number 138 | May 2009

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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On cover:
ESA astronaut Christer Fuglesang, from Sweden, will fly on the 11-day STS-128 Space Shuttle mission to the ISS, scheduled for August 2009. Here he is seen practicing egress procedures to get off the launch pad in case of an emergency (NASA)

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→ contents

02

12

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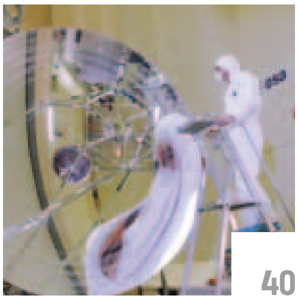

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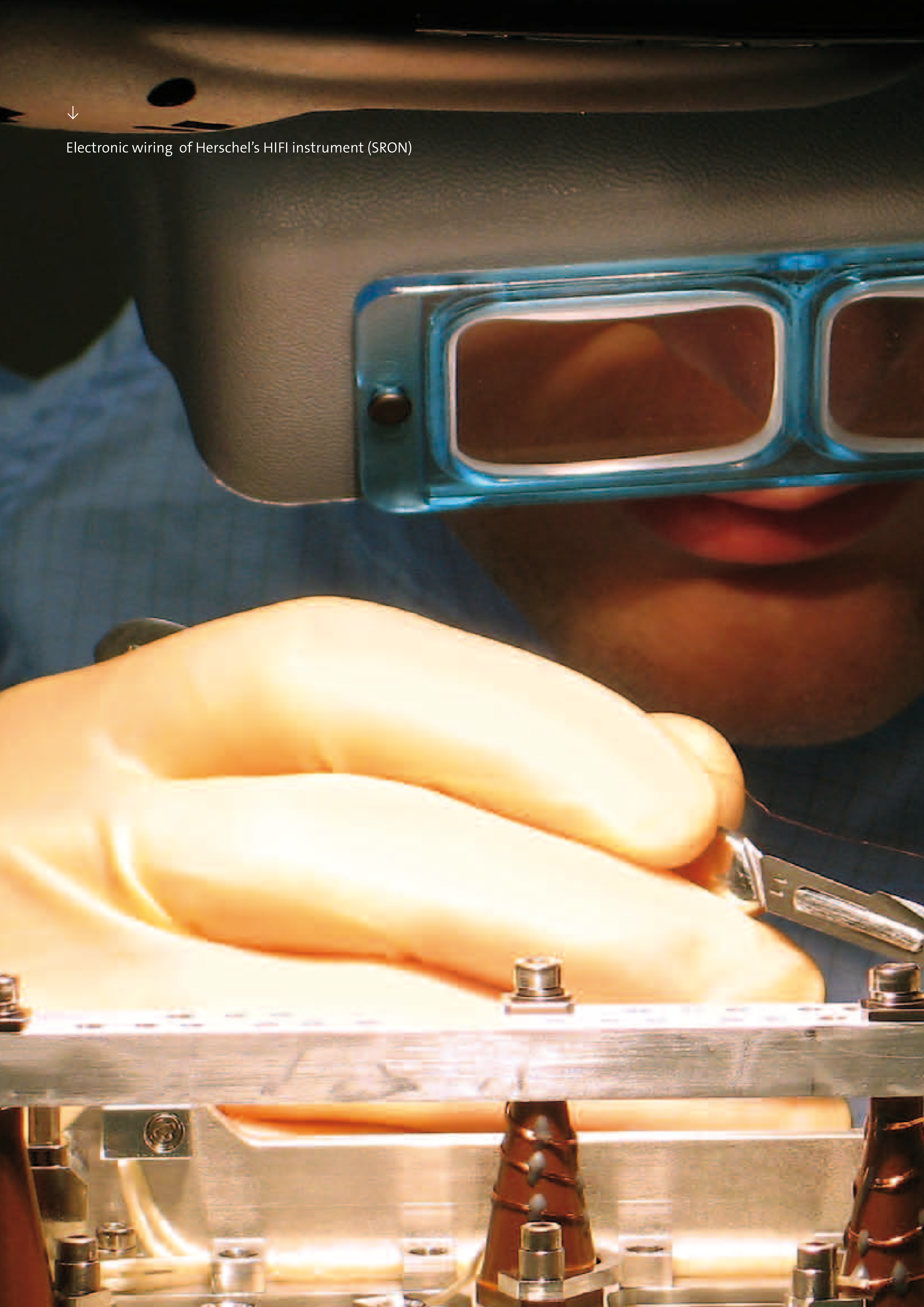

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Electronic wiring of Herschel's HIFI instrument (SRON)

→ POWERHOUSE FOR QUALITY

The ESA Product Assurance and Safety Department

Jack Bosma
Directorate of Technical and Quality Management,
ESTEC, Noordwijk, The Netherlands

With a foreword by **Michel Courtois**,
Director of Technical and Quality Management

→ Foreword

Space project teams have a clear mandate from top-level management: design and deliver the project on time, according to the performance required and within budget. To meet this formidable challenge, project managers and project teams are given a wide responsibility to achieve optimum results. This is the best way to achieve a dedicated objective.

The consequence of this entrusted power is the obligation to provide to top-level management full transparent feedback, to ensure that projects do not stray down a wrong direction and can be reoriented if needed.

In addition to regular progress and financial reporting, two mechanisms have been put in place to ensure correct orientation of the project. The first is a system of reviews at important milestones of each project, carried out by independent teams to address points of concern. These entail independent review of the overall technical and programmatic status at specific points by ESA experts covering the various space disciplines. Of course, full openness to review is the key to avoid errors or failures. The review process is not a substitute for the project managers who have the deciding role.

The second mechanism, for day-to-day life in the project, Product Assurance and Safety (PA&S) managers are integrated into the project team, but not hierarchically dependent on the programme management. They are there to help the project find unavoidable compromises between what should be done and what is feasible in the context of the project.

This scheme has proven its effectiveness, provided that all involved are aware of it and are convinced by experience of its efficiency. The skill of the PA&S manager is to judge when a warning should be raised to corporate management in the case of a problem or a proposed course of action that diverts too far outside recognised practise.

The Head of ESA's Directorate of Technical and Quality Management relies on the Product Assurance and Safety department and the close links with its integrated staff. Together with the project review cycle, they provide ESA's essential backbone for transparency and independent reporting to top-level corporate management.

←

Michel Courtois
Director of Technical and Quality Management, ESTEC, Noordwijk, The Netherlands

The Product Assurance and Safety (PA&S) department is the 'powerhouse' for quality in ESA, with the responsibility to identify and mitigate all aspects of space missions that could have adverse effects on their success.

You will find PA&S managers and engineers in every ESA project and on every ESA site. Of its 160 staff and contractors, one third operates in the field as integrated staff. Moreover, through these integrated managers and engineers, the department is also responsible throughout ESA for its operational Quality Management Systems (QMS).

PA&S experts think of the aspects of human safety – obviously important for astronauts, but also for the operators at a launch pad, during the testing campaigns or in the labs. They work out how these considerations impact the costs and schedule of a space project.

Space projects need PA&S experts for their hardware and software quality, product reliability, safety, electronic and electrical engineering components, standards, materials, mechanical parts, critical industrial fabrication processes and configuration control. In all these areas, PA&S engineers control the supply of parts produced by industry, according to the contractually agreed requirements. They can issue alerts about critical items, deal with non-conformances, changes, deviations, waivers, actions, and so on. Their 'working tools' are laboratories, test facilities, reviews, audits, inspections of processes and products.

The daily business of these specialists is with space projects, where they report to a Project Manager. However they also identify quality and safety issues that affect ESA in general. In such cases, they report to ESA's higher management.

Their main contribution is to reduce and control risks for all ESA projects, as well as to initiate corrective actions. Their experience is essential to other ESA activities that have a great impact on cooperation with industry, such as the European Cooperation for Space Standardization (ECSS) system.

Space environment in the lab

To ensure reliable operation and mission success, it is essential to determine the suitability of the materials and electrical, electromagnetic and electronic (EEE) components used to construct the many different elements of space hardware.

'Suitability' means that all materials and components have passed rigorous tests simulating the launch and space environment. The Q laboratories are well equipped with test facilities simulating the extreme temperature, vacuum and radiation conditions of space. For example, BepiColombo, ESA's mission to Mercury, will experience ultraviolet radiation levels of more than 10 times that in Earth orbit with temperatures on the satellite surface exceeding 200°C. Building test chambers to simulate these extreme conditions is already a formidable task, but ensuring that they operate flawlessly during a materials life test of hundreds of hours in simulation of being in orbit around Mercury is even more daunting. This has nevertheless

→ One of BepiColombo's pair of Mercury orbiters (EADS Astrium)

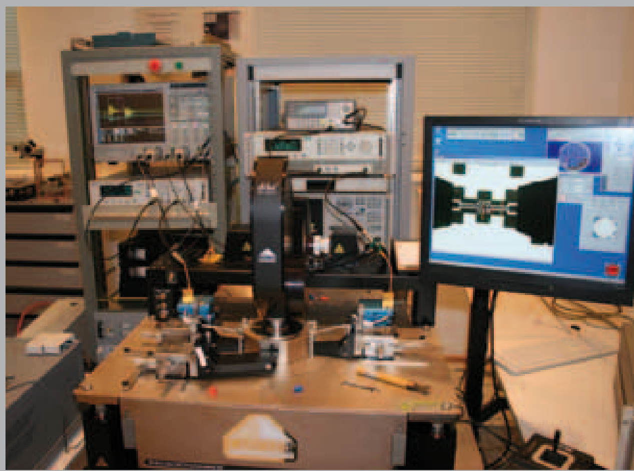
been accomplished in the laboratories and resulted in the selection of the best thermal control materials and solar cell types to complete the mission.

Miniaturisation of technology has made EEE components more susceptible to all types of particle radiation. The Q laboratories are equipped with radioactive sources to screen out weak devices, by simulating the total radiation dose received during mission life in orbit or by simulating radiation-induced change of state due to the impact of single charged particles.

These tests are complemented by more and more sophisticated facilities in other European laboratories, using particle accelerators capable of shooting protons and heavy ion beams over a wide range of energy levels at EEE components. Tests need to be performed in as realistic conditions as possible, since the corruption of any single component, for example in a memory cell of a computer, could upset satellite operations.

"Crime Scene Investigation: ESTEC"

The competence of our staff combined with state-of-the-art laboratories creates a 'centre of excellence' in ESA for improving workmanship standards in European space industry and qualifying space materials, components and processes for space applications. The labs provide a full range of analytical tools: from 3D X-ray tomography, scanning electron microscopes, visible, infrared and acoustic microscopes, atomic force microscopes, gas chromatographs, mass spectrometers, to all types of equipment to screen mechanical, thermal and optical properties and behaviour in vacuum as well as in human space environment. Close to 500 different investigations are carried out per year.



↑ Probing system for wafers in electronic components

The expertise is arranged around three main themes: project-related applications, failure analysis and general technical support. The scope of work ranges from individual materials and components evaluation and qualification up to industrial production capability support. As an example, we are responsible for ESA qualification of printed circuit boards (PCBs). Seven manufacturers of printed circuit boards, with 41 PCB lines, are requalified every two years. Thanks to this investment, ESA programmes are not affected by the EU regulations on restrictions of hazardous substances (RoHS) that prohibit the use of lead-based solders.

Alternative pure tin solders, now being widely adopted in the consumer industry (cars, mobile phones, etc.), are not a good choice for space missions, since tin forms 'whiskers' that can cause short circuits and damage that cannot be repaired in orbit. Although space is exempted by EU regulations for this aspect, the low demand still means lead-solder based PCBs can only be secured through these dedicated ESA production lines.

→ The department

The Product Assurance and Safety (PA&S) department is part of ESA's Directorate of Technical and Quality Management. In 2008, the department moved to a new building at ESTEC in Noordwijk, The Netherlands, where the vast ground floor area houses the state-of-the-art 'Q' laboratories.

These labs include unique environmental and analytical facilities to test materials and components for their suitability in space applications. The labs are also extensively used by our expert engineers to support investigations into anomalous behaviour of space hardware revealed during satellite ground testing, or more sporadically during in-flight operations.

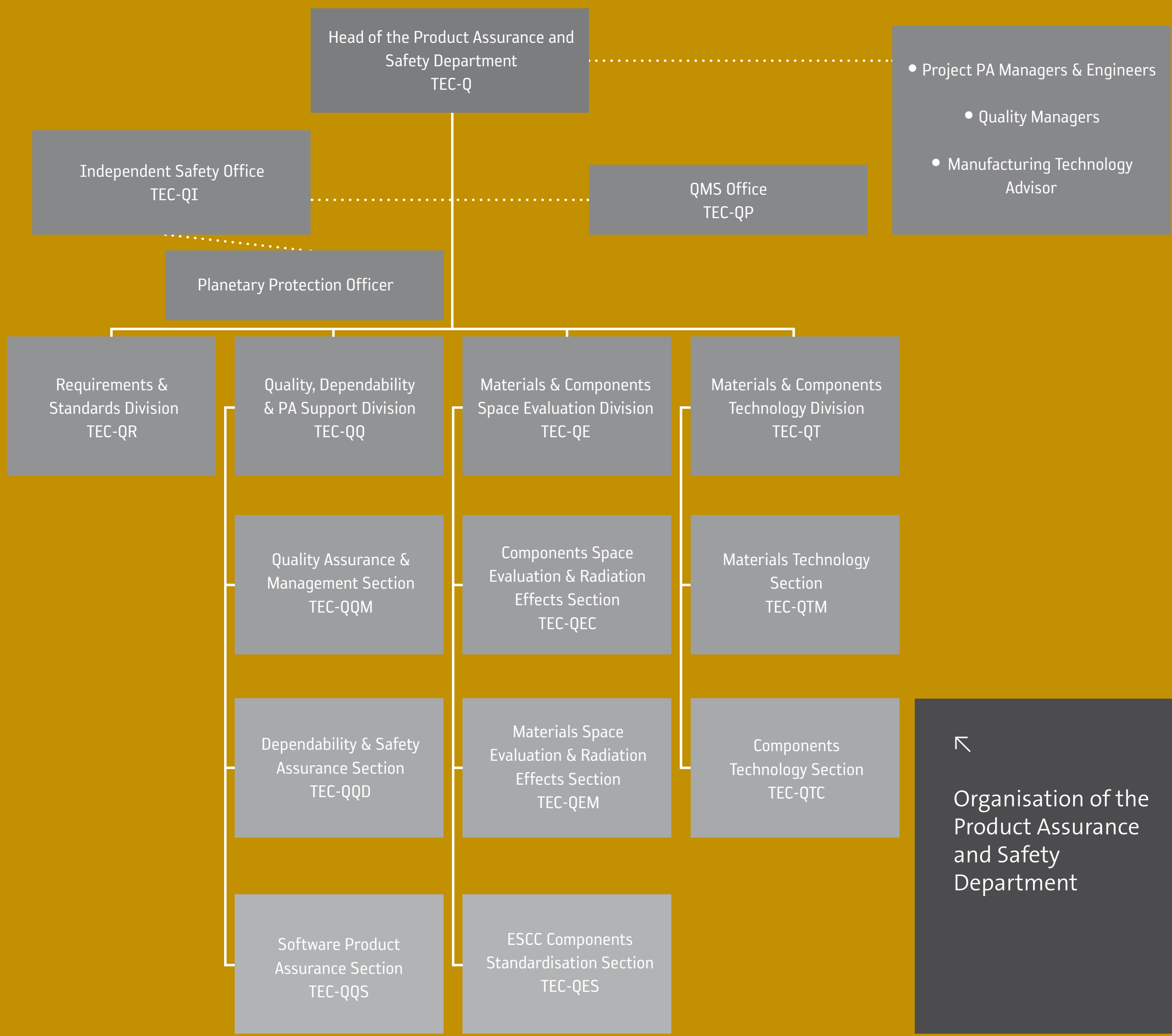
The department was also reorganised to enlarge its role in flight safety by creating an independent safety office (QI) and to accommodate new disciplines in the domain of plane-tary protection, space debris and nuclear safety. The heritage of separate components and materials divisions has been abandoned, having now one division (QT) covering technology and project support in both disciplines, while the other division (QE) concentrates on radiation and environmental testing, components standardisation and regroups all Q-laboratory management.

The QQ division handles the traditional product assurance disciplines but is also expanding into new fields ensuring implementation of the ESA product policy in terms of product catalogue and quality control of recurring product lines. The QR division coordinates the standardisation efforts in ESA and has successfully supported a thorough overhaul of the ECSS system of standards for 2008/9. Finally a QMS office (QP) has been set up to prepare for the implementation of a quality management system and to support an agency-wide ISO initiative.

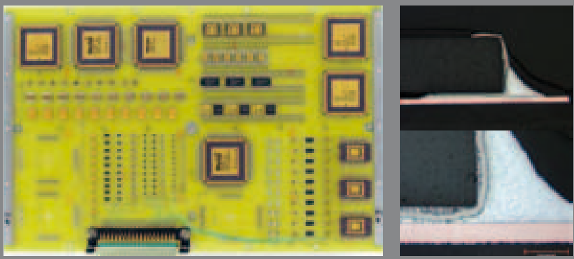
→

Entrance to the new ESTEC 'Q' laboratories building

→ The organisation



↖ Organisation of the Product Assurance and Safety Department



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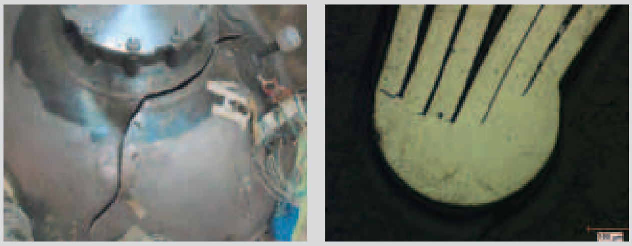
PCBs with Surface Mount Technology (SMT) components undergo several tests such as thermal cycling, vibration and rework simulation. After visual inspection micro-sections are made to evaluate the quality of the solder joints

PCBs are at the heart of all avionics equipment in ESA satellites and launchers, and so the department also certifies manufacturing capabilities of all major European equipment suppliers. This involves the cutting up and micro-sectioning of populated boards to individually analyse the workmanship by utilising the wide range of departmental laboratory inspection capabilities and providing the industry with feedback. Our main effort concentrates however on stressing space materials and components beyond their intended application range during qualification tests, to demonstrate that there is adequate design margin in actual flight. Screening techniques are used to weed out failures during the production process.

→

General view of tin whiskers on electroplated tin; pure tin is a prohibited material for ESA spacecraft

'Failure analysis' is the non-destructive as well as destructive evaluation of failed parts to determine the root cause of failure. The department has built up a large expertise in failure analysis of materials and processes used in the space industry. The failure investigations can range from identifying a broken wire in a crimped joint, to finding out why a large-scale fuel tank ruptured during a test. In cases of failures occurring in an operational environment, the department has an excellent track record and takes pride in not just finding the failure, but also its root cause. In 2008, engineers working on the Planck mission were confronted with a failure of a pressure regulator during the satellite integration and test phase. The department's X-ray facility team were able to take 3D images of the suspect device while it was still mounted on the flight panel. This quick reaction focused the investigation on the 'bellow' design and the cause was quickly established as poor weld quality. The project engineers were able to take immediate corrective action and stay on schedule.



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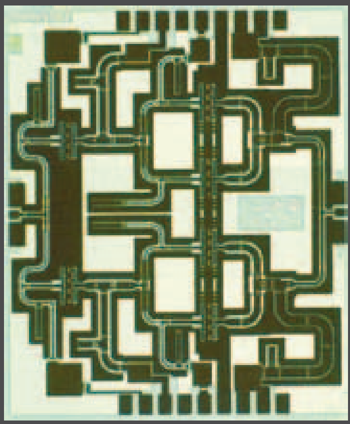
(Left) the large Vega tank where the weld fractured after testing. (Right) a small weld in a Planck bellow which shows cracks in the weld region. Both failures relate to the same type of welding process

Technology for space

The world's technology development is being driven increasingly by global consumer markets, which leads to shorter production cycles and less focus on reliability. Our department is continuously looking out for enabling technologies that can be made suitable for space applications. Our goal is to secure reliable products for European space programmes and to ensure European non-dependence in strategic domains. Comprehensive dossiers have been established identifying 'roadmaps' from feasibility concept to flightworthy end-product, using various funding routes through ESA's technology development programmes.

Success has been achieved through the European Component Initiative (ECI) for a mix of critical EEE components and through the Basic Technology Research and General Support Technology programmes for new cutting-edge technologies, such as the development of microchips at 'deep sub-micron' level (less than 100 nm).

Another promising new technology is based on gallium nitride (GaN). The GaN Reliability Enhancement and Technology Transfer Initiative (GREAT2) is enabling the manufacture of high-reliability, space-compatible microwave transistors and integrated circuits from GaN, and is establishing an independent European supply chain. GaN is a high-potential technology for future space applications. It operates reliably at high voltages and temperatures, and is inherently 'radiation-hard'. So when used in space systems, GaN enables a reduction of size and mass of cooling systems, and increased ability to survive the harsh radiation environment of deep space. It can also provide up to a ten-fold boost in microwave output power.



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GaN Monolithic Microwave Integrated Circuit

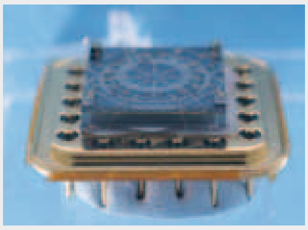
The next challenge is the development and promotion of Micro & Nano Technology (MNT) in ESA spacecraft. MNT has high potential in terms of reducing the power requirements and mass of next-generation spacecraft. In 2008, a European breakthrough was made when a Micro Electro Mechanical System (MEMS) rate sensor was selected as a flight-critical item on the Sentinel-3 Earth observation satellite.

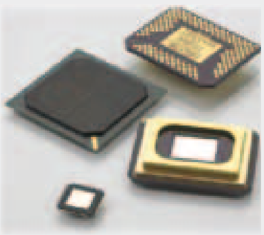
Ensuring the highest standards

Standards make a fundamental contribution to the quality of space products. The department provides the secretariat for two recognised standardisation initiatives for European space cooperation: ECSS and ESCC.

The European Cooperation for Space Standardization (ECSS) provides a complete set of standards (covering management, engineering and quality), which facilitate the set-up of business agreements for development, manufacturing, procurement and operations of any type of space product ranging from the lowest building blocks to high-end space systems. ECSS standards are applicable to every ESA programme, are widely applied in the European space community and have become an essential benchmark in the international context.

Following a complete overhaul of the ECSS system over the last two years, the European space industry is now rapidly integrating ECSS standards into their corporate Quality Management Systems. We will soon see companies advertising ECSS compliance next to their ISO certification.





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Two MEMS components for space applications, (left) the MEMS rate sensor to be flown on Sentinel-3, (right) Texas Instruments 2M Micro Mirrors Arrays investigated for ESA Cosmic Vision activities

Where appropriate, the quality standards are supported by a number of ESA-approved Skills Training Schools, which provide training courses resulting in the certification of operators, inspectors and instructors. ESA supports six schools in Germany, UK, France, Italy and Denmark. By supporting these Skills Training Schools, ESA develops and maintains a pool of personnel trained in best practices for electronic assembly and improving the quality of electronic products used for spacecraft projects. Attendance to these schools is consistently in the region of 700 to 800 students per year.

↑

ESA-approved Skills Training Schools provide courses for operators, instructors and inspectors

The department has also developed and offers specific software oriented services internally and externally to ESA covering:

- the assessment and improvement of the software development processes, with an approach compliant with ISO 15504 (whose precursor was called SPICE), plus the specific space software requirements of ECSS standards (the assessment method is aptly called 'Spice for Space' (S4S) and has been already successfully applied to companies, improving their basic capabilities for the benefits of all ESA projects);

- Software Product Evaluation for Conformity (SPEC) for evaluating software products according to an agreed quality model, using metrics for an objective measurement of the product characteristics;

- software dependability evaluation, applying 'RAMS' (Reliability, Availability, Maintainability and Safety) methods and techniques to software (-intensive) systems or individual software products.

As part of ESA's initiative to develop a new product policy, the department is actively engaged in establishing a space product catalogue. Compliance to ECSS standards plays a key role to ensure that future listed products will meet the highest workmanship standards and that qualification and acceptance have been performed according to commonly agreed requirements. This type of system is already in place for many years in the area of EEE components.

The European Space Component Coordination (ESCC) is based on a partnership between ESA, national space agencies, manufacturers and user industry. It embodies a single quality level system dedicated to the qualification and procurement of space components. On completion of a qualification programme, individual components and component families are listed in the ESCC Qualified Parts List or, in case of technology flow qualifications, the European Qualified Manufacturers List.

Together with the European Preferred Parts List, also produced under the auspices of ESCC, these documents are the primary reference for the selection of EEE components for use in European space projects. Through the years a full range of EEE component technology is being developed and maintained, ranging from passive components to advanced technologies such as hybrid circuits, VLSI technologies, optoelectronic devices, conventional microwave components and MMIC processes.

Project support: the key activity

The Directorate of Technical and Quality Management is a support directorate, and our department's highest priority is the provision of top-level services to ESA programmes. We support all projects throughout their entire lifecycle, to achieve the confidence for a safe and dependable system design, manufacture, operation and disposal. In addition to direct project support, the department provides general quality services, both to ESA projects and the European space community.

Project support covers all the classical product assurance domains like safety, reliability, maintainability, quality assurance, software product assurance, components, materials and processes. The department has recently enforced its role for the implementation of ESA's policy for all aspects of flight safety engineering, planetary protection, nuclear safety and space debris safety, including re-entry safety.

'Planetary protection' is the preservation of planetary conditions for future scientific exploration and the protection of Earth from extraterrestrial sources of contamination. Regulations have been in place since the 1960s and legally covered by the United Nations Outer Space Treaty.

We provide relevant regulations for ESA missions going to Mars, the moons of Jupiter or other destinations, and review their compliance prior to launch. This certification is then reported to the ESA Council and through the Committee on Space Research to the United Nations. Annual planetary protection courses are offered by ESA as a service to the space community. Standards are being developed under ECSS, and the laboratories are being equipped to perform verification, for example, of associated sterilisation techniques for the ExoMars mission.

The ATV *Jules Verne* mission was a 'first' for ESA in terms of safety responsibility for a controlled reentry of a very sizeable space vehicle. The department supported the establishment of a thorough safety dossier and established a formal Board and internal safety process to make sure the probability of a catastrophic event stayed low and within internationally acceptable limits. The department was instrumental in supporting studies of the reentry break-up and subsequent data analysis in September 2008.

→ The European Components Initiative (ECI)

ECI aims to increase the availability of European EEE-components used in European space missions by identifying critical space technologies and then developing capabilities to manufacture them within Europe. This will reduce the dependence of Europe's space sector on non-European (EEE) component suppliers. The policy is coordinated through ESCC and implemented by ESA and national space agency technology development programmes.

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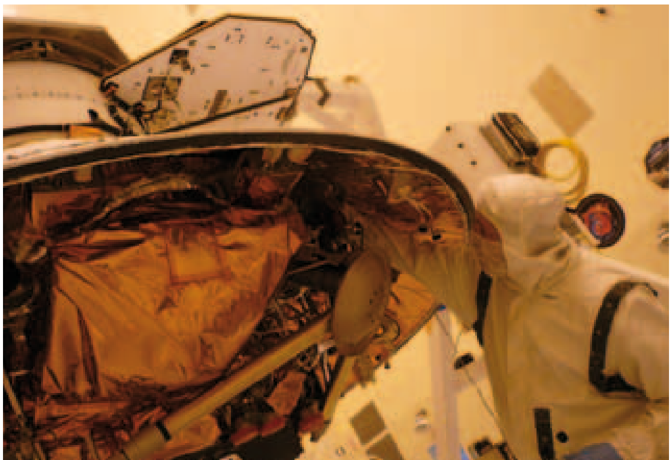
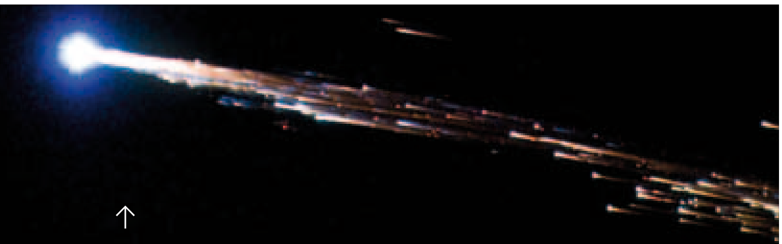
Verification assays on the Phoenix spacecraft at the Kennedy Space Center before leaving for Mars in summer 2007 (NASA)



The Reentry Safety Board is now a permanent feature for future ESA missions such as ATV and the Intermediate eXperimental Vehicle.

Dependability and safety need to be integrated and optimised during the early design and operations definition process. A safe system is not necessarily a dependable system, and a dependable system is not necessarily a safe system. An increase of safety could decrease the reliability and vice versa.

Safety and dependability analyses provide the basis for making space systems more failure-tolerant, within mass and cost constraints, and reducing the risks posed by hazard and failure scenarios. A specific challenge is the study of the dependability and safety assurance for the development and operation of future ESA ground segments performing safety critical operations.



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Reentry of ATV *Jules Verne* on 30 September 2008

ESA has currently two ground segments rated to perform flight operations for human missions in low Earth orbits, namely the ATV Control Centre and the Columbus Control Centre. The efficient design and operation of future human-rated missions will pose new questions. An interesting exercise will be to study the safety requirements applied to 'control centres' performing safety critical tasks in areas other than spaceflight or providing downstream services with concerned with safety of life, such as Galileo, EGNOS or air traffic management systems which must provide 24-hour operational service over years.

Software is crucial in any space programme and software product assurance support is in high demand as systems become more complex and autonomous. Almost all flight software can be patched to help solve and overcome anomalies in space, but it is software product assurance that helps to ensure that software itself does not become a problem. Software product assurance expertise is very specialised, and few ESA projects have such expertise embedded within their project teams. The demand for project support in this domain grows steadily as more and more mission and safety critical functions are implemented in software.

In spite of the fact that quality assurance is to prevent 'fires', quality assurance experts spend a lot of their time as 'firefighters'. Their 'fires' are mostly 'failures' or 'non-conformances'. The first step in dealing with non-conformances is to provide efficient means of reporting and tracking them through the complex structure of space projects. This is done with a tool called the Non-Conformance Tracking System, which has been already widely deployed in many projects.

As part of the problem processing, we are strongly committed to finding root causes: without knowing the cause of a problem, it is hard to find a real solution for it. Often a problem is of general interest and it would be useful for others to learn about it, to avoid making the same mistake. For this reason, the quality section created a system called the ESA Internal Problem Notification, to immediately inform other ESA colleagues when necessary. This system is only for ESA internal use, so it can afford to be informal and hence very fast.

In case of problems of interest for the entire space community, a more formal process is applied, to ensure the validity and correctness of the information and prevent legal problems for ESA. The problems are thoroughly reviewed by technical experts, and ESA Alerts are issued to inform and provide solutions to users, after consulting the manufacturer of the item affected.

Quality assurance also covers audits, failure investigations, the processing of non-conformances, surveillance of activities and the acceptance of products. Another important service is the certification of European test centres to the standard ECSS-Q-20-07, to ensure that they have suitable quality management systems. This is to make sure that any quality inadequacies are discovered and corrected before space projects starting their test campaigns.

The department provides expertise to develop quality management systems in ESA, in particular a new project initiative launched in 2008, to prepare the whole agency for ISO 9001 certification. It also supports the QMS operational systems in ESA that are already ISO-certified and QMS activities in corporate services such as the Financial Management Reform project.

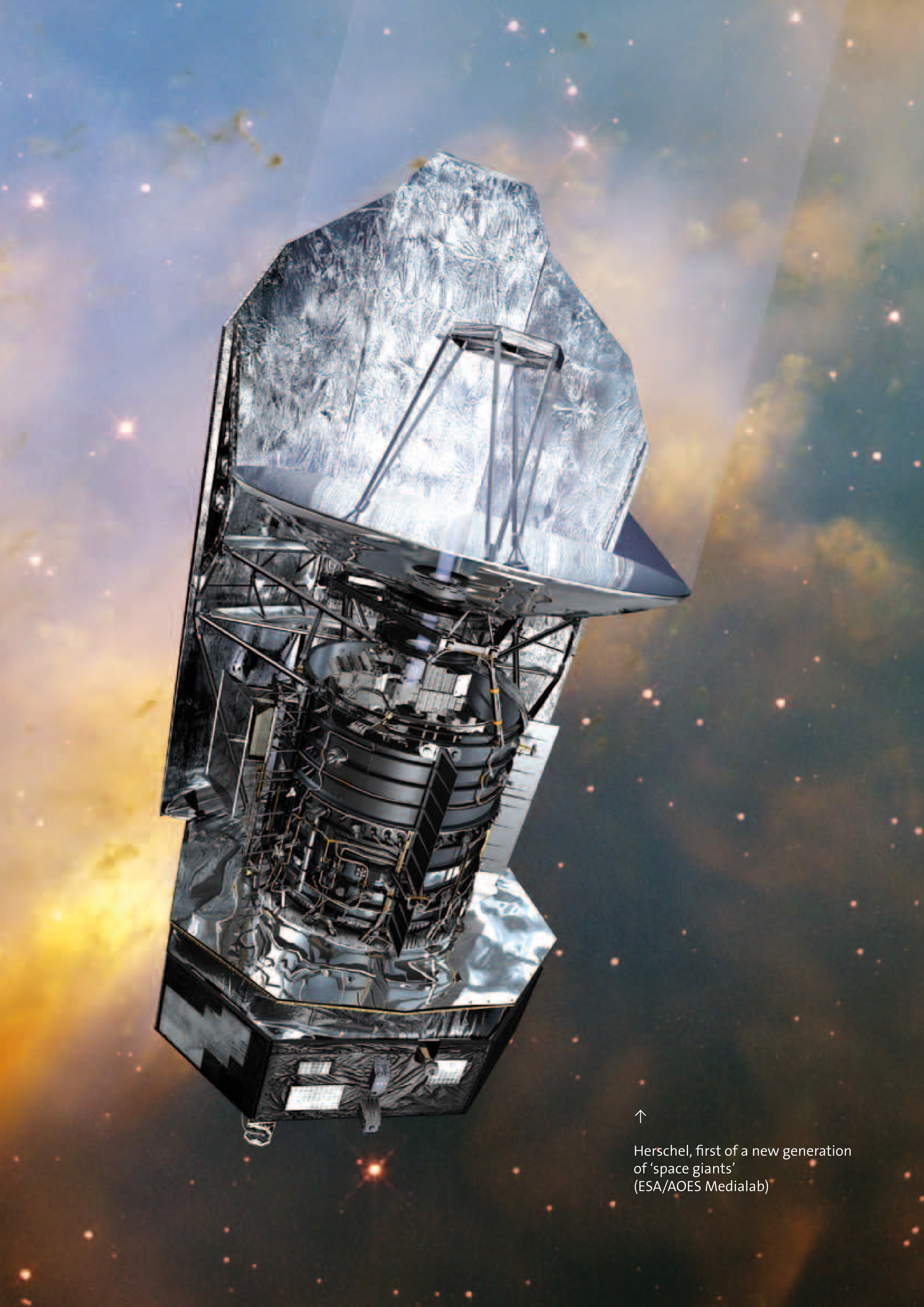
Securing the future

The Product Assurance and Safety department is an ideal starting point for young men and women searching for a career in ESA. Our labs provide great opportunities for 'hands-on' experience, and our engineers are required to provide support to space technology development and space projects from their very start. The department boasts one of the highest turnovers of staff in ESA, with high degrees of mobility from the department to other posts in all ESA programmes.

The 'Q' in Q laboratories stands for 'quality'. By steadily setting our service objectives higher, we meet the needs of ESA programmes on schedule and with the highest level of quality. ■

Acknowledgements

Many thanks to the following for their contributions to this article: Barrie Dunn, Keith Miller, Gerhard Kminek, Roberto Ciaschi, Ralf De Marino, Mikko Nikulainen, Luciano Balestra, Thomas Deak and Tommasso Sgobba.



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Herschel, first of a new generation of 'space giants' (ESA/AOES Medialab)

→ CONTINUING THE INFRARED REVOLUTION

The science behind ESA's Herschel observatory

Göran Pilbratt, Thomas Passvogel and Monica Talevi
Directorate of Science and Robotic Exploration,
ESTEC, Noordwijk, The Netherlands

Today, galaxies fill the Universe. Galaxies are spread like 'curved walls' surrounding huge areas of emptiness – like bubbles in a foam bath. Each one contains several hundred thousand million stars. However, the Universe has not always been like this. There was a time when galaxies did not exist...

Astronomers have long been wondering when galaxies formed, how they formed, if they all formed at the same time in cosmic history, and whether the first galaxies were like those we see now.

Galaxies are made of stars and interstellar matter, and this raises other questions: did stars form in the same way? Were all kinds of stars present at all times, and did they always form at the same rate? Did the situation change depending on the type of galaxy and the age of the Universe?

So far, these questions have proved difficult to answer, and remain some of the key problems in astronomy today.

Astronomers have dreamed of a telescope that could help find the answers. Such a telescope would have to be a sensitive giant. It would have to be capable of collecting and discerning the light from the very faintest galaxies. It would have to observe infrared light.

One of the virtues of infrared light is that it is not blocked by dust. If a star is enshrouded by dust, an optical telescope will not see it, while an infrared telescope can still detect the star's emission. Infrared telescopes have the advantage that they can detect radiation from cold objects that are invisible to optical telescopes.

Planets and dust discs around other stars, asteroids, brown dwarfs ('failed' stars) and protostars are all examples of objects that are too cold to shine in visible light, but stand out when viewed in the infrared.

Now the astronomers' dream is becoming a reality. ESA's latest space observatory, Herschel, is designed specifically to achieve those goals. With its ability to detect infrared light, Herschel will let astronomers see, for the first time, the light emitted by dusty and very cold regions that are hidden from the gaze of optical telescopes and previous infrared observatories.

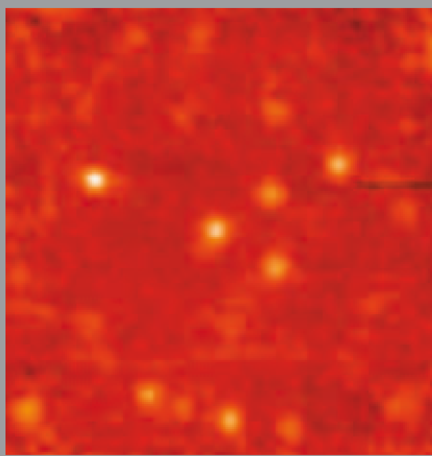
Carrying a huge telescope with a 3.5 m-diameter mirror – the largest ever flown in space – Herschel is the first of a new generation of space giants. It was named after William Herschel, the German-born musician turned British astronomer, who discovered infrared radiation in 1800.

Baby galaxies at work

Astronomers call the era before 'first light' and galaxy formation, 'the dark ages'. It is an appropriate name – no current instrument can peer into that era, since no light was emitted. Not long after the Big Bang, however, the first stars started to form, possibly in small clusters. These stars had no heavy atoms. Most likely they were very massive, therefore had a short lifetime and a violent death.

← Sir William Herschel (1738–1822)

Like a chemical factory, the first stars created the first heavy atoms, enriching the raw material from which the next generation of stars would form. The clusters of stars started to merge and grow, triggering the birth of more stars, which, in turn, created more material for future stars. In this way, the first galaxies were born as vast collections of star clusters. These galaxies would often collide and merge to form larger galaxies, triggering new intense bursts of star formation, and space gradually became the Universe of galaxies we see today.



← Lensed galaxies in galaxy cluster Abell 2390. They might be young galaxies in collision (ESA/ISO/ISOCAM)

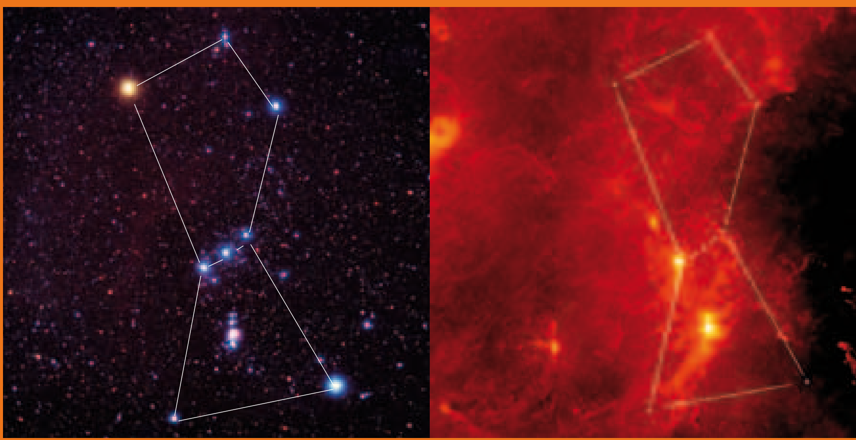
However, this scenario of galaxy formation and evolution leaves many open questions. For instance, from previous space observatories, we now know that when the Universe was half its present age, galaxies were very different. Fundamental new insights into galaxy formation and evolution came from the NASA/ESA Hubble Space Telescope, from pioneering infrared observatories such as the international Infrared Astronomical Satellite (IRAS), ESA's Infrared Space Observatory (ISO), and more recently, the JAXA/ISAS Akari and NASA Spitzer space telescopes.

IRAS made the completely unexpected discovery that some galaxies emit almost all their energy in the infrared. These are usually galaxies that are forming stars at a very high rate: up to thousands of times faster than the rate in our galaxy today. To peer into the unsolved mysteries of galaxy formation, astronomers needed a much larger infrared space telescope. Herschel will be able see the emission from dust heated by the Universe's stellar 'baby booms' across the epochs of most intense star formation – inside 'baby galaxies' at work.

Starbirth in the dark

Stars are shy, at least during their early lives. They begin to form inside clouds of gas and dust, and in thick dust cocoons that protect them until the moment they 'hatch'. In the pre-stellar core, as these cocoons are called, gravity squeezes gas and dust into the centre of the clump, which heats the gas.

→ The dusty revolution



← When you look up and see the constellation of Orion, it appears as in the image on the left (in visible light). But when viewed in infrared, it is very different (right, this image taken by the Japanese Akari satellite) (JAXA)

Human eyes are blind to most types of light. They can see neither infrared nor ultraviolet light. Only visible light, i.e. light in a particular narrow band of wavelengths, is picked up by our eyes.

Because each kind of light reveals different natural phenomena, human vision provides us with only one part of the full story. It is the same with telescopes: optical telescopes detect only visible light.

Previous infrared satellites have allowed astronomers to glimpse the infrared face of the Universe. They have seen enough to realise that in infrared, the Universe looks very different. Herschel has been planned to build on previous successes with its substantially larger telescope and spectral coverage extending into the far-infrared and submillimetre wavelengths.

The success of the Infrared Astronomical Satellite (IRAS) in 1983, a joint venture between the Netherlands, UK and USA that produced the first map of the entire sky at infrared wavelengths, paved the way for ESA's Infrared Space Observatory (ISO).

Launched in 1995, ISO was the world's first general-purpose infrared space observatory, which operated until 1998. ESA then took part in the Japanese Akari mission, which mapped more than 94% of the sky at infrared wavelengths, with higher sensitivity and in more detail than IRAS, in 2006–7. NASA's Spitzer general-purpose infrared observatory, launched in 2003, is still operational.

↗ IRAS

It carries a telescope that is slightly bigger than that of ISO, and a new generation of instruments with more sensitive detectors.

However, Herschel is not just the next step, but also a giant leap forward in infrared technology. Its telescope is significantly bigger and has the capacity to observe considerably more detail. Herschel will also bridge the gap between wavelengths seen by previous infrared satellites and those studied by submillimetre telescopes on ground.

Herschel will be able to discover a large number of unknown objects both within and outside our galaxy, and will even detect emission from cold dust itself. This makes it an ideal tool to study the build-up of galaxies, where interaction often creates massive bursts of star formation in dusty regions that sometimes emit almost exclusively in the infrared.

↙ ISO

Infrared astronomy can only become increasingly important to astronomers in the future. ESA is collaborating with NASA on the James Webb Space Telescope, an infrared space telescope designed to look into the very furthest reaches of space, where visible light is stretched into infrared wavelengths because of its vast journey across space and time.

This heat must radiate into space before the embryonic star can complete its collapse and finish its formation.

Pre-stellar cores are initially deeply embedded in clouds that are incredibly cold. This makes them invisible to all telescopes except those designed to collect radio or infrared radiation. ISO unveiled more than a dozen of these cocoons, and Spitzer many more, but astronomers are waiting for Herschel to shed light on the entire process of star and planet formation. With its large telescope and spectral coverage that extends to very long wavelengths, Herschel will be able to study the earliest unknown stages of star birth and take a complete census of stars forming in our galactic neighbourhood.

Recipe for a planet

Making a planet is simple. After a star is born, leftover gas and dust remain swirling around the young star, forming a circumstellar disc of gas and dust. The grains of dust in this disc are the seeds of the cores of the future planets. Once most of the material has collapsed together to form the planets, the gas disc disappears, leaving behind only a thin ring of debris.

Both circumstellar discs and debris rings are favourite targets for infrared space telescopes. ISO and Spitzer have shown that the formation of planets around stars must be a common event. Observations by Spitzer show that discs of dust and gas surround almost all young stars, but that their lifetime is fairly short – only a few million years. This indicates that the planet-making process is quite rapid, with smaller bodies contributing to the material that eventually forms planets. There is also evidence that discs of debris can be seen around mature stars. Herschel will thoroughly investigate the nature of the material in circumstellar discs for stars of all ages.

The origin of the Solar System

Our Solar System formed about 4600 million years ago, out of the 'proto-solar nebula'. This primeval cloud contained the raw material that formed both the Sun itself and the planets. To reconstruct precisely how the process took place, astronomers need to study the detailed chemical compositions of the atmospheres and surfaces of the planets and their moons, and especially the chemical composition of the comets.

Comets are mostly made of water ice, methane and carbon dioxide. They are the best fossils of the early Solar System because they are made of unprocessed material from the proto-solar nebula. In the atmosphere of a planetary body, the original components are altered by subsequent chemical reactions; in a comet, they are held in a deeply frozen state. Studying the chemical composition of comets will also shed new light on the question of the origin of Earth's oceans.

According to some hypotheses, impacting objects of various kinds, such as comets and asteroids, brought most of the water to our planet early in the history of the Solar System. Herschel has the unprecedented capability to analyse the chemical composition of the Solar System's various bodies.

We are stardust...

Stars are the chemical factories of the Universe. Every atom in the Universe (with the exception of the three lightest elements, hydrogen, helium and lithium) is the result of stellar activity. Many chemical elements, including those essential for life, such as carbon, nitrogen and oxygen, are created in the nuclear fires that burn inside stars, while elements heavier than iron are produced during violent supernova explosions.

When stars age and eventually die, they spread the processed material back to the interstellar medium, either gently or in violent explosions, depending on how massive the star was at the beginning of its life. Many chemical compounds, including those essential for life, are produced around ageing stars, and in the interstellar material enriched by them. Huge amounts of water and complex molecules of carbon, both essential for life, have been detected in the material surrounding stars. Human beings and all other life forms on Earth, as well as our planet itself, are literally 'stardust'.

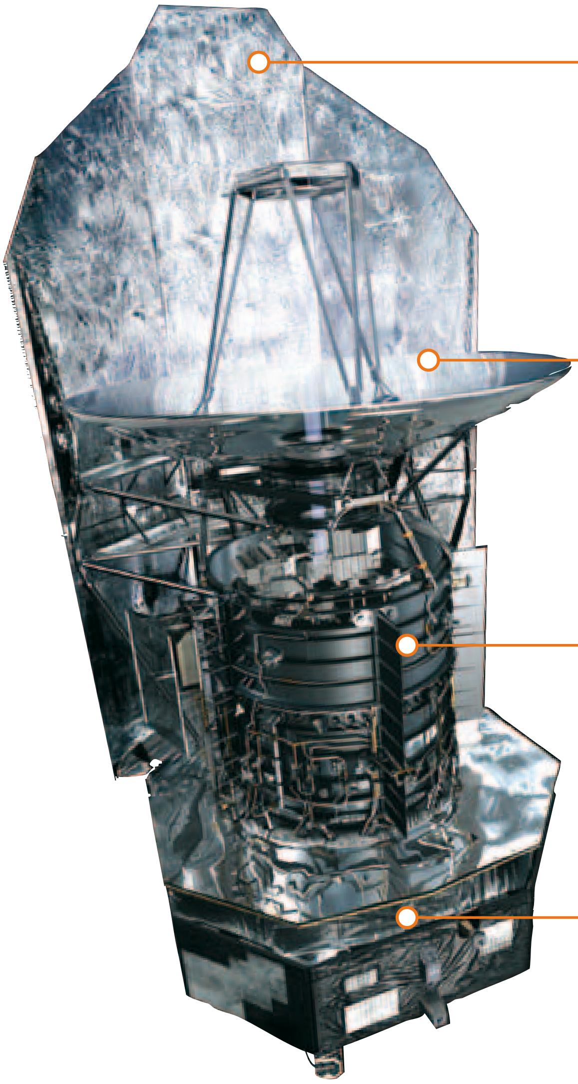
> **When Joni Mitchell, in her song 'Woodstock', sang, "We are stardust..." she was being factual as well as poetic.**

Most molecules show their unmistakable chemical signature at infrared and submillimetre wavelengths. This makes Herschel the ideal tool for detecting and studying them. Herschel will study the chemistry of many regions in the Universe, from stars and their environments to other galaxies. It will observe chemical-rich objects such as molecular clouds, where over a hundred different molecules have been discovered. Some of these molecules need the isolation of space to exist. On Earth, they would rapidly react with other molecules and so can be created only in highly specialised laboratories.

How does Herschel work?

The Herschel satellite has three sections. First is the telescope, protected by a sunshade, with its giant primary and a smaller secondary mirror. The telescope focuses light onto three scientific instruments; their detectors are housed in a giant vacuum flask, known as a 'cryostat'. The instruments' detectors and the cryostat make up the second section, the payload module.

The third element of the satellite is the service module located below the payload module. It houses the instrument electronics and the components responsible for satellite functioning, such as the attitude control, power distribution and communication hardware. The service module hosts the data processing units and spacecraft control electronics, operating at ambient temperature.



The largest telescope ever flown in space

Herschel's 3.5 m-diameter primary mirror makes it more than four times larger than any previous infrared space telescope and almost one and a half times larger than the Hubble Space Telescope. It will collect almost 20 times as much radiation as any previous infrared space telescope.

The primary mirror is the telescope's light collector. It captures light from astronomical objects and directs it towards a smaller second mirror. This collected light is focused to the instruments, where it is detected and analysed. The size of the primary mirror is the key to a telescope's sensitivity: the bigger it is, the more light it collects, and so the fainter the objects it sees. It also determines the telescope's ability to distinguish fine details. The surface of the mirror is equally important. It has to be precisely shaped and perfectly smooth; the slightest roughness can distort the final image.

Building Herschel's mirror was a real technological challenge. The mirror must be very light (as must all satellite components); at the same time it has to withstand the extreme conditions of launch and has to keep its shape at the temperature of –200°C it will reach in outer space; and any irregularities on its surface must be less than thousandth of a millimetre high.

Keeping cool

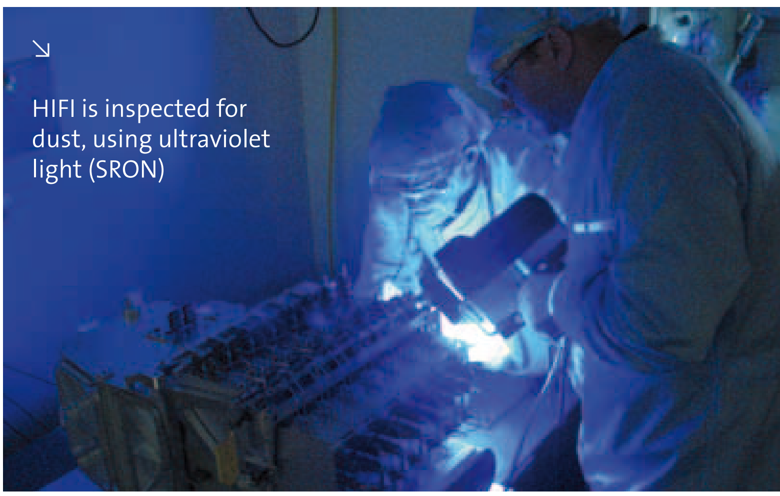
An infrared detector must be cooled to extremely low temperatures to function. The temperature of some astronomical objects is close to absolute zero (–273.15°C), so trying to observe them with a warmer instrument would be like trying to see a star against the glare of the midday Sun. So inside the cryostat, Herschel's detectors are kept at very low and stable temperatures. The cryostat contains liquid superfluid helium at temperatures lower than –271°C, which makes the instruments as sensitive as possible.

All three Herschel instruments will be cooled by the cryostat. The role of the cryostat is key because it determines the lifetime of the observatory. The helium evaporates at a constant rate, gradually emptying the tank. When it has all gone, the temperature of the instruments will rapidly start to rise and Herschel will no longer be able to perform observations.

Three powerful eyes

Herschel's three instruments are complementary: each instrument is designed to study gas and dust, but at different temperatures and states. Thanks to the large range of wavelengths covered, they will be able to witness the entire process of star formation, from the earliest stages of condensation to the moment at which the protostar emerges from its cocoon and is born.

The Heterodyne Instrument for the Far Infrared (HIFI), a very high-resolution spectrometer, is designed to observe unexploited wavelengths. With its high spectral resolution –



↘ HIFI is inspected for dust, using ultraviolet light (SRON) the highest ever in the range of wavelengths it covers – HIFI will observe an unprecedented level of detail: it will be able to observe and identify individual molecular species in the enormity of space, and study their motion, temperature and other physical properties. This is fundamental to the study of comets, planetary atmosphere in our Solar System, star formation and the development of distant and nearby galaxies.

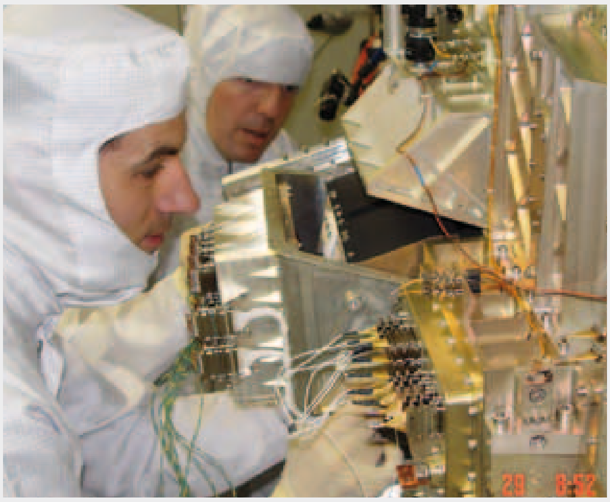
HIFI was designed and built by a nationally funded consortium led by SRON (Netherlands Institute for Space Research). The consortium includes institutes from France, Germany, USA, Canada, Ireland, Italy, Poland, Russia, Spain, Sweden, Switzerland and Taiwan.

The Photoconductor Array Camera and Spectrometer (PACS) consists of a colour camera and an imaging spectrometer. Within its wavelength range (55–210 microns), the PACS camera is the first instrument capable of obtaining the complete image of a target at once. The PACS spectrometer has a lower resolution than that of HIFI, but it is perfectly suited to observing young galaxies and the gas clouds from which stars form.

PACS was designed and built by a nationally funded consortium led by the Max Planck Institute for Extraterrestrial Physics (Germany); the consortium includes institutes from Belgium, Austria, France, Italy and Spain.

The Spectral and Photometric Imaging Receiver (SPIRE) also operates at wavelengths that have not been fully used before (194–672 microns). Like PACS, it consists of a colour camera and an imaging spectrometer, and it covers a complementary range of wavelengths. It is designed to study star formation.

SPIRE was designed and built by a nationally funded consortium led by the University of Cardiff (UK); the consortium includes France, Canada, China, Italy, Spain, Sweden and USA.



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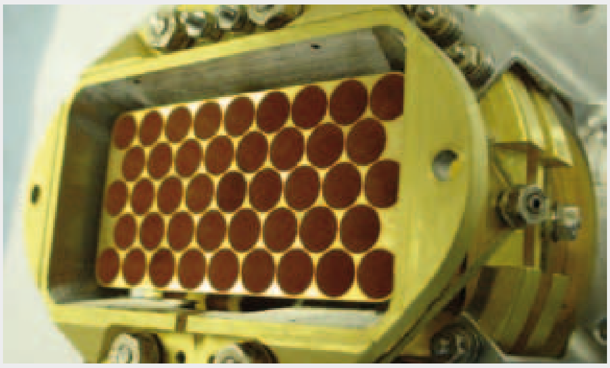
PACS photometer unit during integration into the focal plane unit (MPE/CEA)



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The SPIRE photometer detector assembly (SPIRE Consortium)

→ Operating Herschel

The Herschel Science Ground Segment consists of: the Herschel Science Centre (HSC), Instrument Control Centres (ICC) for each instrument (HIFI, PACS, SPIRE) and the NASA Herschel Science Center.

The HSC (based at ESAC, Madrid) is the prime interface between Herschel and the science community. It provides information and user support related to the entire lifecycle of Herschel observations, including calls for observing time, the proposing procedure, proposal tracking, data access and data processing, as well as general and specific information about using Herschel and its instruments. It also performs scientific mission planning, produces observing schedules and provides these to the Mission Operations Centre at ESOC, Darmstadt, for uplink to Herschel. It systematically processes all Herschel data and makes the data and associated products available through the Herschel science archive.

The ICCs are provided by their respective principal investigators and are responsible for the successful operation of their respective instruments. They perform instrument monitoring and calibration, and develop and maintain instrument specific software and procedures for generating observations and for the processing of the data generated. The NASA Herschel Science Center at IPAC, California, provides additional user support primarily for the US-based users of Herschel, and offers science exploitation funding for Herschel investigators based in the USA.

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ESA's Planck satellite

→ LOOKING BACK TO THE DAWN OF TIME

The science behind ESA's Planck observatory

Jan Tauber, Thomas Passvogel, Monica Talevi and Monica Salomone
Directorate of Science and Robotic Exploration, ESTEC,
Noordwijk, The Netherlands

Only a few decades ago, the origin of the Universe was a scientific topic lacking reliable data. However, scientists now know where to look for answers, and they are steadily gaining the means to do so. ESA's ambitious Planck mission is the next step in solving many of cosmology's biggest questions.

Cosmology, the science that aims to explain how the Universe formed and evolves, has become one of the richest and hottest fields of experimental research, and experiments on the ground and in space are starting to yield new and exciting results.

Key discoveries made during the last eight decades indicate that in the past the Universe was far denser and hotter than it is now, and that it started to cool and expand – a process that is still going on today – about 13 700 million years ago. This version of events, known as the 'Big Bang' theory, is widely accepted. But the picture is still far from complete. Questions such as what triggered the birth of the Universe, or how it will evolve, remain unanswered. Named after the German Nobel-winning scientist Max Planck, one of the founders of quantum physics and noted for his research on blackbody radiation, Planck will provide the most precise and reliable data of its kind ever obtained. By doing so, it will take scientists closer to those answers, and to the origin of our Universe.

Detectives of the past and the future

Scientists trying to reconstruct an event that took place about 13 700 million years ago work very much like detectives. First they have to find the right clues, then they have to squeeze all the useful information out of those pieces of evidence. The case of the Big Bang is a long and difficult one.

It started in the 1920s, when astronomers learnt that the Universe has not always been as we see it today. They discovered that all the time, even right now, the Universe is becoming larger and larger. This means that in the past all the matter and energy that it contains were packed into a much smaller, and also much hotter, region.

Later on a second clue was identified. Scientists learnt that the stars are the 'factories' that make most chemical elements in the Universe – oxygen, carbon, iron – but also that some particular elements must come from somewhere else. They postulated, and confirmed, that those few elements had been produced during the earliest epochs of the Universe, when it was still very hot.

First light

Those findings helped to shape the Big Bang theory. But this general model describing the beginning of the Universe did not gain wide support from the scientific community until the discovery of yet a third clue.

In 1964, radio astronomers Arno Penzias and Robert Wilson serendipitously detected radiation coming from everywhere in the sky, a 'glow' filling the whole Universe with the same intensity. This radiation could best be interpreted as a 'fossil' of the Big Bang itself. The argument goes like this: if the Universe has always been expanding, then there must have been an initial period during which all existing matter and radiation were very tightly coupled together, in a high-temperature mixture.

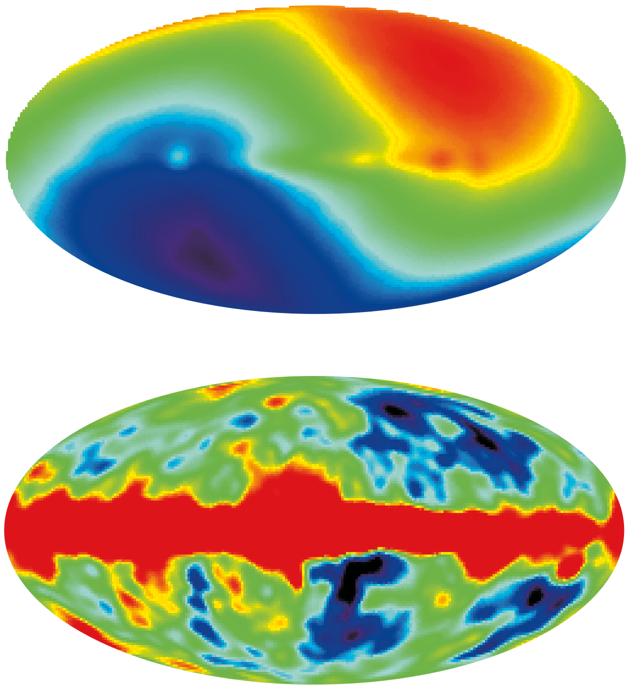
With time the Universe cooled down, and at some point it must have reached a temperature low enough for the radiation to be released from its close embrace with matter. Light would then have travelled freely throughout the Universe for the first time. That 'first light' should still be detectable today. It is, and in fact was the glow detected in 1964.

Scientists called this first light Cosmic Microwave Background (CMB) radiation. It is important not only because it is the third major piece of evidence supporting the Big Bang theory, but also because cosmologists know that they have not yet been able to extract all the information it holds.

At the time of its release, only about 380 000 years after the Big Bang, what we detect as the CMB today had a temperature of some 3000°C; but now, with the expansion and cooling of the Universe, the temperature of this radiation appears to be only a couple of degrees above absolute zero (about –270°C).

'Clots' of information

The CMB comes from every direction in the sky with almost the same brightness. But by measuring its apparent temperature all over the sky, scientists discovered that tiny differences do exist from place to place. These differences can be as small as one part in a million.



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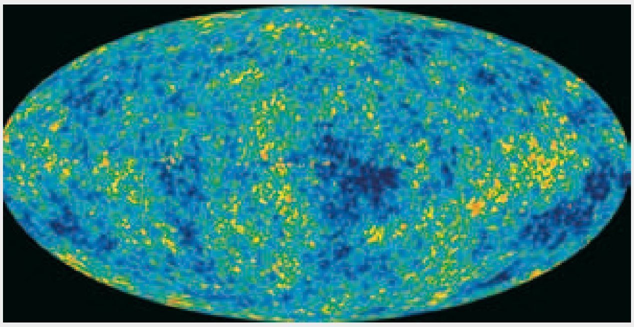
Maps of the sky as seen by NASA's COBE satellite, after different stages of image processing. The top panel shows (in false colour) the temperature of the sky after removing a uniform (2.7K) component due to the CMB; the large-scale diagonal feature (the so-called dipole) is caused by the motion of the Sun with respect to the CMB; and the faint horizontal smudge is due to emission from the Milky Way. The bottom map results when the dipole component is removed. What is left is residual galactic emission (seen as a bright horizontal band), and a background of hot and cold spots, due largely to a mixture of instrument noise and the CMB (NASA)

Although these variations may seem too small to be important, they are precisely what scientists are looking for. They are a goldmine of information. They are nothing less than the 'imprints' left in the past by matter, a reminder of the period when matter and radiation were closely coupled to each other.



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In 1992, NASA's COBE satellite confirmed for the first time that the temperature of the CMB was not uniform over the sky. In 2003, COBE's successor WMAP was able to improve dramatically the map's clarity and sharpness, showing tiny irregularities in the temperature of the CMB across the sky. This image shows CMB fluctuations from the five-year WMAP survey. The average brightness corresponds to a temperature of about -270°C (red regions are warmer and blue are colder than average by 0.0002°C) (NASA)

At that time matter already contained the 'seeds' of the huge structures that we see in the Universe today: galaxies and galaxy clusters. The tiny variations in the measured temperature of the CMB are the imprints left by those clots of matter.

In fact, much of the valuable information that the CMB can provide lies in the precise shape and intensity of these temperature variations, called 'anisotropies'. In 1992, NASA's COBE satellite obtained the first blurry signals of the anisotropies of the CMB. In 2003, its successor, NASA's WMAP, was able to chart maps that have started to reveal their detailed properties. The objective of Planck is to complete the picture by mapping these features as fully and accurately as possible.

Questions for Planck

The anisotropies in the CMB hold answers to many key questions in cosmology. Some refer to the past of the Universe, such as what triggered the Big Bang and how long ago it happened. But some other questions look far into the future. For instance: what is the density of matter in the Universe and what is the true nature of this matter?

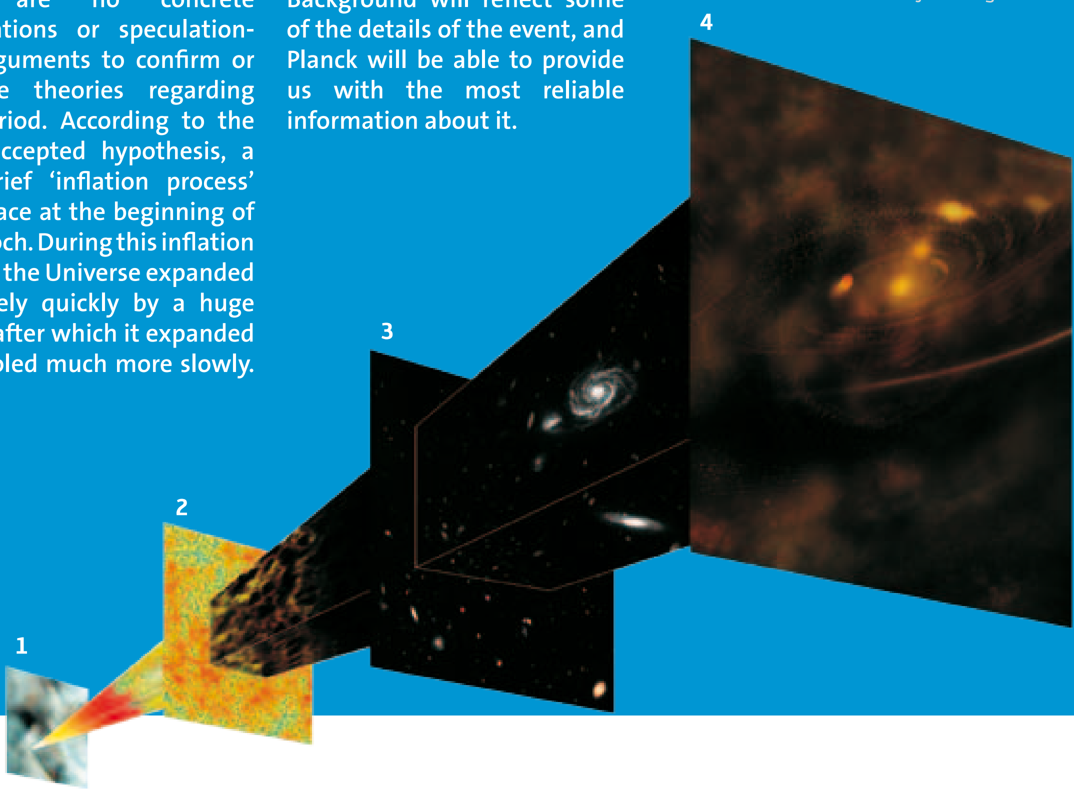
These parameters may tell us if the Universe will continue its expansion forever, or if it will end by collapsing back on itself

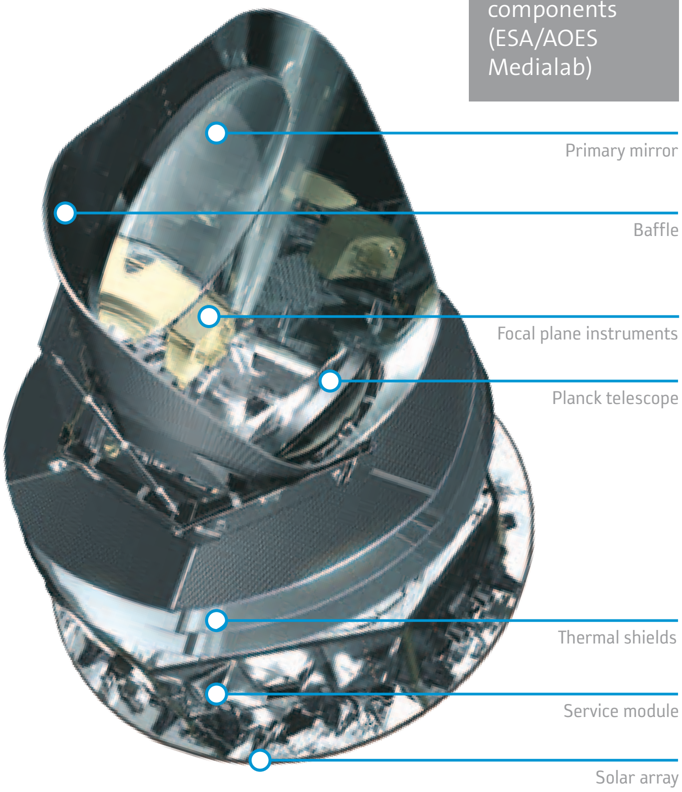
→ The birth of the Universe

The period up to a millionth of a second after the birth of the Universe is full of uncertainties: there are no concrete observations or speculation-free arguments to confirm or disprove theories regarding this period. According to the most accepted hypothesis, a very brief 'inflation process' took place at the beginning of this epoch. During this inflation process the Universe expanded extremely quickly by a huge factor, after which it expanded and cooled much more slowly.

If this hypothesis is correct, then the inhomogeneities in the Cosmic Microwave Background will reflect some of the details of the event, and Planck will be able to provide us with the most reliable information about it.

1 From one second until a few minutes after the Big Bang
2 380 000 years after the Big Bang
3 One thousand million years after the Big Bang
4 5000 million years ago





Planck main components (ESA/AOES Medialab)

in a reverse process of the Big Bang, called the 'Big Crunch'. Now, thanks to WMAP and other experiments, we know that our Universe will most likely not crunch; but new results are telling us that the fate of our Universe is stranger and less predictable than we thought. Some of the new uncertainties are related to the hypothetical 'dark energy', which may exist in large quantities in our Universe, as indicated by observations of light from distant exploding stars. What is dark energy? And what are its effects? ESA's Planck satellite will be the most powerful tool to analyse the anisotropies in the Cosmic Microwave Background, and possibly 'shed more light' on dark energy.

How will Planck work?

Planck will study the Cosmic Microwave Background by measuring its temperature variations all over the sky. Planck's large telescope will collect light from the CMB and focus it on to two arrays of detectors, which will translate the signal into a temperature reading.

The detectors on board Planck are highly sensitive. They will be looking for variations in the temperature of the CMB of about a million times smaller than one degree – this is comparable to measuring the heat produced by a rabbit on the Moon, from Earth!

The spacecraft

Planck has two main elements: a 'warm' service module, and a 'cold' payload module which includes the two scientific instruments and the telescope. The service module houses the data-handling systems and subsystems essential for the spacecraft to function and to communicate with Earth, and the electronic and computer systems of the instruments.

At the base of the service module is a flat, circular solar panel that generates power for the spacecraft and protects it from direct solar radiation. The 'baffle' is an important part of the payload module. It surrounds the telescope, limiting the amount of stray light incident on the reflectors. It also helps to radiate excess heat into space, cooling the focal plane units of the instruments and the telescope to a stable temperature of about –223°C. The baffle forms part of the passive cooling system for the satellite, before the active cooling system takes over.

The solar array, located at the bottom of the service module at one end of the spacecraft, is permanently illuminated. On the other side of the service module are three reflective thermal shields that isolate it from the payload module. These prevent heat generated by the solar array and the electronic boxes inside the service module from diffusing to the payload module.

This passive cooling system brings the temperature of the telescope down to around –220°C The temperature of the detectors is further decreased to levels as low as –273°C by a three-stage active refrigeration chain. The resulting difference in temperature between the warm and cold ends of the satellite is an astounding 300 degrees.

The coldest detectors

A key requirement is that Planck's detectors must be cooled to temperatures close to the coldest temperature reachable in the Universe: absolute zero, which is –273.15°C. The detectors on Planck have to be very cold so that their own heat does not swamp the signal from the sky. All of them will be cooled down to temperatures below –253°C, and some of them will reach the amazingly low temperature of just one tenth of a degree above absolute zero. These detectors could well be the coldest points in space.

Sharp vision

With its unprecedented angular resolution, Planck will provide the most accurate measurements of the CMB yet. The angular resolution is a measure of Planck's sharpness of vision, i.e. the smallest separation between regions in the sky that the detectors are able to distinguish; the smaller the separation, the better will be the information gathered. Planck's sharpness of vision is such that it can distinguish objects in the sky with a much higher resolution than any other space-based mission that has studied the CMB.

Planck's detectors have the ability to detect signals 10 times fainter than its most recent predecessor, NASA's WMAP, and its wavelength coverage allows it to examine wavelengths 10 times smaller. In addition, the telescope's angular resolution is three times better. The resulting effect is that Planck will be able to extract 15 times more information from the CMB than WMAP.

Broad wavelength coverage

Planck's detectors are specifically designed to detect microwaves at nine wavelength bands from the radio to the far infrared, in the range of a third of a millimetre to one centimetre. This includes wavelengths that have not been observed so sharply before.

The wide coverage is required in order to face a key challenge of the mission: to differentiate between useful scientific data and the many other unwanted signals that introduce spurious noise. The problem is that many other objects, such as our own galaxy, emit radiation at the same wavelengths as the CMB itself. These confusing signals have to be monitored and removed from the measurements.

Planck will use several of its wavelength channels to measure signals other than the CMB, thus obtaining the cleanest signal of the CMB ever. In addition, as it is monitoring signals other than the CMB, Planck is gathering data on celestial objects including star fields, nebulae and galaxies with unprecedented accuracy in the microwave, providing scientists with the best astrophysical observatory ever in this wavelength range.

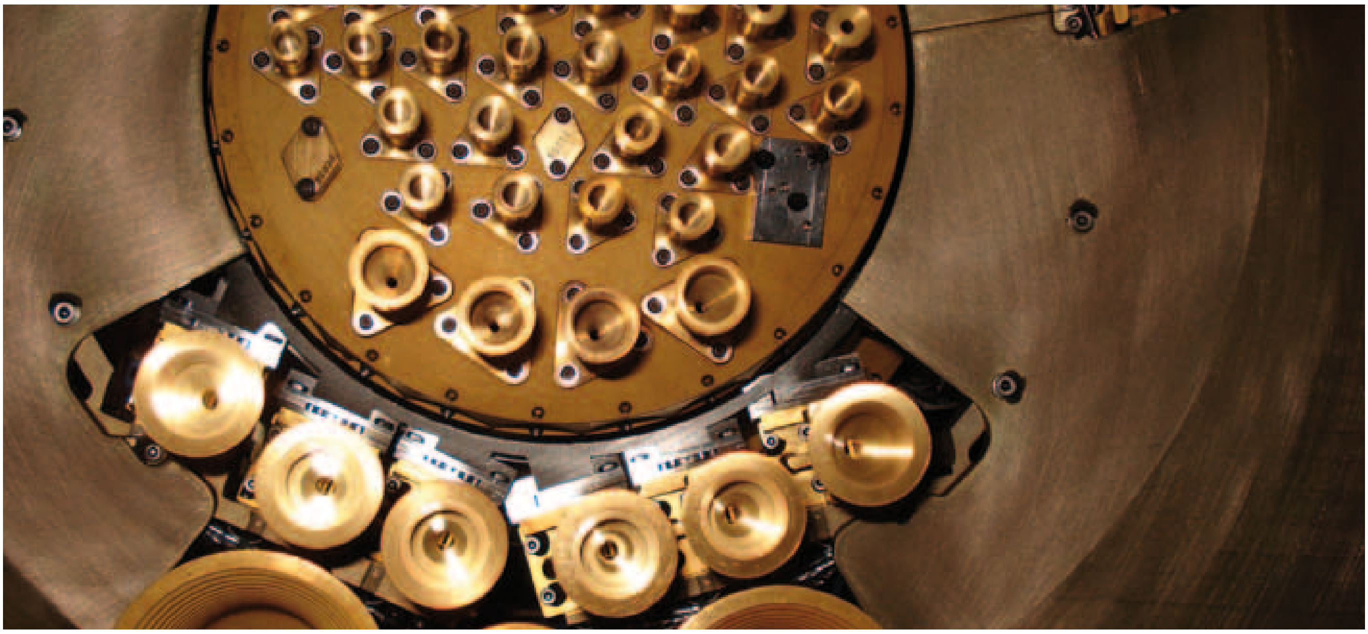
The telescope

The Planck telescope collects radiation from the CMB and delivers it to the detectors. The primary mirror, 1.9 x 1.5 m, is very large for a space mission, but weighs only about 28 kg. The mirror is robust enough to withstand the stresses of launch as well as the temperature difference between launch, when it is at ambient temperature (about –30°C), and operations (about –230°C). The mirror is made of carbon-fibre reinforced plastic coated with a thin reflective layer of aluminium.

The telescope is surrounded by a large baffle, reducing stray light interference from the Sun, Earth and the Moon, and cooling it by radiating heat into space. The telescope mirror was provided by a collaboration between ESA and a Danish consortium of scientific institutes led by the Danish National Space Centre.

The instruments

Planck carries two complementary scientific instruments: the High Frequency Instrument (HFI) and the Low Frequency Instrument (LFI). They will provide the most accurate estimates of the spatial variations of the temperature of the CMB. HFI is designed for high-sensitivity measurements of the diffuse radiation permeating the sky in all directions at six wavelength bands in the range 3.6 mm to 0.3 mm (frequencies 84 GHz to 1 THz). It consists of an array of 52 bolometric detectors placed in the focal plane of the telescope. Bolometric detectors are devices capable of detecting and measuring small amounts of thermal radiation. HFI was built by a consortium of more than 20 institutes, led by the Institut d'Astrophysique Spatiale, Orsay (France).



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Close-up of the focal plane unit during testing, showing the HFI detector array (small feedhorns in the centre) and the LFI larger feedhorns (ESA/Thales)

LFI is designed for high-sensitivity measurements of the microwave sky at three wavelength bands in the range 11.1 mm to 3.9 mm (frequencies 27 GHz to 77 GHz). It consists of 22 tuned radio receivers in the focal plane of the telescope operating at –253°C. These radio receivers will gather microwaves from the sky and convert them into an estimate of the intensity of radiation at each frequency. LFI was built by a consortium of more than 20 institutes, led by the Istituto di Astrofisica Spaziale e Fisica Cosmica, Bologna (Italy).

Several funding agencies contributed to the LFI and HFI instruments and respective data centres. The major ones are: CNES (FR), ASI (IT), NASA (US), STFC (GB), DLR (DE), NSC (NO), Tekes (FI) and the Ministry of Education and Science (ES).

Who built Planck?

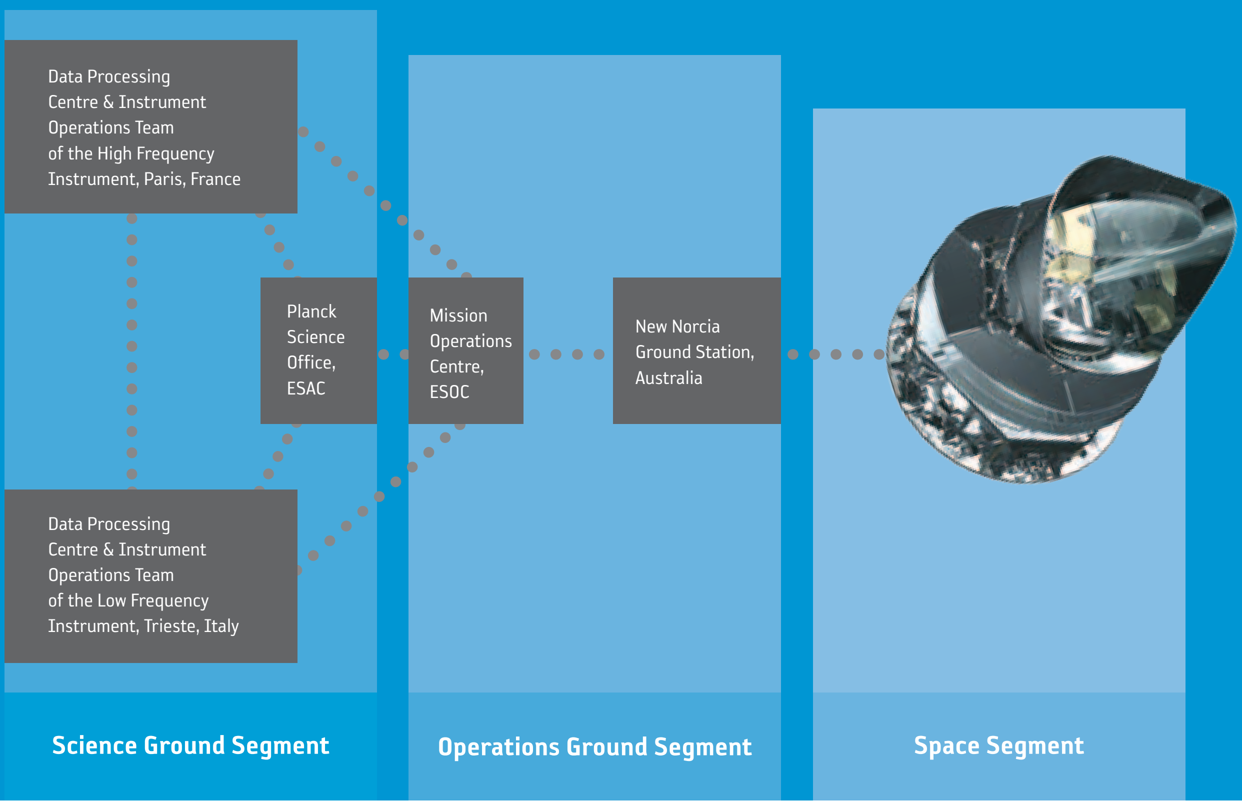
Planck's design presented several technological challenges, in particular its sophisticated cooling system that keeps the spacecraft detectors at extremely cold temperatures – close to absolute zero.

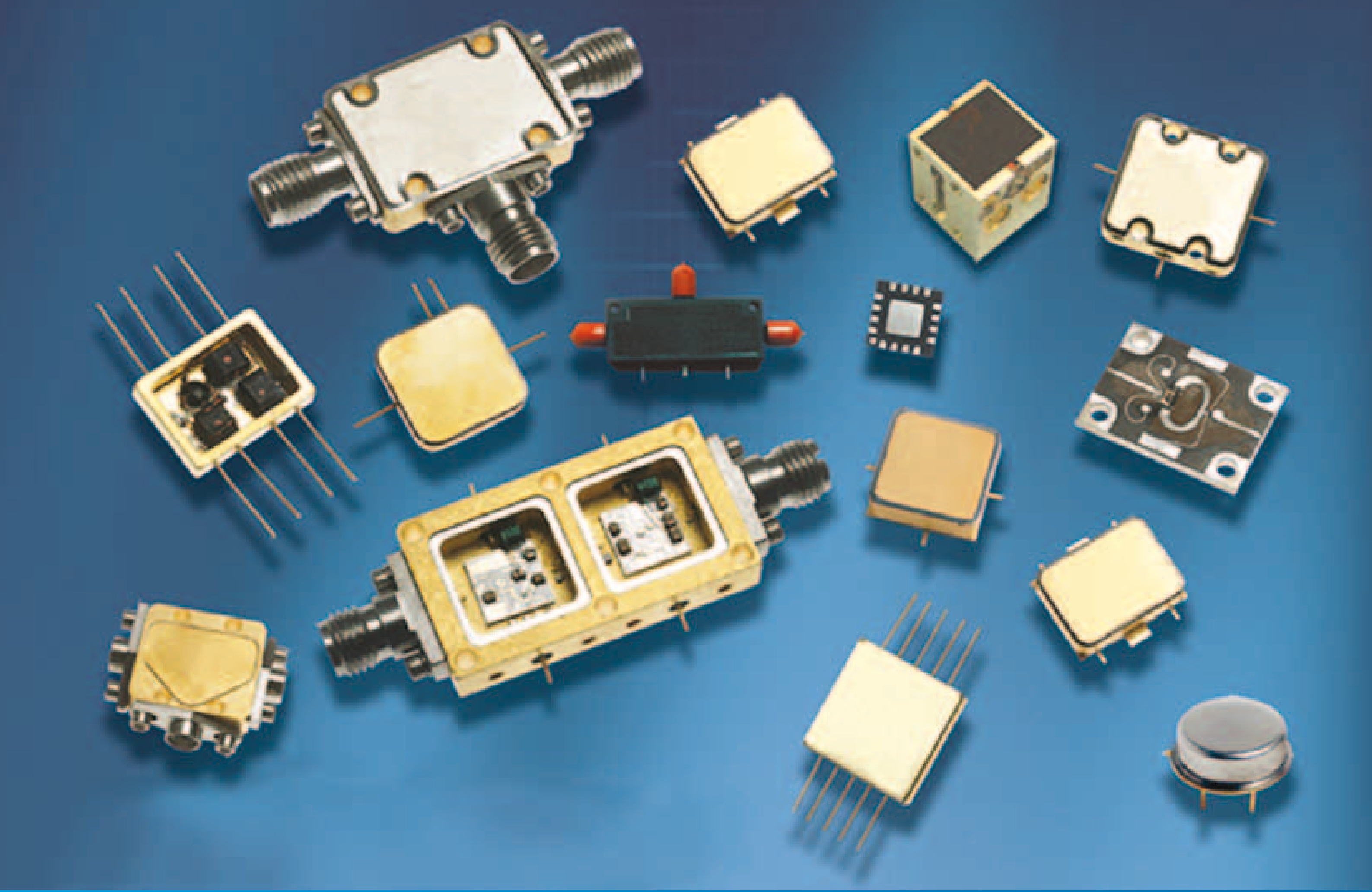
ESA designed and built Planck under a common engineering programme with Herschel, ESA's infrared space observatory that will study the formation of galaxies and stars. But the two satellites shared more than just a launcher: they have undergone a joint development process aimed at optimising resources, by using the same industrial teams and shared design of spacecraft components wherever possible.

ESA's prime contractor for Planck is Thales Alenia Space France, leading a consortium of industrial partners with Thales Alenia Space Italy responsible for the service module. There are also many subcontractors spread throughout Europe and the USA. ESA and the Danish National Space Centre, funded by the Danish Natural Science Research Council, provided Planck's telescope mirrors, which were manufactured by Astrium (Germany).

→ Operating Planck

Scientific operations will be conducted by the Planck Science Office based at the European Space Astronomy Centre, near Madrid, Spain, and the two instrument teams' Data Processing Centres (DPC) and Instrument Operations Teams (IOT). Spacecraft operations will be conducted by the Mission Operations Centre at the European Space Operations Centre in Darmstadt, Germany. The Planck Science Office takes care of the scheduling of the survey strategy and the monitoring of the progress of the survey, while the instrument DPCs and IOTs are responsible for specifying the commanding and processing of the telemetry for their instrument and monitor the instrument operations. For the HFI instrument, the DPC is located at the Institut d'Astrophysique de Paris, France, and the IOT is at the Institut d'Astrophysique Spatiale, Orsay, France. For the LFI Instrument, both the DPC and the IOT are located at the Osservatorio Astronomico di Trieste, Italy.





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Jean-Yves Le Gall, CEO Arianespace
(Arianespace/J. Wallace)

→ ESA'S LAUNCHER FAMILY

Interview with Jean-Yves Le Gall
Chairman and CEO, Arianespace
Paris, France

Ariane is one of Europe's most successful cooperative programmes – not only in terms of technology and execution, but also from the commercial aspect. Arianespace Chairman and CEO Jean-Yves Le Gall talks about this success from the operator's point of view, and provides an outlook for the future of ESA's growing launch vehicle family.

Q: What is the status of the Ariane programme today?
A: Without a doubt, Ariane is the benchmark for the world's commercial launch services marketplace. The heavy-lift Ariane 5 has established itself as a highly reliable vehicle, demonstrating its capability to carry everything from the European Space Agency's Automated Transfer Vehicle to the largest commercial telecommunications satellites ever built.

Q: What is the role of Arianespace in Ariane's operation?
A: Arianespace was founded in 1980 as the world's first launch service and solutions company, demonstrating Europe's ability to develop highly capable space systems, and to establish the infrastructure for their long-term

operation. The company has 23 shareholders from ten European countries, and since our creation, 90% of the world's commercial satellite operators have expressed their confidence in Arianespace. More than half of the commercial satellites in service today have been launched by us.

Q: How does Ariane support Europe's space industry?
A: Ariane represents an important part of Europe's space-related workload, providing a stable source of business over the long term that is responsible for the employment of thousands of people throughout Europe. Our latest agreement for the production of 35 Ariane 5 launchers, signed on 30 January at ESA's headquarters in Paris, is valued at more than €4 billion, and follows the 30 Ariane 5 launchers that were ordered in 2004.

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The agreement for 35 Ariane 5 launchers is signed by Astrium's Alain Charmeau and Jean-Yves Le Gall, Arianespace, at ESA Headquarters in Paris (Arianespace)

It is important to note that Ariane 5's industrial system operates in a highly efficient manner, with EADS Astrium serving as the sole prime contractor, delivering a complete, tested and integrated launcher to Arianespace at the Guiana Space Centre, 'Europe's Spaceport'. Astrium manages all industry contracts for the 12 countries that are partners in the Ariane programme. Once the launcher is delivered, Arianespace takes over for the payload integration and the launch operations.

Q: During French President Nicolas Sarkozy's February 2008 visit to the Guiana Space Centre, he proposed that the European Commission assume management responsibility of this facility. How do you see the future operation of 'Europe's Spaceport' evolving?
A: First of all, we should recall how the launch site is operated today. ESA develops the Spaceport's infrastructure, and it delegates the operation to the French space agency, CNES. This has been an excellent arrangement, ensuring an efficient management of such a strategic European facility, and providing the world's most modern launch base for Arianespace's commercial operations.

The European Union's role is growing significantly in many fields of activity, including space. We can envisage making the Guiana Space Centre a tool that serves the European Union's common interests.

Defining how to operate the facility with this goal will take some time at the political level. However, I am pleased

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Antonio Fabrizi, ESA Director of Launchers, and Joël Barre, Director of CNES/CSG, sign the contract assuring the availability of the CSG launch range to 2013, at Kourou, French Guiana (ESA/CNES/Arianespace/S. Martin)

that change is coming, which was best illustrated by the visit of 27 European Ministers and State Secretaries to French Guiana in July 2008. While the focus of European space had been limited a relatively small 'club', the interest of Europe's politicians increased as the space segment grew in importance. Many of those visiting the Spaceport last July had a relatively out-of-date vision of what has been accomplished, so their tour of the Spaceport was an excellent way to see the launch site up close.

Q: How is the development of ESA's launcher family progressing, towards its exploitation by Arianespace?
A: Ariane 5 is our workhorse, and will continue to play an important role in Arianespace's launch services. The size of the heavy-lift vehicle allows us to pair up two commercial telecommunications satellites, one large spacecraft and another smaller-sized payload on missions to geostationary transfer orbit.

As we expect to see more satellites in the smaller-sized category during the next few years, our introduction of the medium-lift Soyuz will provide capacity to handle these spacecraft on launches that complement Ariane 5 flights. Vega is tailored to carry the growing number of small scientific spacecraft and other lighter-weight payloads that are under development or planned in Europe and worldwide.

With Ariane 5, Soyuz and Vega, Arianespace will exploit ESA's comprehensive launcher family, living up to our motto: "Any payload, to any orbit...anytime."

Q: The launch of the ATV *Jules Verne* by an Ariane 5 was a historic mission. What were the accomplishments for Europe's space exploration programme?

A: The highly successful mission with the ATV was truly a high point in Arianespace's service to European space. With a mass at lift-off of more than 19 000 kg, *Jules Verne* was the largest single payload ever orbited by Ariane 5.

More importantly, with this mission ESA, Arianespace and the European Spaceport joined the ranks of organisations that support operations for the International Space Station.

All of the processing operations performed at the Spaceport were treated as if the ATV was a manned payload, as the vehicle needed to meet the safety and cleanliness levels of the International Space Station.

Out of the 13 launch contracts signed in 2008 by Arianespace, seven were for satellites in the weight category of three tonnes or less. This represents a marked change in the strategy of both telecommunications operators and spacecraft manufacturers. However, by building our long-term strategy with Ariane 5, Soyuz and Vega launch vehicles, we will have a highly capable family that is fully capable of responding to this trend and to other market changes in the future.

Q: Can Ariane 5 be developed further, with the cryogenic Vinci upper-stage engine, for example?

A: As a commercial operator, Arianespace's focus is on ensuring the reliability and production stability for the current Ariane 5, which provides the capacity and capability needed by the market today.

↘ Launch of the ATV *Jules Verne* by an Ariane 5 in 2008 (ESA/CNES/Arianespace)

In addition, it was the first flight for an Ariane 5 ES version of our workhorse launcher, which used an EPS storable propellant upper stage to perform two in-flight burns for the deployment of ATV into its targeted 260 km circular orbit. Ariane 5 ES vehicles will be used during the next several years to launch the other ATVs, and this launcher version also is capable of lofting satellites for Europe's new Galileo space-based navigation system.

Q: As a key part of Arianespace's business, how do you see the commercial launch services market evolving?

A: Arianespace will continue its leadership role even as market conditions may change due to the global financial crisis and other factors. While the market does remain robust today, it seems wise to be prepared for potential consequences of the crisis, such as a slowing of overall order volume, a downward trend in the size and weight of satellites, or the freezing of certain satellite programmes by new or start-up operators.

> **"Any payload, to any orbit… anytime."**

Advanced studies for the Vinci upper-stage engine are being financed by ESA Member States, following the ESA Ministerial Council's decision last November, in preparation for a large programme to be approved at the next Council meeting in 2011. The possibility of having a reignitable upper-stage engine, which our competitors already have with their launch vehicles, would provide greater launch flexibility for Ariane 5 operations in the future. ■

→ AMBASSADORS FOR SPACE

Europe's next astronaut missions

European Astronaut Corps
EAC, Cologne, Germany

This summer, the International Space Station's permanent crew will, for the first time, increase from three to six members. Also for the first time, every ISS partner agency will have a representative astronaut on board.

The launch of Soyuz TMA-15 in May could appear to be just another launch of the reliable Soyuz spacecraft to the International Space Station (ISS). It will be, however, much more than that: when Russian cosmonaut Roman Romanenko, ESA astronaut Frank De Winne and Canadian Bob Thirsk lift off from Baikonur, they will make history.

The crew will be welcomed by Gennady Padalka from Russia, Koichi Wakata from Japan and NASA astronaut Michael Barratt, who have been on board the ISS since March. The arrival of Soyuz TMA-15 will mark the transition to a crew of six on the ISS for the first time. This eagerly awaited milestone will finally open the door to the full utilisation of the ISS, which is particularly important for ESA and its research programme.

Since the installation of ESA's Columbus module on the ISS and successful maiden flight of the Automated Transfer Vehicle (ATV) *Jules Verne*, ESA's role as an ISS partner has become very visible. The coming months and years will take ESA's role to yet another level in the light of the planned sequence of flights to the ISS in 2009 and 2010, involving European astronauts and their roles during these missions.

The next to fly is Frank De Winne, from Belgium, who starts his six-month 'OasISS' mission in May. "I will be involved in the operations of the ISS and the Japanese robotic arm, which will bring us a lot of expertise in the robotic field," says De Winne.

One such complex and important operational task – the capture and berthing of the first HTV (Japanese Transfer Vehicle) – has been assigned to De Winne, Bob Thirsk and NASA astronaut Nicole Stott, together with the JAXA and NASA ground controllers; a truly international cooperation at operational level.

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Bob Thirsk, Nicole Stott and Frank De Winne during a training exercise in Houston (NASA)

But more importantly, De Winne will be, in the last months of his mission, the first non-American and non-Russian commander of the ISS. In past years, the commander position was exclusively given to NASA astronauts or Russian space agency cosmonauts. That this highly visible role is now passed on to an ESA astronaut shows the reputation that ESA and its astronauts have earned in the ISS programme.

During his flight, De Winne will be supported by flight controllers at the Columbus Control Centre (COL-CC) in Oberpfaffenhofen, Germany. Among those controllers will be ESA astronauts André Kuipers and Léopold Eyharts, who will serve together with other colleagues from the European Astronaut Centre as 'Eurocoms', in charge of communication between the ISS and the ground. Kuipers, from the Netherlands, is De Winne's back-up and is

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Fellow Europeans Thomas Reiter and Christer Fuglesang meet in space in 2006

intimately familiar with the 'OasISS' mission. In early 2008, Eyharts, from France, delivered ESA's Columbus laboratory to the ISS together with fellow ESA astronaut Hans Schlegel. Eyharts stayed on board for several months to commission the Columbus module. Both astronauts will bring a lot of experience to ground operations, ensuring the best possible support for De Winne's OasISS mission.

Two Europeans meet again

During his long-duration mission, De Winne will have the chance to welcome another European colleague of the European Astronaut Corps, namely Christer Fuglesang from Sweden. A few days before Christmas 2006, a similar event happened in space when Fuglesang met with German Thomas Reiter, a former ESA astronaut who served on a long-duration flight on the ISS. They both left the ISS together with the crew of Space Shuttle *Discovery* on the STS-116 mission.

Even though his visit to the ISS lasted only eight days, Fuglesang said it contained some of the most memorable days of his near-50 years. "In particular, during the three Extra Vehicular Activities (EVAs) I participated in, we added the new P5 truss segment to the Space Station, we reconnected the Space Station's power system to its final configuration and we managed to get an uncooperative solar array to retract as a spectacular 'grand finale' to a very successful Shuttle mission," says Fuglesang.

The STS-116 mission marked the halfway milestone in terms of mass for the assembly of the ISS and, with the power reconnected, the stage was set for further modules, in particular the Columbus laboratory. Two years later, the ISS is almost fully assembled. The full 108-m long truss with all

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Expedition 19 and 20 members, the first six-man crew of the ISS and the first with representatives from all partner agencies: (back) Michael Barratt, Robert Thirsk, Koichi Wakata, Roman Romanenko, (front) Frank De Winne and Gennady Padalka (NASA)

(Patches: ESA/NASA/spacepatches.nl)

←

Christer Fuglesang training for EVAs (spacewalks) at NASA Johnson Space Center (NASA)

eight solar panels is in place, and only a few modules are still missing (such as the European-built Node-3 and Cupola).

Fuglesang and his crewmates are preparing for a similar mission on the Space Shuttle with STS-128. When *Discovery* docks to the ISS in August 2009, it will carry the Italian-built Multi-Purpose Logistics Module (MPLM) in its cargo bay, bringing equipment and goods to the ISS that will establish and support the full six-person crew capability. Hence the emphasis of the mission is on outfitting and maintenance, including several EVAs (or spacewalks), and not so much on the further assembly of the ISS.

"The next time I enter, it will be a much bigger and livelier Space Station, and I will be greeted by a large international crew and among others, by my ESA colleague Frank De Winne," says Fuglesang, looking forward to his second spaceflight.

2010 missions

The next European long-duration mission has also been confirmed. ESA astronaut Paolo Nespoli, from Italy, has been assigned as Flight Engineer on Expeditions 26 and 27. The launch of his mission is due in November 2010. It will be Nespoli's second mission into space, and it is planned to qualify him for performing EVAs using the Extravehicular Mobility Unit (EMU, or US spacesuit).

In October 2007, he flew on Space Shuttle *Discovery* to deliver the European-built Node-2 to the ISS during the STS-120 mission. Node-2, also known as 'Harmony', is the interconnecting module to which the European Columbus laboratory was attached in February 2008. Nespoli was instrumental in orchestrating four spacewalks from inside the Space Shuttle and the ISS, which were necessary for the further construction of the Station.

> **Keep dreaming. Dreams take you beyond the forefront of science and exploration, and lead us astronauts to expand the frontiers of knowledge.**

Beyond the short-term objectives of his next mission, Nespoli believes it is also important to build for the future. "Wherever we are in the world, holding a conference or addressing youngsters, we astronauts represent our country, our continent, our agency and a culture with certain values," says Nespoli.

"We are also here to show to those enthusiastic young people the validity of trying to be the best you can, to learn as much as you can, to care for our environment and, of course, to keep dreaming. Dreams are what take you beyond the forefront of science and exploration, and lead us astronauts, and therefore humanity, each time to expand the frontiers of human knowledge."

ESA astronaut Roberto Vittori, also from Italy, has resumed his mission specialist training at the NASA Johnson Space

Paolo Nespoli on board the Space Shuttle *Discovery* during the Esperia mission in 2007

Center in Houston in January 2009, and he should perform a Shuttle flight of about 15 days in mid 2010.

Putting the 'International' in ISS

Working within a multicultural team, with individuals who can have different opinions and points of view, is sometimes a challenge. "It requires more work, more attention and more flexibility, but thanks to those different inputs and forces, you're also obtaining a result which would have never come out of a uniform team," says Nespoli.

Considering today's reality, the international cooperation of the ISS is not only a beautiful project, but also a necessity to achieve our common goals. Christer Fuglesang believes that the experience gained with the ISS has one more important aspect with regard to the future exploration of the Solar System.

"Although it has not always been easy, the work done together with all partners, with different cultural and political backgrounds, has nevertheless been outstanding. Over about 15 years, we have learned to work together and overcome differences, and we have mostly found acceptable compromises for all," says Fuglesang.

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Roberto Vittori, now training for another flight

Ambassadors for Europe

An astronaut's space experience is useful, not only for ESA and European space industry, for example, when developing new technologies or preparing for future programmes, but it also helps to raise public awareness. When their missions put them in the public spotlight, astronauts become 'Space Ambassadors'. As such, they are among the best suited for explaining what space exploration is all about.

→

When their missions put them in the public spotlight, astronauts become 'Space Ambassadors'. Here Christer Fuglesang signs autographs for a school visit

The experience of having flown in space and having seen Earth from above fascinates millions of people and helps to open doors to decision-makers. Frank De Winne thinks that our astronauts can also be seen as ambassadors for Europe, bringing our European values to human spaceflight, exploration and space in general.

"All the ISS partners clearly have the same goal and want to work together to achieve great things, but it is also clear that we have different cultures and different backgrounds. It is very important for Europe to be present on the most advanced platform of human exploration of all time, and to be present in the frame of this international cooperation, which will probably lead to further cooperation to go to the Moon and Mars. It is very important to be present from the beginning and to bring our European values to this endeavour," says De Winne.

"One of the values that we bring as Europeans is our diversity. We have managed to overcome our differences in Europe in the last 50 or 60 years, and we have worked through these differences to find a unity in that diversity. Now we strive forward to accomplish shared goals. We are not there to dominate, but more to bring back to Earth the benefits of space exploration. We are a global agency for a global enterprise and we do things in a peaceful way for the entire world."

New generation of ESA astronauts

The upcoming missions of De Winne, Fuglesang and Nespoli demonstrate the increasing role of European astronauts in human spaceflight. But ESA has also taken the steps to ensure that Europe plays a key role in the noble endeavour of human space exploration in the future. In May 2008, the call for the next generation of European astronauts was opened and more than 8000 European citizens responded, many with very impressive applications.

Following rigorous and demanding psychological and medical testing, the most apt and qualified candidates were invited to the final round of interviews with ESA directors and senior managers. It is expected that ESA Director General Jean-Jacques Dordain will nominate at least four new astronauts in May.

The newly selected astronauts will start their basic training at the European Astronaut Centre in Cologne in September this year. On completion of this training, they can be in principle assigned to mission training for the ISS. At least two of the new class of astronauts are expected to make their first spaceflight to the ISS by 2015. However, while the ISS is the near-term goal for ESA's new astronauts, it is assumed that they will play a pivotal role beyond the ISS, when the Moon becomes the next focus of space exploration.

A test bed for the future

The ISS is the first step in a global exploration effort that will eventually take humankind back to the Moon and to more distant destinations. The future exploration of the Solar System will hopefully be based on a similar successful international cooperation.

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King Albert II and Queen Paola of Belgium are guided by Frank De Winne at the European Astronaut Centre, Cologne, Germany

> **"We astronauts represent our country, our continent, our agency and a culture with certain values."**

Today, ESA is looking forward to many years of exciting and multifaceted science on the ISS, using all its unique capabilities. We are moving towards a period of full exploitation of the ISS, during which it will continue to produce the outstanding science for which it was built, while providing European scientists with opportunities for further research in human physiology, biology, physics, astronomy and material sciences.

The experience gained on the ISS will be invaluable for the future exploration of the Solar System. New technologies can be developed and tested in the harsh and demanding environment of space, whether new materials, communications systems or crew support equipment, for example. So far, we have limited operational experience in Europe of developing the latter, but by conducting research on the ISS we have a good opportunity to obtain this experience.

The existing European Astronaut Corps has evolved to acquire significant technical and operational expertise. The new class of astronauts will carry this experience into the future. Europe is now ready to take the next step and to start thinking about developing its own human access to space.

In the future, when we will indeed go to the Moon or to Mars, Europe will continue to demonstrate its technological know-how and operational capabilities, and bring added value as a partner in the international exploration of space. With the commitments already made, ESA has showed determination to be a strong and reliable partner in the international human space exploration effort.

Expanding human presence beyond Earth orbit, to the Moon and later to Mars, will positively and permanently mark humankind, our societies and our citizens. We need to maintain this focus and, at the same time, consider a way to enhance our role and increase our autonomy, both to reinforce partnerships and to better serve European interests. ■

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→ NEWS

In brief

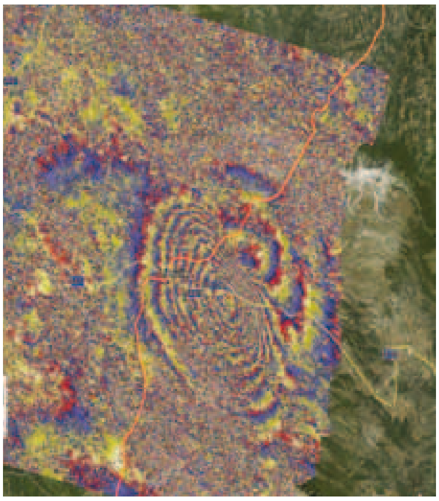
The Herschel telescope during testing at ESA's European Space Research and Technology Centre in the Netherlands. This is a classic Cassegrain design with a 3.5-m primary mirror — the largest ever launched into space. Herschel will provide unprecedented views of the Universe by bridging the gap between previous infrared observatories and ground-based radio telescopes

Satellites see ground move in Italy quake

Scientists studying data from ESA's Envisat and the Italian space agency's COSMO-SkyMed satellites, are analysing the movement of the ground during and after the earthquake that shook the medieval town of L'Aquila in central Italy in April 2009.

Scientists from Italy's Istituto per il Rilevamento Elettromagnetico dell' Ambiente (IREA-CNR) and the Istituto Nazionale di Geofisica e Vulcanologia (INGV) are studying Synthetic Aperture Radar (SAR) data from these satellites to map surface deformations after the earthquake and the numerous aftershocks that followed.

Satellite data provide a unique opportunity to measure fine changes in Earth's surface that are often precursors of an earthquake. Monitoring earthquake-prone regions can assist in the forecasting of earthquakes, as well as in the management and evaluation of earthquake-associated risks. A dataset of SAR products (Envisat and ERS) corresponding to the earthquake of L'Aquila freely available to the scientific community.



Snow maps from space help Arctic reindeer herders

Arctic reindeer herders are having to face the challenges of climate change, as a warmer polar climate makes it harder for herds to find food and navigate.

An ESA-backed initiative, Polar View, is now providing the herders with satellite-based snow maps to help them adapt. The International Centre for Reindeer Husbandry (ICR) has joined forces with Polar View to examine how satellite observations could help by gathering information on snow and snow change in a timely and accurate manner for the vast circumpolar regions.

Anders Oskal, Director of ICR, is working with Sámi reindeer herders in Norway to help them maintain and develop sustainable reindeer husbandry. According to him, Finnmark is the area of Norway that is predicted to experience the largest temperature increases, raising concerns about whether ice layers will form over pastures preventing reindeer from foraging.

"Snow is of paramount importance for reindeer herding because its quality determines whether reindeer are able to access the pastures that lie beneath it for much of the year. Detailed circumpolar snow information is, thus, becoming increasingly important following the recent changes in the Arctic climate," said Oskal.

Under the Polar View initiative, Kongsberg Satellite Services (KSAT) have been providing snow melt maps for Norway and Sweden and Eurasia snow cover maps for the last 18 months. Services are provided in partnership with the Northern Research Institute, the Norwegian Computing Centre and the Finnish Meteorological Institute.

"The experience so far has definitely been positive, and the reindeer herders are extremely interested in the future

utilisation of Polar View products that can relate important information about local snow conditions," said Oskal.

Polar View is supported by ESA and the European Commission (EC) with participation from the Canadian Space Agency. It was established under the Global Monitoring for Environment and Security (GMES) programme – a joint initiative between ESA and the EC to combine all available space- and ground-based information sources to develop an independent European environmental monitoring capacity from planetary to local scales.

Herschel and Planck launched

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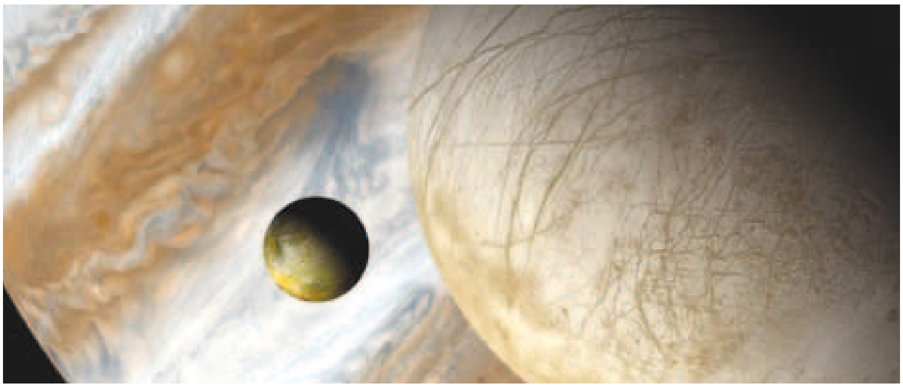
Two of the most ambitious space missions ever attempted got off to a successful start with the dual launch of ESA's Herschel and Planck from Europe's Spaceport in French Guiana. Both of these highly sophisticated spacecraft were lofted into space on an Ariane 5 ECA vehicle at 13:12 UTC (15:12 CEST) on 14 May 2009. Almost 26 minutes later, and about two minutes from each other, they were released separately on escape trajectories toward a virtual point in space, called L2, some 1.5 million kilometres from Earth in the opposite direction to the Sun

Outer planet missions prioritised

NASA and ESA have decided to pursue a mission to study Jupiter and its four largest moons, and plan for another mission to visit Saturn's largest moon, Titan, and Enceladus.



The proposed projects are grand endeavours that set the stage for future planetary science research. These outer-planet flagship missions could eventually answer questions about how our Solar System formed and whether habitable conditions exist elsewhere in the Solar System.

In 2007, ESA initiated a competition to select a flagship mission for the Cosmic Vision 2015-2025 programme. Two missions, called Laplace and Tandem, were selected for further study. Laplace was proposed as a set of spacecraft to orbit Jupiter and possibly land on Europa. Tandem was proposed as a set of spacecraft to orbit Titan and explore its surface, after exploring the surface of another moon of Saturn, Enceladus.

NASA also studied some mission concepts during 2007, which were narrowed down to two proposals in 2008. One finalist was the Europa orbiter. to explore the icy moon of Jupiter. The other was a Titan orbiter to revisit Saturn's moon.

At a meeting in Washington in February, NASA and ESA officials decided to merge the separate NASA and ESA mission concepts, now called the Europa Jupiter System Mission and the Titan Saturn System Mission.

Based on studies and stringent independent assessment reviews, the US Europa Jupiter System Mission (called Laplace in Europe) was the most feasible to implement first. However, ESA's Solar System Working Group concluded that the scientific merits of both missions could not be separated. It was agreed that both missions should move forward for further study and implementation.

"The decision means a win-win situation for all parties," said Ed Weiler, Associate Administrator for NASA's Science Mission Directorate. "Although the Jupiter system mission has been chosen to proceed earlier, a Saturn system mission clearly remains a high priority for the science community."

"This joint endeavour is a wonderful new exploration challenge and will be a landmark of 21st century planetary science," said David Southwood, ESA Director of Science and Robotic Exploration.

Keeping an eye on Etna

Using data from ESA's ERS-1, ERS-2 and Envisat satellites, scientists have for the first time been able to monitor the long-term behaviour of Mount Etna, Europe's highest and most active volcano.

Synthetic Aperture Radar (SAR) images acquired by these satellites from 1992 to 2006 are providing crucial information for understanding how the volcano's surface deforms during the rise, storage and eruption of magma.

Scientists from the Istituto per il Rilevamento Elettromagnetico dell' Ambiente (IREA-CNR) in Naples, Italy, have been able to determine the deformation of Etna's surface to within centimetres over a long period.

The results of the study show how surface deformation relates to eruptive behaviour over a time span much larger than that of a single eruption. The continuity of satellite data is essential for studying and possibly predicting future volcanic eruptions.

Second ATV named *Johannes Kepler*

ESA's second Automated Transfer Vehicle (ATV) has been named Johannes Kepler after the German astronomer and mathematician. Europe's next unmanned logistics spacecraft is scheduled for launch to the International Space Station in mid-2010.

Johannes Kepler (1571-1630) was a German astronomer and mathematician who is best known for discovering the laws of planetary motion. Kepler's work contributed greatly to the scientific and technical progress of Europe and enabled space exploration today.

This year is the 400th anniversary of the publication of one of Kepler's most influential works, *Astronomia* Nova. The choice of this key figure in astronomy is particularly fitting in 2009, the International Year of Astronomy.

ATV *Johannes Kepler* is currently under production at EADS Astrium in Bremen, Germany.

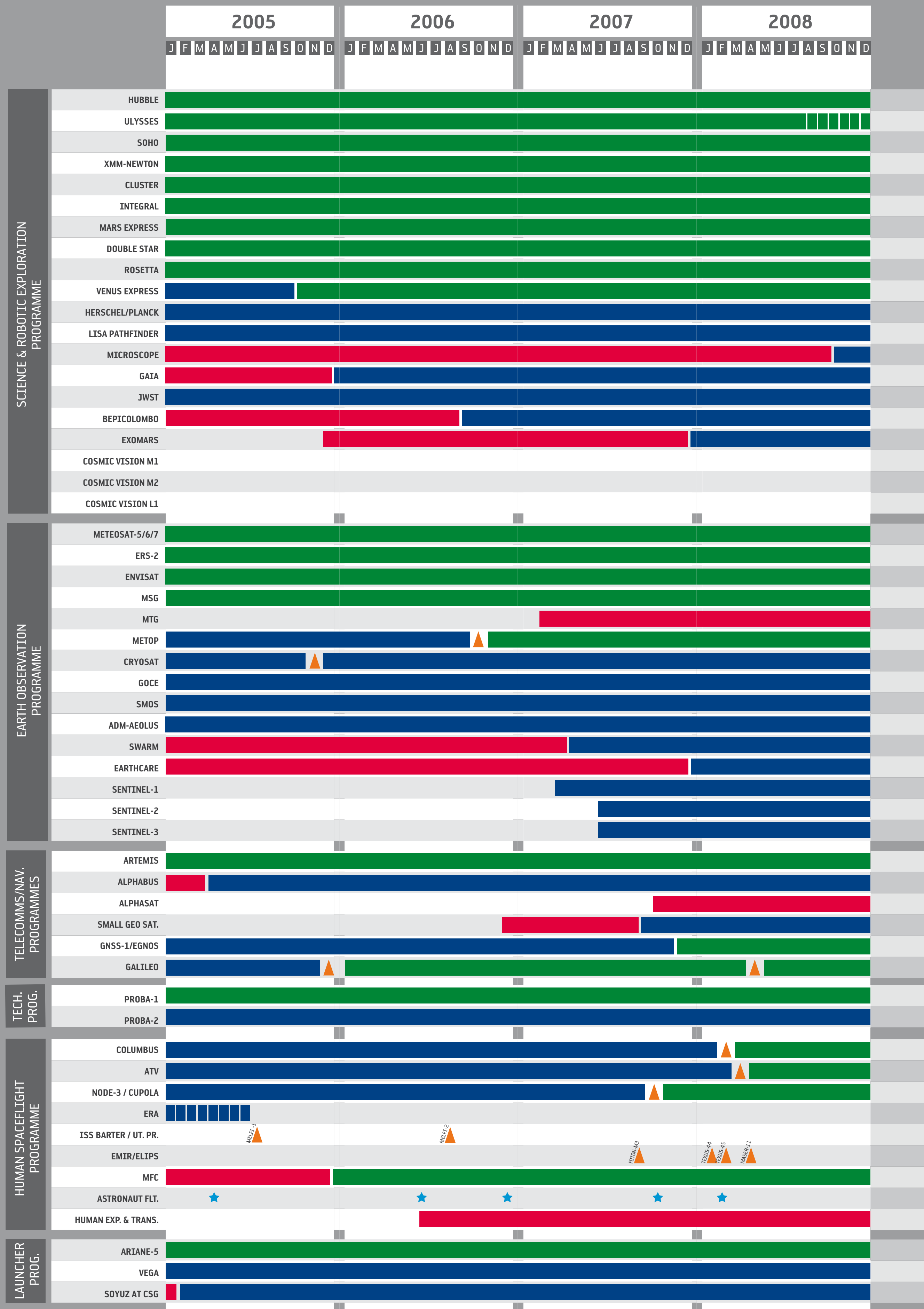
↑ Artist impression of ATV (Astrium)

US president talks with ISS crew

↑ President Barack Obama is joined by school children and Senator Bill Nelson, right, as he talks with astronauts on the ISS from the White House, Washington, on 24 March (P. Souza)

→ PROGRAMMES IN PROGRESS

status at end March 2009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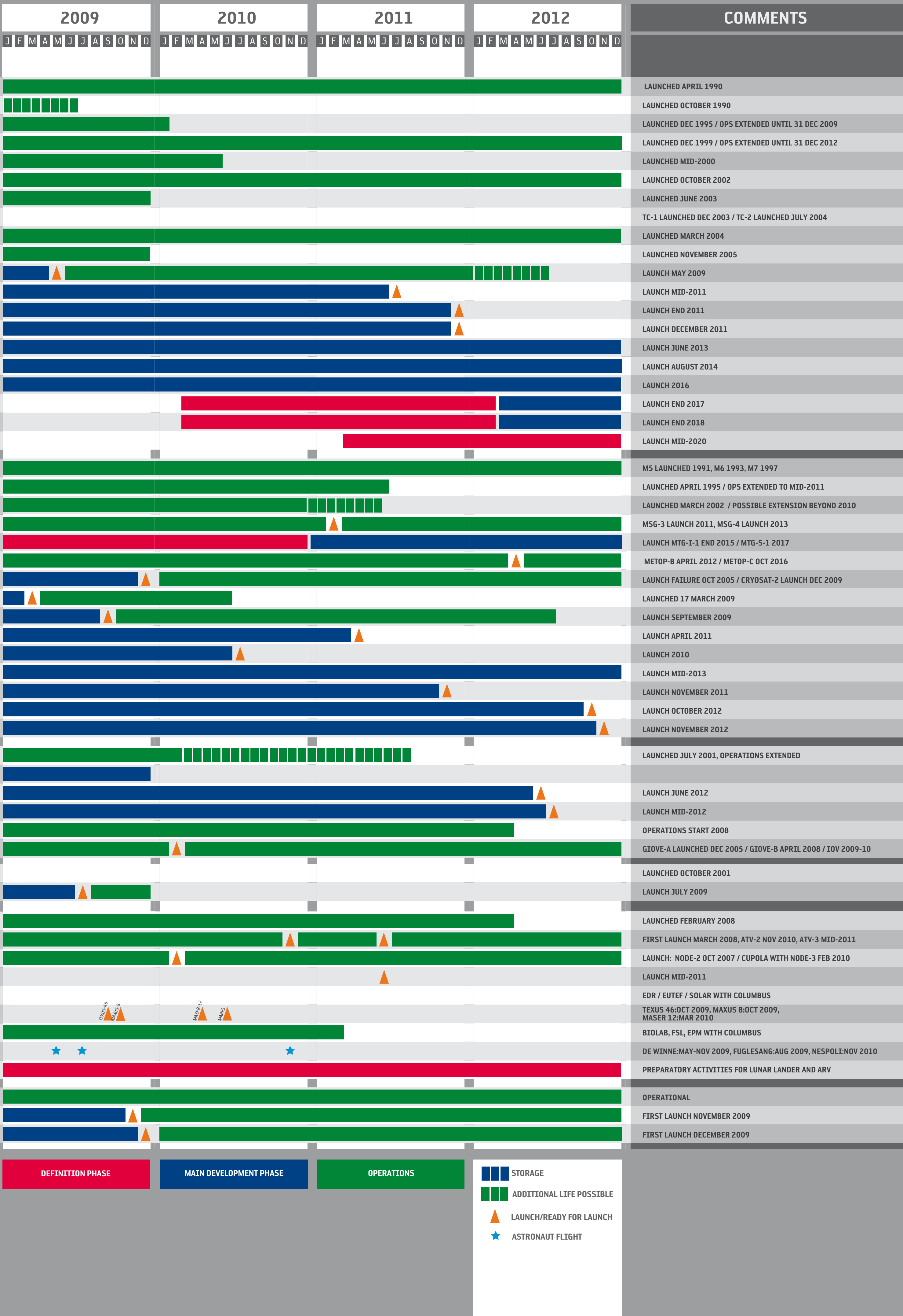
VENUS EXPRESS
HERSCHEL/PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
EXOMARS
COSMIC VISION M1
COSMIC VISION M2
COSMIC VISION L1
EARTH OBSERVATION PROGRAMME
METEOSAT-5/6/7
ERS-2
ENVISAT
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
ADM-AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
TELECOMMS/NAV. PROGRAMMES
ARTEMIS
ALPHABUS
ALPHASAT
SMALL GEO SAT.
GNSS-1/EGNOS
GALILEO
TECH. PROG.
PROBA-1
PROBA-2
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
ATV
NODE-3 / CUPOLA
ERA
ISS BARTER / UT. PR.
MELFI-1
MELFI-2
EMIR/ELIPS
FOTON-M3
TEXUS-44
TEXUS-45
MASER-11
MFC
ASTRONAUT FLT.
HUMAN EXP. & TRANS.
LAUNCHER PROG.
ARIANE-5
VEGA
SOYUZ AT CSG



2009
2010
2011
2012
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
LAUNCHED JUNE 2003
TC-1 LAUNCHED DEC 2003 / TC-2 LAUNCHED JULY 2004
LAUNCHED MARCH 2004
LAUNCHED NOVEMBER 2005
LAUNCH MAY 2009
LAUNCH MID-2011
LAUNCH END 2011
LAUNCH DECEMBER 2011
LAUNCH JUNE 2013
LAUNCH AUGUST 2014
LAUNCH 2016
LAUNCH END 2017
LAUNCH END 2018
LAUNCH MID-2020
M5 LAUNCHED 1991, M6 1993, M7 1997
LAUNCHED APRIL 1995 / OPS EXTENDED TO MID-2011
LAUNCHED MARCH 2002 / POSSIBLE EXTENSION BEYOND 2010
MSG-3 LAUNCH 2011, MSG-4 LAUNCH 2013
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 DEC 2009
LAUNCHED 17 MARCH 2009
LAUNCH SEPTEMBER 2009
LAUNCH APRIL 2011
LAUNCH 2010
LAUNCH MID-2013
LAUNCH NOVEMBER 2011
LAUNCH OCTOBER 2012
LAUNCH NOVEMBER 2012
LAUNCHED JULY 2001, OPERATIONS EXTENDED
LAUNCH JUNE 2012
LAUNCH MID-2012
OPERATIONS START 2008
GIOVE-A LAUNCHED DEC 2005 / GIOVE-B APRIL 2008 / IOV 2009-10
LAUNCHED OCTOBER 2001
LAUNCH JULY 2009
LAUNCHED FEBRUARY 2008
FIRST LAUNCH MARCH 2008, ATV-2 NOV 2010, ATV-3 MID-2011
LAUNCH: NODE-2 OCT 2007 / CUPOLA WITH NODE-3 FEB 2010
LAUNCH MID-2011
EDR / EUTEF / SOLAR WITH COLUMBUS
TEXUS-46
MAXUS-8
MASER-12
MAXES
TEXUS 46:OCT 2009, MAXUS 8:OCT 2009,
MASER 12:MAR 2010
BIOLAB, FSL, EPM WITH COLUMBUS
DE WINNE:MAY-NOV 2009, FUGLESANG:AUG 2009, NESPOLI:NOV 2010
PREPARATORY ACTIVITIES FOR LUNAR LANDER AND ARV
OPERATIONAL
FIRST LAUNCH NOVEMBER 2009
FIRST LAUNCH DECEMBER 2009
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

→ HUBBLE SPACE TELESCOPE

Preparations continue for Servicing Mission 4, with a planned launch date confirmed for 12 May 2009. Space Shuttle Atlantis' 11-day flight, designated STS-125, will include five spacewalks to refurbish and upgrade the telescope with state-of-the-art science instruments. As a result, Hubble's capabilities will be expanded and its operational lifespan extended through at least 2014.

→ ULYSSES

After a short period earlier in the year when the downlink was sufficient to support limited playback of recorded data, the mission is once again in 'real-time only' mode. Nevertheless, and until decommissioning, the spacecraft continues to return useful science data. These data are proving very useful in the study of long-term variations in cosmic-ray transportation in the heliosphere, in particular the Anomalous Cosmic Ray (ACR) component.

ACRs are believed to originate as neutral interstellar gas atoms that become ionised in the heliosphere, picked up by the magnetic field of the solar wind, and accelerated at or near the boundary of the heliosphere. The change in ACR intensity with radius and latitude is a sensitive indicator of the importance of drift motions in the global heliospheric magnetic field and other factors affecting the motion of these particles.

Significant differences were found between the latitudinal variation measured in the present solar cycle minimum by instruments on Ulysses and that measured 22 years ago on the Voyager spacecraft when the Sun's magnetic field had the same polarity. This difference is possibly related to the unusually long period of little or no magnetic activity on the Sun during the current solar minimum, and the associated state of the Sun's magnetic field.

Image of the starburst galaxy Messier 82 (M82) taken by the Optical Mirror and European Photon Imaging Camera instruments on XMM-Newton, obtained as part of International Year of Astronomy 2009 activities

→ SOHO

The SOHO web site now features a 'Movie Theatre' that allows users to instantly create and view movies from all SOHO imaging instruments (EIT, LASCO and MDI) for the whole mission, with freely selectable start and end dates and flexible viewing options.

SOHO participated in a 24-hour webcast, part of the International Year of Astronomy 2009's cornerstone project, '100 Hours of Astronomy'. (www.100hoursofastronomy.org)

→ XMM-NEWTON

Operations continue using the new antenna-switching concept (see *Bulletin 137*) with the spacecraft, instruments and ground segment all performing nominally. The observing efficiency is unchanged compared to before the loss-of-contact anomaly in October 2008.

→ CLUSTER

Cluster continues to reveal new aspects of space plasma physics and the interaction of the Sun and Earth. One recent study used data from all four Cluster satellites and revealed, for the first time, how turbulence develops in space just outside Earth's magnetic environment. This result improves the understanding of turbulence, a key physical process by which energy throughout the Universe is transported from large scales at which it is input, to small scales where it is dissipated.

In another study, data from Cluster and the Double Star spacecraft were used to examine the dynamics of Earth's magnetic environment, the magnetosphere, under the influence of extreme solar activity. Details of the effects of a coronal mass ejection impact on Earth's magnetosphere were presented, including the subsequent dynamic reaction of the radiation belts and monitoring of highly penetrating solar energetic particles.

→ DOUBLE STAR

Contact with Double Star TC2 has still not been re-established. The Chinese operations teams are still regularly trying to contact the spacecraft. Commanding of the European instruments (PEACE and FGM) via the operations centre, EPOS at RAL, has ceased until the recovery of the spacecraft.

→ INTEGRAL

Integral operations continue with the spacecraft, instruments and ground segment all performing nominally. The Integral IBIS imager has been used to measure the polarisation of the prompt gamma-ray emission of the long and bright gamma-ray burst GRB 041219A in the 200–800 keV energy range. A variable degree of polarisation was found ranging from less than 4% over the first peak to 43% for the whole second peak. Time-resolved analysis of both peaks indicates a high degree of polarisation, and the null average in the first peak can be explained by the rapid variations observed in the polarisation angle and degree. The results are consistent with different models for the prompt emission of gamma-ray bursts at these energies, but they favour synchrotron radiation from a relativistic outflow with a magnetic field that is coherent on an angular size comparable to that of the emitting region.

→ MARS EXPRESS

Mars Express, which passed through the longest eclipse (49 minutes) of the spring 2009 eclipse season on 8 March 2009, is in an excellent state of health and all subsystems are operating normally. During the last few months, the pericentre was located over the high southern latitudes with reasonable good illumination conditions for the remote sensing instruments. A recent Mars Express image showed the edge of the martian polar cap, in a region called Rupes Tenuis. It is important to study the polar caps, since they contain the largest known water reservoir on Mars.

A recent study on the evolution of the Martian atmosphere shows, through the use of ASPERA data, that a rapid loss of the primary (and primordial) atmosphere due to atmospheric escape processes is required in the first 2000 million years of Martian history in order to obtain the present-day atmosphere.

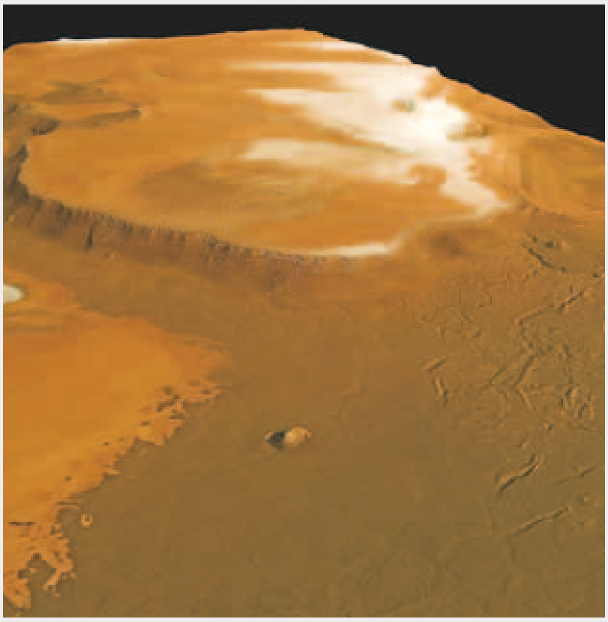
The MARSIS team has demonstrated a simple and accurate technique for measuring the magnetic field around Mars using the ionospheric sounder on Mars Express, which has no onboard magnetometer. Knowledge of the magnetic field is a crucial element in the understanding of the space environment near Mars.

→ ROSETTA

After the flyby of asteroid (2867) Steins, the first results of the detailed data evaluation were already reported at various conferences, confirming an excellent scientific outcome. The surface temperature of the asteroid was found by VIRTIS to vary between −90°C and −30°C. Steins was predicted to be a member of the rare highly evolved E-type asteroids, an assumption that was fully confirmed by the images and spectra taken at optical and infrared wavelengths. This flyby was the first (and might remain the only) spacecraft encounter with this rare compositional type of asteroid.

Ground-based observers had determined that the surface of such asteroids might contain large amounts of 'enstatite', a mineral that is only produced by very high temperatures and melting indicating that (2867) Steins must have been a part of a much larger differentiated body. Images of the asteroid taken by OSIRIS through different colour filters make it possible to see how the surface composition may vary and provide clues to the history and evolution of the surface of this ancient, highly processed body.

Directly after the flyby, stereo observations of gravitational 'micro-lensing' events were obtained by observing in parallel with Rosetta's OSIRIS camera and telescopes on Earth. Seven slots were allotted to these measurements and about 50 images were obtained near the galactic centre. Events were detected and compared to ground-based observations. The analysis is still ongoing.



The snow-laden region of Rupes Tenuis at the martian north pole, as seen by the High Resolution Stereo Camera on Mars Express, in July 2008 (ESA/DLR/FU Berlin)

The spacecraft has spent 10 weeks in the active cruise phase, first dedicated to the download of remaining scientific data from the asteroid flyby phase and then executing remaining payload checkouts (PC8) and investigations linked to anomalies recorded during the asteroid flyby phase. On 17 December 2008 Rosetta entered the conjunction phase, for which the angular separation between Earth and the Sun as seen from the spacecraft will stay below 3 degrees (conjunction) until 6 January 2009 with the minimum (1.65 degrees) on the 27 December 2008. No special activities were planned for this phase.

→ VENUS EXPRESS

After three years in orbit, the observations of Venus continue with all instruments. The southern hemisphere was so far a major target for several of the instruments, but emphasis of observation is increasing on the north polar and middle latitudes. After some problems in one of the three VIRTIS channels, the intensity of operations by the VIRTIS high-spectral resolution channel and the UV/visible channel have increased. The coverage of thermal profiles of the atmosphere based on stellar and solar occultation measurements by SpicaV and radio occultation measurements by VeRa have been improved and corresponding maps have been generated.

An in-depth analysis of data gathered during the pericentre altitude reduction activity in the second half of 2008 has shown that a very small but measurable drag effect can indeed be seen and corresponding density profiles down to an altitude of 185 km have been constructed. These *in situ* measurements are very valuable additions to the remote measurements gathered by the original remote sensing instruments on board, and they will be important for the construction of a new global model of the venusian atmosphere. Such a model will be needed if, at a later stage in the mission, the orbit will need to be changed by 'aerobraking' (where the pericentre altitude is reduced so that atmospheric drag reduces the spacecraft velocity and thereby the apocentre altitude). More data of this kind will be gathered during additional campaigns later in 2009 and 2010.

In March, the spacecraft (and Venus) passed between Earth and the Sun, at the 'inferior conjunction', for the second time during the mission. Special mission operations have ensured that this event has passed without problems. The mission is currently funded for operation until the end of 2009, and an extension until the end of 2012 is under consideration.

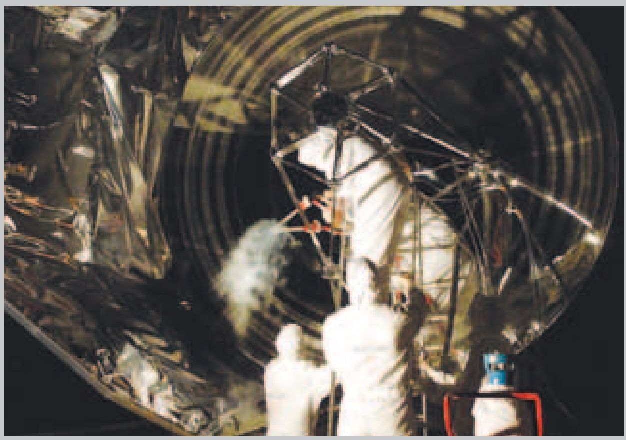
→ AKARI

Akari continues routine operations in its post-helium phase. By March 2009, 342 European observations had been executed. Processed data, reduction software and documentation were recently released. Scientific results from the mission were discussed in the conference 'AKARI, a light to illuminate the misty Universe', held at the University of Tokyo in February, which was attended by 140 participants, around a fifth of whom were from Europe.

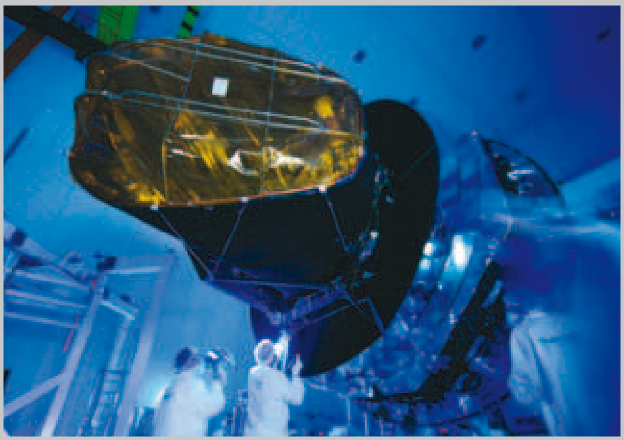
→ HERSCHEL/PLANCK

Both spacecraft were shipped to the launch site in February 2009 and the launch campaign is progressing nominally for a launch in mid May 2009.

After completion of final functional tests in January, Herschel was released for shipment to Kourou. The spacecraft, with the helium tank in the cryostat half-filled, was transported by



At Kourou, Herschel's primary mirror is cleaned using dry ice (ESA/Astrium)



In the S1B Cleanroom at Kourou, Planck's surface is inspected using UV light to detect dust particles

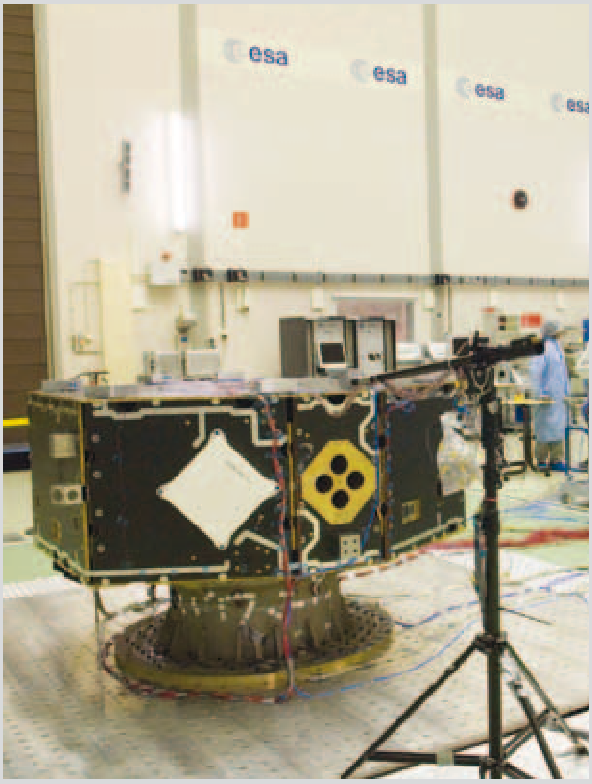
Planck and Herschel launch campaign teams at the Centre Spatial Guyanais, Kourou, French Guiana

air from Amsterdam to Cayenne, French Guiana, in February. After arrival, a final cleaning of the Herschel telescope was performed. Post-transport functional integrity tests and some system integration tests were carried out in parallel with the alignment verification and the refill of the cryostat with helium. At the end of March, the spacecraft was transferred to the S5B cleanroom for propellant fuelling activities.

Similarly for Planck, final verification activities, mainly functional tests, were completed in January before release for shipment was given. The spacecraft was shipped to Kourou one week after Herschel. Post-transport functional testing was carried out in the same cleanroom as Herschel, with overall verification and alignment activities. The HFI dilution cooler tanks have been filled with helium-4 (3 tanks) and helium-3 (1 tank) respectively, the final charge for flight, and the telescope baffle, telescope and the V-groove shields were cleaned. The spacecraft was ready at the end of March for hydrazine fuelling.

→ LISA PATHFINDER

The LISA Pathfinder industrial team has been working to the completion of actions raised from the system Critical Design Review (CDR). The main topics were the software requirements consolidation, the onboard computing load and the allocation of resources to the Real-time Test Bench



LISA Pathfinder science module during structural testing, on 'shaker' at ESTEC, Noordwijk

(RTB) verification. For the close-out review, the Board will meet in early May.

On the testing side, the science module Flight Model has completed its structural tests. The propulsion module Flight Model structure has been tested to acoustic, separation and shock tests in ESTEC and is now ready for static test in IABG. The verification of the onboard software is continuing on the Software Verification Facility and on the two parallel RTBs at Astrium Ltd (UK) for the attitude control and power aspects, and at Astrium GmbH (D) for the drag-free attitude control.

Nearly all the slit caesium thruster micropropulsion CDRs have been held at subsystem level. The FEEP Cluster Assembly CDR close-out will be held soon.

The LISA Pathfinder American payload DRS is awaiting shipping to Europe. The various Electrical Model (ELM) units of the European payload (LTP) have been delivered to Astrium GmbH for the Real-time Test Bench. The electronic Flight Model units delivery has been delayed and will only be delivered by mid 2009. Launch is not expected to take place before mid 2011.

→ MICROSCOPE

Phase C of the T-SAGE payload is progressing on schedule at ONERA. ONERA has run the levitation test of both proof masses of the EM model of the T-SAGE sensor unit with the EM flight electronics (FEEU-EM) driving the sensor, verifying six-axis control.

CNES has decided to proceed with the phase B1 of the cold-gas propulsion system activities with Thales Alenia Space, to study an alternative to the FEEP-based concept. The main concern of Microscope linked to the micro-perturbations induced by the moving masses will be studied in detail during this phase and tested by CNES. These test activities are planned in May/June this year.

→ GAIA

Production of flight hardware continued as planned and several flight panels of the mechanical structure within the Service Module have already been delivered to Astrium Ltd to commence the integration of the Chemical Propulsion System to be followed by the Micro Propulsion System. The Qualification Model of the 10-m diameter sunshield is nearing completion. This model, a quarter of the entire sunshield, will be deployed in Europe's largest thermal vacuum chamber at ESTEC in early summer 2009.

A number of engineering models of electrical subsystems as well as an advanced version of the central software have been delivered to the avionics test bench for electrical testing. In parallel, the assembly of the test set-up of the Focal Plane Assembly is progressing by taking deliveries of the necessary detectors, amplifiers and data processing units in Toulouse (F).

The production and testing of the individual elements of the torus are progressing as planned and 13 out of 17 have passed post-production review and associated proof load testing. Some of the smaller flight mirrors have already completed their polishing phase and await final silver coating. The big flight and test-mirrors are still in the year-long polishing process.

Project-related working groups, involving DPAC and industry representatives, have held further meetings to coordinate activities in their respective areas, for instance CCD radiation testing and evaluation, ground segment engineering and the preparation of the ground- and in orbit calibration activities.

→ JAMES WEBB SPACE TELESCOPE

Two JWST Primary Mirror segments have completed the first cryogenic cycle test. Another four have been assembled and are being tested at ambient condition. The initial mechanical design and analysis of the radiative shield outside the MIRI Optical Assembly was completed, leading to its Conceptual Design Review in mid-May.

The Near Infrared Spectrograph (NIRSpec) development model passed its mechanical testing and is now ready to start the cryogenic campaign. Following the instrument-level Critical Design Review (CDR), the integration of the instrument Flight Model has started with the first sub-assemblies being integrated on the optical bench. The development of the cryogenic mechanisms remains critical for both ESA and NASA deliveries.

The Mid Infrared Instrument (MIRI) flight model assemblies are nearing completion. The flight Spectrograph Main Optics (SMO) has been delivered to the Rutherford Appleton Laboratory (RAL) in UK and delta qualification review passed. The flight Instrument Control Electronics (ICE) box has completed its test campaign and is now undergoing its final bake-out. The flight Filter Wheel Mechanism also completed its functional test and is being instrumented and mounted on the vibration adaptor. The Focal Plane Modules have been released for integration into the Focal Plane System. The design changes in the control electronics, due to a heater short-circuit problem, are now being implemented. This is now driving the Focal Plane System delivery to Europe.

→ BEPICOLOMBO

The design baseline for the Preliminary Design Review (PDR) was completed. The PDR data package was delivered and the kick-off presentations, providing the overall project and design status, were conducted with the Board and review team. The SPC Tracking Committee also attended the kick-off meeting. The Board provided guidance to the review team and made recommendations for work during the review process, in particular on the critical mass status, the solar array, the assembly integration and test, and the software and attitude control development schedule. The review should be concluded by the end of May.

Testing on several solar cell assembly configurations continue at high ultraviolet radiation levels and temperatures (200°C and 230°C). Performance degradation results so far are within expectations, as assumed for the solar array design baseline. The equipment procurement phase is continuing with about half of the equipment suppliers selected and ITTs for another third being issued and/or under evaluation.

The remaining Instrument Preliminary Design Review (IPDR) was completed, demonstrating an adequate payload definition status and compliance with spacecraft interfaces. Payload resource allocations have been adjusted according to the IPDR results.

The launcher coupled load analysis confirmed the acceptable environment for the Mercury Magnetospheric Orbiter (MMO). At JAXA, the MMO Structural and Thermal Model tests are being prepared and tests of the MMO electrical model are continuing. The onboard software requirements review was completed.

→ EXOMARS

Participating states decided not to fund the full Enhanced ExoMars mission at the ESA Ministerial Council 2008 due to financial limitations in some of the leading participant states. A Phase B2 Extension from April 2009 to March 2010 was agreed for injection in the programme to reform the mission. The first quarter of 2009 was dedicated to the reformation of the ExoMars mission.

January opened with the first formal meeting with NASA at JPL as a potential partner for international cooperation to discuss potential contribution elements. These efforts carried on throughout the quarter with positive indications on international cooperation between ESA and NASA in the frame of a much broader multi-mission programme with a series of shared missions to be launched in 2016 (the new ExoMars launch date), 2018 and 2020. The cooperation is focused on a NASA-provided launcher and Radioisotope Heater Units, and a rescoping of the ExoMars Carrier Module to become a cooperative orbiter mission including science instruments.

There is also discussion for potential cooperation with the Russians through Roscosmos, for a back-up launcher, communications support for the Russian Phobos-Grunt mission and science cooperation. The formalisation and ratification of agreements with international partners has yet to be done and is expected to be undertaken in the next reporting period. In parallel, discussions with industry were initiated to identify cost reductions through design changes, usually associated with descoping of the mission objectives, and to try to find a more efficient industrial structure wherever possible.

On the technical side, the Interim Preliminary Design Review was held with the Board meeting on 18 March. This review was oriented to assure the work performed during the original Phase B2 in 2008 was complete and correct, even though it was understood that the mission was in a state of change at the time. The Board declared its satisfaction that in general the project definition is appropriate for a PDR. A System Preliminary Design Review will be held at the end of the Phase B2 Extension in early 2010.

The payload of ExoMars, consisting of 23 instruments, was also reviewed in light of the general mass increases experienced during 2008. The Payload Confirmation Review (PCR) 2, which was a step beyond the original PCR held in 2007, took place in February and March. The revised payload complement will enter the ExoMars reformation process after it has been ratified in May. The reformed mission scenario will be provided to industry for their work during the Phase B2 Extension.

→ ALPHABUS/ALPHASAT

The Alphabus Large Platform Programme encompasses:

- the development in cooperation between ESA and CNES of the generic Alphabus product line for large telecommunication satellites;
- the provision by ESA of a first Alphabus service module, to be used on a commercial satellite, Alphasat;
- the provision by ESA of Technology Demonstration Payloads to be flown on Alphasat;
- the Alphabus Extension to address the very high-power end of the communication satellite market;
- the Alphasat Ground and User Segment and Applications development.

Service Module

The industrial team is progressing well with subcontractors gearing up to complete their unit qualification campaigns and flight model acceptance. Already, key flight model hardware deliveries have taken place in the last months. The central tube (CASA, E) and the internal deck (Oerlikon, CH) has been delivered for start of the assembly of the flight model structure in Thales Alenia Space in Cannes. Progress has been made on the propellant tanks (MT Aerospace, D) and the Qualification Model has now completed its mechanical qualification. In Toulouse, Astrium has received the flight model harness that is now integrated on a mock-up of the

Alphabus central tube Protoflight Model during manufacture (CASA)

spacecraft structure. This will allow the pre-integration of flight model avionics, in advance of the completion of the flight structural items.

Repeater Module

The north/south large repeater module panels are in the final stages of production, together with all the heat pipes necessary for thermal control of the satellite. All this hardware will be sent later to Thales Alenia Space Italy for integration into two half Repeater Modules, fully equipped with all thermal hardware. Preparations are being made in Turin for procurement of all necessary toolings and review and approval of all the necessary processes to be used.

Inmarsat payload

The Inmarsat extended L-band payload will support advanced geomobile communications and augment Inmarsat's Broadband Global Area Network (BGAN) service with its coverage centred over Africa and providing additional coverage to Europe, the Middle East and parts of Asia.

Following the system-level payload Preliminary Design Review (PDR) at the end of 2008, the activities have concentrated on the finalisation of the accommodation of the payload in the Repeater Module and PDRs at unit level. The large deployable antenna has passed successfully its Critical Design Review.

Technology demonstration payloads (TDPs)

TDP1: Advanced Laser Communication Terminal to demonstrate geostationary to low Earth orbit communication links (supplied as customer-furnished item by DLR);
TDP5: a QV-band communications experiment to assess the feasibility of these bands for future commercial applications;
TDP6: Advanced Star Tracker with active pixel detector;
TDP8: Environment effects facility to monitor the geostationary radiation environment and its effects on electronic components and sensors.

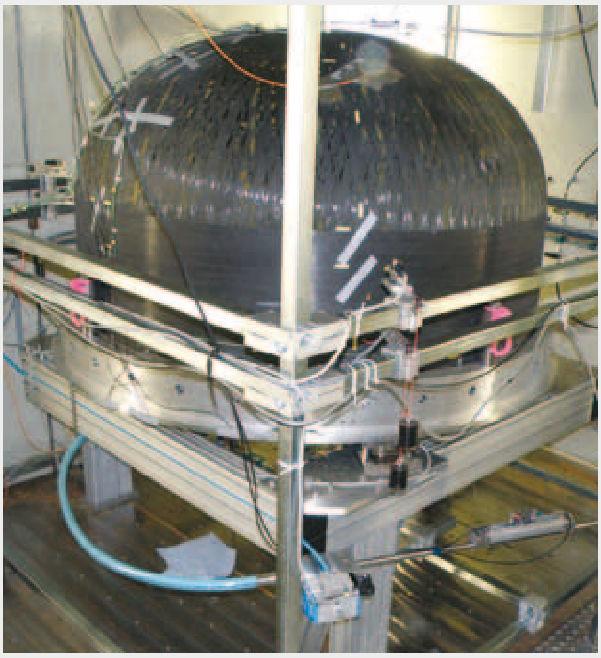
Work has concentrated on the finalisation of the accommodation on Alphasat and the detailed review and agreement on inserts locations to release external satellite panels. The functional User Requirements Documents, required by the satellite software development team, are agreed by all parties. For TDP8, a special redesign effort has been initiated with the objective to produce and test a breadboard model by mid-2009.

Alphabus extension

The Alphabus extension programme is to address the very high-power end of communication satellite market. A preliminary workplan is being submitted to JCB Programme Board in May presenting the Alphabus extension activities with different levels of priorities, in line with the available funding.

User segment

The Alphasat User Segment and Application programme aims to develop new services with enhanced performances, and



Alphabus large propellant tank Qualification Model during proof-testing (MT Aerospace)

ESA photographer Stephane Corvaja captured this view of GOCE just after lift-off on 17 March

will allow for the provision of value-added applications to mobile institutional and public users on a pan-European scale. The initial activity foreseen in the 2009 workplan covers the feasibility analyses, early design, prototyping and preliminary performance validation required to formulate requirements for the different product and service developments. Proposals for Phase 1 of the first two activities are expected in May.

→ GOCE

After a 24-hour postponement, GOCE was launched into a 283.25 km altitude Sun-synchronous orbit at 15:21 CET on 17 March 2009. Three days later, the launch and early orbit phase was completed with the satellite in Fine Pointing Mode. Since then, the satellite and ground segment commissioning operations were progressing nominally. All systems are working and there were no failures on board.

The satellite had remained stored in its transport container at Plesetsk until mid-February, awaiting the completion of the upgrade of the power supply unit of the Breeze-KM upper-stage gyro assembly. After resuming the launch campaign, inspection of the satellite, especially the thorough inspection of the solar cells, did not reveal any degradation.

At the end of February, both satellite and launcher had reached the readiness stage to start the mating operations of the satellite and the launch vehicle upper stage. The mating operations were completed when closure of the fairing took place. Subsequently, the assembled launcher third stage, satellite and fairing were transported to the launch pad and mated with the first and second stages, followed by a final series of electrical checks. Readiness for launch was achieved as planned on the 15 March.

The following day, all the steps preceding the launch were performed nominally until L–10 minutes when the command to start the operations necessary to move away the service tower was issued. Due to the failure of an electromechanical relay, the hydraulic motor that opens the service tower doors did not operate and the launch was aborted less than two minutes before lift-off. The problem was corrected within a few hours and the launch sequence was successfully repeated the day after.

The Payload Data Ground Segment received science telemetry and processed the first Level 0 products within 24 hours after launch, and the first Level 1b product one day later. At present, telemetry is routinely received, Level 1b products are systematically generated and distributed to the High-Level Processing Facility responsible for the Level 2 processing and to the Calibration and Monitoring Facility.

→ CRYOSAT

After six months in storage at IABG (D), CryoSat-2 was removed from its container for resuming tests. Most of the equipment that had been removed for repair work has been replaced, with remaining items ready for shipping to IABG. In parallel the qualification of the onboard software is near completion. The interface with the launch vehicle was refined and a test adapter is ready to be shipped to IABG for a fit-check and a test of the separation system. The ground segment upgrade (from the original CryoSat configuration) is almost complete and an exhaustive series of tests is concluding.

→ SMOS

The satellite remained in storage at Thales Alenia Space, Cannes (F). The flight operations ground segment is ready, with procedures being exercised for operator training purposes for the launch and early orbit phase and routine operations. The final version of the data processing ground segment is planned for May 2009. The launcher authority Eurockot announced a launch delay of a Russian satellite, which had a direct impact on the SMOS/Proba-2 launch, now scheduled for 9 September 2009, pending confirmation by Russian authorities.

→ ADM-AEOLUS

In functional tests, the ALADIN engineering model laser accumulated about 26 hours of operation in vacuum and at reduced pressure (0.02 mbar), respectively. During these tests, the laser showed good beam stability in line with predictions. An observed energy loss in vacuum could be tracked to laser-induced contamination on some optical components in the ultraviolet section of the laser. This effect was limited to 'old' optics that had not been refurbished to the final flight configuration. The new upgraded optics were not affected, however, additional risk-reduction measures will be implemented to further reduce the risks of laser-induced contamination, in preparation for a new vacuum test sequence foreseen for June 2009.

Formal tests at platform level have continued. A major project milestone was achieved by the completion of the first System Validation Test, in which ESOC remotely controlled and operated the Aeolus platform for the first time. The completion of the nominal platform programme is expected in autumn 2009.

→ SWARM

The Critical Design Reviews (CDRs) at mission and satellite level were completed and manufacturing activities started for the flight models at unit level. The engineering model of the accelerometer instrument, and its locking mechanisms for the proof mass, underwent environmental tests. The Absolute Scalar Magnetometer performance functional and environmental tests were completed on the engineering qualification model to verify the suitability of the design, secure the development schedule and reduce the risks on the Proto Flight Model.

A peer advisory group of instrument specialists met at ESTEC for the Electrical Field Instrument and provided their recommendations on performances, characterisation tools, measurement accuracy, in-orbit validation methods (incoherent scattering radars, models), in-orbit validation accuracy and geophysical performance accuracy.

The preparation for the second Swarm international science meeting to be held on 24–26 June 2009 in Potsdam (D) has started. The web site is www.congrex.nl/09c24. An Announcement of Opportunity for calibration and validation for Swarm is being prepared, which will be publicly opened just before the Swarm science meeting.

→ EARTHCARE

The System Requirements Review (SRR) was completed in February 2009. Meanwhile, the project and industry have been working to resolve issues and implement the recommendations and conclusions of the SRR Board. Noting that the EarthCARE baseline configuration was not compatible with a Phase A candidate launch vehicle, Dnepr, the board highlighted the affordability of the two compatible launchers, Soyuz and Zenit.

In parallel with the investigations for the potential EarthCARE launch vehicle, industry has progressed in completing SRR action items that need resolving before the Preliminary Design Review. Discussions have taken place with JAXA to confirm the size of the cloud-profiling radar (CPR) dish, and with the Dnepr launcher authorities to clarify the fairing restricted envelope and its unsuitability for EarthCARE.

An alternate launch vehicle, PSLV, equipped with a larger fairing is presently investigated, but difficulties with this option are expected with the vehicle's mass capability, higher expected environmental loads and risks associated with International Traffic in Arms Regulations. The draft ESA/JAXA Memorandum of Understanding, defining the cooperation agreement for EarthCARE and the provision of the CPR by JAXA, has been finalised after iteration with JAXA and is being circulated between the agencies.

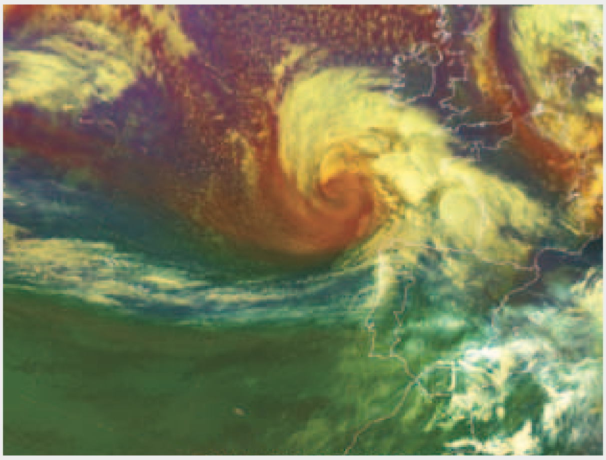
→ METOP

MetOp-A

The Advanced High Resolution Picture Transmission (AHRPT) system is operational again following a successful two-month trial in October/November. The AHRPT on MetOp-A failed in July 2007 when its Solid State Power Amplifier stopped working due to heavy ion radiation affecting a power transistor. The probability of this incident occurring again has been greatly reduced by excluding north and south polar regions (high in heavy ion flux) and the 'South Atlantic Anomaly' area (high in proton flux) from the new operating area. However, there are no totally safe operational areas and a further failure cannot be completely ruled out during the lifetime of MetOp-A. Meanwhile, the MetOp-A satellite is still in very good health and the instruments continue to perform excellently in orbit.

MetOp-B and MetOp-C

Following the Component Health Assessment Process Reviews (CHAP) for MetOp-A, it was concluded that MetOp-A should be capable of continuing its mission beyond a six-year lifetime. This allowed for a shift in the MetOp-B launch date to 2 April 2012. A further optimisation of the Assembly, Integration and Testing (AIT) planning has meanwhile been negotiated, whereby the shift has been used to start MetOp-C integration activities, to bring it to an integration stage that would allow for 'quick relaunches' (within 12 to 15 months) of MetOp-B in case of MetOp-A major mission failure, or of MetOp-C in case of launch failure of MetOp-B. The new MetOp-B and C launch dates and the optimised AIT schedule are subject to approval by the Eumetsat spring delegate sessions. Full integration activities on the PLM-3 will start after the summer. SVM-1 destorage is planned for April 2010.



On 23–25 January 2009, western Europe was hit by a severe storm that killed at least 26 people and caused damage worth hundreds of millions of euro. The progress of the storm, one of western Europe's worst for a decade, was tracked by Meteosat-9 as it blew in from the Atlantic Ocean and left a trail of destruction in south-western France and northern Spain. The first signs of the storm could be seen with infrared and water vapour imagery by Meteosat-9 on 22 January. The effects of the storm could have been even worse had not been for the early warning provided by Meteosat-9. French President Nicolas Sarkozy said his country's response to the storm was better than it had been to the 1999 storm, the worst of last century, reported Agence France Press (Eumetsat).

→ METEOSAT

Meteosat-8/MSG-1

Meteosat-8 satellite is in good health with instruments performing flawlessly. All parameters are still nominal. The loss of the two thermal frames, on the side of the radial thrusters, due to the centrifugal forces of about 19g experienced by these frames (with the satellite spinning at 100 rpm) resulted in larger thermal gradients during eclipse nights and in sun illumination Some local tank heating is compensating for effects on attitude. The satellite serves as back up for MSG-2 and performs the Rapid Scan Service.

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 and MSG-4

MSG-3 is in long-term storage at Thales Alenia Space, Cannes (F), awaiting the restart of the AIT campaign begin 2010, to prepare for its launch in early 2011. MSG-4 is still awaiting its completion of the MSG-4 Pre-Storage Review. The MSG-4 launch is planned not earlier than 2013.

→ METEOSAT THIRD GENERATION (MTG)

MTG is based on a twin-satellite concept in which two types of three-axis stabilised satellites will be developed, one for

Artist impression of the MTG-1 imager satellite imaging (MTG-I) and one for sounding (MTG-S). The payload for MTG-I will consist of the flexible combined imager, a lightning imager, a data collection system, and search and rescue system (GEOSAR), while MTG-S will embark the infrared sounder and an ultraviolet, visible and near-infrared sounder, the latter to be provided from the GMES Sentinel-4 programme. The MTG space segment is composed of six satellites: four MTG-I and two MTG-S.

The two consortia that performed the MTG Phase A studies, Astrium GmbH and Thales Alenia Space France, started the work on the Phase A extension. During this phase, with the scope of work equivalent to a B1, it is intended to progress the definition of the baseline MTG space segment designs, and associated supporting analyses, to a level of maturity that will allow preparation of the proposals for Phases B2/C/D in line with the specific MTG procurement constraints.

For the MTG procurement, there are four major elements to be considered: MTG Prime, Common Platform, Flexible Combined Imager (FCI), and Infrared Sounder (IRS), whereby ESA will ensure, at the contract award and final selection of the elements, that no more than two of these four elements would be allocated to industrial leads in France and Germany respectively ('2 + 2 rule').

→ SENTINEL-1

Sentinel-1 will carry a Synthetic Aperture Radar (SAR) in C band in response to user requirements from the European Commission and to ensure continuity of radar observation initiated with ERS-1/2 and continued with Envisat ASAR. Weighing about 2.3 tonnes, it is scheduled for launch at the end of 2011 with a design lifetime of seven years (and consumables for 12 years).

With the completion of the procurement of the equipments via the Best Practices procedure, the industrial team is now complete. The Sentinel-1 system and sub-system Preliminary Design Reviews (PDR) were held in 2008; the last equipment PDRs are ongoing.

Initial tests of the SAR antenna transmit-receive modules (produced at Thales Alenia Space, L'Aquila) delivered results exceeding specified requirements. The qualification of the second most critical antenna technology, the slotted waveguide radiating elements (produced in Germany), is complete, releasing the production of the flight model. Production of the engineering model hardware is under way. Following authorisation by the IPC, the procurement started for the second satellite Sentinel-1B.

→ SENTINEL-2

Sentinel-2 is the optical multispectral mission of the GMES space component programme ensuring continuity and further development of the SPOT/Landsat land observing missions (vegetation and human habitation). This mission is based on the concurrent operations of two satellites flying in a unique Sun-synchronous orbit with a separation of 180 degrees.

The Sentinel-2 payload instrument and system Preliminary Design Reviews (PDRs) were completed in November 2008. The Best Practice procurement phase is now very advanced. Equipment PDRs and first hardware deliveries are taking place, for example, the silicon carbide telescope mirrors. The Critical Design Review of the first payload instrument and satellite is scheduled for the end of 2010, and the satellite Flight Acceptance Review in 2012. The build-up of the industrial consortium will be finalised in 2009, and the Sentinel-2A ceiling price conversion and the Sentinel-2B contractual negotiations will be completed. Preparatory activities have also been initiated with Arianespace (Vega) and Eurockot.

→ SENTINEL-3

The last remaining instrument Preliminary Design Review, for the SLSTR instrument, was concluded in April. This was the last milestone related to the Industrial Phase B2 activities, which are now complete. All contractors have now started working on the C/D tasks, which include consolidation and freezing of the design based on the recommendations and actions placed during the satellite and instrument PDRs and the performance of all level equipment PDRs, planned until summer 2009.

The Sentinel-3 Ground Segment Requirements Review was concluded, confirming that the management provisions, as well as the technical and operational requirements for the implementation of the Sentinel-3 ground system, are complete and sufficiently detailed to initiate the implementation phase. In parallel, the conversion of the C/D ceiling price to a fixed price has entered the negotiation phase. In addition, a proposal for the procurement of the second Sentinel-3 model (B model) is in preparation.

On the technical side, the main effort at satellite level is still the consolidation of the mass budget. Despite a continuous and extensive effort from all contractors in trying to reduce the mass, the update mass budget still shows little margin compared to the current maximum estimated launch mass for the candidate launchers (Vega and Rockot). Most of the mass reductions have been used to compensate for mass increases in areas where the technology maturity levels are still very low. However, with the completion of selection of contractors in charge of flight hardware, the

The Vega Mobile Gantry at Kourou (ESA/CNES/Arianespace)

Sentinel-3 design maturity is now reaching a good level all across the consortium and the risk of a major mass changes is decreasing.

Procurement through competitive Invitations to Tender (ITTs) is proceeding in all fields. Out of around 120 procurement contracts to be placed, 78 have either been concluded or are under final negotiation.

→ VEGA

Launcher system activities continue on the qualification loop. The final review of guidance, navigation and control (GNC) algorithms was completed for the Flight Program Software Critical Design Review. The final qualification test firing of the Zefiro 9A solid rocket motor will be made at Salto di Quirra (I) on 28 April. The manufacturing of the Inert Motor Case of the flight unit was completed.

The Zefiro 23 Qualification Review Steering Board was held and the Zefiro 23 Flight Model 1 manufacturing was completed. Thermal analyses on the Payload Fairing, following the evolution of aerothermal fluxes, were completed, with no impacts on the cork pattern and equipment qualification. The AVUM Propulsion System test firing campaign (UCFire) is continuing at the EADS facilities in Lampoldshausen (D) with the finalisation of long-duration runs. The P80 activities are focused on the P80 Ground Qualification Review preparation.

The Vega mobile gantry, inside which the launch vehicle will be integrated and tested, completed its first movement tests on 18 February at Europe's spaceport in Kourou. The translation test checked both the translation system performance – in preparation of final acceptance tests – and the interfaces with the launch pad structures (umbilical mast, fluid connections, launch vehicle origin). All external networks, except those for the liquid propellants (UDMH and NTO) have been completed. After qualification, the first release of the Vega Control Centre (CCV) is being installed at the Vega site.

The activities related to the preparation of the qualification flight mission (LARES and Cubesats) have progressed with the finalisation of the interfaces and the identification of the required tuning for the qualification flight mission. The agreement between ESA and ASI for the LARES mission on the qualification flight has been finalised.

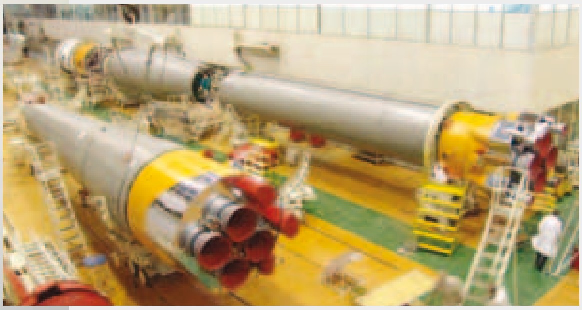
→ SOYUZ AT CSG

A high-level board meeting of Russian and European partners in March confirmed all coming major milestones. The Head of the Russian Federal Space Agency and ESA's Director General confirmed the objective of a first Soyuz launch before the end of 2009 from French Guiana.

Aerial view of the Soyuz at CSG launch pad taking shape

View from the flame trench underneath the Soyuz at CSG launch pad

Soyuz Mobile Gantry assembly in Sergiev Posad, Russia



The first two Soyuz launcher stages ready in Samara

The second shipment of Russian equipment arrived at Kourou in January. A Russian team of around 100 technicians and engineers is currently assembling all equipment for interface with the launcher on the launch site.

The Mobile Gantry assembly is progressing in Sergiev Posad (Russia) towards an on-site acceptance test. This activity is on the critical path and delivery to CSG is still scheduled for the first half of 2009.

On the launcher side, the first two launcher stages are assembled, tested and ready in Samara for a delivery to CSG after summer 2009 (the Soyuz-ST launcher is a version Soyuz-2 launcher with the following adaptations: a payload fairing of 4.11 m diameter and 11.4 m length, a Fregat upper stage, boosters adapted to sink after splashdown, and new S-band telemetry systems). The European Safety Kit, to be fitted on the launcher, was delivered in 2008 and tested by the TsSKB-Progress team in Samara.

The next milestone is the Soyuz Launch System Critical Design Review, beginning on 25 May. The technical qualification followed by the operational qualification will last from July to the end of October. The first commercial launch campaign will begin in November for a flight at the end of December.

→ FLPP

The Steering board of Intermediate eXperimental Vehicle (IXV) System Preliminary Design Review (PDR) took place on 13 January, opening the way for the preparation of sub-systems PDRs. The Request for Quotation for IXV Phase C2 was issued, giving a view to completion of the vehicle.

The final presentation of CUST-1.1 took place in February presenting the Technology Development and Verification Plans for the selected cryogenic upper-stage technologies. The Request for Quotation for CUST-1.2 (related to the technology maturation) was issued in March.

In the area of solid propulsion, the pre-Tender Evaluation Board for the initiation of the development of the Pressure Oscillation Demonstrator took place in February and the Request for Quotation was sent to industry early March. In the High Thrust Engine area, the liquid oxygen-liquid methane (LOx/LCH4) test campaign is in progress and pre-burner as well as coupled pre-burner/main combustion chamber tests took place. Catalytic bipropellant igniter tests are also in progress.

For the Vinci engine, in parallel with the hot-firing tests of the Thrust Chamber performed in the frame of FLPP, the bridging phase from Expander Demonstrator towards Ariane 5 Post-ECA is being implemented and a Tender Evaluation Board took place in March.

→ HUMAN SPACEFLIGHT

The ESA astronaut selection campaign is in its final phase. The medical selection was conducted at the Institute of Space Medicine and Physiology (MEDES), Toulouse, and the German Aerospace Centre (DLR) in Cologne. The ESA Medical Board qualified 22 candidates for the next round, the professional interviews, which were conducted at ESTEC in March by a Board chaired by the Director of Human Spaceflight. The recommendations of the Board have been forwarded to the ESA Director General for a final selection.

On 5 February, the name of ESA's second long-term ISS mission (for Frank De Winne) was announced: OasISS. The name was chosen by ESA from among 520 proposals received in response to a competition launched by ESA last September. The mission logo features the ideas of water being the basis of life as we know it, and of seeing the ISS and Earth as 'oases' for astronauts and mankind.

The final training of the crews for the Mars500 isolation study started in Russia in January with four ESA participants. The final two ESA participants selected to take part in the anticipated 105-day simulated Mars mission were announced on 26 February: Oliver Knickel (D), a mechanical engineer in the German army, and airline pilot Cyrille Fournier (F). The remaining four crewmembers are Russians: cosmonauts Oleg Artemyez and Sergei Ryazansky, Alexei Baranov, a medical doctor, and Alexei Shpakov, a sports physiologist. The six-person crew entered the isolation facility at the Institute for Biomedical Problems (IBMP) in Moscow, Russia, on 31 March for the execution of the 105-day study until mid July.

OasISS mission logo

Mars500 crew enter the isolation facility in Moscow (ESA)

Press photo opportunity during the visit of Albert II, King of the Belgians, and Queen Paola to EAC in Cologne. From left: Michel Tognini, Head of EAC and ESA astronaut, Sabine Laruelle, Belgian Federal Minister of Science Policy, Pieter De Crem, Belgian Minister of Defence, Jean-Jacques Dordain, ESA Director General, Albert II King of the Belgians, Queen Paola, Frank De Winne, ESA astronaut, Simonetta di Pippo, ESA Director of Human Spaceflight, Johann-Dietrich Wörner, Chairman of DLR Executive Board

King Albert II and Queen Paola of Belgium visited the European Astronaut Centre (EAC), Cologne, on 19 March. They met with Frank De Winne (B), who was there training for his upcoming mission on board the ISS. They were also informed by ESA Director General and the ESA Director of Human Spaceflight of ESA's activities and Belgium's participation.

The European Columbus laboratory celebrated its first birthday on 11 February 2009. At 22:44 CET on 11 February 2008, ISS Commander Peggy Whitson initiated the final capture of the newly delivered module. From that moment on, firmly attached to the right side of the Node-2 module, Columbus officially became a part of the ISS. Since then, Europe has its first permanent human outpost in orbit.

→ INTERNATIONAL SPACE STATION

Space Shuttle *Discovery* lifted off from Kennedy Space Center (KSC), Florida, for the 15A assembly mission to the ISS on 15 March. Discovery delivered the final pair of power-generating solar array wings and the S6 truss segment. Installation of S6 will enable the ISS to house a six-member crew and allow the operation of many research payloads simultaneously. *Discovery* undocked from the ISS on 25 March and landed on 28 March, completing the 13-day mission.

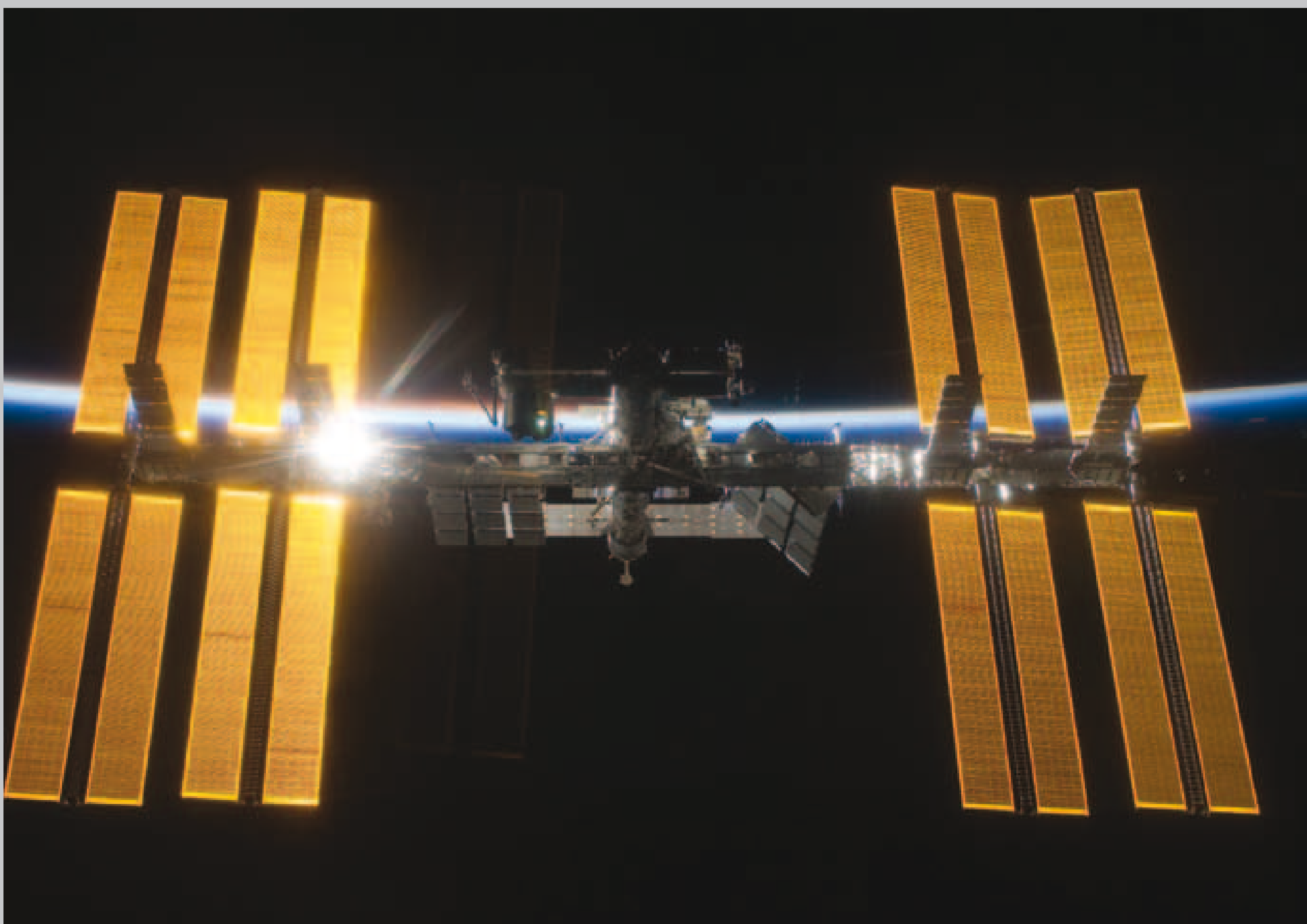
→ SPACE INFRASTRUCTURE DEVELOPMENT AND EXPLOITATION

Node-2, Node-3 and Cupola

The hardware to accommodate the Treadmill-2 and the crew quarters in Node-2 has been delivered to NASA. Node-3 development is near completion and the pre-shipment activities are supporting a delivery to KSC in May. The Flight Acceptance and transfer of Node-3 ownership to NASA are set for October 2009. ESA supported NASA for Cupola ground operations at KSC. The Cupola observation module will be attached to Node-3 in July.

ATV production and cargo integration

The ATV *Jules Verne* Post Flight Review was concluded on



Latest view of the ISS, as seen by the crew of STS-119 during a Space Shuttle fly-around after undocking on 25 March (NASA)

ATV *Jules Verne* seen after separation from the ISS in 2008 (NASA)

21 January and resulted in a list of 132 recommendations. Of those, 22 recommendations were considered to have a potential design impact on ESA's second ATV, ATV-2, and will be further elaborated up to a level for a decision on whether implementation is required on ATV-2. The results will be presented to the Post Flight Review Board on 27 April 2009.

Beyond *Jules Verne*, ESA has already contracted industry to produce four more ATVs, to be flown before 2015. The last programmatic review in frame of this procurement is the Production Readiness Review (PRR) 2, which will release the ATV-3 integration and the equipment procurement for ATV-4/5. This review took place on 31 March but could not be concluded due to the outstanding deliverables. So far, the postponement of the further releases has no schedule impact on the follow-on launch dates.

ATV-2, Europe's next unmanned logistics spacecraft is scheduled for launch to the ISS in November 2010. It has been named *Johannes Kepler*, after the German astronomer and mathematician. The ATV-2 high-level cargo manifest was sent to NASA. These data are now being processed for the preliminary mission analysis, and the propellant required for the mission is being estimated.

The ATV-3 equipment procurement was initiated and is running without any problems for an ATV-3 launch in 2011. The negotiations with industry for the implementation of the ATV Production Sustainability Activities began in January.

Operations status

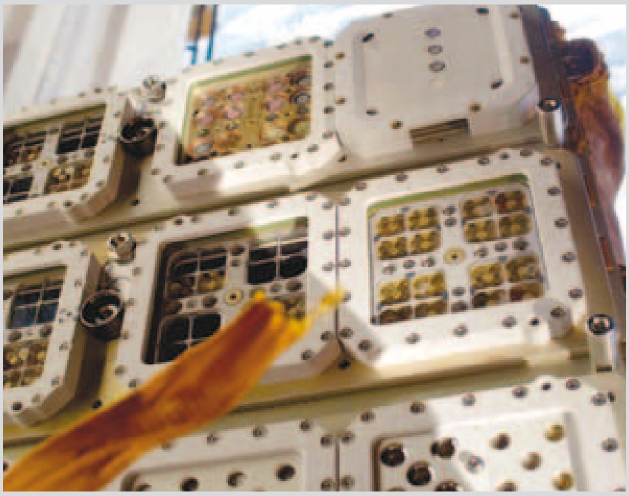
The Columbus module continues to function nominally in support of the various payload activities. The nine European User Support Operations Centres are performing the ESA ISS utilisation operations under the overall coordination of the Columbus Control Centre.

Discussions with the industrial operator (IOT) and CNES have been initiated to finalise the procurement approach for the services related to the ATV-2 and ATV-5 operations. The procurement activities should be completed by mid 2009.

→ UTILISATION

The principal focus of the European utilisation of the ISS in recent months has been the Columbus laboratory. The European Technology Exposure Facility (EuTEF) platform, with a total of eight technology instruments, and the exobiology payload Expose (five experiments), were operated continuously with good results. A EuTEF software upgrade was performed in mid-January, making it possible to operate the DEBris In-orbit Evaluator (DEBIE-2) and FIPEX experiments simultaneously. The DEBIE-2 is designed to be a standard, in situ space debris and micrometeoroid monitoring instrument, and the FIPEX sensor is helping to build up a picture of the atmospheric environment in low-Earth orbit by measuring atomic oxygen.

The SOLAR facility has so far produced excellent scientific data during a series of Sun observation cycles (from 15 until 28 January and from 23 February until 4 March). A new Sun observation window opened on 23 March and is expected to end on 2 April. Unfortunately, the SOVIM instrument stopped working due to a failure of its internal power distribution system. After thorough analysis, this instrument was declared lost for the rest of the SOLAR mission. On 18 March, calibration of the SOLSPEC instrument was performed, followed by the calibration of the SOLACES instrument. SOLACES and SOLSPEC continue to acquire excellent scientific data. A mission extension of SOLAR beyond the nominal return date in spring 2010 is under analysis.



Close-up image of the Expose-R experiment, installed on the outside of the Russian segment of the ISS. The European experiment is equipped with three trays containing a variety of biological samples (ESA/NASA)

The Geoflow experimental programme in the Fluid Science Laboratory (FSL) continued in January performing 10 out of 67 planned runs with excellent interferometric image results. Further operations have been stopped due to a failure of the experiment hardware. The Geoflow Experiment Container was removed from the FSL on 18 February and was returned with the Shuttle mission STS-119/15A on 28 March for detailed inspection. The experimental programme will be resumed as soon as possible.

The troubleshooting and maintenance of the following Columbus facilities: Biolab and the European Modular Cultivation System (EMCS) have been completed and they are ready for the next experiments, Waving and Coiling of *Arabidopsis* Roots (WAICO-2) and GENARA.

Final calibration of the Multi-Electrode Electroencephalogram Measurement Module (MEEMM) was carried out by NASA Flight Engineer Sandra Magnus on 21 January. The European Physiology Modules (EPM) are ready for the NeuroSpat experiment. This experiment will take place when the next European astronaut, Frank De Winne, arrives on the ISS at the end of May.

The Processing Unit of the Protein Crystallisation Diagnostic Facility (PCDF) was launched in active mode to the ISS on 15 March. Full commissioning of all functions of the PCDF started on 20 March and lasted a few days. Science commissioning has been completed and the first science run started on 24 March. The first DLS data on nucleation are nominal and gave expected results. The performance of the instrument is nominal. The protein experiment series will last 3–4 months comprising three subsequent crystallisation cycles. The final set of organic protein macromolecules will be returned to Earth on the subsequent Shuttle flight 2J/A for detailed analysis in various European science labs.

On 23 March, ISS Flight Engineer Koichi Wakata set up and performed his first session of the 3D-Space experiment (Mental Representation of Spatial Cues During Space Flight). Wakata is the second human test subject for the experiment.

The Flywheel Exercise Device will be removed from its on-orbit storage location in the European Transport Carrier rack of the Columbus Laboratory for deployment and first functional checkout tentatively during Increment 19.

Wrap-up meetings concluding the BIO-4 experiments were held at ESA on 13/16 January where the preliminary science results of the four biology experiments which flew to the ISS in October 2008 were presented by the science teams. All experiments worked as planned.

The Expose-R payload was installed outside the Zvezda Service Module during the Russian-based spacewalk on 10 March. The Expose-R is functioning well. Expose-R is a suite of nine new astrobiology experiments (eight from ESA and one from IBMP, Moscow), some of which could help us to understand how life originated on Earth.

On 26 March, two plant biology experiments (Polca and Gravigen) were launched with Soyuz TMA-14 on flight 18S to the ISS. The ground reference experiment containers were installed on 27 March. The Gravigen experiment will investigate the effect of weightlessness on gene expression in rapeseed plants *(Brassica napus)*. The Polca experiment will investigate the effect of weightlessness on the distribution of calcium in the statocytes (gravity-sensing cells in plant root tips) of rapeseed plant roots. These experiments will be processed on the ISS in the Kubik incubator on 3–6 April, with samples being returned with Soyuz TMA-13 (17S) on 7 April.

Preparation for the 50th ESA Parabolic Flight Campaign scheduled for May 2009 has begun. The launch of TEXUS-46 sounding rocket mission from Kiruna, Sweden, has had to be deferred from April to November 2009 due to launch system availability constraints.

→ ASTRONAUTS

The German Minister of Defence visited the EAC on 20 March. Training is ongoing for astronauts Frank De Winne and his back-up André Kuipers (NL) ahead of the OasISS mission. De Winne is due to fly aboard a Russian Soyuz spacecraft (19S) scheduled for launch on 27 May 2009. The arrival of De Winne and the other two members of the Soyuz TMA-15 crew on board the ISS will mark the first six-member ISS Expedition crew.

ESA astronaut Christer Fuglesang (S) is training for the STS-128 mission (17A), scheduled to be launched in August 2009. Paolo Nespoli (I) is in training for Expeditions 26 and 27 (to be launched in November 2010). Roberto Vittori (I) is in training for a third ASI-owned short-duration flight opportunity on the Space Shuttle.

Astronauts André Kuipers and Frank De Winne during underwater EVA training in NASA's Neutral Buoyancy Facility in Houston

→ CREW TRANSPORTATION AND HUMAN EXPLORATION

Crew Space Transportation System (CSTS)

In the frame of the CSTS breadboarding activities, the open-loop Soft Docking System tests (part of the avionics activities) and the test of the CSTS Thermal Protection System (at the Scirocco facility) have been completed. Longer-duration tests are foreseen in following this first test. Verhaert have completed the Alternative Load Sensor unit test campaign and the test report has been delivered to the prime contractor (Thales Alenia Space Italy).

Advanced Reentry Vehicle (ARV)

The two Phase O industrial studies of the ARV are proceeding satisfactorily with the consolidation of requirements to support the subsequent Phase A.

A proposal for the Phase A study has been approved for implementation by the programme's participating states on mid March. The industrial contract is expected to be in place by June 2009 with a plan of activities lasting until end 2010. Another procurement proposal for the ARV Operations Avionic Subsystem has also been submitted to the Industrial Policy.

International Berthing Docking Mechanism (IBDM)

A conceptual review for the Integrated Actuation Unit and a design review for the latching subsystem were held on 21 January, during which an aluminium model of the novel gearbox was presented to prove the concept kinematics. The gearbox using this concept will now be designed to drive the latch.

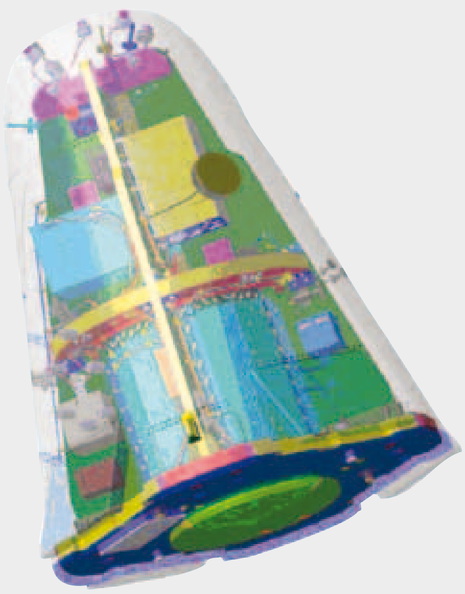
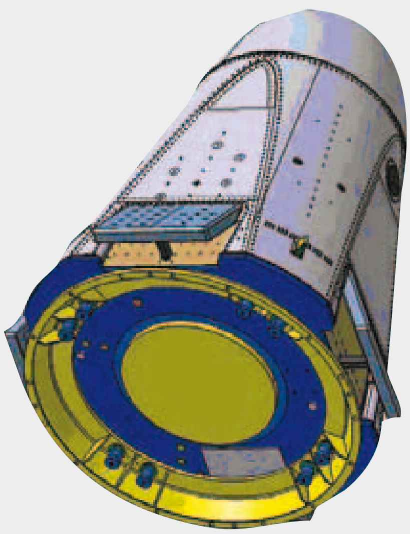
A number of activities concerning the IBDM design and test, as well as the Control and Display, have been endorsed by the programme's participating states on 17/18 February. Work on the IBDM interoperability aspects is making progress, with the IBDM system and the equivalent NASA Low Impact Docking System (LIDS) becoming the standard for future ISS and Exploration applications. A Technical Interface Meeting took place on the 5/6 February in Houston with the participation of ESA, NASA, JAXA, Roscosmos and CSA. NASA has confirmed their positive position to a collocation of engineers from European industry in Johnson Space Center for the detailed definition of the IBDM interface.

The validation and acceptance testing of the Electromagnetic (linear) Actuators has now been completed. The Final Acceptance and Qualification Review meeting was successfully held at ESTEC on 14 January 2009. Open-loop tests involving the IBDM avionics started in March 2009. The avionics have been integrated with the IBDM Soft Docking System and the commissioning phase has been completed.

EXPERT

The EXPERT Payloads Qualification Review was completed and the Payloads Flight Models manufacturing activities were initiated by the institutes and payload providers. The EXPERT subsystems Critical Design Reviews (CDRs) have been completed by Thales Alenia Space Italy with ESA support. The system CDR was performed in February; all outstanding items were completed by the 1 April.

The contract for the Launch and Recovery activities has been negotiated with Makeyev. The application of Makeyev for the launch of EXPERT is expected to be approved by the Russian authorities shortly.

Two views of the EXPERT design

Lunar Lander activities

Alternative approaches for the development of a European Lunar Lander have been explored, including, besides the Cargo Mission based on a full Ariane 5 launch and the MoonNEXT concept, a smaller mission on a shared Ariane 5 geostationary transfer orbit launch. In preparation and support of future work on these missions, a Lunar Lander Request for Information (RFI) was posted on the ESA web site on 2 March. ESA's Directorate of Human Spaceflight invited industrial, technology and scientific communities to provide inputs for experiments and payload elements for accommodation on its first lunar lander. The RFI has drawn a remarkable interest and participation, the last submissions are due by 14 April.

Concerning the Ariane 5 shared launch, ESA proposes to implement the assessment of this mission as additional work to the MoonNEXT studies. Both mission concepts would provide a precursor mission supporting technology demonstration, as well as providing a suitable payload delivery capability. It is envisaged that the additional industrial studies would take about six months. A trade-off between these different mission concepts would be needed before deciding which lander version would enter the development phase.

The planned studies on Moon Surface Infrastructure and the Cargo Lander Phase A are expected to start at the end of 2009 or in early 2010.

International architecture development and scenario studies

A final presentation on 'International Architecture Development and Scenario Studies' was held on 16 January at ESRIN, Frascati, with about 90 participants from industry, research organisations, national agencies and Programme Board Delegates. The study has helped to increase the understanding of integrated architectures for human operations in low Earth orbit and human missions to the Moon and Mars, and in particular, has provided a strong rationale for a European-provided lunar cargo lander in support of international human missions to the Moon.

The ESA/NASA Comparative Architecture Assessment (CAA) is progressing into Phase 2. The last meetings on 9 January and 2/6 February 2009 focused on the development and consolidation of mission scenarios and requirements for the Ariane 5 based Lunar Cargo Lander. A meeting on the ESA/JAXA CAA, to identify commonalities and differences in their current lunar exploration architecture, was held at ESTEC on 19/21 January 2009.

In the framework of the International Space Exploration Coordination Group (ISECG), an international lunar architecture workshop was held on 3/5 February in Houston, with participants from ASI, BNSC, CNES, DLR, ESA, NASA, JAXA and Roscosmos. During the workshop, three reference scenarios (sortie, extended stay, outpost) for human lunar exploration were defined which will serve as a framework for the assessment of the architecture elements. The next lunar architecture workshop will take place on 2/4 June and will be hosted by ESA.

ESA and NASA are currently in the process of negotiating a study agreement which will enable the exchange of more detailed information in support of this work.

The 3rd ISECG Meeting was held on 10/12 March 2009 in Yokohama, Japan. Representatives from 10 space agencies around the world adopted, for further study, three scenarios for conducting internationally coordinated robotic and human exploration activities on the Moon.

A 'Tripartite Space Dialogue' meeting led by the ESA Director General with the Russian space agency Roscosmos and the European Commission on the continuation of the cooperation with Russia on crew transportation took place in Moscow on 17/18 March. During the meeting it was agreed with Roscosmos to redirect the spaceship working group to cover also scenarios for orbital infrastructure after the ISS, as well as shorter term aspects concerning the scientific exploitation of the ISS.

Human exploration technology

On Habitation and Life Support, two activities for implementation, namely the development of a Water Treatment Unit Breadboard and further development of the MELiSSA Pilot Plant, were endorsed by the programme's participating states on 17/18 February. The MELiSSA Pilot Plant inauguration is planned for 4 June 2009.

On the Aurora Core programme, work has continued on the package of autonomous soft-landing technology development activities, with the completion of the early phases of the vision-based navigation demonstrator and sensor architecture activities. The LIDAR-based navigation demonstrator was initiated and coordinated with the ongoing Technology Research Programme bread-boarding activity. Work has also progressed on the flight performance of an autonomous helicopter which will form part of the Precision Landing GNC Test Facility.

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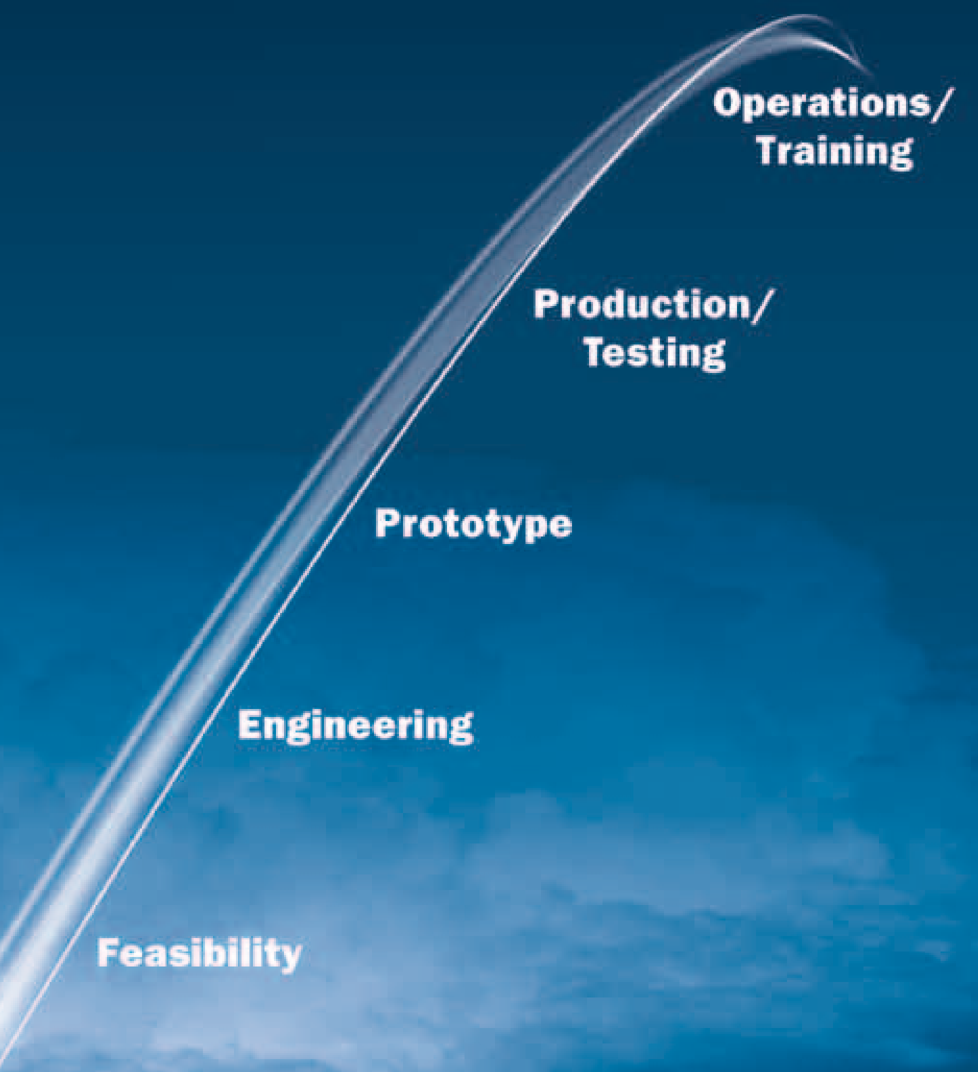

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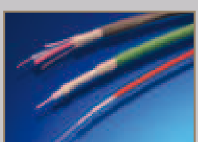

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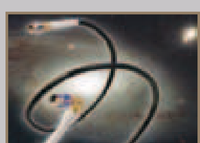

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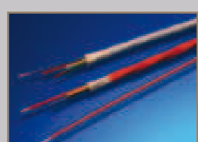

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