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bulletin

SPACE FOR EUROPE

European Space Agency
Agence spatiale européenne

European Space Agency

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

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The ESA HEADQUARTERS are in Paris.

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ESRIN, Frascati, Italy.

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Chairman of the Council: P. Tegner

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Agence spatiale européenne

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

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(a) en élaborant et en mettant en oeuvre une politique spatiale européenne à long terme, en recommandant aux Etats membres des objectifs en matière spatiale et en concertant les politiques des Etats membres à l'égard d'autres organisations et institutions nationales et internationales;
(b) en élaborant et en mettant en oeuvre des activités et des programmes dans le domaine spatial;
(c) en coordonnant le programme spatial européen et les programmes nationaux, et en intégrant ces derniers progressivement et aussi complètement que possible dans le programme spatial européen, notamment en ce qui concerne le développement de satellites d'applications;
(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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ESA's Automated Transfer Vehicle (ATV) *Jules Verne* seen from the ISS during a rendezvous test on 31 March 2008. On Demonstration Day 2, Expedition 16 flight engineer Yuri Malenchenko (RUS) took this photo of ATV approaching to within 11 metres of the ISS before the actual docking on 3 April (NASA)

The Next Decade with XMM-Newton

Mission Analysis
Towards a European Harmonisation

Flight of the Phoenix
ESOC Supports NASA Mars Mission

Getting Customer-oriented
ESA Procurement in Cooperation with Other Organisations

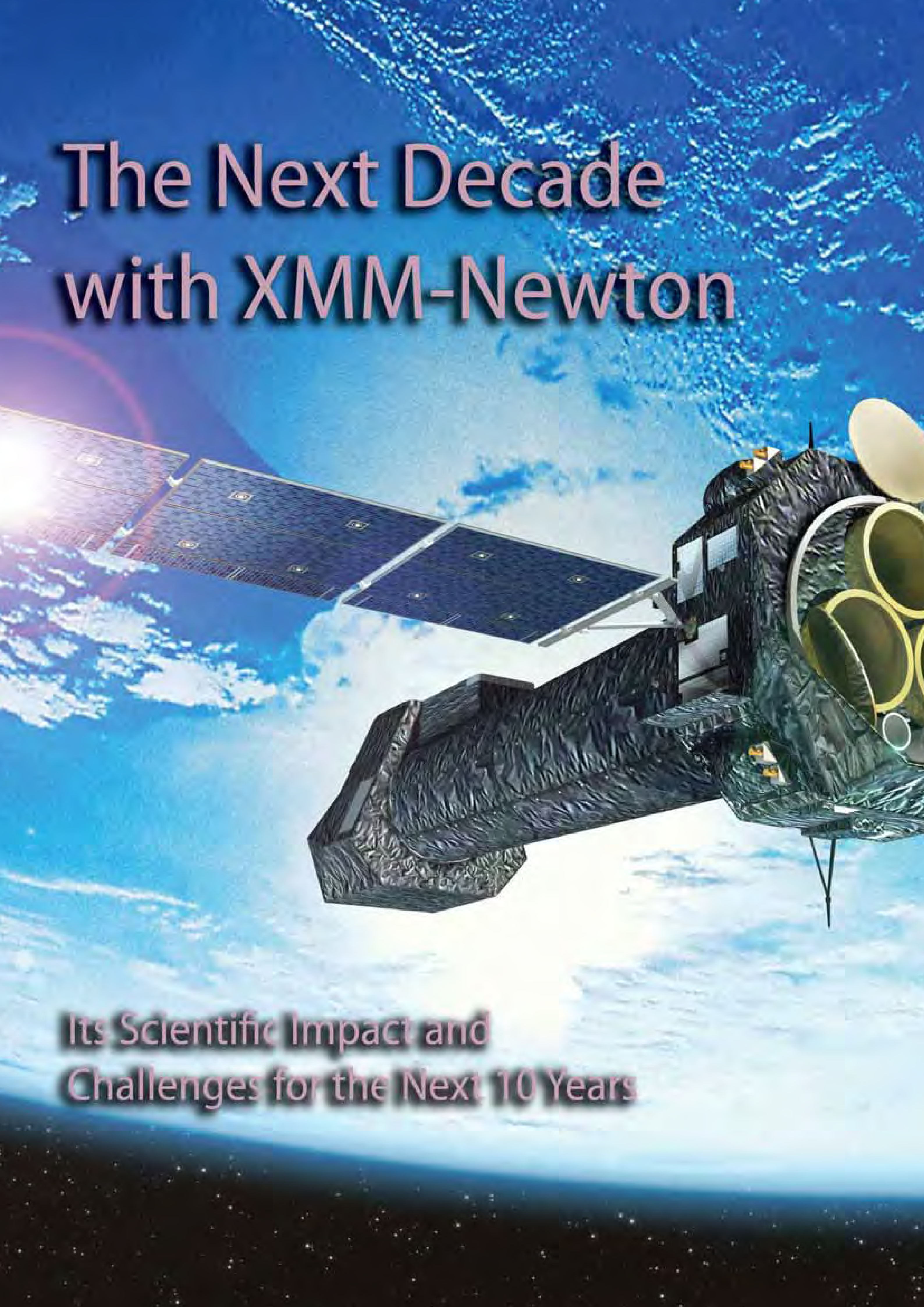
Expander Demonstrator
Paving the Way for European Advanced Upper-stage Engines

Ariane-5 ES Launch of ATV

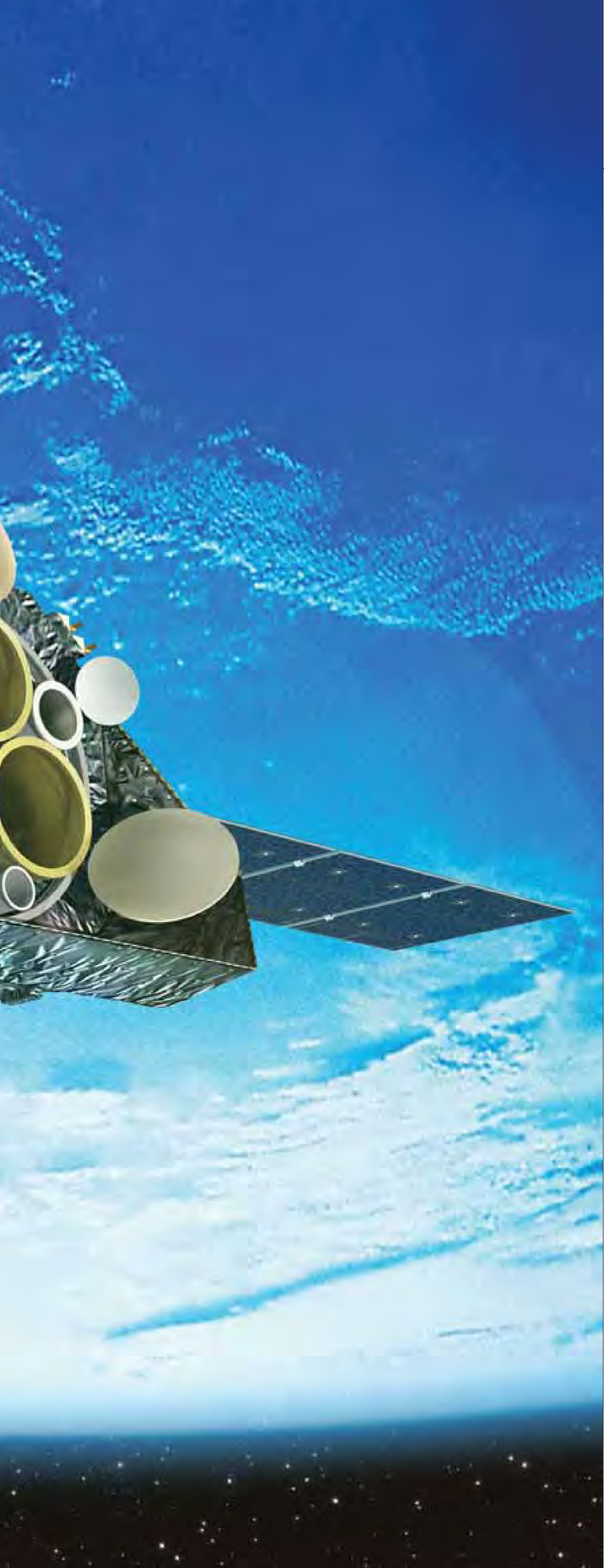
esa bulletin 134 - may 2008

Contents

The Next Decade with XMM-Newton



Its Scientific Impact and Challenges for the Next 10 Years



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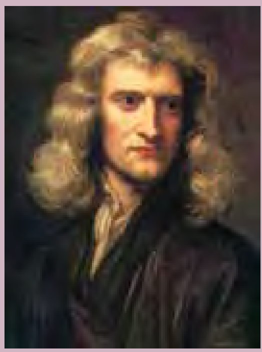
XMM-Newton is one of ESA's most successful science missions. Launched in December 1999, the spacecraft is technically able to continue this scientific success story and now, encouraged by its impressive scientific output, ESA has already extended XMM-Newton's operations well beyond its original 10-year design lifetime.

Introduction

X-rays open up a universe unseen to our eyes. In 1901, the German physicist Wilhelm Röntgen won the first Nobel Prize in Physics for the production and detection of X-rays. The prize was awarded only six years after the discovery, due to the immediate importance of X-rays as a medical diagnostic tool.

X-rays are also an important diagnostic tool for astronomers, since they are emitted by very hot gas or plasma at temperatures of several million Kelvin that cannot be detected by other means. Because X-rays are absorbed by Earth's atmosphere, astronomers had to wait until the advent of the space age to observe the X-ray sky.

Sir Isaac Newton



Sir Isaac Newton (1643–1727) was an English physicist, mathematician, astronomer, natural philosopher and alchemist. His book of 1687, *Philosophiæ Naturalis Principia Mathematica*, described universal gravitation and the laws of motion, which provided the foundations for classical mechanics and dominated scientific thinking for the next three centuries. Newton proved that the motions of objects on Earth and of celestial bodies are governed by the same set of natural laws by demonstrating the consistency between Kepler's laws of planetary motion and his theory of gravitation.

Newton discovered the principles of conservation of momentum and angular momentum. He invented the reflecting telescope and developed a theory of colour based on the observation that a prism decomposes white light into a visible spectrum. Newton shares the credit with Gottfried Leibnitz for the development of calculus.

The first cosmic X-ray source was discovered during a short rocket flight in 1962 (American astrophysicist Riccardo Giacconi was awarded the Nobel Prize in 2002, almost exactly 100 years after Röntgen, for his pioneering work leading to this discovery). X-ray astronomy then developed rapidly during the 1960s; the first X-ray satellite was launched in 1970 and discovered several hundred X-ray sources.

European involvement started shortly after with ESA's first X-ray observatory, Exosat, launched in 1983. The early and continued involvement in the field is an important factor in maintaining Europe's strong position in X-ray astrophysics today.

XMM-Newton, ESA's large X-ray observatory and second cornerstone of the Horizon 2000 programme, was launched in December 1999. It was named after the technique behind the mission (XMM stands for 'X-ray Multi-Mirror') and Sir Isaac Newton, the man who first explained the significance of gravity in the heavens (see box). Gravity is the driving force that creates black holes, neutron stars and other collapsed objects, which are among the main targets of XMM-Newton's studies, so it was only fit to associate Newton's name to this very successful mission.

XMM-Newton has been routinely collecting scientific data for more than eight years. With almost 200 000 individual sources, the XMM-Newton catalogue is the largest of its kind. Last autumn, ESA's Science Programme Committee approved mission operations until the end of December 2012, with further extensions possible assuming that the outstanding scientific return continues and that there are no major technical problems.

An XMM-Newton mirror module comprising of 58 nested mirror shells (ESA/Dornier Satellitensysteme GmbH)

XMM-Newton's Scientific Payload

The power of an astronomical telescope depends on how much incoming light can be collected. Nearly all materials absorb incident X-rays. It is therefore impossible to construct a mirror that reflects and focuses X-rays in the same way as in an optical telescope.

Instead, X-ray optics use a physical effect called 'total reflection' which occurs only with very small reflection angles, when the incoming ray is almost parallel to the mirror surface and thereby 'grazes' it. We can experience this effect with normal visible light, for instance when driving along a wet road at sunset, you can be suddenly dazzled by the reflection of the Sun's rays.

XMM-Newton carries three grazing incidence telescopes. Each telescope consists of 58 gold-coated mirror shells that are nested inside one another like a Russian doll. XMM-Newton provides high-quality X-ray and optical/UV data from six instruments simultaneously: three European Photon Imaging Camera (EPIC) cameras, two Reflection Grating Spectrometers (RGS) and the Optical Monitor.

An EPIC detector is positioned behind each of the three X-ray mirror modules. Two MOS-CCD cameras share two of the modules with the RGS grating arrays and a pn-CCD detector is located behind the other telescope position, providing images of the X-ray sky as well as spectra with moderate resolution and timing information. The spectrometers disperse the light from the telescope to produce high-resolution X-ray spectra of all types of celestial objects.

Importance to the Scientific Community

An objective measure of the impact of XMM-Newton is the number of scientists who use its data, and there are several ways to estimate this number.

- As of January 2008, refereed publications based on XMM-Newton data have been published by 575 different main authors and 3500 co-authors.
- As explained below, every call for observing proposals has been heavily

	EPIC-pn	EPIC-MOS	RGS
Energy bandpass (keV)	0.15-12	0.15-10	0.35-2.5
Field of view (arcmin)	30	30	5
Spatial resolution (arcsec)	6	5	N/A
Temporal resolution (ms)	0.03	1.5	16
Energy resolution at 1 keV (eV)	80	70	3.2

The main characteristics of XMM-Newton's X-ray instruments

over-subscribed. For example, 586 valid proposals were received in response to the 2007 announcement. These were submitted by 424 different principal investigators. If co-investigators are included, about 1560 scientists from 33 different countries participated in this call.

– 1730 registered scientists retrieve data from the XMM-Newton on-line archives or download the software needed to process them.

We estimate that between 1500 and 2000 scientists use XMM-Newton routinely. This is approximately 20% of all professional astronomers worldwide. Indeed, XMM-Newton is an observatory open to the entire scientific community. However, because observing time is so valuable, its use is strictly regulated and optimised.

Each year, ESA issues an Announcement of Opportunity to which scientists from all over the world are invited to respond by submitting an observing proposal. The scientific importance and quality of all proposals are assessed by an Observing Time Allocation Committee (OTAC) composed of senior astronomers selected for their scientific excellence.

The OTAC evaluates all the submitted proposals and awards XMM-Newton observing time only to those proposals with the largest potential for discovery. The proposals that fail to get observing time do so, not because they are bad, but because the pressure is so high that only the best ones survive the selection. In 2007 for instance, the total amount of observing time requested was nearly eight times larger than was available. This large rejection rate is distressing but is also an indicator of the importance of XMM-Newton to the scientific community.

Scientific Impact

The number of publications based on XMM-Newton data is growing steadily at a rate of around 300 articles in refereed scientific journals each year. But quantity does not say it all. What about the quality and importance of XMM-Newton results? It is possible to assess the importance of a given scientific publication by counting the number of times it was mentioned, or cited, in other refereed articles. A 2007 analysis by Prof. V. Trimble and Dr J.A. Ceja showed that, with an average of 31.4 citations per article, XMM-Newton results have the highest impact ratio of all observatories. Furthermore, 47% of XMM-Newton articles are amongst the top 10% most cited publications, and 9.1% belong to the top 1% most cited class.

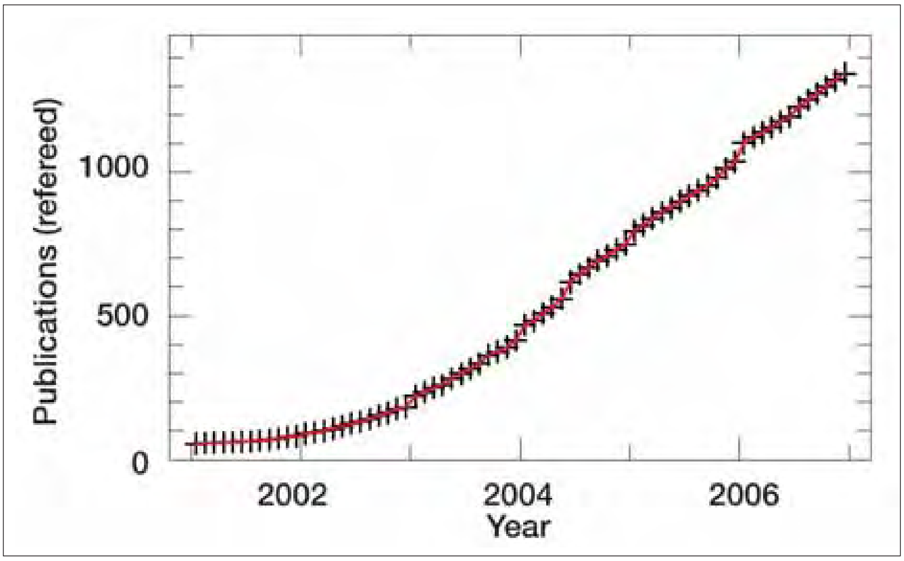
Extended Mission Operations

XMM-Newton operations were originally approved for 2.25 years of operations with a design lifetime of 10 years. XMM-Newton will exceed its design lifetime at the end of 2009. To plan for operations beyond this date, an independent review of operations (the Mission Extended Operations Review) was conducted in 2007.

The review focused on the expected performances of the spacecraft, the instruments and ground segment, and examined a new simpler operations concept. This concept strongly reduces costs by combining the Integral and XMM-Newton Mission Operations teams at ESOC and automating the real-time monitoring of the instruments. Combined operations started in the winter of 2007 and have been running smoothly since then.

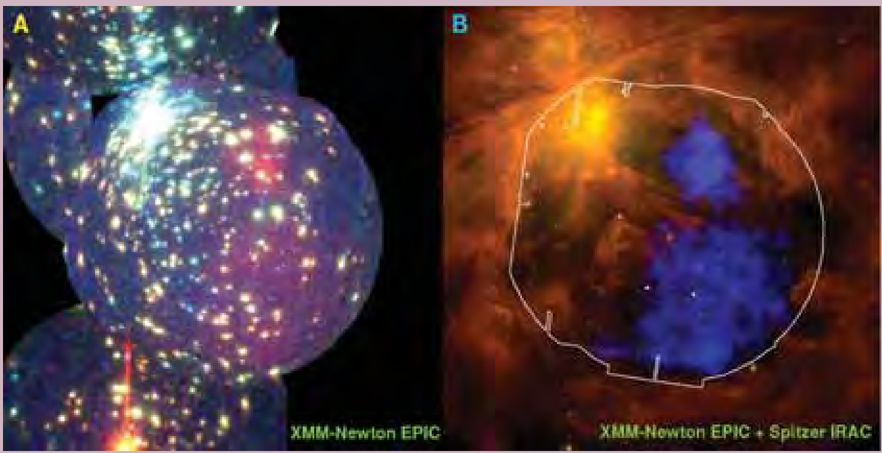
The status of the satellite and the instruments remains excellent. On-board consumables are sufficient to operate for at least another 10 years. The spacecraft is being operated on all its prime hardware chains with no redundant units having been used so far. The instruments are standing up to the harsh environment of space very well and are expected to continue providing outstanding results for many years to come.

The cumulative number of publications in refereed journals that use XMM-Newton data



Scientific Highlights

The far-reaching impact of XMM-Newton is illustrated by some recent scientific highlights.



The Orion nebula with its hot gas cloud. (Left panel) An X-ray image obtained with XMM-Newton. The diffuse X-rays emitted by the million-degree cloud appear reddish in this false colour picture. (Right panel) The same diffuse X-rays from the hot gas discovered by XMM-Newton (blue) overlaid on Spitzer IR data of the Orion region (AAAS/Science XMM-Newton EPIC (Guedel et al.), AAAS/Science (ESA XMM-Newton and NASA Spitzer data)

Million-degree plasma in the Orion nebula
XMM-Newton observations allowed Dr M. Guedel and colleagues to discover a huge cloud of very hot gas filling part of the Orion Nebula. The hot gas seems to stream out of the nebula into the neighbouring interstellar medium.

The Orion Nebula is the nearest dense star-forming region to Earth. It contains stars much more massive than the Sun. It is visible to the naked eye as a fuzzy patch of light located just below the three belt stars in the constellation of Orion. While gas in star-forming regions is usually relatively cool, XMM-Newton discovered that the Orion Nebula also contains a huge cloud of extremely hot gas, or plasma, heated to millions of degrees.

This cloud is invisible in optical or infrared images but is prominently seen in XMM-Newton images. The researchers speculate that the plasma originates from shocks formed as the fast stellar wind ejected by the most massive star in the nebula's centre runs into the cool and dense Orion gas. That a single massive star could create such huge hot plasma cloud came as a surprise since it was generally thought that powerful supernova explosions would be required, or at least a large number of massive stars whose winds collide with each other.

The XMM-Newton observations therefore suggest that such X-ray outflow phenomenon should be common in star-forming regions, and therefore widespread throughout our galaxy. This discovery is not just a matter of scientific curiosity. The outflows help enrich the interstellar medium with heavy elements such as carbon and oxygen. Accordingly, this result changes our view of how material may have come together in the formation of Earth-like planets and possibly life itself.

Stellar remains linked to the oldest recorded supernova
When a massive star runs out of nuclear fuel, it collapses and explodes as a supernova that can briefly outshine an entire galaxy. The explosion ejects the outer layers of the star into space producing powerful shock waves. The remains of the star and the material it encounters are heated to millions of degrees and emit intense X-ray radiation for thousands of years as a supernova remnant.

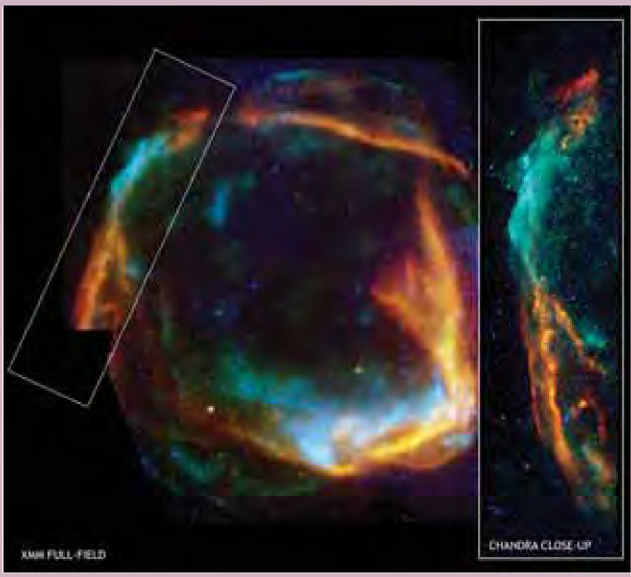
Dr J. Vink and colleagues examined XMM-Newton observations of a supernova remnant called 'RCW 86', along with data from a similar but complementary NASA X-ray observatory AXAF-Chandra, to estimate when the star exploded. They calculated how quickly the shell is expanding. Combining the expansion velocity with the

The Future

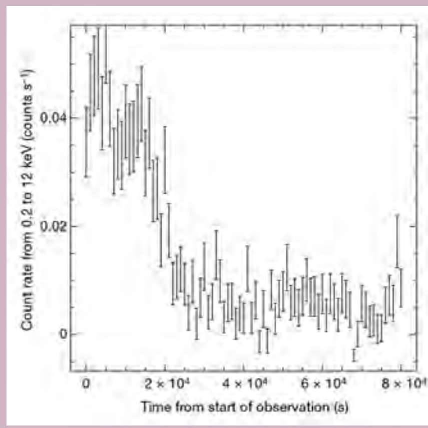
In June 2007, 125 scientists gathered at ESA's European Space Astronomy Centre to discuss the future science objectives of XMM-Newton. Many new scientific questions were presented and many scientifically exciting and innovative research programmes were outlined. Although the hazards of the peer review process make it impossible to predict what exactly will XMM-Newton's next great discovery, the workshop participants were not short of ideas for new avenues of research exploiting XMM-Newton's unique capabilities.

The formation of stars and, ultimately, of planetary systems, is a topic of expanding interest and attacks one of the most fundamental problems in astrophysics. The great prospect lies ahead of combining the spectroscopic diagnostics from XMM-Newton with those of ESA's soon-to-be-launched Herschel infrared observatory. This will provide unprecedented insights into the formation of stars and the nursery of planetary systems.

XMM-Newton with its large field of view, good spatial resolution and excellent sensitivity is uniquely suitable



A combined XMM-Newton and AXAF-Chandra X-ray image of RCW 86 showing the expanding ring of debris, or shell, that was created by the supernova explosion. Both images show low, medium and high-energy X-rays in red, green and blue, respectively. The AXAF-Chandra observations focused on the north-east side of RCW 86. (ESA, NASA/CXC, University of Utrecht/J. Vink)



Results from a 100 000-second XMM-Newton observation of NGC 4472. The EPIC-pn count rate is plotted against time since the start of the observation. The rapid decrease in count rate by a factor of seven is the key to identifying the object as a black hole (Nature)

size of the shell allowed them to determine the age of the remnant and demonstrate that it is only 2000 years old, much younger than the previous estimate of 10 000 years.

The revised age for RCW 86 probably explains an astronomical event observed almost 2000 years ago. In 185 AD, Chinese astronomers (and possibly the Romans) recorded a new bright star. The star took about eight months to fade from sight, which is consistent with modern observations of supernovae. RCW 86 had previously been suggested as the remnant from the 185 AD event, based on the historical records of the object's position. But uncertainties about the age provided significant doubt on the identification.

First black hole found inside a globular star cluster
Thanks to XMM-Newton observations, Dr T. Maccarone and colleagues discovered the first black hole located inside a globular star cluster. This finding is important to help astronomers understand how stars move in clusters and how black holes grow and evolve.

Globular clusters are dense groups of thousands to millions of stars and many scientists doubted that black holes could survive in such regions as the gravitational pull of the cluster's myriad stars would mean that newly formed black holes would be rapidly ejected from the cluster in a kind of 'slingshot effect'.

Black holes are by definition invisible, but the region around them can flare up when the black hole 'feeds'. When material falls into a black hole, it is heated to very high temperatures and radiates brightly in X-rays. XMM-Newton is extremely sensitive to variable X-ray sources and can efficiently search across large parts of the sky.

Dr Maccarone's team found the X-ray signature of a 'feeding' black hole in a globular cluster orbiting the giant elliptical galaxy NGC 4472. NASA's AXAF-Chandra confirmed that the black hole was indeed located inside the globular cluster.

This new object is so luminous and varies so rapidly that this rules out any type of explanation other than a black hole. Its X-ray luminosity changed by a factor of seven in a few hours, implying that the source cannot be a chance superposition of several close objects. The new findings provide the first convincing evidence that some black holes might not only survive, but also grow and flourish in globular clusters.

for following up on one of the most unexpected discoveries of recent years. In 2006 the remnants of a new class of supernovae were detected in XMM-Newton images of the Small Magellanic Cloud, one of the galaxies closest to our own. The importance of collecting large and complete samples as a way to uncover rare galactic objects cannot be overemphasised. This is best achieved by carefully mapping nearby galaxies such as Andromeda or the two Magellanic clouds, a task for which XMM-Newton is ideally suited.

XMM-Newton's sensitivity and good spectral resolution pay off in so many ways. In 2006, *Astronomical Notes* devoted an entire issue to the properties of iron lines emitted in the vicinity of black holes. General relativity tells us that the strong gravitational field from the black hole extracts energy from the light. The net effect is to distort the profile of an emission line, giving it a characteristic broad and asymmetric shape easily spotted with XMM-Newton.

XMM-Newton recently uncovered the existence of broad asymmetric lines in neutron stars as well. This opens the possibility of measuring directly the mass of neutron stars and thereby the equation of state of the extremely dense matter they are made of. This one discovery opens up a whole new research avenue and illustrates the mission's powerful capabilities.

The existence of dark energy was discovered only ten years ago, when XMM-Newton was under final construction. Together with dark matter, dark energy accounts for over 95% of the energy content of the Universe. Not surprisingly, understanding its nature has become one of the key questions in physics today, and XMM-Newton has a part to play here.

Dark energy cannot be detected and measured directly. Significant progress is expected in the next few years when it becomes possible to combine data from XMM-Newton with those from ESA's Planck mission, to be launched at the end of 2008. Planck will discover thousands of clusters of galaxies. In particular, it will increase the number of known distant clusters by a factor of 100. These far-away clusters can be used as yardsticks to measure the growth of structures in the Universe from the time when it was several billion years younger.

Using XMM-Newton data in combination, it will be possible measure the mass and the temperature of these far-away clusters and compare them with those of nearby 'modern' clusters. By studying how the cluster properties evolve with cosmic time, it will be possible to infer the effects of dark energy on normal matter as the Universe expands. This technique will provide important clues as to what dark energy really is.

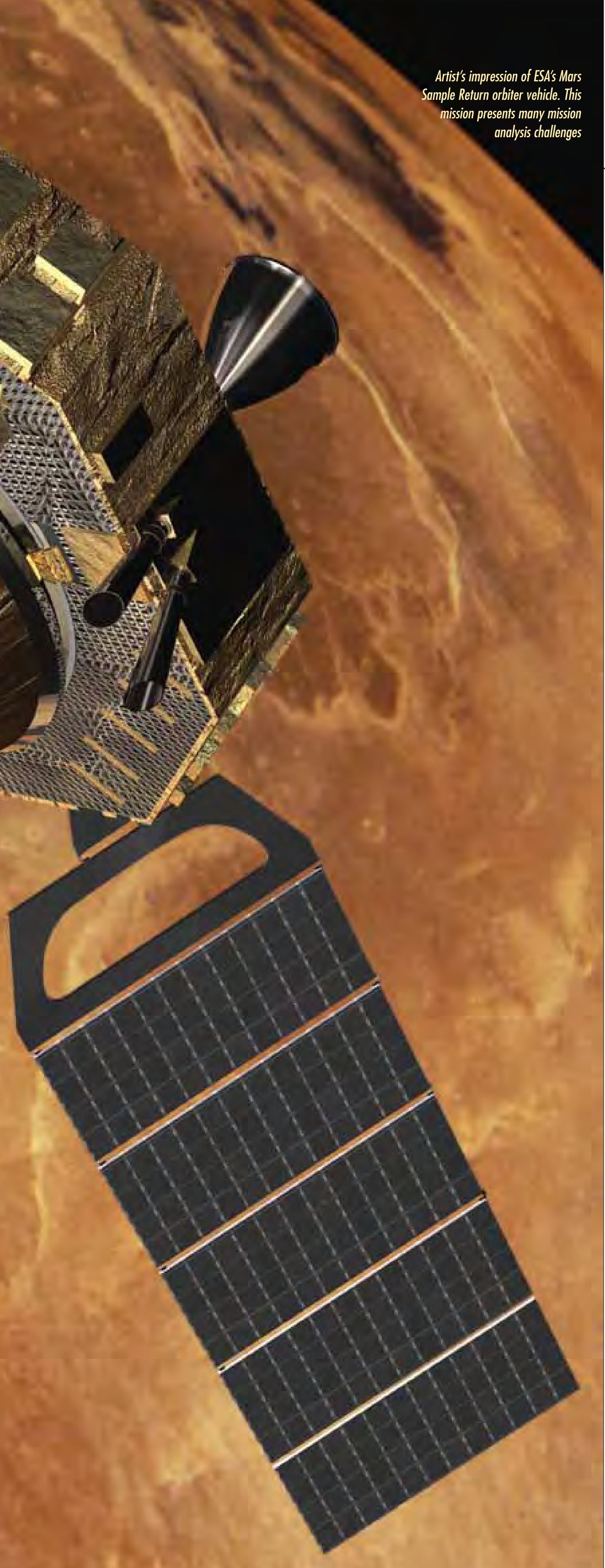
XMM-Newton is one of ESA's most successful science missions ever, and while we may look forward to its eventual successor, both scientifically and technically, XMM-Newton has the potential to continue observing and making discoveries in the X-ray sky for at least another decade. The large amount of observing time requested each year and the lively debate in the scientific community show that astronomers worldwide are well aware of this. esa

Explore the XMM-Newton sky in Google Earth:

Astronomical images and spectra taken with XMM-Newton can be displayed in Google Earth.
http://earth.google.com/gallery/kml_entry.html#tXMM-Newton%20Gallery

Mission Analysis

Towards a European Harmonisation



Artist's impression of ESA's Mars Sample Return orbiter vehicle. This mission presents many mission analysis challenges

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Mission analysis forms an integral part of every space project, and strongly influences the mission and element design. Once an exclusive activity of ESA experts, mission analysis now relies on a network of competent European industrial, academic and ESA partners, all integrated into the process.

Introduction

'Mission analysis' is the analysis of satellite orbits to determine how best to achieve the objectives of a space mission. This is performed during the entire definition, development and preparation phases of each project.

Mission analysis support has been provided to ESA projects by the European Space Operations Centre (ESOC) mission analysis team since the early 1970s. For many years, this team has been the focal point for mission analysis within ESA, coordinating activities with units at the European Space Research and Technology Research Centre (ESTEC), which concentrate on Earth observation, astrodynamic tools and research, as well as cooperation with national agencies.

In recent years, the network has been enlarged to include European industrial and academic partners. The European workshops on space mission analysis, the first of which was held at ESOC on 10–12 December 2007, acknowledge this evolution and provide a unique platform for technical exchange between the experts involved. With 87 participants and 40 presentations, the first workshop covered the entire spectrum of mission analysis subjects.

Several joint presentations on major projects such as BepiColombo, LISA Pathfinder and Mars Sample Return showed the high degree of harmonisation. They are used here to illustrate the mission analysis process and the way in which the cooperation with industry and universities is implemented, while at the same time guaranteeing continuity and completeness of the mission analysis support, system optimality and industrial competition.

Mission Analysis Process

At the start of a project, the mission requirements are evaluated in order to provide an overview of the available trajectory options. For each option, the mission analyst computes the information needed by the project to perform a proper trade-off between the different options and to define one or more baseline and back-up solutions for further detailed analysis, definition and optimisation.

This information usually includes: the timeline of major events; launcher injection orbit and mass; delta-V budget; power and thermal aspects, such as eclipses and distance from the Sun; Earth distance; Sun-spacecraft-Earth and Sun-Earth-spacecraft angles and their influence on communications; coverage of science targets; and a qualitative assessment of complexity and operational risk. At this stage the emphasis is on a good overview, rather than on accuracy and optimality.

The information is usually compiled in a Mission Analysis Guidelines (MAG) document. A frequent interaction with the project team allows the mission analysts to adjust their work to evolving mission requirements and design and ensuring that the information provided is properly interpreted.

A generalist, familiar with all mission analysis aspects, is preferable at this stage to ensure that the best solutions are chosen. In this context, a close link to operations or, even better, operational experience is of high value.

Later on in a project, the baseline solution is studied in more detail in order to demonstrate feasibility and further optimise performance, in addition to generating all the information needed for platform, payload, ground segment, launcher service and operations design.

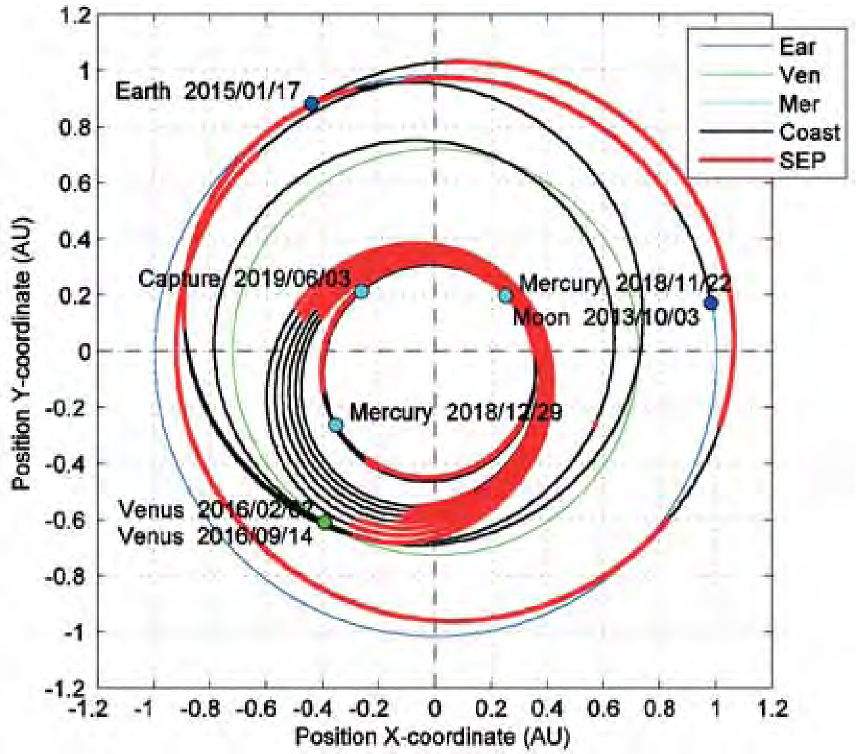
The orbit analysis includes the determination of the frequency of manoeuvres to maintain the operational orbit and the fuel needed for these, bearing in mind payload operations and spacecraft safety. Usually the manoeuvres compensate for known orbital perturbations, such as third-body gravitational effects, and those caused by the asymmetries of the planet's gravitational field.

The navigational analysis has to show that the stochastic disturbances affecting the trajectory can be sufficiently measured and corrected in order to guarantee spacecraft safety and achieve the accuracy needed for payload operations. The fuel needed to correct these errors is also computed. Typical disturbances are launcher injection errors, orbit correction manoeuvre errors, uncertainties in the solar radiation pressure and atmospheric drag, as well as velocity increments associated with attitude control.

The contingency analysis quantifies the consequences of spacecraft failures, such as a missed orbit manoeuvre or a spacecraft safe mode, proposes risk mitigation or recovery strategies, and quantifies the fuel and time penalty to implement them.

The launch window analysis determines the days during which the spacecraft can be launched and the time slots when lift-off can occur, as well as the target injection orbit. It has to be proved that the mission objectives can be achieved in each of these windows. The

The BepiColombo interplanetary cruise to Mercury, ecliptic projection showing swingbys



Artist's impression of BepiColombo in cruise configuration (exploded view). From top to bottom, the Mercury Magnetospheric Orbiter (MMO), the sunshield, the Mercury Planet Orbiter (MPO) and the BepiColombo transfer module

extra fuel required to compensate for the non-optimal injection time and orbit also has to be quantified. This task requires interaction, via the project, with the launcher authorities.

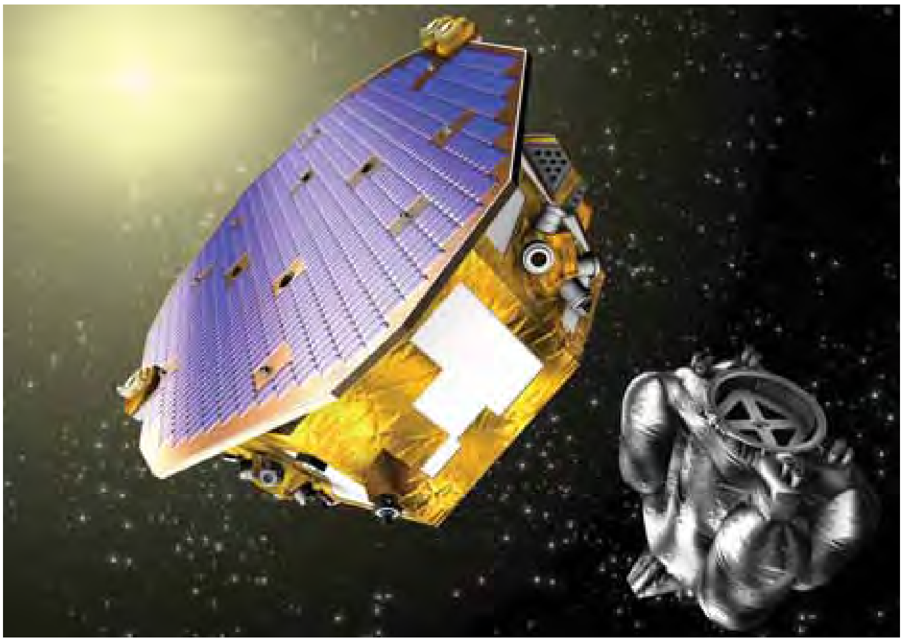
The results of the in-depth analysis for the baseline solution are compiled in the Consolidated Report on Mission Analysis (CREMA).

Launch delays, spacecraft mass overruns, technology development problems or other difficulties often prevent the baseline mission from being flown as planned. During mission operations, contingencies may also require a mission redesign within the constraints of the existing spacecraft, payload and ground segment. Continuity in the mission analysis support throughout the entire lifecycle of the project guarantees a continuing awareness of the possible alternatives that were assessed in the early phase of the project. Typical examples are the redesign of the Cassini-Huygens mission after the identification of a transponder design problem and the redefinition of the Rosetta mission after losing the option to fly to Comet Wirtanen in January 2003.

BepiColombo

The first assessment studies for an ESA mission to Mercury started in November 1993. Since then, the mission design evolved from a single Mercury orbiter that used chemical propulsion and gravity assists to reach the planet, to a system with two orbiters, based on electrical propulsion. Now, as the fifth cornerstone mission of the ESA Horizons 2000 scientific programme, BepiColombo consists of two scientific spacecraft, the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO). The latter spacecraft will be built and operated by the Japan Aerospace Exploration Agency (JAXA) and passively attached to the MPO during the cruise to Mercury. The two spacecraft will study the origin and evolution of Mercury, its interior dynamics and the origin of its magnetic field.

Going to Mercury is not simple: if no planetary flybys are used, it would cost even more fuel than a journey to Pluto! So, before starting the competitive definition study with Alenia Spazio and



Artist's impression of LISA Pathfinder, showing the science spacecraft and propulsion module after separation

EADS Astrium, the framework of the mission had to be defined. A complex interplanetary trajectory was designed, working together with mission experts at the Institut d'Astrophysique Spatiale in Orsay, France. Originally, when the powerful Ariane-5 rocket was to be used, just two flybys at Venus and two at Mercury were required, in combination with solar-electric propulsion. The target could then be reached in less than three years. But mission analysis does not end when a good trajectory is found. In the case of BepiColombo, the Ariane rocket became unaffordable and solutions with the smaller Soyuz rocket had to be found.

To compensate for the missing thrust from the powerful Ariane-5 rocket, one lunar flyby and an Earth flyby were introduced. The solar arrays had to be reduced in size, cutting the available ion engine thrust in half. As a consequence, the transfer duration increased to five years.

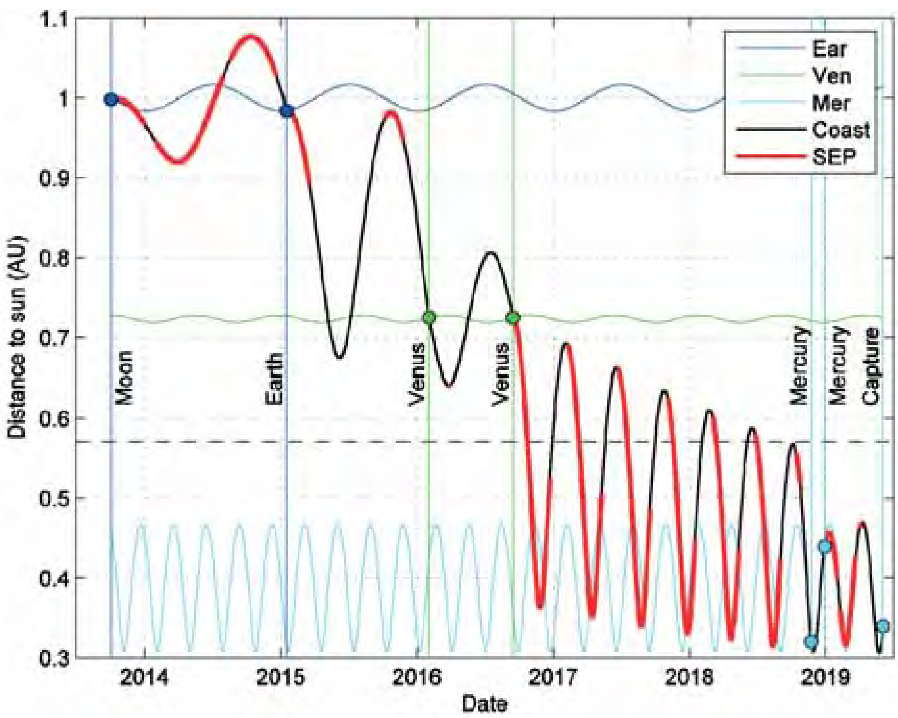
The current interplanetary trajectory is shown on the previous page. It includes single flybys at the Moon, Earth, two at Venus and two at Mercury, as well as several long thrust arcs provided by solar-electric propulsion. However, the mission analysts already have back-up options available, with up to six Mercury flybys giving even more fuel savings.

One way to compensate for a potential mass crisis in the mission is a 'gravity capture' on arrival at Mercury. In collaboration with EADS Astrium, a sophisticated arrival strategy was designed in which the Sun's gravity is used in such a way that the spacecraft is decelerated enough to be temporarily captured in a high orbit around Mercury. If the orbit insertion fails, there are multiple opportunities to attempt another capture burn before the spacecraft eventually drifts away and the mission is lost.

For such a demanding ESA cornerstone mission, the ESOC mission analysis team relies on industrial support to analyse all aspects of the mission in the required detail. One example is navigation, a key issue for the safety of the mission. When six flybys may need to be performed with high precision, a detailed simulation of the orbit determination and trajectory correction is required. This resulted in dedicated software being written by Deimos Space, building on ESA's long-standing expertise and prototype software.

As a consequence, we now know which trajectory correction manoeuvres can be made with solar electric

BepiColombo cruise from lunar swingby to capture at Mercury



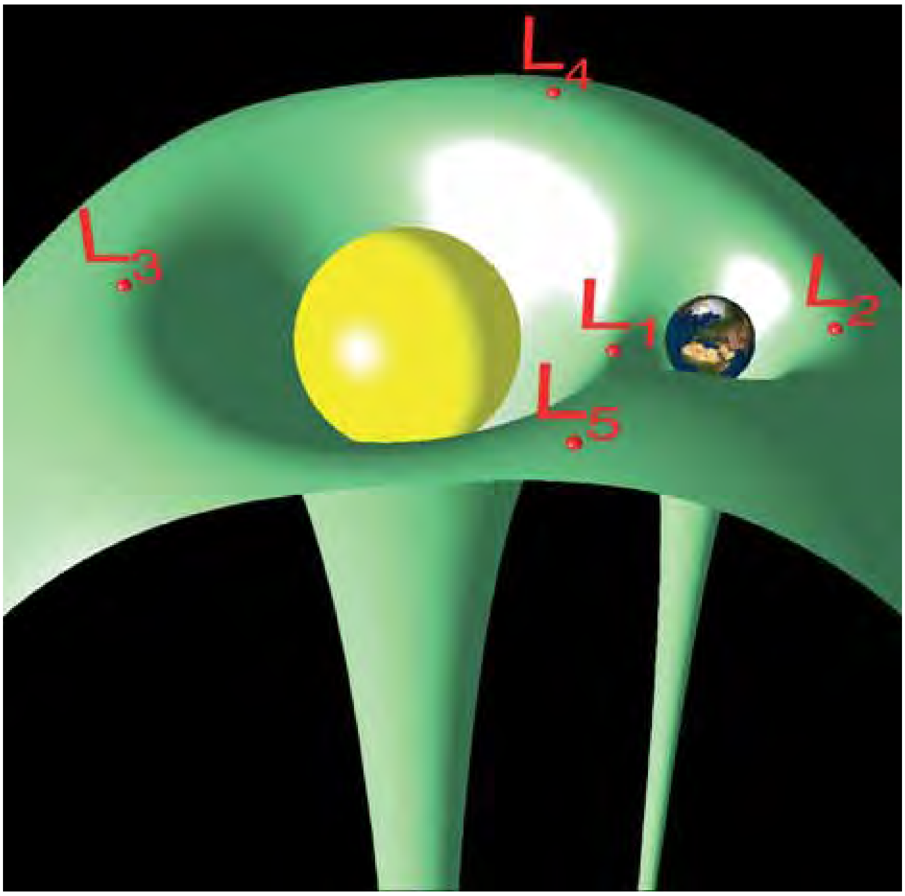
propulsion or have to be done using chemical propulsion. Mission analysts from the University of Glasgow and Politecnico di Milano have been called upon to write software for trajectory optimisation and graphical user interfaces to make the very complex trajectories easier to present and to understand. Finally, the Spanish technological business group GMV has delivered the 'ASTRO' toolbox to visualise the complex navigational aspects and simplify many day-to-day astrodynamic calculations.

LISA Pathfinder

As a precursor for the Laser Interferometer Space Antenna (LISA) gravity wave hunter, the LISA Pathfinder mission is required to perform its experiments in an extremely low-force, low-disturbance environment. For example, any force differences of more than one billionth of a g (1g = 9.81 ms^{-2}, the gravity acceleration on Earth's surface) between the proof masses of the payload is to be avoided, ruling out Earth's vicinity up to distances of 120000 km.

Given these requirements, the dayside L1 Lagrange point of the Sun-Earth system was chosen as the target location for LISA Pathfinder. There, at 1.5 million kilometres from Earth, the forces of Earth's gravity, Sun's gravity, and the centrifugal force of Earth's motion around the Sun cancel each other, so that the spacecraft moves about like a three-dimensional pendulum with a period of roughly 180 days. The pendulum motion in the plane of Earth's orbit has a slightly different period than the motion perpendicular to it, causing non-repeating orbits about the Lagrange point. The size of the free pendulum, or libration, motion is of the same order as the distance of the Lagrange point from Earth, so that the spacecraft appears to be circling the Sun on an annulus between 10° and 45° when viewed from Earth.

LISA Pathfinder is not an unusual case when it comes to the coordination of mission analysis activities in Europe.

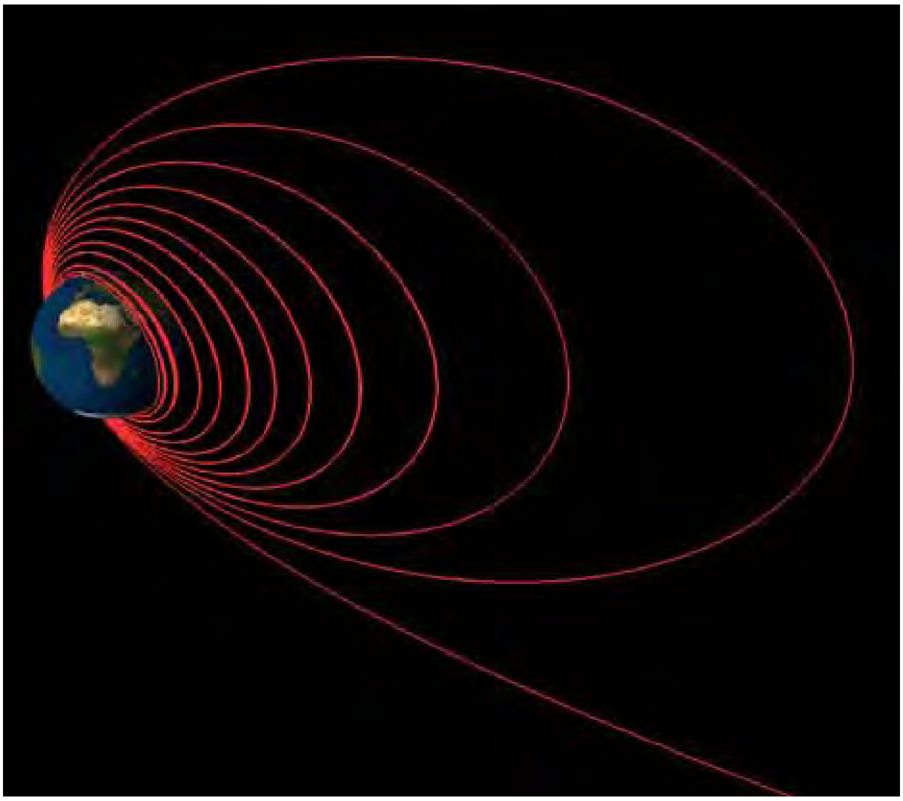


Lagrange (libration) points L1 to L5 on the 'Jacobi surface' (green) in the Sun-Earth system (not to scale)

There are industrial and academic players who work with ESA's experts, sometimes in parallel, sometimes by providing tools, and sometimes by reviewing each other's results.

The possibility of putting LISA Pathfinder as a co-passenger on a commercial Ariane-5 launch was excluded in phase A. This means that, instead of being injected into a geostationary transfer orbit, a dedicated small Russian Rockot launcher will place the spacecraft in a slightly elliptical low Earth orbit below an altitude of 1000 km. The most efficient way to transfer the vehicle from this initial low-energy orbit and send it towards the Lagrange point was sought. The strategic approach to use a number of perigee burns was regarded as the only possible solution. Since this transfer strategy could only be optimised under the constraints given by the spacecraft capabilities, it was a logical decision to assign this task to the prime contractor and have it reviewed by ESA experts.

One important trade-off in this optimisation was the total number of manoeuvres, with an increase in manoeuvres reducing the propellant expenditure, but at the same time increasing the LEOP duration and complexity. Mission designs with up to 25 manoeuvres were considered by the prime contractor in order to achieve the minimum change in velocity (delta-V, or ΔV). Concerns about the operability of this approach were evaluated, eventually resulting in a reduction to 15 manoeuvres. This number allowed a credible approach for the nominal operations in the Earth-orbiting phase, while also catering for simple contingency situations during that phase. In addition, the radiation exposure could be kept within the constraints given by the spacecraft and payload requirements.



LISA Pathfinder orbits before departure from Earth

Artist's impression of the Mars Sample Return Mission, showing lift-off of the Mars Ascent Vehicle (MAV) from the descent module

This example shows nicely that the system overview provided by ESA experts, including spacecraft, mission, operations, and ground segment, is invaluable when it comes to the realisation of solutions that are often driven by a desire to improve the propellant budget situation.

For the everyday work on Lagrange point missions, ESA specialists use the LODATO software package that has its roots in the rapid prototype development undertaken by them in the past. LODATO was improved by Deimos Space under contract with ESA, using software design guidelines.

The results from educational partnerships with academia have been included in LODATO, so that the rendezvous problem at the Lagrange points can be treated, as well as lunar flybys and navigation aspects. From an insider's point of view, it pays to have the competence for new developments in mission design software within ESA, while also using industrial and academic capabilities to expand and maintain the software to the latest standards.

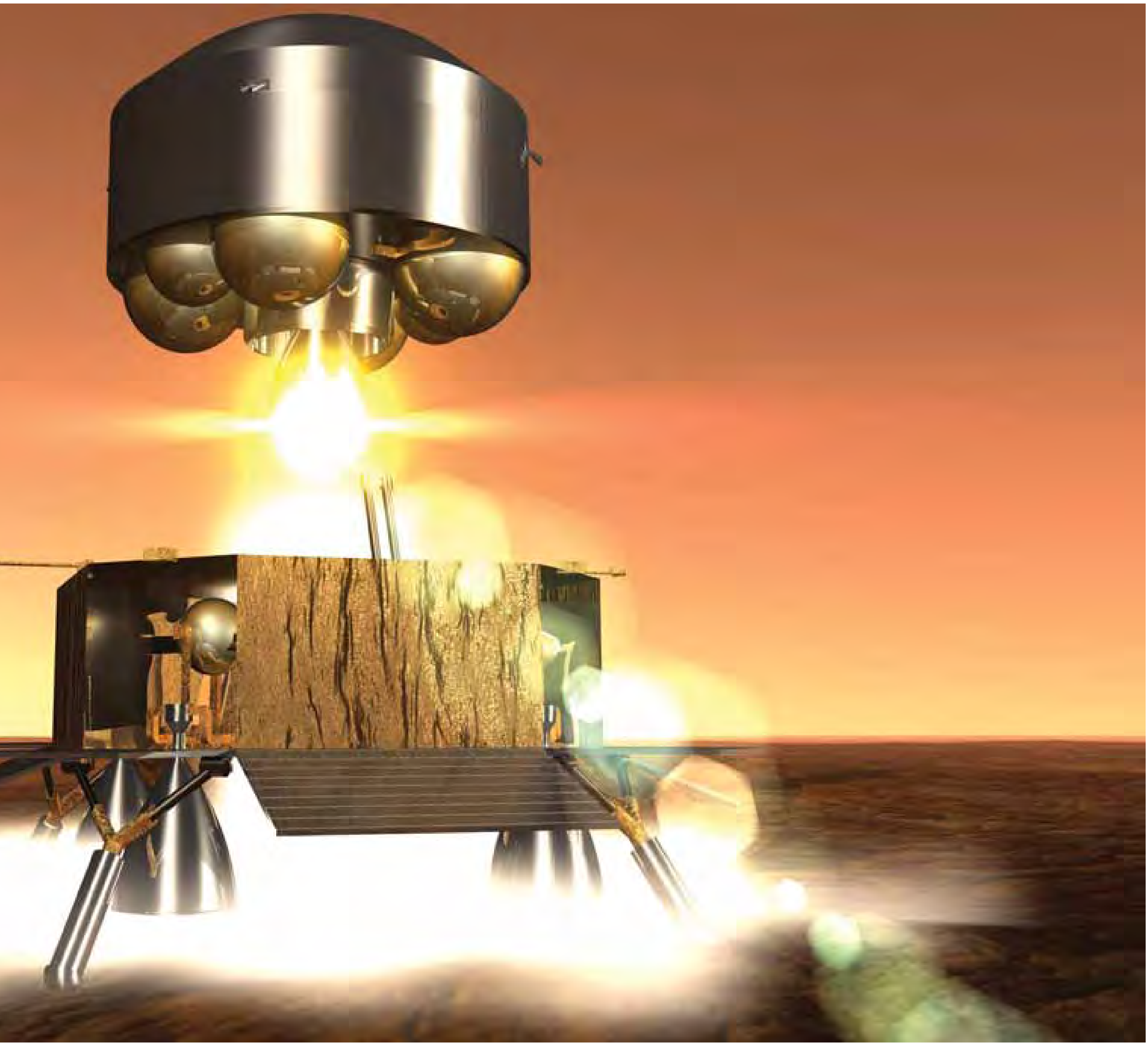
Mars Sample Return

Following ExoMars, the first Mars mission of ESA's Aurora Programme, which is due for launch in 2013, and a technology demonstration mission due in the 2016 timeframe, the Mars Sample Return (MSR) mission is planned to take place towards the end of the coming decade.

The most complex unmanned ESA mission ever, MSR will require two Ariane-5 launches. One will launch a Mars orbiter and an Earth Return Vehicle, the second will launch the Surface Element and Mars Ascent Vehicle (MAV). The Surface Element will probably involve a rover and possibly a drill for sample extraction. After collecting about 500 grams of soil, rock and atmosphere samples, the MAV will launch into a low Mars orbit where the orbiter will gather the sample container, seal it hermetically, carry it back to Earth and place it on an atmospheric entry trajectory.

Among the numerous technical challenges inherent to MSR are:

– targeted soft-landing of a large module on the Mars surface;
– automatic, accurate launch from the Martian surface into low Mars orbit;



– aerobraking to the target orbit around Mars;
– rendezvous and capture of the launched sample container;
– safe Earth return and precise insertion into a narrow re-entry corridor;
– compliance with stringent planetary protection requirements to avoid forward and backward contamination – MSR is by definition a Class V mission involving return of samples to Earth;
– long duration: 5–7 years between first launch and sample return.

Since the sheer magnitude and complexity will result in a mission cost that is too high for a single agency to shoulder, MSR is likely to be a multiagency endeavour. Current studies focus on a NASA/ESA cooperation.

More than most missions, MSR features a series of bottlenecks for which there is no workaround. Mars entry and landing, sample collection, sample launch, rendezvous and capture, sample container sealing, and Earth return and targeting all involve single points of failure with no chance for a second try. Failure to execute any of these steps exactly as planned will result in a total loss of the mission.

The challenges also extend to mission

Artist's impression of the latest concept for the ExoMars rover, now ready for the next phase of development, Phase-B2

analysis. The design of the interplanetary transfers and the Mars operational phase is driven by compliance with the numerous technical requirements. These include arrival at Mars at least six months before the start of the dust storm season, a minimum stay time of six months and no superior conjunctions at Mars approach or during surface operations.

A typical mission analysis product is the timeline shown on the next page, which presents the possible transfers in correlation with these mission requirements and allows the project to make a proper selection. The individual mission analysis tasks comprise launch window optimisation, interplanetary navigation, Entry, Descent and Landing (EDL) optimisation, aerobraking, maximisation of the data relay capabilities, analysis of the effect of natural orbit perturbations and identification of possible mission risks and problems. For each of these tasks, considerable know-how is present within ESA and industry. The key to success, especially in view of the fairly tight schedule, is to make the best possible use of the available expertise.

MSR stands out from 'usual' missions in several ways. Firstly, to a deeper extent than with other projects, MSR mission analysis is linked with programmatic and systems aspects. Furthermore, it requires profound knowledge of the Martian environment, the scientific goals and the political situation. The extraordinary list of technical challenges has already been mentioned. In combination with the unprecedented mission cost, the mission also faces significant political risks. Both need to be addressed at a fundamental level. Early identification and proactive mitigation of any mission risk are the keys to meeting the challenging schedule. Conversely, failure to address a technical issue in a timely fashion is likely to raise the likelihood of delays or cost overruns and expose the project to political risk.

MSR is not a standalone mission; it will enable Europe to act as an equal partner in even more challenging future projects, such as manned planetary missions. As stated, mission analysis should be seen and conducted as an integral part of global mission design. In view of the complexity, optimising the involvement of all available mission analysis capabilities is essential. The long preparation phase and mission duration and the need for a global, long-term view mandate that ultimately ESA retains full control of the key aspects, of which mission analysis is one.

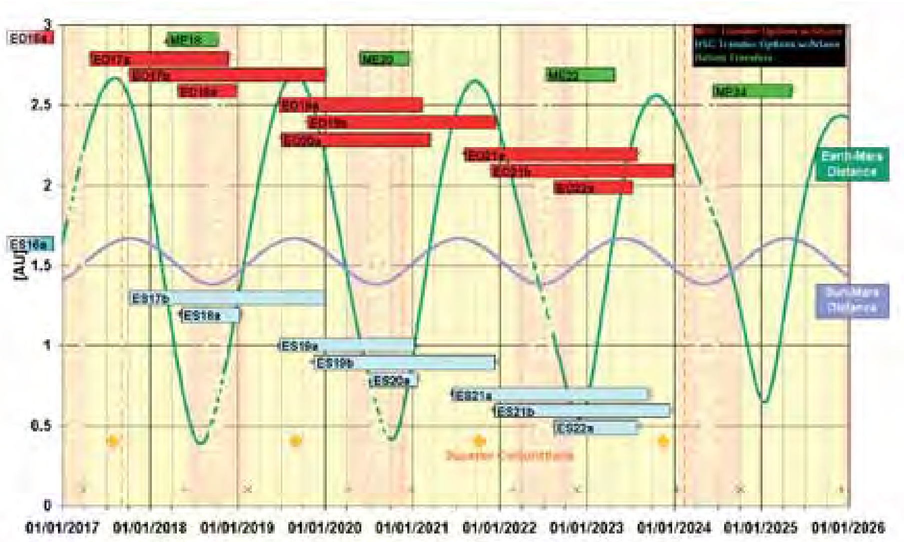
Summary

While remaining responsible for the mission analysis of ESA's projects, the ESOC mission analysis team shares the work with industrial partners, academic researchers, other groups in ESA and, occasionally, other agencies. The industrial contribution is either indirect, in the frame of a system design study or spacecraft procurement contracts, or direct, in the form of a study contract.

Usually a Mission Analysis Guidelines document is produced as input to industrial system design studies, to avoid a complete mission analysis being performed by the contractor. This is cost efficient, in particular for parallel studies. As only a limited number of companies can afford to maintain a sufficiently broad mission analysis expertise, this allows a much larger number of companies to make an offer, thus improving competition. Benefit is taken from the contractor's available expertise by inviting the company to review and enhance the mission analysis guidelines.

Often, the prime contractor of a spacecraft procurement or one of its major subcontractors has significant mission analysis expertise and uses it extensively to optimise spacecraft design. This valuable contribution is coordinated with ESA's work and integrated in the Consolidated Report on Mission Analysis (CREMA). The responsibility for the CREMA remains with the ESOC mission analysis group in order to maintain coverage and optimality of the entire system, including platform, payload, ground segment, launcher service and operations.

Direct industrial support is used for well-defined, specialised, offline study tasks which do not need frequent interaction with the projects. Study contracts are also used to develop new methods and tools, when universities focus on the conceptual work and industry focuses on the implementation.



Timeline chart showing possible outbound and return transfers and environmental conditions

Working groups are a useful platform to harmonise the work of several ESA and non-ESA experts in the case of complex, urgent or critical problems, such as the Rosetta lander mission analysis, the Rosetta mission redesign after losing the Comet Wirtanen opportunity and, recently, the mission definition for the Cosmic Vision missions to Jupiter and Saturn.

Recurring workshops dedicated to mission analysis enable the partners to present their work for feedback, to get an overview on the ongoing activities, to create awareness of the available expertise and, last but not least, establish good personal contacts, which are crucial for our cooperation to function. esa

Flight of the Phoenix

ESOC Supports NASA Mars Mission

Peter Schmitz, Olivier Reboud,
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With the landing of the US Phoenix spacecraft scheduled for 25 May, NASA has requested the assistance of ESA's Mars Express, in orbit around Mars since December 2003, as one of three orbiters used to monitor the dramatic arrival at the Red Planet.

Landing on Mars is one of the most difficult tasks any spacecraft can undertake. In the past, efforts to explain failed landings have sometimes been hampered by a lack of data from the atmospheric entry, descent and landing phase. Since the summer of 2007, specialists at ESA's European Space Operations Centre (ESOC) have been designing and testing a new communications mode that will allow Mars Express to support the Phoenix mission.

Under the new ESA/NASA 'Network and Operations Cross-support Agreement', NASA requested support from the European Space Operations Centre (ESOC) for its first Mars Scout Mission, Phoenix. This mission was launched on 4 August 2007 and is expected to land on the Red Planet on 25 May 2008.

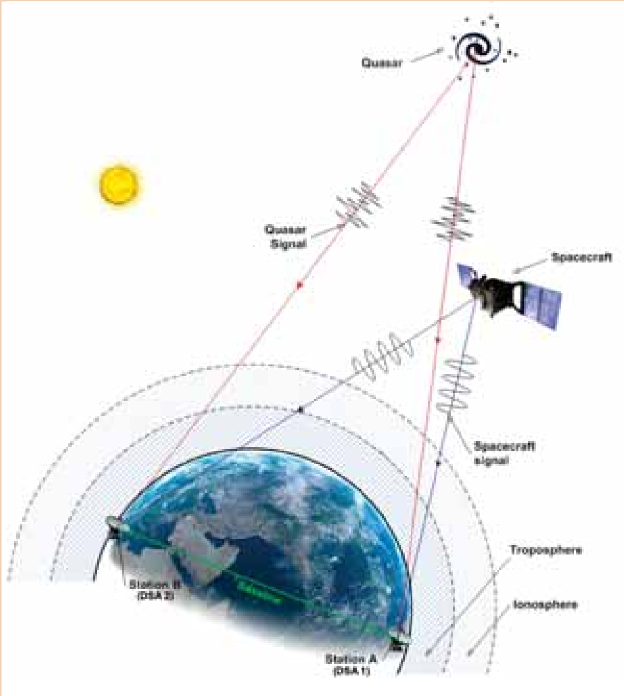
‘Delta-DOR’

Delta-DOR as a tool for the navigation of interplanetary spacecraft is based on a simple but quite effective concept. It uses two widely separated antennas (whose connecting line is known as the baseline) for simultaneous tracking of a transmitting probe in order to measure the delay in the signal arrival time between the two stations. The measurement of this time delay is named Differential One-way Range (DOR).

Theoretically, the obtained delay value depends only on the geometry of the system, that is, on the position of the two antennas and of the source being tracked. However, in real cases, this delay will be affected by several error sources. Delta-DOR corrects these errors using a quasar as a calibration source. This is possible since the quasar’s position (its direction) is extremely accurately known, typically to better than 1 nanoradian.

A delta-DOR measurement is directly related to the component of the angular separation between the spacecraft and quasar, parallel to the baseline between the two antennas. As two angles are required to define a direction, full exploitation of delta-DOR calls for measurements from two different baseline orientations – the closer to orthogonal the better.

For Phoenix navigation with delta-DOR, NASA’s Deep Space Network (DSN) uses the baseline between the Goldstone and Canberra complexes. Since the ESA baseline (New Norcia to Cebreros 35 m deep space antennas) is almost perfectly orthogonal to the DSN one, it complements angular results obtained using the DSN-only baseline and can be used to improve navigational accuracy. Analysis carried out beforehand by JPL demonstrated that use of the ESA baseline would improve the uncertainty in Phoenix orbit determination by 15%.



Delta-DOR tracking of a deep-space probe and of a nearby quasar from DSA-1 (New Norcia, Australia) and DSA-2 (Cebreros, Spain). The effects of common error sources between spacecraft and quasar observations are cancelled by the quasar tracking.

Throughout the journey to Mars, ESOC has provided support for critical Phoenix mission phases, such as ground station tracking support during the launch and early orbit phase, delta-DOR (Differential One-way Range) ranging support during Mars approach, communications support during entry, descent and landing and post-landing data relay support through Mars Express.

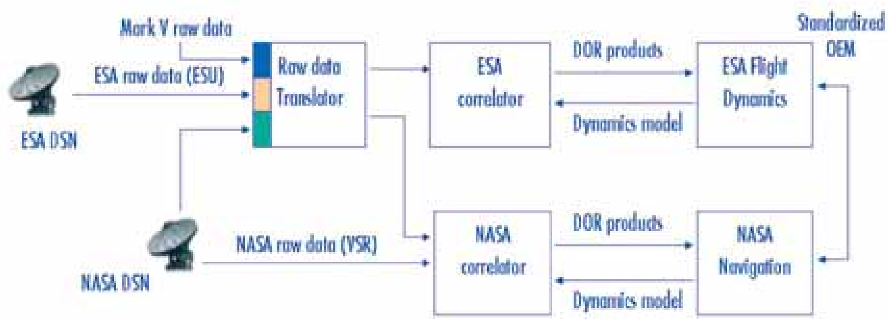
Phoenix Launch Support

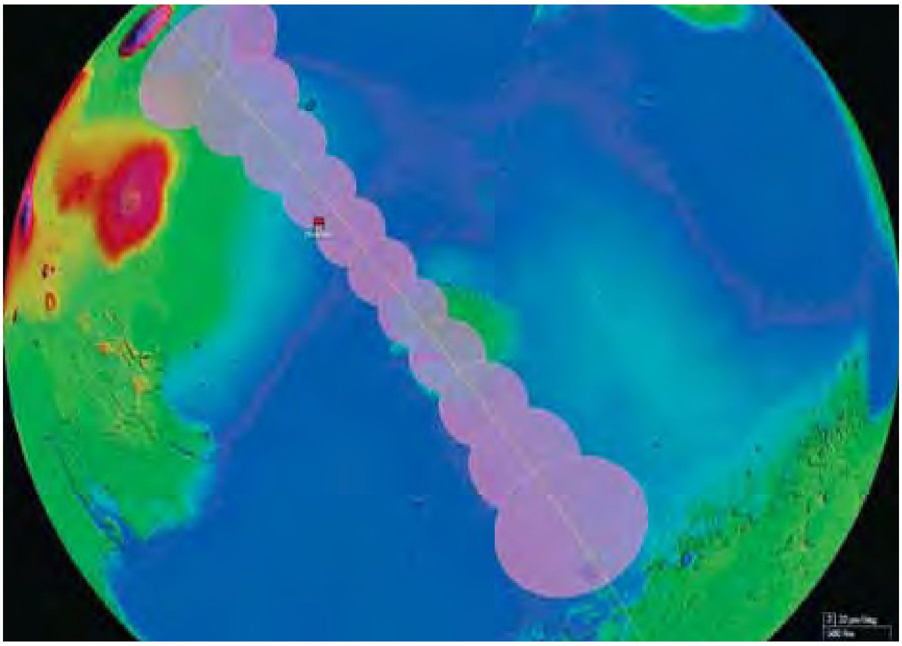
After the successful launch of Phoenix on 4 August 2007, the ESA Kourou ground station provided tracking support to the NASA project. Kourou is the only station able to guarantee 24-hour coverage during this critical mission phase by bridging the ‘Atlantic gap’ in spacecraft communications between US tracking stations in Madrid and Goldstone.

Phoenix Delta-DOR Navigation Support

Phoenix navigation has very stringent requirements in terms of orbital solution accuracy. In order to achieve the desired level of precision, a heavy use of a technique known as ‘delta-DOR’ is foreseen. Delta-DOR has already been used operationally by ESA to support Venus Express before Venus orbit insertion in 2006 and before

ESA Delta-DOR interoperability concept using software data translator to ensure data compatibility among different agencies





MELACOM 70° footprints (pink) pass over the Phoenix lander during Mars Express (yellow line) nadir over-flight

Rosetta's flyby of Mars in early 2007. The technique demonstrated high-level performance, meeting requirements that were based on a 1 nanosecond measurement accuracy (corresponding to a spacecraft position uncertainty of 4.5 km at 1 astronomical unit).

After these successful operational campaigns, ESA has developed a software data translator that is capable of processing not only data coming from its stations, but also from NASA DSN or other astronomical institutions, thus enabling the possibility of delta-DOR interoperability with other space agencies such as NASA or JAXA and extending the number of possible baselines to be used.

The new system has been validated with NASA by using Venus Express orbiter as a target that was tracked simultaneously by one ESA and one DSN antenna on several occasions during June–July and September–October 2007.

Thanks to the new data translation capability, ESA can now exercise a full interoperable delta DOR with NASA. The delta-DOR support to NASA foresees two scenarios:

– support from ESA baseline only;
– support from a mixed ESA-DSN baseline.

The support from the ESA-only baseline is made of 19 delta-DOR passes – plus a test pass carried out on 1 December 2007 – starting on 25 January 2008 and occurring with increasing frequency as the Phoenix Entry Descent and Landing (EDL) phase approaches. The last ESA-only delta-DOR is foreseen on 23 May 2008, one day before the last Trajectory Correction Manoeuvre and two before EDL.

Together with the ESA-only baseline support, a limited number of passes to be taken on the baseline New Norcia – Robledo has been foreseen. The first operational attempt to have a fully interoperable delta-DOR measurement between two agencies has two objectives: validating the interagency delta-DOR capabilities in an operational environment and cross-checking results obtained with ESA antennas only. This represents a huge improvement in the ability of both agencies to support deep-space missions.

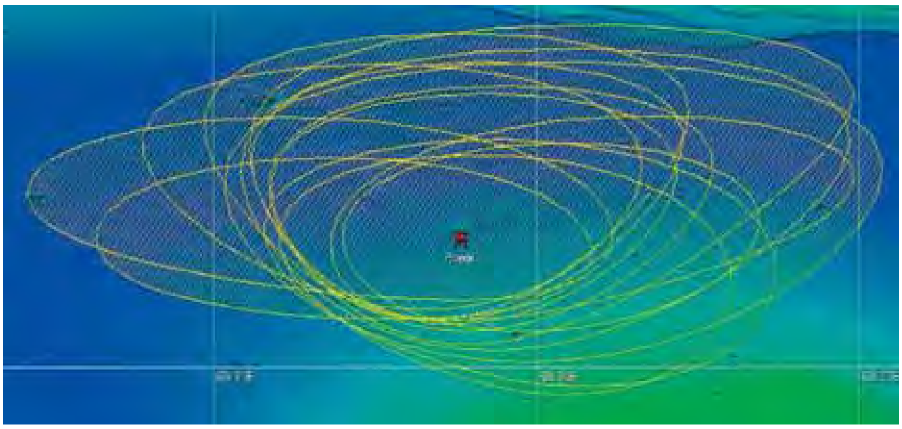
A total of five test passes (plus the one carried out on 1 December 2007) are foreseen for this option. The data, collected either at ESA or at DSN stations, are transferred to ESOC to be processed by the ESA delta-DOR correlator. Reduced data are then converted into CCSDS standard format and transferred to JPL for orbit determination purposes.

Phoenix Support by Mars Express

In 2007, NASA requested the use of Mars Express to support the Phoenix lander during two critical phases, the Entry, Descent and Landing (EDL) and subsequent on-surface characterisation phase. During EDL, Mars Express will record RF signals emitted by the probe in open loop ('Canister mode'), which will provide NASA with valuable information on Phoenix's behaviour while it descends through the Martian atmosphere.

Once Phoenix has landed on Mars it will undergo a 10 Sol (Sol = Martian day) characterisation phase, when Mars Express will act as a communications

Mars Express MELACOM antenna spot-pointing footprints over the Phoenix lander during the nominal mission



relay between the lander and Earth. The objective of this on-surface support is to assist NASA in determining Phoenix's health and to demonstrate Mars Express relay capabilities should they be needed later in the mission. In this respect, Mars Express could complement the communications coverage of Phoenix, which is nominally supplied by the NASA orbiters Mars Reconnaissance Orbiter (MRO) and Mars Odyssey (ODY). Thanks to its elliptical orbit, Mars Express can, in some mission phases, provide longer periods of contact with Phoenix than MRO or ODY.

Bringing the Two Missions Closer

One of the key issues to meet NASA's request was a proper phasing of the Mars Express orbit, allowing the ESA spacecraft to track the descent module with an optimised visibility. By taking advantage of the Mars Express orbit change to an 18/5 resonance orbit (planned for scientific reasons), the phase of the orbit has also been changed with minimum additional fuel consumption. If needed, the phase may have to undergo last-minute tuning one week before Mars arrival, when the final entry trajectory parameters of Phoenix are known.

During EDL, the recorded data will be secured by a copy stored on board Mars Express in a dedicated area of its Solid State Mass Memory, and then dumped three times to Earth to avoid any data gap caused by potential ground station problems, bad weather conditions or network issues. The EDL data would be of highest importance in a contingency situation when Phoenix would not have landed as expected, making the analysis of the sequence of radio tones transmitted by Phoenix during EDL critical for investigations.

In the seven days after the EDL, ESOC has booked each over-flight of the Phoenix landing site above 10° elevation, so that the Mars Express Lander Communications (MELACOM) system will be ready to support any contingency plan decided at any time during this week. Assuming Phoenix lands nominally, some of these passes will be used for communications to command the lander and/or relay science data to Earth.

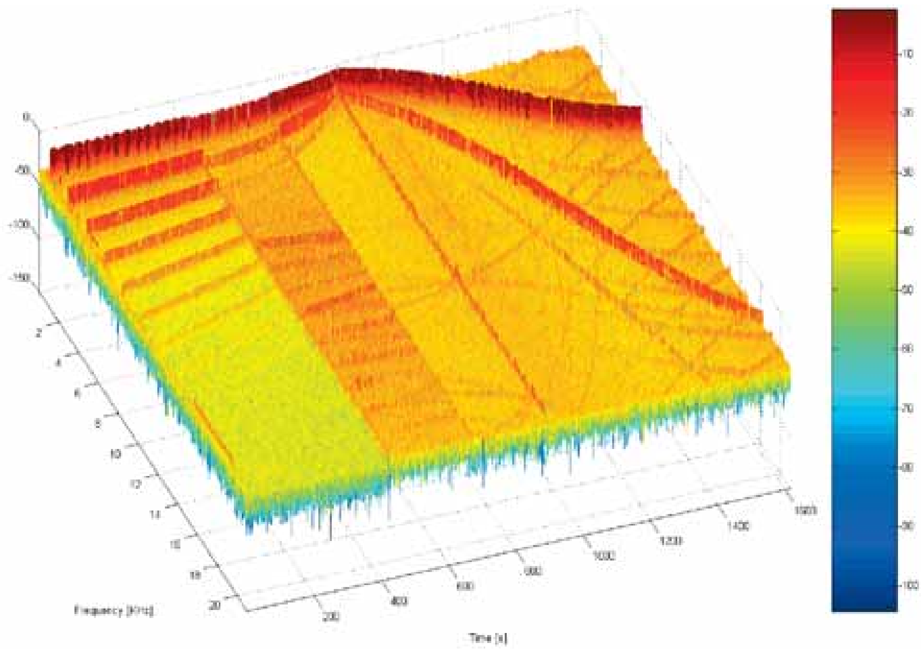
In-flight Tests and Preparation

The principle of a test campaign between Mars Express and the Mars Exploration Rovers (MER) Spirit and Opportunity was decided in April 2007. This was to provide operational confidence for Mars Express–Phoenix communications because the rovers both carry the same CE505 model of UHF radio transponder as Phoenix.

The beginning of the test campaign was hindered by a severe dust storm on Mars between mid-July and mid-August 2007, leading to the cancellation at short notice of three tests due to excessive atmospheric dust levels affecting the power situation of the rovers. Fortunately, the weather at Mars improved, allowing a series of 12 tests with both rovers. A total of 900 commands were sent and 145 Mb of lander communication data were successfully relayed to Earth via Mars Express during duplex links utilising the CCSDS Proximity-1 protocol. In addition, to prepare for the Phoenix EDL event, the MER transmitted a sequence of RF tones that simulated the RF signature of Phoenix during the descent and were recorded in MELACOM 'Canister' mode.

On board Mars Express, 'standalone' tests (without the rovers) were also conducted to determine whether other Mars Express instruments interfere with the frequency spectrum of the MELACOM receiver channel. Dedicated interference tests were conducted to verify that neither AOCS (Attitude and Orbit Control System) units nor payloads like the HRSC (High Resolution Stereo Camera) or SPICAM (Spectroscopy for Investigation of Characteristics of the Atmosphere of Mars), which are planned to operate during the EDL event, would generate adverse effects on the RF spectrum while MELACOM is scanning in 'Canister mode'.

Those interference tests have shown, for instance, that the MARSIS (Mars Advanced Radar for Subsurface and Ionosphere Sounding) instrument can operate together with MELACOM, but that severe interference is generated by



Waterfall diagram processed by ESOC: MELACOM recording in 'Canister' mode of mock Phoenix EDL tones transmitted by Opportunity MER-B (28 August 2007)

Artist's impression of Phoenix on the surface of Mars

ASPERA (Analyser of Space Plasmas and Energetic Atoms), resulting in an exclusion rule for science planning which prevents both instruments from operating together.

The main objectives of this intensive test campaign in 2007 were successfully achieved:

- health check of the MELACOM transponder which had not been switched on for 20 months;
- definition and set-up of operational interfaces between JPL and ESOC, being able to cope with different planning cycles between Mars Express and Phoenix;
- insertion of the MELACOM pointing requirements and resource allocation into the medium-term planning cycle by ESOC, three months before start of activity;
- generation of the MELACOM operations request by ESOC one month before start of activity;
- generation of the MELACOM command files by JPL up to two days before onboard execution;
- transfer to ESOC for final checks and uplink in the next available ground station pass;
- execution on board Mars Express, i.e. forwarding of rover telecommands and reception and recording of rover telemetry during the over-flight;
- transfer of the recorded data to ground in the next available ground station pass;
- retrieval of the telemetry data from the ESOC archive by JPL for analysis.

Following the Mars Express/MER test campaign in 2007, seven follow-on tests were carried out between Mars Express and the Opportunity rover in early 2008. The objectives were to test the RF link performance while Mars Express was performing a dedicated 'lander pointing', targeting the MELACOM antenna towards the rover during the over-flight in order to optimise the RF link budget and improving the return link efficiency.

Phoenix and Beyond

Success in the Mars Express support to Phoenix and the ability to meet the Mars lander's requirements will provide excellent proof that Mars Express can, in addition to being an excellent science orbiter, also act as a Martian communications relay and support future Mars surface missions such as NASA's Mars Science Laboratory or ESA's ExoMars.

In any case, the intensive test campaign with the Mars Exploration Rovers and the support to Phoenix was a great opportunity to involve several agencies and mobilise various competences within ESA that were required to work together, such as Flight Dynamics, Mars Express Flight Control, Mission Planning and Project Scientist teams, the RF and Signal Processing team, Mission Control System Software support, ground station and navigation teams. It also established a fruitful partnership with our NASA JPL colleagues from the MER and Phoenix projects. We thank all of these groups, and hope it is just the beginning.

Getting Customer-oriented:

ESA Procurement in Cooperation With Other Organisations

Signature of procurement contract for Sentinel-1 with Thales Alenia Space, at the Paris Air Show,18 June 2007. From left to right: Volker Liebig, ESA Director of Earth Observation, Jean-Jacques Dordain, ESA Director General, and Pascale Sourisse, President and CEO Thales Alenia Space.

Stefano M. Fiorilli
ESA Procurement Department,
Directorate of Resources Management,
ESTEC, Noordwijk, The Netherlands

ESA is entering more and more cooperative undertakings with other organisations, whether providing assistance in procurement, or in jointly developed space systems and infrastructures. This role acknowledges ESA's expertise as a public procurement agent, but challenges us to maintain and adapt our procurement processes to suit both internal and external needs.

Introduction

Procurement is the channel for ESA both to implement our mandate assigned to us by Member States and to secure the means required for such implementation. Indeed, within the classical ESA institutional frame, the Director General proposes programmes to the Member and Cooperating States which, in turn, give mandate to the Director General to implement them within defined technical, financial and schedule boundaries.

To implement the programmes, the Director General concludes contracts with European industry and research institutions that conduct the studies, develop the satellites and build the infrastructures. As such, procurement is

ESA and Astrium signing the contract for Sentinel-2 Earth Observation satellite. From left to right: Karl Trauernicht, German Ministry of Transport, Evert Dudok, President of Astrium Satellites, Volker Müller, Astrium Contracts Dept., Volker Liebig, ESA Director for Earth Observation, Jonas Amnéus, ESA Contracts Dept., Valère Moutarlier, European Commission, Head of GMES Bureau and Uwe Minne, Director of Earth Observation & Science for Astrium (Astrium)

at the centre of ESA's daily operations. Each year, the largest part of our budget is spent on contracts in the Member and Cooperating States for research or project-related activities. The efficiency of the procurement process then greatly impacts on ESA's overall functioning.

Both the public and international nature of the process means that its efficiency is measured primarily against its achievement in the most effective use of the European taxpayer's money. The procurement process has developed around boundaries that are important for satisfying specific goals, such as: maximising competition and securing its fairness, and transparency in the decision process towards contract awards.

Today's ESA procurement process is the result of practices that have applied to a variety of programmes over a period and that have seen major changes in the industrial and programmatic landscapes. These practices have led to procurement becoming multidisciplinary and going well beyond the setting-up of contract clauses. Procurement thus encompasses a combination of techniques and dimensions starting from, indeed, the definition of Technical Requirements and Cost Estimation to legal formulation, Industrial Policy and Financial Control, going through Technical Monitoring, Cost Engineering and Auditing.

In parallel to this internal evolution, ESA has maintained a constant interface with not only European industrial and academic actors, but also intergovernmental and national organisations. As far as these organisations are concerned, ESA has been acting as procurement agent for, or joint customer with, the other organisations (also referred to as 'Third-Party Organisation'), such as Eutelsat, Eumetsat, the European Commission and national governments.

What is the specific added value that ESA offers to these third parties? What responsibilities and challenges does this role entail for ESA? To what extent does the experience of such joint undertakings reinforce a customer-oriented culture in ESA? These issues are now explored.

Which Cooperations?

Procuring in cooperation with other European organisations was initially seen as a natural way for ESA to act within its mandate of developing an organisation, while preparing the ground for other, dedicated organisations to take over the operations of the space systems developed. Whether in the field of telecommunications or meteorology, ESA would be in charge of the procurement for the development phase (the 'prototype' satellite), while the procurement for the operational phase (operation of the prototype and, sometimes, procurement of the recurrent satellites) would be retained by these organisations, respectively Eutelsat and Eumetsat.

In a second stage, and mainly for what concerns the cooperation with Eumetsat, the two organisations realised that grouping the procurement of the prototype and – at least some of the – recurrent satellites would allow achieving economies of scale. Therefore, and in spite of the fact that, for instance in the case of Meteosat Second Generation (MSG), the prototype would be mainly financed by ESA and the two recurrent models entirely by Eumetsat, the two organisations agreed that ESA would award one single contract to industry, covering the three satellites, with ESA thus acting as Eumetsat's procurement agent for the purpose of the part of the contract covering the two recurrent satellites. In the case of the MetOp series of satellites, and while the basic framework was rather identical to the one of MSG, the agreement between the two organisations foresaw that they would both sign the contract with industry covering the development, manufacture, test and delivery for launch of the three satellites.

To affirm ESA's role as the 'Space Agency of Europe', and in line with the Framework Agreement between ESA and the EC, the last years have seen the two organisations cooperating on two major programmes, i.e. Galileo and GMES (Global Monitoring Environment and Security). In both cases, the programmes aim at ultimately providing services that have been recognised as strategic by the Union and that go much beyond the objectives that had been classically pursued by previous ESA programmes. In both cases, the choice has been made to entrust ESA with the responsibility of conducting the procurement, irrespective of the particular funding arrangements prevailing, but with adjustments to the usual ESA procurement rules so as to make the procurement compatible with the rules applicable to EU public procurements.

Recently, an assistance agreement was concluded between ESA and Spain's Centro para el Desarrollo Tecnológico Industrial (CDTI). According to that agreement, the Agency provides assistance to CDTI for the purpose of the procurement of the SEOSAT/Ingenio satellite, which is exclusively financed by the Spanish government. Taking into account that particular context, the industrial contract(s), although fully funded by CDTI, will be placed by ESA, but they will secure delivery to and ownership by CDTI of all results thereof.

Visibility to the Financing Organisation and Management Autonomy to ESA

As suggested, one of the first peculiarities of procuring in cooperation with another organisation is that the subject of the procurement is not, or not exclusively, financed by the ESA Member or Cooperating States, but, in whole or partly, by that other organisation. It is therefore only normal that, irrespective of the extent of the procurement mandate given to ESA, sufficient visibility is granted to the financing organisation on the progress of the procurement.

The experience shows how important it is for the organisations to clarify the modalities of such visibility. Special separate treasuries must be put in place in the ESA financial books to accommodate the financial instalments paid by the third-party organisation and that will eventually allow ESA to pay the contractor's invoices when justified by achievement of the technical milestones. Clear procedures must also be put in place between the organisations for ensuring swift and timely handling of these invoices. Regular Bilateral Review Groups must be accommodated for the two organisations to review the changes to the contract, being proposed by industry or by one of the two organisations, and to decide on the allocation of their costs between them.

In all cases however, it is essential for the efficiency of the procurement that those bilateral exchanges do not affect the empowerment of the ESA Project Manager to act as sole customer vis-à-vis industry, and to be perceived as such by all stakeholders.

All these implementation modalities are put in place in Project Implementation Plans between ESA and the third-party organisation, allowing ESA to efficiently fulfil its two mandates: being the customer of industry and satisfying the operational needs of its own customer, the third-party organisation.

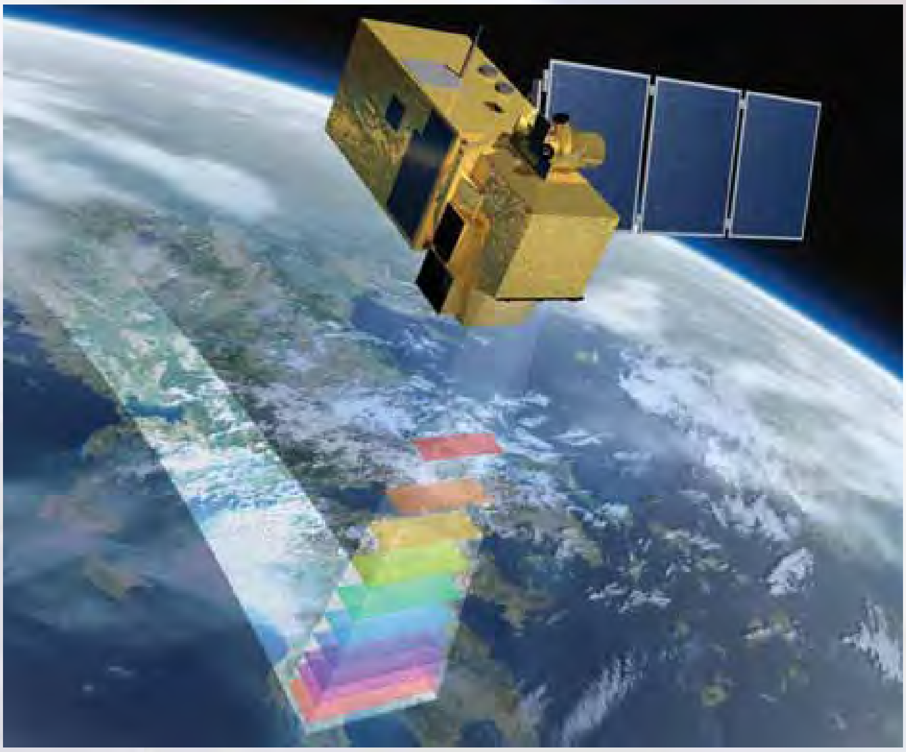
Risk Management

The specificity of ESA's experience in procuring space systems and infrastructures lies in the volume of the procurements it has conducted over 30 years, and the fact that they all involved developments that were at the forefront of the existing technologies, and that they expanded in a timespan that saw substantial evolution in the industrial landscape. This has led to the devising of procurement approaches aiming at the completion of such ambitious and non-standard projects within controlled schedules and financial envelopes, through tailored risk management schemes.

ESA, in dialogue with the European space industry, is in constant evolution on this aspect of the procurement approach and is in a position to put its experience at the disposal of its own customers.

Because of the non-standard, often pioneer, nature of space projects, their cost-estimation is difficult. Also based on the experience gathered over the years and within the framework of systematic and – as far as comparable – data, ESA conducts parametric cost estimations that can contribute to

Artist's impression of Sentinel-2 in orbit



Volker Liebig, ESA Director of Earth Observation, and Pascale Sourisse, President and CEO of Thales Alenia Space, signed the contract for Sentinel-3 Earth Observation satellite on 14 April 2008 in Paris. Sentinel-3 will provide crucial data for information services to the European Union and its Member States as part of GMES

validating those estimations or quotations submitted by industry and providing the basis of estimated financial envelopes. During the Preparatory Phases of the Programme/Project, pre-feasibility and feasibility studies not only cover the technical scope of their intent, but also, indeed, produce cost estimations that are based on the design assumptions they have produced.

A central concept in the overall ESA project management culture is the one of 'Phasing'. 'Phases' are not only important in terms of sanctioning the reaching of cardinal technical milestones towards the manufacturing and operation of a satellite (e.g. Pre-feasibility Study, Feasibility Study, Preliminary Design Review, Critical Design Review, Acceptance Review and Commissioning Review), but they also guide the process of what must be a consolidation of the requirements, the identification of the risks, their management and progressive (but never complete) mitigation.

Based on its experience, ESA promotes approaches, also for third-party procurements, dedicating sufficient funding to the preparatory phases and, during the latter, to maximise, as far as possible, the initiation and maintaining of competitive, parallel contracts with industry. These preparatory phases must allow the generation of a detailed set of requirements documents (management requirements and tasks, deliverable item list, system requirements, Ground Segment Interface Requirements, Product Assurance Requirements, Documents Requirements List, Interface Control Documents, etc.) that will form the contractual baseline for the development, manufacturing and commissioning phases, document the industrial contractor commitment for these phases and, in the case of fixed price arrangements (see below), constitute the reference against which contract modifications will be assessed and the bearing of their financial consequences will be allocated.

From the above, it results that, irrespective of the programmatic and funding arrangements made with the third-party organisation, ESA articulates procurement approaches around the principle of conditioning the start of the development and manufacturing phases to the consolidation of the requirements, including the closing of those technical trade-offs that are inherent to the feasibility studies.

Even when such progressive and systematic consolidation of requirements is pursued, the very nature of the space projects makes it unavoidable to still face risks during the manufacturing and development phases. The ESA procurement approach in that area pursues the separate identification, in the contract, of those risks covered by a dedicated financial margin and those – if any – which, typically because of their nature or potential magnitude, remain outside of the industrial contractor's commitment. This proactive approach must provide funding third-party organisations with the same transparency on the reality of industrial commitments to the one that is being provided to the Member/Cooperating States within the regular institutional ESA framework.

Prime Contractor and Subcontractor Selection

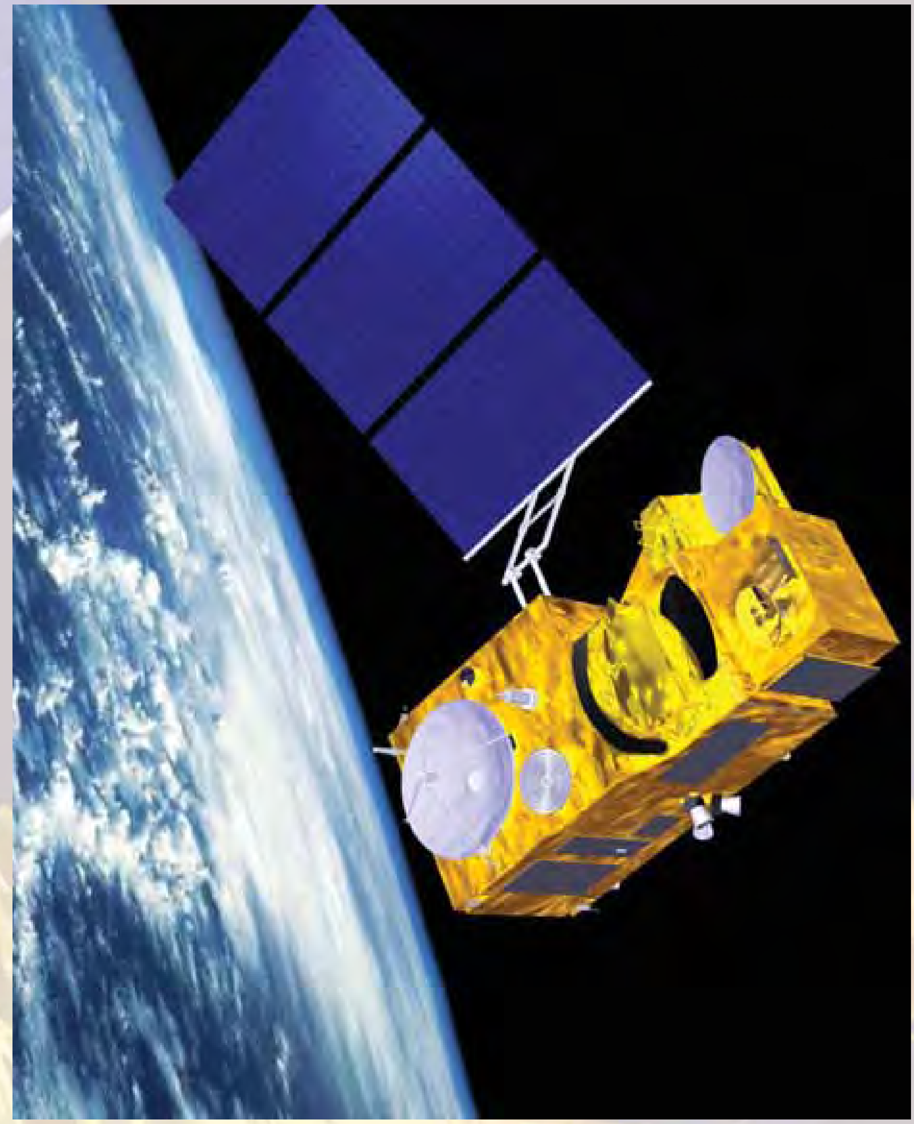
Given the international public nature of the ESA procurement process, the internal rules that govern the preparation of the Invitations to Tender/Request for Proposals, their publication, and the evaluation of the industrial offers, as well as the decision of contract award are characterised by a strong formalism, which aims at securing the fairness of the competition at each stage. The process is, however, based on a strong technical presence that, being it at the stage of the requirements definition or at the one of the assessment of the industrial offers, mobilises specialised ESA engineers and scientists at both system and sub-system level, and that constitutes the very core of ESA's added value. This technical competence is not only represented by ESA's dedicated project team, since the latter benefit also from the detailed expertise of the ESA Technical Directorate, that is in a position to provide support in all areas and technologies concerned by satellite and space infrastructure development.

When procuring in cooperation with other organisations, ESA tailors the above-described process, so as to allow, at the same time, these organisations to benefit from its competencies and to fully involve them in all steps.

The process described above does not only apply to the selection of prime contractors, but also to the one of the subcontractors. ESA has over the years developed a so-called 'Best Practices for the selection of subcontractors by prime contractors in the frame of ESA's major procurements' ('Best Practices'). The Best Practices are based on the concept that ESA guarantees, by its presence in the process, that the principle of fair competition is applied also to the subcontractors selection process. Under Best Practices, ESA is given full visibility – and right to participate to – the Invitation/Request for Quotation preparation by the prime contractor, its evaluation process, its selection of the tenders, including the right to perform audits on the prime's overall procedure. In conducting the Best Practices, ESA has put at the disposal of the European space industrial community dedicated tools, like EMITS (European Mail Invitation to Tender System), that ensures the publication in line of all invitations to tender.

Within the regular institutional ESA framework, the Best Practices have, with time, evolved towards also including a function of implementing tool for specific ESA Industrial Policy considerations, like geographical return or share of the work between prime contractors and non-primes, etc.

Even when the funding third-party organisation does not subscribe to any, or to the same considerations of Industrial Policy, ESA organises the subcontractor selection process so as to safeguard the Best Practices' role of a management tool, allowing the end customer to keep visibility, to the extent desired, on the process followed by the prime to constitute its consortium, without impairing the absoluteness of its contractual commitment at end-system level.



Artist's impression of Sentinel-3 in orbit

Furthermore, ESA is in a position, depending on the third-party organisation's wishes and/or constraints, to either put EMITS at their disposal, or to ensure a parallel publication of the Invitations to Tender/Requests for Quotations through both EMITS and other means. An example of this is provided by the Sentinel-1, Sentinel-2 and Sentinel-3 satellites developments in the GMES programme. Given that part of the space element of the programme would be deemed to be funded from the EC Frame Programme 7, the relating Invitations to Tender for subcontractors are currently published not only through the ESA EMITS, but, in parallel, through the dedicated EC tool, 'CORDIS' (Community Research and Development Information Service).

Finally, the Industrial Policy considerations that have contributed to the ESA procurement process over the years have allowed generating data and information that benefit today the third-party organisations cooperating with ESA: industrial competitiveness at large, mapping of national and European competencies, industrial networks, etc.

Contract Management and Monitoring

Detailed and focused technical competence does not only determine the tendering phase of the ESA procurement. It is also at the centre of the contract management and monitoring performed by ESA customer, it being in the frame of its own programmes or for the benefit of those of third-party organisations. During the entire timeframe of the development, and without taking over the financial and contractual responsibility that must and does remain the one of the industrial contractor, ESA puts in place the tools allowing a close technical monitoring of the work progress, at all critical levels of such undertaking and of the industrial consortium.

This technical monitoring takes the form of regular progress reports from, and progress meetings with, industry, which allow the keeping abreast of the real status of the project, reinforce the technical and schedule control of those elements that are on the critical path, and impose redirections and additional investigations where judged necessary.

The strictly contractual tools have, also, been developed and adapted over the three decades of ESA's operations, with a view to match the particular context in which contracts are placed and to serve the particular reality these contracts cover (development of complex, innovative, precursor space satellites and infrastructure).

This has led to the progressive development of clauses and practices, including all aspects of the contract. As is the case for its own procurements, ESA pursues, in contracts covering third-party procurements, clauses that secure the timely and performing delivery of the end product, within the agreed price. The contractual areas that are more primarily concerned by these three elements are the price-type, the guarantees, and incentive/penalty schemes.

The three types of prices commonly practiced by ESA in its contracts are the fixed price, the ceiling price and the cost-reimbursement price. While the ceiling price is by nature and as its name indicates a price subject to refinement 'within its ceiling' at a later stage of the contract and when uncertainties have been clarified, different schools of thought continue to coexist on the respective merits of fixed price and cost reimbursement price.

Since the fixed price is essentially not subject to any refinement, irrespective of the actual evolution of the cost incurred by industry, it is seen that to be sustainable by the latter it must contain a sufficient margin to accommodate unforeseen events. This would, in turn, plea for the fixed price to be concluded for portions of the development where such risks are reasonably foreseeable and measurable, or, as suggested above, keep the unforeseeable or immeasurable risks out of the fixed price.

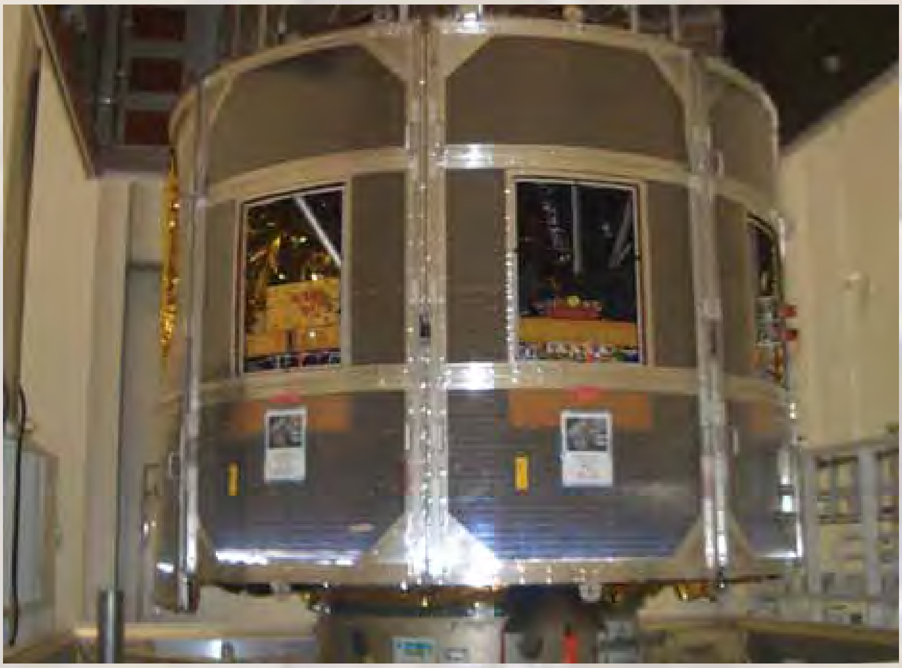
The cost-reimbursement price foresees the reimbursement of the allowable costs incurred by the contractor, plus a profit, that can be either fixed or linked to the achievement of schedule, costs or performance objectives. By its nature, it thus implies a much stronger and systematic implication of ESA in the administrative management of the project, and it would provide, if not a protection against, at least a better visibility on the elements eventually generating costs overruns.

Whatever the price retained, however, it looks obvious that none of them could make up for an insufficient financial envelope. It is therefore essential to invest time, skills and competencies in the accurate cost-estimation exercises that are leading to the definition of such financial envelopes, and ESA pursues constant improvements in these domains.

The concept of 'guarantee' takes a different resonance in the context of space satellite or infrastructure procurement than it has in the field of ordinary consumables: it does not appear feasible to pursue replacement of an in-orbit faulty satellite as would be the case for, e.g. a non-functioning car. Contracts have adapted to that reality, and, as an example, the obligation of satellite manufacturers under guarantee clauses may take the form of them investigating and providing, at their expenses, ground-segment based remedies: engineers would, from Earth and thanks to software 'patches' try to correct the defect observed or to mitigate its effects.

When the contract covers a series of satellites, the guarantee clause may take the form of a 'retrofit' obligation: the

MSG-2 was launched on 21 December 2005 from Kourou, French Guiana. Two more MSG satellites should guarantee continuity of service through to around 2018. MSG-3 is in storage, and is planned to launch early 2011. MSG-4 is planned for a launch not earlier than 2013



obligation of the satellite manufacturers will consist in bringing to the not-yet launched satellites, at their expense, all corrections necessary to avoid reoccurrence of the defect on these not-yet launched satellites. However, such clauses are of a very onerous nature for industry, and ESA's practice has therefore been to associate them with a limitation of the financial liability to which the contractor would be exposed under their application.

As suggested here, third-party organisations cooperating with ESA for the purpose of their procurement very often have stringent operational needs and constraints. ESA is committed to proposing industrial contracts that serve such reality. To do so, clauses contributing to the timely and performing completion of the undertaking are of key importance. For many years, the standard way of dealing with that aspect of the contract was to agree on financial penalties, to be paid by the industrial contractor – in fact subtracted from the agreed price – in the event of late of non-performing delivery.

Over the years, the contracting parties took the measure of the not optimal effect of such a negative exclusively sanctioning approach. In an attempt to deal with the issue in a more positive and effective manner, they have developed mixed incentive/penalty schemes. The principle of such schemes is that part of the agreed price, including sometimes part of the nominal profit of the industrial contractor is put at risk and may be lost, nominally earned, or multiplied, depending on the reaching of criteria that can be of calendar (achieving acceptance and/or delivery of the satellite on or before a given date) or technical (achieving technical parameters after a defined timeframe in-orbit) nature.

Another aspect of the procurement where ESA strives to adapt itself to the operational needs of its partners is the regime of Intellectual Property Rights (IPRs). Within the regular institutional ESA framework, the industrial contractor retains IPR on the information/intellectual property generated under ESA contract, but ESA and its Member/Cooperating States have the right to use the data for their own purposes, often including the right to grant sub-licences.

The contract and cooperation agreement for construction of the MSG-4 satellite being signed at ESA Headquarters in 2004 by Jean-Jacques Dordain, ESA Director General, Lars Prahm, Eumetsat Director General, Pascale Sourisse and Volker Liebig

Depending of the nature of the cooperation with the third-party organisation, the contract placed by ESA will foresee adjustments to such regime, and provide for either a share of the rights between ESA and the third-party organisation or even the granting to the latter of increased, exclusive rights, for instance in the case of full funding by the third-party organisation.

Conclusions

For more than 30 years, the ESA procurement process has constituted the formal and concrete way for the organisation to interface with the European space industry and research organisations, thereby implementing the mandate derived from the ESA Convention.

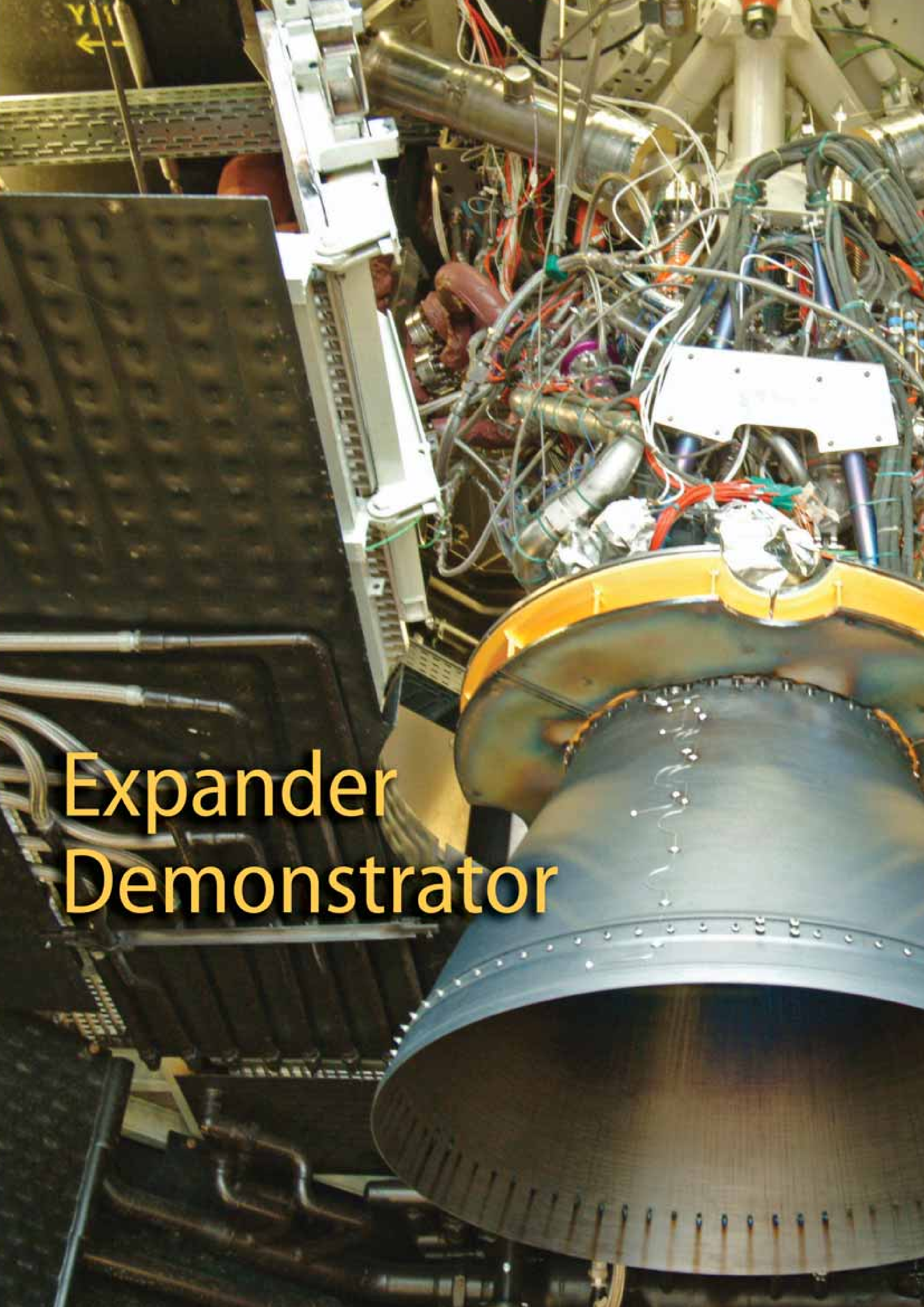
In doing so, the process has had to adapt to the evolving landscapes it applies to, to implement the Industrial Policy decided by Member and Cooperating States, while securing Europe's presence in space and guaranteeing its access to space. This adaptability has sometimes led us to touch on the very fundamental principles of public procurement: ESA has concluded contracts that were at the centre of public–private partnerships, deviating from the classical governmental contribution to space developments.

All these experiences have made ESA procurement develop into much more than a process. They have contributed to make it into a combination of multidisciplinary skills, which are all geared at reaching the same goal: conducting and completing complex technical undertakings in time, within budget and to an uncompromised level of technical standard.

As such, today's ESA procurement is a robust and flexible tool that is in a position to integrate contexts other than our internal ones, and that can thus be used by our partner third-party organisations for satisfying their operational needs.

At the same time, with the ever-renewing challenges that these new realities represent, ESA finds a nurturing and dynamic element that will also contribute to the constant improvement of our service to Europe and to its citizens.

Expander Demonstrator



Paving the Way for European Advanced Upper-stage Engines

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The technical difficulties encountered by other spacefaring countries in similar 'expander-cycle' engine projects show how demanding it is to master this kind of technology. So the achievements of ESA's Future Launchers Preparatory Programme (FLPP) Expander Demonstrator Project, including several European 'firsts', are essential contributions to the development of future cryogenic upper-stage engines.

Introduction

In launch vehicles, one of the key enabling technologies is the propulsion system, but this is complicated to acquire and takes a long time in development. This is especially true for upper-stage engines, where use of cryogenic propellants such as liquid hydrogen and oxygen and reignition capability are essential in order to reach high-energy orbits with heavy payloads. Upper-stage engines also operate in specific conditions (vacuum, micro-gravity) that are difficult to reproduce on Earth, and involve significant development risks that have to be mitigated.

In 1998 ESA, CNES and Arianespace decided to develop an enhanced cryogenic upper-stage for the Ariane-5 launcher in order to respond to the rapid evolution of the global commercial market towards more heavy payloads. In recognition of the quick emergence of this new commercial need and the comparatively long development time of a propulsion system, it was decided to select a two-step approach to increase Ariane-5's in-orbit delivery capability.

The first step was the development of an adaptation of the existing Ariane-4 H10 propulsion system for a new upper-stage called ESC-A. The second step involved the development of an adaptation of this stage to create the ESC-B version with a new cryogenic engine, the 'Vinci'. The initial ESC-B flight was planned in 2006, following on from the introduction of ESC-A. However, although Ariane-5 ECA entered operational service, a combination of factors including a downturn in the commercial market delayed and then stopped the development of the ESC-B stage and the Vinci engine.

At the same time, launch system studies within FLPP showed clearly the need for a versatile, high-performance, evolved cryogenic upper-stage engine capable of delivering payloads to all kinds of orbits, ranging from Low Earth Orbit up to exploration missions in deep space. A high-performance upper-stage engine appeared to be a central element for the future launcher scenarios of the FLPP, and a cryogenic expander engine offered high expectations in terms of performance and reliability.

It became quickly obvious that the availability of a set of expander-cycle upper-stage engines offered a unique opportunity to progress in the preparation of upper-stage engines for all future launcher configurations.

It was, therefore, decided at the end of 2005 to transfer the management and existing assets of the former Vinci development to the FLPP in order to form the basis of a demonstration project called the 'Cryogenic Reignitable Upper Stage Engine – Expander Demonstrator'.

Project Objectives

The main aim of the FLPP Expander Demonstrator Project is to supply elements allowing a sound, informed decision about the next steps in the development of the cryogenic reignitable upper-stage engine. More precisely, the implementation of this objective requires detailed studies of the engine's operating domain and assessment of its design through extensive, full-scale engine testing in hot-firing conditions.

This will make it possible to increase our knowledge and understanding of expander-cycle engine operations and technologies, yielding propulsion data for launcher system optimisation, in addition to the proper development and safeguarding of the relevant European competencies in cryogenic propulsion. It should be noted that the development of the Vinci engine, before it was interrupted, had just reached a stage that allowed the Expander Demonstrator Project to gain direct experience at the engine hot-firing test level.

Assessment of operating domain and design maturation

The Technological Readiness Level (TRL) of the engine and its components, currently estimated between 3 and 5, depending on the subjects under study, must be raised to level 6 (prototype test in a relevant environment), in order to properly assess the risks, cost and duration of a further development phase up to qualification (TRL 8).

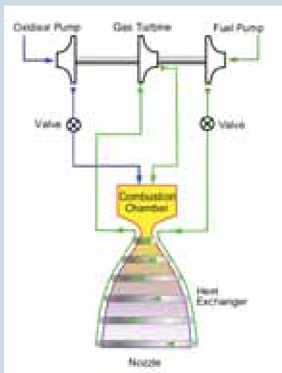
Most engine components have already reached a TRL of 5 and are close to achieving the target of TRL 6. The most significant issues to process are linked to component life duration and performance assessment or behaviour in operational conditions (pollution, transient conditions, etc.). The Technological Readiness Levels of some innovative components, like the Nozzle Extension Deployment system or the igniter, are lower compared to other engine technologies and require dedicated subsystem technology tests if they are to be improved.

There are many more significant technological steps in the FLPP Expander Demonstrator Project that contribute to the improvement of the engine TRL. These are:

- definition of an optimised starting and shutdown sequence with respect to progressivity, duration and propellant consumption;
- verification of engine stability over

Expander closed-cycle engine: how does it work?

The expander thermodynamic cycle is a 'closed cycle', meaning that the propellants flow together through the thrust chamber, hence maximising the specific impulse, an indicator of engine performance. The combustion chamber pressure is higher than the tank pressure (~60 bars compared to 2–5 bars). This pressure rise is ensured via two centrifugal turbopumps driven by turbines installed on the pump shafts.



The turbines are activated by the flow of high-pressure gaseous hydrogen obtained by circulating the hydrogen pump discharge flow around the hot combustion chamber walls. After being heated up in the combustion chamber jacket, the hydrogen flows through the turbines and is injected into the combustion chamber. Then, mixed with the liquid oxygen flow, it combusts and produces the hot-gas flow that provides the rocket engine's thrust.

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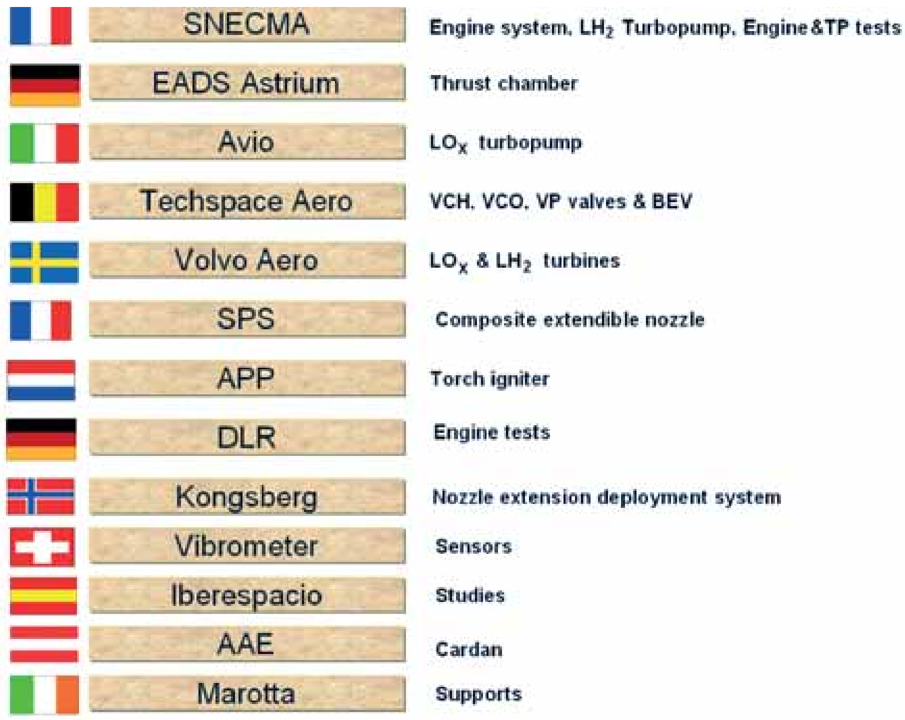
(including reliability, projected mass and performance, production cost, development duration and cost).

This exercise is initiated at an early stage of the launcher design because experience and theory show that an overall optimised design is not necessarily the assembly of optimised subsystems. The highest performance engine, optimal from a propulsion point of view, might not be the best global solution due to specifications and constraints at a higher system level. There is a continuous exchange of data between the engine and the launcher system throughout the entire preliminary design process, starting with high-level performance data, such as the following:

– thrust level;
– mixture ratio;
– specific impulse;
– restart capability;
– thrust-to-weight ratio;
– physical interfaces;



– pump inlet propellant conditions and constraints;
– dynamic environment;
– lifetime/burn duration.

These contribute towards the supply and maintenance of complete propulsion mechanical, thermal or thermo-dynamic validated models.

Safeguarding European Competencies

The cryogenic propulsion technologies currently used for commercial launchers require highly skilled engineers and technicians in a wide range of specialities. These competences are specific to space transportation propulsion and are only obtained after several years of practice and experience in these domains. In addition, some specific liquid-propulsion competences in system engineering can be safeguarded only through the operation of complex integrated demonstrators.

This is a significant investment for Europe's future and represents a strategic asset for operational launcher services. It is, therefore, important to safeguard these competencies and maintain a high level of motivation through advanced demonstration projects that employ cryogenic propulsion specialists and maintain a buffer of highly skilled engineers able to solve any difficult technical issues for the benefit of the entire launcher activity. In this respect, FLPP is one of the major contributors for safeguarding cryogenic liquid propulsion competence in Europe.

An expander demonstrator engine running in a hot-firing test, early 2008 (ESA/DLR/SNECMA)

Industrial Organisation

Under the leadership of SNECMA Prime, which is responsible for project management, planning, quality, costing and control, as well as propulsion system engineering, a set of sub-contractors from a wide range of European countries is involved in the FLPP Expander Demonstrator Project, representing the highest competence in cryogenic propulsion. This organisation, in place and operational, ensures a low level of project risk in the execution of the activity.

The project is supported by 11 ESA Member States (Austria, Belgium, France, Germany, Ireland, Italy, Norway, Spain, Sweden, Switzerland and The Netherlands) and ensures a large and efficient industrial organisation.

The Achievements: European 'Firsts'

The FLPP Expander Demonstrator Project is structured into various evaluation testing and simulation efforts. It encompasses engine tests as well as subsystem tests, with both levels of testing complementing one another. Tests at engine level are best suited to reveal performance limitations or unforeseen interactions between sub-systems. Tests at subsystem level (combustion chamber, turbopumps, etc.) are more focused on fine functional characterisation, technology demon-stration, further software tool validation and investigation of shortcomings.

Out of a total of four, two test campaigns have been performed up to now in the FLPP and they have already yielded notable results, namely, the first reignition in Europe of a cryogenic engine, the demonstration of the viability of the high-pressure expander-cycle design, with massive power extraction from the combustion chamber, as well as the operation of a large-scale and long-duration vacuum test cell.

More specifically, four test campaigns have been completed under vacuum conditions at the DLR P4.1 test bench in Lampoldshausen (Germany), totalling 35 tests with six reignitions and

The DLR P4.1 test bench in Lampoldshausen, Germany

a cumulated firing time exceeding 4000 seconds. The fifth test campaign is ongoing, and the overall activity is progressing normally. However, significant tests remain to be logged to reach the typical qualification values for this kind of engine of approximately 60 000 seconds of operating time during 180 tests.

Full-scale hot-firing tests are certainly the most complex ground testing activities in the launcher sector, comparable to in-flight tests. The complete test sequence necessitates the mastering not only of the tested equipment but also of the test bench. The P4.1 vacuum test bench is unique in Europe. It allows near-vacuum (a few mbars) ignition and steady state tests of cryogenic engines of several tens of tons of thrust, representing power dissipation exceeding 420 MW, equivalent to half the output of a nuclear power plant. This necessitates the use of several high mass flow steam generators to operate the vacuum ejectors, plus a huge condenser and underground water reservoir to cool down and condense the engine exhaust gases. During the tests more than 450 engine parameters are recorded and monitored to ensure safe testing conditions.

Engine Global Testing

- 35 engine tests
- 10 tests to adjust engine chill-down
- 6 tests with partial start-up
- 19 tests with complete start-up, 6 of them with reignition
- Validation of closed-loop control
- 3 tests with a composite nozzle cone

4110 seconds cumulated firing time with 5 engines

View inside P4.1 Test Bench with Expander Demonstrator (DLR /SNECMA Moteurs)

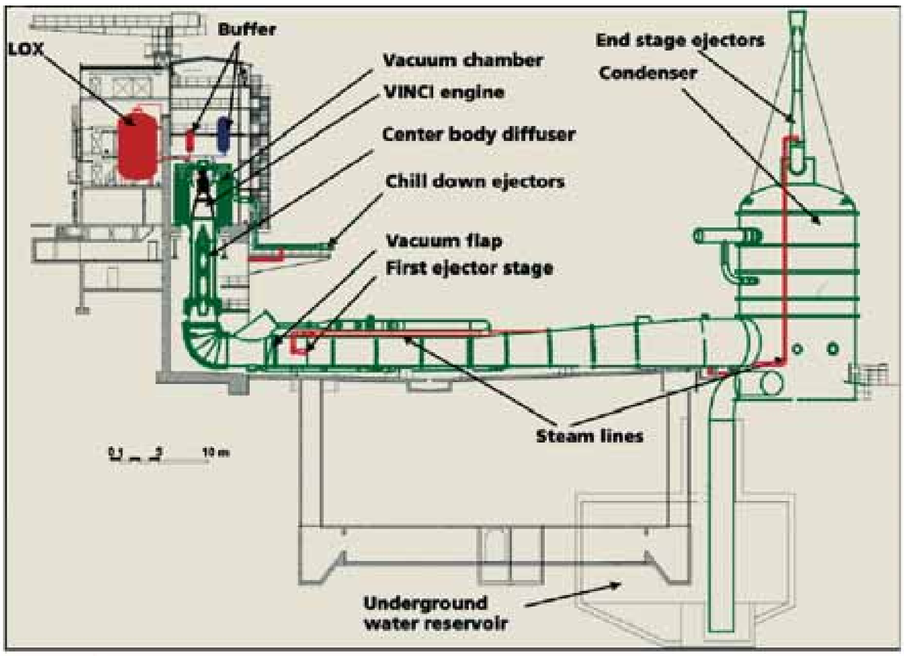
The test sequence starts with the test cell emptying to reach near vacuum conditions. Then, prior to ignition, the engine is chilled to cryogenic propellant temperatures (i.e. –250°C for liquid hydrogen and –180°C for liquid oxygen) in order to avoid thermal shocks during the very short start-up sequence. When all the desired conditions for ignition are achieved, the start-up sequence is initiated through a precise sequencing of the opening and closure of the engine valves and igniter activation. This ensures that the turbomachinery is safely started, followed by ignition of the propellant in the combustion chamber. The nominal steady state is then reached in less than two seconds, with a total test duration of several hundreds of seconds.

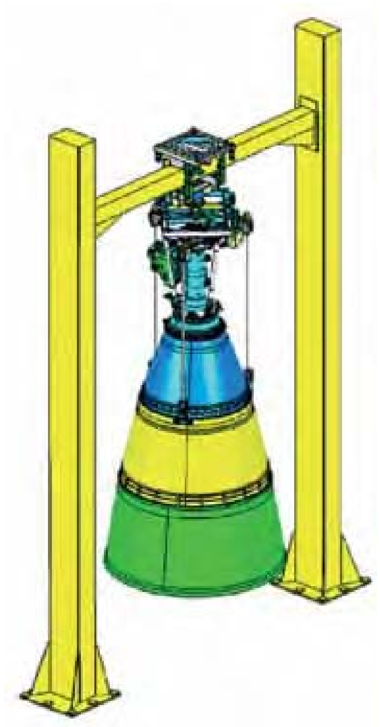
Different operating conditions can be tested, thanks to proportional bypass valves equipped with electric actuators in the engine. At the end of the test, the engine is shutdown in a controlled way and purged of remaining propellant to start the simulation of the stage ballistic coast phase. Then reignition in vacuum is activated, repeating the first test sequence, for a second boost before test termination.

This significant amount of testing experience at engine level is required in order to investigate the chill down sequence, adjust the ignition criteria and transient sequences, and assess the thrust and mixture ratio limitations, as well as the duration. In addition, the limited quantity of hardware fosters the fulfilment of the expander demonstration objective of design maturation by forcing the intensive use of the few available units. The testing of five engines has already revealed some marginal aspects of the design, and, as FLPP is still at an early stage of this engine's hot-fire testing, may reveal more in the future. Difficulties encountered in the course of testing and manufacturing are the object of roadmaps to find solutions if they are serious enough to challenge the major goals of the Demonstrator Project.

The Expander Demonstrator Project also fosters focussed engineering in order to prepare the integration with a cryogenic reignitable upper-stage for several potential launcher applications. The baselines of these engineering activities are the functional, thermal and mechanical models that are to be further improved with regard to physical suitability, prediction ability, and interconnectivity or versatility. In this way, they will be a more valuable asset for engine trade-off analysis,

A schematic showing elements of the P4.1 Test Bench





Expander Demonstrator mechanical test configuration (SNECMA Moteurs)

preliminary design, design justification or test analysis.

The expander cycle and the reignition function are the major uncharted fields of the demonstration. Priority in the engineering effort is being given to increasing and consolidating the models' Technology Readiness Level in these areas. Significant progress has been made on thermal, mechanical and functional system models in steady state and transient phases. For example, the constant use of transient system simulation was one of the major factors contributing to the success of the first engine tests, by limiting the number of tests needed to establish reliable start and shutdown sequences, as well as by avoiding any major functional problems during the tests.

The year 2007 ended with an exhaustive review of the technical status and results of the Expander Demonstrator Project, with the participation of more than sixteen experts from the entire European propulsion community, who recognised the achievements of the demonstration phase and did not identify any 'showstoppers' for the continuation of the activities.

Activities in 2008

For 2008, the contracted FLPP Expander Demonstrator activities ensure continuity in the P4.1 test campaign with the hot-firing test of two complete engines. This third year of FLPP activity will permit further exploration of the engines' capabilities and the first validation of focused design improvements.

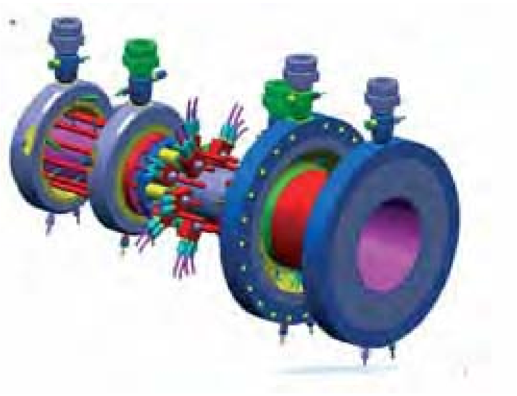
A complete engine dynamic test campaign will also make it possible to finely characterise the engine behaviour and validate the mechanical model, representing an important milestone towards future launcher applications.

Using the same approach, the effect of microgravity on engine operation will be introduced in the modelling and its impact will be checked. The year 2008 will also feature subsystem testing, such as full-scale combustion chamber tests to be performed at the DLR P3.2 test bench, or similar subscale tests at the P8 Research test bench, both at Lampoldshausen.

At subsystem level, several upgrade studies will be continued, with eventual prototype manufacture. At the same time, subsystem tests, such as water testing of a liquid oxygen turbopump in diphasic conditions, or testing of components such as bearings, are planned to investigate operations in off-design conditions and to validate limited definition upgrades.

In a classical approach, the complete batch of simulations is performed in parallel in order to achieve the validation, accuracy, prediction, and data supply objectives of the Project, as well as to support the corresponding test campaigns.

A second technical status and results review is foreseen at the end of 2008 to monitor the progress of the activities, contribute to risk mitigation and provide independent technical analysis of any issues encountered.



Subscale combustion chamber (Astrium GmbH)

Conclusion

The Expander Demonstrator Project is now well advanced, resulting in many useful elements for possible improvements of existing launchers and new developments for future launchers. The maturation of the design and the assessment of the engine capabilities have made significant progress and showed the technical viability of the expander cycle concept.

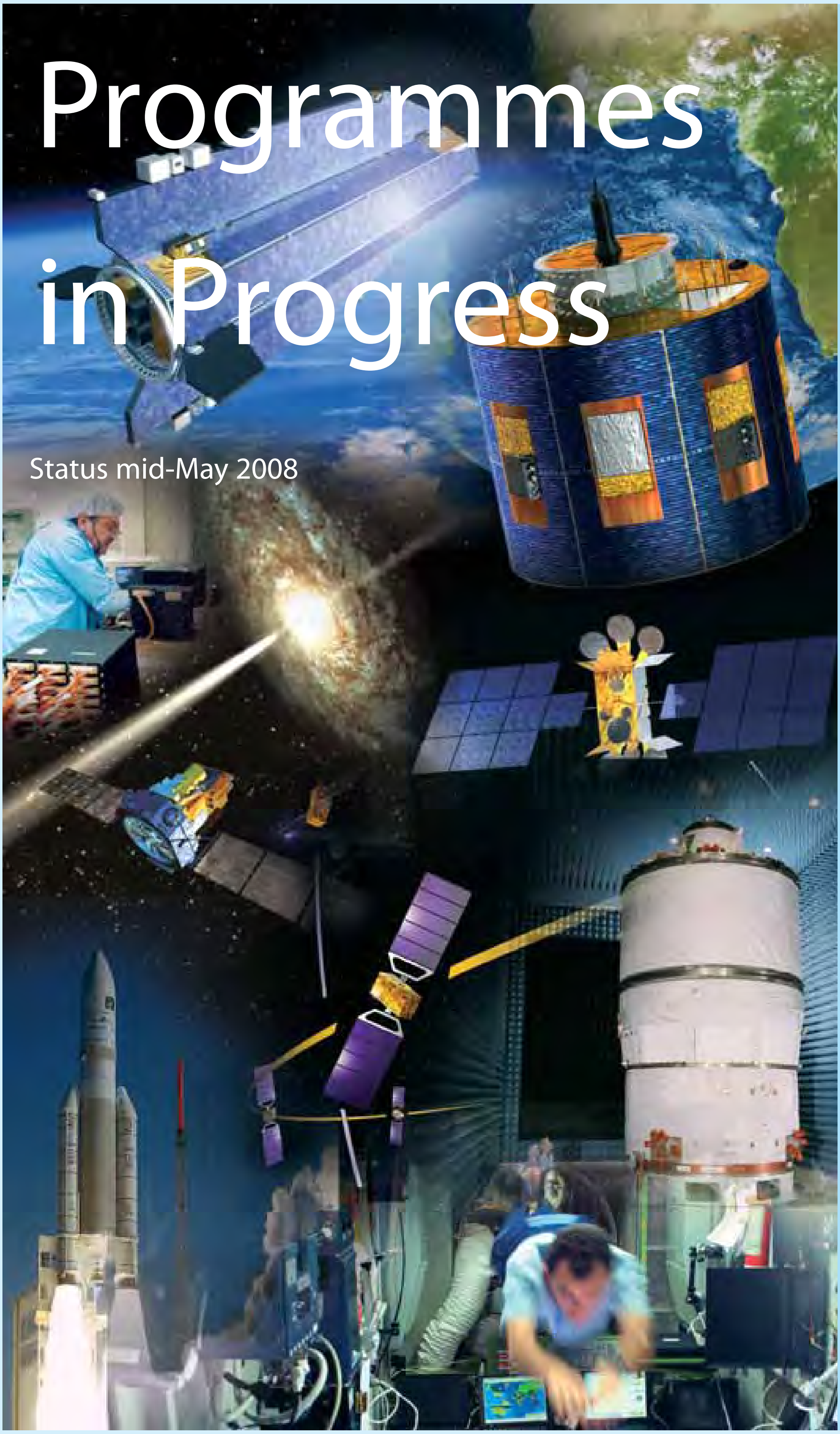
It is important to highlight the technical achievements that, for the first time in Europe, have been delivered in a relatively short timeframe, namely sustained closed-cycle operation, high-pressure expander-cycle operation and cryogenic engine reignition.

In Europe, the FLPP Expander Demonstrator Project contributes significantly to the safeguarding of the corresponding competences. During the last two years of the FLPP Expander Demonstrator activities, several of the lessons learned have been capitalised upon, whether in terms of operation of a complex integrated engine test bench such as P4.1 or in terms of expander-cycle specificity.

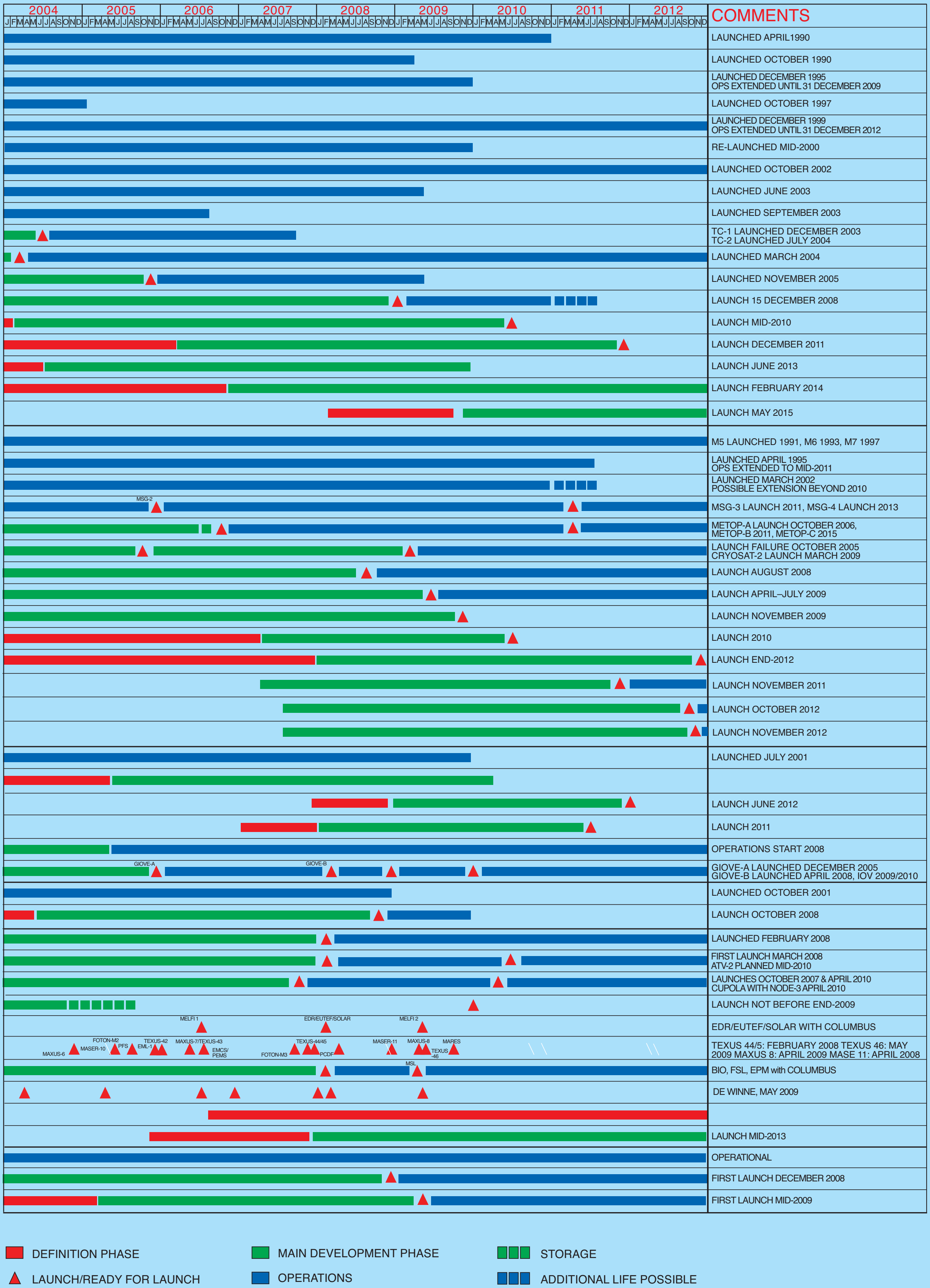
As a common foundation for several future launcher configurations, the FLPP Expander Demonstrator will continue to yield technology achievements and advancements in the years to come, and will enable efficient transitions towards development applications as well as innovative perspectives. esa

Programmes in Progress

Status mid-May 2008



	PROJECT
SCIENTIFIC PROGRAMME	SPACE TELESCOPE
	ULYSSES
	SOHO
	HUYGENS
	XMM-NEWTON
	CLUSTER
	INTEGRAL
	MARS EXPRESS
	SMART-1
	DOUBLE STAR
	ROSETTA
	VENUS EXPRESS
	HERSCHEL/PLANCK
	LISA PATHFINDER
	GAIA
	JWST
	BEPICOLOMBO
	SOLAR ORBITER
EARTH OBSERVATION PROGRAMME	METEOSAT-5/6/7
	ERS-2
	ENVISAT
	MSG
	METOP
	CRYOSAT
	GOCE
	SMOS
	ADM-AEOLUS
	SWARM
	EARTHCARE
	SENTINEL-1
	SENTINEL-2
	SENTINEL-3
COMMS./NAV. PROGRAMME	ARTEMIS
	ALPHABUS
	ALPHASAT
	SMALL GEO SAT.
	GNSS-1/EGNOS
	GALILEO
TECHNOL. PROG.	PROBA-1
	PROBA-2
HUMAN SPACEFLIGHT, MICROGRAVITY & EXPLORATION PROGRAMME	COLUMBUS
	ATV
	NODE-2 & -3 & CUPOLA
	ERA
	ISS BARTER & UTIL. PREP.
	EMIR/ELIPS
	MFC
	ASTRONAUT FLT.
	AURORA CORE
	EXOMARS
LAUNCHER PROG.	ARIANE-5
	VEGA
	SOYUZ AT CSG


2004
2005
2006
2007
2008
2009
2010
2011
2012
COMMENTS
LAUNCHED APRIL1990
LAUNCHED OCTOBER 1990
LAUNCHED DECEMBER 1995
OPS EXTENDED UNTIL 31 DECEMBER 2009
LAUNCHED OCTOBER 1997
LAUNCHED DECEMBER 1999
OPS EXTENDED UNTIL 31 DECEMBER 2012
RE-LAUNCHED MID-2000
LAUNCHED OCTOBER 2002
LAUNCHED JUNE 2003
LAUNCHED SEPTEMBER 2003
TC-1 LAUNCHED DECEMBER 2003
TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004
LAUNCHED NOVEMBER 2005
LAUNCH 15 DECEMBER 2008
LAUNCH MID-2010
LAUNCH DECEMBER 2011
LAUNCH JUNE 2013
LAUNCH FEBRUARY 2014
LAUNCH MAY 2015
M5 LAUNCHED 1991, M6 1993, M7 1997
LAUNCHED APRIL 1995
OPS EXTENDED TO MID-2011
LAUNCHED MARCH 2002
POSSIBLE EXTENSION BEYOND 2010
MSG-3 LAUNCH 2011, MSG-4 LAUNCH 2013
METOP-A LAUNCH OCTOBER 2006,
METOP-B 2011, METOP-C 2015
LAUNCH FAILURE OCTOBER 2005
CRYOSAT-2 LAUNCH MARCH 2009
LAUNCH AUGUST 2008
LAUNCH APRIL–JULY 2009
LAUNCH NOVEMBER 2009
LAUNCH 2010
LAUNCH END-2012
LAUNCH NOVEMBER 2011
LAUNCH OCTOBER 2012
LAUNCH NOVEMBER 2012
LAUNCHED JULY 2001
LAUNCH JUNE 2012
LAUNCH 2011
OPERATIONS START 2008
GIOVE-A LAUNCHED DECEMBER 2005
GIOVE-B LAUNCHED APRIL 2008, IOV 2009/2010
LAUNCHED OCTOBER 2001
LAUNCH OCTOBER 2008
LAUNCHED FEBRUARY 2008
FIRST LAUNCH MARCH 2008
ATV-2 PLANNED MID-2010
LAUNCHES OCTOBER 2007 & APRIL 2010
CUPOLA WITH NODE-3 APRIL 2010
LAUNCH NOT BEFORE END-2009
EDR/EUTEF/SOLAR WITH COLUMBUS
TEXUS 44/5: FEBRUARY 2008 TEXUS 46: MAY
2009 MAXUS 8: APRIL 2009 MASE 11: APRIL 2008
BIO, FSL, EPM with COLUMBUS
DE WINNE, MAY 2009
LAUNCH MID-2013
OPERATIONAL
FIRST LAUNCH DECEMBER 2008
FIRST LAUNCH MID-2009
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
STORAGE
LAUNCH/READY FOR LAUNCH
OPERATIONS
ADDITIONAL LIFE POSSIBLE

Ulysses

The third northern solar polar pass was completed on 15 March. In spite of the reduced data rates following the X-band anomaly in mid-January and the transition to an S-band mission, key parameters characterising the solar wind, magnetic field and energetic particles continued to be measured. The picture that emerges shows great similarity to that observed in 1995, during the first northern polar pass, with the spacecraft immersed in the fast solar wind flowing from the Sun's northern polar coronal hole.

Efforts to delay hydrazine freezing will continue in the coming months. It is very difficult to estimate exactly when the hydrazine will freeze since predictions are based on thermal modelling rather than actual temperature measurements in telemetry. However, a projected mission operations end date of 1 July 2008 has been agreed. It is possible that operations could continue beyond that date but it is also possible that the mission will end earlier.

Once freezing occurs, it may be possible to thaw the fuel again for a while by switching off instruments but the science mission will essentially be over. When thawing is no longer possible, the loss of manoeuvrability will result in an increasing Earth off-pointing angle and the loss of telemetry after about a week.

SOHO

Barely three months after SOHO observed the first active region of new Solar Cycle 24 on 4 January 2008, old Solar Cycle 23 returned in late March, when three big active regions with magnetic polarity of the old cycle appeared. This suggests that currently there are two solar cycles in progress at the same time.

Solar Cycle 24 has begun, but Solar Cycle 23 has not yet ended. Strange as this sounds, it is perfectly normal. Around the time of solar minimum – i.e., new – old-cycle spots and new-cycle spots frequently intermingle. Eventually Cycle 23 will fade to zero, giving way in full to Solar Cycle 24. Based on this latest spate of 'old' activity, solar physicists think that the next solar maximum probably will not arrive until 2012

XMM-Newton

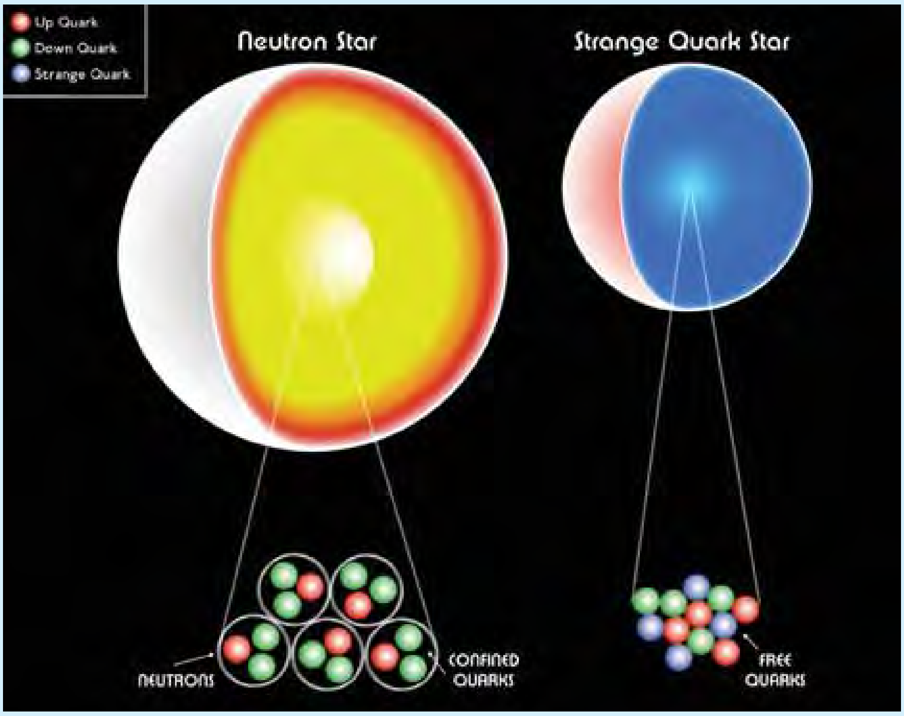
XMM-Newton has given astronomers and physics a valuable new insight into the most exotic stars in the Universe. Known as neutron stars, the composition of these extremely dense stellar objects has always been something of a puzzle. Now, XMM-Newton has revealed that they almost certainly resemble over-sized atomic nuclei whereas other postulated exotic models containing uncommon particles, such as pions, kaons or quarks (quark star), can be excluded.

Astronomers worldwide have reacted very positively to the announcement of the symposium on 'The X-ray Universe 2008' taking place in Granada, Spain, 27–30 May 2008. Abstracts for more than 350 contributions, either talks or posters, have been submitted.

Cluster

The electron diffusion region at the heart of the reconnection process can be 100 times larger than previously expected, revealed scientists at the University of California (Berkeley) (Phan et al.) in *Physical Review Letters*. This study used a combination of Cluster observations and numerical simulations. For the first time, the simulations could use a box large enough to observe this phenomenon. This has an impact on future missions where the

Continuum image, magnetic map and He II 304 Å image showing three big active regions of old Solar Cycle 23 on 27 March 2008, almost three months after the first active region of new Solar Cycle 24 was observed by SOHO on 4 January 2008 (SOHO/MDI, SOHO/EIT, ESA, NASA)



A neutron star/quark star interior. In a neutron star (left), the quarks that comprise the neutrons are confined inside the neutrons. In a quark star (right), the quarks are free, so they take up less space and the diameter of the star is smaller (NASA/CXC/M.Weiss)

reconnection process is a prime scientific objective and these results show that the probability to observe the electron diffusion region is greatly enhanced.

The 15th Cluster/Double Star workshop was held in Tenerife on 9–15 March 2008 and attended by around 120 people. The workshop incorporated the first Cluster Active Archive (CAA) school which aimed at providing the attending community with an in depth overview of the CAA data products and tools. A refereed proceedings book is being compiled.

Double Star

After the recovery of Double Star TC-2 in November 2007, the instruments were switched on and acquired data in December 2007 and January 2008. Instrument operations were then interrupted during the eclipse season starting end January until end March. In April, data return has started slowly with a data return of 4 hours per 12-hour orbit. In May the power on board the spacecraft will increase and full orbit instrument operations are planned.

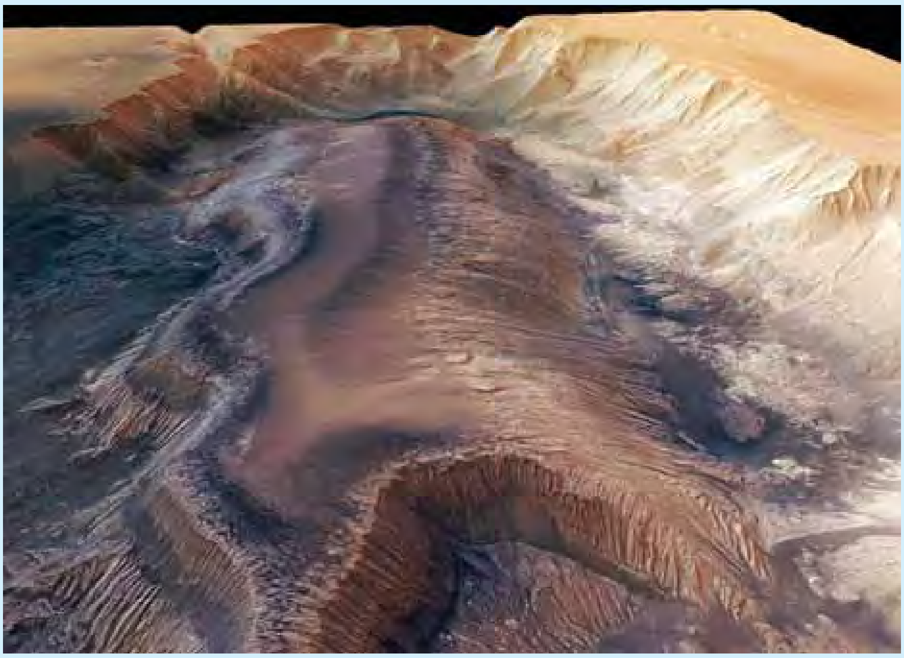
Integral

The peer review process of the proposals received in response to the Announcement of Opportunity AO-6 for Integral open time 'Key Programme' observations was completed in January 2008. The TAC recommended Key Programmes were approved by ESA's Director of Science. The Announcement of Opportunity AO-6 for Integral (standard) open time observing proposals and for proposals on targets associated with the above six Key Programmes, opened on 10 March as scheduled.

Mars Express

Several important scientific papers about Mars were published over the last two months. The first one reported the detection of dust haze in Valles Marineris, observed by HRSC and OMEGA. The haze appeared thinner after three days and disappeared in nine days. It was limited to a 2-km layer at

Perspective view of Hebes Chasma obtained by the High Resolution Stereo Camera (HRSC) on ESA's Mars Express spacecraft. Hebes Chasma is located at approximately 1° South and 282° East. The HRSC obtained image data on 16 September 2005 with a ground resolution of approximately 15 m/pixel (ESA/DLR/FU Berlin (G. Neukum))



the bottom of the canyon. This is a very good example of a multi-instrument study.

The second paper was about atmospheric water vapour above the Tharsis volcanoes, observed by OMEGA. The most striking result is the increase of water vapour mixing ratio from the valley to the summit of volcanoes. The enrichment is possibly generated by the local circulation characteristics of the volcanic region. A third paper focused on a good comparison between model and ultraviolet emissions of CO_2^+ and CO during the summer season at northern mid-latitudes.

Rosetta

The Rosetta mission is proceeding nominally and according to plan. Both the spacecraft and the ground segment are operating flawlessly. After the second Earth swingby, the spacecraft went into a three-month cruise phase with a passive payload check-out successfully executed in early January 2008. The final trajectory correction manoeuvre after the Earth swingby was performed on 21 February 2008.

Several configuration changes took place following the evolution of the Earth and Sun distance. All operations were conducted according to plan. A new TM modulation scheme with higher TM bit rates was validated and is now successfully used.

A test of the asteroid flyby scenario was successfully run in the second half of March. The ground segment has been upgraded to support the new TM bit rates, both at ESA and NASA stations. This will guarantee a higher science data return for the mission.

By the end of March 2008, Rosetta was 65.3 million kilometres (0.43 AU) away from Earth, and 211.65 million kilometres (1.41 AU) away from the Sun. The spacecraft is now in Near Sun Hibernation Mode until July 2008 when it will be reactivated to execute a payload check-out in preparation of the flyby phase at asteroid 2867 Steins with closest approach on 5 September 2008.

Venus Express

A very successful Science Working Team workshop with about 60 participants was held 3–8 March in La Thuile, Italy. Most scientific fields were addressed during the 11 topical sessions and many new results were presented.

Sulphur dioxide (SO_2) has now been detected also above the clouds and at a fairly high temporal and spatial variability. This is of great interest for determining possible present volcanism, however no conclusions have been drawn yet. Possible alternatives could include dynamical (transportation) effects and/or chemical cycles not yet accounted for.

Further new data include detailed multilevel maps of atmospheric circulation, improved understanding of the polar phenomena (including vortex dynamics), three-dimensional thermal structure maps of the atmosphere, surface temperature and emissivity maps derived from spectral window infrared data, high-quality plasma and magnetic field measurements, to mention just a few of the many exciting topics.

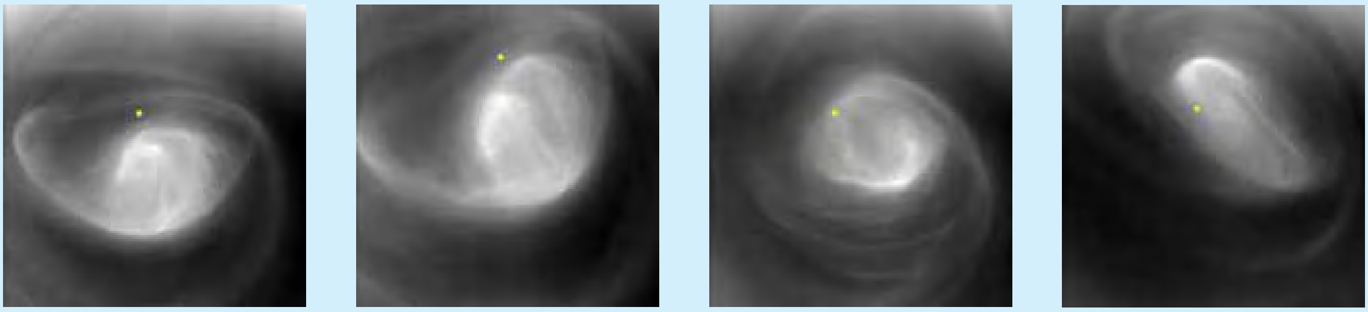
Many of these results are now being written up for papers to appear in two dedicated issues of a major journal. The first issue is expected to appear mid-2008. The total number of papers for these two issues is expected to reach about 60.

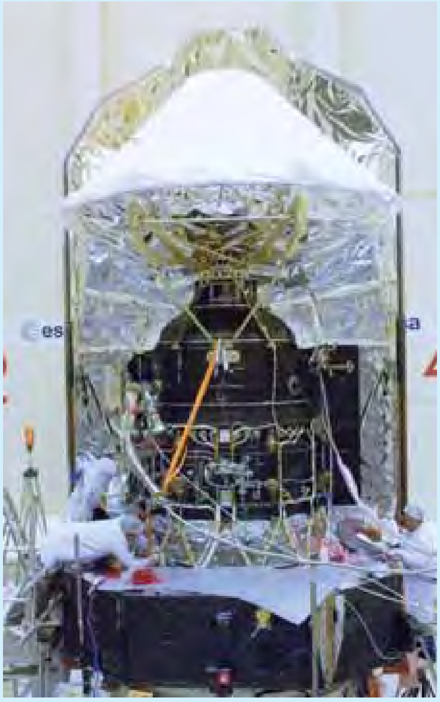
COROT

COROT has been in orbit for more than one year and has in the meantime acquired more than 40 000 light curves with unprecedented length and photometric precisions as precise as 1 part per million for the brightest objects.

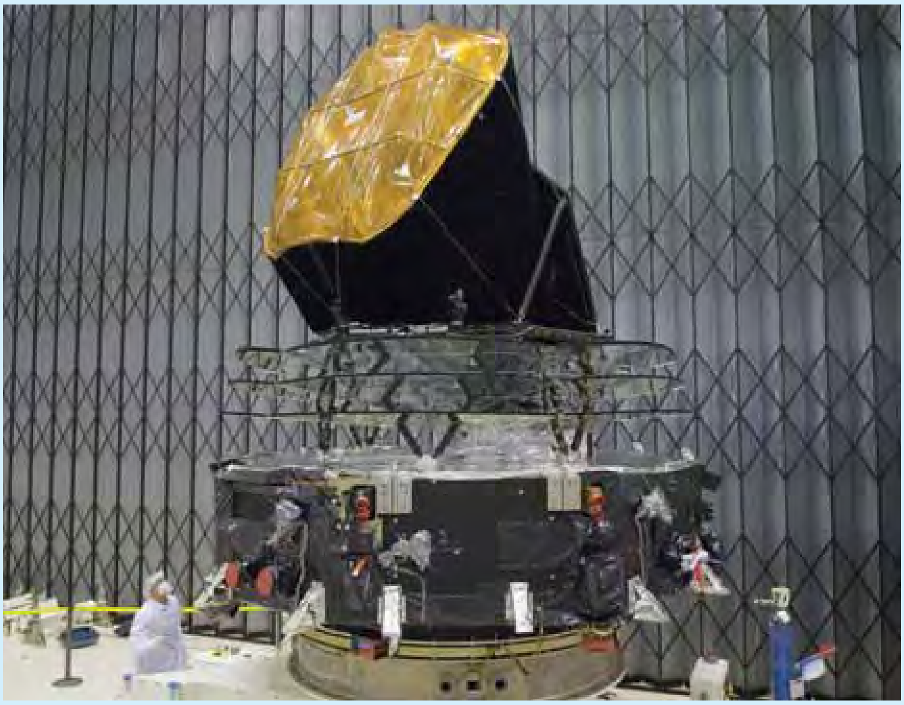
Several hundred extrasolar planet candidates are being followed up from space and the ground, and the first confirmed new extrasolar planets have been reported in scientific journals. The lightcurves of dozens of objects belonging to several different classes of stars are being analysed for the acoustical variations caused by waves

The 'eye of the hurricane' on Venus, as seen by the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on board Venus Express. These pictures show a region in the venusian atmosphere about 60 km from the surface, at a wavelength of about 5 μm. In the first image (left), the dipole assumes an eye-like shape and from here until the last image, it is possible to see how its shape evolves rapidly in a span of only 24 hours. The second image is taken 4 hours after the first of the series, and the third after one complete Venus Express orbit. Here the vortex has become more circular and less elongated. The yellow dot in the image indicates the location of the south pole (ESA/VIRTIS/INAF-IASF/Obs. de Paris-LESIA/Univ. Oxford)





Herschel spacecraft fully integrated at ESTEC Test Centre in the final preparation for environmental testing



Planck spacecraft at ESTEC Test Centre during the spacecraft balancing campaign

travelling through the stellar body and carrying information from the central parts.

Literally thousands of new eclipsing binaries and variable stars – some with unprecedented small amplitudes – have also been discovered.

Hinode

The formation of the slow solar wind has been debated for many years. Now evidence of persistent outflow at the edges of an active region (measured by the EUV Imaging Spectrometer on board Hinode) has been found by a team of scientists led by L.K. Harra from the Mullard Space Science Laboratory, UK. They identify these regions with the source regions of at least part of the slow solar wind.

The measured Doppler velocities range between 20 km/s and 50 km/s and are consistent with a steady flow seen in Hinode's X-Ray Telescope. The results are published in the 1 April issue of *Astrophysical Journal* and were presented at the RAS National Astronomy Meeting in Belfast on 2 April.

Herschel/Planck

The development of both Herschel and Planck spacecraft has made very good progress. Both flight models are now in the acceptance test phase.

With arrival of the Herschel flight model at ESTEC at the end of 2007, the cryostat evacuation and bake-out started. Shortly afterwards the cryostat was cooled down and the liquid helium tank filled. In parallel, the functional testing started with verification of the spacecraft and the instruments. As major functional test the integrated system test was started and the system validation test completed. After some final close-out activities on the spacecraft, Herschel was ready for the integration of the solar array, the sunshade and finally the 3.5 m-diameter Herschel telescope. Now the system is fully integrated and prepared for the upcoming mechanical test campaign.

The Planck flight model has completed the first integrated system test, followed by the radiated EMC test in the anechoic chamber in the test facilities of Thales Alenia Space in Cannes and the system validation test. As part of the EMC test, the alignment of the Planck telescope was verified by a focus position measurement at operational frequencies (at 320 GHz). After completion of the testing in Cannes, Planck was shipped to ESTEC for a fine balancing exercise in April 2008.

The ground segment development on the mission operation side in ESOC has demonstrated a well-advanced development commanding the spacecraft during the system validation tests on both spacecraft that went very successfully.

With the acceptance test campaign under way, the programme is moving well towards the launch date at the end of 2008.

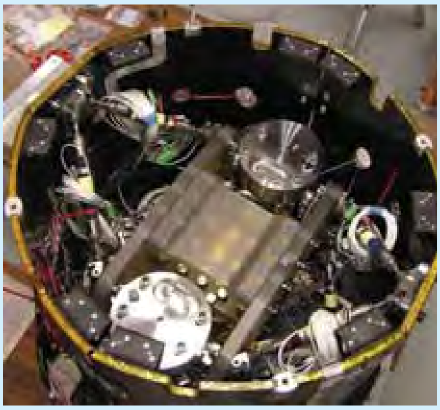
LISA Pathfinder

The LISA Pathfinder development is in progress despite some delays in the schedule. The main engineering activities are related to the finalisation of the spacecraft design, in preparation for the spacecraft CDR. Most of the subsystems have already had their own subsystem CDRs and many equipment suppliers have delivered their flight models.

The science module FM structure that was damaged during the static test has been repaired and will be used in the summer together with the propulsion module structure for a combined acoustic test and separation test. A new FM structure is being built by Oerlikon Space (CH) to be used for flight. The onboard software development is proceeding. Two test set-ups (Real Time Test Benches), one at Astrium GmbH for Drag Free Attitude Control (DFAC) and one at Astrium Ltd for the other system tests, are proceeding in parallel initially with electrical units and later with flight units until spacecraft flight model integration.

The two European micropropulsion technologies (needle indium thrusters and slit caesium thrusters) continue their challenging development to prove the readiness of the technologies. Problems are solved and progress is made: in particular for the slit FEEP, a test of the complete thruster assembly was performed successfully, from lid cover opening to priming and continuous nominal thrust. However also in this area the advancement has been less than planned, mainly due to difficulties intrinsic to uncharted technologies. It is now expected to select the technology suitable to the needs of LISA Pathfinder only towards the end of 2008.

For the LISA Technology Package (LTP), after completion of the system CDR, the work is focused on the critical subsystems, e.g. caging mechanism, electrode housing and Data Management Unit software. Other subsystems previously causing concern, like the electrostatic suspension front-end electronics, have now been successfully



The LISA Technology Package Central Assembly mounted inside the LISA Pathfinder science module flight structure under vibration test at Astrium GmbH in Friedrichshafen

tested at EM level and the flight models are being manufactured. All the LTP Electrical Models (ELM) have been built and delivered to Astrium GmbH for the Real Time Test Bench. The LTP schedule is however driven by the mentioned critical subsystem and affects the overall programme schedule.

The launch is expected to take place in the second half of 2010.

Microscope

Testing on the T-SAGE accelerometer is ongoing at ONERA with good results. CNES has initiated the procurement of the payload structure, and completed the microdisturbances analysis on the MLI. In the micropropulsion area, following a joint ESA/CNES status review, it was recognised that a decision cannot be made now on the thruster technology to be adopted for Microscope: objective criteria have been defined for selecting between FEEP and cold-gas micropropulsion, with identification of the tests required to fulfil these criteria.

Gaia

Following the successful close-out of the Preliminary Design Review (PDR), the Gaia project entered Phase-C/D during which the spacecraft will be built and tested. The contractual coverage for this phase has been intensively negotiated with the prime contractor Astrium with a view to sign the contract in late spring 2008. Despite these negotiations, the normal work continues.

One of the major achievements in this period was the start of the production of the optical bench, also known as the ‘torus’. This 3 m-diameter torus consists of 17 different and complex elements, brazed together to form a lightweight structure carrying all mirrors and the entire focal plane assembly while still meeting the extremely demanding stability requirements. Meanwhile, the first element is ready for sintering.

The implementation of the science ground segment moves ahead as well. The first meeting of the Steering Committee of the Data Process and Analysis Consortium (DPAC) has taken place. Its immediate task will be to staff the project office overseeing the implementation by the distributed national centres.

BepiColombo

A major mass increase was identified by the BepiColombo team in the frame of the planned design freeze in preparation for the PDR. Detailed system design activities revealed severe mass problems. Furthermore, subcontractor proposals contained mass values higher than allocated on system level. A mission ‘Tiger Team’ was set up to address this issue in detail. The Tiger Team reported that to satisfy all mission requirements an Ariane-5 launch was needed. The impact on the programme will be addressed by the Science Programme Committee in June.

The work on key technologies is continuing in parallel with the selection of contractors for, in particular, multilayer insulation, solar arrays including blocking and shunt diodes, high-temperature rotary joint and high gain antenna.

The Instrument Science Requirements Review were successfully completed for all Mercury Planetary Orbiter payload. Subsequently, the related Experiment Interface Control Documentation has been updated and signed for all experiments. The experiment performance is demonstrated as compliant with the scientific objectives, with overall payload resources being marginally within allocation.

A short-term workplan was agreed with the Principal Investigators, including Instrument Preliminary Design Reviews (IPDR) in the period March 2008 to Autumn 2008. The BELA and MIXS experiment definitions are progressing, with a more robust/compact laser design and a more elaborate optical design respectively.

The PDR for the Mercury Magnetospheric Orbiter (MMO) was completed successfully in March 2008.

JWST

The JWST Mission PDR and the Non-Advocate Review have been passed successfully. The JWST project can therefore formally enter the Implementation Phase. The tight cost constraints imposed for the project for 2008–10 have been eased, thus eliminating the need to further delay system activities. The overall programme is therefore stabilising and the launch date remains unchanged, June 2013.

Significant progress has been made on the ESA-developed NIRSpec infrared spectrograph. The optical bench qualification model proof-load testing has been successfully completed and the flight optical bench manufacturing has been completed. The cryogenic performance test of the input Three Mirror Anastigmatic mirror assembly was passed successfully with wave-front errors well within specification. These two milestones qualify the mechanical and optical design philosophy of NIRSpec.

Intensive work with breadboard models continues for the grating and prism mount

JWST NIRSpec Fore Optical Assembly Qualification Model after successful testing at Sagem, France

and for the refocus mechanism mirror. The main issue is the cryo-deformation of the optical components. Recovery from problems with contamination and damage of the flight bearings for the filter and grating wheel mechanism is ongoing. Several mitigations actions are ongoing to keep a positive schedule margin.

The MIRI Verification Model completed the first cryo-test campaign successfully. 'First light' was seen by both the imager and spectrograph. Both the MIRI Cooler PDR and the imager qualification review were passed successfully. The cryo-cooler is developed by JPL. The contamination control cover flight and spare models have been successfully delivered.

The JWST/Ariane-5 Launcher Interface Control Document is in the final review process. Signature is planned for June.

Solar Orbiter

Building on the two parallel study contracts, placed with Alcatel Alenia Space and EADS Astrium, in which the Heat Shield technology breadboards were tested successfully, the Solar Orbiter Phase-B1 was initiated in March 2008. This Definition Phase is being performed by an industrial team led by Astrium Ltd and includes Astrium GmbH and Thales Alenia Italy.

The definition phase will be performed in 2008 and 2009 and will culminate in a System Requirements Review. The spacecraft baseline design relies heavily on the reuse of technology and equipment from the BepiColombo project.

Many proposals were received from Europe and USA in response to the Solar Orbiter Payload Announcement of Opportunity released in October 2007. They have been under scientific and technical evaluation by both ESA and NASA. When the selection process is completed, the spacecraft definition will be adjusted to take into account the detailed payload complement as selected.

Solar Orbiter will be built by ESA and launched by NASA. It will carry a significant number of US payload contributions. The measurements performed by the instruments on Solar Orbiter will be coordinated with those performed by NASA's Inner Heliospheric Sentinels, to be launched two years later

In parallel, technology development activities are ongoing in several key elements such as a Sun-filter window, detectors, polarisers and sun sensors.

LISA

The Mission Formulation activity performed by Astrium GmbH is proceeding well and the contract is approaching completion in July 2008. The mission architecture is being finalised and requirement specifications are being prepared. All the material will be subject to the Mission Design Review to be held in June.

Technology activities are ongoing in the field of pointing mechanisms; a new invitation to tender for the Optical Bench has recently been issued and an update of the technology plan has been prepared to reflect the results of the Mission Formulation. This input will be merged with that of other Cosmic Vision candidate missions to prepare a general coordinated plan. All technologies required by LISA will be at least at TRL 5 at the time of start of the Implementation Phase for the L1 mission, at the end of 2011.

Cooperation with NASA in the system engineering area is producing good results. A costing exercise for the US part has recently been completed and results presented to NASA HQ on related to potential respective roles and responsibilities of the partners.

Currently both projects are preparing the required material and documentation for the Astro2010 Decadal Review, performed by the NRC on NASA mandate.

GOCE

After completion of the environmental test campaign, the full satellite functional test campaign was also completed, leading to the Flight Acceptance Review held in March/April. The satellite is ready for shipment to the launch site. One issue related to the loss of some telemetry packets during switch-over between the nominal and redundant command and data management units (the central on-board computer) was reported recently and will be fixed prior to shipping the satellite.

Due to a recent failure of the 'Breeze' upper stage rocket on the Proton launcher, however, the Russian State Commission had put on hold all activities related to the Breeze programme, including Rockot launches. As a consequence, GOCE is facing a delay in the Rockot launcher readiness of probably three months, putting back the launch date accordingly.

The Ground Segment Readiness Review was successfully completed at the end of February. All ground segment facilities have been accepted and subject to overall validation. The time until launch will be used to fine-tune the operational configuration of the various facilities. A final series of System Validation Tests was also performed

GOCE inside the Large Space Simulator at ESTEC

successfully with exchange of commands/ telemetry between ESOC and the satellite protoflight model in ESTEC.

Several Launch and Early Operations Phase simulations have been performed in ESOC involving industry and ESA engineers. They were organised in the two teams that will carry out the 24-hr satellite operations during the first few days after the launch.

A GOCE press day took place at ESTEC on 3 April to advertise the flight readiness of the satellite and ground segment, and to provide the opportunity to brief the press before shipment of the satellite to the launch site in Plesetsk.

CryoSat-2

CryoSat-2 is almost fully integrated, only missing two items of equipment and the solar arrays. The solar arrays are needed later in the programme and will be installed just before shipping the satellite for environmental testing at IABG in mid-July 2008. System testing has proceeded to plan, with the major milestone being the full testing of the main payload, the advanced SIRAL radar. This test represented a full system demonstration, with captured data being fed through the CryoSat ground segment. The first System Validation Test was also performed in March, where the satellite was in contact with ESOC to validate the command and control system. This test went smoothly, thanks to the excellent preparation and working practices established between the ESA and industrial teams.

Overall the satellite activities are proceeding well and on schedule. Similarly the ground segment upgrade from the original CryoSat mission is complete and the full system is undergoing testing, called the Ground Segment Overall Validation, which will demonstrate its readiness to support the mission after launch.

The launcher to be used for CryoSat has changed from a Rockot to a Dnepr. This was driven by the limited availability of Rockot launchers in the required time period. Even with this change, a delay to November 2009 (from March 2009) is necessary to allow for preparation of the launch vehicle. This means the satellite will spend time in storage before the launch campaign.

SMOS

The Thermal Vacuum Test at satellite level, with folded antenna arms, was passed without any significant problem. The antenna arms were suspended beneath the antenna zero-g jig and deployed one by one, using live pyrotechnic firings. This campaign was successfully completed with only one end-of-travel sensor needing realignment. The

SMOS satellite with Rockot launcher adaptor

recorded pyrotechnic shocks were in line with the equipment qualification limits.

The satellite was moved to Thales Alenia Space's Compact Antenna Test Range and the arms unfolded for the Radiofrequency Autocompatibility Test. This test confirmed previous element-level tests with no interference identified between the platform and the sensitive payload. However, a minor payload internal interference was observed in one specific mode of one of the X-band transmitters.

The satellite level test programme is now basically complete with only a few remaining activities (mass properties, propulsion system leak test, multilayer insulation repair) before satellite storage until to launch.

As the Russian launch service provider is experiencing production bottlenecks for the third Breeze KM stage, a launch of SMOS is now expected from 15 April to 15 July 2009.

The ALADIN primary mirror during inspection at Astrium Toulouse

ADM-Aeolus

The first flight model of the transmitter laser assembly of the ALADIN instrument was installed in a thermal vacuum chamber at Galileo Avionica Firenze's premises. First operational tests of the laser in vacuum showed some unexpected performance variations of the laser output energy and beam characteristics. These effects were investigated and could be pinned down to a larger than expected air-to-vacuum shift of the transmission characteristics of an optical element inside the laser master oscillator. An alternative supplier of the optical component was found and characterisation tests at ESTEC confirmed that the air-to-vacuum shift of the replacement part is negligible.

After reassembly and realignment of the transmitter laser assembly a new sequence of vacuum tests was started which confirmed nominal operation of the laser master oscillator. With the achievement of nominal performance of the master oscillator the further stages of the transmitter laser assembly, the amplifier section and the harmonic section generating the ultraviolet laser beam, could be operated in vacuum at full energy for the first time. A certain amount of beam shift of the output beam is as yet unexplained and needs further investigation.

During the course of the preparation for further vacuum tests an anomaly at the level of the master oscillator occurred, which prevented the continuation of the vacuum test sequence. Investigations into the causes of the output beam shift and the master oscillator anomaly are in progress.

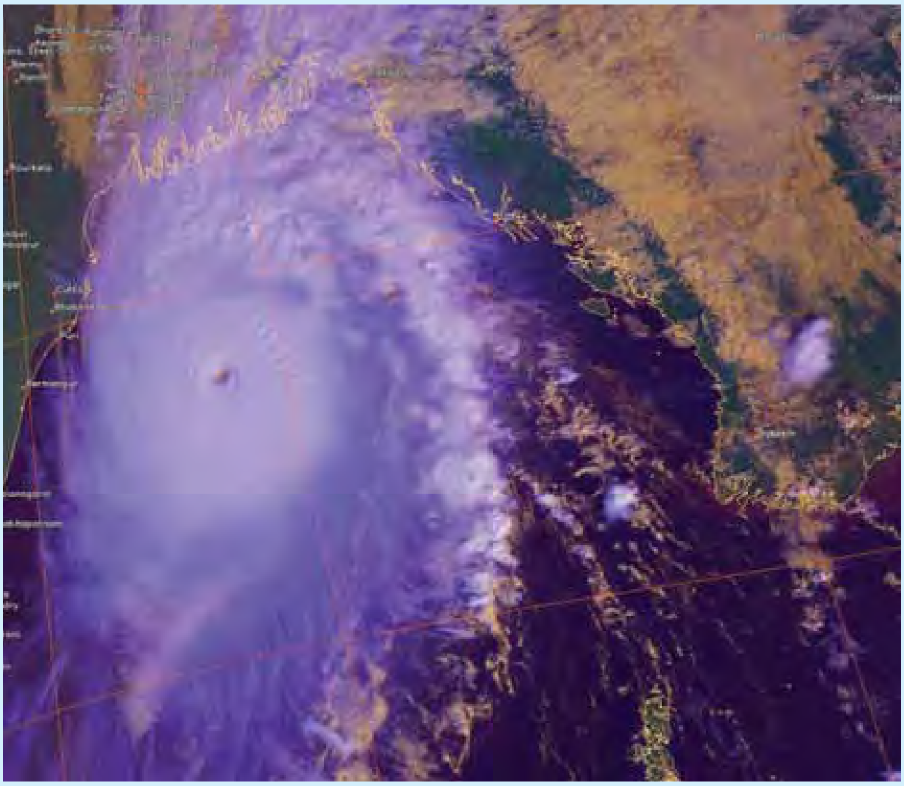
The ALADIN optical bench assembly has been fully completed and a comprehensive set of performance and optical characterisation tests demonstrated good performance of the unit.

The satellite platform programme at Astrium Ltd continues nominally. A 'micro-vibration test' confirmed the compatibility of the fibre-optic gyroscope with the vibration levels generated at satellite level by the reaction wheels.

Swarm

The major elements of the mission are in progress. The procurement activity has been completed with the adjudication of the Level 1b processor contract and the selection

Analysis of the plasma potential around Swarm spacecraft confirming potential of the spacecraft is below 2V. With this, the electric field measurement performances can be achieved



Tropical Cyclone Sidr was the fourth named storm of the 2007 North Indian Ocean cyclone season. The storm formed in the central part of the Bay of Bengal, and quickly strengthened to reach peak sustained wind speeds of 215 km/h. The storm made landfall near Bangladesh on 15 November causing large-scale evacuations and thousands of casualties. The MetOp-A AVHRR image shows Sidr a few hours before landfall (Eumetsat)

of the MGSE contractors. The satellite consortium is now complete.

Development/manufacturing reviews are going on for all satellite units and instruments. The magnetic signature of the optical bench as measured by the Niemegk magnetic observatory confirmed that the magnetic signature of the SIC mast supporting the vector magnetometer (VFM) sensor head is not compatible with the Swarm mission performance need. Astrium implemented a back-up solution where the mast supporting the VFM sensor head will be in carbon fibre while the support of the star tracker (STR) will remains in SIC material.

The mechanical, thermal design and manufacturing dossier of the structure has matured significantly. The CDR for the structure is planned for April this year. A significant step forward has been achieved by all parties for the definition of the interfaces between the EFI instrument and the satellite.

The AIT activity preparation initiated during the last quarter with the development of the Real-time Test Bench for the satellite software and interfaces verification is in progress. The EFI and ASM instrument CDR are now respectively scheduled for June and September 2008. Rockot and Dnepr are confirmed as viable launchers for Swarm, following the completion of a preliminary coupled load analysis. The ground segment PDR for the definition of the operation facility and the payload data processing and archiving centres is now scheduled for September.

Metop

MetOp-A

The HRPT anomaly investigations concluded the root cause to be the CLY-38 transistors. Dedicated tests in ESTEC and Louvain revealed the sensitivity of these transistors to heavy ions. The transistors on MetOp-B and MetOp-C HRPTs will be replaced by Mitsubishi transistors, once they successfully pass their radiation testing. MetOp-A instrument performance is excellent. Level 1B products from GOME-2, ASCAT and GRAS are declared operational.

MetOp-B and MetOp-C

Although the MetOp Payload Modules PLM-1 and PLM-3 are in long-term storage, there are still some AIT activities to be performed that require dismounting of the instruments for repair, recalibration and/or alignment, to be performed in blocks. Block activities on PLM-1 (MetOp-B) were finished, with the PLM-1 re-entering storage, and block activities on PLM-3 just started. The MetOp Service Modules are kept in hard storage at Astrium Toulouse's premises, waiting for the restart of AIT activities in 2009 for a planned MetOp-B launch in 2011.

MSG

Meteosat-8/MSG-1

On 1 February, the Meteosat-8 spacecraft again experienced an event similar to that of May last year. In the light of this, an object impact is no longer considered probable. Investigations into other causes are ongoing but are so far not conclusive. The performance of the imaging service has not suffered from this: the satellite experiences larger thermal gradients during eclipse nights, but all parameters remain in the nominal area.

The dynamic disturbances of the satellite spin axis were eliminated by using a different setting of the thermal control system. The spacecraft was moved to 9.5°E, the same orbital location that was used by the first generation, to continue the rapid scanning service (producing one image between 15°N and 70°N every five minutes).

Meteosat-9/MSG-2

Meteosat-9 is Eumetsat's nominal operational satellite at 0° longitude (Meteosat-8 is its back-up). Satellite and instruments performance are excellent.

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

Sentinel-1

Sentinel-1 is a mission carrying a Synthetic Aperture Radar (AR) in C-band in response to user requirements issued by the European Commission and to ensure continuity of radar observation initiated with ERS-1/2 and continued with Envisat ASAR. Weighting about 2.3 tons, it is scheduled for launch at the end of 2011 and is designed for a 7-year lifetime (with consumables for 12 years of operation).

The industrial team is led by Thales Alenia Space Italy as prime contractor (responsible for the spacecraft and the Transmit-Receive Modules). Astrium GmbH is responsible for the SAR instrument and antenna, and Astrium Ltd is responsible for the SAR electronics subsystem. The Phase-B2 has started in May 2007 and will culminate with the PDR starting in May 2008. The completion of the industrial team through competitive Invitations to Tenders will be finalised soon.

Sentinel-2

Sentinel-2 is the optical multispectral mission of the GMES space component programme ensuring continuity and further development of the SPOT/Landsat land observing missions (vegetation and human settlement). This mission is based on the concurrent operations of two satellites flying on a unique sun-synchronous orbit with a separation of 180°. This orbital configuration, combined with the very wide 290-km instrument swath, provide a 5-day revisit between +83° and –56° latitude. A versatile set of 13 observation and calibration bands ranging from VNIR to SWIR provide a range of spatial resolution between 10 m and 60 m.

Artist's impression of Meteosat-9/MSG-2 in orbit, spinning at 100 rpm

Following contract signature for the first satellite model between ESA and prime contractor Astrium GmbH on 17 April 2008, phase B2 activities are intensifying in two directions: the consolidation of the baseline satellite design, including ground segment and launcher external interfaces, and the organisation of about 65 platform and payload instrument procurement actions. The multispectral instrument constitutes the project critical path and a number of procurements related to the two instrument detection chains have already been finalised (detectors, filters). The Sentinel-2 Payload Instrument and System PDR should start in September 2008. The Satellite FAR is scheduled in July 2012, with a launch on Vega (back-up launcher Rockot) in October 2012.

Sentinel-3

The signature of the phase B2-C-D-E1 contract on 14 April represented the official start of the Sentinel-3 development phase, even though the Phase-B2 industrial kick-off already took place mid-October 2007 and the technical activities have been proceeding at a pace.

During the past months, few trade-offs took place following the recommendations raised during the proposal evaluation period and expressed at the kick-off. At platform level, the structural configuration has been revised resulting with a selection of a compromise configuration containing the best elements from the Prima concept and from the Phase-B2 Sentinel-3 configuration derived from the Proteus concept. The power sub-system architecture has also been discussed to ensure compliance with the ESA/ECSS requirements. The maximum power point tracking boost technology has been selected as a baseline power management approach, together with a reconfiguration concept implemented in hardware through the on-board computer.

All support specifications have undergone a preliminary review involving ESA, having reached a status for which they can be used as a good basis for all procurement activities. The execution of the procurement tasks through competitive Invitations To Tender represents the main effort in this phase of the programme. Approximately 100 procurement contracts are required to obtain the remaining satellite and support equipments and to complete the industrial set-up. Most of them are planned during the 12 months duration of the Phase-B2. The first offers were received and are currently under evaluation.

The first major programme review is the PDR, planned for August 2008. This is about the same time that the PDR of the four Sentinel-3 instruments will take place.

Artemis

On 1 April 2008, Artemis completed its fifth year of in-orbit operations and will reach seven years in orbit in July.

Artemis has recently fulfilled another important mission objective with the data relay support to the ATV *Jules Verne* during the initial stages of its journey to the ISS. At 05:46 UTC, 9 March 2008, the first telemetry link with *Jules Verne* was established as planned, to be followed by the first telecommand at the next orbital pass. One of the propulsion burns of the ATV was performed with a telecommand sent through Artemis, due to a gap in the TDRSS coverage, demonstrating once again the interoperability of the European space infrastructure.

The docking of ATV to the ISS marked the beginning of a new operational phase for Artemis. In fact, Envisat operations, which had been suspended due to mutual incompatibility with ATV during the free-flying phase, have been resumed fully. As a consequence, the dual Ka- and S-band steerable reflector of Artemis is constantly tracking the two spacecraft from orbit to orbit. Thanks to a very carefully planned onboard duty cycle, Artemis system availability has also remained very high during the combined ATV/Envisat operations, exceeding 99.0%. ATV will be supported for the entire duration of its mission, until the planned deorbiting in August 2008. Artemis is currently the baseline data relay system for the subsequent ATV flights.

This important operational achievement comes in the wake of an exceptional 2007, in which Artemis proved the solidity of the system architecture and of the potential for data relay satellite systems.

The first flight of the Italian CIRA Unmanned Space Vehicle (USV) took place on 24 February 2007 when the USV was lifted by a stratospheric balloon to an altitude of 20 km and then released over the drop zone off the eastern coast of Sardinia. The vehicle fell, reaching a speed of Mach 1.05, and was tracked by the Artemis S-band steerable antenna. Telemetry data were relayed to the Artemis Mission Control Facility in Redu, Belgium. The experiment was considered a success by CIRA, with over 80% of the original telemetry data received and processed during the flight. A second flight is now foreseen in October 2008.

Vega

Industrial activities relevant to the additional slice of Vega development declaration, in particular the Zefiro motor recovery plan, the Zefiro-9A and the testing of the AVUM engine, as recommended by the System CDR, were successfully negotiated.
The first development model of the AVUM propellant tank, manufactured according to the new welding procedure, has been assembled and successfully tested at burst pressure. The Qualification Review of the Interstage 0/1 was achieved during the Steering Board on 7 February.

On 27 March, the second-stage motor for Vega completed a static firing test at the Salto Di Quirra Interforce Test Range in Sardinia, Italy. This was the second and final firing test for the Zefiro-23.

A sequence of photos showing the development of the Soyuz launchpad at the Guiana Space Centre (CSG)

Qualification Flight preliminary analyses of the Lares mission are ongoing to prepare the safety submission data package and to confirm the possibility to tune the first mission as required for Vega launcher qualification.

Soyuz at CSG

The CDR of the Mobile Gantry took place from 26–29 February. The production was supervised on a day-to-day basis. So far, a two-week delay was reported and corrective actions were requested to meet the planned target of delivery at the end of August in French Guiana.

Soyuz Launch Site activities were conducted in line with a final acceptance review planned at the end of August. Equipment factory acceptance test is in progress and the Service Cabin is confirmed arriving on the first ship.

A Soyuz consultation committee took place in French Guiana on 27 March to demonstrate the readiness of the European launch site to the Russians.

FLPP

The Expander Demonstrator has been tested for a period of over 4000 s in total, including six reignition tests, which is a first-ever achievement in Europe for a cryogenic engine.

Within Main Stage Propulsion activity, pre-burner tests were performed successfully with two more European 'firsts': highest combustion pressure and highest mass flow per injector. Coupled pre-burner and main combustion chamber tests have also been performed.

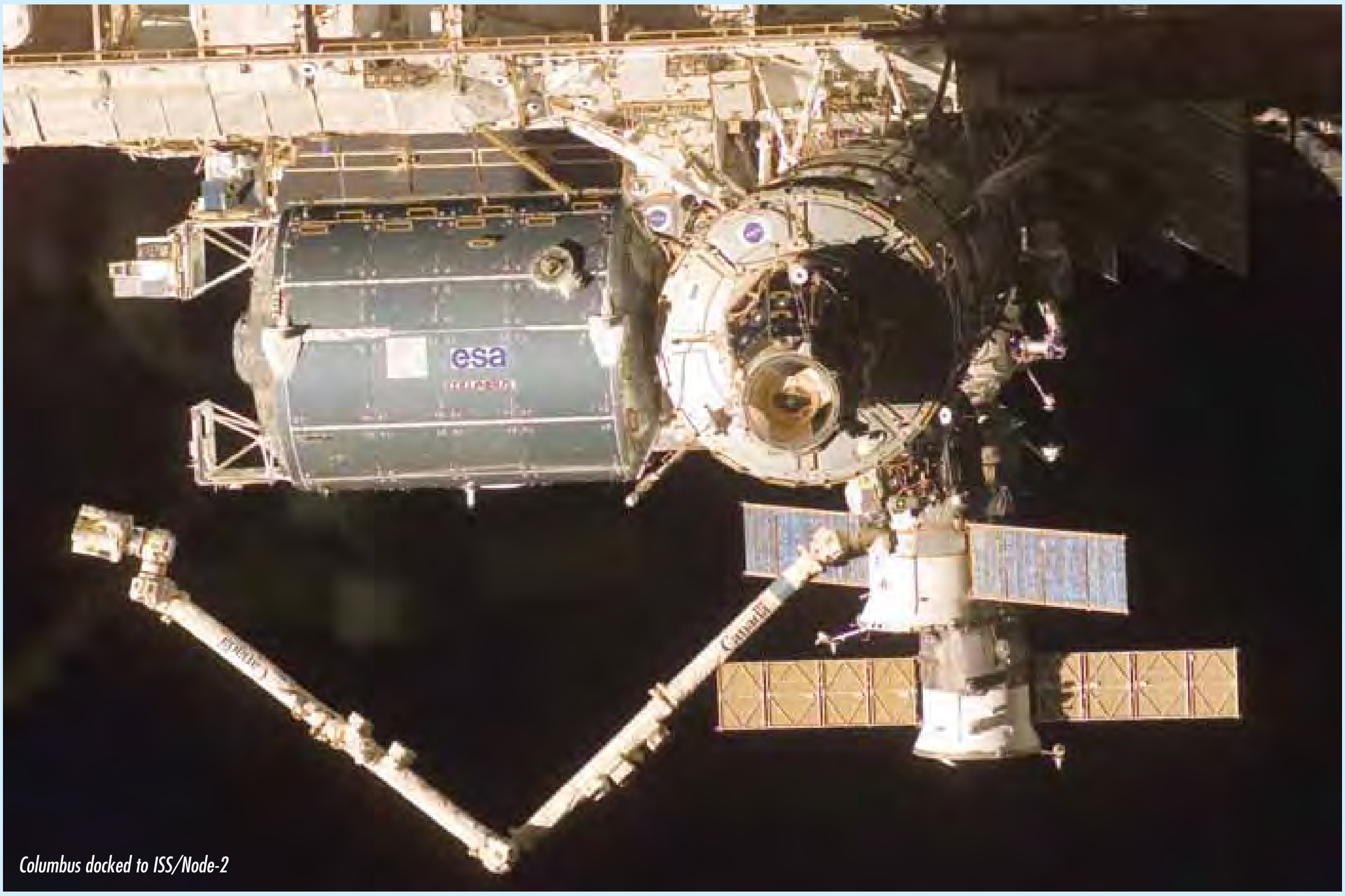
An industry day was organised in ESTEC on 5 February gathering together all parties to share knowledge of the important volume of results produced under this programme.

The FLPP Expander Demonstrator engine on teststand P4.1 at Lampoldshausen, Germany

Human Spaceflight, Microgravity and Exploration

International Space Station
After months of hard work by NASA engineers, ESA's Columbus laboratory was launched in the cargo bay of Shuttle *Atlantis* on 7 February from the Kennedy Space Center (KSC). Flight STS-122/1E also carried ESA astronauts H. Schlegel (D) and L. Eyharts (F) to the ISS.

On 11 February, the 7 m-long, 12.8 tonne Columbus module was attached to the Harmony (Node-2) module of the ISS. After external payloads were successfully deployed and Columbus was attached to Harmony, on-orbit commissioning tasks were performed by the crew. On 20 February, Space Shuttle



Columbus docked to ISS/Node-2

Atlantis STS-122 landed at KSC, Florida, returning Schlegel back to Earth.

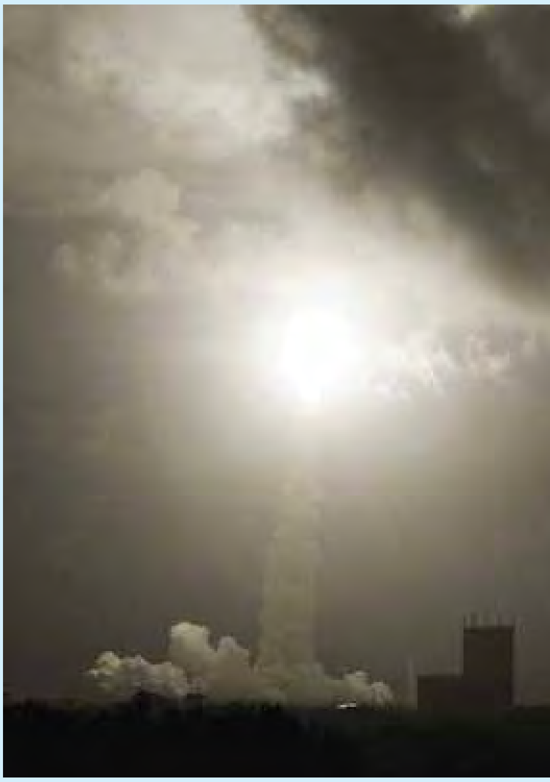
On 9 March 2008 the first of ESA's Automated Transfer Vehicles, ATV *Jules Verne*, was launched into a low Earth orbit by an Ariane-5 ES launcher. This was the culmination of more than 11 years of development and production. The lift-off occurred at 05:03 CET (04:03 UT) from Europe's Spaceport in Kourou, French Guiana. The rendezvous and docking of the ATV occurred with the ISS as planned on 3 April 2008.

A still from a video camera on the ISS showing the ATV docking

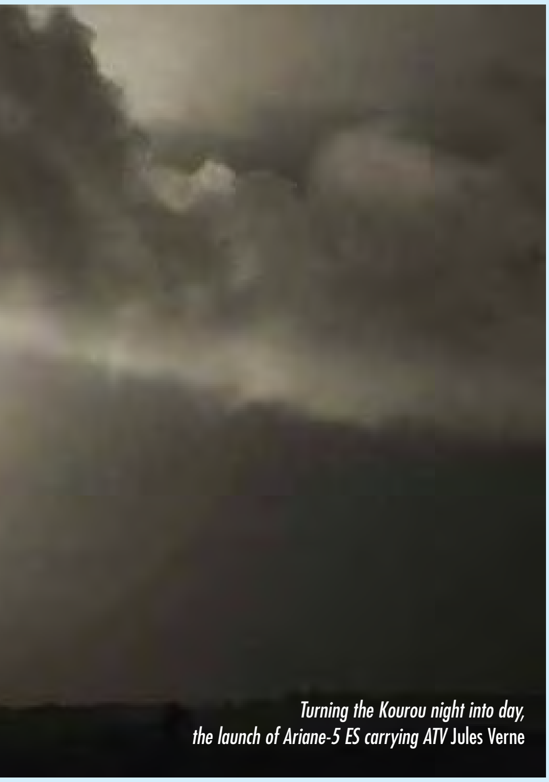
On 11 March, Space Shuttle *Endeavour* (STS-123) lifted off at 07:28 CET (06:28 UT) from KSC, on a 16-day mission to the ISS. This mission continued ISS assembly, carrying aloft the logistics module of the Japanese Kibo laboratory and a Canadian remote-controlled high-precision robot, called 'Dextre' or the Special Purpose Dextrous Manipulator (SPDM). *Endeavour* returned to Earth with Eyharts on 27 March.

Space Infrastructure Development and Exploitation

Following the docking of Columbus to Node-2 on 11 February, the Columbus Control Centre (Col-CC) operations teams took charge of activating the Columbus systems on 12 February. Despite some early problems, Columbus activation was successfully completed on 14 February 2008.



Columbus Control Centre, Oberpfaffenhofen, Germany



Turning the Kourou night into day, the launch of Ariane-5 ES carrying ATV Jules Verne

The Columbus payload hardware: the multi-user payload racks Fluid Science Lab (FSL), Biolab, European Physiology Modules (EPM) and the European Drawer Rack (EDR) were activated. EuTEF and SOLAR were installed on Columbus's external accommodation sites during the Flight 1E's third EVA on 15 February 2008. Both have both been turned on and are now operating well.

SOLAR deployment

SOLAR mounted outside Columbus

EuTEF mounted outside Columbus

The Col-CC operations teams are settling into routine operations after the intense operations of the STS-122/1E mission. The relocation of the EXPRESS-3 and MSG Payload Racks from the US Destiny laboratory to the Columbus laboratory was performed nominally during Increment 16.

After the launch of ATV on 9 March, the ATV Control Centre (ATV-CC) operations teams took control of the vehicle and conducted an almost perfect mission, leading to a spectacular Demonstration Day 2 on 31 March.

During the launch, a degradation of a thermal blanket occurred which means that more heat would be lost to space than originally designed for. However, there was additional power available to compensate for this heat loss, with the perfect functioning of all the power generation subsystems. Therefore there was no effect on the nominal operation of the spacecraft.

The Launch Early Operations Phase (LEOP) activities were nominal. The ATV collision avoidance manoeuvre was demonstrated on 12 March. On 27 March, orbit burns were initiated from ATV-CC to move the ATV from its parking orbit and, on 29 March, Demo Day 1 was successfully conducted to bring the ATV to within 3.5 km of the ISS and demonstrate its capability to perform navigation using relative GPS. On 31 March, Demo Day 2, the ATV manoeuvred to within 11 m of the ISS, demonstrating its guidance and navigation capabilities using its optical sensors. All systems performed nominally and docking occurred on 3 April 2008.

SPERO

The 'Study on a Columbus external platform capability for small payloads' (SPERO) is ongoing with industry. A Call for Interest for small payloads using the SPERO platform has been released on 12 March to more than 3000 addresses all over Europe.

65 letters of interest have been received from industry, universities, research institutes and national space agencies. Proposals cover various areas of research: exobiology, astrophysics, Earth observation, materials science, technology demonstrators, robotics, etc. This result confirms the overwhelming interest in developing SPERO.

ATV Production

The ATV Production Readiness Review (1.2) is due to be concluded on 17 April, releasing the ATV02 system integration and ATV03 equipment procurement. The ATV-2 launch is scheduled for the second quarter of 2010. The ATV rack design has been optimised and qualification tests are currently running without any problems.

Utilisation

The ISS Increment 16 experimental programme has been running since October 2007 with four long-term experiments in human physiology (ETD and Immuno) and radiation research (Matroshka and Altcriss). The first Columbus experiment,

ATV Control Centre, Toulouse, France

WAICO Run#1, was started in the Biolab on 28 February by astronaut Eyharts.

A significant software bug in the SOLAR Sun-tracking algorithm forced the first solar observation period to be skipped. The SOLAR Coarse Pointing Device software patch was uploaded and the parameters optimised. All instruments have now been commissioned, are active and are providing science data. The EuTEF science programme has started.

The Foton-M3 post flight activities continued nominally in the first quarter of 2008. The data download from the TELESUPPORT mass memory device was completed and the data distributed. A full mission report was received from TsSKB-Progress The Foton Co-ordination Board meeting and Post Flight Review (PFR) were held 10–14 March at ESTEC. The progress of the Polizon scientific experiment evaluation was presented and the experiment samples from the TUBAF experiments were handed over to the Russian experimenters.

The TEXUS-44 and TEXUS-45 sounding rockets were successfully launched from Esrange, in Sweden on 7 and 21 February 2008 respectively. The 48th ESA Parabolic Flight Campaign was performed in March. The new contract for the 2008 and 2009 drop tower campaigns at ZARM/Bremen (D) has been signed. So far, three drop-tower experiment campaigns, with 35 drops in total have been undertaken in 2008.

The MULTIGEN-1 – Batch 1-A (Multigeneration Plant Growth in Space) experiment was completed aboard ISS in the European Modular Cultivation System (EMCS) during week 46. The dried-out plants have been returned to ground with STS-122/1E mission. ANITA continues to operate flawless in the US laboratory Destiny and provides invaluable ISS atmosphere composition data.

The Long-Term Medical Survey (LTMS) prototype device has been shipped to Concordia for testing on site. The final presentation of the Technologies for Psychological Support (TPS) took place on 11 January.

Astronauts

As members of the STS-122 crew, ESA astronauts H. Schlegel and L. Eyharts were launched to the ISS on 7 February on board Space Shuttle *Atlantis*.

During STS-122, Eyharts supported the docking of Columbus, first at the controls of the Station's robotic arm, to extract the European module from the Shuttle's cargo bay, and later by activating the motorised bolts from inside the Harmony Node-2 to secure the junction. He then assisted the third spacewalk of the mission by operating the station's robotic arm.

Schlegel performed the second of the three STS-122 spacewalks (Schlegel's first ever spacewalk) on 13 February with fellow astronaut Rex Walheim of NASA. He also coordinated the other two spacewalks during the mission, supporting the Columbus module's transfer from the Shuttle payload bay to the ISS, plus the transfer of two payload suites, SOLAR and EuTEF, to the external platforms on Columbus.

Both ESA astronauts participated in the outfitting and commissioning of the Columbus laboratory. Commissioning of the European laboratory will be finalised by the resident ISS crew of the Expedition 16 and 17 increments.

As if in a scene from a science fiction movie, Schlegel moves along a truss section of the ISS in the darkness of a 'night' part of an orbit. Taken during Schlegel's 6 hr 45 m spacewalk, this image gives an impression of the scale of the ISS (NASA)

Eyharts had joined the ISS Expedition 16 crew as Flight Engineer for 33 days, but when *Endeavour* docked with the ISS on 13 March he swapped crew assignments again, this time with NASA astronaut Garrett Reisman, and joined the crew of STS-123 for the return to Earth.

As a qualified mission specialist in robotics, Eyharts contributed to the STS-123 assembly mission as operator of the Station's robotic arm alongside Reisman and Bob Behnken, another NASA mission specialist. Together, they added a new module to the ISS – the Japanese Experiment Logistics Module, Pressurised Section (JLP) – and supported the assembly and activation of the Canadian-built Dextre robotic telemanipulator.

ESA officially announced that astronaut F. De Winne (B) will be a crewmember of Increment 20/21 starting in May 2009, with A. Kuipers (NL) as his back-up. De Winne and Kuipers started Japanese Experiment Module system training at JAXA in January. Kuipers continued his Russian Onboard Segment training at the Gagarin Cosmonaut Training Centre, Moscow, in February and March.

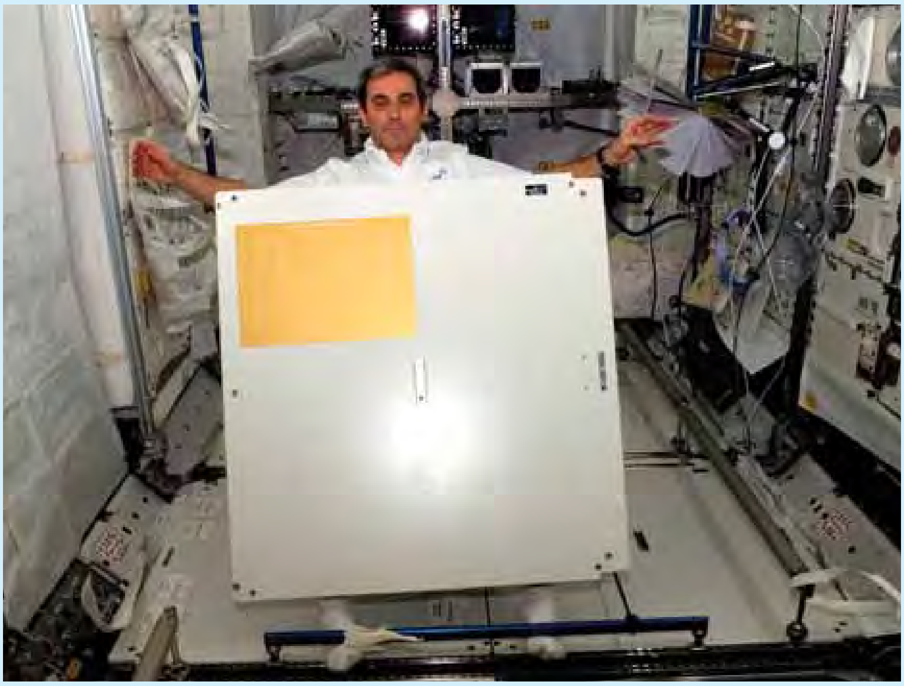
STS-122 and Expedition 16 crews including Hans Schlegel and Léopold Eyharts inside Columbus (NASA)

Exploration

ExoMars – The Enhanced Mission

An ExoMars (full 2 metre) drilling test has been successfully completed. Phase-B2 has been kicked-off to cover the prime and the core contractors. All main Phase-B2 contracts have been negotiated successfully. The Pasteur Payload accommodation and the Sample Processing Distribution System (SPDS) design are under review to improve the bio-barrier designs. A dedicated Humboldt payload design meeting was held in the ESTEC Concurrent Design Facility, resulting in agreements on instrument layout and deployment methods.

Eyharts with one of two plaques bearing 800 names and signatures of people from ESA, Astrium and consortium companies who contributed to the Columbus project (NASA)



The ExoMars Instrument Multilateral Agreement (IMA) was endorsed at the Human Spaceflight, Microgravity and Exploration Programme Board on 12 February.

The ESA/Roscosmos ExoMars Cooperation Agreement was ratified by Council (Russian Partners Agreement still pending). The

ESA/NASA LOA was signed by the NASA Partner on 21 March. Generally, the project is moving towards a system PDR at the end of 2008.

Core Element

The activities of the International Mars Exploration (IMEWG)/iMARS Working Group have further progressed with a refinement of the Mars Sample Return (MSR) mission concept. A working meeting took place in Windsor (UK) on the 18/20 March. The preparation of the 8 July IMEG meeting and the MSR conference (9/10 July) is progressing well, and the iMARS Preliminary Report is under preparation. On the same subject, a Technical Assistance Agreement (TAA) between ESA and NASA/JPL has been signed to allow more detailed engineering work to be performed on the single MSR mission elements.

The proposal for the High-Velocity Re-entry Demonstration activity (CP20) has been received and is under evaluation.

The updated Systems Requirement Review (SRR) Data Package for ARES has been received and reviewed.

The latest (Phase-B2) ExoMars rover concept

An ITT for a Pressurised Lunar Rover Study has been published. The deadline for proposals is 14 May after an extension of the bidding period.

GSTP Interim Technology Phase

All of the International Berthing Docking Mechanism (IBDM) activities are progressing well. In the GSTP-funded interim technology phase, the mechanical design and ground verification activities of the IBDM are nearing completion with Verhaert (B). For the European Berthing Docking Mechanism (EBDM), two units of the new hook design have been completed and a stiffness test has been conducted. The avionics and simulation activities have progressed as planned. All the electronic hardware has been built and the unit tested. The software has been completed, tested and preliminarily deployed to the target processor.

The industrial activities for the closure of the technical issues raised by the EXPERT Integrated Project Review have been completed. ESA has negotiated an acceptable proposal for the complete Phase C/D with the industrial prime contractor, with a target launch in June 2010, assuming a start of the full development in June 2008. All the payloads have completed the Critical Design Review, and the Qualification Review shall be completed by autumn 2008.

CSTS

As a result of the trade-off analysis on vehicle system concepts, Roscosmos and ESA, together with their respective industries, have arrived at the conclusion that the new crew transportation spacecraft must be based on the cone-shape body option.

The parties have agreed to proceed with a detailed design phase of the advanced Crew Space Transportation System (CSTS). It has been concurred that as this takes place, a Russian launch vehicle of 18-tonne payload capability to be launched from the Vostochny cosmodrome, will be used as the design baseline. It is assumed that the flight tests will be conducted in 2015, with the first manned launch to be performed in 2018.

In view of the experience of the parties involved, the Russian side will be responsible for the design and development of the crew (re-entry) capsule, while the European side will be responsible for the design and development of the service/propulsion module. At the same time, RSC Energia will be in charge of the overall integration of the CSTS development activities.

By October 2008 it is planned to complete the preparation of documents that will define technical and programmatic aspects of the vehicle concept, which will enable the parties to make decisions on launching the CSTS project activities. An intermediate system concept report will be prepared in June 2008 to be reviewed jointly by ESA and Roscosmos.

In Brief

Ariane-5 ES Launch of ATV *Jules Verne*

When the new Ariane ES launched ATV *Jules Verne* into the expected orbit with high precision on 9 March 2008, it was not just another perfect launch of Ariane-5 – it was something very special and frontier-breaking, opening up new perspectives for Europe.

The mission was the most complicated ever undertaken by any Ariane launch vehicle: a first boost of the upper stage over the Atlantic Ocean to reach an elliptical orbit, followed by a ballistic phase flying over the most populated parts of Europe, then a second boost over the Pacific Ocean to circularise the orbit at 260 km, then separation of the ATV *Jules Verne* in this orbit followed by a full orbit in order to perform a braking boost and a destructive reentry over the Pacific Ocean.

In order to monitor the Ariane-5 ES ATV mission, the most comprehensive tracking network ever established for an Ariane launch had to be deployed. It employed telemetry reception from Kourou, a vessel in the Atlantic Ocean, ESA's new tracking station in the Acores, tracking stations in Adelaide and Dongara in Australia and Invercargill in New Zealand.

This launch not only marked Ariane's first mission to the International Space Station (ISS), establishing Europe as a major partner in the ISS collaboration, but it also opened up new aspirations and opportunities for Ariane-5 in terms of missions needing reignition, such as for the deployment of the Galileo constellation.

The Ariane-5 ES-ATV launcher poised at Ariane Launch Complex No.3 (ELA-3) at the Guiana Space Centre. On board is Jules Verne*, ESA's first Automated Transfer Vehicle for the ISS*

Lift-off of the Ariane-5 ES-ATV launcher from the Guiana Space Centre, Europe's Spaceport, in Kourou, on 9 March 2008

Jules Verne Boosts ISS Orbit

ESA's ATV *Jules Verne* was used for the first time to raise the orbit of the International Space Station on 25 April. A 740-second burn of the ATV's main engines successfully lifted the altitude of the 280-tonne ISS by around 4.5 km to a height of 342 km above Earth's surface.

The reboost manoeuvre came just three weeks after *Jules Verne* successfully docked with ISS on 3 April 2008 delivering 1150 kg of dry cargo, including food, clothes and equipment, as well as additional supplies of water, oxygen and fuel. Since then, the European resupply spacecraft was in dormant mode attached to the docking port on the Russian Zvezda module.

The reboost set up the ISS for the arrival of Space Shuttle *Discovery* on the STS-124 mission to deliver the Japanese Kibo laboratory. Further reboost manoeuvres using *Jules Verne* are scheduled for 12 June, 8 July and 6 August.

"The Station's altitude naturally decreases with atmospheric drag. Until now this has been compensated for by performing a reboost using the Russian Progress, the Space Shuttle or by the ISS itself," explains Alberto Novelli, ESA's Mission Director at ATV-CC. *"Today, ATV has successfully demonstrated that it too is able to perform this vital function. Only Progress and ATV can provide this high level of reboost. ATV is unique due to the quantity of fuel available for such manoeuvres."*

ATV *Jules Verne* is scheduled to remain docked to the ISS until early August. At the end of its mission, loaded with up to 6.5 tonnes of material no longer required by the ISS, *Jules Verne* will undock and then burn up completely during a guided and controlled reentry high over the Pacific Ocean. esa

Backdropped by the blackness of space, ESA's ATV Jules Verne *approaches the ISS on 31 March 2008, for its 'Demo Day 2' practice manoeuvres. It moved to within 11 m of the Zvezda Service Module in a rehearsal for docking (NASA)*

Yuri Malenchenko (RUS), Expedition 16 flight engineer aboard the ISS, used a digital still camera to record several images of the ESA's Jules Verne *ATV during a the rendezvous test on 29 March 2008. Malenchenko took these photos while the ATV sat about 3 km from the ISS during the first of two demonstration days in the lead up to a first ISS docking attempt on 3 April (NASA)*

ESA to Select New Astronauts

The ESA Astronauts in 2008

ESA's human spaceflight activities have entered a new era and it is now time for ESA to seek out new talent to join the European Astronaut Corps for future manned missions to the ISS, the Moon and beyond.

We need to increase the size of ESA's Astronaut Corps in order to successfully accomplish our present and future programmes, and have therefore decided to initiate the process of selecting new astronauts.

Candidates from all 17 Member States (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom) are welcome to apply.

"*Europe has long been involved in exploration, even before the days of Christopher Columbus. After exploring Earth, space is the logical next step – and a new generation of explorers are needed to follow their illustrious predecessors and embark for those new worlds. I am therefore very pleased that at the beginning of 2009, we will be welcoming a new intake of men and women to the European Astronaut Corps to undertake missions to the ISS and beyond,*" said Daniel Sacotte, ESA's Director of Human Spaceflight, Microgravity and Exploration.

ESA made its first astronaut selection in 1978, followed in 1983 by the first Spacelab mission. Preparations for ESA's Columbus laboratory project, meanwhile, involved a second selection of astronauts in 1992.

The overall selection process starts on Monday, 19 May.

The final appointments will be officially announced in 2009. The selected candidates will then join the European Astronaut Corps and begin basic training at the European Astronaut Centre (EAC) in Cologne, Germany.

The first step in the formal application will be online screening at *www.esa.int/astronautselection*

Hubble Finds First Organic Molecule on Extrasolar Planet

The NASA/ESA Hubble Space Telescope has made the first ever detection of an organic molecule in the atmosphere of a planet orbiting another star. This breakthrough is an important step in eventually identifying signs of life on a planet outside our Solar System.

Under the right circumstances, methane can play a key role in 'prebiotic' chemistry – the chemical reactions considered necessary to form life as we know it. Although methane has been detected on most of the planets in our Solar System, this is the first time any organic molecule has been detected on a world orbiting another star.

The planet now known to have methane and water is located 63 light-years away in the constellation Vulpecula, HD 189733b. It is so massive and so hot though that it is considered an unlikely host for life. However this observation is proof that spectro-scopy can eventually be done on a cooler and potentially habitable Earth-sized planet orbiting a dimmer red dwarf-type star.

Artist's impression of the extrasolar planet HD 189733b ESA/NASA/UCL (G. Tinetti)

The discovery comes after extensive Hubble observations in May 2007 that confirmed the existence of water molecules in the planet's atmosphere, originally discovered in 2007 by ESA fellow Giovanna Tinetti while at the Institute d'Astrophysique de Paris, France, using NASA's Spitzer space telescope.

Tinetti, now affiliated to University College London, added, "*Water alone could not explain all the spectral features observed. The additional contribution of methane is necessary to fit the Hubble data.*"

Methane, composed of carbon and hydrogen, is one of the main components of natural gas, a product of petroleum. On Earth, methane is produced by a variety of natural sources, but also from livestock and manmade sources such as waste landfills and as a byproduct of energy generation.

Tinetti is however quick to rule out any biological origin of the methane found on HD 189733b. "*The planet's atmosphere is far too hot for even the hardiest life to survive – at least the kind of life we know from Earth. It's highly unlikely that cows could survive here!*"

The ultimate goal of studies like these is to identify prebiotic molecules in the atmospheres of planets in the 'habitable zones' around other stars, where temperatures are right for water to remain liquid rather than freeze or evaporate away.

Endeavour Brings ESA Astronaut Back to Earth

The landing of STS-123 took place at 01:39 CET on 27 March, at the Kennedy Space Center shuttle landing strip at Cape Canaveral, Florida (NASA)

After its 16-day STS-123 mission to the International Space Station in March, NASA's Space Shuttle *Endeavour* safely returned to Earth with its crew of seven including ESA astronaut Léopold Eyharts (F).

Eyharts had been sent to the ISS on the previous Shuttle flight of *Atlantis* on 7 February with another ESA astronaut, Hans Schlegel (D), and then he spent nearly 49 days in space on a mission to dock and commission ESA's Columbus laboratory.

On 10 February, shortly after *Atlantis* had docked with the ISS, Eyharts was inducted in the resident ISS crew, replacing NASA astronaut Dan Tani as a member of the Expedition 16 increment alongside NASA's Peggy Whitson and Russian astronaut Yuri Malenchenko.

On 12 February, Eyharts became the first astronaut to enter the Columbus laboratory in orbit. He wore a mask and goggles and carried a flashlight to check the laboratory's status before the atmosphere was scrubbed and the lights were turned on. As soon as Columbus was cleared for access, together with Schlegel and other crewmembers, he immediately started reconfiguring and activating the module. Eyharts remained on the ISS when *Atlantis* departed with Schlegel to return to Earth.

As a qualified mission specialist in robotics, Eyharts also contributed to the STS-123 mission as an operator of the ISS's robotic arm. Together with NASA astronauts Garrett Reisman and Bob Behnken they added another new module to the ISS – the Japanese Experiment Logistics Module, Pressurised Section (JLP) – and supported the assembly and activation of the Canadian-built Special Purpose Dextrous Manipulator.

Eyharts spent 44 days on the ISS and devoted a large part of his time to activation and checking of the Columbus module and its racks in order to be able start up actual science experiments inside the laboratory. When he left the ISS, he brought back with him the very first results of an experiment carried on Columbus.

Eyharts was the second ESA astronaut to have become part of the resident ISS crew, Thomas Reiter having spent six months onboard in 2006. This was Eyharts' second mission to a space station, having already flown to the Russian Mir station back in 1998.

esa

De Winne is Next ESA Astronaut to Join ISS Crew

With the Columbus laboratory now attached to the ISS, ESA long-duration flights will be carried out more often. The next ESA astronaut to go to the ISS will be Frank De Winne (B) in 2009. André Kuipers (NL) will be his backup.

Frank De Winne

From 2005, De Winne had been in training as back-up for Léopold Eyharts on his ISS expedition and the delivery of Columbus. In January 2008, De Winne was assigned as a prime crewmember of Expedition 19, a long-duration mission to the ISS.

Test-pilot De Winne joined ESA in 2000 and he flew on the Odissea mission to the ISS, serving as flight engineer on the updated Soyuz TMA spacecraft during ascent, and on a Soyuz TM during reentry.

During his nine days on board the ISS, De Winne carried out a programme of 23 experiments in the fields of life and physical sciences and education, including experiments in an important new research facility designed and developed in Europe, the Microgravity Science Glovebox.

esa

Royal Opening for New ESTEC Labs

Dutch Crown Prince Willem Alexander officially opened the new laboratory building at ESA's European Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands, on 8 April.

The Prince and other guests were impressed with the high-tech facilities, including the Propulsion Lab and the Concurrent Design Facility. Dutch Minister of Economic Affairs Maria van der Hoeven and ESA Director General Jean-Jacques Dordain spoke about the importance of ESTEC for the Netherlands, for Europe and for European success in space.

HRH Prince Willem Alexander looks at an operating Hall-effect thruster in ESTEC's Propulsion Lab in April 2008

Forty years ago the same week, the Prince's mother, then HRH Princess Beatrix, officially opened ESA's technical centre in Noordwijk. At that time, the opening was testimony to the faith put in the spaceflight pioneers of the 1960s and in European cooperation on an international space stage. ESTEC has since played a leading role in over 80 successful spaceflight projects.

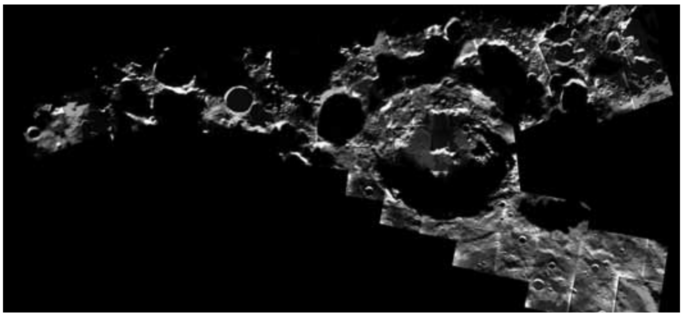
"ESTEC has to keep developing," said Michel Courtois, ESA Director of Technical and Quality Management and Head of ESTEC. *"These laboratories are a drastic improvement compared to the old ones. Engineers and scientists from all over Europe come together here to work on the design of space missions and new technologies. Now they can do so using the newest techniques and methods."* esa

New Lunar South Polar Maps from SMART-1

Newly-released images of the lunar south-polar region obtained by ESA's SMART-1 are proving to be excellent tools to pinpoint suitable study sites for potential future lunar exploration missions.

SMART-1's Advanced Moon Imaging Experiment (AMIE) has collected many images of the lunar south-polar region with unprecedented spatial resolution. The images, obtained over a full year of changing seasons were used to study the different levels of solar illumination on the Moon's surface.

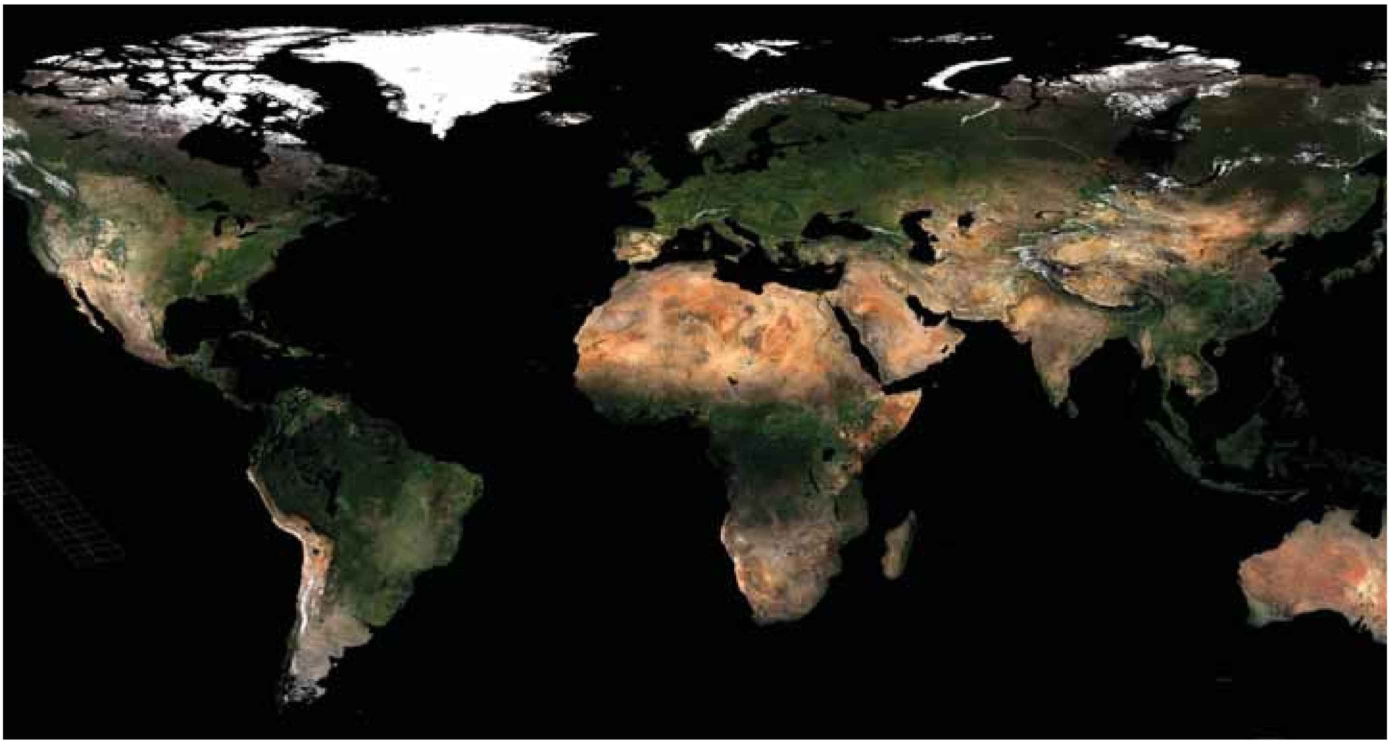
"The SMART-1 south polar maps indicate very exciting targets for science and future exploration, within travel reach from a rover or humans at the south pole," said Jean-Luc Josset, Principal Investigator for AMIE.



This mosaic of the lunar south pole is made of about 40 images taken by the Advanced Moon Imaging Experiment (AMIE) on board SMART-1 between December 2005 and March 2006. The images were taken from an altitude of 500 km, over more than 30 orbits, and cover an area of about 500 by 150 km at a resolution of 50 m/pixel (ESA/SMART-1/Space-X)

These high-resolution SMART-1 south polar mosaics were produced and analysed in study project for the design and operations of lunar polar robotic landers and rovers, by Marina Ellouzi, a Master's student in space engineering at the Paris-Meudon Observatory. The images were presented by the SMART-1 AMIE team and collaborators at the 39th Lunar and Planetary Science Conference in Texas in March 2008. esa

Earth Land Cover as Never Seen Before



A composite of images taken by Envisat's MERIS instrument, at a resolution of 300 m per pixel, over the whole globe

A new global portrait taken from space shows Earth's land cover with a resolution never before obtained. ESA, in partnership with the UN Food and Agriculture Organisation, presented the preliminary version of the map to scientists in March at the Second GlobCover User Consultation workshop in Rome, Italy.

Earth's land cover has been charted from space before, but this map, which will be made available to the public upon its completion in July, has a resolution ten times sharper than any of its predecessors.

Scientists, who will use the data to plot worldwide land-cover trends, study natural and managed ecosystems and model climate change extent and impacts, are hailing the product – generated under the ESA-initiated GlobCover project – as 'a milestone'.

"*The GlobCover system is a great step forward in our capacities to automatically produce new global land cover products with a finer resolution and a more detailed thematic content than ever achieved in the past,*" said Frédéric Achard of the EC's Joint Research Centre (JRC).

"*Land cover data is an essential requirement of the sustainable management of natural resources, environmental protection, food security, climate change and humanitarian programmes,*" said John Latham of the Food and Agriculture Organisation (FAO). "*The GlobCover product will be the first freely available product at 300m resolution and is therefore a milestone product which will be fundamental to a broad level stakeholder community.*"

The map is based on 20 Terabytes of imagery – equivalent to the content of 20 million books – acquired from May 2005 to April 2006 by Envisat's Medium Resolution Imaging Spectrometer (MERIS) instrument. There are 22 different land cover types shown in the map, including croplands, wetlands, forests, artificial surfaces, water bodies and permanent snow and ice. For maximum user benefit, the map is compatible with the UN Land Cover Classification System (LCCS).

GlobCover, launched in 2005, is part of ESA's Earth Observation Data User Element. An international network of partners is working with ESA on the project, including the UN Environment Programme (UNEP), FAO, JRC, the European Environmental Agency, the International Geosphere-Biosphere Programme (IGBP) and the Global Observations of Forest Cover and Global Observations of Land Dynamics (GOFC-GOLD) Implementation Team Project Office.

esa

Students to Take Part in Sounding Rocket and Balloon Campaigns

Eight student teams from various ESA Member and Cooperating States have been selected to fly their experiments on future sounding rocket and balloon campaigns.

An announcement of opportunity was issued by the ESA Education Office in November 2007 for the REXUS and BEXUS programmes (Rocket/Balloon Experiments for University Students). After evaluation of the initial entries, the shortlisted teams were invited to present their proposals to experts from ESA and Esrange during a workshop in March 2008. The winners join six teams chosen earlier in the week for the same flights by the German Aerospace Center (DLR).

Three of the successful ESA-sponsored teams will have the opportunity to place their experiments on the REXUS-5 and -6 sounding rockets, to be launched from Kiruna, Sweden, in March 2009. The payloads developed by the other five teams will fly on the BEXUS-6 and -7 stratospheric balloons that will be launched from Kiruna in September 2008.

Each flight will carry a payload consisting solely of student experiments. Half of the overall payload is available only to German students through a DLR Announcement of Opportunity, while the other half is opened up to students from all other ESA Member States and Cooperating States by the Swedish National Space Board (SNSB) through a collaboration with ESA.

The three experiment teams selected for the REXUS sounding rocket campaign are from: the University of Bergen, Norway, the University of Oulu, Finland and the Finnish Meteorological Institute; the Castor Space Club of the Tampere University of Technology; and the Universitat Politecnica de Catalunya, Spain.

The teams selected for the BEXUS balloon flights are from: Luleå University of Technology, Sweden, with Charles University, Prague, and the Czech Technical University, Czech Republic; the 'Erasmus Mundus' Space Masters course, currently based at Luleå University of Technology, Sweden; the Scuola di Ingegneria Aerospaziale, Rome; the University of Rome 'La Sapienza', Italy; Romanian Space Agency with Warsaw University of Technology, Poland.

The next announcement of opportunity to fly experiments through the REXUS and BEXUS programmes will be issued in September 2008. These flights will take place during 2009 and 2010.

Galileo's GIOVE-B Launched

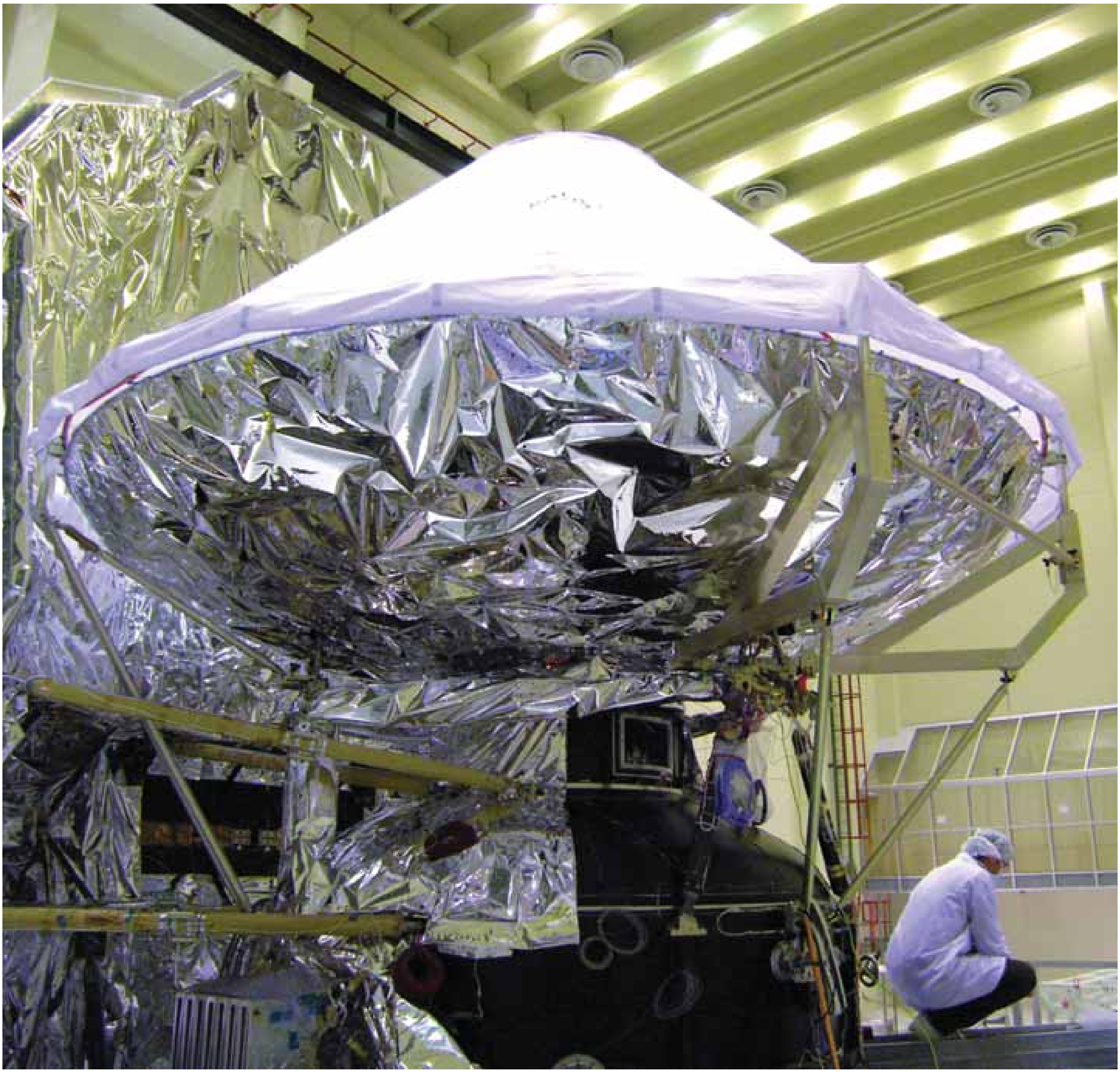
A further step towards the deployment of Europe's Galileo global navigation satellite system was made on 27 April 2008, with the launch of ESA's second Galileo In-Orbit Validation Element (GIOVE-B) satellite.

Carrying the most accurate atomic clock ever flown into space, the GIOVE-B satellite was launched into a medium-Earth orbit by a Soyuz-Fregat rocket from the Baikonur Cosmodrome in Kazakhstan by launch operator Starsem. Lift-off occurred at 04:16 local time on 27 April, and the Fregat upper stage then performed a series of manoeuvres to safely deliver the satellite into its orbit at an altitude of about 23 200 km some 3 hours and 45 minutes later.

This 500 kg satellite was built by a European industrial team led by Astrium GmbH, with Thales Alenia Space performing integration and testing in Rome. Two years after the highly successful GIOVE-A mission, this latest satellite will continue the demonstration of critical technologies for the navigation payload of future operational Galileo satellites.

The Soyuz-Fregat launcher carrying GIOVE-B lifts off from Baikonur on 27 April 2008

Herschel Spacecraft Assembly Complete



The Herschel telescope resting on its cryostat at ESTEC, 16 April 2008

At the end of April, the Herschel telescope was connected to its payload and service modules, at ESA's European Space Research and Technology Centre (ESTEC) in The Netherlands, completing the assembly of the entire spacecraft.

This powerful telescope will allow scientists to look deep into space, at long infrared wavelengths. Herschel's spectral coverage, which ranges from far-infrared to sub-millimetre wavelengths, will be made available for space-based observations for the first time. Herschel will make it possible to observe and study relatively cool objects everywhere in the Universe, teaching us much more about the birth and evolution of stars and galaxies.

esa

Successful Test-firing for Vega Motor

Zefiro-23 second firing test at the Salto Di Quirra Inter-force Test Range in Sardinia, Italy, on 27 March 2008 (AVIO Space)

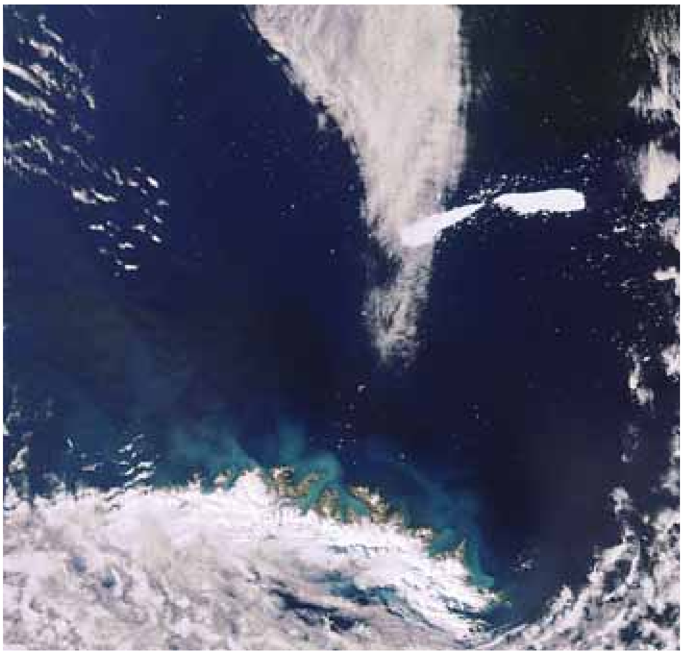
On 27 March 2008, the Zefiro-23 second-stage motor for Vega – Europe's new small launcher – successfully completed a static firing test at the Salto Di Quirra Inter-force Test Range in Sardinia, Italy.

Ignition of the qualification model of the solid-propellant rocket motor occurred at 13:15 CET. In just 14 seconds, the thrust reached 930 kN, equivalent to nearly 95 tonnes of force. This was the second and final firing test for the Zefiro-23, in which over 24 tonnes of propellant was consumed in 75 seconds with a flame temperature of over 3000°C.

Vega is a single-body launcher composed of three solid-propellant stages and a liquid-propellant upper module. It is approximately 30 m high, and weighs a total of 137 tonnes at lift-off. Vega will be able to carry a 1500 kg payload into a 700 km altitude polar orbit, but the launcher is also designed to serve a wide range of other scientific and Earth observation missions.

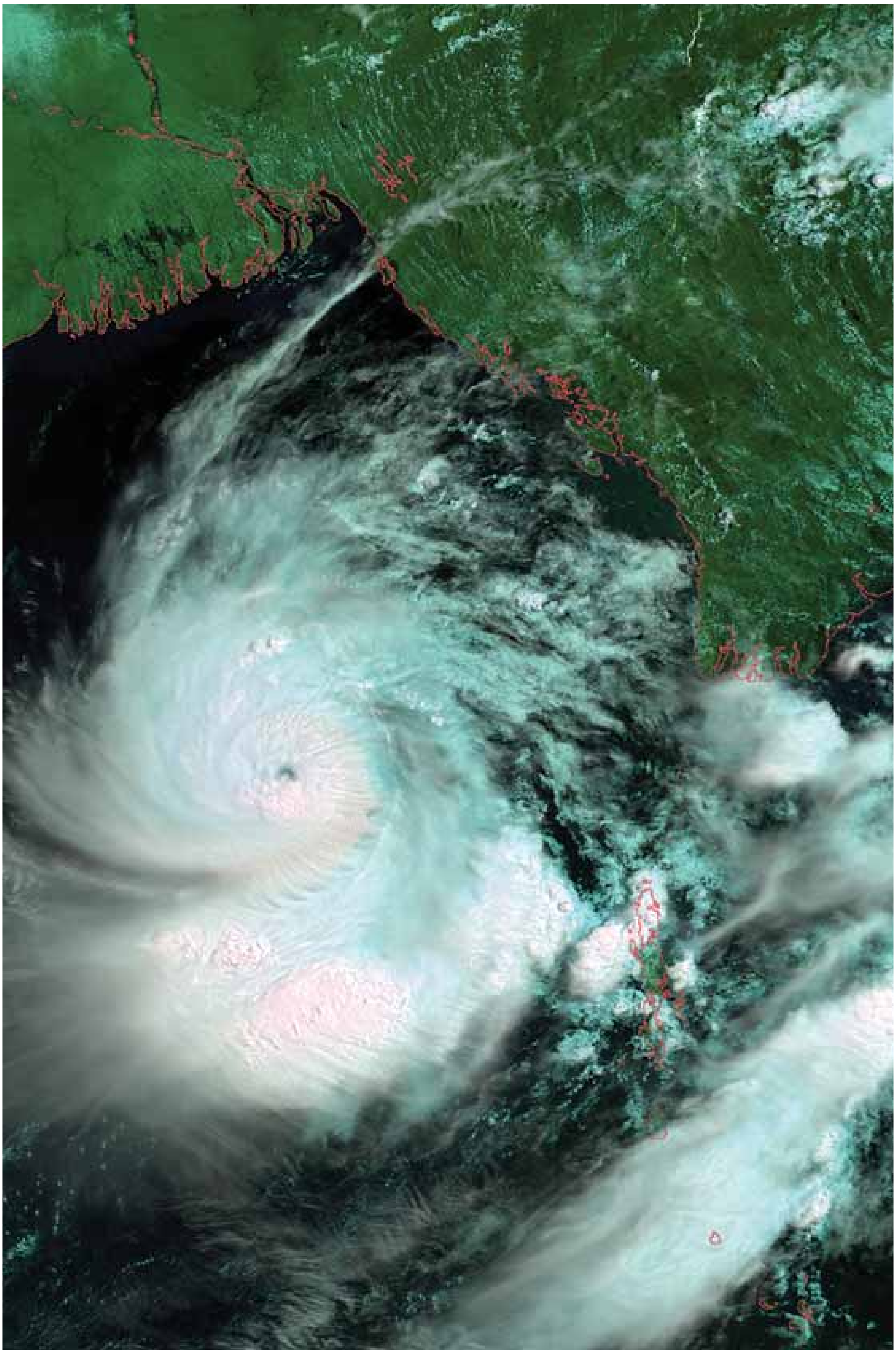
Envisat Tracks Berg Break-up

On 1 March 2008 Envisat's Advanced Synthetic Aperture Radar (ASAR) instrument spotted a huge fissure running south to north through the massive A53A iceberg (visible at top right) drifting to the east of South Georgia Island in the southern Atlantic Ocean. ASAR is able to produce high-quality images of icebergs and ice sheets and is capable of differentiating between different types of ice because it is able to see through clouds and local darkness – conditions often found in polar areas



Envisat's Medium Resolution Imaging Spectrometer (MERIS) sensor captured the break up of the A53A iceberg east of South Georgia Island in the southern Atlantic Ocean. The resulting two new bergs are around 30 km in length. As a reference, South Georgia Island is approximately 180 km long

Cyclone Nargis Approaches Myanmar



Envisat captured Cyclone Nargis making its way across the Bay of Bengal just south of Myanmar on 1 May 2008. The cyclone hit the coastal region on 3 May and devastated large areas of the country

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 Brochures

European Astronaut Selection / Selection d'astronautes européens
A. Wilson (Ed.)
ESA BR-271 // CD-Rom & Booklet // 88 pp
Price: 15 Euro

Proceedings of SeaSAR 2008, 21–25 January 2008, Frascati, Italy (April 2008)
H. Lacoste & L. Ouwehand (Eds.)
ESA SP-656 // CD-Rom
Price: 40 Euro

ESA Special Publications

Proceedings of the 2008 Dragon Symposium – Dragon 1 Programme – Final Results 2004-2007, 21-25 April 2008, Beijing, P.R. China (April 2008)
H. Lacoste & L. Ouwehand (Eds.)
ESA SP-655 // CD-Rom
Price: 40 Euro

Proceedings of FRINGE 2007, 26–30 November 2007, Frascati, Italy (February 2008)
H. Lacoste & L. Ouwehand (Eds.)
ESA SP-649 // CD-Rom
Price: 40 Euro

ADM-Aeolus – Science Report (April 2008)
P. Clissold (Ed.)
ESA SP-1311 // 121 pp
Price: 30 Euro

GOCE – ESA's Gravity Mission (April 2008)
ESA SP-1314 // CD-Rom
Price: 10 Euro

ISSI Scientific Report

Multi-Spacecraft Analysis Methods Revisited (February 2008)
G. Paschmann & P.W. Daly (Eds.)
SR-008 // 100 pp
Price: 30 Euro

ESA Scientific & Technical Memoranda

Assessment of Chemical Conversion Coatings for the Protection of Aluminium Alloys – A Comparison of Alodine 1200 with Chromium-Free Conversion Coatings (February 2008)
K. Fletcher (Ed.)
ESA STM-276 // 62 pp
Price: 20 Euro

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