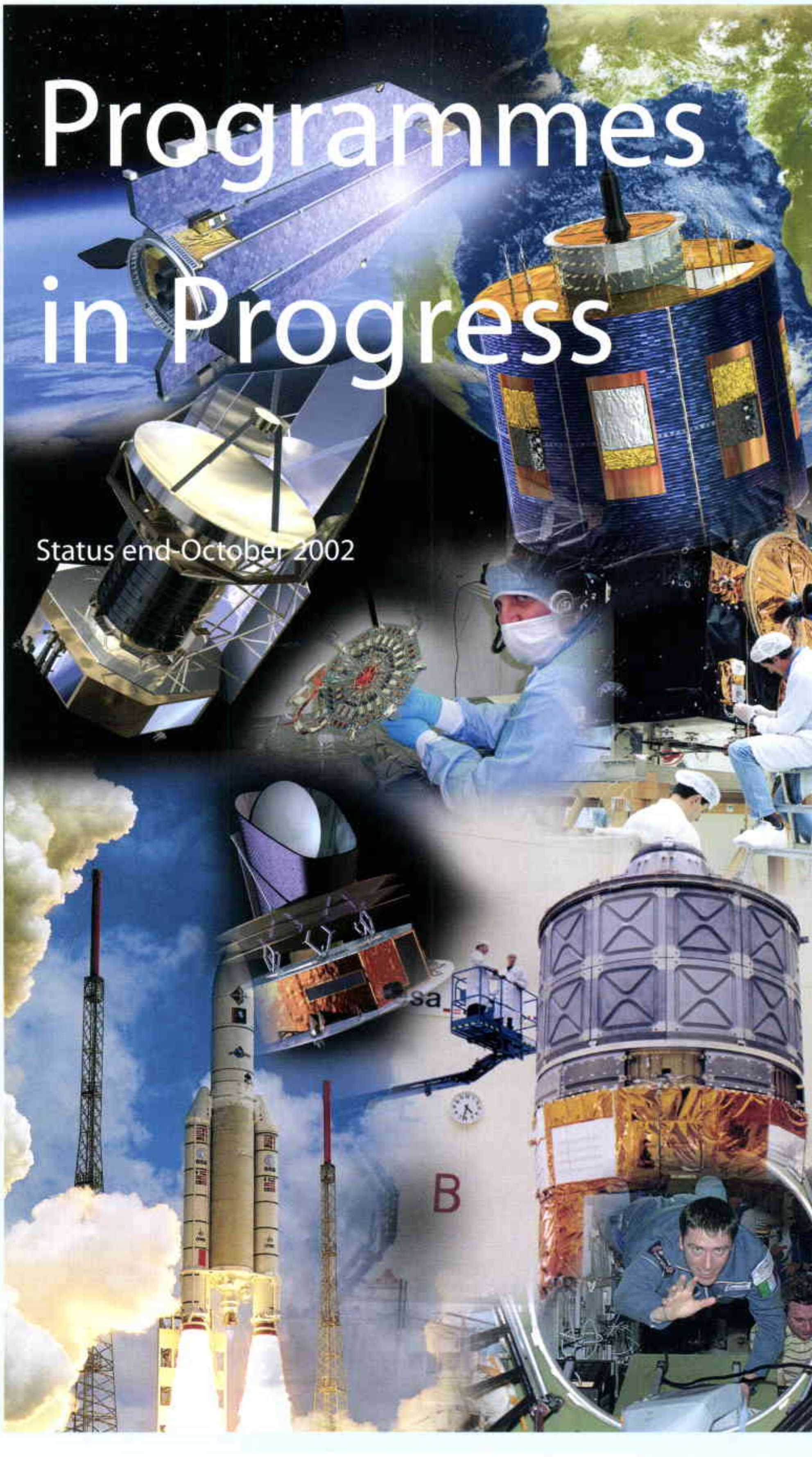
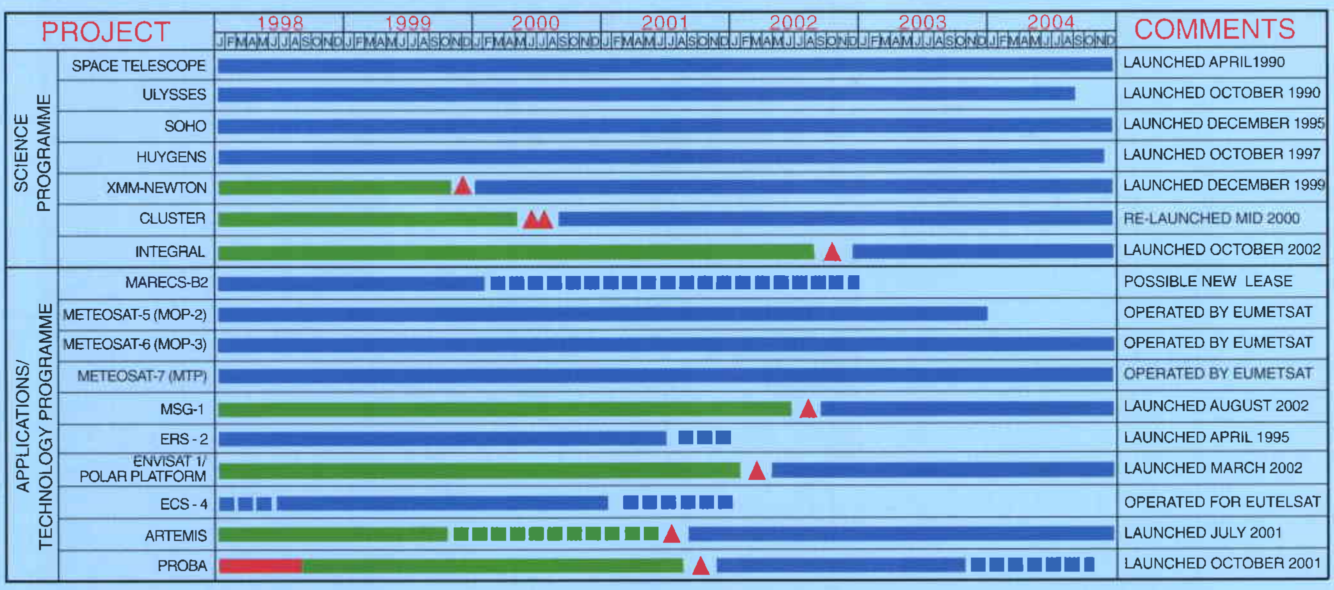
* The BMS applies to all Optional Programmes, except the GSTP and PRODEX Technology Programmes, and the associated budgets (CSG Kourou, etc.).

Programmes in Progress

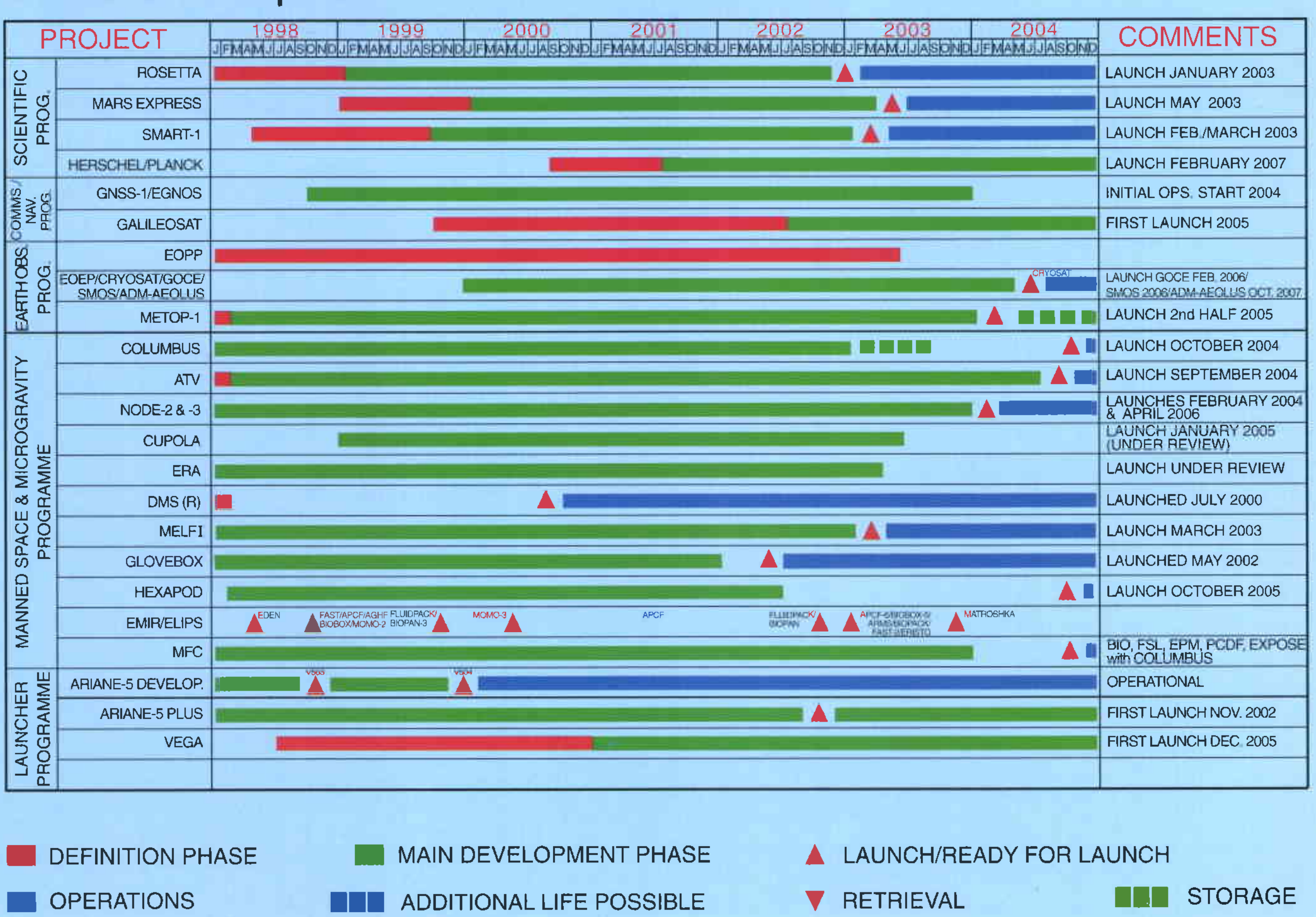
Status end-October 2002



In Orbit



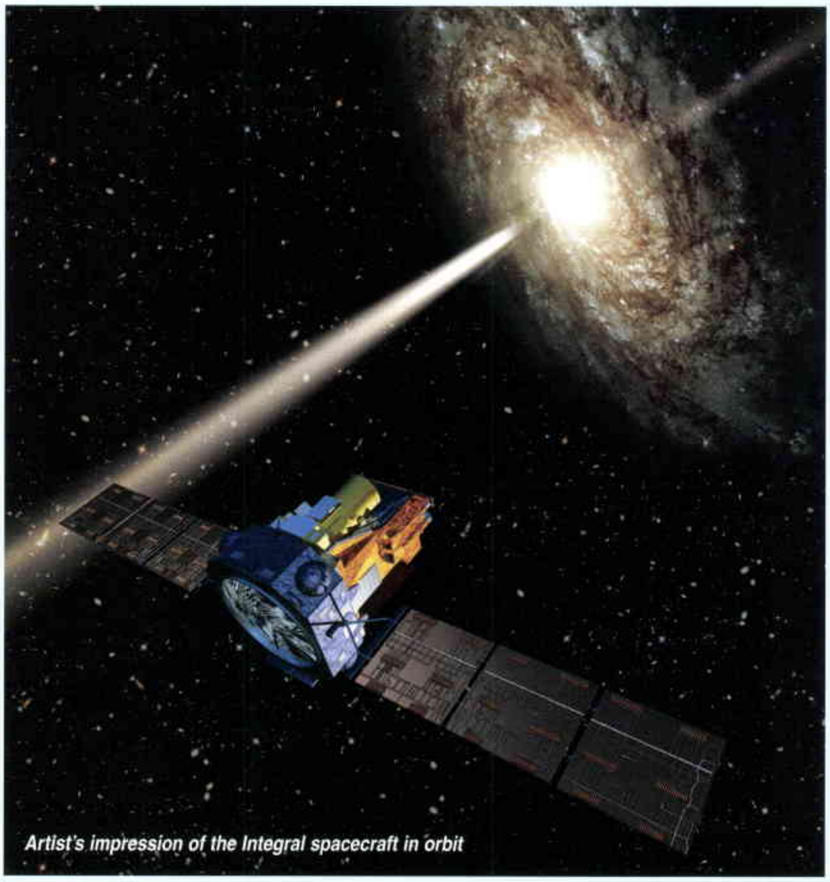
Under Development



Integral

The Integral spacecraft was successfully launched from the Baikonur Cosmodrome in Kazakhstan on 17 October by a Proton launcher. Separation from the launcher and the initial automatic spacecraft operations, including pointing the spacecraft correctly with respect to the Sun and deploying the solar arrays, went according to plan. The subsequent early flight operations under the control of ESA's Space Operations Centre (ESOC) in Darmstadt (D) have also been problem-free.

Integral is now in its final operating orbit and all spacecraft service-module functions are nominal. Payload activation is proceeding as planned for the four instruments on board: IBIS, SPI, JEM-X and OMC. The Mission Commissioning Results Review is scheduled to take place in December 2002.



Artist's impression of the Integral spacecraft in orbit

The Integral ground segment, consisting of the Integral Science Operations Centre at ESTEC in Noordwijk (NL), the Mission Operations Centre at ESOC in Darmstadt (D) (using ESA and NASA ground stations), and the Integral Science Data Centre in Geneva (CH), is working well.

Further coverage of the launch campaign and in-orbit commissioning can be found elsewhere in this issue of the Bulletin.

Rosetta

The flight-model spacecraft successfully completed its environmental and functional test campaign in Europe and is now in Kourou, French Guiana, undergoing final launch preparations. All subsystems are working as expected, and the software for the spacecraft's early in-orbit phase is being loaded and checked out.

Some anomalies have been detected in an engineering-model transponder and tests are underway to demonstrate that they do not apply to the flight model. The spacecraft qualification-model programme has been continuing in parallel at ESTEC to verify the software and on-board control procedures.

Several of the scientific payload's detectors have been exchanged during the summer and there is now a fully optimised set of experiments on the flight spacecraft.

The Lander needed to be demounted from the Orbiter in Kourou to replace some faulty actuators, which attach the Lander to the mothercraft, but it has also now been re-integrated, in fully functional flight configuration, on the spacecraft.

The ground segment, including the Rosetta Science Operations Centre, has successfully passed the Ground Segment Readiness Review. The performance of some subsystems is still being optimised, but no launch-critical items have been identified. The New Norcia ground station in Western Australia is now operational and has already been used for tracking other spacecraft.

The preparation of the Ariane launch vehicle itself is going according to plan, with the new elements unique to the Rosetta mission currently completing qualification. The final mission-analysis review has been held.

In summary, all of the Rosetta mission elements are 'code green' for a launch on 13 January 2003.

Artemis

The Artemis satellite continues on its journey towards its planned operating position in geostationary Earth orbit. Driven by electric propulsion using the single functional ion thruster, it gains 15 to 16 km of altitude every day. With just 1500 km to go, it is expected to reach its final operational orbit by the end of January 2003.

With no ion thruster now operating on the south face of the satellite, it will be necessary to abandon orbit inclination control for the mission. Nevertheless, since the approximately 1.5 deg inclination at the beginning of the satellite's on-station lifetime will grow by 0.8 deg/year or less, Artemis will still have an expected operational lifetime of the order of 10 years.

Services to users will begin soon after the satellite's arrival on station, with a regular data-relay service for Envisat and Spot-4, operation by EGNOS of the navigation payload, and Eutelsat's use of the land-mobile payload.

Meteosat Second Generation (MSG)

As reported in detail in ESA Bulletin 111, the MSG-1 spacecraft was successfully launched on 28 August 2002, together with the European telecommunications satellite Atlantic Bird-1, by an Ariane-5 vehicle.

After lift-off, ownership of the MSG-1 spacecraft was transferred from ESA to Eumetsat as per the agreed contractual arrangements. On Eumetsat's behalf, ESA's Space Operations Centre (ESOC) in Darmstadt (D) was responsible for the launch and early orbit activities for the spacecraft, and successfully placed MSG-1 into its geostationary operational orbit at around 10 deg West above the equator. The handover of operations from ESOC to Eumetsat, which will run all of the spacecraft's future geostationary operations, took place at the end of September. Eumetsat then began the spacecraft-commissioning exercise.

Rosetta in the integration hall in Kourou, French Guiana

Envisat

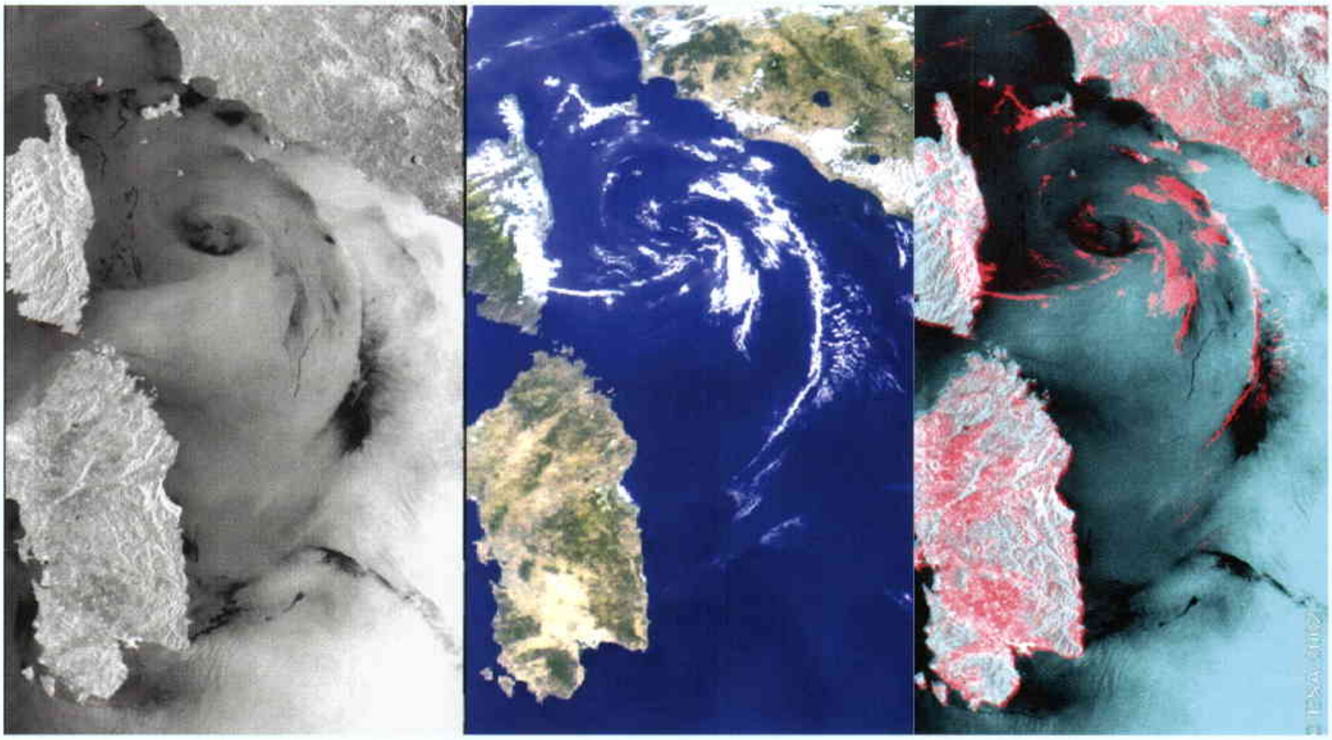
The satellite operations have been very stable since mid-June, with just one planned interruption from 8 to 11 September to correct the inclination of the spacecraft's orbit.

With the mission planning systems of the Flight Operations Segment (FOS) at ESOC (D) and the Payload Data Segment (PDS) at ESRIN (I) operating nominally, it has been possible to confirm the stable performances of the various instruments. Several updates to the ground and onboard instrument software have been implemented to correct for the few anomalies that have been encountered.

The PDS instrument processors have also been updated with the corrections identified by the Expert Support Laboratories during the calibration activities. Despite the problems encountered with the irregular throughput of the PDS, the Calibration/Validation teams received sufficient data to perform their calibration activities on time and the Calibration Review was held successfully on 9-13 September at ESTEC (NL).

Based on these results, the progressive phasing-in of the services to Principal Investigators (PIs), in particular for ASAR and MERIS image data products, was initiated in mid-September and is continuing through the last quarter of 2002. Over this period, priority will still be given to servicing the Cal/Val Teams, to provide them with the data products needed to prepare for the Validation Workshop planned for 9-13 December at ESRIN. The goal is still to achieve full operational readiness of the mission by end-2002.

The interim Kiruna-Svalbard dual-ground-station operation scenario will be introduced early in November. It will allow load-sharing between these two stations for global mission data recovery, for 10 orbits a day over Kiruna (S) and 4 to 5 orbits per day over Svalbard (N). The Svalbard data will be routed to ESRIN for processing. This interim scenario will allow mission operations to proceed whilst waiting for the Artemis data-relay satellite to become available in the first quarter of 2003.



Simultaneous obervation by Envisat's ASAR and MERIS instruments of a depression between Corsica and the Italian mainland: the MERIS image (centre) shows the situation at the cloud tops, while the ASAR image (right) shows the situation at sea level with no wind at the depression's centre (black spot). The ASAR-MERIS composite image (left) illustrates the synergy between the two instruments for observing this type of weather phenomenon

Thereafter, real-time data-product delivery will be available for all of the day's orbits.

The Envisat Commissioning Phase has been extended to the end of the year, and all efforts are now focussing on achieving a successful Operational Readiness Review in December.

ADM-Aeolus

The first few months of the industrial design phase contract (Phase-B) for this mission have concluded with the establishment by industry of the Satellite Design Specification and an Instrument Requirements Specification. These two documents will allow industry to produce equipment specifications to accompany a coherent set of Invitations to Tender (ITTs) to be issued early next year.

There has been significant progress in the development of the pulsed lasers needed. Both industry and the Executive are now convinced that a laser with adequate output power can be manufactured to meet the Aeolus programme's schedule constraints. This laser will deliver a 7 sec burst of pulses every 28 sec.

To maximise the system performance margins, it has been agreed to increase the telescope diameter from 1.2 to 1.5 m, and to increase the platform's capability accordingly, whilst still maintaining compatibility with the smaller and cheaper launchers likely to be available, such as Eurockot, Vega and Dnepr.

CryoSat

The CryoSat project is now well into its main development phase (Phase-C/D), and the industrial partners are well advanced with manufacturing the satellite components. Some elements have already been delivered to Astrium GmbH, the satellite prime contractor.

The launch-preparation work with Eurockot has started, and a review of the CryoSat requirements for launch services was successfully completed in September.

Development of the ground segment is also progressing according to plan and the definition activities for the Level-2 processing algorithms have begun.

One of the baffles for CryoSat's star trackers being manufactured at TERMA in Denmark

Following the Announcement of Opportunity (AO), a first meeting of the Calibration and Validation group took place in September. One outcome of this meeting was the definition of a pre-launch validation campaign, which should take place early in 2003 in the Fram Strait, between Norway and Greenland.

GOCE

Following successful completion of the space-segment Preliminary Design Review (PDR) in April and the subsequent close-out of related action items, the system prime contractor Alenia Spazio has authorized industrial core-team members Astrium GmbH and Alcatel Space Industries to proceed with all main-development-phase (Phase-C/D) activities associated with the platform and gradiometer instruments.

Tribological tests have recently been performed to find a gradiometer proof-mass stop material or coating that reduces material transfer between the corner stops and the proof-mass to an acceptable level. This is a key factor in assessing the ability of the gradiometer accelerometer design to withstand the launch vibrations. Mechanical testing of an accelerometer sensor head equipped with the selected stop material/coating is planned at the end of November. An updated gradiometer calibration scenario has been worked out, supported by a dedicated simulation campaign, to consolidate the instrument's in-flight calibration.

The Preliminary Design Review (PDR) for the second primary payload, the twelve-channel dual-frequency GPS receiver provided by Laben (I), began at the end of October, and the conclusions are expected towards the end of the year.

The make-up of the GOCE space-segment consortium is now almost complete. The last Invitation to Tender (ITT), addressing the selection of the independent software validation contractor, was issued at the beginning of July.

The micro-propulsion and solar-generator selection processes are also approaching a conclusion. The Tender Evaluation Board (TEB) for the micro-propulsion thruster assembly met in mid-July. Negotiations with the recommended field-emission electric-propulsion (FEEP) thruster supplier are in progress. The evaluation of the proposals submitted by potential solar-generator suppliers was also completed in July, and negotiations with the recommended supplier are in progress.

The predicted launch date for Cryosat is currently mid-February 2006.

SMOS

The CASA-EADS industrial proposal for the payload design phase (Phase-B) was received on 21 October and is currently under evaluation/negotiation. The timing should allow a seamless transition between the extended Phase-A (definition phase) and the Phase-B.

System-support studies with CNES and Alcatel are in preparation, but an assessment is needed first of whether the Proteus attitude and orbit control system requires a fourth gyroscope. If so, a major redirection of work might be needed.

The breadboarding activities within the framework of the MIRAS Demonstrator Pilot Projects (MDPP) 1 and 2 are about to be completed, with a full one-arm deployment test and an image-validation test with a set of 12 receivers.

Studies for the definition of the payload-data ground segment and the scientific algorithms for instrument calibration and image reconstruction are about to be kicked-off.

MetOp

The MetOp integration programme continues to make good progress. The first flight Payload Module was delivered from Astrium in Friedrichshafen (D) at the end of September for thermal-vacuum testing in the Large Space Simulator at ESTEC in Noordwijk (NL). The MetOp-1 Service Module is also progressing towards its thermal-vacuum testing, this time at the Intespace facilities in Toulouse (F), which should be completed at the end of the year.

The impact of the problem discovered with the IASI detectors has been assessed and already partially resolved via a work-around that will respect the critical schedule leading to launch-readiness of the first MetOp. This is, however, being achieved at the expense of the MetOp-3 integration programme, which will need to be restructured accordingly. Other concerns arising from the IASI Critical Design Review have been largely resolved. Good progress has also been made in understanding and implementing the measures needed to accommodate the IASI-specific constraints during the Assembly, Integration and Verification programme.

The ASCAT instrument's switching front-end unit definitely needs modification to mitigate the impact of its radiation sensitivity. The details of this modification are still being discussed with industry. GOME-2 continues to make good progress, with the second flight instrument undergoing calibration at TPD Delft (NL). The first flight-model GRAS instrument has completed its acceptance testing and will be available for integration once the acceptance review is completed. Solutions for the antenna metallisation problems are still being examined, but this does not threaten the overall schedule.

International Space Station

Overall Assembly Sequence

One logistic flight was made to the ISS during the third quarter, with the launch from Baikonur on 25 September of Progress re-supply flight 9P. Investigations and recovery procedures to resolve the problems in the fuel-supply lines of the four Orbiters of the Shuttle fleet were completed and the next flight scheduled for early October.

Discussions are continuing regarding the so-called 'End State' configuration of the ISS, which has been put into question due to NASA's budgetary situation.

Columbus Laboratory
ESA/NASA bilateral qualification tests on the flight-model power and audio interfaces and command and control verification have shown these systems to be extremely robust. System functional qualification testing with the Electrical Test Model (ETM) is in progress and preparations for the major ESA/NASA bilateral hardware/software compatibility testing is underway.

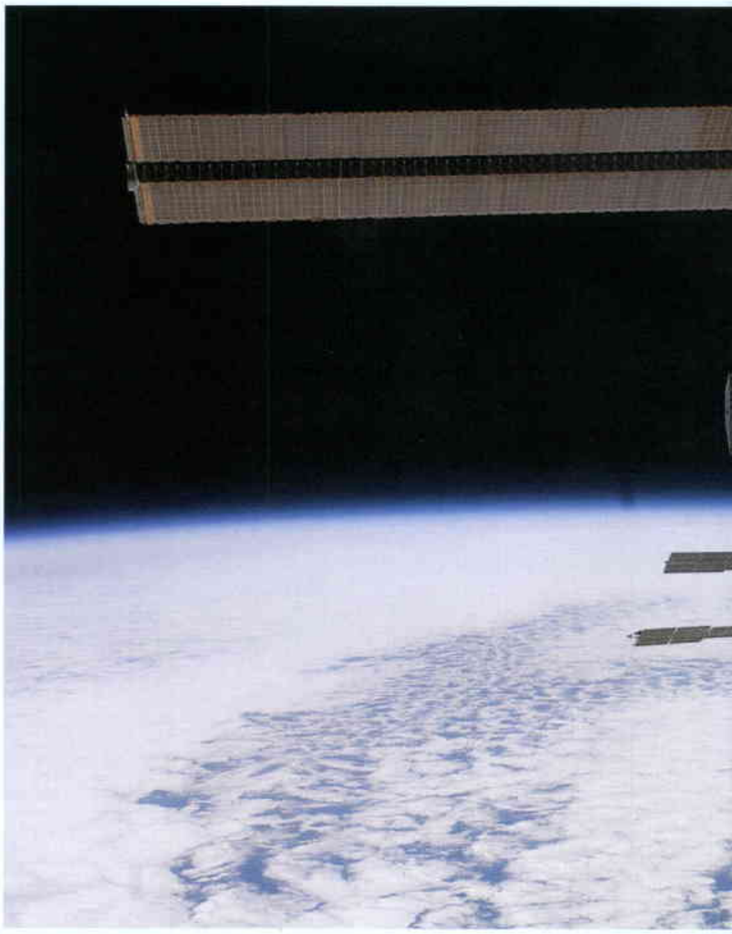
The Columbus launch is on the Shuttle manifest for October 2004 and a Columbus Mission Manager has been appointed to ensure that all aspects of the flight and ground segments in Europe and the USA are actively monitored and managed.

Columbus Launch Barter
Nodes-2 and -3
Integration of the Node-2 flight unit is progressing well, and the Safety Review Phase III has been successfully completed. System Design Review 2 for Node-3 has also been completed successfully. Structure acceptance testing has been delayed until January 2003, but without impacting the planned delivery date.

Crew Refrigerator/Freezer (RFR)
Manufacture of the RFR qualification model is progressing, with the Qualification Review planned for March 2003.

Cryogenic Freezer (CRYOS)
The CRYOS System Requirements Review, due to start in late-October, is in preparation.

Cupola
Vibro-acoustic testing of the Structural Test Article (STA) has been successfully completed and it has subsequently been delivered to Johnson Space Center in Houston. Manufacture of the flight-unit dome is progressing and all shutter mechanisms are now available for integration. Flight-unit delivery is now expected to take place in July 2003.



Backdropped by a dark blue and white Earth, this photograph of the International Space Station (ISS) was taken by a crew member on board the Space Shuttle 'Atlantis' following the undocking of the two spacecraft. Atlantis pulled away from the complex at 8:13 a.m. (CDT) on 16 October. The newly added Starboard One (S1) Truss is visible centre frame. *(Photo NASA)*

Automated Transfer Vehicle (ATV)
Thermal-vacuum testing at ESTEC (NL) on the Structural-Thermal Model (STM) has been successfully completed, thereby concluding that model's test campaign. The Cargo Carrier has now been returned for refurbishment into a Crew Trainer and the spacecraft part of the STM is being shipped to Bremen (D). Tests on the avionics Electrical Test Model (ETM) have been completed and manufacture and integration of the first flight unit is progressing well, although the Stage-3 propulsion firing test has been further delayed to November 2002.

The first ATV launch is scheduled for September 2004 and an ATV Mission Manager has been appointed to ensure that all aspects of the flight and ground segments are actively monitored and managed.

X-38/CRV and Applied Re-entry Technology (ART)
Formal notification of the X-38's cancellation was received from NASA in August, and detailed consultations relating to the termination of the programme are to take place. Work on all European contributions to the X-38 vehicle will be completed within 2002.

Ground-segment development and operations preparation
The ATV Control Centre (ATV-CC) Preliminary Design Review (PDR) has been successfully completed and the main development phase (Phase-C/D) proposal has been delivered. Regarding the Columbus Control Centre's (COL-CC) development, subsystem requirements reviews have been successfully conducted for the major subsystems, and preparation of the COL-CC system PDR and the Phase-C/D proposal is ongoing.

The ground segment for the 'Odissea' Taxi Flight to the ISS was set up and checked-out. Simulations and training of ground controllers are ongoing.

The PDR for the ATV Crew Trainer and ground

in preparation for an ESA/NASA meeting in October.

Concerning the Atomic Clock Ensemble in Space (ACES), significant progress has been made in finalising the Phase-C/D contract. Phase-A for the RapidEye commercial Earth-observation instrument was in preparation. The Acceptance Test of the Neutral Buoyancy Model for Matroshka, the radiation-monitoring instrument for the Russian segment, was completed at the European Astronaut Centre (EAC) and the Critical Design Review (CDR) has started. Analytical payload integration for the Columbus pressurised facilities Biolab, FSL, EPM and EDR is in progress.

The European Drawer Rack (EDR) CDR data package was presented in September and is under review. Due to a major contract change, implemented to make Agency-furnished equipment compatible with Columbus interfaces and EDR design constraints, the delivery of the engineering model has shifted to early-March and the flight-model delivery to early-September 2003.

The contract for the European Transport Carrier (ETC) will start in mid-October 2002.

simulator has been successfully completed and the design review for the ATV training mock-up has also been conducted satisfactorily. The Columbus Crew Trainer has been successfully integrated into the Mechanical Mock-Up and European Astronaut Centre (EAC) infrastructure and has been used to support the first ISS Advanced Crew Training session (reported in greater detail elsewhere in this ESA Bulletin).

In terms of ATV operations preparation, the System Operations Reference was released and an agreement to use the Artemis satellite in place of the Russian ground stations as the data relay for the attached and proximity phases was negotiated with the Artemis Project. Preparation of the Columbus operations has also taken a step forward with the definition of the core members of the Flight Control Teams (FCT) and the nomination of the lead Flight Directors for the Columbus launch (1E) mission.

Utilisation

Preparation

Following-on from the Heads of Agencies meeting in June, the International Partners have provided estimated up-load-mass and crew-time requirements resulting from their respective Research Plans 2004-2008. The integrated research requirements, which include the American, Canadian, Japanese and European needs, will serve as input to analyse path options for the ISS 'End-State'.

43 of the 44 Microgravity Applications Promotion (MAP) projects originally planned are now in progress, with some approaching first-phase completion. They will be evaluated using a procedure based on 3-4 monthly batch evaluations by an expert panel.

Payloads and their integration

Following the agreement with NASA that two ESA External Payloads, SOLAR and EuTEF mounted on the ICC-Lite carrier, could fly on the 1E Columbus flight, assessment work to determine the technical implications continued

In-orbit commissioning of the Materials Science Glovebox (MSG), which was delivered to the ISS in June, is in progress. The first two US experiments using the MSG were run successfully and Acceptance Review 3, which will define the terms for transfer of ownership to NASA, is planned for end-October.

The flight unit (FU1) of the MELFI −80°C freezer has been at Kennedy Space Center since late-March. All interface tests with the ISS have been completed successfully and the launch of FU1 is planned for March 2003.

Subsystem-level testing of the Hexapod pointing system has been completed and mechanical integration of the flight unit is now in progress.

A number of experiments to be performed during the 'Odissea' Taxi Flight in October were delivered to the ISS on 25 September by the Progress logistics flight, whilst preparation of the remaining experiments to be launched together with ESA astronaut Frank de Winne on the Soyuz vehicle continued.

Astronaut activities
Frank de Winne continued his training at Star City for the 'Odissea' Taxi Flight, following his earlier experiment training in Brussels, at ESTEC and in the USA. Christer Fuglesang continued his training at Johnson Space Center for his STS-116/12A.1 Shuttle mission scheduled for June 2003.

The first ISS Advanced Training session at the European astronaut Centre (EAC) for an international class of 10 astronauts took place from 26 August to 6 September. The participants, who included four ESA, four Japanese (NASDA) and two NASA astronauts, received a total of 32 classroom and hands-on lessons on the Columbus and ATV systems, as well as an introduction to the ESA ISS payloads.

Early deliveries
Data Management System for the Russian Service Module (DMS-R)
The DMS-R on-board the Russian Service Module continues to operate problem-free.

European Robotic Arm (ERA)
Functional qualification testing of the ERA flight model is continuing and a new baseline schedule has been agreed, resulting in a Flight Model Qualification Review in March/April 2003.

ISS Exploitation Programme
The Request for Quotation (RFQ) for the ATV Follow-on Production Contract was released to Industry and a proposal is expected in October. A major Contract Change Notice (CCN) to the Exploitation Contract for the implementation of the operations-preparation Initial Tasks is under negotiation with industry.

Microgravity

Preparation of ESA's payloads for the Spacehab mission (STS-107) was completed by mid-2002, but the delayed launch is not now expected to take place until January 2003. All of ESA's facilities for the Foton M-1 mission have been completed and accepted for flight, and the Foton capsule itself was transferred to Plesetsk for launch on 15 October. Preparations for the Maxus-5 sounding-rocket flight continued, with launch planned for March 2003. The first parabolic-flight campaigns with the overhauled Airbus 300 Zero-G aircraft were performed in September.

Development of payloads for the ISS continued. NASA announced a July 2004 launch for the European Modular Cultivation System (EMCS) botany facility, and the EXPOSE facility for exobiology, for which the CDR was successfully completed in August, will now be launched in October 2004 together with Columbus. Delivery to NASA of the HGD/PFD and PEMS physiology instruments was also completed. Development of the MARES (physiology) and PCDF (proteins) facilities for the European Drawer Rack (EDR) continued, and the MARES CDR started in July.

Microgravity Facilities for Columbus (MFC)
All the laboratory facilities that are to be carried in Columbus are on schedule for its October 2004 launch. The flight-model subsystems for the Fluid Science Laboratory have been manufactured and are now being tested. Integration of the system flight model with the secondary structure has begun. Integration of the Biolab's flight hardware has been progressing well and will be completed in early-2003.

NASA's Human Research Facility (HRF-2), including the ESA Pulmonary Function System, has been shipped to Kennedy Space Center for launch, which is expected to take place early in 2003. The system CDR for the European Physiology Module (EPM) was successfully concluded in September, the engineering model completed its testing, and flight-model integration has started.

Testing of the Materials Science Laboratory (MSL) engineering model has been completed and integration of the flight model has started. The Final Presentation completing the Materials Science Laboratory design phase (Phase-B) with the Electro-Magnetic Levitator was held in June, consolidating the design.

Ariane-5 Plus

The filling-model (MR) campaign for Ariane-5 Evolution and Ariane-5 Plus referred to in previous reports, and aimed at validating the upper-stage tank-filling procedures, was successfully completed at the end of July. This

Artist's impression of Ariane-5 Plus

important achievement, together with the significant progress made with the Launcher Qualification Review, allowed the holding on 8 August and 9 September of the Flight-Readiness Review for the V157 flight, the first launcher configuration combining the Ariane-5 Evolution and Ariane-5 Plus developments. With all major problems identified having been resolved, authorisation was given to start the launch campaign on 22 August. At the end of September, the lower composite with the Vehicle Equipment Bay was erected. The Launcher System Rehearsal is planned for the beginning of October and the V157 launch, carrying Hot Bird-7 for Eutelsat and Stentor for CNES, is presently scheduled for the end of November.

Vega / P80

The proposal from Industry for the Vega Small Launcher Development Programme was evaluated in June by the Tender Evaluation Board. Following a series of discussions between the Programme Team and Industry, a new proposal was issued in late July. Based on this new version, a Preliminary Authorisation to Proceed was released to the Industrial Consortium in order to start time-critical activities. Final contract negotiations have started in late September.

A successful Preliminary Design Review for the Vega Ground Segment was held during June and July, and a first proposal for the Ground Segment Technical Management Engineering and Test Contract was issued. Discussions with the Programme Team to agree and issue an improved version of this proposal are in progress.

Artist's impression of the lift-off of the Vega small launcher

The P80 development activities have concentrated on finalising the contract negotiations. Some schedule delays associated with long-lead-item procurement are being recovered by applying a modified development logic.

Successful Odissea to the Space Station

ESA astronaut Frank De Winne came back to Earth on Sunday 10 November after a successful Soyuz mission to the International Space Station involving nine days of ground-breaking scientific research and the delivery of a brand new TMA-1 Soyuz spacecraft.

The Odissea mission crew – Frank De Winne and the Russians Sergei Zaletin, Soyuz Mission Commander, and Yuri Lonchakov, Soyuz Flight Engineer – were lifted into orbit on the first ever flight of the new Soyuz model TMA and returned in the old TM-34 Soyuz that had been attached to the Space Station as an emergency return vehicle for the last six months.

Safely descending to Earth in their Soyuz TM-34 capsule, the crew ended a 11-day mission with a flawless night landing near the town of Arkalyk on the plains of Kazakhstan at 06:04 local time (00:04 GMT).

Frank De Winne during his mission in the ISS

Frank De Winne and his fellow crew members after landing

ESA astronaut Frank De Winne, a former Belgian Air Force fighter pilot, described his first voyage into space as "*the most intense, challenging and unbelievably fulfilling 11 days of my professional life.*" During his nine-day stay on the Space Station, De Winne worked on a substantial programme of 23 scientific experiments, including four physical sciences experiments with the newly installed Microgravity Science Glovebox (MSG) facility. He also made several inflight calls to schools and TV stations in Belgium and the Netherlands, and performed educational experiments.

Foton M-1 launch failure

A Russian Soyuz launcher exploded some 20 seconds after lift-off from the Russian Plesetsk cosmodrome on 15 October at 20:20 CEST, killing a Russian soldier.

The launcher carried the unmanned Foton M-1 research satellite, using capsules of the Foton/Bion family containing 44 experiments supported by ESA. The experiments covered a wide range of scientific disciplines, including fluid physics, biology, crystal growth, radiation dosimetry and exobiology.

ESA's contribution included the FluidPac Physics Facility with four experiments, Biopan hosting nine experiments, the upgraded Telescience Support Unit to assist both FluidPac and the German AGAT furnace, six Autonomous Experiments (three developed by university students), Stone simulated meteorites, and the 'Soret Coefficient in Crude Oil' experiment.

The report of the State Inquiry Board headed by Russian space officials is expected to report soon on the causes of the accident. A press conference given by the Head of Rosaviakosmos, Yuri Koptev, on 18 October provided initial information. One of the strap-ons took 2 s to reach full thrust, pulsed for 1.5 s and 4 s after launch lost all power. It then fell away from the vehicle, as it is designed to do when thrust no longer holds it in place. It fell back to Earth, where the ruptured tanks led to a large fire that significantly damaged the pad. The launcher automatically shut down the other three strap-ons 20 s after launch, and it struck the ground about 1 km from the pad and exploded.

Preliminary analysis indicated that the hydrogen peroxide supply to the propellant turbopumps was blocked by a metallic object. France's IBIS biological incubator, Germany's AGAT, Russia's Polizon furnace and five Russian experiments (Biokont, Komparus, Mirage-M, Sinus-16 and Chistata) brought the spacecraft's overall payload to a total of 650 kg.

Sadly, a soldier watching from the integration building was killed. Fortunately, all of the engineers and experts from ESA, the French space agency CNES and the German space agency DLR involved in the preparation of the spacecraft in Plesetsk were unharmed.

ESA satellites watching Mount Etna

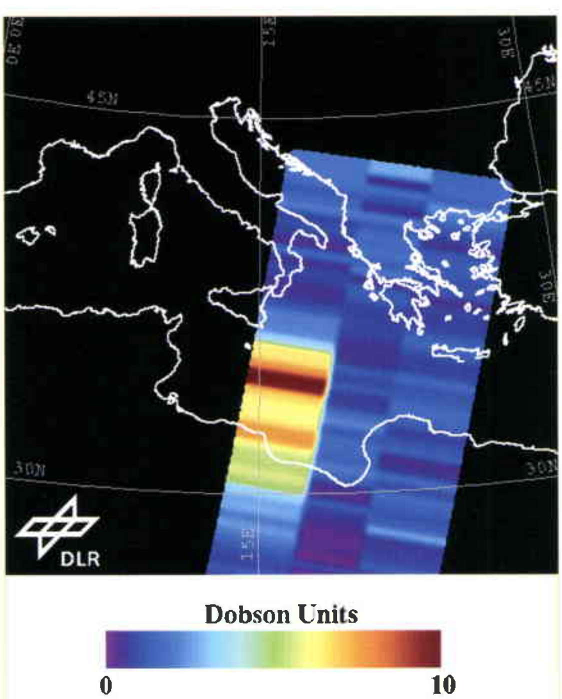
The recent eruptions of the Mount Etna volcano in Sicily are throwing huge amounts of ash and gases into the atmosphere. Instruments on three different ESA spacecraft – ERS-2, Envisat and Proba – have acquired imagery of the eruptions, shedding new light on the event and its impact on the Earth's environment.

Data from the Global Ozone Monitoring Experiment (GOME) sensor onboard ESA's ERS-2 spacecraft reveal that levels of sulphur dioxide from the eruptions at the end of October are at least 20 times higher than normal.

The normal background level of sulphur dioxide is typically below 0.5 Dobson Units (DU), a measure of atmospheric gas concentrations from ground level to the top of the atmosphere, about 70 km in altitude. "*In the plume, we measured the atmospheric content of sulphur dioxide at about 10 DU*", said Werner Thomas, an atmospheric scientist with the Remote Sensing Technology Institute of the German aerospace centre (DLR).

Sulphur dioxide in the troposphere, the lowest part of the atmosphere where most weather changes occur, is known to be responsible for the so-called "acid rain" phenomenon. Etna is one of the most prominent sources of natural sulphur dioxide worldwide.

The Italian government declared a state of emergency in Sicily in the wake a series of earthquakes, measuring between 3.6 and 4.3 on the Richter scale, that forced the evacuation of approximately 1000 homes, according to reports from BBC and Italian newspapers.



GOME-based sulphur-dioxide retrieval on 29 October 2002 over the Mediterranean Sea. The maximum content close to the volcano is around 10 Dobson Units, which is 20 times higher than the background concentration.

Meanwhile, three streams of lava from the eruption flowed down the south, northeast and northwest slopes of the mountains, the media reports stated.

Europe's highest and most active volcano (3370 m) hurled lava and ash from several craters into the sky with speeds between 350 and 450 metres per second, exceeding the speed of sound. According to data from volcanologists, the lava and ash were ejected from the main crater and from at least nine new craters that developed in the mountain at between 2300 and 2700 metres in altitude.

Images from the Medium Resolution Imaging Spectrometer (MERIS) onboard ESA's Envisat satellite show that the eruptions spewed significant amounts of ash into the atmosphere. The larger volcanic ash particles are expected to settle out in a short period of time, but the sulphuric acid aerosols produced by the sulphur dioxide will persist for several years.

Aerosols containing black graphite and carbon particles are dark, thus absorbing sunlight. As these atmospheric particles reduce the amount of sunlight reaching the planet's surface, they increase the amount of solar energy absorbed in the atmosphere, thus simultaneously cooling the surface and warming the atmosphere.

The ability of the MERIS instrument to observe the spatial distribution of these aerosol plumes can be exploited to measure the amounts of airborne particles and to examine the role of these aerosols as cloud condensation nuclei and their impact on the hydrologic cycle through changes in cloud cover, cloud properties and precipitation.

Just 60x60x80 cm and weighing only 94 kg, ESA's Project for On-Board Autonomy satellite, better known as Proba, is one of the most advanced small satellites ever flown in space. Since its launch exactly one year ago, Proba's high-performance computer system and technologically advanced instruments have enabled it to demonstrate and evaluate onboard operational autonomy, with new spacecraft hardware and software, and to test new Earth observation and space environment monitoring instruments in space.

The imagery captured by Proba demonstrates the capabilities of CHRIS, the Compact High Resolution Imaging Spectrometer, which is providing important information on the Earth and its environment, and will be a valuable remote sensing tool during the extended mission.

EIROforum and education

EIROforum was formally established on 12 November with the signature of a common EIROforum Charter by the Directors General of the seven European intergovernmental research organisations (CERN, EMBL, ESA, ESO, ESRF, ILL and EFDA) during the EU-conference on "European Research 2002 – The European Research Area and the Framework Programme".

A few days prior to this ceremony, the Directors General had met to discuss the areas of EIROforum collaboration. One of the key points on the agenda was the formation of a European Science Teachers Initiative (ESTI). This Initiative aims to pool the EIROforum's considerable expertise and resources in a coordinated approach towards the European science teaching community.

Previous joint education projects such as 'Physics on Stage' have identified the need of Europe's science teachers to have access to cutting-edge science and to receive support in bringing the excitement of new scientific discoveries into classrooms. The EIROforum organisations are natural focal points for public interest in science and they emphatically support Europe-wide efforts to raise interest in science and technology and to secure a sound recruitment base for European research efforts in the future.

With this in mind, the Directors General agreed on a Statement of Principles for ESTI, which will form the basis of an application to the European Commission for collaboration in this major initiative.

"*The establishment of EIROforum is a concrete example of the dynamics created by the European Research Area. Europe has unquestioned excellence in science. By working together, Europe's leading research organisations can make that more visible on the European and world stage,*" commented EC Commissioner for Research Philippe Busquin.

esa

The DGs of the seven organisations signing the Statement of Principles for a European Science Teachers Initiative

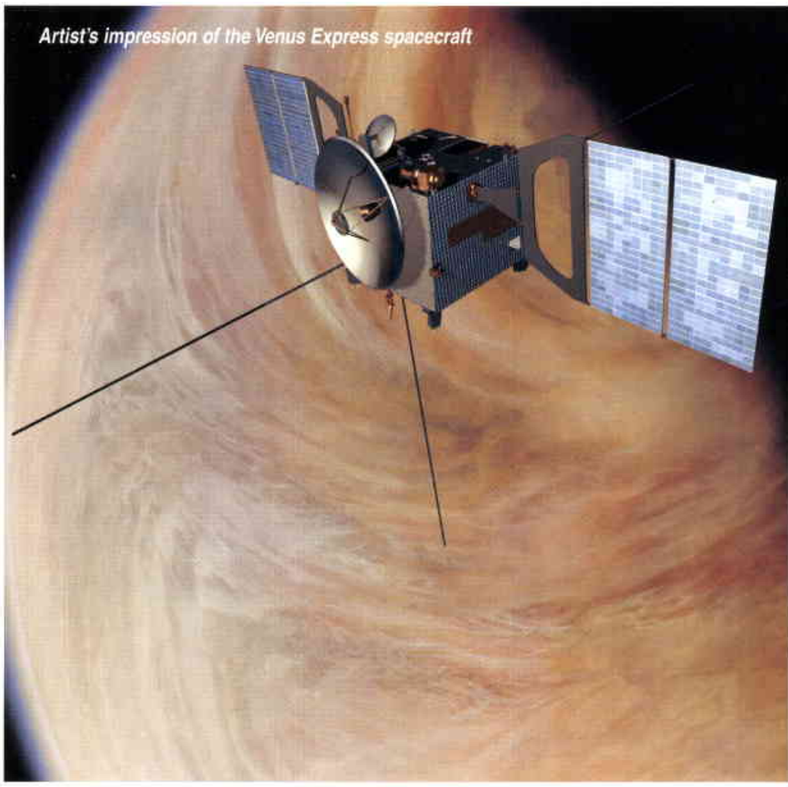
DeVIL inside: Satellite technology "prêt à porter"

The European Space Agency (ESA) has started a 50-million-Euro initiative to bring together Europe's leading aerospace companies for the next four years. The aim of DevILS is to develop 'intelligent', lightweight spacecraft systems that ESA can use on future missions. Having these 'plug- and-play' systems will allow Europe to create lighter spacecraft that perform better.

The aim is to reuse similar systems on many different spacecraft, which has already proven to save time and money. For example, the recently launched Integral gamma-ray observatory has reused part of XMM-Newton's design. Mars Express reuses hardware designed for Rosetta. The Venus Express mission is likely to use the same hardware design again.

DeVILS uses 'intelligent' systems on-board satellites. These are multipurpose components that perform the same tasks as a number of previous units. In this way, you reduce the number of components, the size and hence the mass of individual spacecraft, enabling cheaper missions. Industry is the creative catalyst in the project, by telling ESA what they can do to make spacecraft cheaper, lighter and perform better. Besides improved science missions, this could well lead to more efficient applications in telecommunications, global navigation, and Earth observation. esa

Using the same design for different spacecraft can save weight and money.



Artist's impression of the Venus Express spacecraft

Venus Express confirmed

ESA's Science Programme Committee (SPC) has given the final go-ahead for the Venus Express mission. On 5 November, the SPC unanimously confirmed its strong will to undertake the mission. Furthermore, the Committee endorsed and agreed on a solution to the financial issues that had cast serious doubts on the mission.

Venus Express will reuse the Mars Express spacecraft design and needs to be ready for launch in 2005. Since the last meeting of the SPC in July 2002, ESA has invested 7 million Euros to start the first mission design phase. However, the mission's fate was not yet sealed because one nation, Italy, had still not confirmed its participation in the payload. To rescue the mission, the ESA Science Directorate in collaboration with the Italian Space Agency (ASI) came up with several financial proposals, one of which was eventually endorsed by the SPC.

The Italian contribution to Venus Express will consist of parts of the VIRTIS and PFS experiments and the ASPERA instrument. ESA will contribute 8.5 million Euros, covering the integration and testing of the parts of the instruments Italy has agreed to provide and other items needed to allow the Italian instruments to fly. In exchange for ESA's support, the VIRTIS Science Team will be further Europeanised. esa

XMM-Newton closes in on space's exotic matter

For the first time, XMM-Newton has been able to measure the influence of the gravitational field of a neutron star on the light it emits. This measurement provides much better insight into neutron stars and might be able to prove the theory that the primordial soup of dissolved matter that existed a fraction of a second after the Big Bang can still be found in today's Universe, in the core of certain very dense neutron stars.

Neutron stars are among the densest objects in the Universe. They pack the mass of the Sun into a sphere just ten kilometres across. A sugar-cube-sized piece of neutron star weighs over a billion tonnes! Neutron stars are the remnants of exploding stars up to eight times more massive than our Sun. They end their life in a supernova explosion and then collapse under their own gravity. Their interiors may therefore contain a very exotic form of matter.

Scientists believe that in a neutron star, the densities and temperatures are similar to those existing a fraction of a second after the Big Bang. They assume that when matter is as tightly packed as it is in a neutron star, it goes through important changes. Protons, electrons, and neutrons – the components of atoms – fuse together. It is possible that even the building-blocks of protons and neutrons, the so-called 'quarks', get crushed together, giving rise to a kind of exotic plasma of 'dissolved' matter.

Scientists have spent decades trying to identify the nature of matter in neutron stars. To do this, they need to know a star's mass and radius, or the relationship between them, to obtain its compactness. However, no instrument has been advanced enough to perform the measurements needed, until now. With ESA's XMM-Newton observatory, astronomers have been able for the first time to measure the mass-to-radius ratio of a neutron star and obtain the first clues to its composition. These clues suggest that the neutron star contains normal, non-exotic matter, although they are not conclusive. The authors say this is a "key first step" and they will keep on with the search.

The way that they made this measurement is a first in astronomical observations and it is considered a huge achievement. The method consists of determining the compactness of the neutron star in an indirect way. The gravitational pull of a neutron star is immense – thousands of million times stronger than the Earth's. This makes the light particles emitted by the neutron star lose energy. This energy loss is called a gravitational 'red shift'. The measurement of this red shift by XMM-Newton indicated the strength of the gravitational pull, and revealed the star's compactness.

The result was obtained by observation of the neutron star EXO 0748-676. XMM-Newton detected the light in the form of X-rays. In particular, thanks to analysis of this X-ray radiation, the astronomers were able to identify some chemical elements, namely iron, present in the material surrounding the neutron star. They then compared the distorted signal emitted by the iron atoms in the neutron star with the one produced by iron atoms in the laboratory. In this way, they could measure the actual degree of distortion due to the gravity of EXO 0748-676. Their work is published in the 7 November 2002 issue of Nature.

Space experts: The next generation

Thanks to the ESA Education Office, 220 European and two Canadian students took part in the 53rd IAF Congress in Houston, Texas from 10 to 19 October. The students had the opportunity to create many valuable contacts with their peers and professionals alike. They attended the Congress like all regular participants, allowing for an intense "generation handover" of existing expertise and knowledge.

The European students at the IAF Congress.

To gain a better understanding of ESA, the students visited ESTEC on 8 October 2002 before leaving for the United States. They were given presentations on Earth Observation, Science, Navigation and the International Space Station and visited the main facilities.

Thousands of delegates participated in the various sessions of the World Space Congress and activities over ten days, and more than 10000 were involved in various aspects of the exhibition or education outreach programme. The students sent by ESA attended as many sessions as they could, and some presented their research on the special Student Stand. 70 of them were even given the opportunity to make presentations in the IAF Technical Sessions.

Students on the way to SUCCESS

The SUCCESS 2002 Student Contest is a competition for European university students to propose an experiment that can be conducted on board the International Space Station. The winner will receive a one-year paid internship at ESTEC, during which the experiment can be built and possibly flown to the ISS.

The competition was announced earlier this year and a lot of European students, studying various disciplines, responded to it. From all of the entrants, 50 students were selected, on the basis of a written essay, to participate in the second phase of the competition.

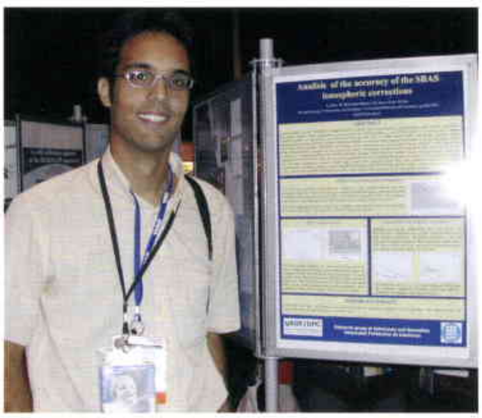
These students who were selected for the second phase were invited to ESTEC for an introductory visit, during which lectures were given by various ESA scientists and engineers. The lecture topics varied from the International Space Station in general to already conducted and future experiments, as well as personal experiences on board. There was also the chance for the students to share their ideas for an experiment in the form of a presentation to other SUCCESS 2002 participants. Many students considered the in-flight call with the ISS the climax of their visit. There were two opportunities during which the students were able to talk to Frank De Winne for 15 minutes.

During a workshop the students had the opportunity to talk personally with ESA scientists in a more relaxed environment. They also took a guided tour through ESTEC's spacecraft testing facilities.

The overall aim of the SUCCESS 2002 Student Contest visit to ESTEC was to teach them about the ISS and the experiments already conducted, to stimulate international cooperation, and to provide the motivation for writing a detailed experiment proposal in the second phase. This detailed experiment proposal should be delivered at the beginning of December, after which the selection of the contest winners can commence. They will be announced early next year.

Avventura «spaziale» per due studenti

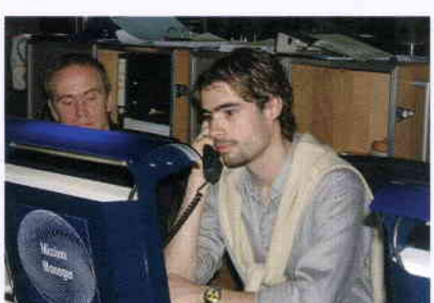
An Italian newspaper writes about two students and their project.



Student presenting his paper.

A special poster session on the ESA Education Office stand was organised for student projects. Many of the regular participants had a look what the new generation of space experts had to offer. One of them was so impressed by Italian Andrea D'Ambrogio's experiment on "vibration effects on bone metabolism in astronauts" that they are discussing the possibility of flying it on the ISS. "*It would be a dream come true!*" says the biotechnology student. If it happens, there would be "*a formal agreement, this will be my final project for my M.Sc degree in Biotechnology, and we will prepare the protocols, we will train astronauts in performing the experiments, and we will assist the astronauts during the mission.*" His success story has already appeared in the Italian press.

Ulf Merbold gives scientific support during the SUCCESS 2002 workshop.



Roberto Araújo speaking to Frank De Winne on board the ISS.

Publications

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

ESA Newsletters

EDU NEWS NO. 3 (OCTOBER 2002)
NEWSLETTER OF ESA'S EDUCATION OFFICE
ED. WARMBEIN B.
NO CHARGE

SPACELINK NO. 2 (NOVEMBER 2002)
NEWSLETTER OF ESA'S TECHNOLOGY TRANSFER PROGRAMME
EDS. BRISSON P. & BATTRICK B.
NO CHARGE

ECSL NEWS NO. 24 (DECEMBER 2002)
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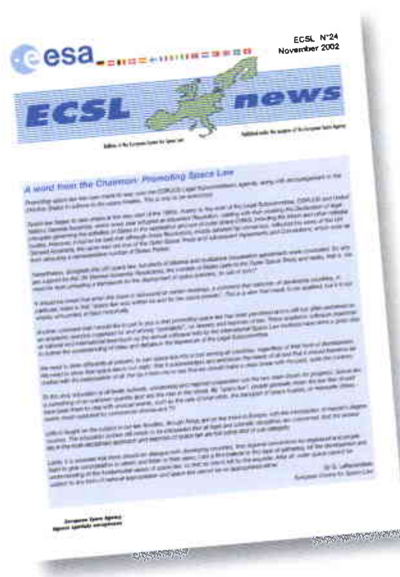

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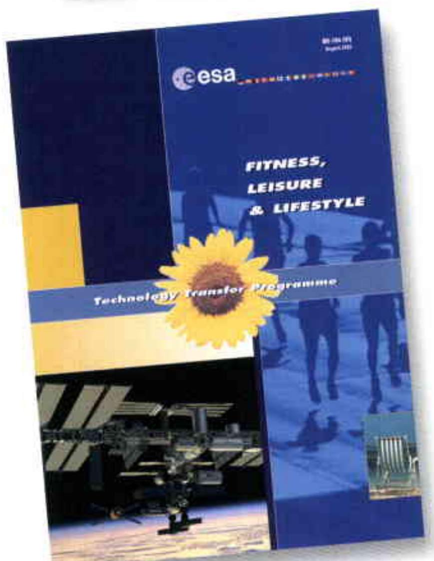

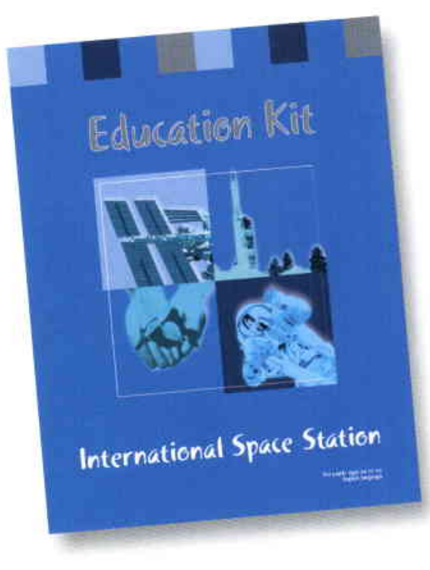

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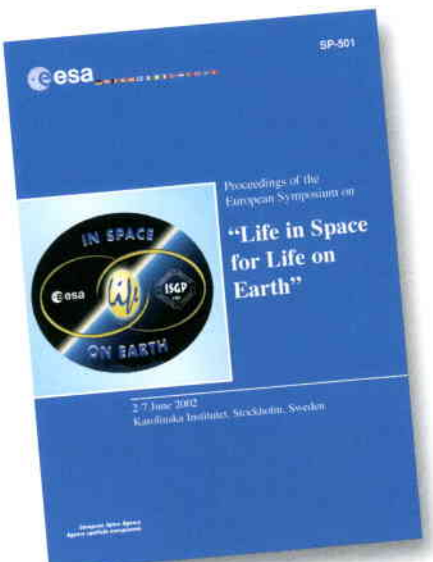

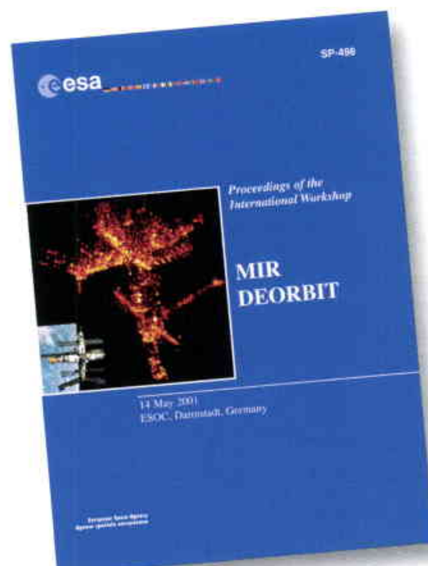

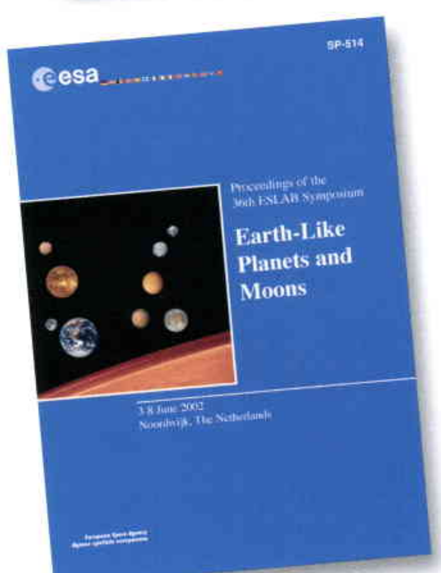

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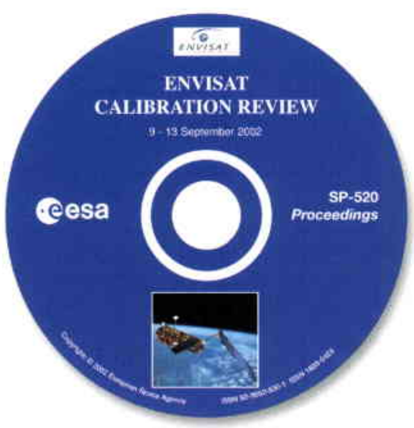

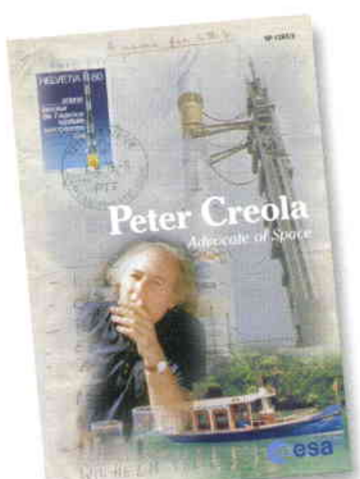

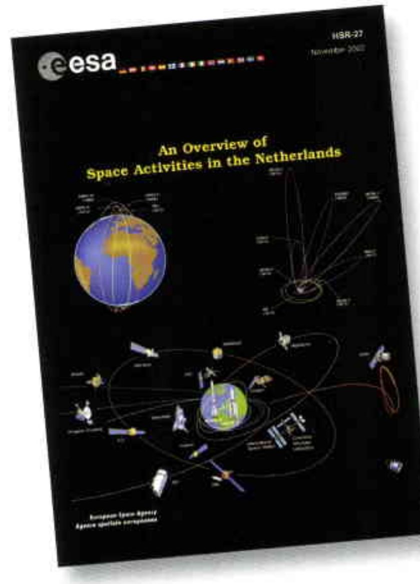

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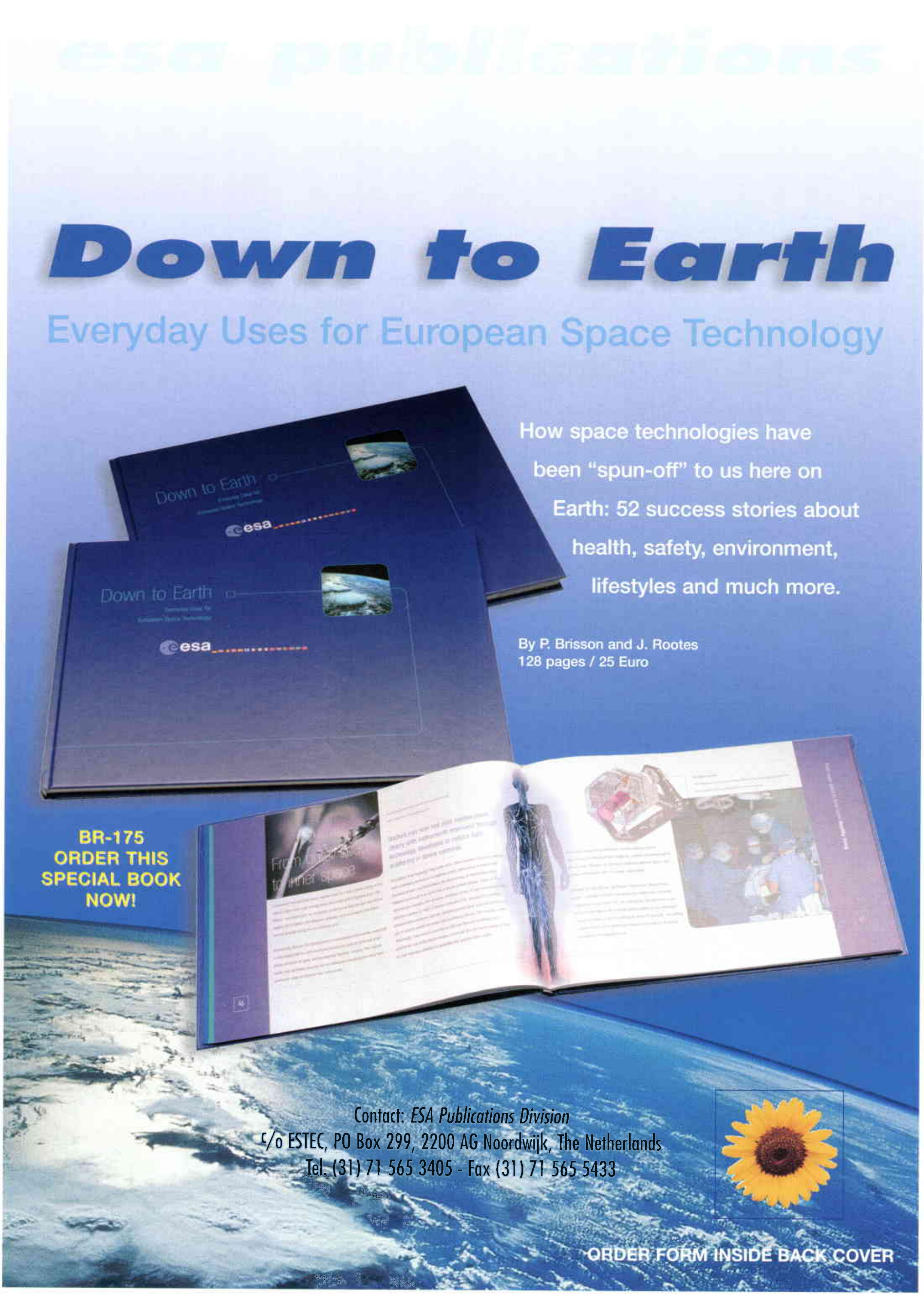
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