number 141 | February 2010

# bulletin

→ space for europe

# European Space Agency

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

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

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

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

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

Chairman of the Council: M. Lucena

Director General: J.-J. Dordain

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CryoSat-2, ESA's 'ice' mission, scheduled for launch in February 2010. The question of whether global climate change is causing the polar ice caps to shrink is one of the most hotly debated environmental issues we currently face. By monitoring precise changes in the thickness of the polar ice sheets and floating sea ice, CryoSat-2 aims to help answer this question.

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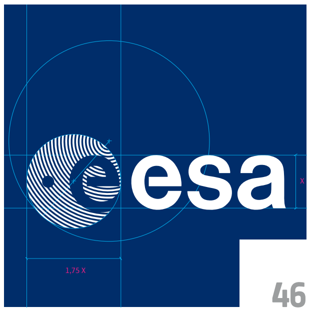

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XMM-Newton in ESTEC

# → 10 YEARS OF DISCOVERY

## Commemorating XMM-Newton's first decade

**Norbert Schartel, María Santos-Lleo, Arvind Parmar & Jean Clavel**
Directorate of Science and Robotic Exploration, ESAC, Villanueva de la Cañada, Madrid, Spain

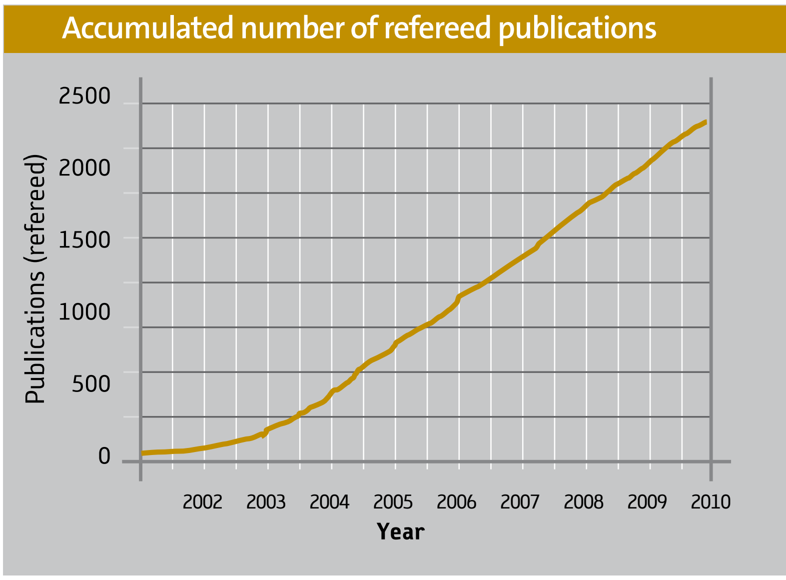
**XMM-Newton has had a major impact on modern astrophysics, with a steady stream of new results. The XMM-Newton spacecraft, instruments and ground segment are ready to continue this success for many years to come, and provide the worldwide scientific community with the means to address many exciting new challenges.**

On 10 December 1999, an Ariane 5 lifted off from Europe's Spaceport in Kourou, French Guiana, carrying the 10-metre long XMM-Newton satellite. On this tenth anniversary, the leading scientific journal *Nature* reviewed the scientific impact of XMM-Newton and NASA's Chandra satellite. While both missions are X-ray observatories, they have very different strengths, with Chandra delivering magnificent images of the X-ray sky and XMM-Newton providing superb spectra. By combining these capabilities, astronomers have the best of all possible worlds.

XMM-Newton continues to be extraordinarily productive. Each year, between 1500 and 2000 scientists use XMM-Newton and publish around 300 peer-reviewed articles in leading journals. As of January 2010, around 2300 scientific papers have been published in major peer-reviewed journals based on data collected by XMM-Newton. Such a high scientific return places XMM-Newton among the most productive space- and ground-based astronomical observatories, including the Hubble Space Telescope.

Another way of judging the success of a scientific mission is by measuring how much scientists want to use it. Each year, scientists from all over the world apply for observing time on XMM-Newton and each year the cumulative amount of observing time requested exceeds by a factor of six or more the total time available. The time allocation committee can afford to be picky and select only the very best observing proposals, thereby contributing to the extraordinary success of the mission.

XMM-Newton has observed all types of astronomical sources, from nearby Solar System objects, such as comets, to some of the most distant objects known in the Universe. Astronomers use X-rays to explore the extreme Universe – matter just about to fall into a black hole, or trapped in the intense gravitational and magnetic fields around a collapsed star, or in giant intergalactic shocks in distant clusters of galaxies. Using XMM-Newton, astronomers have probed the distortions of space–time around black holes and discovered the role that supermassive black holes play in shaping the surrounding galaxies.




## The Solar System

XMM-Newton has also observed X-ray emissions from Mars, Jupiter, Saturn, several comets and from Earth's exosphere, the outermost part of the atmosphere that streams into space.

X-ray emission from comets was only discovered four years before the launch of XMM-Newton. This was totally unexpected, since comets are cold objects and X-rays typically come from sources with temperatures over a million degrees. Thanks to XMM-Newton, astronomers discovered that X-rays are also produced by a mechanism called 'charge exchange' which occurs when a highly ionised atom of the solar wind collides with a neutral atom of the comet gas. This atom captures an electron in an excited state and radiates a characteristic spectral signature as it drops into a less energetic state, which is easily observed by the sensitive instruments on XMM-Newton.

XMM-Newton has shown that Jupiter's aurorae emit copious amounts of high-energy X-rays. Although it had already been predicted theoretically, such an effect could not be detected before, because previous satellites lacked the required sensitivity. Jupiter's emissions have a different origin to that of X-rays from comets. They vary with time, probably as a result of changes deep inside Jupiter's magnetosphere.

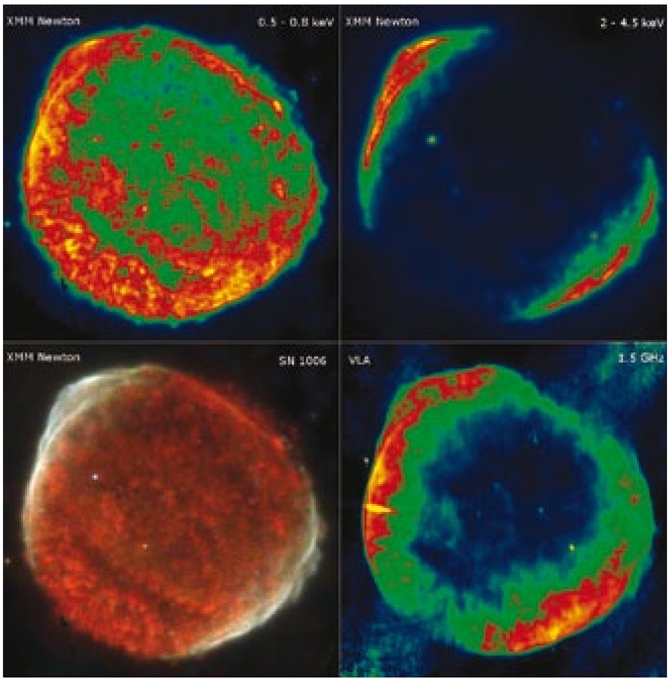
←

The starburst galaxy M82, taken by the Optical Monitor and European Photon Imaging Camera instruments on XMM-Newton, obtained as part of International Year of Astronomy 2009 activities (ESA/P. Rodriguez)

XMM-Newton also observed Mars. In contrast to the compact emission from Jupiter's poles, the faint X-ray halo observed around Mars extends out to at least eight times the planet's radius. This emission arises from charge-exchange interactions in the tenuous martian exosphere, much like those in comets. This was the first definite detection of charge-exchange induced X-ray emission from the exosphere of another planet. Charge-exchange interaction is an important escape mechanism for atmospheric atoms that most likely contributed to the near-complete loss of the martian atmosphere in the early life of the planet.

## The birth and death of stars

Star formation regions are the stellar nurseries where recently born stars coexist with protostars – objects that have not yet had enough time to evolve into stars – and giant molecular clouds that have not begun to collapse to form stars. XMM-Newton has made an extensive study of the nearest star-forming region, the Taurus Molecular Cloud. The cloud contains many 'T Tauri' stars, stars formed so recently that they are still contracting and accreting gas from the molecular clouds. As the gas spirals inward, it settles into a disc around the star. XMM-Newton observations have shown that this cool gas emits intense X-rays when it subsequently crashes into the surface of the star. The X-ray emission is bound to play an important role in the formation and subsequent evolution of planetary system around young stars.

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Supernova remnant SN 1006. The upper images show how the X-ray emission varies with energy. The distribution of the high-energy X-ray emission is strikingly similar to that seen in the radio band (bottom right) (R. Rothenflug/CEA/DSM/DAPNIA/SAP and ESA)

Supernovae are the cataclysmic 'deaths' of massive stars. When a massive star runs out of nuclear fuel, its core collapses, leaving behind a neutron star or a 'black hole', depending on its mass. The resulting 'supernova' explosion ejects the outer layers of the star into space, producing powerful shock waves. The ejected material and the interstellar gas that sweeps away are heated to millions of degrees. Such supernova remnants therefore continue to emit intense X-ray radiation for thousands of years after the explosion. Investigations of the X-ray properties from the supernova remnant Cassiopeia A have concluded that the progenitor star had a mass of 12 times that of our Sun before it exploded. Furthermore, the bulk of the X-ray emission comes from two large clumps of iron-rich gas, which suggests that the supernova explosion was asymmetric and ejected 'bullets' instead of spherical shells.

In 1006 AD, monks at the Benedictine abbey of St Gallen in Switzerland described the observation of a new bright star in the sky. We know today that this was a supernova explosion, now labelled SN 1006. XMM-Newton observed its remnant almost exactly 1000 years later. SN 1006 is a shell supernova remnant, in which X-ray emission originates from electrons spiralling in an intense magnetic field. XMM-Newton measurements indicate that shell supernova remnants are important sites for the acceleration of the energetic cosmic rays that shower down on Earth's atmosphere and can endanger astronauts in space.

Neutron stars have a mass slightly greater than our Sun, but a radius of only a few kilometres. They are effectively whole stars compressed into the size of a city. Their gravity and internal pressures are so high that protons combine with electrons to form neutrons in their interior. Many neutron stars rotate rapidly and emit narrow beams of radio radiation – like a sort of cosmic 'lighthouse'. We detect the radio signal only when the rotating beams point in our direction, resulting in short and periodic pulses of emission, hence the name 'pulsars'.

Thanks to XMM-Newton, it has been possible for the first time to map the X-ray emission from pulsars, leading to the discovery of hot spots on their surface. Such hot spots had been predicted but could not be observed before XMM-Newton. Spectroscopic investigations of the neutron star 'Geminga' revealed a hot spot that is only 60 m across, about the size of a football field. It is amazing that such a tiny

↑ Artist impression showing HLX-1 (blue source to the upper left-hand side of the galactic bulge), located on the edge of the spiral galaxy ESO 243-49, and the strongest candidate to date to be an intermediate-mass black hole (H. Sagerud)

emission region can be detected in a star 500 light years (or 450 trillion km) away! XMM-Newton found hot spots in two further isolated neutron stars. The hot spots have different sizes and properties, varying in phase in one case and in anti-phase in the other. These findings show that the magnetic field and the surface temperature distributions of neutron stars are much more complex than expected.

## Black holes

When a star more than eight times as massive as our Sun explodes as a supernova, it leaves behind a black hole. There are many of these stellar black holes within our galaxy, detectable via X-ray emission from gases heating up as they fall into the black hole. However, there is another sort of black hole, with masses in the range from millions to billions of solar masses.

These 'heavyweights' are located at the very centre of galaxies, such as in our own Milky Way. Understanding how these supermassive black holes form and their interaction with the surrounding galaxy is a key question in astronomy today.

The only way to assemble supermassive black holes is by repeatedly merging stellar-mass black holes together, and so we would expect to find many black holes of intermediate masses, say a few hundred times the mass of the Sun. Until recently however, the hunt for such intermediate-mass black holes had been unsuccessful. Several candidates had been proposed, but none confirmed. It is only recently that astronomers, using XMM-Newton, could finally claim success. They detected an X-ray source in galaxy ESO 243-49, called HLX-1, whose emission varies strongly and rapidly, implying that it originates from one single compact object rather than from a collection of unresolved independent sources.

Furthermore, the measured X-ray luminosity is so large that it can only come from a black hole whose mass is at least 500 times that of the Sun. This means that HLX-1 is the first definitive example of the long-sought intermediate-mass black holes.

Stellar black holes often exhibit rapid variations of their X-ray flux that are almost, but not exactly, periodic (hence they are called quasi-periodic oscillations, or QPOs). The importance of this quasi-period is that it provides a direct measure of a fundamental scale in the source, such as the time it takes for a hot blob of gas to complete one revolution around the black hole. In other words, QPOs provide a yardstick with which we can estimate how the size and mass of black holes. For the last 25 years or so, scientists have also been searching for quasi-periodic oscillations in active galactic nuclei (AGN) and 'quasars', which are known to surround supermassive black holes. Their hunt was unsuccessful until, in 2008, thanks to its large sensitivity, XMM-Newton discovered quasi-periodicity in the X-ray emission from a bright AGN. Whereas oscillations in stellar black holes typically occur on a timescale of milliseconds, the AGN quasi-periodicity is about one hour, roughly a million times longer. This is consistent with the fact that massive black holes at the centre of AGNs are also about one million times larger and more massive than their stellar cousins.

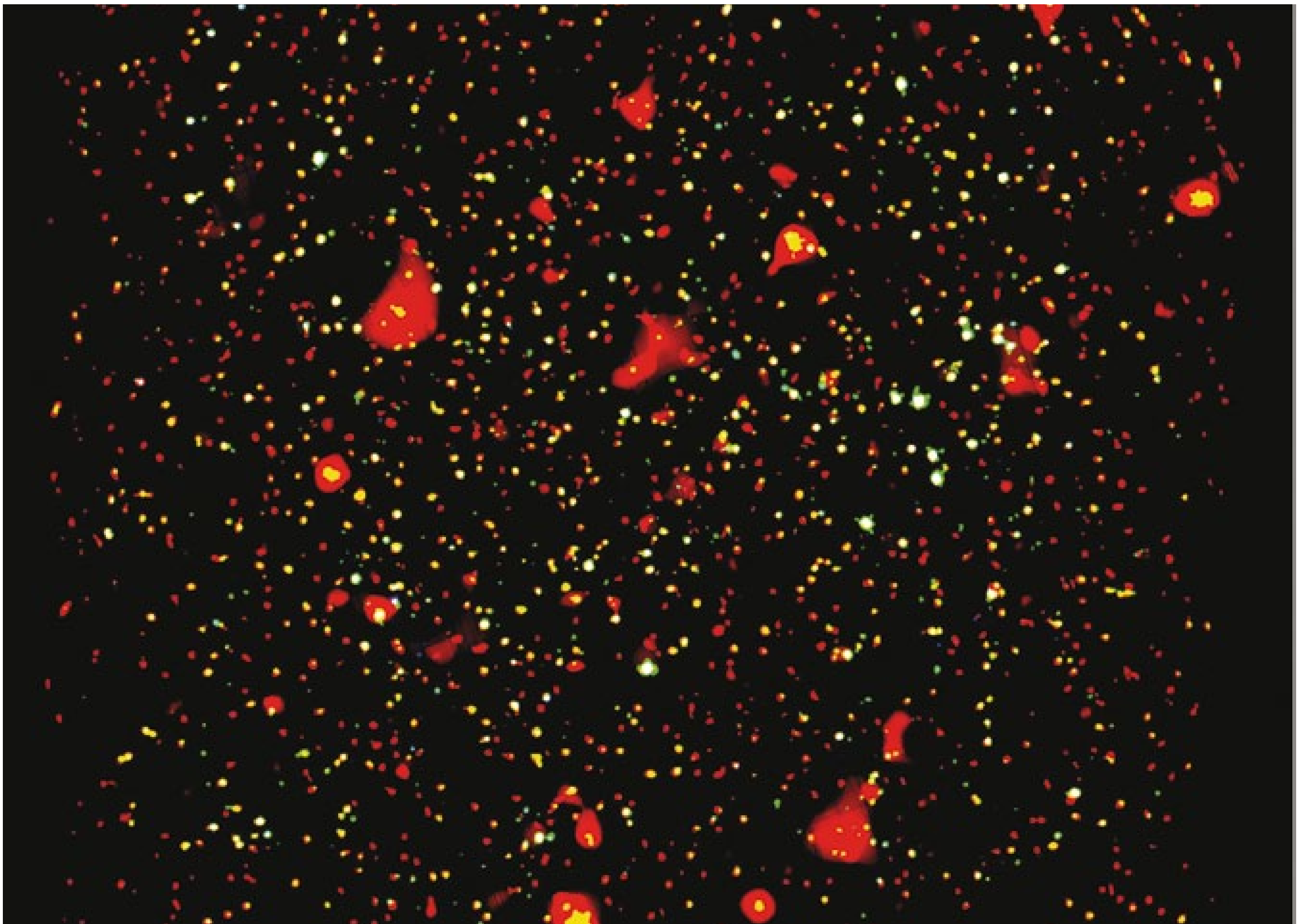
## Galaxy clusters

Clusters of galaxies are the largest bound structures in the Universe and can contain many thousands of galaxies. But galaxies contribute only about 5% of the cluster mass. About 80% consists of 'dark matter', an unknown substance which is invisible, but reveals itself only through the gravitational pull it exerts on normal matter.

The hot gas emits intense X-rays, making clusters among the brightest sources of the X-ray sky. Theory predicted that, pulled by gravity, intergalactic gas would accumulate toward the centre of the cluster and become denser and cooler than at the periphery. Much to everyone's surprise, however, early XMM-Newton observations immediately ruled out the existence of such cooling flows. Indeed, the emission line characteristics of a cool gas were completely missing from the observed clusters' X-ray spectra.

Investigators concluded that some unknown mechanism existed that was able to warm up the gas and prevent it from cooling as it accumulated toward the centre of the clusters. Here, deep images obtained with Chandra played a significant role, as they revealed gigantic jets and winds originating from the AGN located at the centre of the cluster. Calculations immediately showed that such jets inject tremendous amount of energy into the intergalactic gas, thereby keeping it warm. The emerging picture is therefore that of a self-controlling 'cosmic feedback' machine: as intergalactic gas cools and falls towards the central galaxy in the cluster, it piles up in the vicinity of the supermassive black hole which lies at its centre. A fraction is eventually swallowed by the black hole but excess amounts of gas are ejected back into the intergalactic

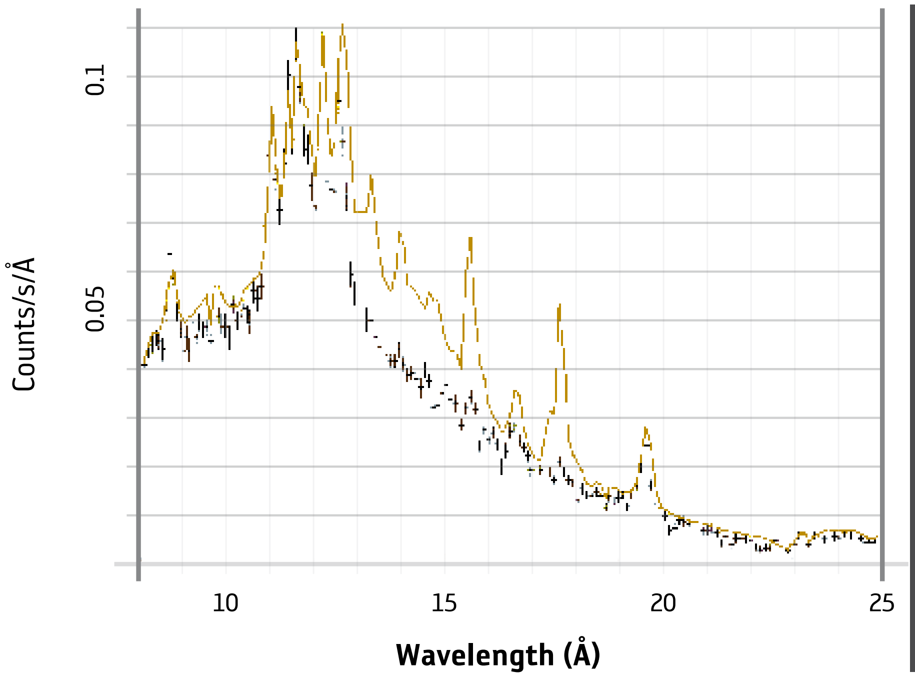
↓ This false X-ray colour image is XMM-Newton's view of the deep Universe, showing thousands of faint X-ray sources in the XMM-COSMOS survey field. Most of the sources are distant active galactic nucleii with about 10% being extended clusters of galaxies (G. Hasinger/N. Cappelluti/XMM-COSMOS/ESA)



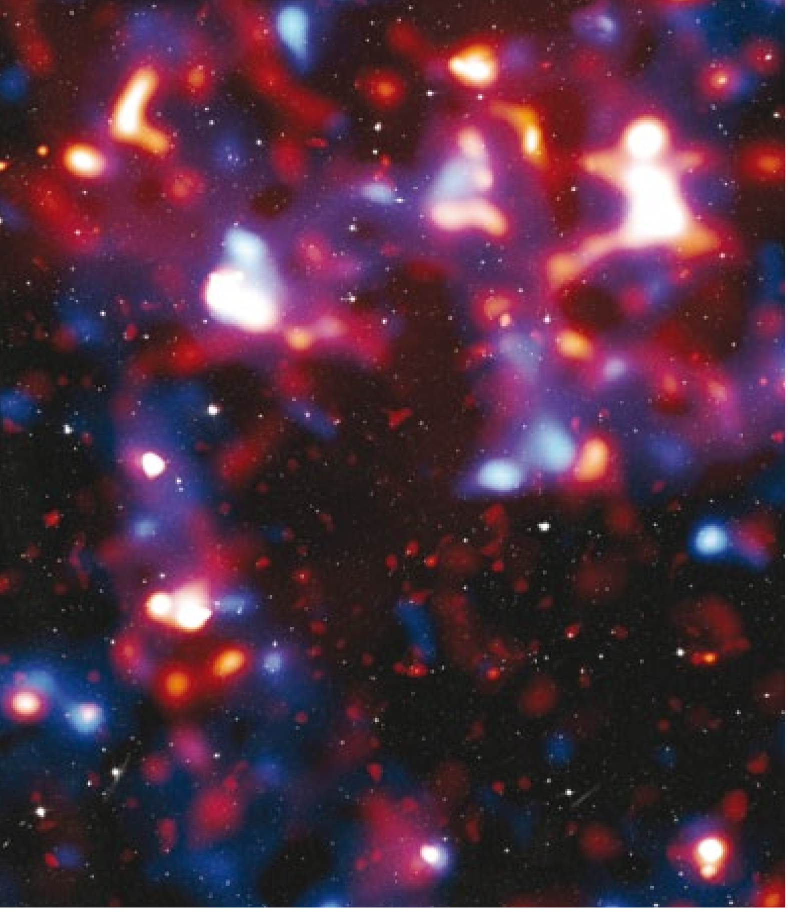
↑ Composite of XMM-Newton and Hubble Space Telescope colour images of NGC 7009, the Saturn Nebula, showing the hot X-ray-emitting gas (blue) relative to the cool, ionised nebular shell seen in visible wavelengths (M. Guerrero, Univ. Illinois/ESA)

medium in the form of jets and winds that then heat the gas. Since it cannot cool, the gas stops raining toward the central galaxy in the cluster. Without inflowing material, the black hole is starved and shuts down its wind and jet. A new cycle is thus ready to start.

This mechanism is of central importance in astrophysics today, because it connects clusters of galaxies, galaxies and the supermassive black holes at their centres. All these objects were previously thought to evolve independently. Now we have a mechanism that not




← An XMM-Newton spectrum of the cluster of galaxies 2A 0335+096. The black crosses are from the Reflection Grating Spectrometer and the red line shows the predicted spectrum from previously favoured cooling models. The difference between the two reveals the lack of cool material and indicates that the cluster core is much hotter than predicted (J. de Plaa/SRON/ESA)



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The distribution of normal matter (red) determined mainly by XMM-Newton, dark matter (blue) and the stars and galaxies (grey) observed with the Hubble Space Telescope. It shows that normal matter, mostly in the form of clusters of galaxies, accumulates along the densest concentrations of dark matter (NASA/R. Massey, Cal. Tech./ESA)

only connects them, but also even regulates and somehow coordinates their growth. The discovery of this mechanism is as fundamental for the understanding of galaxies and clusters as was the discovery some 60 years ago of nuclear fusion for the understanding of stars.

## Dark matter and dark energy

The new millennium has seen a revolution in our understanding of the nature of the Universe. Astronomical observations have shown that only 4% of the Universe consists of the normal matter, the atoms and molecules we are used to here on Earth. Another 23% is made of the mysterious 'dark matter', while the remaining 73% of the Universe consists of the even more mysterious 'dark energy'. X-ray observations have made important contributions to this revolution and a deeper understanding of these mysterious components is one of the most promising areas for future missions such as the International X-ray Observatory.

By combining deep XMM-Newton and Hubble Space Telescope observations of the same region of the sky, scientists were able to reconstruct the first three-dimensional large-scale map of the distributions of both normal and dark matter. On such large scales, the Universe appears patchy, with matter distributed along a gigantic network of filaments and clumps. Clusters of galaxies – normal matter – tend to concentrate toward the nodes of this network where the density of dark matter is the highest. These observations provide a striking confirmation of current models of structure formation in the Universe, whereby normal matter is pulled by gravity toward concentrations of dark matter, where it collapses to form stars and galaxies.

## The future

As we look into the future it is difficult to predict with any reliability the next major areas of discovery and impact, although it is probable that deeper and wider surveys with XMM-Newton will yield a wealth of new discoveries. There are potential investigations that span from the study of the large-scale structure of the Universe to understanding the sub-nuclear composition of neutron stars.

Targets of interest extend from the Sun's wind to deep surveys of the extragalactic sky to provide a complete census and evolutionary history of AGN. In addition, long uninterrupted studies of broad emission lines emitted near black holes will furnish unique insights into strong gravity. Long observations of individual galaxy clusters will probe and refine our understanding of the feedback mechanism by which the energy from AGN is coupled to the intra-cluster gas temperature and density.

The scientific return from XMM-Newton will continue to be enhanced by collaborations with ground-based and other space telescopes. Understanding the birth of stars and planetary systems is one of today's most important astronomical topics. Combined X-ray, infrared and sub-millimetre measurements from ESA's Herschel and XMM-Newton observatories and ground-based facilities will be crucial to studying accretion and outflow processes in young stars and proto-planetary discs.

The nature of dark energy will be investigated by X-ray observations of distant galaxy clusters, such as those being discovered with ESA's Planck satellite. As a matter of fact, the growth rate of galaxy clusters, as a function of cosmic time, is a sensitive measure of the relative strengths of dark matter (which causes the clusters to collapse) and dark energy (which causes them to expand). Measuring the interplay between these two forces and how it varies with time will undoubtedly shed light on this mysterious stuff that makes up 96% of the Universe. ■

# → ESA'S ICE MISSION

## CryoSat: more important than ever

**Richard Francis, CryoSat Project Manager**
Directorate of Earth Observation, ESTEC, Noordwijk, The Netherlands

In 2005, the first CryoSat satellite was destroyed in a launch failure. However, following its loss, the mission was judged to be even more important than when it had first been selected, and approval to rebuild the satellite was secured within a record-breaking four months.

←

The launch of CryoSat in October 2005

During the evening of 8 October 2005, a Rockot launch vehicle lifted off from the Plesetsk Cosmodrome, some 800 km north of Moscow. This rocket was carrying CryoSat, ESA's first Earth Explorer 'Opportunity' satellite intended to measure changes in the thickness of Earth's ice fields: both ice caps – thick domes of ice resting on land – and sea ice floating in polar oceans.

As expected, telemetry was lost from the launcher some eight minutes later as it travelled towards the North Pole, out of range of the receiving station at Plesetsk. After passing into radio silence, there were almost 90 minutes to wait before we could expect the upper composite of CryoSat and the rocket's third stage to travel around the Earth and into range of the Redu ground station in Belgium, with slightly later acquisition at Villafranca in Spain and then Kiruna in Sweden.

Separation from the third stage would occur five minutes after this acquisition of signal, when the satellite would be in range of Kiruna.

No signal was received.

The ground stations tried to acquire the signal, some using a search pattern to 'sweep' the expected region of the sky. Then a series of 'blind' telecommands was sent in an attempt to reconfigure the satellite's telemetry system. Searching and commanding was continued from four ground stations (including Svalbard, which was due to acquire after Kiruna) for the duration of the nominal pass: almost 20 minutes.

It proved impossible to learn whether the launcher authorities had received any signal from the third stage, so we were unable to tell if it was a satellite failure, a launch into a grossly wrong orbit or a launch failure. The Flight Dynamics team at ESOC in Germany computed a possible orbit, based on a theoretical failure of the apogee boost burn of the third stage. So, in the second pass, over an hour after the first, the four ground stations made a search based on this orbit and again sent blind commands to reconfigure the telemetry system.

But now, some three hours after launch, reports started appearing on the Internet of a launch failure. A specific failure mechanism was identified, which lent them credibility. Nevertheless, ESOC continued trying to contact the satellite even though the prospects of success were bleak. Eventually, about four hours after launch, the Russian authorities made their first announcement of a launch failure. The Internet reports were confirmed.

## CryoSat background

*ESA Bulletin* 122, May 2005 (www.esa.int/SPECIALS/ESA_Publications/SEMLML6DIAE_0.html)
More information at: www.esa.int/cryosat

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The last view of CryoSat, only minutes before it was destroyed

## Fiery destruction

After liftoff, the Rockot launcher had discarded its first-stage booster and then the fairing, which protects the payload during its ascent through the atmosphere.
At 298 seconds after launch, the shutdown of the second-stage cruise engine was due, before its separation. However, the command for this shutdown was not sent to the second stage, so the engine continued to burn until all its fuel was used up. This resulted in an unknown, but catastrophic, event that started a severe tumbling motion.

Some 10 seconds later, the deviation in pitch exceeded the specified limits: this was the trigger to issue a mission failure command from the onboard computer. All further onboard commands stopped and the composite of second stage, a fully fuelled third stage and CryoSat continued on an unpowered ballistic trajectory, tumbling in all axes.

At the time of the failure, this composite was travelling at more than 5 kilometres per second (18 000 km/h), at a height of almost 200 km. The spacecraft effectively underwent a full reentry into the atmosphere, combining severe g-forces, continued tumbling and the fury of reentry heating. Somewhere in the upper stratosphere, this punishing combination inevitably caused a rupture of the fuel tanks in the vehicle's third stage.

The full load of propellant then exploded, completing the job of destroying CryoSat. The remains fell within the planned second-stage drop zone, close to the North Pole, just over 12 minutes after liftoff. The subsequent investigation rapidly identified the cause of the failure: two onboard commands had been incorrectly juxtaposed. The error was undetected because of inadequate testing: the validation process used was unable to detect this fatal condition.

## Picking up the pieces

Following the failure, there was an immediate consensus that the lost satellite should be replaced. But transforming that consensus into a practical implementation required considerable effort and goodwill from all those involved: industry, the science community, the delegations of our Member States and ESA.

Resources needed to be found. It was important to demonstrate that funding would not require any 'new' money. By reallocating some existing budgets, delaying some activities and exploiting synergies, this turned out to be possible. Another important resource was staff: most of the team had already been earmarked for other projects, but again this was solved.

We also had to move quickly to set up the legal and contractual basis of the project. Almost immediately we were able to order the 'long-lead items', that is, items that have a long delivery time. Some of the high-reliability electronic parts have delivery times of up to a year, so ordering early would be very important to maintain a reasonable schedule.

A significant coordinated effort was needed to establish all of the technical documents that define the industrial work (which is necessarily different for a rebuild), the preparation of a binding offer by industry, and the evaluation and eventual negotiation of this offer. In preparing these documents, a fundamental question was the extent to which improvements in the satellite might be implemented.

The main payload, the SAR/Interferometric Radar Altimeter (SIRAL), had been the only single instrument on the original CryoSat, and it was full of 'single-point failures', that is, single components whose failure would cause the loss of the whole instrument. It was an easy decision.

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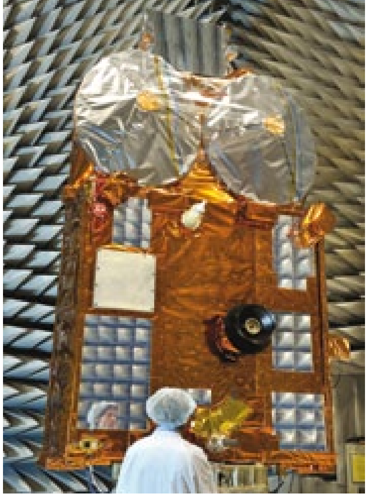
CryoSat-2 during testing at IABG



We would implement full redundancy in this payload. Parts of the original satellite design were obsolete, both at the level of components and in some complete pieces of equipment. Here there were no options: they had to be replaced by current designs. With these changes in place, it was a minor decision to rectify a number of shortcomings in the original design, found during system testing and to make improvements in operability of the satellite. Usually these improvements took the form of small changes to the central flight software.

## → CryoSat more important now than ever

It is over ten years since Prof. Duncan Wingham (Professor of Climate Physics and Head of Earth Sciences at University College London) first proposed the CryoSat mission. It was selected from about 30 proposals to become ESA's first Earth Explorer Opportunity mission. Our level of knowledge about the polar regions has changed a lot during this time, and, for that matter, so have the polar regions themselves. In 2006, during the process of approving the rebuild, the question was first raised, "Is CryoSat still relevant?" The unequivocal response from independent scientific advisors was, "CryoSat is more important now than when it was first selected."

Almost four years after that statement, the situation is still evolving. On one hand, the signs of change in the polar regions continue unabated, while on the other, our ability to extract subtle details from satellite data is still improving.

## → A decade of climate change

One of the most dramatic signs of climate change is in the extent of Arctic sea ice. Since 2000, the area covered by sea ice in the summer has reduced drastically.

The absolute minimum occurred in September 2007, and 2008 would have been a new record if it had not been for 2007, and 2009 was similar. These great reductions in the area of sea ice in the middle of the summer are much worse than expected if we simply extrapolated from the previous trends.

There are several factors involved: the prevailing winds have a great influence (floating ice can be simply blown out of the Arctic Ocean, passing Greenland and Iceland and disappearing into the Atlantic). Thermodynamics is also playing a role: as the amount of ice reduces, more heat is absorbed by the ocean in summer, and consequently less ice formed by freezing in winter, accelerating the trend in reducing ice cover.

While these reductions in the area of sea ice are readily observable using a variety of satellite remote-sensing techniques, there is only one practical way of converting this knowledge of sea-ice area into the *amount* of sea ice. We need information about the thickness of the ice, and the only way to measure that on a large scale is by satellite. This is where CryoSat comes in.

Apart from floating sea ice, the other characteristic manifestations of ice in polar regions are the ice caps: thick domes of ice resting on land, from relatively small islands up to the complete continent of Antarctica. The two largest, Antarctica itself and Greenland, are several kilometres thick and, at the summits, very cold.

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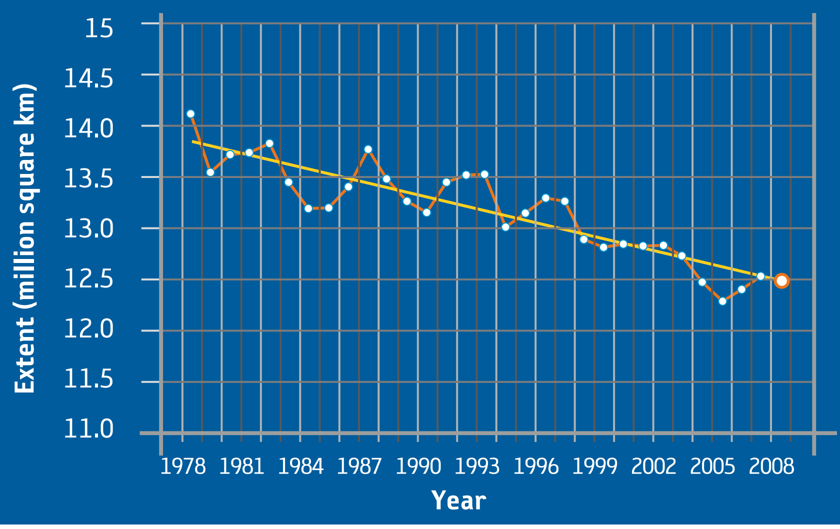
Monthly December ice extent for 1979 to 2009, showing a decline of 3.3% per decade. December 2009 had the fourth-lowest average ice extent since the beginning of satellite records (NSIDC)



Some updates were required in the ground segment too. These were partly a direct consequence of the updates in the satellite design: for example, a means of handling the two redundant radar systems had to be developed and implemented.

Other changes were needed to avoid obsolescence and to improve the way corrections for environmental effects are made, in common with other satellites such as Envisat.

## A better CryoSat

The radar on the original CryoSat was 'non-redundant'. If any part failed, there was no back-up and the radar would stop working. Of course, the electronics had very high reliability, but you can never be sure that a random failure, however unlikely, would not happen. This contrasted with the rest of the satellite where there was spare equipment for every function. This follows normal practice with space missions.

Thus they may seem immune to the influence of a few degrees of global temperature rise. Indeed, prior to 2000 the indications were that these major ice-caps were largely stable, at least in their interiors. The principal means of determining this was, again, satellite altimetry. However, the capabilities of such instruments to measure change at the ice cap margins, where most change is expected, is limited by their design.

But, already by 2006, skilled analysis of the existing altimeter data was teasing out details that were beginning to cast doubt on this picture of stability. A very large glacial basin at the coastal boundary of West Antarctica, the Pine Island Glacier, was sufficiently large that it could be resolved in the conventional altimeter data. And the ice was thinning.

In the years since 2006, this thinning has been characterised and linked to Synthetic Aperture Radar (SAR) interferometry measurements of ice flow, which show an increased flow rate into the sea. The rate of thinning is stunning, at about 16 m per year.

While this has been reported by several groups, it has been put into perspective by the late-2009 report by the Scientific Committee on Antarctic Research, *Antarctic Climate Change and the Environment*, which projects a sea-level rise of about 1.4 m by 2100, significantly higher than the well-known 28–43 cm projections of the Intergovernmental Panel on Climate Change. The difference is largely attributable to melting of the ice-caps at their base by warming oceans.

Change is not limited to Antarctica. Greenland, being smaller and at lower latitudes, may be even more vulnerable. Gravity measurements from the NASA/DLR GRACE mission have revealed large-scale mass changes and even sensitive GPS receivers placed around the coast show signs of uplift as the burden of ice is reduced.

So indeed, in the decade since the CryoSat mission was proposed, the signs of change in the polar regions have become unambiguous and this trend is also clear in the four years since CryoSat-2 was approved.

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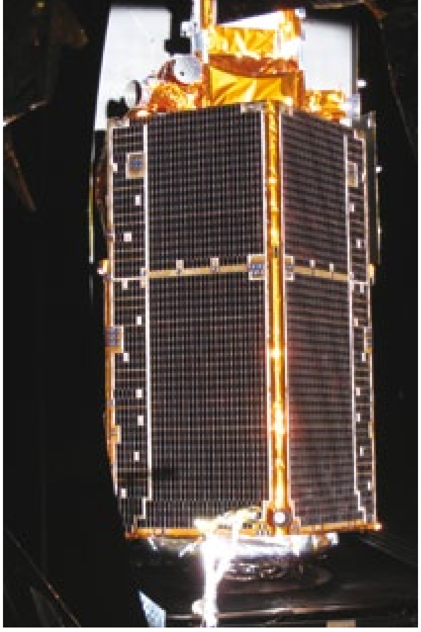
Antarctic ice meets the ocean, Pine Island Glacier seen from the air in November 2009 (Jim Yungel/NASA)



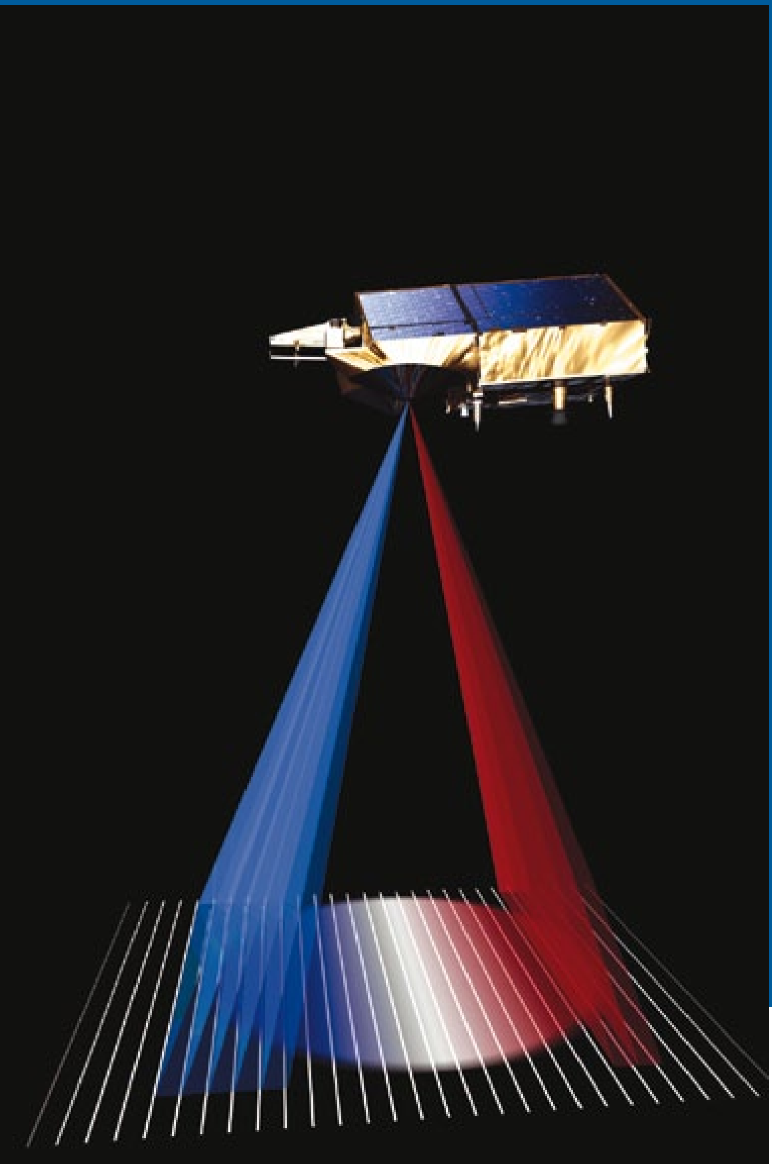
CryoSat-2 in the solar simulation chamber at IABG's facilities in Ottobrunn, Germany, 2009

The reason why the SIRAL was non-redundant was simply down to cost. The radar represented a significant portion of the overall cost and providing an onboard spare would have exceeded the strict limit on cost placed on the mission. This decision was hotly debated during the development phase, and it was perhaps this debate that triggered one comment after the launch failure, that "Non-redundancy saved us quite a lot of money!"

There was, however, no debate when it came to the rebuild. If we could afford to rebuild the mission, we could not afford to risk losing it again due to a single component failure. So CryoSat-2 carries a redundant SIRAL. This has introduced a few complications.

## → So how will CryoSat help?

When it was proposed, the objective of CryoSat was to distinguish between the genuine trends in ice thickness and, quoting the proposal, 'the ephemera of inter-annual variation'. Ten years on, there seems little doubt that there are trends: now the challenge is to better characterise them, and extend our knowledge to more intractable surfaces.



To understand how a reduction in area of sea ice may be linked to the amount of ice, a means of measuring sea-ice thickness over a large area is needed.

As far back as 1998, Dr Seymour Laxon of University College London developed a way to distinguish between the radar echoes from floating sea ice and those from the ocean in which they float. The difference in height is not much, some tens of centimetres, but using a more elaborate version of the well-known idea that 7/8 of an iceberg is underwater, this measurement enabled the ice thickness to be estimated.

This is fine in theory but, in practice, it has proved tricky to fully exploit the technique, because the 'footprint' of the radar instruments on satellites used so far (ERS and Envisat) is so large that it is difficult to distinguish ice from open water, given that many of the open water 'leads' are relatively narrow. Thus the probability of retrieving the sea-ice thickness is about 0.1 and there are many gaps in the existing measurements.

Given Laxon's success in measuring sea-ice thickness at all, Wingham recognised that the method could be usefully improved by changing the characteristics of the radar, so that the sampling area was very much reduced. Studies of such a radar concept were already under way with European industry. This is one of the several key innovations of the CryoSat mission.

Returning echoes from the radar 'footprint' can be processed to separate them into strips arranged across the track by exploiting the slight frequency shifts (caused by the Doppler effect) in the forward- and aft-looking parts of the beam (AOES Medialab)

The number of onboard connections has multiplied significantly: for example, where there were two connections from the main and redundant power source, there are now two for each SIRAL, making four in total. The SIRAL is connected to a lot of other equipment: the central computer, high-speed data lines to the onboard mass memory, a frequency reference from the DORIS receiver, several power supplies, and so on.

There was a further consequence of this decision. The systems on the ground that control the satellite and process its data had been built on the assumption of one radar. Now there are two and, inevitably, they are subtly different.

The precision of the measurements made by these radars is astonishing: better than one part in a hundred million, so it is not surprising that subtle differences in their characteristics have to be taken into account.

This is handled by a database of many parameters. But now the ground system had to recognise which radar was providing the data it had to process and call up the correct database.

**The timing of the radar pulses is increased so that pulses, sent in rapid bursts, result in echoes that are correlated, since the geometry is effectively frozen during the burst. Then complex processing, exploiting the Doppler properties of the echoes, enables a sharpening of the along-track resolution to about 250 m. This 'synthetic aperture radar' (SAR) mode will enable a great improvement in the discrimination of sea ice and the leads between the floes, with the expectation that the probability of retrieval will be increased.**

**Combined with an increase of geographic coverage of the CryoSat orbit, extending to latitudes of 88° North and South, compared with 82° for the sun-synchronous ERS and Envisat orbits, this will represent a great improvement of the regions where sea-ice thickness can be reliably determined.**

**We have already seen that the challenge in understanding changes in the ice caps lies at their edges. Pine Island in Antarctica is a huge drainage basin but there are many smaller ones. The increase in spatial resolution afforded by the SAR mode is a great help but there is also the problem, over such varied topography, that the point we measure today may not be the same point that we measure next time, so that determining the height difference is misleading. This problem arises because the radar altimeter naturally measures range to the closest point on the surface. If the ground track is not identical (and it never is) then such a point may be a hillock to the side of the track, and a different hillock next time.**

**CryoSat solves this problem with an innovative technique. In a variant of the SAR mode, called the SAR Interferometry mode (SARIn for short), it uses a second antenna and receiver. The phase difference between the signals received by these two systems is a function of the angle of arrival of the echoed signal. With precision electronics and clever data processing, this can be exploited to determine exactly where on the surface the echo came from, allowing a much more confident determination of surface elevation change.**

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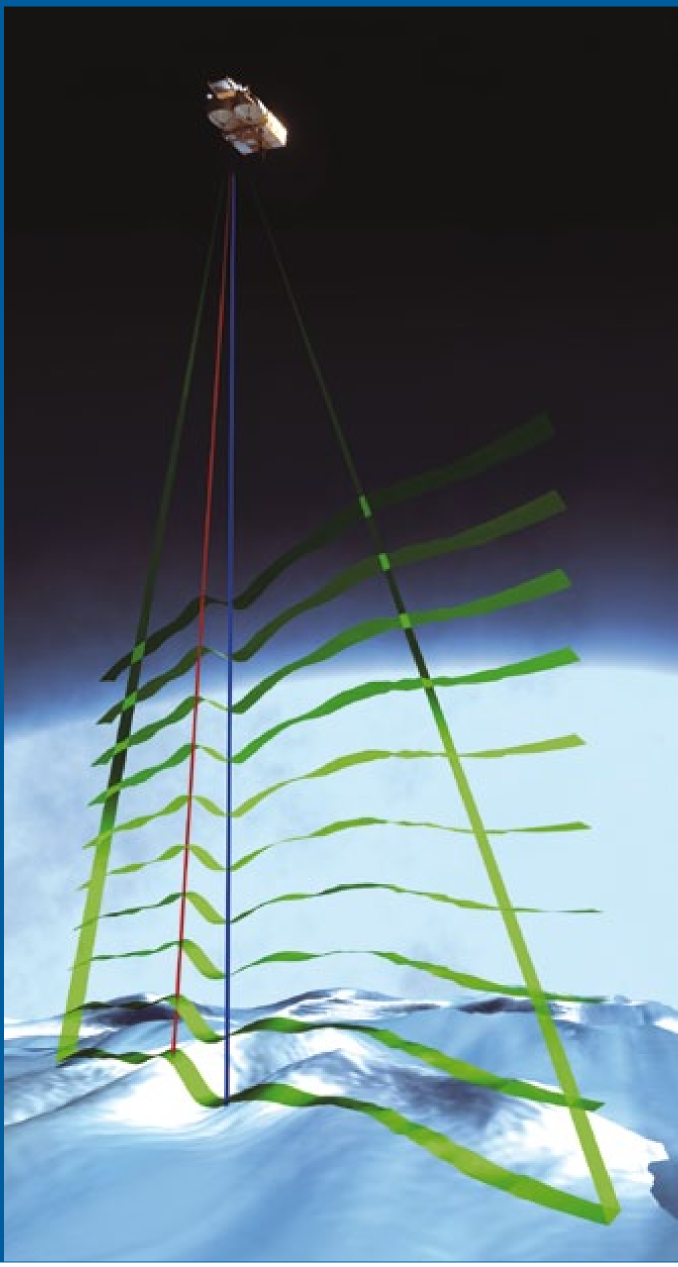
Over topographic surfaces, the first radar echo comes from the nearest point to the satellite. CryoSat can measure the angle from which this echo originates, so that the source point can be located on the ground, allowing the height of that point to be determined (AOES Medialab)



→ Launch of a Dnepr rocket (Kosmatras)

This may sound simple, but finding all the places affected, making the process work and testing everything were not so trivial.

There is another, very obvious difference between CryoSat-2 and its earlier sibling. CryoSat-2 will be carried into space on a different launch vehicle. It is misleading to assume that this change was a result of the previous failure. In fact, we were completely satisfied that the cause of the CryoSat launch failure had been effectively found and cured. Indeed, last year, Rockot launch vehicles put two other ESA Earth Explorer satellites into orbit: GOCE in March and SMOS in November 2009.

The problem was instead one of availability. It was not possible to obtain a Rockot within the timescale we needed and so, in early 2008, we switched to a back-up launcher: the Dnepr. Like Rockot, Dnepr is also based on a Russian missile design, in this case the SS-18. Unlike Rockot, it is launched from a silo, being expelled like a mortar round with a charge of black powder, before the main engine ignition some 30 m above the ground. CryoSat-2 will experience this unusual and, we have to admit, rather nerve-wracking launch from the Baikonur Cosmodrome. The launch is scheduled for 25 February.

## Four short years

The CryoSat-2 rebuild began in March 2006. In February 2010, just under four years later, it will be launched. Of those four years, the first year was spent consolidating the design updates and starting to build the pieces, leading up to delivery of the structure a year after the kick-off. During the second year, the equipment was delivered and gradually installed and checked out. In the third year, in mid-2008, the satellite was shipped to the test centre in IABG where it remained until being shipped to the launch site in January 2010. The satellite had been in storage for nine months because of the scheduling of the launch.

At the end of a short launch campaign, the satellite will be projected into space, to continue the mission that was so unfortunately interrupted in October 2005.


← CryoSat-2 in cleanroom at IABG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Europe at night, a composite of Earth observation images from orbit (www.nasaimages.org)

# → SPACE FOR SECURITY AND DEFENCE IN EUROPE

## Strengthening commitment in an evolving context

Luca Del Monte, Florent Mazurelle, Erwin Duhamel & Charlotte Mathieu
Office for Security Strategy and Partnership Development, DG's Policy Office, ESA, Paris

**Europe's involvement in security is developing, both politically and operationally, and ESA has an important role to play in giving Europe the space-based tools it needs for the delivery of its political priorities in security.**

With the endorsement of the 'European Security Strategy' (ESS) in 2003, European Member States have committed to provide the European Union (EU) with the policy framework to tackle contemporary security challenges, whether inside Europe or abroad.

The relevance and importance of space to Europe's security is today a well-recognised dynamic. The European Space Policy (ESP), supported by Member States through a parallel Space Council Resolution, clearly stated that space assets are instrumental and strategic for the delivery of European security and defence policies.

The European Commission (EC) has recently reaffirmed the fundamental role space has in the scope of European security. On 15 October 2009, José Manuel Durão Barroso, the recently re-elected President of the EC, declared that space would be one of his priorities, including in security and defence, stating that, "We need more security in space and from space. Our space assets and infrastructure are indispensable for our economy and security and we need to protect them."

Mr Barroso continued, “The EU should develop an independent capacity to monitor satellites and debris orbiting Earth and the space environment, and tackle possible hazards. We should also exploit the potential of space infrastructure (already available, for example through GMES) to protect our citizens and our ground infrastructure against natural and manmade hazards and to be at the service of European Security and Defence Policy goals. These capacities should be developed in partnership with Member States.”

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Mr José Manuel Durão Barroso, President of the EC, declared that space would be one of his priorities (C. Coelho)

## The European security context

Since the establishment of the Common Foreign and Security Policy (CFSP), Europe’s security dimension has gradually developed to cover an increasing number of areas. The CFSP, established by the 1992 European Union Treaty pursues five main objectives: safeguarding the common values and fundamental interests of the Union; strengthening the security of the Union; preserving peace and international security in accordance with the UN Charter; promoting international cooperation; and developing democracy and the rule of law, including human rights.

The European Security and Defence Policy (ESDP), formally launched by the Cologne European Council in 1999 as a distinctive part of the CFSP, is the operational security component of the CFSP. It completes and strengthens the EU’s external ability to act through the development of civilian and military capabilities for international conflict prevention and crisis management at international level, thus helping to maintain peace and international security, in accordance with the United Nations Charter.* The 1997 Amsterdam Treaty provides for the objective of strengthening ‘the security of the Union in all ways’ as one of the five fundamental objectives of the CFSP and further incorporated the Western European Union’s ‘Petersberg Tasks’ (humanitarian and rescue tasks, peacekeeping tasks and tasks of combat forces in crisis management, including peacemaking).

Europe’s ESDP strategy relies on the ESS of 12 December 2003, as recently reinforced in late 2008. One of the challenges the ESS has set for Europe is to increase its capabilities, by making a more effective and coherent use of resources, avoiding duplications and by pooling assets. In order to do so, EU Member States created the European Defence Agency (EDA) in 2004, under the policy control of the General Secretariat of the EU Council, ‘to support the Member States and the Council in their effort to improve European defence capabilities in the field of crisis management and to sustain the European Security and Defence Policy as it stands now and develops in the future’.

The civil and military dimensions of European security policy translate into a complex EU institutional framework of decision-making and responsibilities, with a clear institutional difference between civil and military dimensions of security. The EU Council, its General Secretariat and the EDA all play a significant institutional role in the delivery of Europe’s security policy, but the EC plays an equally substantial task through its various policies. Several Directorates General of the Commission therefore have a security mandate (such as DG-Environment with civil protection, DG-Enterprise for security and space), or agencies with crisis management responsibilities (such as Europol for police, Frontex for border control, EMSA for maritime safety). EU processes are slowly being rationalised to take into account the increasingly ‘hazy’ border between

*In terms of operations, as of November 2009, the EU has been actively engaged in 13 ESDP missions, from Bosnia-Herzegovina to Congo, from Georgia to the seas off the coast of Somalia, in either civilian or military operations, sometimes both depending on the mission’s objectives (e.g. the 2005–6 civilian mission and military operation in support to AMIS II in Sudan/Darfur). Since 2003, the EU has engaged in 23 ESDP missions (military and civilian). These external actions are the backbone of Europe’s role in the world and the expression of its commitment to international law, multilateralism, world peace, stability and security in the scope of the UN Charter.

→

Keeping a watchful eye, the crew of a Greek frigate joined French, British and German naval vessels off the coast of Somalia in January 2009 (EUNAVFOR/EU) civil and military capabilities and operations, as illustrated by the recent creation within the EU Council of the Crisis Management and Planning Directorate.

Regarding crisis management, areas such as civil protection, humanitarian aid, crisis response, maritime safety, or climate change** are among the areas coordinated by the EC. Crisis management is already well integrated into EU activities, whether in policy-making, prevention, preparedness or reaction. As an illustration, in 1991, the EU began a process for improving mutual aid between Member States in the event of natural or technological disaster. The Community Action Programme for civil protection began in 1999, followed in successive phases by the establishment of a mechanism to facilitate reinforced cooperation in civil protection assistance interventions, and by a dedicated Civil Protection Financial Instrument.

**As highlighted by the Space Council on 26 September 2008, "The European Council welcomed on 14 March 2008 the joint report from the High Representative and the European Commission on Climate Change and International Security which in particular recalled that the majority of UN emergency appeals for humanitarian aid in 2007 were climate related, and identified the multiplier effect of climate change on security risks."

## The growing political momentum and coordination

The political momentum regarding space and security has gradually increased with the turn of the century. The European Parliament made clear that one of the main attractions of space is to enhance the planning and implementation of defence operations and to assist in conflict prevention, identifying humanitarian crises or enhancing the surveillance of sensitive facilities.

Moreover, while a dedicated 2004 'ESDP and Space' paper from the EU Council General Secretariat to the Committee of Permanent Representatives highlighted the added value space assets had in security at European level, further momentum was achieved with the ESP which mandated ESA to provide the EU with the appropriate space tools required for the efficient delivery of its policies including security. As recalled by the European Parliament, "Space policy must not be seen solely in terms of ESDP. The security implications are far wider."

> **The strategic mission of a European space policy will be based on the peaceful exploitation of Outer Space by all states and will seek to meet Europe's security and defence needs as regards space.**

The ESP and EC/ESA Framework Agreement, which provides for the possibility of conducting joint 'security' activities in its Article 2.3, have been instrumental in strengthening and organising this area of activity, by linking space applications to policy requirements.

Today, with a sustained ESA/EU cooperation, expectations are that space for security activities will grow, including in situational awareness and crisis response, being understood that ESA's space for security activities remain politically dependent upon European security and defence policy and associated political ambitions and constraints.


The approach is thus to focus on *capabilities*, based on clear user requirements, thorough gap analyses and common capability objectives (for example, in command, control, communication, information, advance alert, etc.). Namely, ESA's added value in security and defence is its ability to enhance synergies by integrating security-related requirements, as gathered by the most appropriate and mandated civil and military organisations into the design of European space programmes.

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ESA Director General Jean-Jacques Dordain in discussion with Adam Sowa, EDA Deputy Chief Executive, and Claude-France Arnould, Deputy Director General CMPD of EU Council, at the 'Space for Security and Defence' workshop in September 2009 (EDA)

ESA and EU Member States through the Space Council have been instrumental in seizing opportunities to strengthen 'space for defence' rationales: the fourth Space Council (May 2007) recalled that space contributes to the security of Europe and its relevance for CFSP and called for the creation of the Structured Dialogue working group, while the fifth Space Council (September 2008) further urged action in developing space situational awareness capabilities.

Several other events will have an impact on future ESA/EU cooperation with respect to space for security. On top of the ESDP and security responsibilities, the Treaty of Lisbon, which entered into force on 1 December 2009, gives the EU new competences in space and in civil security.

Moreover, the creation of a High Representative for Foreign Affairs and Security Policy, which merges the positions of the High Representative for the CFSP and the EU Commissioner for External Relations, bodes well for the political and operational strengthening of security, and is expected to have positive repercussions on civil and military synergies. The High Representative, Catherine Ashton, may also become instrumental in shaping a more comprehensive and sustainable 'space for security' policy.

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Ministers in charge of space activities within ESA and EU Member States met in Brussels on 26 September 2008 for the fifth Space Council

## ESA's contribution to Europe's security

The importance of space capabilities for Europe's security has been a continuously stressed dynamic, even before the ESP. In the context of the development of the European security policy and the increasing number of EU security interventions, European actors have regularly emphasised the lack of appropriate space capabilities to support their actions and the need to provide Europe with appropriate space capabilities.

An assessment of ESA's contribution to Europe's security has been undertaken, given the significant technical base shared by civil and defence communities and in light of the repeated calls for a stronger exploitation of synergies in Europe. ESA's Council addressed for the first time the issue of ESA's relations with the defence sector in December 2003. The Council furthermore addressed the fact that conducting activities for 'exclusively peaceful purposes', as defined in the Article II of the ESA Convention, does not restrict its capacity to conduct activities of a multiple use or military nature, as 'peaceful' is understood as 'non-aggressive' under international space law. The ESA Council also discussed the relevance of a European contribution to the space dimension of ESDP. At the time, ESA was already active in the field of security with, for example, a leading role in the inception and operations of the 'Space and Major Disasters Charter' initiative from November 2000.

Another element for evolution will be the new Commission, expected to take office in February 2010: the newly designated Commissioner in charge of space, Antonio Tajani, Commissioner for Industry and Enterprise, is expected to set a political agenda for his tenure.. One of these topics could be the development of a comprehensive and dedicated 'space for security and defence' policy orientation as a subset of the ESP.

In order to face these novel challenges, ESA had to adapt to the specific security constraints of multiple use and defence programmes. This is why a comprehensive legal framework with the security agreement, security regulations and implementing procedures was set up, enabling ESA to manage classified information (institutional prerequisites for any possible involvement in space for security and defence). Corresponding security infrastructure at ESA was thereafter successfully audited by the competent EU bodies.


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At the EC/EDA/ESA Workshop on 'Space for Security and Defence', from left: Claude-France Arnould, Deputy Director General CMPD of EU Council, Heinz Zourek, EC Director General, Jean-Jacques Dordain, ESA Director General, Adam Sowa, EDA Deputy Chief Executive, Paul Weissenberg, EC Director (EDA)

## Ongoing security-related activities

ESA's ongoing security-related activities can be divided into programmes dealing with security in space and those contributing to security on Earth. To ensure security in space and to allow for a sustainable use of space, Europe has decided to set up an independent system to monitor activities in space and the space environment.

In November 2008, as a first step in the development of a European system, the ESA Council decided to launch a Preparatory Programme for Space Situational Awareness (SSA) geared to 'support the European independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, the threats and the sustainable exploitation of the outer space surrounding our planet Earth'.

The Preparatory Programme is investigating the overall system architecture, defining user requirements and providing a set of precursor services. The European SSA system will be designed to make an extensive use of already existing national and European capabilities.

Besides its contribution through launchers and technology development and particularly within General Support Technology Programme (where an element is devoted to security), ESA supports security on Earth through several specific programmes. In addition to the cooperation mechanism of the Major Disasters Charter and to the EU programmes with security implications such as Galileo and GMES, ARTES 20 (Integrated Applications), and the new European Data Relay Satellite (EDRS) system/ARTES 7, are expected to make a significant contribution to space services for crisis management in operational theatres worldwide.

In the framework of the Structured Dialogue on Security working group, ESA is also conducting activities in cooperation with other European institutional organisations. For instance, in order to exploit the existing synergies between civil and military needs, ESA is working in coordination with EDA on the use of satellite telecommunications for Unmanned Aerial Vehicles, and is cooperating with EDA and the EC on critical space technologies.

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The Roman god Janus (or Gianus) symbolised new historical ages, and when the doors of Janus's temple were closed, then it signified peace. The GIANUS initiative (Global Integrated Architecture for Innovative Utilisation of Space for Security) will contribute to a comprehensive set of services to the EU and its Member States for efficiently addressing their security needs

## Proposed future activities on security on Earth

Space-based services can help support the full spectrum of internal and external civil security missions in the context of EU policies, including border surveillance, maritime surveillance, illegal activities monitoring, non-proliferation and treaties monitoring, as well as natural disaster, technological accident and man-made crises management. The contribution of space capabilities to Europe's security however suffers limitations.

> **"GIANUS will contribute to bringing the right information or services to the right people, when they need it."**

Reflecting on their experiences, civil security and defence organisations have expressed the need for operational and sustainable space-based services that would be more responsive and timely, affordable, integrated and under European control. The existing and planned programmes can and will address some of these limitations, but a more comprehensive approach is required to provide European security actors with all the services they require in the most efficient manner.

More specifically, the approach should be based on a clear understanding and federation of all European security organisations' needs and on the development of European integrated solutions. It requires increased cooperation between all European stakeholders, the setting up of a consultation process with potential user communities and an integrated design of potential architectural solutions.

With its new GIANUS initiative (Global Integrated Architecture for Innovative Utilisation of Space for Security), ESA is studying how to improve the space contribution to Europe's security through a holistic and integrated approach, with the design of options for a European space system-of-systems for security.

Its potential comprehensive set of services would support the monitoring and management of security-related events within and outside EU borders, providing European and national security organisations with guaranteed and timely access to space-based services both of a strategic and operational nature.

In practice, this approach would contribute to providing routine monitoring services as well as dedicated crisis response services in all the these areas, covering all phases of a crisis (prevention, preparation, response and recovery). In all these instances, the envisioned infrastructure would bring the right information or services to the right people, when they need it. In this context, the GIANUS initiative focuses on integrated crisis response services to be delivered in the field, as these are not yet widely covered by existing programmes.

The GIANUS architecture builds on existing and planned national and European programmes and is coordinated with other relevant European organisations and Member States. GIANUS is conceived to initially focus on civil security needs, with the perspective of exploiting synergies between civil and defence space programmes. The progressive opening of the architecture to services for non-civil user communities will allow potential future integration of civil and defence needs, hence providing capabilities to the entire spectrum of security user constituencies.

At national level, end users for potential services could therefore include civil protection agencies, fire brigades, ministries of interior, ministries of defence, ministries of foreign affairs, police authorities, customs and coast guards. Regarding EU institutions, EC Directorates General in charge of international cooperation, humanitarian aid and crisis response, of home affairs or of industry and entrepreneurship could be among prospective users.

In addition to these, the Office of the High Representative for Foreign and Security Policy, the EU Council Situation Centre, the EU Satellite Centre or European agencies, such as Europol and Frontex, could be interested by the added value of GIANUS. Potential users of this system-of-systems are being consulted in order to explore preliminary requirements and to investigate possible architectures, including existing or planned national and European systems, in a user-driven approach.

The significance and scope of GIANUS is testimony that a specific element of the European security and defence policy is gradually emerging, increasing the need to develop an appropriate infrastructure. Although the GIANUS concept is still in its early stages, future European policy initiatives, agreed by Member States, supporting the concrete development of a space dimension of the European Security Strategy would be a critical 'stepping stone' in giving security users, and citizens, the capabilities they require for a more secure Europe and for a more proactive European role in international policy dynamics. ■

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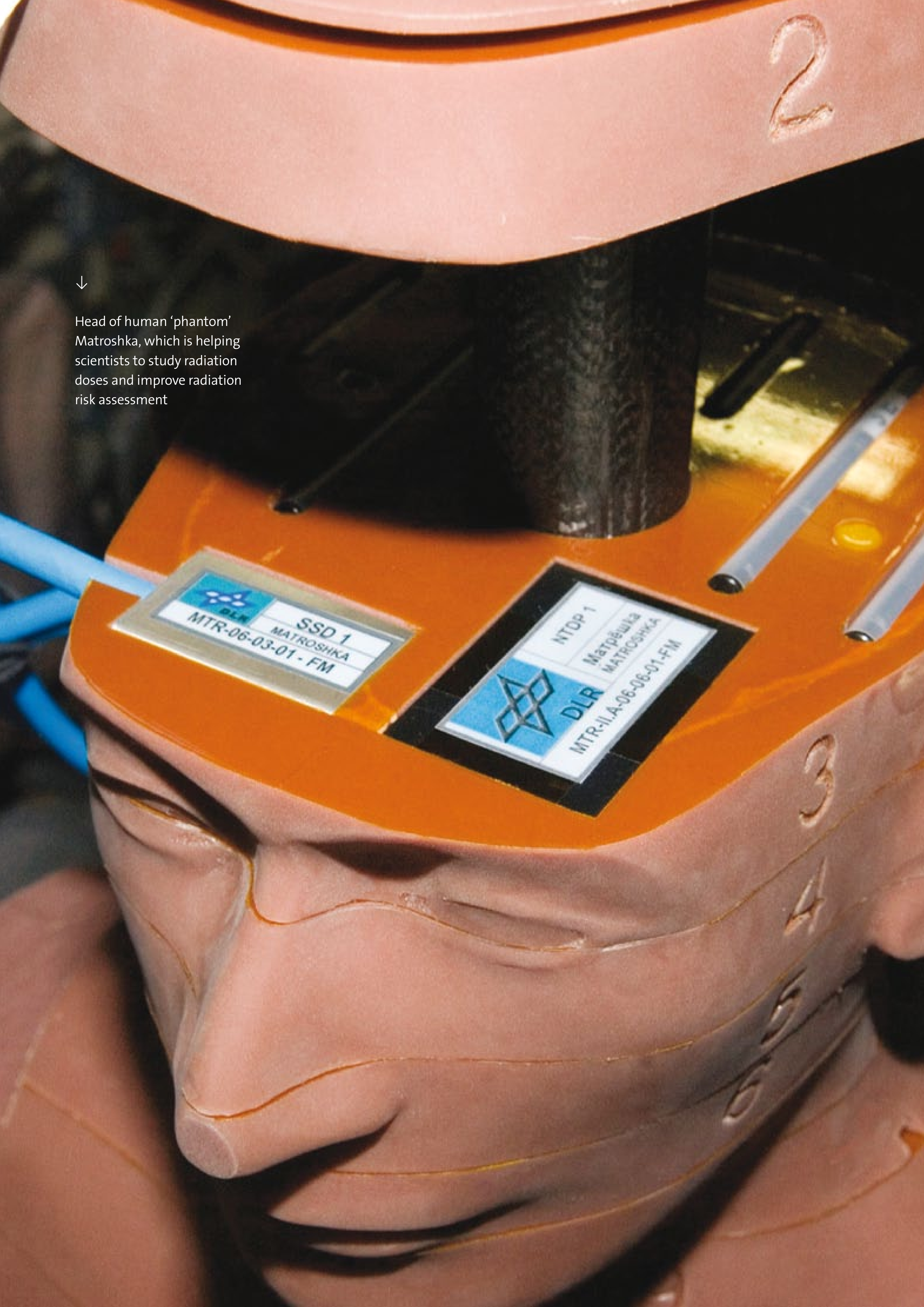


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Head of human 'phantom' Matroshka, which is helping scientists to study radiation doses and improve radiation risk assessment

# → REDUCING RADIATION RISK IN SPACE

## The Matroshka project

**Günther Reitz & Thomas Berger**
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**Patrik Sundblad & Jan Dettman**
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**With longer missions, the radiation safety of astronauts has become one of the most important areas of study for biomedicine in manned spaceflights.**

Even after nearly five decades of spaceflight, sending humans into space still has inherent and significant risks. The exploration of space exposes astronauts to a hostile environment that, if not properly mitigated, could have some serious health impacts. Exposure to cosmic radiation is one risk that can be reduced with careful mission planning and constructive measures, such as providing radiation shelters. However, this risk cannot be completely avoided, because of the extremely high energies of these particles and their high penetration depth in matter.

The exact determination of radiation dose in space is a demanding and challenging task, which is tackled in a close cooperation of all the International Space Station (ISS) partners.

The daily dose rates – up to a few hundred of microsieverts (μSv) in low Earth orbit – are among the highest reached for humans working in a natural radiation environment.

Various research activities are trying to understand better the interactions of the space radiation environment with the human body, aiming for a better system of radiation risk estimation for future exploration missions – such as going to the Moon or to Mars.


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ESA astronauts Christer Fuglesang and Thomas Reiter on the ISS wearing their European Crew Personal Dosimeters (EuCPDs) – the blue belts around their waists

Currently, the biggest radiation experiment is Matroshka. Operating on the ISS since January 2004, Matroshka is designed to show the radiation distribution in the human body under different shielding conditions, inside and outside the ISS. The key part of the Matroshka facility is the human 'phantom', equipped with thousands of radiation sensors, which is helping scientists to understand more precisely the dose and particle distribution in a human body for an improved radiation risk assessment.

## Research objectives

Radiation safety of the astronauts has become one of the most important problems of biomedical maintenance during manned spaceflights. There is a requirement to provide a high level of safety for crews for their health and their capacity to work. With extended mission durations, the conservative approaches used in the past cannot be continued. Instead, the effective dose (E) as recommended by the International Commission on Radiological Protection (ICRP) needs to be determined as accurately as possible. The effective dose is the appropriate quantity to assess radiation cancer risk.

Effective dose, as a risk-related quantity, is based on the determination of the doses in various organs of the human body. The current system of radiation protection in space relies on astronauts using their own personal radiation dosimeter. With this type of detector it is only possible to determine the dose at the skin's surface, but not inside the body of the astronaut.

To solve the problem of dose determination inside organs, Matroshka investigates the depth dose distribution inside an anthropomorphous 'phantom' body inside and outside the ISS and considers physical and biomedical aspects.

Its 'human body' form, generally accepted for space experiments, is designed to measure the dose distributions in critical organs taking into account mass distribution anisotropy of both the phantom itself and its shielding, thereby allowing the effective dose to be determined. Knowing the effective dose is a prerequisite in calculating reliable cancer risk numbers for the astronauts.

## → The space radiation environment

At the height of the ISS, the radiation environment is determined by three main sources: galactic cosmic radiation, solar particle radiation and charged particles trapped in Earth's magnetic field ('Van Allen Belts').

The first source comprises protons and heavier particles, and electrons of all energies that come from all directions in the Solar System.

With solar particle radiation, only particles from energetic solar events, such as coronal mass ejections (CMEs), have sufficient energies to contribute directly to radiation exposures. These particles are mainly protons and electrons with varying, but usually small amounts, of heavier ions.

The third source of charged particles is produced by interactions of the first two sources with Earth's atmosphere. It consists of protons and electrons that are trapped in Earth's magnetic field.

In addition to its variation with location, the intensity and composition of the total radiation environment is subject to slow temporal variations due to oscillations of solar activity in an approximately 11-year cycle and to impulsive disturbances caused by solar particle events that may last for several days.

While passing through this complex and variable external radiation field, the field inside the spacecraft and an astronaut's body is complicated further by the interactions of these particles with the atoms of the structural materials, and with those of the body itself.

The main objective of Matroshka is to determine the empirical relations between measurable absorbed doses and the required tissue-absorbed doses, in a realistic 'human body' exposed to the actual radiation field to be monitored. Since spacewalks (EVAs) make up a substantial fraction of the time astronauts spend on the ISS, these measurements have highest priority.

Once the ratios for the tissue-absorbed doses and surface-absorbed doses are known for a given radiation field around the human body, these values may be used in future exposures to determine the required tissue-absorbed doses from measurements of surface-absorbed doses only. Using these results, it will also be possible to derive the effective dose values for astronauts by using the readings of their personal dosimeter systems.

Matroshka measurements will be used as a benchmark for model calculations. Several institutes from Europe, Japan and USA contribute to the radiation measurement programme.

## History of 'phantom' experiments

An essential parameter for the assessment of radiation risk on humans in space is the determination of the organ dose. Measurements inside tissue-equivalent 'phantoms' are therefore essential in order to solve this complex task, and to improve our knowledge of the dose distribution inside the human body.

In 1987, the Matroshka research group first developed the idea of measuring the depth dose distribution with an onion-like arrangement of detectors embedded in layers of absorbing materials. Based on these ideas, a proposal was made in 1992 to fly a human-shaped 'phantom' equipped with radiation detectors.

## → Dose quantities

**The absorbed dose (D) is defined as energy deposited by unit mass (J/kg) with the SI unit gray (Gy). The absorbed dose does not take into account the different biological effects of different radiation fields (such as heavy ions, neutrons or x-rays). Therefore a unitless quality factor (Q) was defined, which is dependent of the linear energy transfer and gives an indication of the 'danger' of the incident radiation.**

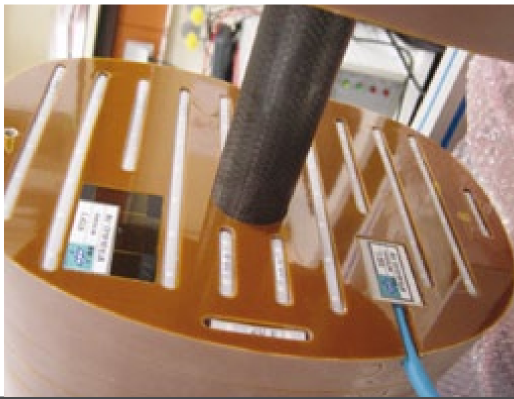
**Multiplying D and Q leads to the 'dose equivalent' with the SI unit sievert (Sv). Since each organ of the human body has a different radiosensitivity, which has to be taken into account for radiation risk estimation, the effective dose E is derived as the summation of all the organ dose equivalents multiplied with the appropriate tissue-weighting factor ($w_T$).**

The name 'Matroshka' was chosen after the onion-like design of the well-known Russian Matroshka doll sets.

It took another three years before the experiment was selected by an international peer review for flight on the ISS. ESA then performed a Phase-A study and a performance study, resulting in the manufacture of the ESA facility starting in 2000 and ready for launch in January 2004. After a further call for proposals by ESA in 2004, a second peer review decided to continue the experiments as an outstanding priority.

↓

From left: Expedition 8 Flight Engineer Mike Foale unpacks Matroshka in February 2004; Mastroshka stayed outside for 539 days until 18 August 2005, and was brought back by Expedition 11 crew Sergei Krikalev and John Phillips



↑ Assembling the Matroshka phantom, left to right: anthropomorphic upper torso equipped with active and passive detector systems; torso with poncho and hood equipped with passive detector systems for skin dose measurements; carbon-fibre container to simulate the astronaut's spacesuit; facility ready for launch, equipped with multi-layer insulation for thermal protection

Meanwhile, only three space experiments dealt with the determination of the depth dose profile inside tissue-equivalent phantoms. They included measurements inside a phantom head, and an 'Alderson' phantom upper torso, applying a combination of various active and passive radiation detectors systems. These experiments were performed on Space Shuttle flights, resulting in an exposure time limited by the length of Shuttle missions.

In late 2001, during ISS Expedition 2, an Alderson phantom torso (nicknamed 'Fred') was also flown inside the US laboratory module's Human Research Facility. Russian scientists had simplified their phantom concept to a spherical water-filled phantom, which was first exposed on the Mir space station. Its successor, a tissue-equivalent spherical phantom, is currently measuring the radiation load in the Russian segment of the ISS.

Matroshka was launched on a Russian Progress cargo spacecraft in January 2004. It was placed on the outside of the Russian Zvezda ISS module during a spacewalk by the Expedition 8 crew, Alexander Kaleri and Michael Foale, on 27 February 2004. It was the first time that measurements of the radiation distribution inside a human phantom had been made under EVA conditions.

## The ESA Matroshka facility

Inside Matroshka's 'phantom' human upper torso, spaces are provided at the surface and in different depths inside (at sites of organs of interest) in which active and passive dosimeter packages are accommodated.

The instrument suite is made up of thermoluminescence detectors (TLDs), plastic nuclear track detectors with and without converter foils, a silicon detector telescope, plastic scintillators and a tissue-equivalent proportional counter. The phantom is mounted on an aluminum base, which provides space for experiment and facility electronics, and is covered by a carbon-fibre container.

These form a closed, pressurised volume of 1.05 atm for the phantom and therefore also protect the phantom material against other space environment factors such as ultraviolet radiation and vacuum.

The carbon-fibre container provides shielding thickness of about 0.5 $g/cm^2$ which is comparable to an EVA suit. The facility has a mass of 68 kg and occupies a cylindrical volume of 600 mm in diameter and a height of 1.1 m. Matroshka is designed to be disassembled to exchange experiments inside the Russian Service Module Zvezda.

Besides providing space for passive and active experiment packages, Matroshka is able to send 'housekeeping' data (experiment/facility status, temperature and pressure) and experiment data. These data are temporarily stored and then transferred to the Russian onboard Data Management System. Temperature, pressure and the main status data are delivered as service telemetry continuously to the Payload Data Control Server (for facility status monitoring from the Mission Control Centre near Moscow).

The phantom's anthropomorphic upper torso is made of tissue-equivalent polyurethane, which includes a human skeleton (RANDO®, The Phantom Laboratory, Salem, NY, USA). The torso is cut into 33 slices, each 25 mm in thickness. In the 33 slices, 4800 TLDs are distributed in 354 polyethylene tubes, enabling determination of the absorbed dose and depth-dose distribution at over 1600 measurement points in a 2.5 x 2.5 cm grid.

## → Nuclear track etch detectors

**Nuclear track etch detectors (also known as CR39s) are plastic detectors. When a heavy charged particle passes through the detector, it breaks up the molecular bonds within the detector, producing a nano-sized track. After etching in caustic solution, these tracks can be made visible for measurement under a microscope. The track size is related to the linear energy transfer of the passing particle, enabling the determination of the mean quality factor of the incident radiation field.**

←

Inside Matroshka, revealing integrated passive and active radiation detectors. The sensor for the active Silicon Scintillator Device (SSD) is shown with the blue cable connecting to the base structure

→

The phantom's 'poncho' is equipped with TLDs sewn into plastic strips and neutron dosimeters

## → Thermoluminescence detectors

TLDs have been used for over 50 years on Earth and in space for the determination of the absorbed dose, partly as area monitors, but also as part of the personal radiation detectors of astronauts. A TLD is a small crystal (mostly lithium fluoride) doped with various materials such as magnesium or titanium. Energy from ionising radiation is stored in the crystal lattice. After exposure, the TLD is heated up and the stored energy is released in the form of light. This light can be measured by a photomultiplier tube and is proportional to the absorbed dose.

Combinations of TLDs and plastic nuclear track detectors assembled in polyethylene boxes (60 x 40 x 25 mm) were placed at selected organ locations (eye, lung, stomach, kidney and intestine) as well as in a NOMEX® travel jacket ('poncho'). For the determination of the skin dose, detectors were sewn into polyethylene strips directly on the surface; measuring thereby average dose at a depth of 0.6 mm. Seven active radiation detectors monitored the instantaneous dose rate. Five scintillation detectors were installed at the positions of the selected organs to monitor the interior heavy ion and neutron component.

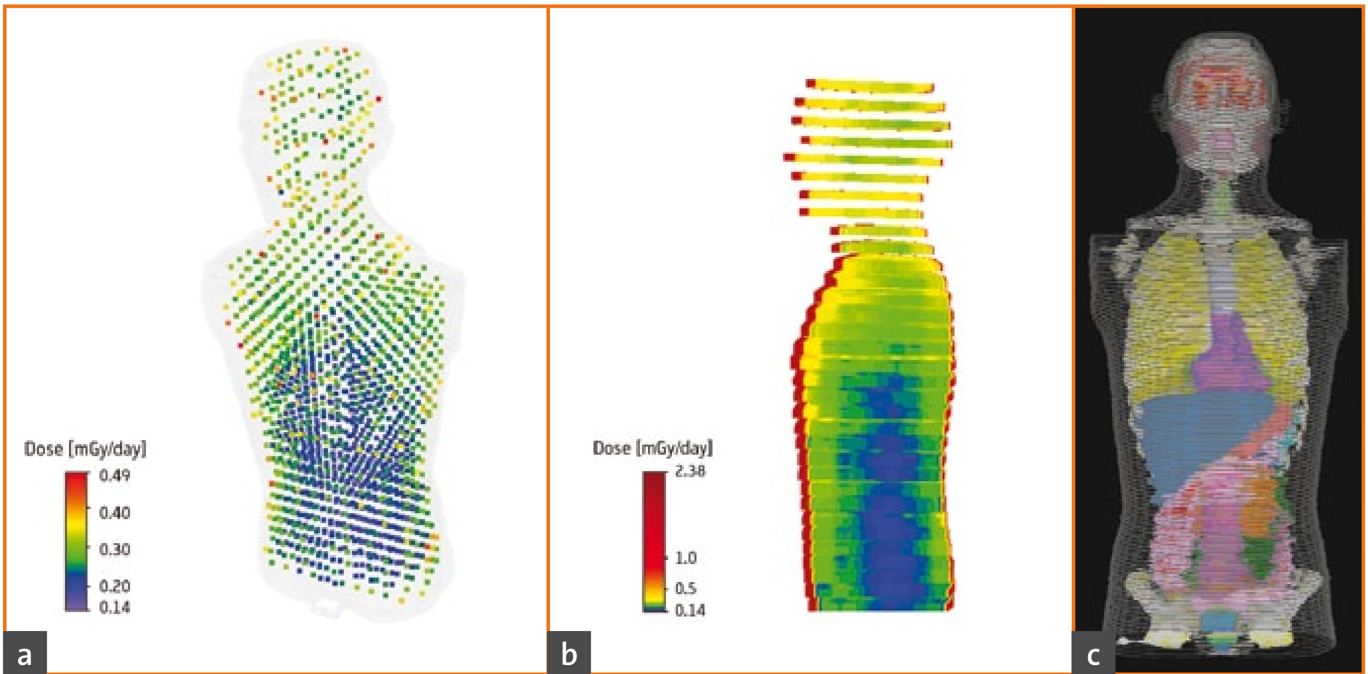
A silicon telescope (DOSTEL) on top of the phantom head and a tissue equivalent proportional counter (TEPC) in front of the torso monitored its ambient exposure rate.

For comparison with dose rates inside the ISS, additional detector packages were stored at several reference locations.

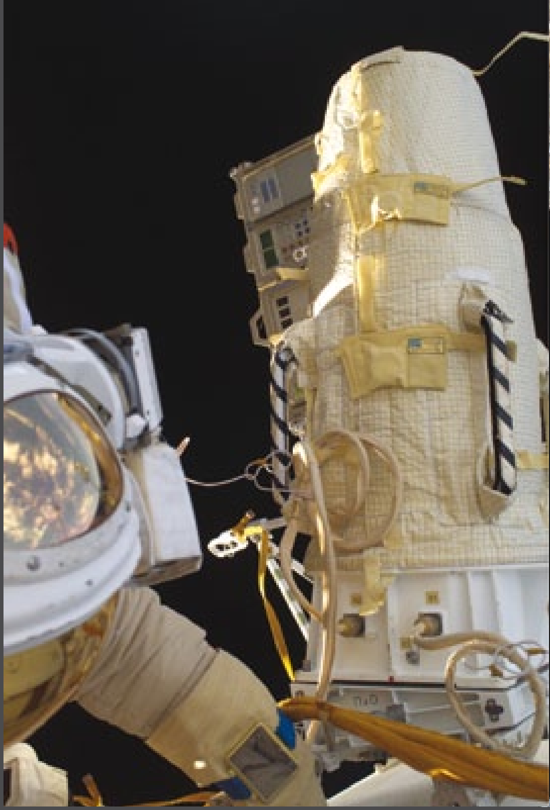
### Selected results of Matroshka outside exposure (MTR 1)

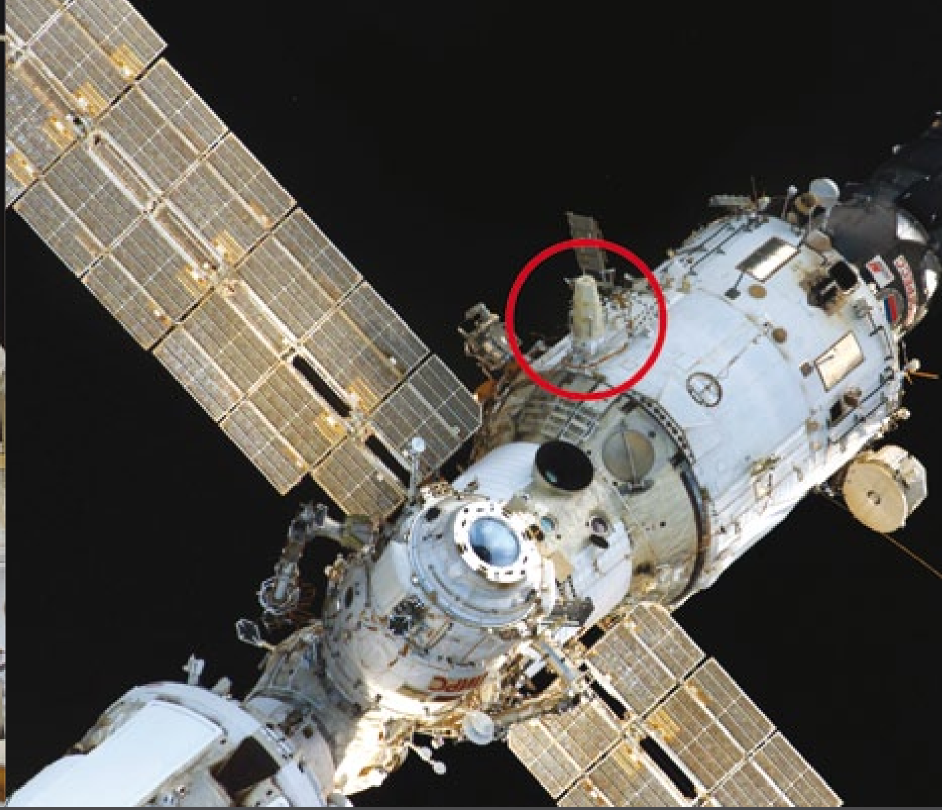
For the determination of the radiation exposure, and thereby the assessment of the effective dose, of an astronaut, the sum of all organ dose equivalents is needed. One way to determine organ dose is the use of a combination of TLDs and plastic nuclear track detectors, in this case 'polyallyl diglycol carbonate' (with trade name CR39).

From the TLDs, the absorbed dose of sparsely ionising particles up to an energy deposit of 10 keV/µm is calculated.




↑ a: depth dose distribution of absorbed doses measured with TLDs inside the human phantom; b: inclusion of the absorbed doses measured with the poncho detectors; c: location of organs based on the Zubal phantom





↑ ↗

Matroshka (circled) mounted outside the Zvezda module in February 2004 by Expedition 8 crew Alexander Kaleri and Michael Foale

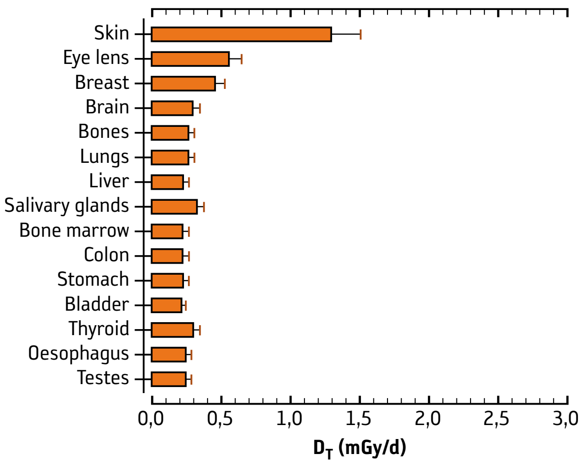
The contribution of the densely ionising component (above 10 keV/µm) is obtained from energy deposit spectra measured in the CR39 detectors.

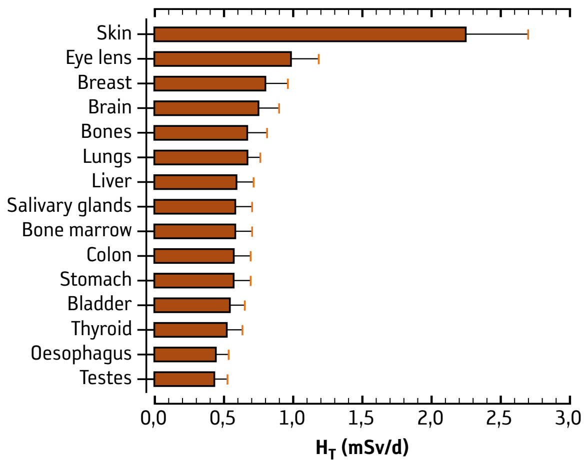
Different groups contribute to the overall results, but due to the intense calibration activities the received results agree well with each other. Compared to the first measurement point at 8 mm depth (see diagram on previous page), the dose rate decreases by a factor of about two at the innermost organs.

The significantly higher rates in the head, neck and shoulder region reflect the smaller self shielding of the body. The minimum at the bottom of the torso is also due to the shielding of the ISS. The depth dose distribution of dose rates including the skin measurement highlight the very steep decline within the first 8 mm by a factor of about ten.

From this depth-dose distribution, an average organ dose rate was determined for each critical organ as the average of the dose rates in those volume elements which were assigned to it in a Voxel model. The diagram also shows the organs of the Zubal phantom mapped and scaled into the Voxel representation of Matroshka obtained from the computer tomography slides.

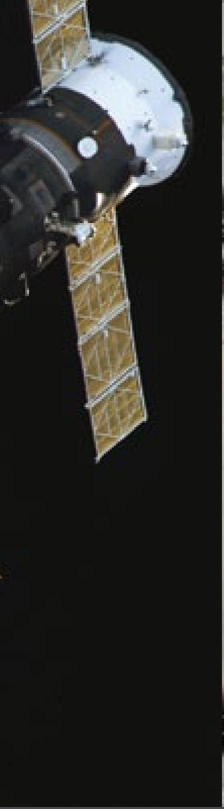
The calculated skin dose rate represents an average of the outermost 3 mm. With about 1 mGy/d it is by far the highest, followed by the dose rate in the eye. With the exception of the breast and the salivary glands, the dose rates for the other organs are in the range of 0.2–0.3 mGy/d.




←

Calculated organ absorbed doses (left) and organ dose equivalents



↗

MTR 2B, Matroshka inside Zvezda

## → Benefits of Matroshka data products

- Determining doses absorbed by critical organs of astronauts and radiation exposure under various geo- and heliophysical conditions, determining the radiation hazard under intra- and extravehicular activity conditions
- Determining doses experienced by crews in different shielding locations and under low-protection conditions
- Benchmarking models used for the calculation of radiation transport through spacecraft shielding and through tissue material in order to calculate organ doses
- Improving methods for assessment of absorbed and equivalent doses for better future risk assessment hyphen in long-duration spaceflight
- Assessing spacesuit shielding efficiency
- Serving as source data for experimental assessment of ISS shielding efficiency in different compartments, not only in units of dose but in units of radiation risk
- Updating models describing the radiation field In near-Earth orbits (Earth's radiation belts, galactic cosmic rays, solar cosmic rays, planet distribution for geomagnetic cut threshold under various conditions)
- Defining the requirements of equipment needed for fundamental and application studies on radiation safety for national programmes of ISS space research

The values for the skin represent measurements for the poncho, which is calculated for a skin depth of 3 mm. Relative precisions for organ dose values range between 4% and 8% and for $\langle Q_T \rangle$ between 9% and 12%.

The effective dose as sum of all organ doses, weighted with tissue-weighting factors defined by the ICRP, approaches the value of 0.59 ±0.04 mSv/d.

Comparing the Matroshka 'personal' dosimeter result with this value, a personal dosimeter of an astronaut would show 2.1 times this exposure, which is a large overestimate.

### Operations on the ISS

Up to now three experiment phases have been performed with the Matroshka facility inside and outside the ISS. The MTR 1 exposure was outside the Zvezda module. MTR 2A was performed in the Pirs module in 2006, and MTR 2B from 2007 to 2009 inside Zvezda.

A fourth exposure (MTR 2 KIBO) is in preparation for measurements inside the Japanese 'Kibo' Experiment Module (JEM). A potential second outside exposure is considered.

Matroshka has been operating on the ISS for six years and is the biggest collaboration in space dosimetry so far. The amount of data gathered is huge and will be held in a database which could be used as reference for radiation risk estimate calculations.

### Ground segment

Calibration of TLDs and CR39s, as well as for the active experiments, were performed at several proton and heavy ion accelerators, such as Loma Linda, NASA Space Radiation Laboratory at the Brookhaven National Laboratory, USA, and the Heavy Ion Medical Accelerator, HIMAC, at the National Institute for Radiological Sciences, Chiba, Japan.

The phantom is also used for depth dose studies using detectors and kidney cells as part of the ESA Investigations into Biological Effects of Radiation (IBER) programme. IBER is a European effort to contribute to an improved understanding of the radiation risk of cancer and non-cancer effects. It recognises that radiation is, besides physiology and microgravity, one of the limiting factors for exploration missions.

## → HAMLET

HAMLET (Human Model Matroshka for Radiation Exposure Determination of Astronauts) is a project of the EU's Seventh Framework Programme (FP7). To exploit the data obtained from Matroshka, leading European scientists in space dosimetry have come together to increase and enhance the output of the project and present it to the European scientific community as well as the public.

See www.fp7-hamlet.eu

↑

Cosmonaut Yuri Lonchakov, Expedition 18 Flight Engineer, demonstrates replacement of the passive detector packages, first removing the container, then mounting a rod on top of the phantom to allow lifting of the phantom's slices

An ESA topical team was built and chaired by Marco Durante, GSI, Germany, to advise ESA. The problem of radiation exposure in interplanetary missions, which represents a major operational risk for acute radiation syndrome and limits mission durations, can only be solved with a large accelerator-based research programme.

In a second Matroshka phantom, exposure to the impact of a solar particle event was simulated at the NSRL in Brookhaven. In this experiment, blood cells were exposed together with detector systems to see the depth dose effect in a human body and also to benchmark radiation transport calculations. Ground experiments are an essential part of the Matroshka programme.

### Computer simulations

Computer simulations represent a strong corner stone in the Matroshka programme. It is not possible to perform measurements for all potential projectile-target-energy-geometry combinations, so computer simulations are the only way to provide the necessary information estimation of the radiation risks for humans on board a spacecraft. However, the space radiation field is very complex and simulations need careful benchmarking through measurements.

### Preparing for Mars

Mastroshka is the only human phantom experiment where organ doses are calculated based on depth dose measurements. Effective doses have been determined, demonstrating that personal dosimeters overestimate the dose during an EVA by more than a factor of two.

The detailed investigation of these results is part of HAMLET: the project which is exploiting the scientific data obtained from Matroshka. These results have a great impact on the extrapolation of radiation risk assessment models for future long-duration spaceflights.

Matroshka and all the current radiation experiments on the ISS (such as the Dose Distribution inside Columbus (DOSIS) experiment) contribute to our understanding of the radiation field in space, the variation in the radiation environment due to different shielding conditions and the impact of radiation on the human body. They forming the prerequisite information we need to set up a 'human computer model' of the Matroshka in free space, and to assess the radiation risk for a future flight to Mars. ■


### Acknowledgements

These results could be only achieved in an international cooperation: 19 institutions located in USA, Japan, Russia, Japan and Europe.

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↑ Node-3 and Cupola at KSC

# → ISS HARDWARE HAND-OVER

## Transferring ownership of Node-3 (with Cupola attached)

**Philippe Deloo & Sara Pastor**
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**Twelve years of hard work in design and development came to fruition with the formal handover of Node-3 from ESA to NASA in November, the last leg of its journey before launch to the International Space Station (ISS) in 2010.**

Node-3 is the second and last ISS module that ESA had to build for NASA as part of the Columbus launch barter agreement signed in 1997. In what was known as the 'Columbus Launch Offset Agreement' or 'Nodes Barter', ESA agreed to build Node-2 and Node-3 in exchange for the Space Shuttle launch of Columbus.

This was a win-win situation, as the money for the Columbus launch would be spent in Europe, enhancing European industry know-how in human spaceflight engineering, while NASA would acquire two modules without having to pay their development costs.

A couple of years later, another barter agreement between NASA and ESA was signed in which ESA would provide Cupola in exchange for the launch and return with the Shuttle of five European payloads for Columbus.

Node-2, developed under ASI-delegated management, was delivered to Kennedy Space Center (KSC) and the ownership transferred to NASA in June 2003. It has been operating flawlessly for over two years following its launch with STS-120 on 23 October 2007. The Cupola was delivered to KSC in September 2004 and the ownership transferred to NASA in July 2005.


← Node-3 shipped by road at KSC in Florida

→ Node-3 was named 'Tranquility' in April and delivered to NASA at KSC in May 2009


Node-3 was shipped to KSC in May 2009. Following six months of ground operations during which the Cupola was mated to Node-3 for launch, the module underwent an acceptance process concluded by the transfer of ownership of the element to NASA. This transfer marks the completion of ESA's barter obligations in terms of ISS pressurised infrastructure hardware development.

## Node-3 at Kennedy Space Center

At KSC, Node-3 underwent the last integration and verification activities that were either impossible or just not practical to perform in Europe.

These activities included loading ammonia into the heat exchanger systems, outfitting of modified Boeing hardware as a result of Node-3 relocation to the port side of Node-1, the On-Orbit Constraint test, the Digital Pre-Assembly measurements, loading the flight software, system regression tests, mating the Cupola, installing the Integrated Stowage Platform, fit-checks, inspections, crew walkdown and finally the element close-outs.

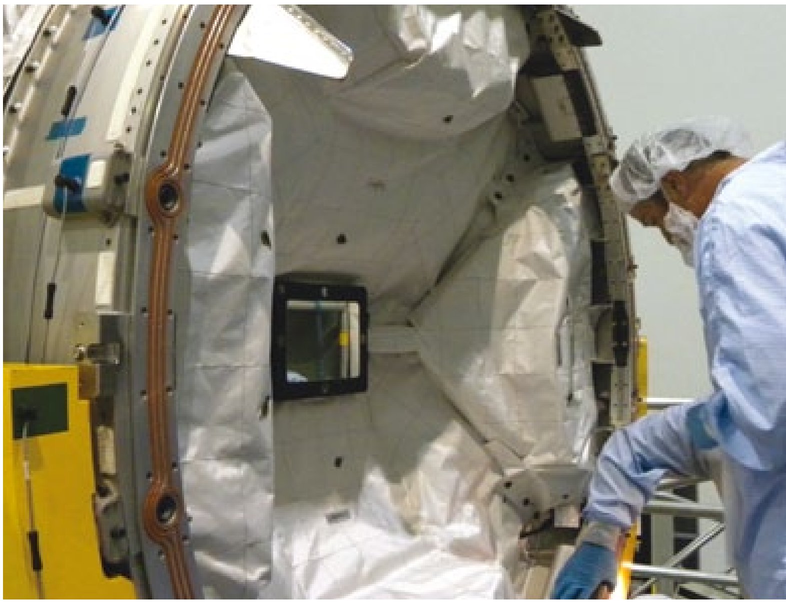
In addition to these planned activities, several unplanned tasks were also performed at NASA's request. The major one was the removal of the Condensing Heat Exchanger (CHX), in response to a last-minute NASA direction to replace this NASA unit following the failure of its absorption bed in a wet-ability test.

Although designed as an 'orbital replaceable unit', the replacement was not an easy task because the weight of the unit on Earth (a '1g' environment) did not allow manual handling. Back in Turin, the CHX was first integrated offline in the mid-bay and then the pre-integrated mid-bay itself integrated in the Node.

Therefore, no ground support equipment was available to perform the standalone CHX removal and replacement inside the module.

With the help of KSC, many solutions were proposed and, after several days of investigation and discussion, a safe and efficient way of doing the job was eventually found.

Thanks to the hard work of the organisations involved and, in particular, to ESA's contractor Thales Alenia Space Italy, these unplanned tasks were completed with minimal programme impact on our partner.



↑ Looking inside Cupola just before mating with Node-3


## Incremental acceptance process

Owing to the substantial changes to the baseline plan over the years, the acceptance process evolved from a classical acceptance on hardware delivery, into an incremental acceptance process composed of three reviews. Initially, Node-3 was supposed to be delivered and transferred to NASA in 2007. NASA was then in charge of the final ground operations.

However, in 2006, NASA asked ESA to delay the shipment of Node-3 to KSC as long as possible and transfer to ESA the responsibility for all KSC ground operations.

Following negotiation, the acceptance process was revised with a first pre-shipment acceptance review at the end of the development and verification phase. This review took place in July 2007.

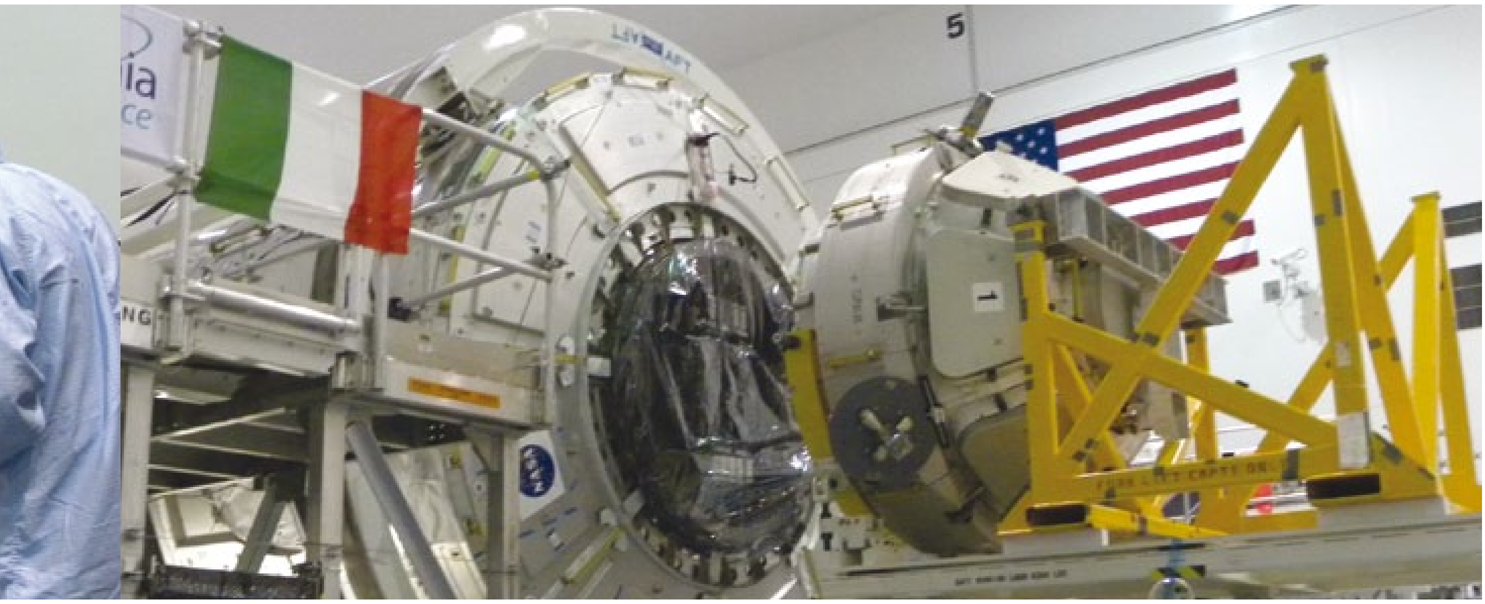
It confirmed the compliance of the hardware and documentation against the baseline and authorised the storage of the element until it was due for shipment to KSC for launch preparation.

In the meantime, the evolution of the ISS required changes to be made to Node-3 while it was in 'so-called' storage, such as the accommodation of the 'Colbert' treadmill. To ensure the correct implementation of these changes, a second pre-shipment review was held in May 2009 to authorise shipment to KSC.

The final acceptance review took place on 20 November 2009. It concluded this incremental acceptance process by focusing on the acceptance of the ground operations activities performed at KSC.

There were no issues to report, no more work for ESA to do, and only a handful of minor documentation discrepancies. The closure of the few remaining open requirements was qualified as a formality by the review experts.

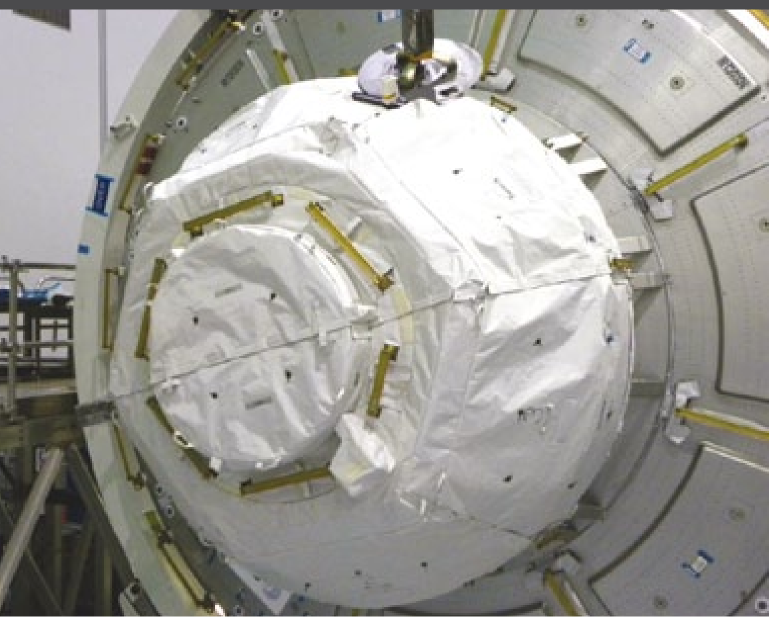
The NASA board members expressed their satisfaction and confidence in the quality of the hardware and documentation.



↑ Cupola approaching Node-3


↑ Cupola secured to Node-3 end port

↓ Cupola mounted on Node-3 with multilayer insulation shroud



Such a clean acceptance did not happen by luck. It was the result of innovative processes throughout the project. Indeed, not only the reviews themselves were incremental, but also the whole process of verification and documentation buy-out. The NASA and ESA project teams enforced the rule that documentation delivered by Thales Alenia Space Italy in the course of the project had to be reviewed within a month of its delivery. After that period, if no issues were raised against the document, it would be accepted for good.

To support that process, the project opened a 'Review Item Discrepancy' (RID) database to collect discrepancies from the start of the documentation being generated for the next review. The RID acceptance and disposition was processed as normal project work and, most of the time, documents were updated by the contractor before the review so that most RIDs on the data-package documentation would be closed at the review.

Similarly, ESA introduced an internet-based system to track the requirements status in order to streamline the requirement closure process. This tool, called the VCS, proved to be very helpful for an incremental processing of the requirement closure. Once the contractor considered the closure documentation for a requirement complete, the requirement was submitted via the VCS to ESA for closure evaluation. Following review of the documentation, ESA further submitted the requirement to NASA for closure concurrence. If there were issues with the closure material, they were documented as RIDs and recorded in the VCS as the reason why the requirement closure was not acceptable.

The internet-based VCS allowed the process to be transparent to all parties and to reflect accurately the actual requirement status, so that no requirement closure remained in limbo because of miscommunication. Thanks to the VCS, a smooth incremental requirement closure process was achieved, which would not have been possible with the old 'Verification Control Document' approach, in particular with a partner agency where closure concurrence on all requirements was required.

Finally, another incremental process was introduced, dedicated to Product Assurance and Configuration Management built documentation. Node-3 is a complex element with over than 40 000 lines of CIDL/ABCL (Configuration Item Data Lists/As Built Data Lists) and 15 000 drawings.

To ensure correct documentation and its consistency with the execution documentation and the non-conformance reports (close to 1300), dedicated week-long reviews at the contractor premises were held every quarter starting from the beginning of the integration process. It was intense work,


←

ESA's Bernardo Patti speaking at the transfer of ownership ceremony

→

Bernardo Patti and Michael Suffredini sign the handover agreement



but it has given confidence in the accuracy and completeness of the as-built documentation. This is an essential aspect for a module that will probably be subject to evolution and further modifications during its on-orbit life.

## A successful inter-agency partnership

Although the Node-3 system design and development was fully under ESA responsibility, the NASA involvement in the project was much stronger than in any other ESA Human Spaceflight project for two main reasons. The first was because an extremely close interaction with NASA was required to address system design problems and integration/verification issues. NASA/Boeing was providing a large amount of equipment and hardware for integration in Node-3 as 'Government Furnished Equipment'.

The second reason was because, being the final owner of the hardware in charge of its operation, NASA legitimately wanted to ensure that top-quality hardware was being built with adequate documentation for its operation and maintenance. This strong NASA insight was a fact of life that ESA had to accept but, more importantly, closely control to avoid schedule delays and cost overrun.

To complicate matters, the NASA Nodes project is not a single entity but is composed of an army of individuals working from various sites and for multiple organisations, such as KSC, Johnson Space Center, Marshall Space Flight Center, Boeing (Houston) and Boeing (Hunstville). To ensure we were all 'rowing in the same direction', strict rules were established and enforced to channel the enormous workforce potential of this team in the right direction.

Fortunately, extremely good relationships had been developed at the management level between the Thales, ESA and NASA project managers. These relationships were the result of a common project-oriented approach, striving to take the best technical decision for the hardware, knowing that each party could rely on its counterparts to take their responsibilities and honour their obligations. This mutual trust and respect allowed for a strong management with clear and timely directions to the team for addressing and resolving issues as soon as they arose, rather than penalising the project with endless programmatic discussion.

Having a solid management surely helped in creating the right environment to motivate the team, but it was the dedication, expertise and hard work of every individual in the team that made Node-3 a successful project. They should be proud of the Node-3 success, because it is entirely theirs.

## Transfer of ownership

The formal handover of Node-3 from ESA to NASA took place in front of the Node-3 flight hardware in the Space Station Processing Facility at the KSC in Florida, on 20 November 2009. The master of ceremonies was William Dowdell, NASA's Deputy for Operations for ISS and Spacecraft Processing. He introduced the speakers: Robert Cabana, Director of KSC, Michael Suffredini, NASA ISS Programme Manager, Bernardo Patti, ESA ISS Programme Manager, and Secondino Brondolo, Head of the Space Infrastructure at Thales Alenia Space Italy.

The speakers underlined the outstanding build quality of the hardware, the significant benefits that both the Cupola and Node-3 will bring to the ISS and finally the remarkable team spirit and project-oriented attitude of all members of the organisations involved in the project and, in particular, Thales Alenia Space Italy.

Bernardo Patti commented, "Once attached to the ISS in February, more than one third of the pressurised ISS elements will have been built in Europe. The ISS is now almost complete and since we were able to add our European Columbus laboratory in 2008, our scientific and technological utilisation programme is at full swing and we are looking forward to its results."

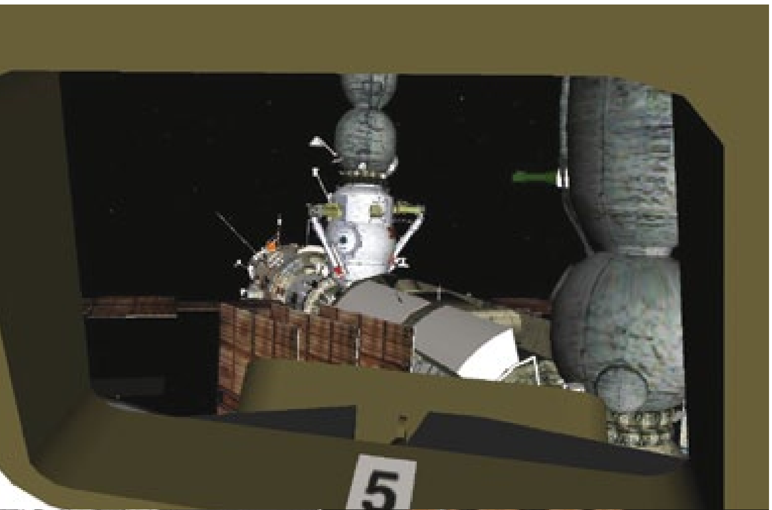
Mr Patti and Mr Suffredini concluded the handover with the official signing of the Transfer of Ownership agreement for Node-3. The handover completes the final major element of the barter agreement between ESA and NASA signed in Turin on 8 October 1997.

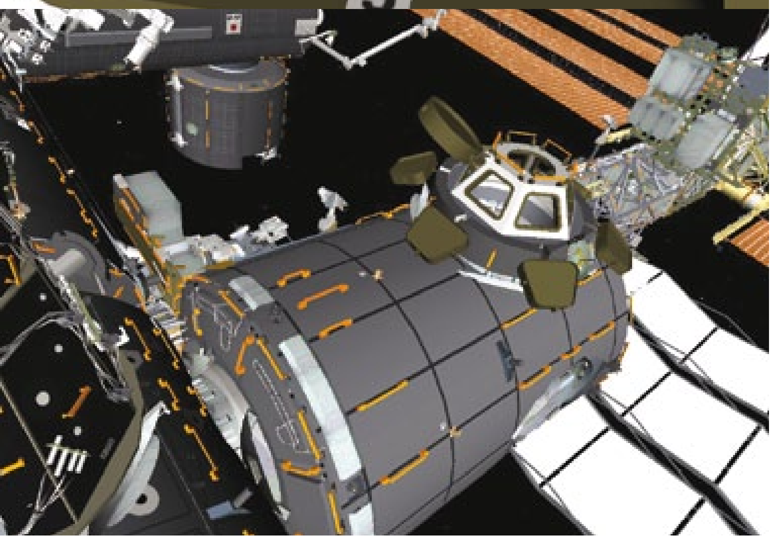
## Proud achievement

The addition of Node-3 and Cupola frees up space in the ISS laboratory elements, such as Columbus and Destiny, which are then clear of life support and maintenance equipment. The laboratories can be used to their full extent for scientific purposes. Cupola will also provide an unprecedented capability for the ISS.

We are confident that both Node-3 and Cupola will perform to the satisfaction of NASA and the ISS crews for many years to come, a proud achievement for European industry and ESA.

The outstanding success of the ESA Nodes development project demonstrates to the space community that inter-agency projects can be completed in a win-win, cost-efficient manner for the partners, and are not bound to be the sore experience that has often been the case in the past. The precedent set by the Nodes project gives confidence that future inter-agency endeavours in human exploration can be managed in a way that gives our governments the high return on investment that they are entitled to expect.



## → Node-3 and Cupola timeline*

During the launch and activation phases, the Cupola is protected by a multilayer insulation shroud. Node-3/Cupola is carried at the back of the Shuttle's payload bay, fixed in place by its trunnions and keel fittings.

Following launch and the opening of STS-130 Space Shuttle *Endeavour*'s payload bay doors, the Node-3 heaters are powered up to provide temperature control of the module.

**FLIGHT DAY 2** The Shuttle docks to the Pressurized Mating Adaptor 2 (PMA-2) on the front of the European-built Node-2 'Harmony'.

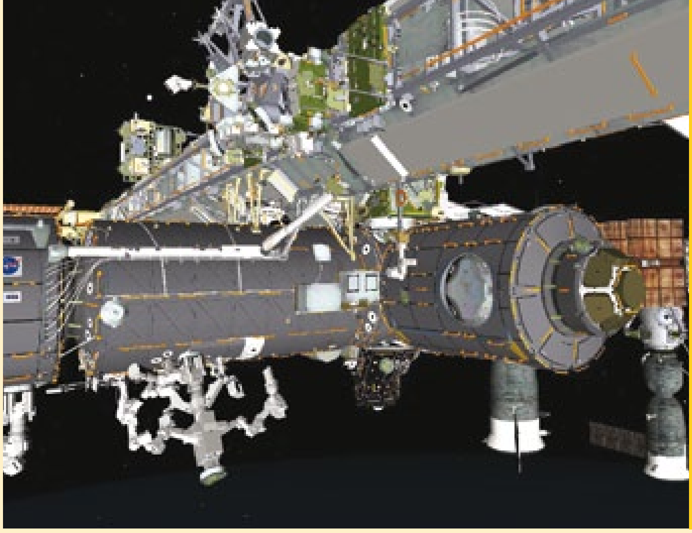
**FLIGHT DAY 5** Two Shuttle EVA astronauts make their way to the Shuttle's payload bay to carry out preparations for unberthing Node-3 and Cupola. They remove the cover from the Node-3 Passive Common Berthing Mechanism, i.e. from the port of Node-3 that is attached to the ISS, and disconnect the cables that provided power to the Node-3 heaters. These are used to counter the extremely low temperatures during the Shuttle's journey to the ISS.

The ISS robotic arm grabs Node-3. The special latches that hold Node-3 in place inside the Shuttle are released. Once free, the robotic arm manoeuvres Node-3 out of the payload bay to its attachment point on Node-1's port radial location. It takes about three hours from unberthing Node-3 until Node-1/Node-3 docking mechanisms are completely secured.

The EVA astronauts, still on their first spacewalk, connect the cables to Node-1 that restore power to the heaters that were use during transport in the Shuttle, and connect the avionics cables from the S0 truss to Node-3 before finishing the spacewalk. Now Node-3 is thermally stable, but cannot be fully activated yet because it is still missing thermal dissipation capability via the ammonia loop.

Inside the ISS, the volume between the hatches of Node-1 and Node-3, known as the 'vestibule' is pressurised. After a leak check is made, the Node-1 port hatch is opened.

**FLIGHT DAY 6** The crew performs all utilities connections at vestibule level (such as audio and video, air ventilation). The Node-3 hatch is opened and the crew make an 'early ingress', meaning that they enter Node-3 even though it is not fully activated. The air ventilation is established using the temporary vestibule intermodule ventilation duct, and lighting provided with portable lamps.



During this interim configuration, the crew prepares Cupola for moving to its final location on the Node-3 nadir port. They open the Node-3 port hatch to install, on the external side of the Node-3 bulkhead, the cap that will isolate Node-3 from Cupola prior to its depressurisation. The crew now manoeuvre the ISS robotic arm to grab Cupola by the dedicated FRGF (Fixed Release Grapple Fixture). In parallel, the first two racks (Advanced Resistive Exercise Device and Air Revitalization System) are transferred and installed inside Node-3, waiting for their activation.

**FLIGHT DAY 7** During the second EVA, Node-3 is connected to the ISS ammonia lines (which are an integral part of the ISS thermal control). Thermal cover 'booties' are installed over connections and over the trunnions and keel used to fix Node-3 in the Shuttle's payload bay. Other external outfitting tasks are the installation of EVA handrails, worksite foot interface points, gap spanners and a non-propulsive air-venting device.

During the same EVA, the locking pins are removed from the Node-3 nadir mechanism and the associated petals are opened to allow for berthing of the Cupola. When the ammonia lines are connected, Node-3 can be activated as a fully functioning element of the ISS either from ground or, as a back-up, by the crew.

While the second EVA is still going on, the cargo in Node-3's Integrated Stowage Platform is removed and the platform dismounted to make way for the racks that will be permanently installed in these locations.

Dedicated valves for nominal intermodule ventilation are installed in Node-3, replacing the pressure relief valves that were in place during launch and activation in order to prevent negative pressure inside Node-3.

At the end of the second EVA, Cupola is depressurised.

**FLIGHT DAY 8** The Cupola is unberthed from Node-3's end docking port and manoeuvred to the Earth-facing (nadir) port of Node-3 where it is redocked.

Before the Node-3 nadir hatch is opened, Cupola must be repressurised and checked for leaks. At this point, Cupola's electrical, ventilation and water lines are connected and the window heaters are activated.

Inside Node-3, the crew transfer and install the life support racks, namely the Water Recovery System (WRS1 and WRS2) racks, the Oxygen Generation System rack and the Waste and Hygiene Compartment rack. The last rack to go inside Node-3, the second treadmill, will be relocated from the Node-2 after the Shuttle has left.

**FLIGHT DAY 9** Other Node-3 outfitting tasks are performed (such as water sampling tools installation, cabin fan anti-vibration mounting devices removal) as well as the installation of the Audio Terminal Unit and the two Utility Outlet Panels inside Cupola.

The crew relocate PMA-3 docking adaptor to its final location on Node-3 (i.e. the port where the Cupola was at launch). In this scenario, the Node-3 hatch towards PMA-3 will remain open to grant additional storage place on the ISS and Node-3 will distribute to all resources (power, data and air ventilation), needed by PMA-3.

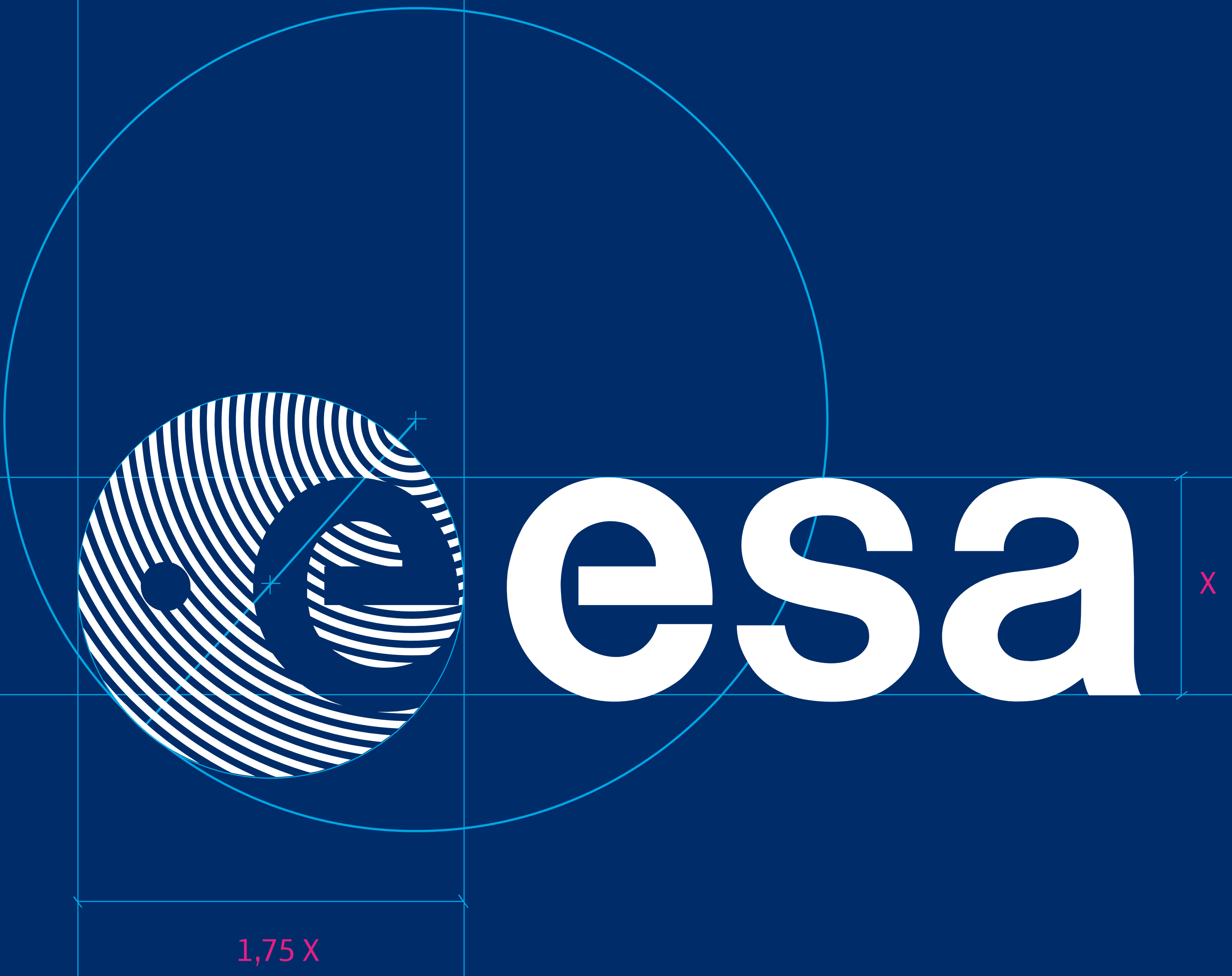
**FLIGHT DAY 10** During the third EVA, the thermal shroud covering Cupola and the launch bolts that secure its window shutters in place are removed (three bolts per shutter). The thermal shroud is jettisoned on removal. External utility connections to PMA-3 are made. Additional Node-3 related tasks during the EVA include the disconnection of the temporary heater power line (providing 'survival' power to Node-3 until its final activation).

Inside the ISS, the outfitting of both Cupola and Node-3 continue with the filling of the Cupola water lines and the relocation of internal closeout panels, as well as the removal of all launch support items (pump launch brackets, launch bolts, etc.). The robotic workstation can now be installed inside the Cupola and used by the crew to drive the robotic arm, monitor dockings of Automated Transfer Vehicles and HII Transfer Vehicles, make observations – or just relax and enjoy the views of Earth and the stars.

**FLIGHT DAY 11** Crew rest and preparation for Shuttle undocking.

**FLIGHT DAY 12** The Shuttle undocks from the ISS and is scheduled to land on Flight Day 13 back at KSC.

(*) All timeline details listed are subject to change prior to launch.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# → THE WAY WE ESA

## Introducing ESA's corporate visual identity

**Fulvio Drigani, Fabrizio L'Abbate & Hugo Simões**
Communication Department, ESRIN, Frascati, Italy

**Carl Walker**
Communication Department, ESTEC, Noordwijk, The Netherlands

**The role of ESA is evolving. The way we work in ESA is changing. In periods of change like this, a strong and recognisable ESA 'Corporate Visual Identity' is vital.**

In recent months, you may have noticed changes in some of our products, for example, our website, our brochures, our videos and, of course, this ESA *Bulletin*.

Visual communication is very powerful, and many people respond more strongly to visual cues than to written messages, especially when we are working across the daunting boundaries of language and cultures. We realise that, much like wearing a new suit to a job interview, the way we present ourselves can raise our profile, increase pride in belonging and contribute to success.

The way we visually express ourselves as ESA is called our Corporate Visual Identity. This includes the logo, fonts, signage and other design templates. Maintaining a strong corporate visual identity is one of the most difficult and complex challenges facing organisations like ours today, and all organisations strive for a strong identity because this gives instant recognition.

# → THE WAY WE ARE

**Our attitude shapes our personality**



This is an integral element of our overall communications and is fundamental in increasing awareness of ESA in European citizens and decision-makers. But another area is becoming increasingly important: recruitment. Our image has a major impact on our ability to attract potential recruits (see 'Welcome to Space: ESA's Strategy for Retaining European Space Competencies', *Bulletin* 133, February 2008).

Effective management of the Corporate Visual Identity is the only way to ensure that we keep the image we want. This is both a creative and highly disciplined process, requiring a well-defined approach for the application of a visual identity system (accompanied by a 'house style' for written communication). A powerful 'brand architecture' has been created that lets people recognise immediately the 'sub-brands' of the ESA brand.

Throughout 2010, ESA will be progressively appearing in this new style.

The ESA *Bulletin* and Web Portal were launched in this new livery in 2008 and 2009.

## Why does ESA need to update its visual identity?

Designed in the late 1970s, ESA's original Corporate Visual Identity guidelines needed refreshing, modernising and adapting to new media, with more range and consistency in application. For instance, the logo, the only widely used visual symbol, needed clear rules for its use on both printed and digital applications in order to always be perceived coherently.

The new visual identity is adding an extra dimension to messages about ESA's heritage, credentials and achievements, and about the opportunities it offers to new staff, to research and business partners and to society.

## European, visionary, human

The updated 'identity' communicates a set of values that are derived from ESA's culture, history and ambitions. The three most important values are those that appear to differentiate the organisation from others – the 'differentiating values'.

# → THE WAY WE LEAD

**There are three most important values that make our organisation unique**

**VISIONARY**

**We are visionary in setting new challenges and creating a view of the future**

**EUROPEAN**

**In ESA, we Europeans are working together, building on and using our different talents**

**HUMAN**

**We go into space with a human perspective, we want to bring the benefits back to Earth**


## The ESA colour palette

These values of 'European', 'Human' and 'Visionary' have been translated into the basic elements of design for all publications and products. These include a new typeface, 'arrows', 'orbits', 'hotspots', a well-defined corporate colour palette and a guide to picture style. ■

## → THE WAY WE SPEAK

**ESA's visual identity emerges from our values, culture, history and ambitions**

## The ESA brand architecture

esa

esa site name

esa site name

programme name

mission name

# → Evolution, not revolution

## A history of the ESA logo

When ESA was formed in 1975 by merging the European Space Research Organisation (ESRO) and European Launcher Development Organisation (ELDO), ESA's first Director General Roy Gibson decided to create and promote the name 'ESA'. A graphical 'mark', similar to the one that we associate with the 'ESA' initials in our logo today, was used between 1975 and 1977.

In those early days, only this 'mark' was needed for official documents and ESA stationery. The idea of having a corporate visual identity and a guide for wider use came later, when the young agency needed to widen its communications from politicians and decision-makers to the general public.

The first full ESA logo was created in 1977 with the idea of a logo made of two elements: the Earth/Europe disc (symbol) and the ESA mark (name). The 'e' stands for Europe and the disc represents Earth. The dot on the left represents a satellite, and the concentric lines represent parallels and orbits of satellites. They also give the impression of a rotating planet.

Later it was realised that the lines on the disc looked like a 'fingerprint'. This added a 'human' dimension (a human fingerprint is a unique signature, in line with emphasising ESA's uniqueness). Because a fingerprint is also basic genetic characteristic, it would also symbolise part of ESA's vision to study the origins of life on Earth and other worlds.

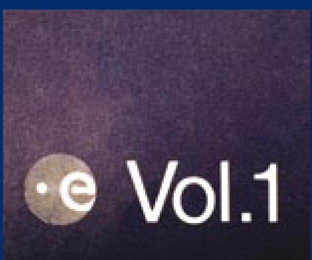
The first set of Corporate Visual Identity guidelines, containing the rules for use of this logo was produced in 1980. The logo remained unchanged until 1997, when a version of the logo with a reduced number of lines in the fingerprint was created to cope with the needs of television and video.

In 2000, with the development of the Web Portal, the issue of a consistent ESA Corporate Visual Identity on the Internet was tackled for the first time. For the web, the 'fingerprint' was again updated to reduce problems with screen resolution. It was decided not to use the flags that had been linked to some versions of the logo, because on the web, images of flags are normally used as links to different language versions of texts.

In fact, the flags were never part of the original logo. They were added later as extra graphical devices for more effect. This arrangement of flags has changed through the years, as can be seen on the many different variations of mission logos and astronaut patches, and their number has grown with more Member States.

↓

The first ESA 'thumbprint' as it appeared in 1975 in the first ESA *Bulletin*










↑

The ESA astronaut shoulder patch evolves, with the logo and changing sets of flags (1983-2009)

The problems caused in printing this increasing line-up of flags have prompted some of the developments in the new identity.


Towards a safer world.

# → NEWS IN BRIEF

Frank De Winne, Expedition 21 commander, relaxes in the helicopter that picks up the returning crew, shortly after the Soyuz TMA-15 spacecraft touched down in Kazakhstan on 1 December


esa

# Space agencies join forces on climate change

**During the UN Climate Change Conference (COP15) in Copenhagen in December, an ESA-hosted side event, called 'Global Monitoring of our Climate: the Essential Climate Variables', highlighted the role of Earth observation satellites in providing systematic global climate observations.**

The UN Framework Convention on Climate Change (UNFCCC) has long recognised the need for global observations of climate variables in order to quantify the state of our climate. These observations are essential for climate change research and for managing mitigation and adaptation strategies.

Within ESA's Climate Change Initiative a set of long-term global records of essential climate variables will be provided using space technology. These data are required by the Global Climate Observing System (GCOS) – an organisation in the framework of the World Meteorological Organization (WMO) – to support the UNFCCC and the International Panel on Climate Change.

Dr Stephen Briggs, ESA's Head of Earth Observation Science, Applications and Future Technologies Department, explained how ESA is responding to the needs of UNFCCC with its new Climate Change Initiative.

"ESA has developed the Climate Change Initiative to generate, preserve and give access to long-term data sets of the essential climate variables and make them freely available to climate research and modelling communities worldwide," said Dr Briggs.

The initiative will build on the availability of Europe's global data sets and on data delivered by a network of other space agencies. It will also guarantee the provision of space-based information for the future, in a form readily usable by scientific communities and government bodies.


↑

Speakers at the 'Global Monitoring of our Climate: the Essential Climate Variables' event included (left to right): Gilberto Camara, Director of the Brazilian Institute for Space Research; Carolin Richter, Director of GCOS Secretariat; Vicky Pope, UK Met. Office Head of Climate Research; Olivier Arino, ESA's Head of the Earth Observation Projects Section; Dr Stephen Briggs, ESA's Head of Earth Observation Science, Applications and Future Technologies Department; and Jacqueline McGlade, Director of the European Environmental Agency

# Pioneering images of martian moons

**For the very first time, the martian moons Phobos and Deimos were caught on camera together by ESA's Mars Express orbiter last November. These pioneering images will help the High Resolution Stereo Camera (HRSC) team validate and refine existing orbit models of the two moons.**

It is not often that both moons are located directly in front of the camera, lined up one behind the other. The chance to image both moons together came on 5 November 2009, when the viewing geometry was especially favourable.

The plan to image both moons was years in the making, made possible by the unique elliptical orbit of Mars Express, precise knowledge of the orbits of the planet, the moons and the spacecraft, as well as fortuitous viewing geometry, and perfect planning by the ESA and HRSC teams.

↑

Phobos and Deimos as seen by Mars Express (ESA/DLR/FU Berlin)

The exploration of Phobos is a scientific priority for the HRSC team, as well as producing high-resolution maps of the surface of Mars in colour and in 3D.

The potato-shaped moon has already been photographed 127 times by Mars Express, improving our knowledge of the topography of the moon, and providing insight into its origins and development.

# New European Cooperating States

**Estonia and Slovenia became the fifth and the sixth European countries to sign the Cooperating States Agreement with ESA.**

ESA's Director of Legal Affairs and External Relations, Peter Hulsroj, and Estonian Minister of Economic Affairs and Communications, Juhan Parts, signed the Cooperation Agreement on 10 November in Tallinn.

← ESA's Peter Hulsroj and Estonian Minister of Economic Affairs and Communications Juhan Parts (right) sign the Cooperation Agreement

Mr Hulsroj also signed the Cooperation Agreement with Slovenian Minister of Higher Education, Science and Technology, Gregor Golobic, at ESTEC, Noordwijk, The Netherlands, on 22 January.

The signed agreements strengthen relations with ESA and define the legal basis for developing a Plan for European Cooperating State (PECS) Charter, describing activities, projects and budget cooperation with ESA.

Hungary was the first country to gain this status in April 2003, followed by the Czech Republic in November of the same year. Romania and Poland joined in 2006 and 2007 respectively.

# Rosetta's view of home

**ESA's Rosetta comet chaser captured this spectacular image of Earth as it approached our home planet for the third and final swingby in November 2009.**

Taken by the OSIRIS instrument on Rosetta, from about 633 000 km away and with a resolution of 12 km per pixel, images through three colour filters were combined to create this one. The illuminated crescent shows South America and the South Pole (south at bottom). The outline of Antarctica is visible under the clouds and reflective pack ice near the coastline causes the bright spots on the image.

OSIRIS (Optical, Spectroscopic and Infrared Remote Imaging System) is the wide/narrow-angle camera system that will take high-resolution images of the Comet 67P/Churyumov-Gerasimenko to help in identifying the best landing sites.

↑ Earth seen by Rosetta (ESA/MPS for OSIRIS Team MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA)

# Students get taste of space

**Four student teams from five European countries took advantage of a new educational initiative to conduct microgravity experiments on an Airbus A300 'Zero G' aircraft.**

ESA's 'Fly Your Thesis!' programme made a successful debut during ESA's 51st Parabolic Flight Campaign, held in October and November 2009.

The initiative was introduced by ESA's Education Office, in coordination with ESA's Directorate of Human Spaceflight, in 2008. It provides students with a unique opportunity to perform scientific experiments in microgravity as part of their Masters or PhD theses.

The first participants were chosen in January 2009, after a rigorous selection process. A group from the University of Münster, Germany, studied the behaviour of tiny particles under different illumination conditions in order to improve understanding of dust storms on Mars.

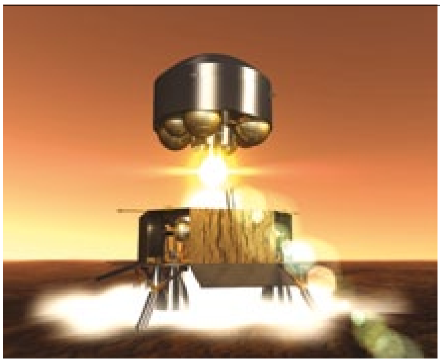
Students from the UK's Open University and the University of Nice-Sophia Antipolis, France, simulated the loose surface material on asteroids as a precursor to sample-return missions.

A group from the University of Science and Technology in Trondheim, Norway, investigated the behaviour of clay nanoparticles in water, research with potential applications such as the prevention of catastrophic landslides.

Another team from the Autonomous University of Barcelona and the Polytechnic University of Catalonia, Spain, recorded the behaviour of enzymes that modify assimilation of drugs by the human body.

↑

The 2009 campaign students together with the 'Fly Your Thesis!' team before their second flight on the Airbus A300 Zero-G aircraft



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A Mars sample return mission is long-term goal for the 2020s

# ExoMars programme goes ahead

**ESA's ExoMars received the go-ahead for implementation from ESA Council. This decision paves the way for two Mars exploration missions, in cooperation with NASA, in 2016 and 2018.**

The ExoMars programme will investigate the martian environment, particularly astrobiological issues, and will develop and demonstrate new technologies for planetary exploration, with the long-term view of a future Mars sample return mission in the 2020s.

Two missions are planned as part of the ExoMars programme: one consisting of an orbiter and an entry, descent and landing demonstrator (to be launched in 2016) and the other consisting of two rovers (to be launched in 2018).

# GENESI-DR: responding to global needs

**GENESI-DR (Ground European Network for Earth Science Interoperations - Digital Repositories) is an EC-funded project that has the challenging task of reducing the 'time to science' for Earth science data kept in large distributed repositories.**

GENESI-DR will improve the discovery, access and use of historical and recent data obtained from space, airborne and in situ sensors. It will operate, validate and optimise the integrated access and use of available digital data repositories, demonstrating how Europe can best respond to the emerging global needs relating to the state of our Earth, a demand that is unsatisfied so far.

Initiated in 2008 under ESA coordination, the project builds on the existing operational European Earth observation infrastructure and involves key Earth science centres responsible for operational data acquisition, processing, archiving and distribution. Partners include space agencies (DLR, ASI, CNES), space and non-space data providers such as ENEA (IT), Infoterra (UK), K-SAT (NO), NILU (NO), JRC (EU), and industry, such as Elsag-Datamat (IT), CS (FR) and TERRADUE (IT).

This common dedicated infrastructure will allow Earth science communities to derive objective information and share knowledge in all environmentally sensitive areas over time and a variety of geographical scales, addressing many urgent challenges such as global change.

Exploiting these data and knowledge for the management of our fragile planet is one of the major goals of international environmental programmes such as GMES and GEO/GEOSS.

As of today, 12 different digital repositories, hosting more than 60 heterogeneous dataset series, are federated in GENESI-DR. Series include satellite data, in situ data, images acquired by airborne sensors, digital elevation models and model outputs.

ESA has started providing access to Category-1 data, systematically available on Internet, level 3 data (e.g. GlobCover maps, MERIS Global Vegetation Indices), Advanced Synthetic Aperture Radar products available in ESA Virtual Archive and related to the Supersites initiatives.

In all cases, existing data policies are fully respected. GENESI-DR also gives access to grid computing resources, allowing authorised users to run a number of different processing services on the available data.

The project is adopting ISO 19115, ISO 19139 and Open Geospatial Consortium (OGC) standards for geospatial metadata and processing, and is compliant with INSPIRE Implementing Rules for Metadata and Discovery, using OpenSearch protocol with Geo extensions for data and services discovery.

GENESI-DR is gaining momentum in the Earth science community, thanks to the active participation to the GEO task force 'Data Integration and Analysis Systems' and to collaborations with EC projects. It is now extending international cooperation agreements, specifically with key players in GEO-GEOSS and CEOS-WGISS activities.

ESA's Director of Science and Robotic Exploration, Prof. David Southwood, said: "This marks an important moment for Europe in its steps towards space exploration on a world scale. We have been to the planets before, sure. But now we have a plan for exploration to build our technical capability and explore Mars in a long-term partnership."

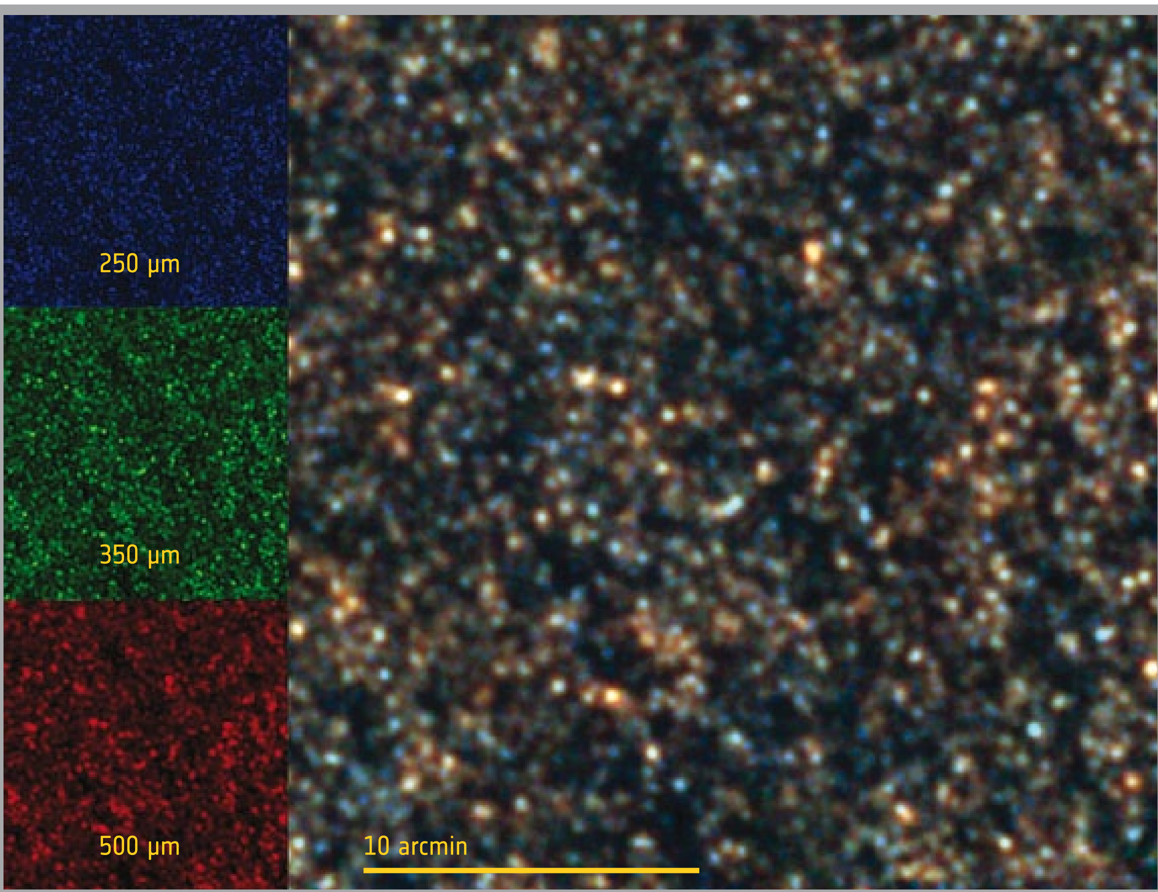
Thirteen of ESA's 18 Member States are participating in ExoMars: Austria, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the United Kingdom, plus Canada.

←

The ExoMars rover

# Views from Herschel

Launched only last year, Herschel is the largest, most powerful infrared telescope ever flown in space. During the lifetime of this mission, Herschel will study the infrared sky providing an important, and at times completely new, view of the Universe. These images clearly demonstrate the potential of this remarkable observatory.

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This image is an area of sky called the 'Great Observatory Origins Deep Survey' (GOODS), which has been observed by many telescopes at a range of wavelengths, seen now by Herschel's Spectral and Photometric Imaging Receiver (SPIRE) in sub-millmetre wavelengths.

This area of sky is devoid of foreground objects, such as stars within our galaxy or any other nearby galaxies, which makes it ideal for observing deeper into space. Every fuzzy blob is a very distant galaxy seen as they were three to ten billion years ago when the star formation was very widely spread throughout the Universe. The image is made from the three SPIRE bands, with red, green and blue corresponding to 500µm, 350µm and 250µm respectively.

Dr Seb Oliver, from the University of Sussex and head of the Herschel Multi-tiered Extragalactic Survey (HerMES) project, said: "In just one picture we can see ten times as many galaxies as have been seen before by all sub-millimetre telescopes like this one, up until today. Seeing such stunning images after just 14 hours of observations gives us high expectations for the full length observations over much larger regions of the Universe."
(ESA/Univ. Sussex/HerMES)

↑

Herschel's view of a stellar nursery around 1000 light-years away in the constellation Aquila (the Eagle). This cloud, 65 light-years across, is so shrouded in dust that no infrared satellite has been able to see into it, until now. Thanks to Herschel's greater sensitivity at the longest infrared wavelengths, astronomers have their first picture inside this cloud.

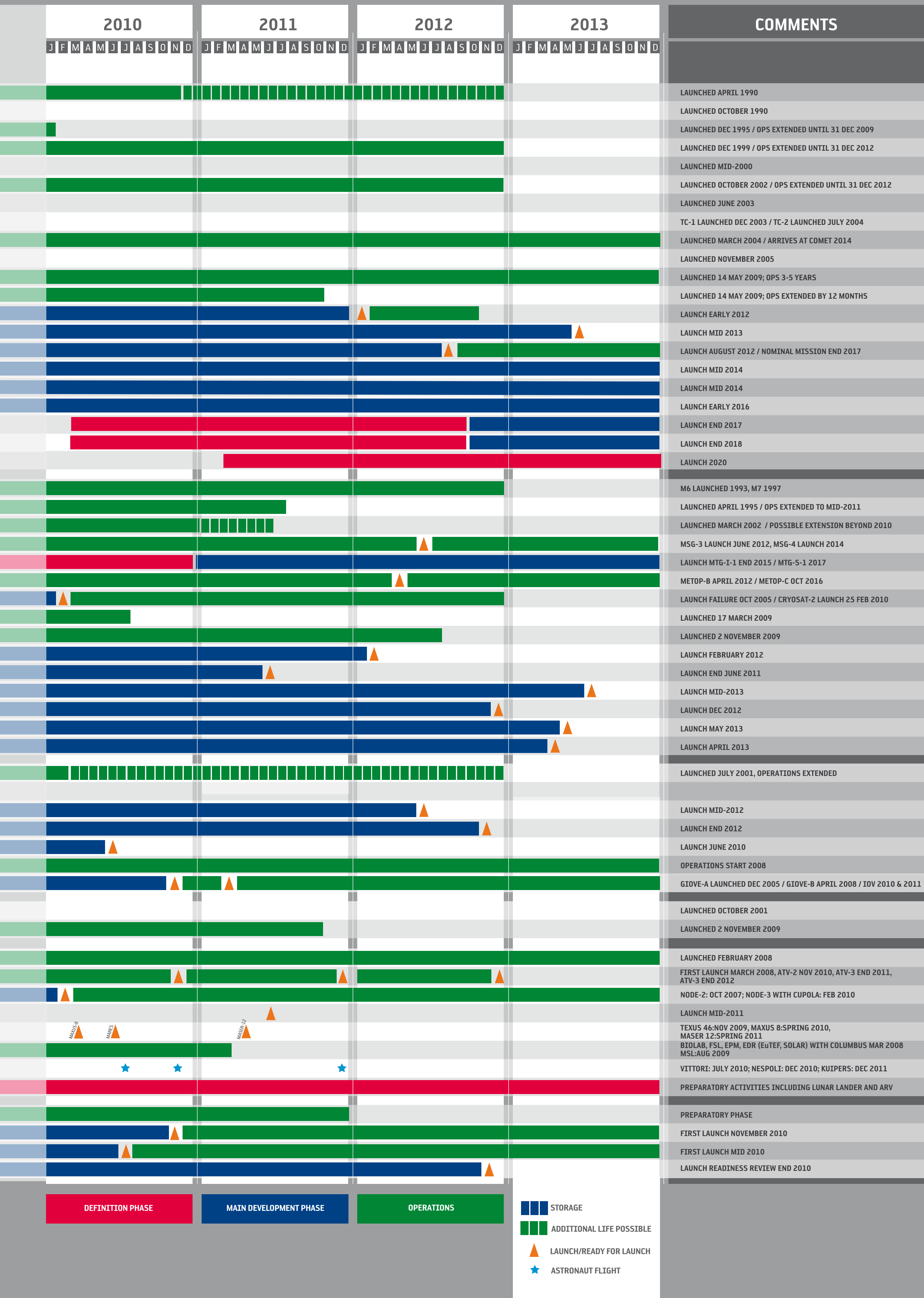
Taken on 24 October 2009, using Herschel's PACS and SPIRE instruments at the same time, the image shows two bright regions where large newborn stars are causing hydrogen gas to shine. Embedded in the dusty filaments are 700 condensations of dust and gas that will eventually become stars. Astronomers estimate that about 100 are 'protostars', celestial objects in the final stages of formation. Each one just needs to ignite nuclear fusion in its core to become a true star. The other 600 objects are not developed sufficiently to be called protostars, but eventually they will become another generation of stars.

Observing these stellar nurseries is a key programme for Herschel, which aims to uncover the demographics of star formation and origins, or in other words, the quantities of stars that can form and the range of masses for these newborn stars.
(ESA/SPIRE & PACS/P. André, CEA Saclay)

# → PROGRAMMES IN PROGRESS

**Status at end December 2009**


2006
2007
2008
2009
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
ULYSSES
SOHO
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
DOUBLE STAR
ROSETTA
VENUS EXPRESS
HERSCHEL
PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
EXOMARS
COSMIC VISION M1
COSMIC VISION M2
COSMIC VISION L1
EARTH OBSERVATION PROGRAMME
METEOSAT-6/7
ERS-2
ENVISAT
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
ADM-AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
TELECOMMS/NAV. PROGRAMMES
ARTEMIS
ALPHABUS
ALPHASAT
SMALL GEO SAT.
HYLAS
GNSS-1/EGNOS
GALILEO
TECH. PROG.
PROBA-1
PROBA-2
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
ATV
NODE-2 / NODE-3 / CUPOLA
ERA
EMIR/ELIPS
MFC
ASTRONAUT FLT.
TRANS. & HUMAN EXP.
LAUNCHER PROG.
ARIANE 5 POST-ECA
VEGA
SOYUZ AT CSG
IXV



2010
2011
2012
2013
J F M A M J J A S O N D
COMMENTS
LAUNCHED APRIL 1990
LAUNCHED OCTOBER 1990
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 31 DEC 2009
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 31 DEC 2012
LAUNCHED MID-2000
LAUNCHED OCTOBER 2002 / OPS EXTENDED UNTIL 31 DEC 2012
LAUNCHED JUNE 2003
TC-1 LAUNCHED DEC 2003 / TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004 / ARRIVES AT COMET 2014
LAUNCHED NOVEMBER 2005
LAUNCHED 14 MAY 2009; OPS 3-5 YEARS
LAUNCHED 14 MAY 2009; OPS EXTENDED BY 12 MONTHS
LAUNCH EARLY 2012
LAUNCH MID 2013
LAUNCH AUGUST 2012 / NOMINAL MISSION END 2017
LAUNCH MID 2014
LAUNCH MID 2014
LAUNCH EARLY 2016
LAUNCH END 2017
LAUNCH END 2018
LAUNCH 2020
M6 LAUNCHED 1993, M7 1997
LAUNCHED APRIL 1995 / OPS EXTENDED TO MID-2011
LAUNCHED MARCH 2002 / POSSIBLE EXTENSION BEYOND 2010
MSG-3 LAUNCH JUNE 2012, MSG-4 LAUNCH 2014
LAUNCH MTG-I-1 END 2015 / MTG-S-1 2017
METOP-B APRIL 2012 / METOP-C OCT 2016
LAUNCH FAILURE OCT 2005 / CRYOSAT-2 LAUNCH 25 FEB 2010
LAUNCHED 17 MARCH 2009
LAUNCHED 2 NOVEMBER 2009
LAUNCH FEBRUARY 2012
LAUNCH END JUNE 2011
LAUNCH MID-2013
LAUNCH DEC 2012
LAUNCH MAY 2013
LAUNCH APRIL 2013
LAUNCHED JULY 2001, OPERATIONS EXTENDED
LAUNCH MID-2012
LAUNCH END 2012
LAUNCH JUNE 2010
OPERATIONS START 2008
GIOVE-A LAUNCHED DEC 2005 / GIOVE-B APRIL 2008 / IOV 2010 & 2011
LAUNCHED OCTOBER 2001
LAUNCHED 2 NOVEMBER 2009
LAUNCHED FEBRUARY 2008
FIRST LAUNCH MARCH 2008, ATV-2 NOV 2010, ATV-3 END 2011,
ATV-3 END 2012
NODE-2: OCT 2007; NODE-3 WITH CUPOLA: FEB 2010
LAUNCH MID-2011
MAXUS-8
MARES
MASER-12
TEXUS 46:NOV 2009, MAXUS 8:SPRING 2010,
MASER 12:SPRING 2011
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MSL:AUG 2009
VITTORI: JULY 2010; NESPOLI: DEC 2010; KUIPERS: DEC 2011
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER AND ARV
PREPARATORY PHASE
FIRST LAUNCH NOVEMBER 2010
FIRST LAUNCH MID 2010
LAUNCH READINESS REVIEW END 2010
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

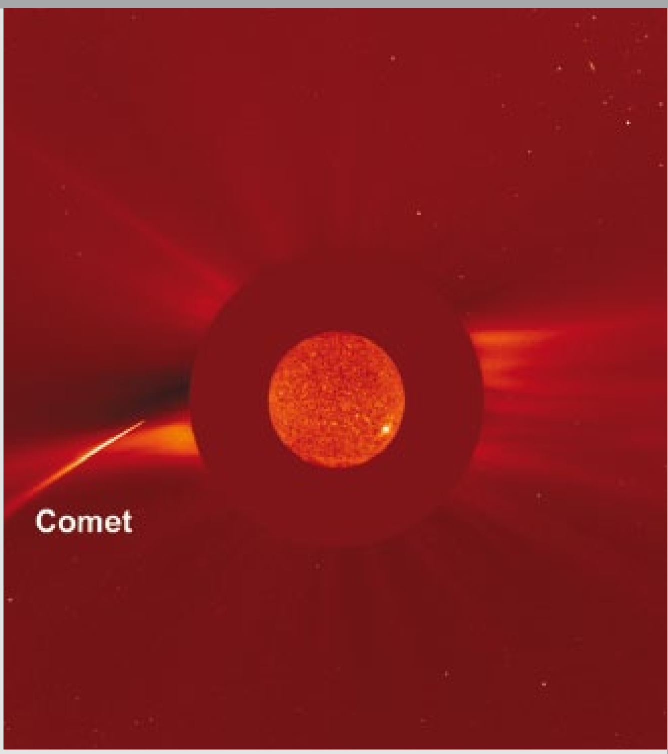
## KEY TO ACRONYMS

| | | | |
|---|---|---|---|
| AM | Avionics Model | MoU | Memorandum of Understanding |
| CDR | Critical Design Review | PDR | Preliminary Design Review |
| ELM | Electrical Model | QM | Qualification Model |
| EM | Engineering Model | SM | Structural Model |
| FAR | Flight Acceptance Review | SRR | System Requirement Review |
| FM | Flight Model | TM | Thermal Model |
| ITT | Invitation to Tender | | |

## → SOHO

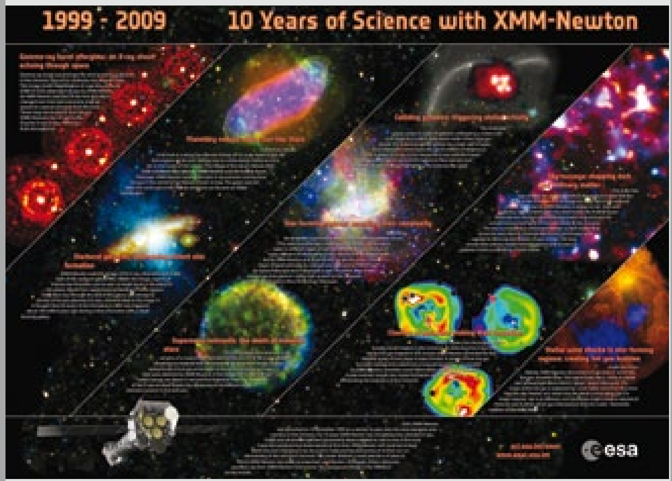
On 3 January, SOHO captured the arcing orbit of a particularly bright 'Sungrazing' comet as it approached the Sun and evaporated. The comet, discovered by Australian amateur astronomer Alan Watson, is probably a member of the Kreutz Sungrazer family. Named after the 19th century German astronomer who studied them in detail, Kreutz Sungrazers are fragments from the break-up of a giant comet some 2000 years ago. This comet was one of the brightest of the nearly 1700 Sungrazing comets observed by SOHO in its 14 years of operation.

Finally there seems to be little doubt that solar cycle 24 has come to life at last. New cycle activity dominated recent months and solar minimum seems to have occurred late in 2008.




One of the brightest Sungrazing comets observed by SOHO

## → XMM-NEWTON




An educational poster celebrates 10 years of science with XMM-Newton, and can be downloaded from http://xmm.esac.esa.int/external/xmm_news/items/10th_Anniversary/

On 10 December, we marked a decade of remarkable discoveries, outstanding achievements and extraordinary scientific insights with XMM-Newton. In 1999, an Ariane 5 lifted off from Kourou in French Guiana carrying XMM-Newton, ESA's flagship X-ray observatory. In the intervening decade, this astronomical workhorse has played a significant role in revolutionising the field of X-ray astronomy.

The breadth and scope of the science that has been influenced by this observatory is vast, encompassing, for example, the detection of X-ray emission from Solar System objects, detailed studies of star-formation regions, investigation of the formation and evolution of galaxy clusters, probing the environment of supermassive black holes, and mapping 'dark matter'.

## → CLUSTER

Cluster safely passed through its long eclipse season in October and November 2009, including a number of complete power-downs and restarts of the spacecraft. In the autumn, the apogee was lowered by 5000 km to improve data download volume. During winter, Cluster made the first plasma measurements in the auroral acceleration regions with four satellites and passed into the dayside magnetosphere to examine the magnetopause, magnetosheath and bow-shock.

The Cluster Active Archive continues its success and now has around 1000 users. This year sees the publication of the book *The Cluster Active Archive: Studying the Earth's Space Plasma Environment*. This book contains 35 peer-reviewed papers related to presentations made at the 15th Cluster Workshop and first CAA school. It includes several articles about the CAA, its datasets and their calibration and a number of scientific results on the physics of the solar wind, magnetosheath, magnetopause and magnetosphere.

## → DOUBLE STAR

Unfortunately, contact with Double Star TC2 was not reestablished by the end of 2009, which marks the end of the predicted operational mission lifetime. The Chinese and European operations, project science and instrument teams have initiated the archiving phase of the mission.

## → INTEGRAL

All Integral instruments are operating normally. During the active cooling phase following the last SPI spectrometer annealing, a switch anomaly led to a brief interruption of the cooling. While the coolers were quickly reactivated, a side effect was that the next annealing may be needed sooner than usual.

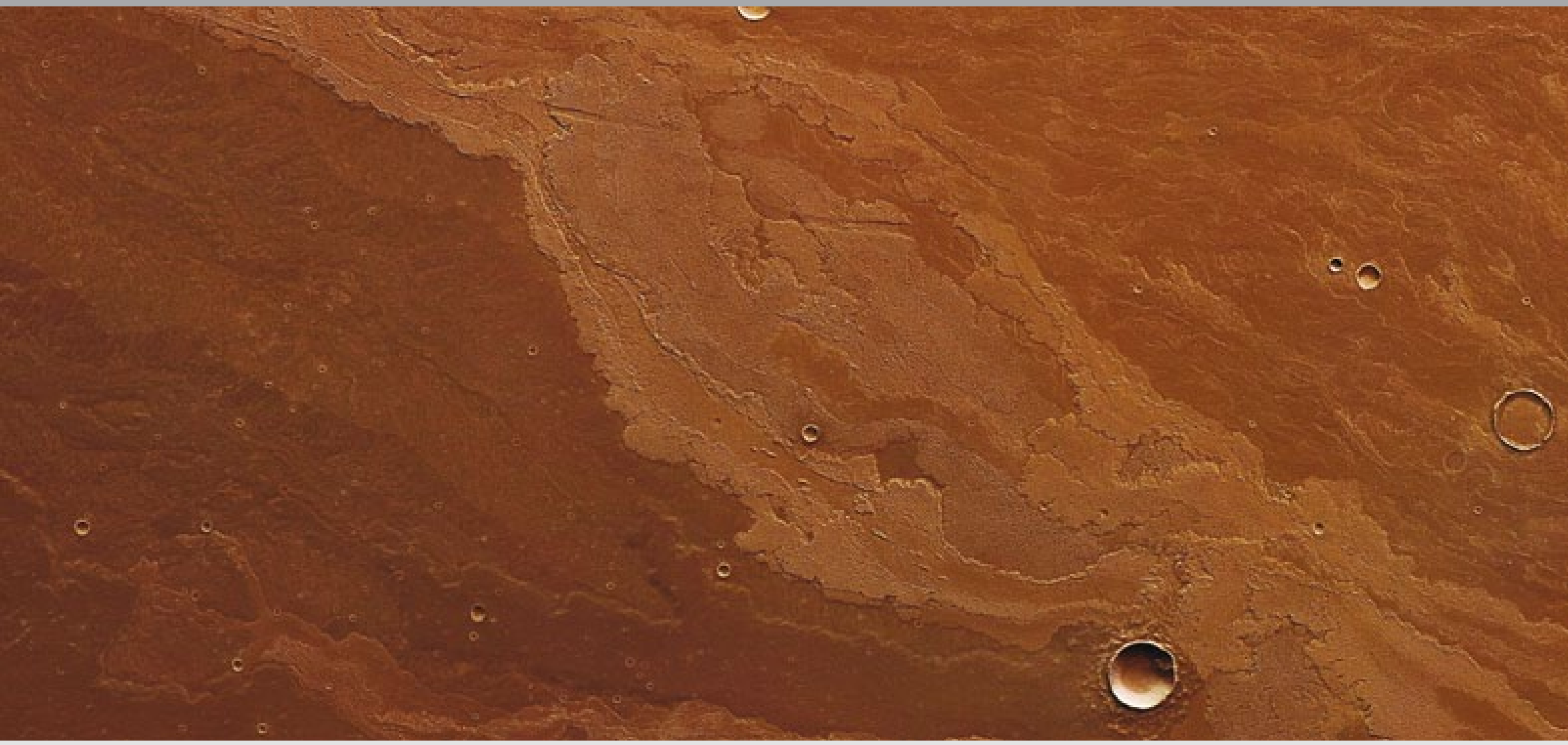
The Crab nebula is a very efficient particle accelerator, showing evidence for electrons accelerated up to energies of around $10^{15}$ eV. Throughout the nebula, the maximal energy of the relativistic electrons changes, and therefore only an instrument with sufficient resolving power can probe the particle acceleration processes in the different regions of the nebula.

With unprecedented angular resolution in the hard X-ray/soft gamma-ray energy range, and a very accurate calibration, the IBIS telescope on Integral has been used to show that the size of the nebula is decreasing with increasing energy, and to calculate the maximal energy of electrons in the outer regions of the X-ray nebula, found to be just below $10^{14}$ eV.

## → MARS EXPRESS

On 5 November, Mars Express imaged the martian moons Phobos and Deimos together. For the first time in the six-year mission, the geometrical configuration of the two moons relative to the spacecraft presented a unique opportunity to capture them in a sequence of images. These unique images will help the camera team validate and refine existing orbit models of the two moons.

In 2009, Mars Express also image, Daedalia Planum, a sparsely cratered, untextured plain on Mars that features numerous solidified lava flows.



Daedalia Planum features solidified lava flows of different ages, originating from the southern flank of Arsia Mons, one of the largest volcanoes on Mars. This image covers about 11 250 sq km, roughly the size of Jamaica, with a ground resolution of about 17 m per pixel (ESA/DLR/FU Berlin)

## → ROSETTA

Rosetta performed its third and final Earth swingby on 13 November 2009, with its closest approach at an altitude of 2481 km over the ocean south of the Indonesian island of Java, at 08:45 CET. The swingby was planned and fully automated, and the spacecraft was in direct communication with Earth at the time, via the ESA New Norcia station.

The swingby was confirmed at 09:05 CET when contact with Rosetta was reestablished via ESA's Maspalomas station in Spain. Some instruments had been switched on before and during the swingby, making imaging, magnetospheric and atmospheric observations of Earth, as well as searching for water on the Moon.

The spacecraft has gained sufficient orbital energy to fulfil its ultimate goal, the rendezvous with Comet 67P/Churyumov-Gerasimenko in 2014, and is also correctly positioned for its second asteroid flyby later this year. Rosetta is now on its way to the main asteroid belt between Mars and Jupiter to meet asteroid (21) Lutetia on 10 July 2010.

## → VENUS EXPRESS

In-depth analysis of stellar occultation data in ultraviolet light by the SpicaV instrument, at wavelengths just shorter than visible light, has revealed the ozone in the upper atmosphere of Venus. Ozone has never been detected on Venus before. The abundance is highly variable, both temporally and spatially, with an observed concentration varying between 0 and 100 parts per billion.

This low abundance will not have a significant effect on the temperature in the region, unlike on Earth (most of the ultraviolet radiation reaching Earth from the Sun is absorbed by a much larger amount of ozone in our stratosphere, so protecting Earth), but it has significant implications on the chemistry, in particular for the hydroxyl molecule (OH). Tracking the spatial variations of the ozone also gives an independent handle on studying the dynamics in this region.

## → HERSCHEL

Herschel is gradually making the transition into routine science operations. The PACS and SPIRE instruments have completed their Performance Verification and Science Demonstration Phase activities. They are now performing Routine Science Phase observations. A workshop was held near Madrid at the end of 2009, at which most of the Key Programmes presented initial Science Demonstration Phase results, and was attended by more than 200 astronomers. By way of example, this demonstrated the superb capabilities that Herschel has to offer for observers in a hitherto almost completely unexplored region of the electromagnetic spectrum.

HIFI recovery has been in progress since the beginning of this year. So far, recovery activities have proceeded to plan and HIFI should be returning scientific results again by the first half of February.

## → PLANCK

The Planck spacecraft, payload and ground segment operations are working normally and providing excellent data. By mid-January, Planck had completed five months of routine operations since the end of its First Light Survey and, in this time, has surveyed around 80% of the sky with all its detectors. The operations of Planck have been remarkably smooth, marred only by a few minor anomalies that have all been fixed.

The excellent performance of the cryo-cooling system in maintaining the nominal temperature of 100mK required for the operations of the payload has been confirmed, and the extension of the mission operations by 12 months has now been approved, allowing Planck to complete at least four full surveys of the sky.

A meeting of the Planck scientific consortia took place in Bologna in November 2009, attended by more than 250 scientists. They discussed the status of the data processing of the Planck data. The data processing pipelines are able to process the data from end to end and the quality of the results is improving very quickly. Preliminary results shown at the meeting give very encouraging glimpses of the science that will be produced by Planck.

## → COROT

COROT has now completed more than 1200 days in space. The spacecraft is operating normally, albeit with only half of the focal plane active. Recently, the mission was extended by CNES until the spring of 2013. The data archive contains more than 200 Gb of processed data from 10 separate pointings of the satellite covering about 80 000 stars. Several interesting planets have been found, one of them being COROT-7b, which is the first low-mass planet outside the Solar System with a density similar to Earth.

The number of planets discovered by COROT and currently published or under study is about 20 with another 80 candidates actively being followed up. COROT has carried out extensive work in asteroseismology, among which are the first studies of solar-type stars from space, studies of pulsations in stars evolving towards the end of their lives and various studies of (micro-)variability in different stellar objects. A dedicated issue of *Astronomy & Astrophysics* (October 2009) contained 55 articles reporting these and other results.

## → LISA PATHFINDER

The satellite integration and testing phase of LISA Pathfinder is progressing well. Most of the spacecraft equipment flight models have been integrated on the Science Module and their electrical integration is under way. Virtually all platform units of the Science Module have been delivered. As soon as the integration of the platform units will be completed, the Science Module is shipped to the special magnetic facility in IABG, Munich, where the system magnetic test will take place in February.

The Propulsion Module FM integration is proceeding on schedule, to be completed by March. The verification of the on board software is continuing on the Software Verification Facility and on the two parallel Real-time Test Benches at Astrium Ltd for the Attitude Control and System Control aspects and at Astrium GmbH for the Drag-Free Attitude Control.

Some modifications to the caesium slit thruster unit still have to be implemented on the accelerator design before it can go through a series of demonstration and qualification tests. The manufacture of the new accelerators is under way, while additional material tests are being performed in Alta (Pisa, IT), in the Electric Propulsion and Material Laboratories in ESTEC and in other specialised laboratories in Europe. The new thruster will be integrated and tested in the next couple of months.

The needle indium FEEPs are continuing their technology development as a back-up.

The flight hardware for the American Disturbance Reduction System payload is mechanically and electrically integrated on the Science Module. The suppliers of the various parts of the European LISA Technology Package (LTP) have delivered all the ELM units to Astrium GmbH for the Real-time Test Bench. The ELM units of the Optical Measurement System have recently passed a complex closed-loop performance test at the Albert Einstein Institute in Hanover.

The flight models of the Laser Modulator, the Inertial Sensor Front-End-Electronics and the LTP software have been delivered, while the remaining units (Laser Assembly, Phasemeter Unit and UV-lamp Unit) have encountered some problems during tests and will be delivered in the first quarter of 2010. The inertial sensor remains the most critical item, with the caging mechanism, the electrodes housing and the vacuum system.

Launch is not expected before early 2012.

## → GAIA

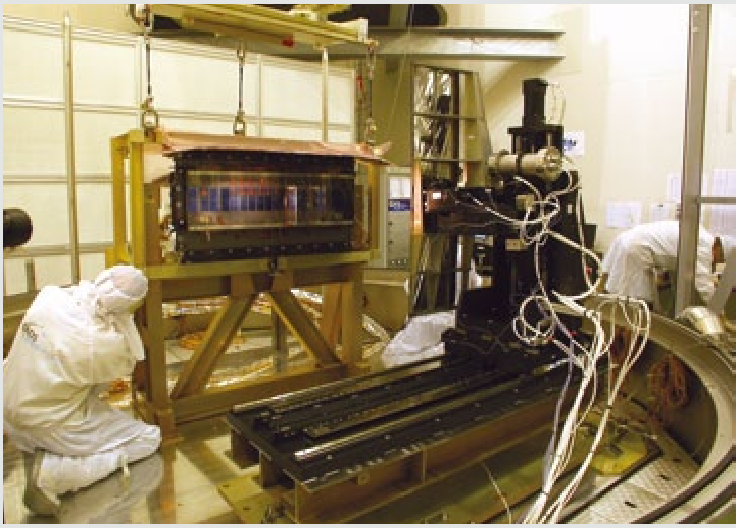
The integration of the structural elements on the Gaia optical bench ('torus') is proceeding. The supports for the primary mirrors have been glued and the integration of the 'bipods' is imminent. The folding optics structure, a very complex structural element made of silicon carbide that will host part of the optics, is ready for mechanical tests. The first three flight mirrors have been delivered.

The integration of the chemical propulsion and part of the thermal hardware on the Service Module FM is progressing. Activities on the spacecraft AM continue with many engineering model units integrated and tested and with the first priority given to the AOCS subsystem. All central software is now coded and tests are under way.

In October, a second attempt to deploy in vacuum the 10 m diameter sunshield QM (quarter-size of the actual sunshield) failed and it is now clear that design modification is needed. The performance tests of the Focal Plane Assembly EM in vacuum took place at the end of 2009. 'First light' from several optical sources was collected, demonstrating that the detection chain works and the centroid performance is very close to the theoretical one. The focal plane was then coupled to the atomic clock and to the video processing unit (including the scientific software). This test showed, for the first time, the autonomous star detection and processing operation.

The proposal from Arianespace for the procurement of the Soyuz launcher and related services was negotiated and agreed. The contract was signed at the end of December 2009.

The Electrical Service Module CDR was completed in December and the Mechanical Service Module CDR is under way. The Payload Module CDR is planned in April. Completion of these major reviews will pave the way to the Spacecraft and Mission CDR in summer 2010.



The Gaia Focal Plane Assembly engineering model being prepared for the functional tests at Astrium SAS (Toulouse)

## → MICROSCOPE

CNES is proposing a likely postponement of the target launch date to 2013, due to difficulties being encountered in technology developments. The integration of the Sensor Unit QM is ongoing. Functional tests on the EM with flight electronics were postponed to 2010 due to delays on both sensor and electronics side. Development activities continue on both FEEP under LISA Pathfinder and cold-gas technologies.

## → JAMES WEBB SPACE TELESCOPE

NASA has completed the CDR of the optical telescope and is now busy preparing for the mission CDR in April 2010. The telescope manufacture is ongoing. The first primary mirror segment has been repolished to cancel out the measured cryo-deformation at its operating temperature (40K). Another four mirrors have also been cryo-tested and a third test involving five mirror segments is being prepared. Cryo-testing, followed by a final repolishing, is required to achieve the very high surface quality.

The ESA contribution to JWST consists of the launch of JWST on an Ariane 5 ECA, support to the science operations and two of the four scientific instruments (the Near-Infrared Spectrograph, NIRSpec, developed by ESA, and the Mid-Infrared Instrument, MIRI, developed by a consortium of European institutes).

The NIRSpec full-scale development model completed its cryo-test campaign. The authorisation for shipment to NASA was given and delivery is due in mid-February. The integration of the flight instrument is proceeding after the delivery of all the main mirror assemblies and the refocus mechanism. The 'first light' was received at the detector plane and the measured image quality is very promising. Three flight subsystems remain to be delivered; the detector system, the micro-shutter system and the grating wheel assembly.

The completion of the MIRI flight subassemblies is proceeding. The structure, the Spectrometer Main Optics and the control electronics were delivered to Rutherford Appleton Laboratories (RAL) for instrument integration. The imager completed the environmental acceptance testing and is being prepared for delivery to RAL.

Three flight subsystems remain to be delivered: the input calibration optics is in final testing before delivery; the Spectrometer Pre-Optics completed the acceptance testing and is waiting for the grating wheel to finish testing; the detector system electronics is in final rebuild, after repair of a noise problem. The detectors are ready for final test with the electronics.

The procurement of the launch adaptor was initiated and the PDR of a test adaptor was concluded. The launcher system performance analyses are all being updated as input to the mission CDR.

The launch is currently planned for mid-2014.

## → BEPICOLOMBO

The system PDR was concluded, clearing the way for the start of Phase-C/D. The build up of the industrial team is nearing completion, with more than 90% of the equipment subcontractors selected.

For the solar arrays, the high-temperature environment in orbit around Mercury remains a challenge for the technology. A mission was defined and accepted on the basis of a solar-array qualification limit at 200°C (previously 230°C) in order to reduce the development risk. The resulting electrical power available to the payload generally exceeds the requirement, except during a small part of the orbit where operational constraints need to be implemented. The predicted power availability is regarded as conservative.

Meanwhile, in support of the final selection of the flight hardware configuration, tests of the solar-cell assemblies are characterising their performance at high temperature and high solar intensity. PDRs for a series of equipment and subsystems are progressing.

The manufacturing and test phase for the scientific instruments is ongoing in support of hardware deliveries for the SM/TMs and EMs scheduled in 2010. The thermal analysis for the Mercury Planetary Orbiter instruments is being updated, reflecting the agreed payload configuration, while a few incompatibilities are being addressed by local interface adaptations.

Development of the Japanese Mercury Magnetospheric Orbiter is progressing as planned. The SM was converted to a TM and the thermal test at one solar constant is nearing completion at the Tsukuba Space Centre. The ELM tests for spacecraft and payload equipment are nearing completion. The Ground Segment SRR was completed.

Launch is planned in the Mercury launch opportunity in mid- 2014.

## → EXOMARS

In December, the ESA Council approved the ExoMars programme based on a broad international cooperation between ESA and NASA for the ExoMars missions. The ExoMars programme consists of two missions to be launched in the 2016 and 2018 planetary 'launch windows' to Mars. NASA will provide the launchers for both missions. Furthermore, the contributions to the missions are divided as follows:

2016: ESA-led mission with an ESA Orbiter and an ESA Entry, Descent and Landing Demonstrator Module. NASA contributes scientific instruments on the Orbiter as well as communications equipment to be used in Mars orbit.

2018: NASA-led mission carrying the ESA ExoMars rover and a NASA rover on a NASA spacecraft and Entry, Descent and Landing Module. NASA also provides thermal radioactive heater units for the ESA rover and some instrumentation.

The industrial team is proceeding with these new missions in 2010 with a PDR planned for the end of 2010 and a start of the Phase-C/D implementation in the second quarter of 2011.

## → ALPHABUS AND ALPHASAT

### System and launch

The Alphasat CDR started with the System and IP part 1 reviews in December. The CDR will be completed by April 2010. Launch of Alphasat on an Ariane 5 is scheduled for mid-2012.

Visit of ESA delegations to see the Alphabus Service Module at Thales Alenia Space Cannes before its shipment to Toulouse (TAS)

### Service Module

A pre-shipment review was held in December to confirm the transport of the Service Module from Thales Alenia Cannes to Astrium Toulouse (FR). The Service Module consists of the main structure, the central tube, internal deck and several other structural elements equipped with thermal hardware, the chemical propulsion system with the main apogee boost motor, pressure control assembly with three helium tanks and the two large propellant tanks (inside the central tube) and part of the plasma propulsion system with the xenon tanks.

During December, the last important tests on the chemical propulsion system, namely the global proof and leak tests, were conducted. The remaining activities on the Service Module are on track and it is expected to leave Cannes on 26 January.

Beyond this shipment date, some Alphabus items will be still in production in Cannes for integration on the satellite at a later stage, for example the xenon propulsion system gas plate or the PPS 1350 thrusters mounted on their orientation mechanisms.

### Repeater Module

In parallel, the Repeater Module activities are progressing. The Delivery Review Board of the north-half Repeater Module structure took place end of December. The hardware will be shipped to Portsmouth (UK) in January for payload integration activities. The second half of the Repeater Module structure will be shipped to Portsmouth in March.

### Payload

The Inmarsat extended L-band (XL) payload will support advanced geomobile communications and augment Inmarsat's Broadband Global Area Network (BGAN) service.

For the most of the equipment in the payload, Equipment Qualification Model (EQM) manufacturing is currently under way. The state-of-the-art integrated processor remains a priority in the programme owing to its pivotal role in the payload performance, and the EQM is being built. The Application Specific Integrated Circuit required for the digital signal processing function has been manufactured and passed initial tests. The payload flight hardware integration will begin, with testing of payload elements on the test bench in February.

### Technology Demonstration Payloads

The CDRs for TDPs are nearing completion. The payloads are now entering the manufacturing phase. Each TDP development offers unique challenges but all are progressing towards the installation on Alphasat. Satellite interfaces are now finalised and the operational concept for the TDP commissioning and routine operations has begun.

### Alphabus extension

The Alphabus extension will increase the platform's power, mass and thermal rejection capabilities. The industrial contract will be placed in the first quarter of 2010.

### Alphasat User and Application segment

The work plan contains a set of activities defined together with Inmarsat, based on their plans for new services and terminal classes to be incorporated into Inmarsat's portfolio for Alphasat, as well as for the complete Inmarsat satellite constellation. The first two activities began in October.

## → CRYOSAT

In September 2009, the satellite was put into its transport container at the IABG facility in Ottobrunn, for storage until shipment to the launch site. During November, the Flight Acceptance Review was completed, giving the formal 'consent to ship'.

With the launch scheduled for 25 February, the spacecraft and all of the test and other equipment were shipped by air to Baikonur, Kazakhstan, on 12 January.

The shipment left Munich Airport to the Yubileyny airfield at the Baikonur Cosmodrome, with a stopover in Ul'yanovosk for customs clearance.

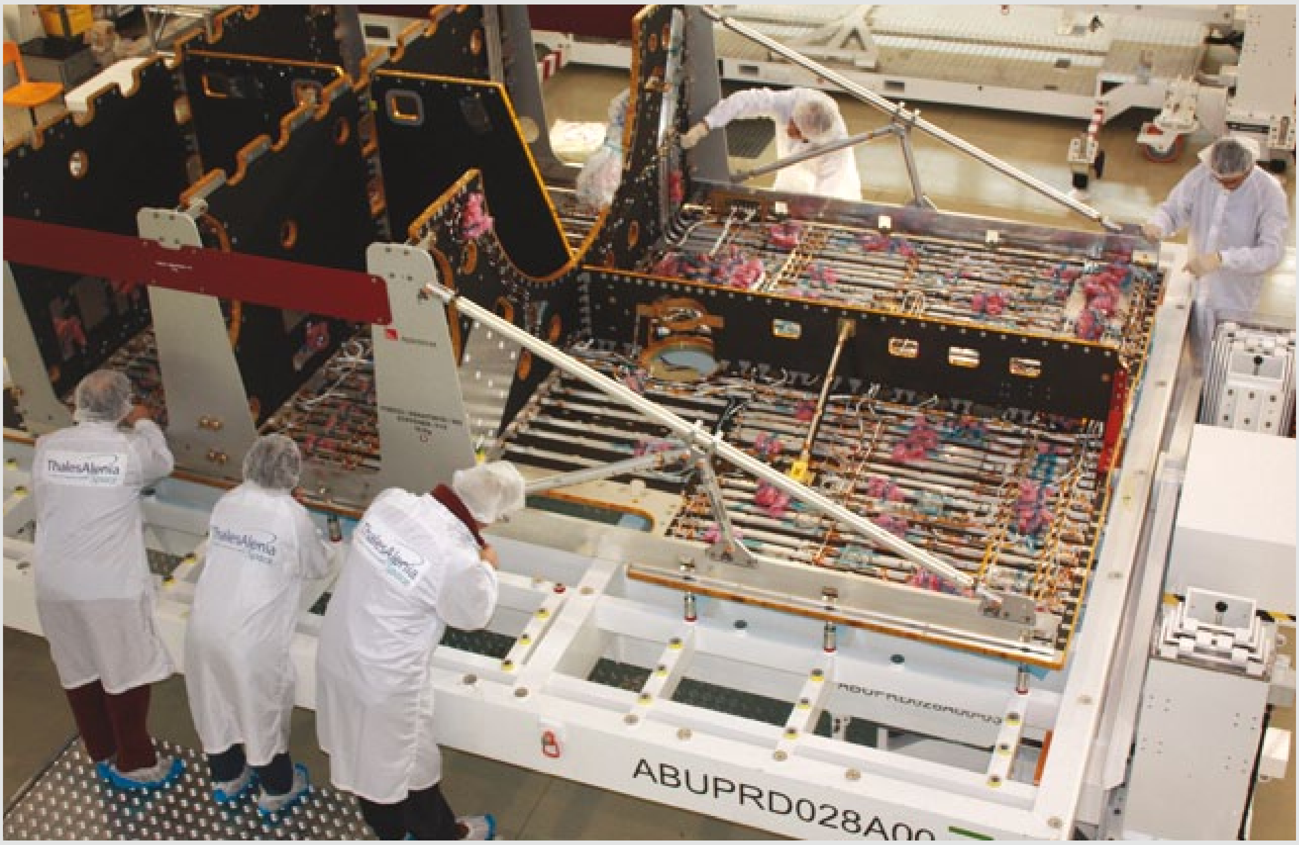
The launch campaign is in progress despite the cold weather conditions at Baikonur. Preparations are also under way at ESOC (DE), where a series of simulations are being run to train the mission control teams in both normal and contingency operations.

## → SMOS

After a flawless launch and orbit injection of SMOS and Proba-2 by a Rockot on 2 November 2009, the satellite, payload and overall ground segment are being commissioned.

Satellite and payload deployments and initial switch-on have been without problems and a 'functional' first image from the ground segment was obtained a few hours after the first science data downlink.

The interaction between the satellite ground segment, operated by CNES in Toulouse (FR), and the mission and payload

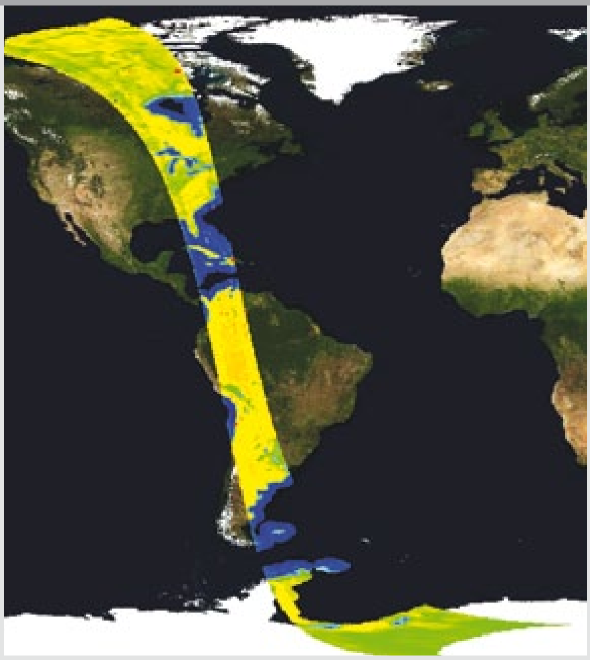


Alphasat Half Repeater Module built by Thales Alenia Space Italy ready for shipping to Portsmouth, UK (TAS)


CryoSat-2 arrives at the Baikonur launch site in Kazakhstan on 13 January

flight operations ground segment, at ESAC in Villafranca (ES), works excellently and both facilities are close to being declared operational.

Instrument calibration and fine-tuning of the data processors is ongoing and it is expected to release first routine processed data products to the calibration/validation team by end of March. After a quick look at the initial processed data, it is already obvious that there is a lot of radio frequency interference within the protected band, which is, normally, reserved for radio astronomy and passive remote sensing.



One of the first processed orbits of SMOS brightness temperature data (vertical polarisation, calibration not complete)

## → ADM-AEOLUS

Integration of the first flight model of the ALADIN laser has started and the first performance tests of the laser Master Oscillator are under way. In parallel to the FM integration activities, the laser EM is being used for further tests and investigations to determine the root cause of the small energy degradation seen during the previous long-duration test in flight-representative conditions.

The satellite platform integration and testing has been completed. To support a formal close out of the platform-related activities, a platform Qualification Review was completed in December 2009. After the completion of the preparatory activities and the remaining actions from the Qualification Review, the platform will be put into storage until preparations for the instrument integration can start.

In order to reduce the risk of laser-induced contamination, preventive measures similar to the ones used in the laser will be implemented in the complete instrument transmit path (Optical Bench Assembly). The preliminary design of this upgrade at instrument and satellite level is well under way.

## → SWARM

The Swarm Phase-D is proceeding normally with the delivery of the FM structure for the first satellite, equipped with the cold-gas propulsion sub-system. The delivery of the second structure is planned for February.

Instrument calibrations were completed for the Absolute Scalar Magnetometer, the Vector Field Magnetometer and the star tracker. A specific calibration was organised at the Calar Alto Observatory (ES), for the fine characterisation of the Euler angles from the vector magnetometer as mounted on its optical bench. The Accelerometer and the Electrical Field Instrument (EFI) together with the satellite avionics were electrically tested.

The ground segment CDR took place before Christmas. Good progress was observed overall in the definition of the ground segment concept, the definition of the requirements and the test approach for both the Flight Operation Segment and the Payload Data Ground Segment.

Two studies for the validation of the EFI were initiated with University of Calgary (CA) and LATMOS (FR). The data stream from instruments on the Demeter satellite (FR) will be compared with measurements from the US ground-based incoherent scattering radar based in Millstone Hill.

## → EARTHCARE

The EarthCARE System PDR took place in September/October and the main review findings were presented to the PDR board in mid-October 2009.

The board considered that the PDR was successful with the exception of the Atmospheric Lidar (ATLID).

Noting the ATLID instrument evolution from a monostatic to bistatic concept, and the test plan for the laser-induced contamination effect on the external laser transmitter window, the board identified the need to further detail the configuration and performance and confirm instrument-to-spacecraft interfaces. The board will reconvene in spring 2010, after the ATLID Instrument PDR.

Following the PDR, the prime contractor initiated activities for the ATLID Instrument PDR, and to address the other issues that were raised during the PDR. In parallel, the equipment procurement under the Best Practices scheme continued in order to complete the industrial team. Because the PDR board is reconvening in spring 2010, the project is formally still in Phase-B2 but advanced Phase-C/D activities have started for mature base platform and payload elements to ensure the continuity into Phase-C/D.

The ESA/JAXA Cooperation Agreement for EarthCARE was approved by JAXA and by the ESA Council in December.

## → METOP

### MetOp-A

MetOp-A, launched on 19 October 2006, is still in good health. All instruments continue to perform excellently in orbit. Only the HRPT is transmitting in restrictive mode.

### MetOp-B and MetOp-C

For MetOp-B, the Payload Module (PLM-1) has been brought out of storage and integration and test activities have restarted. Software on the IASI instrument has been updated. The Service Module (SVM-1) remains in storage. MetOp-B is planned for launch in April 2012.

For MetOp-C, the integration of US instruments (A-DCS and SEM) on PLM-3 has been completed. The SVM-3 remains in storage. MetOp-C is planned for launch in October 2016.

## → METEOSAT (MSG)

### Meteosat-8/MSG-1

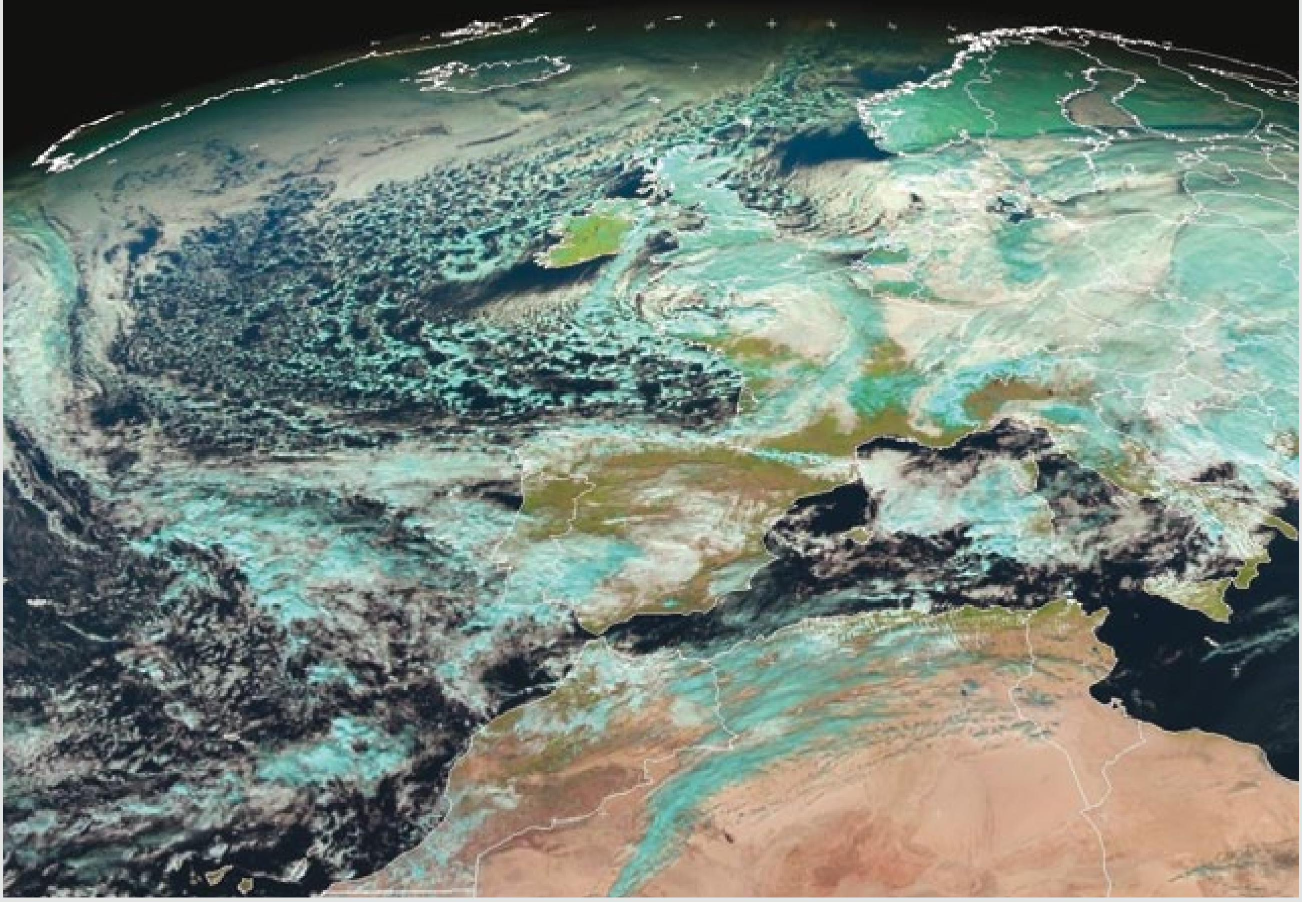
The satellite is in good health with instruments performing flawlessly. It is providing the Rapid Scan Service (RSS), complementing the 15-minute High Resolution Image data generated by the operational Meteosat-9.

### Meteosat-9/MSG-2

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

### MSG-3

MSG-3 is in long-term storage in the Thales Alenia Space Cannes. The launch date has been shifted due to unavailability of a suitable co-passenger and is now planned for June 2012 on an Ariane 5. MSG-3 will be brought out of storage in spring 2011.



This colour image from Meteosat-9, taken on 6 January 2010, shows the cyclone that created the unusual weather situation responsible for the heavy snowfall in the UK, The Netherlands, Belgium and Germany (Eumetsat)

MSG-4

The assembly of the new SEVIRI Drive Unit is under way. Once the qualified unit is available, dismounting activities on the satellite will be started. After reintegration of this unit, the satellite will be submitted to mechanical, acoustic and reference testing.

## → METEOSAT THIRD GENERATION

Two competing offers for the MTG Phase-B2/C/D (and support to Phase-E) were delivered from Thales Alenia Space (FR) and Astrium GmbH respectively on 2 October 2009. These were passed to the Technical Evaluation Board in early November. In the meantime, the MTG project team is being built up in readiness for final negotiations and programme kick-off.

## → SENTINEL-1

In line with the contract proposal approved in September 2009, the rider 2 contract (covering both Sentinel-1A and Sentinel-1B) was signed in December by ESA and the prime contractor, Thales Alenia Space (IT). For Sentinel-1B, the contract covers the spacecraft production until the FAR. The industrial prices for the Sentinel-1B Laser Communication Terminal (LCT) integration and test as well as for the Phase-E1 activities are included in the contract as negotiated options.

The procurement of the launcher for Sentinel-1A has progressed and negotiations are on going with the selected bidder.

Progress has been made in the LCT embarkation on Sentinel-1A. The first LCT official review since the DLR/ESA MoU in June 2009 and the Interface Requirements Review took place at the end of November 2009. The review highlighted a number of interface issues that will have to be resolved prior to the Sentinel-1 System CDR, the most important of which include compliance with the mechanical levels as induced by the launcher.

The technical activities are focusing on the equipment and subsystem CDRs that are taking place on a very compressed schedule, aiming at the Sentinel-1 system CDR at the end of March 2010. One of the most important subsystem CDRs, for the SAR instrument, has started.

As a result of the L'Aquila earthquake (which affected the production of active elements for the SAR antenna), the launch date of Sentinel-1A is delayed to December 2012.

## → SENTINEL-2

The Sentinel-2A ceiling price conversion, the contractual negotiations of the second satellite model, and the integration, test and in-orbit commissioning of two LCTs (optional) are covered by a rider to the contract that was signed in December 2009.

The Best Practice procurement phase is now completed and the industrial consortium is finalised. Equipment PDRs, CDRs and first hardware deliveries are taking place, for example, of the silicon carbide telescope mirrors or for optical detectors. The payload instrument and satellite CDRs are scheduled at the end of 2010 and the satellite FAR early in 2013. The first half of 2010 will focus on the delivery of EM/EQM equipment to initiate the Assembly, Integration & Test activities prior to the instrument and system CDRs.

The Sentinel-2 ground segment SRR was held, demonstrating the maturity and coherence of the space and ground-based elements of the Sentinel-2 system. Preparatory activities were initiated with Arianespace (Vega) and Eurockot, to demonstrate satellite compatibility with the two launchers. Initiation of the launch vehicle procurement is anticipated in the first half of 2010.

## → SENTINEL-3

The rider implementing the Sentinel-3B model in the industrial contract has been signed and now all Sentinel-3A and Sentinel-3B activities up to their respective FARs are released.

Contractually, procurement through competitive Invitations to Tender is proceeding in all fields. Out of about 120 procurement contracts to be placed, 107 have been either concluded or are under final negotiation. The remaining contracts, not schedule-critical, are planned in the coming months.

At space segment level C/D, detailed design activities are proceeding and lower-level equipment CDRs started in the last quarter of 2009.

On satellite issues, the main area of concern remains the overall satellite mass, still marginal with respect to the launcher capabilities. In addition, the energy provision in case of extended mission lifetime is marginal if the worst-case transition in 'safe mode' is considered. Technical ways to reduce these criticalities are being analysed and discussed as part of the CDR.

On the instrument side, there are no major technical issues for the SAR Radar Altimeter (SRAL). It should be noted that a model of the altimeter antenna passed all performance tests and is now with the prime contractor for compatibility tests with the satellite X-band antenna. On the Ocean Land Colour Instrument (OLCI), the criticality identified in the past months in the development of the Scrambling Window Assembly seems resolved subject to final confirmation by later testing.

The selection of the flight Camera CCDs is ongoing. On the Sea and Land Surface Temperature Radiometer (SLSTR), the major criticality remains the finalisation of the instrument structure, which affects the freezing of a certain number of instrument subsystems. On the Microwave Radiometer, activities are proceeding normally and the start of some EQM and SM testing is planned in January 2010.

The collection of the satellite characterisation data necessary to populate the Spacecraft Characterisation Data Base is continuing regularly.

At optical and topographic mission level, the implementation of the optical Ground Prototype Processor (GPP) and System Performance Simulator (SPS) is proceeding well, following the closure of respective CDRs. For the topography mission, all GPP/SPS sub-contractors have been selected and activities have begun.

The Sentinel-3 ground segment PDR, planned for spring 2010, is being prepared through the consolidation of space-to-ground interface requirements and the reissue of associated documentation. The procurement of the Sentinel-3 Payload Data Ground System began with the first Invitation to Tender.

Support studies are ongoing with Vega and Rockot launchers, while the ESA documentation to support the selection of the nominal Sentinel-3 launcher is being prepared. The Invitation to Tender is expected in the first half of 2010.

## → VEGA

Launcher qualification took place of the inter-stage 2/3, and payload adapter, propellant tanks and liquid propulsion qualification reviews were completed following the successful system test-firing campaign (UCFire). The main critical item remains the Roll and Attitude Control subsystem qualification, not yet completed. The data package of the launch vehicle was delivered in December for the launch system qualification review, and is under analysis. The update of the flight programme software and activities for the LARES mission (Vega qualification flight) have started.

The last P80 test (case-burst test) was made at the beginning of December. Activities on the P80 Thrust Vector Control are complete, and the data package for this qualification review is under finalisation.

In the ground segment, integrated tests are ongoing and are planned to complete by April, except for activities of washing columns, optical shelters and security systems, modified recently after Soyuz experience. The preparation of the ground qualification review and ground segment Technical Qualification Review has started.

## → SOYUZ AT CSG

The final infrastructure acceptance review took place on 18 November. Two launchers and their propellant arrived by boat in Kourou on 23 November. Both launchers are stored

The 'Fardier' specialised transport vehicle in front of the Vega mobile gantry at the Guiana Space Centre, Kourou. The Fardier (French for 'dray' – a vehicle for carrying heavy loads) carries the Vega P80 first stage from the Regulus propellant-loading plant to the launch table. This Fardier is carrying dummy loads, each weighing 20 tonnes, to simulate the P80 during testing of the mechanical systems on the launch table

on ELA2. On the launch table, installation of pipelines and air gas lines on the KZM mast is completed.

The technical qualification review (Bilan Technique) was held on 22 October. On the launch site, at the liquid oxygen/liquid nitrogen (LOX-LIN) store, the installation of pipelines and valves on the LOX tanks and connection of lines to the launch zone is completed. At the compressed gas storage area, pressure tests are in progress.

At the end of November, all containers carrying the mobile gantry had arrived in French Guiana and formal authorisation to start assembly of the gantry was given.

According to planning for mobile gantry agreed at the last Soyuz Consultation Committee in December 2009, delivery of the gantry structure to the European area was postponed to end of March 2010.

## → FUTURE LAUNCHERS PREPARATORY PROGRAMME

### Next Generation Launcher (NGL)

In system activities, an industrial proposal was received from Astrium-ST, enabling a second slice of NGL system activities to be triggered on the down-selected concepts.

In solid propulsion, the SRR for the Pressure Oscillation Demonstrator took place in November and the Steering Board was held in January. For liquid main-stage propulsion, the Preliminary Requirement Review of the High-thrust Engine Demonstrator began in December.

In storable propulsion, the industrial proposal for the first phase of a demonstrator of a 3–8 kN engine was received in October and evaluated. Negotiations were initiated in December.

In the technology area, the industrial activities of the Cryogenic Upper-stage Technologies (CUST 1.2) were initiated.

### Intermediate eXperimental Vehicle (IXV)

The contract proposal for Phase-C2 phase and the procurement proposal for Phase-D of the IXV reentry demonstrator were approved by ESA's Industrial Policy Committee in November. The Phase- C2 contract was placed in December.

The industrial activities are advancing with high motivation and commitment from industry. Developments and qualification activities have been harmonised with ESA's General Support Technology Programme for electromechanical actuators for flap control, and FLPP Materials and Structures for ceramic materials used in thermal protection.

## → HUMAN SPACEFLIGHT

Ministers from the 29 ESA and EU Member States met in Prague on 23 October for the first EU/ESA International Conference on Human Space Exploration, to prepare a plan leading to the definition of a common vision and strategic plan for space exploration. Before the start of the conference, José Manuel Barroso, President of the EC, stated that, "Space exploration is one of the European Commission's priorities and human exploration is the backbone of this strategy."

The timeliness of the discussion was also underlined by the publication of the final NASA Augustine Committee report on 22 October. ESA's Director General, Jean-Jacques Dordain, Director of Human Spaceflight, Simonetta Di Pippo, and Director of Science and Robotic Exploration, Prof. David Southwood, attended the conference.

The ESA/CNES PHARAO agreement was signed on 15 December at the headquarters of CNES in Paris. This paves the way for the launch of the ACES high-accuracy atomic clock ensemble, which will be attached outside the European Columbus laboratory.

The PHARAO (Projet d'Horloge Atomique par Refroidissement d'Atomes en Orbite) atomic clock, will be combined with another atomic clock, the Space Hydrogen Maser, to form ACES. This will have an accuracy of $1 \times 10^{-16}$, corresponding to a time error of about one second over 300 million years.

On 30 October, ESA issued a 'Call for Ideas' to gauge the interest in using the ISS as a platform to conduct research into global climate change. ESA's Directorates of Human Spaceflight and Earth Observation Programmes aimed this call at scientific institutes and industries, and depending on the level of interest and the suitability of the research proposals, it may be followed by a specific Announcement of Opportunity for instruments or multi-user payloads.

ESA astronaut Frank De Winne with the Portable Pulmonary Function System stowage bag

## → INTERNATIONAL SPACE STATION

The six-month OasISS mission concluded on 1 December with the landing of Soyuz TMA-15, bringing ESA astronaut Frank De Winne (BE) back to Earth. De Winne became the first European to take command of an ISS Expedition on 11 October, following the undocking of Expedition 20's Soyuz TMA-14/18S (returning Gennadi Padalka, Michael Barratt and spaceflight participant Guy Laliberté to Earth).

Expedition 21 milestones included the docking of the Russian Progress 35 spacecraft with a delivery of supplies and equipment for the ISS, the unberthing of the first Japanese H-II Transfer Vehicle on 30 October using the Station's robotic arm, the docking of the Russian Mini Research Module and an 11-day visit of Space Shuttle *Atlantis* and the crew of STS-129.

De Winne also carried out a European research programme covering human physiology, biology, radiation dosimetry, exobiology, fluid physics and materials sciences.

During the second spacewalk of STS-129 on 21 November, the Antenna Identification System (AIS) was installed on Columbus.

This VHF antenna is designed to pick up signals from the standard AIS transponders carried by all international ships over 300 tonnes, cargo vessels over 500 tonnes and all types of passenger carriers. The spacewalkers began by installing a 'Grappling Adaptor To On-Orbit Railing' (GATOR) on one of Columbus's handrails, to which the antenna was attached. GATOR also enabled the attachment of a second 'Amateur Radio on the International Space Station' (ARISS) antenna on Columbus, to be used for communication with amateur radio enthusiasts. Both AIS and ARISS antennas were developed by the ARISS organisation in collaboration with ESA.


ISS Commander Frank De Winne gathers Expedition 21 crew members for one last team photo in November 2009. Next to Frank is Bob Thirsk, then Roman Romanenko, Nicole Stott, Jeff Williams and Maxim Surayev

A traditional Kazakh welcome home for the Soyuz TMA-15 crew

During a six-hour spacewalk on 21 November, NASA astronauts Randy Bresnik and Mike Foreman (out of frame) install the Grappling Adaptor To On-Orbit Railing Assembly, or GATOR, on the Columbus laboratory

## → SPACE INFRASTRUCTURE DEVELOPMENT/ ISS EXPLOITATION

### Cupola and Node-3

Node-3 was handed over by ESA to NASA on 20 November. One of the three ISS interconnecting modules, Node-3 will now undergo final preparations for a February 2010 launch on Space Shuttle *Endeavour*, together with the attached European-built Cupola observation module.

### ATV production and cargo integration

Europe's second Automated Transfer Vehicle, ATV-2 *Johannes Kepler*, an unmanned logistics spacecraft, is set for launch readiness on 30 November 2010, with a docking window opening on 17 December. The ATV-2 Equipped Avionics Bay (EAB) Thermal Vacuum Test was completed at ESTEC. The sub-system final Mandatory Inspection Point was held on 5 November and the EAB and Equipped Propulsion Bay (EPB) were mated. The Integrated Cargo Carrier (ICC) complementary integration is now under way.

Integration of ATV-3's EAB, EPB and ICC is proceeding normally. ATV-3's 'ready for launch' date is still 30 October 2011. However the agreement to submit the future EABs to thermal/vacuum test will have an impact, still to be quantified. .

## → UTILISATION

The ISS Increment 20 experiment programme was concluded on 11 October with the undocking of Soyuz 18S. Despite the ISS cargo logistics constraints, a high degree of the mission objectives could be accomplished and a record of about 100 crew hours was used for European experiments in Columbus. The Increment 21/22 experimental programme is planned to run until April 2010.

### External payloads

The SOLAR facility continues to produce excellent scientific data during the Sun observation windows and the Expose-R payload continues to function well and will stay on-orbit at least until March 2010, with a possible extension until November 2010.

### ISS biology

On 2 October, Frank De Winne installed the YEAST-B1/-B2 experiments containers in the Biolab facility. Following activation and runs of the two YEAST experiments, the Experiment Containers were returned to Earth with Soyuz 18S and were handed over to the science team. The TripleLux B and ArtEMISS-A experiments are tentatively two of the next experiments to take place in the Biolab facility during Increments 23/24 in 2010.

The second part of the Waving and Coiling of Arabidopsis Roots (WAICO) experiment in Biolab is planned for spring 2010.

Frank De Winne works on the Materials Science Laboratory

Students working in microgravity during the 51st ESA parabolic flight campaign in November 2009

### Human physiology and performance

On 14 October, De Winne conducted hardware testing activities in preparation for the next session with the Wearable Augmented Reality (WEAR) experiment that took place on 28 November. WEAR is demonstrating the usability of augmented reality technology on the ISS.

Three sessions of the 3D-Space experiment were carried out on 8 and 15 October and 10 November by NASA's Mike Barratt and Canadian Bob Thirsk respectively.

On 6 October, De Winne assisted Flight Engineer Nicole Stott in undertaking her first session of NASA's Integrated Cardiovascular experiment. After completion of the Portable Pulmonary Function System experiment, ESA has started two new physiology experiments: Thermolab which examines the thermoregulatory and cardiovascular adaptations in rest and exercise during a long-term exposure to microgravity and EKE, which investigates the assessment of endurance capacity by gas exchange and heart-rate kinetics during physical training.

These experiments are performed in conjunction with NASA's Maximum Volume Oxygen (VO2Max) activity, which aims at measuring oxygen uptake and cardiac output in particular, during various degrees of exercise.

The Flywheel Exercise Device was removed from its storage location in the European Transport Carrier rack of Columbus for deployment, and was activated and checked out by De Winne.

### Materials research

Frank De Winne completed the first day of the Materials Science Laboratory (MSL) commissioning on 14 October. Runs of ESA's CETSOL and MICAST experiments took place in the MSL between 4/8 November.

### Fluid physics

The Fluid Science Laboratory (FSL) was activated several times to complete the optical diagnostic system commissioning and vibration measurements. Continuous runs of the SODI-IVIDIL ('Influence of Vibrations on Diffusion in Liquids') experiment were performed in October and November using the European-built Microgravity Science Glovebox (MSG). De Winne performed six runs of the FOAM Stability experiment on 2 October as voluntary science activities. The DOSIS experiment continues to work.

### Non-ISS missions

Last year marked 25 years of ESA's participation in Parabolic Flight Campaigns. The 51st ESA campaign was conducted in November 2009. During the microgravity conditions (up to 22 seconds of microgravity in each parabolic path), 14 experiments were performed, six in physical sciences, four in life sciences and four student experiments as part of ESA's 'Fly Your Thesis!' programme.

Launch of Texus-46 from ESRANGE, northern Sweden (EADS Astrium)

Texus-46, the latest in the series of ESA-funded sounding rocket campaigns, was launched on 22 November in Sweden to provide 388 seconds of microgravity for its two experiment payloads. The Texus flights are conducted by ESA's Directorate of Human Spaceflight and the German Aerospace Centre (DLR). The research is performed as part of the European Programme for Life and Physical Sciences (ELIPS).

Following the Mars500 105-day precursor study completed in July 2009, ESA is now looking for four candidates for the full 520-day study, due to start before mid-2010. 262 applications have been received, including 15 from female applicants.

## → ASTRONAUTS

Crew training for ISS Expeditions 23–30 is on schedule. ESA astronauts Roberto Vittori (IT) and Paolo Nespoli (IT) are training for their missions in July, and December 2010 respectively. On 26 October, André Kuipers (NL) started mission training for the ESA ISS increment in 2011 at NASA in Houston. Basic training for the new ESA astronaut class is progressing to plan.

## → CREW TRANSPORTATION AND HUMAN EXPLORATION

### Advanced Reentry Vehicle (ARV)

A set of Advanced Tasks have been undertaken by industry in preparation for the Phase-A contract, which will be completed by a Mission Definition Review. In the meantime, the industrial proposal for the Phase-A activities was provided by Astrium.

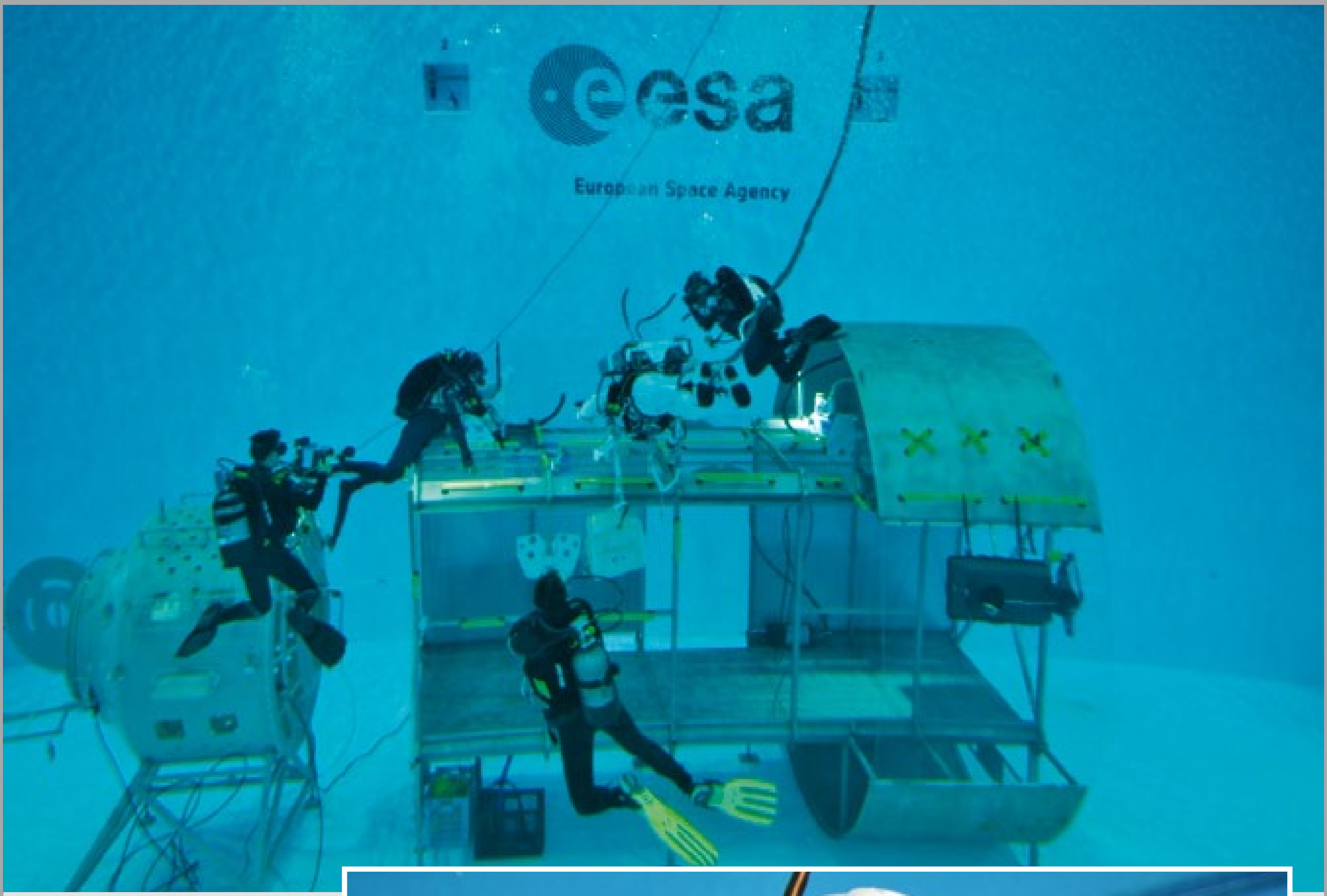
### International Berthing Docking Mechanism (IBDM)

A Technical Interchange Meeting was held in Houston in October between NASA, CSA, Roscosmos/Energia, JAXA and ESA to define an international standard for the docking and berthing interface.

The International Docking Standard Working Group has identified a suitable configuration for the new docking standard. It is now necessary to achieve convergence by all partners (NASA has expressed a preference for a new configuration based on the soft-docking system of the LIDS/IBDM). The next meeting of the International Standard Working Group will take place in February 2010. JAXA is interested in joining the IBDM programme.

### Expert

The launch and vehicle recovery contract for ESA's European Experimental Reentry Testbed (Expert) was signed on 2 December in Moscow by ESA's Director of Human Spaceflight Simonetta Di Pippo and Makeyev State Rocket Centre's Deputy General Director for Economics and Finance, Sergei Glazyrin. Under the contract, Makeyev has the responsibility of integrating the Expert vehicle on to a Volna rocket. This will be launched on a suborbital trajectory from a Russian submarine in the central Pacific Ocean in October 2010.




↑ In November, ESA astronaut André Kuipers (centre, in white) had a very special training session on his schedule: EVA pre-familiarisation refresher training in the Neutral Buoyancy Facility at EAC, to prepare for resuming his EVA training in Houston in January 2010

→ Kuipers ready for his 'dunk' in the Neutral Buoyancy Facility at EAC

## Lunar lander activities

A Request for Information issued by ESA received an enthusiastic response from industry and research institutes. Nearly 200 proposals were received and submitted to the Lunar Exploration Definition Team (LEDT) for review and assessment. On this basis, the LEDT has defined the priority objectives for the first Lunar Lander mission. A model payload has been devised for the industrial Phase-B1 study.

## Human exploration technology

Most of the technological activities focused on landing, approved in the Aurora Core Programme, are proceeding normally. A coordination meeting prepared activity proposals for the Advanced Closed Loop System (ACLS), formerly known as the Air Revitalisation System (ARES) in the General Support Technology Programme (GSTP-5) work plan. The basic content of the activities was agreed for proposal to the ESA Industrial Policy Committee in January.

## International architecture development and scenario studies

The 6th International Architecture Working Group/ International Objectives Working Group/Common Interface Team Workshop was held in ESTEC in November. Discussions included the consolidation of the international common goals for human lunar exploration, the development of different lunar utilisation scenarios and the consolidation of the campaign definition and evaluation approach. Representatives from ASI, CSA, DLR, ESA, JAXA and NASA attended the meeting.

The main outcome was the drafting of the mission statement for global human lunar exploration, finalised at the 4th International Space Exploration Coordination Group (ISECG) meeting held in ESTEC in December, chaired by ESA. This will be part of a broader document to be presented to Heads of the Exploration programmes of the ISECG members. All these activities converge on the definition of the ISECG 'reference architecture for human lunar exploration by mid-2010'.

The ESA Human Spaceflight, Microgravity and Exploration Programme Board approved the implementation and procurement approach for Space Exploration Scenario Studies in November 2009. The Invitation to Tender for 'Scenario Studies for Human Spaceflight and Exploration' was issued in December 2009.

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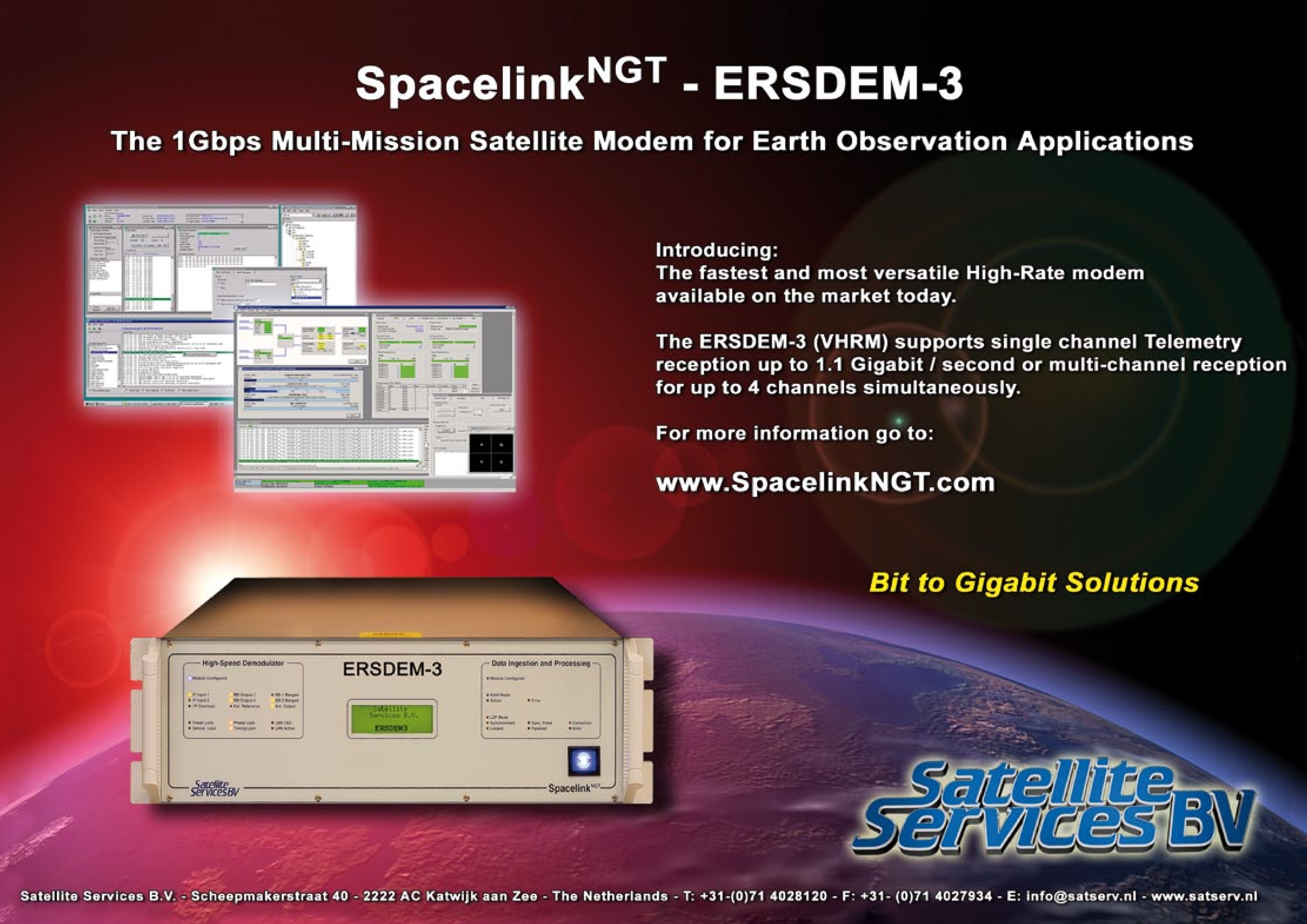

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