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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.

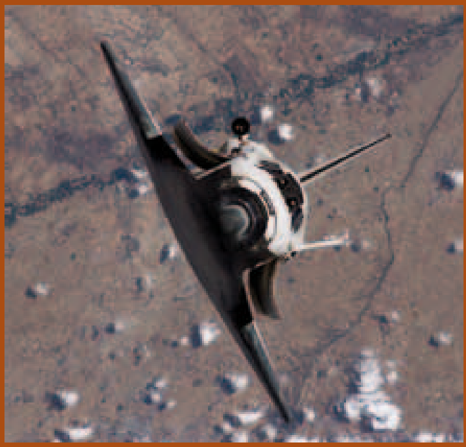
ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

Chairman of the Council: M. Lucena

Director General: J.-J. Dordain



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On cover:
Space Shuttle *Discovery* seen in orbit before docking with the ISS. *Discovery* lifted off on 29 August 2009 on its 13-day STS-128 mission with with ESA astronaut Christer Fuglesang on board

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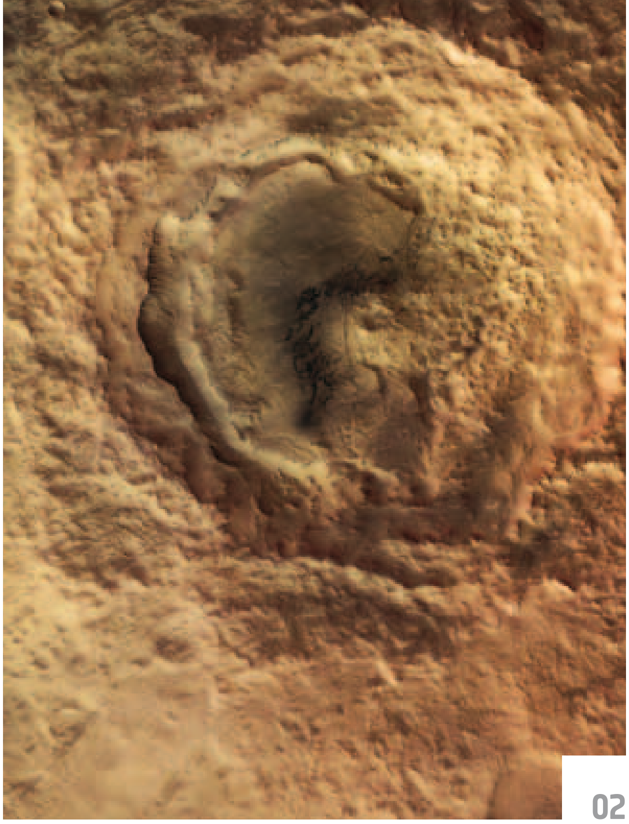

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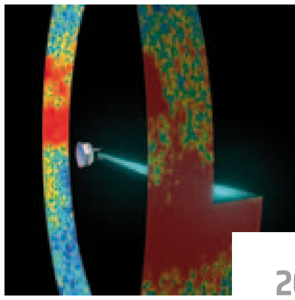

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Maunder crater, 90 km wide and 900 m deep, named after British astronomer Edward Maunder, in the Noachis Terra region on Mars as seen by the High Resolution Stereo Camera on Mars Express in 2005 (ESA/DLR/FU Berlin)

→ MARTIAN CHRONICLES

Automatic recognition of potential impact craters

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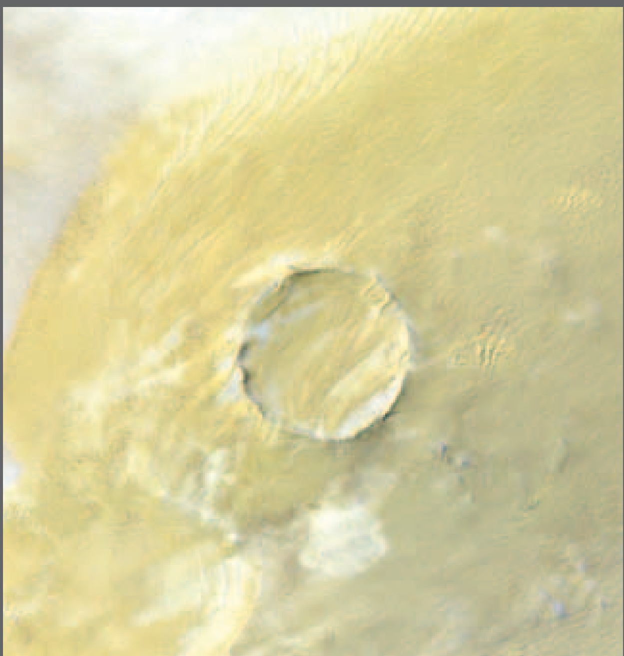
When Ray Bradbury published his 1950 science fiction classic *The Martian Chronicles*, could he have imagined that today, not only are we studying impact craters on the 'Red Planet' from martian orbit, but we are also using them to learn about the history of Earth and the whole Solar System?

Making an inventory of impact craters on Earth, and indeed on all solid planetary bodies in our Solar System, is of prime importance to our understanding of how the Solar System evolved. This helps us to determine the formation ages of planetary surfaces, for example, but it also helps us assess the evolving meteoroid and small-body impact flux, essential for identifying potential impact hazards on Earth and elsewhere.

Fulfilling both objectives has a direct bearing on the science and exploration of our Solar System. Experts from ESA's Directorates of Science & Robotic Exploration and Earth Observation have embarked on this multidisciplinary task, to develop a software tool with these objectives. The tool is also being tuned for crater counting of planetary surfaces in order to estimate their relative age. It may also be used to re-evaluate the impact flux on terrestrial planets, and thus to contribute to an accurate assessment of potential impact hazards.

Impact craters are important because they occur everywhere in the Solar System, providing precious information on the nature of the projectiles, the surface conditions of the target at the time of impact and also on the interior of the planet, if excavation is sufficient. Rather than passive remnants of planetary collisions, impact structures have driven the geological evolution of all solid planetary bodies, especially in the early history of our Solar System.



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Roter Kamm crater, Namibia, an example of a well-preserved bowl-shaped simple crater. The crater itself is partially filled with aeolian (windborne) deposits (Aster near-real colour satellite image)

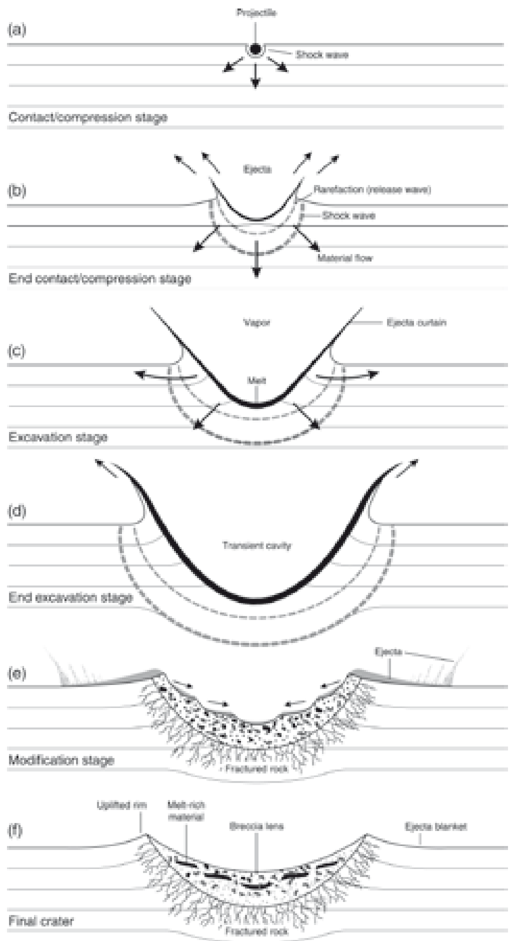
The study of terrestrial impact craters started gathering momentum in the 1960s, together with the early missions to the planets. Today, about 175 impact craters have been identified on Earth. However, a significant number of craters remain to be discovered on our planet.

Impact craters on Earth are formed when large meteoroids, asteroids or comets enter our planet's atmosphere and hit the surface at very high velocities. Impact cratering occurs on surfaces of all solid planetary bodies in the Solar System and the resulting excavated cavities range in size from micrometres (on bodies without an atmosphere) to several hundreds of kilometres, with morphology changing with the type of rock or gravity of the target.

Impact crater formation

Studies show that the morphology of impact structures changes systematically with crater diameter for a given planetary body, which, in turn, depends largely on the target properties and projectile size, type, velocity and trajectory, and thus on the amount of energy released during the impact. Comets and asteroids hit solid planets at a wide range of impact speeds, on average at about 20 km per second for asteroids and about twice as much for comets. Resulting impact craters have diameters that are typically 10 to 20 times larger than the incoming projectiles.

Much of the material ejected from the crater during the impact is deposited in a continuous 'ejecta blanket' near and around the crater, which becomes discontinuous at greater distances from the crater rim. Large blocks ejected from the crater may lead to secondary cratering, occurring radially from the crater structure. Material below the surface of the crater is significantly fractured by the impact event. The uppermost layer is made of 'breccia' (angular fragments of older rocks). At greater depths, the highly fractured bedrock remains in place. The amount of fracturing decreases with depth.



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Steps in the formation of an impact crater caused by a meteoroid impact on Earth

The energy of the impact typically causes some material to melt, ranging from pockets of impact melt within the breccia layer to extended impact sheets for large craters. At a microscopic scale, deformed rocks display a characteristic suite of mineralogic and crystallographic indicators, including planar deformation features and high-pressure minerals, which are uniquely characteristic of shock metamorphism during the impact. On larger scales, conical fractures of the bedrock, known as 'shatter cones', represent an important indicator of an impact origin.

Planetary impact craters

During the formation of our Solar System about 4600 million years ago, the condensation of the primitive 'solar nebula' and the accretion of the different planetary bodies were followed by a period of intense bombardment. This seems to have peaked at about 3900 million years ago, and resulted in craters covering all solid planetary surfaces. The lunar far side is saturated with craters of all sizes, produced by an early cratering rate perhaps 100 times higher than today. Earth experienced the same heavy bombardment as the other planetary bodies.

The differing gravities on each planetary body lead to different diameter ranges for each morphological type of crater. On Earth, the higher gravity with respect to the Moon produces smaller versions of the three main types of craters: simple, complex and basin. The crater morphology reflects characteristics of the target material at the time of the impact. For instance, fluidised ejecta craters on Mars might indicate that water/ice-rich materials were excavated by the impactor. The size and shape of craters on Venus is governed by the high atmospheric pressure at the surface of the planet. No impact-related structure smaller than about 2 km in diameter has been found on Venus, owing to the impactor fragmentation during atmospheric descent. Only large pieces survive the passage through the atmosphere.

Terrestrial impact craters

Most of the impact craters that formed on Earth's surface have been obliterated by erosion, tectonics, volcanism and other geological processes. Those that remain have been preserved either because of their young age, large size, occurrence in a geologically stable region (Precambrian shields), or through rapid burial by sediments that were subsequently removed by erosion. Craters that have been eroded and modified from their pristine state are generally called 'impact structures' instead of craters. About 175 impact structures have been identified on Earth mostly in regions with well-studied geology (North America, Europe, Russia and Australia, for example).

Missing craters

Considering the planetary impact record, it is likely that many more craters exist on Earth, so there are potentially numerous structures awaiting discovery in the lesser-studied shields of Africa, Asia and South America. On the other hand, smaller and more recent craters (less than a few million

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Distribution of confirmed impact craters and structures on Earth

years old) are best preserved in the desert areas of the world. In any case, satellite imagery both in radar and visible infrared wavelengths can be a valuable information source that may lead to more discoveries.

Hazards and extinctions

The Cretaceous–Tertiary (K/T) mass extinction is widely believed to have been caused by the impact of a large asteroid on Earth. The impact signature of the K/T boundary can be identified worldwide from a layer enriched in the meteoritic element iridium and shocked minerals, because large impact events have the ability to distribute dust and gases globally.

From terrestrial cratering rate estimates, the frequency of K/T-sized impacts on Earth is of the order of one every 100 million years. Smaller events occur on shorter time-scales affecting the terrestrial climate and ecosystem to varying degrees due to chemical changes in the atmosphere produced by the vaporisation of the projectile and impacted material.

Impact events at sea can cause huge tidal waves (tsunamis). Smaller projectiles release their energy in the atmosphere as an 'air burst' and in general do not make it to the surface (depending on their composition). As an example, the Tunguska event in 1908 in Siberia was probably due to a meteorite or comet nucleus about 40 m in diameter, exploding at 10–15 km above Earth's surface.

Remote sensing of impact craters

There is no preferred wavelength or spectral channel that can be used to search for or to identify impact craters, as craters appear in all states of degradation in all types of rocks and in all types of regional environments (continental, marine, covered in vegetation, rural with villages inside, lake-forming, etc.). No craters have been found so far on the ocean floor, although two are known on the continental shelf. So, there is no clear-cut answer to the question of what are the best channels, wavelengths and techniques to use to search for and identify terrestrial impact craters by remote sensing. Many techniques and wavelengths have some merit for analyses of geological features, and can be used in their own way.

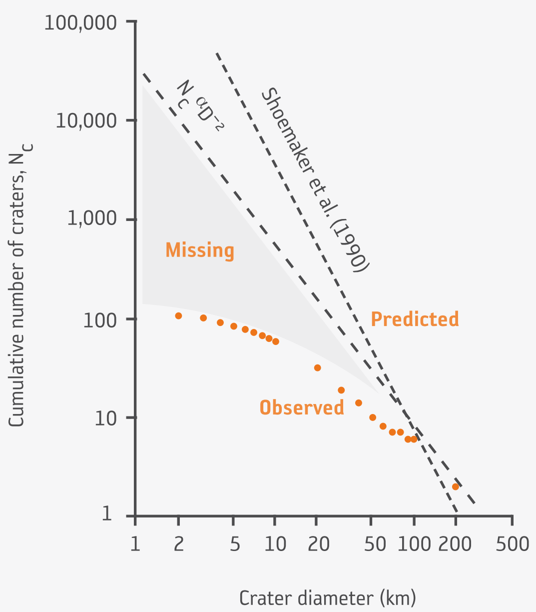
There are several issues that need to be considered in order to develop the best strategy for such impact crater studies:

- The terrestrial environment often works against remote sensing techniques to study bedrock features, due to atmospheric effects, vegetation cover, water cover, human influences like settlements, and weathering or degradation.
- Impact craters can occur in any type of rock, so compositional studies at the spatial and spectral resolution afforded by remote sensing are not directly diagnostic. Shocked minerals cannot be remotely detected because of their low abundances and similarity in spectral parameters to unshocked minerals.

Radar imaging

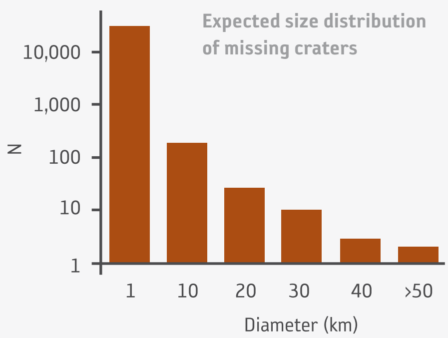
Synthetic Aperture Radar (SAR) imagery has a wide range of geological applications. Different rock types and properties affect the radar backscatter, together with the viewing geometry, allowing the mapping of different rock and sediment outcrops. Geological features, such as scarps or ridges are well imaged with radar data, allowing detailed mapping of tectonic structures such as faults or folds. Radar remote sensing has been used for the observation and study of impact craters and structures.

The unique capability of radar systems to penetrate vegetation cover and, therefore, show possibly hidden surface morphologies might be very useful in identifying unknown impact structures. Moreover, subtle differences in surface properties (such as roughness or moisture) could be detected with radar wavelengths. These characteristics make



Full exploration of continental crust could increase this estimate by a factor of two or three.

No craters have been detected on oceanic crust.



← Estimate curve of undiscovered craters on Earth (V. Sharpton)

→ Case study: Brent crater, Canada

The Brent crater is a large, simple crater structure, which was created about 450 million years ago. It is a particularly interesting structure for crater detection because the diameter (about 3.8 km) is near the theoretical upper limit for that of a simple terrestrial impact crater.

The centre of this crater has been filled with about 250 m of sedimentary rock. The two lakes lie in a pair of hollows in this sedimentary layer. This gives the crater a distinctly different profile from that of the theoretical 'fresh' simple crater.

The crater rim has been very heavily eroded, and the surrounding vegetation makes it difficult to see the 'bowl' shape of the crater at anything other than very low altitudes. Brent is an example of an impact structure for which the main evidence available from satellite-borne remote sensing is the basic circle structure and not so much the morphology.

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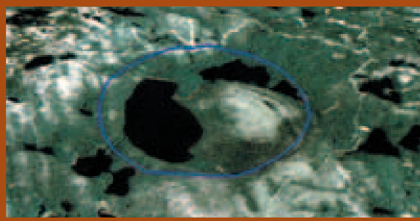
Landsat near-real colour 3D representation of Brent crater with detected crater outline



radar data very powerful for discovering unknown impact structures, in both arid and densely vegetated areas where optical sensors would fail.

Also indirect information derived from radar imagery could be used for identifying possible impact structures, such as the presence of a relic drainage network, both visible from SAR images or from SAR-derived topographic data.

> **"About 175 impact structures have been found on Earth – considering the planetary impact record, it is likely that many more exist..."**

Using multiple wavelengths and polarisation could also be of help in detecting features on the surface (or in the shallow subsurface in certain cases and with longer wavelengths).

Radar-interferometry data, such as ERS- or Envisat-based high-resolution digital terrain models or Shuttle Radar Topography Mission (SRTM) elevation data, could allow new discoveries, even in the case of structures which have a poor expression in remote sensing imagery, but some weak topographic signature (such as a deeply eroded central uplift or poor circular or annular relief). In any case, knowledge of the geology of the study areas is very important for first order selection of possible target structures to be investigated.

Field study and geochemistry of impact craters

An important question is how to recognise an impact crater on Earth. Many structures exist on Earth that superficially might resemble (eroded) impact craters. Remote sensing studies, such as those described here, with better resolution and more spectral information, help to weed out structures that are clearly not of impact origin. Morphological and structural criteria can be applied to high-resolution images taken from space, but confirmation can only be obtained from studying the rocks.

This has made it necessary to develop diagnostic criteria for the identification and confirmation of impact structures on Earth. The most important of these characteristics are: crater morphology, geophysical anomalies, evidence for shock metamorphism, and the presence of meteorites or geochemical evidence for traces of the meteoritic projectile. Morphological and geophysical observations are important in providing supplementary (or initial) information. Geological structures with a circular outline that are located in places with no other obvious mechanism for producing near-circular features may be of impact origin and at least deserve further attention.

Geophysical methods are also useful in identifying promising structures for further studies, especially in the case of subsurface features. In complex craters the central uplift usually consists of dense basement rocks and usually contains severely shocked material. This uplift is often more resistant to erosion than the rest of the crater, and, thus, in old eroded structures the central uplift may be the only remnant of the crater that can be identified. Geophysical characteristics of impact craters include gravity, magnetic properties, reflection and refraction seismics, electrical resistivity and others.

Of the criteria mentioned, only the presence of diagnostic shock metamorphic effects and in some cases the discovery of meteorites, or traces thereof, are generally accepted as providing unambiguous evidence for an impact origin. This means that actual rock samples from the potential crater site have to be obtained. Shock deformation can be expressed in macroscopic form (shatter cones) or in microscopic form. The 175 known terrestrial impact structures on Earth have been identified based on these criteria.

In nature, shock metamorphic effects are uniquely characteristic of shock levels associated with hypervelocity impact. Controlled shock wave experiments, which allow the collection of shocked samples for further studies, using various techniques, have led to a good understanding of the conditions for the formation of shock metamorphic products and a pressure-temperature calibration of the effects of shock pressures up to about 100 GPa. Shock metamorphic effects are best studied in the various breccia types that are found within and around the crater structure. During impact, shock pressures greater than 100 GPa and temperatures over 3000°C are produced in large volumes of target rock. These conditions are significantly different from conditions for endogenic metamorphism of crustal rocks, with maximum temperatures of 1200°C and pressures of usually 2 GPa. Shock compression is not a thermodynamically reversible process, and most of the structural and phase changes in minerals and rocks are uniquely characteristic of the high pressures and extreme strain rates associated with impact.

A wide variety of shock metamorphic effects has been identified. The best diagnostic indicators for shock metamorphism are features that can be studied easily by using the polarising microscope. Planar microstructures are the most characteristic expressions of shock metamorphism and occur as planar fractures and planar deformation features (PDFs). The most important characteristics of PDFs are: they are extremely narrow, closely and regularly spaced, completely straight, parallel, extend through the whole grain, and usually show more than one set per grain. This way they can be distinguished from features that are produced at lower strain rates, such as the tectonically formed 'lamellae', which are not completely straight, occur only in one set, usually consist of bands that are 10 µm wide, and are spaced at distances of about 10 µm.

The detection of small amounts of meteoritic matter within the normal upper crustal compositional signature of impact breccias is extremely difficult. Only elements that have high abundances in meteorites, but low ones in terrestrial crustal rocks are useful. It is also necessary to take into account that different meteorite groups and types have different compositions. Elevated 'siderophile element' contents in impact melts, compared to target rock abundances, can be indicative of the presence of either a chondritic or an iron meteoritic component. It is also necessary to sample all possible target rocks to determine the so-called indigenous component (i.e., the contribution to the siderophile element content of the impact melt rocks from the target).

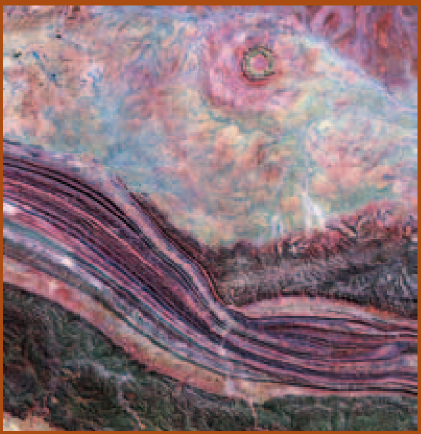
Meteoritic components have been identified for just over 45 out of the 175 impact structures that have so far been identified on Earth. This number reflects mostly the extent to which these structures have been studied in detail, as only a few of these impact structures were first identified by finding a meteoritic component (the majority has been confirmed by the identification of shock metamorphic effects). Iridium is most often determined as a proxy for all noble metals, because it can be measured with the best detection limit of all of those metals.

The use of abundances and ratios of noble metals such as iridium, osmium, or platinum avoids some of the ambiguities that result if only moderately siderophile elements, such as chromium, cobalt, or nickel are used to try and demonstrate the presence of a meteoritic component.

→ Case study: Gosses Bluff, Australia

This crater is an example of an eroded complex structure. The structural remains that can still be seen are the remains of the central uplift, which rises metres above the floor of the surrounding desert. The false-colour Landsat composite of bands 4, 3 and 2 at 28.5 m resolution show a pink 'halo' pattern surrounding the uplift, which is possibly the original extent of the crater.

↓ The Gosses Bluff crater seen from the ground at Tyler's Pass several kilometres away



↑ Landsat image of Gosses Bluff

It is also possible (and more selective) to determine the presence of a meteoritic component from the study of the isotopic compositions of the elements chromium and osmium, but these measurements are difficult and time consuming. Nevertheless, rocks from any automatically detected candidates for impact craters need to be checked out for evidence of impact origin.

Automatic crater recognition

Algorithm design

There are two main classes of technique that have been used for the initial detection of crater-like objects on other planetary bodies: pattern matching techniques, whereby a given object is compared to a training set of known objects; and voting techniques, whereby a model is constructed and a given object is scored by how well it fits to the model.

Impact structures on Earth exhibit a far greater degree of variation than impact structures on other planetary bodies in the Solar System. This variation means that the use of a pattern matching technique is not suitable for terrestrial impact structure detection, since the construction of a suitable training set is not possible. Accordingly the study focused on algorithms based on the voting technique.

The key drivers of the algorithm design were:

• that the algorithm chosen should not focus too heavily upon specific crater morphology, since similarly sized craters on Earth's surface can exhibit contrasting characteristics (for example, Barringer crater in Arizona and Tswaing crater in South Africa have a similar diameter, but a very different diameter/depth ratio since Tswaing crater has been partially filled with sediment).

• the need to be able to apply the algorithm to datasets derived using a variety of imaging techniques. Datasets considered for inclusion in the study included those produced by synthetic aperture radar, optical, multispectral and digital elevation data.

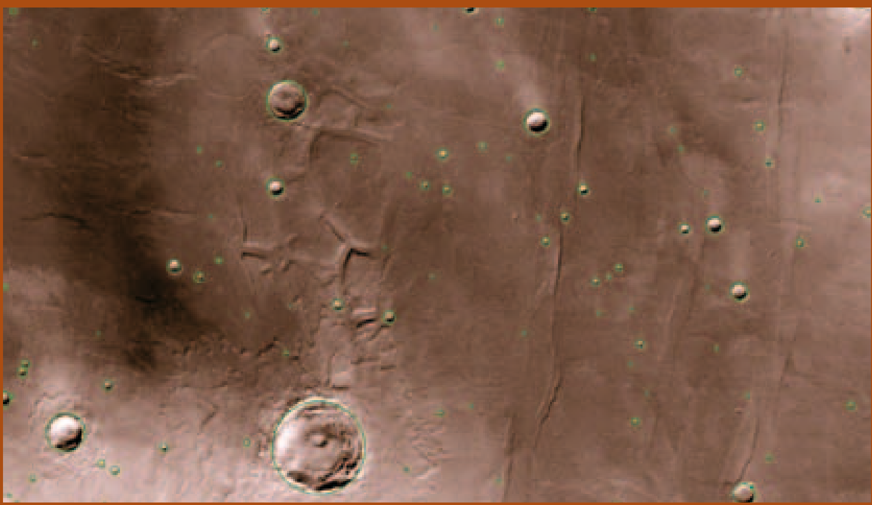
• the need to be able to combine these results to improve the structure detection.

• to leave open the possibility of applying more specific expert knowledge to further improve the efficiency of the structure detection process.

A previous ESA study considered the first two of these issues, and came to the conclusion that terrestrial craters could most efficiently be detected by employing a first order approximation to the shape. Specifically, the general complicated crater structure could be modelled by considering the basic shape to be a circle. This, while an oversimplification, allows a given algorithm to operate on data obtained from different sensors under a range of conditions. The use of this approximation does however reduce the accuracy of the detection process, necessitating the introduction of further steps to reduce the number of false detections.

→ Case Study: Mars Express images

The High Resolution Stereo Camera on ESA's Mars Express is able to image the surface of Mars in 3D and in colour to a resolution of about 2.5 m. These high-resolution images can be embedded within a lower resolution swath to enable the areas imaged to be precisely identified.



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An image from Mars Express of a moderately cratered plateau (61° W, 17° S). The detected craters are highlighted in green. The image covers 29814 km² at 100 m per pixel resolution (ESA/DLR/FU Berlin)

Circular Hough Transform

Paul Hough developed the Hough Transform in 1962 for the identification of lines in pictures. A 'quantised parameter space' is produced, in which each cell corresponds to a possible line in the image under consideration. The transform maps the contents of the original image into this parameter space, by casting a vote in each cell for which a given pixel contributes to the corresponding line. Lines can then be found in the image by counting the votes' peaks in the Hough Transform space describe how likely a given line exists.

The Circular Hough Transform is a variation on this technique whereby a circle is described parametrically and

votes are cast for each cone surface passing through the cell. To improve the results obtained, the algorithm can be applied to an edge enhanced image and the gradient of the edge accumulated in the cell. This gives a measure of the likelihood that a given point belongs to an edge.
After the Hough Transform parameter space has been created, an unsupervised classification can be applied to the parameter space to enable circles to be distinguished. A caveat to this, which needs to be carefully considered for operational systems, is that unsupervised classification algorithms are significantly sensitive to the selected initial seeds and the number of clusters expected. This can have undesirable effects when the density of expected circles is not known.

The Circular Hough Transform does, however, have a number of disadvantages when we consider the detection of terrestrial impact structures – not least of which is that the edge of the crater may not be particularly clear in terrestrial imagery due to erosion and/or vegetation cover.

Radial Consistency algorithm
The Radial Consistency algorithm was developed as part of the study to try and deal with these cases. It models impact craters as having localised rotational symmetry (referred to as radial consistency). This means that the profile, taken through the centre of a circular feature at different angles, has a degree of consistency due to the circular symmetry that is not present for non-circular features. This view of the problem has an additional valuable property over and above techniques that focus solely upon edges: it can be used to pick up more general circular symmetry in land cover patterns.

The Radial Consistency algorithm can be related to the Circular Hough Transform by replacing the test that each pixel (x,y) lies on the circle defined by the triple (a,b,r) with the test that the pixel lies within a region of circular symmetry centred at (a,b). Consequently the peaks in the parameter space {a,b} correspond to the most likely locations of the regions of Radial Consistency in the input image. The most likely radius for the circle centred on (a,b) can then be determined as the radius providing the greatest contribution to the final result.

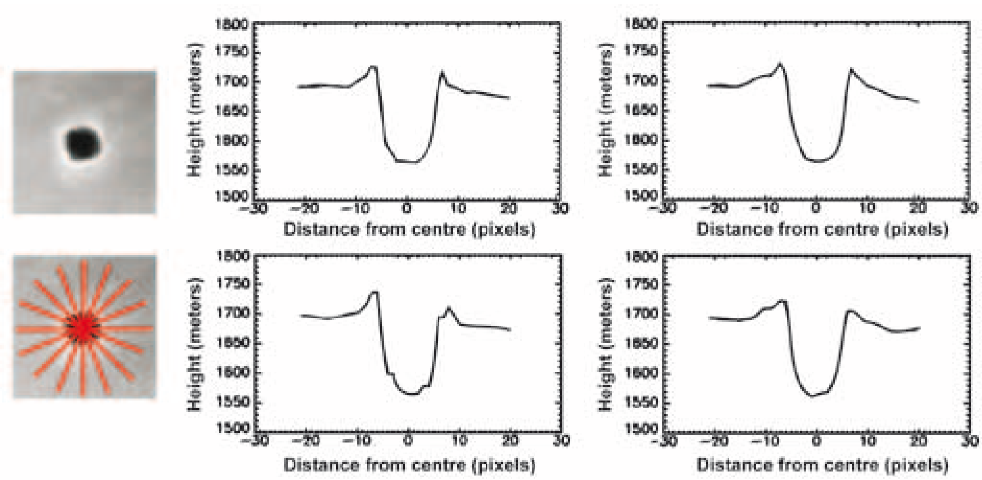
The key difference between the Radial Consistency and the Circular Hough Transform algorithms is therefore that the Radial Consistency algorithm is not applied to an edge-enhanced image, since this edge-enhanced image may well be lacking the very circular patterns the algorithm is attempting to detect. Further advantages of the Radial Consistency approach include the greater ease with which the output two dimensional parameter set can be visualised (as opposed to the multi-dimensional Hough parameter space), and the way with which the algorithm scales with increasing radius: order O(R) as opposed to order O(R2) with the standard Circular Hough Transform.

Data fusion
Terrestrial impact craters exhibit a high degree of complexity, which makes the recognition of all but the most obvious craters difficult when making observations using a single sensor. Accordingly some degree of data fusion (or data combination) is needed to help reduce the number of obvious false positives from the detected data set, the choice of where and how to perform this fusion depends upon the application.

Fusing the input imagery in the data space, i.e. fusing the original imagery may well be a difficult process. The image samples will almost certainly be incommensurate, and hence difficult to reconcile. This type of fusion shows most promise when visualising the data set (e.g. combining SAR or optical data with a Digital Elevation Model) rather than automatic analysis.

The same issue applies in the pre-processed space, if the pre-processing is merely dealing with individual sensor specific issues (such as cloud detection/extraction in optical imagery, or speckle reduction in SAR imagery). To properly begin the fusion process the imagery needs to be transformed into an information space.

During the course of this work the fusion was performed in an information space, which included the Radial Consistency parameter spaces prior to the feature peak detection process. This has the advantage that overlapping areas of high radial consistency detected via different techniques will reinforce one another, while false positives introduced due to



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'Radial Consistency' demonstrated by looking at a digital elevation model of the Barringer Crater (red lines overplotted show the cross-sections sampled in each case). The cross-sections through the centre of the crater are fairly similar, while those through the point outside the crater exhibit a greater degree of variation detector-specific issues will be reduced at the combination stage.

After peak detection has taken place, a further refinement of the results can be obtained by considering the known common properties of terrestrial craters, and by mitigating against known deficiencies in the algorithms employed. This process involves scoring each detected crater candidate against a set of criteria amenable to automatic analysis, including such characteristics as:

- the depth-to-diameter ratio, which for a given planetary body has an experimental maximum. The depth is measured for the purposes of this study using a DEM.
- the height of the crater above the surrounding plain. This can be used to reject some volcanic features.
- checks on the symmetry and visible rim that are possible using the original transform.
- further checks upon the original datasets to ensure that the signal is not due to detector noise, or to specific common terrestrial features (e.g. small circular, or near circular lakes).

Care needs to be taken to avoid specifying rules so tightly that the majority of terrestrial impact craters are automatically ruled out.

Prototype design

One of the main products of the study is a program, written in IDL and using the functionality of ENVI, whose purpose is to allow the rapid prototyping of circular feature detection and crater classification algorithms. The program is designed so that it can be run in two distinct modes:

- A fully featured mode requiring a full ENVI/IDL license. This version is able to manipulate multiple datasets from a wide range of different data sources and run in a batch-processing mode to allow longer, chained, runs of algorithms. This allows the systematic analysis of a wide area comprising multiple satellite scenes.

- A standalone mode that can be run without the need for a full license. This software can only deal with single datasets, and the provided set of algorithms are fixed for a given release. This environment does, however, provide a convenient environment for testing new algorithm variations quickly on small regions of data and can be used to review the results from the full prototype. The ability to run in this mode without the need for a full license also expands the potential user base. Results from the prototype are stored in standard formats, including XML, JPEG and PNG.

Impact cratering on solid planets and satellites is increasingly being recognised, not only as the passive record of marginal events in the early history of the Solar System, but as one of the driving mechanisms of planetary geological evolution, even on our own planet. Spaceborne remote-sensing methods are the best way to discover a large number of still undiscovered impact craters. Automatic recognition algorithms provide the practical means to process the large amounts of satellite data required. ■

Acknowledgements

The Impact Crater Discovery (ICDY) tool project was a study performed under an ESA contract.

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Building C, the Science Operations Building at the European Space Astronomy Centre near Madrid, Spain - home to the Herschel Science Centre

→ A FIRST IN ASTROPHYSICS MISSIONS

The making of the Herschel Science Ground Segment

Johannes Riedinger
Directorate of Science and Robotic Exploration,
ESTEC, Noordwijk, The Netherlands

Although Herschel is a major multi-million euro space observatory, it will be operated scientifically by only a handful of relatively small teams. This is made possible by the Herschel Common Science System, a set of computer applications that have been developed over almost 10 years.

The Herschel Science Centre, based at the European Space Astronomy Centre (ESAC) near Madrid, Spain, conducts scientific operations, with support from three Instrument Control Centres (ICCs). The Mission Operations Centre at the European Space Operations Centre in Darmstadt, Germany, conducts spacecraft operations.

The NASA Herschel Science Centre (NHSC) is part of the Infrared Processing and Analysis Centre (IPAC) at the California Institute of Technology. IPAC is NASA's multi-mission centre of expertise for long-wavelength astrophysics. The NHSC interfaces and supports Herschel users in the USA, contributes to the common software effort, supports the three ICCs with specific expertise and provides a service to Herschel for the observation of Solar System objects.

The three ICCs are associated with the Principal Investigator institutes for the three nationally funded instruments of the Herschel payload. These are the Photodetector Array Camera and Spectrometer (PACS) from MPE, Garching, Germany; the Spectral and Photometric Imaging Receiver (SPIRE) from the University of Cardiff, United Kingdom; and the Heterodyne Instrument for the Far Infrared (HIFI) from SRON, Groningen, The Netherlands.

The ICCs monitor their instrument's behaviour and carry out analyses and calibrations. The Herschel Science Centre plans and maintains the overall scientific schedule of the mission and its scientific products, and the Mission Operations Centre maintains contact with the satellite. There are almost 50 people in the Herschel Science Centre at ESAC, and up to 20 people at each of the ICCs and at the NHSC.

All these centres and the astronomical community interact through a common repository: the scientific ground segment software, known as the Herschel Common Science System (HCSS).

The HCSS handles submission of observing proposals via the internet, scheduling of observations on the spacecraft, generation of commanding requests for the instruments and spacecraft and processing of the resulting scientific data, which are then placed in a web archive for access by the astronomical community. Based on the input and requirements from a number of representative users, the HCSS software was developed by ESA in collaboration with the instrument teams and the NHSC.

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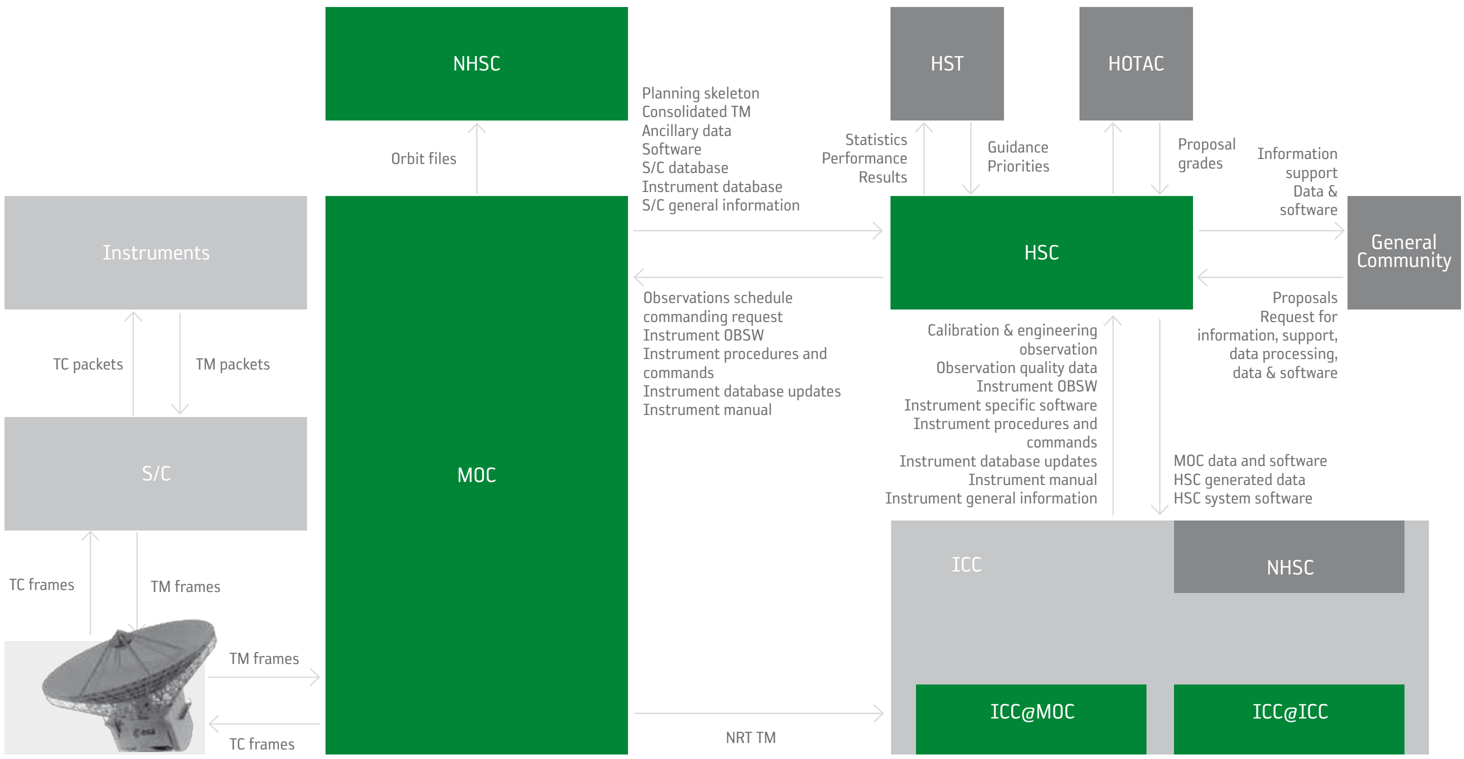
The Herschel Science Ground Segment



Development of the Herschel Common Science System

The development and operation of instruments in scientific satellites requires much software, to support instrument and satellite tests, for calibration and for scientific data gathering and analysis. Traditionally, different software systems are built for different mission phases. To support Herschel, ESA adopted a novel approach: an integrated system for data management and processing. The system allows for continuous reuse of software components over the project's entire 20-year lifespan.

In space missions, reliability and robustness is a prime concern; the software must be extremely well tested and verified. This is especially important for software elements involved with commanding the instruments, as incorrect commands may have – in the worst case, permanent – adverse effects on instrument performance. Since the detailed behaviour of the instrument in flight might change with time, for instance, due to ageing effects or subsystem failures, an essential requirement on all software is that it is not only robust, but also easily modifiable.

> "To support Herschel, ESA adopted a novel approach: an integrated system for data management and processing"

Preparations to define the Herschel operational environment and 'business model' started as early as 1996. These meetings fixed a number of 'goal-posts', one of which was to enforce harmonisation of the check-out with the operational environment. Initially this concept was called a 'seamless', and later more modestly, a 'smooth' transition.

From the very start, the Herschel Science Ground Segment was specified and designed to support this concept, in which an ever-expanding software system would not only support the in-flight mission, but also, as early as possible, instrument component development and instrument-level tests at the institutes of the Principal Investigators and, later in the programme, integrated system tests conducted on the satellite with industry involvement.

The advantages of this concept are obvious: whereas on previous missions, different systems would be used for checkout and operations – which resulted in having to 'port' from one system to another and then retest checkout sequences and procedures – we would only have one single system to accompany all these tests, resulting in software and scripts which are well-tested and fully debugged before launch.

Smooth transition implies a long lead time and, as a result, the ESA team consisted of only around 20 developers. This compares favourably with the more than 80 people who were employed by ESA to ready the Infrared Space Observatory (ISO) mission for launch in 1995.

With years in between major ESA observatory missions, paralleled by advancements in information technology, it was impractical to reuse or carry forward software implementations from one project to the next. However, the right concepts can take you a long way: ESA has flown all Horizon 2000 missions reusing the concepts developed for the first such mission, ISO, which was launched in 1995 and ended operations in 1998.

For their instrument tests, all three Herschel instruments used a combination of ESA's SCOS-2000 system and incrementally expanded versions of the HCSS.

Although the limited functionality of the HCSS did occasionally create some hardship in the early years of characterising instrument parameters, with short turnaround times between tests, this approach of 'smooth transition' has worked well, with instrument Flight Model tests started in 2006.

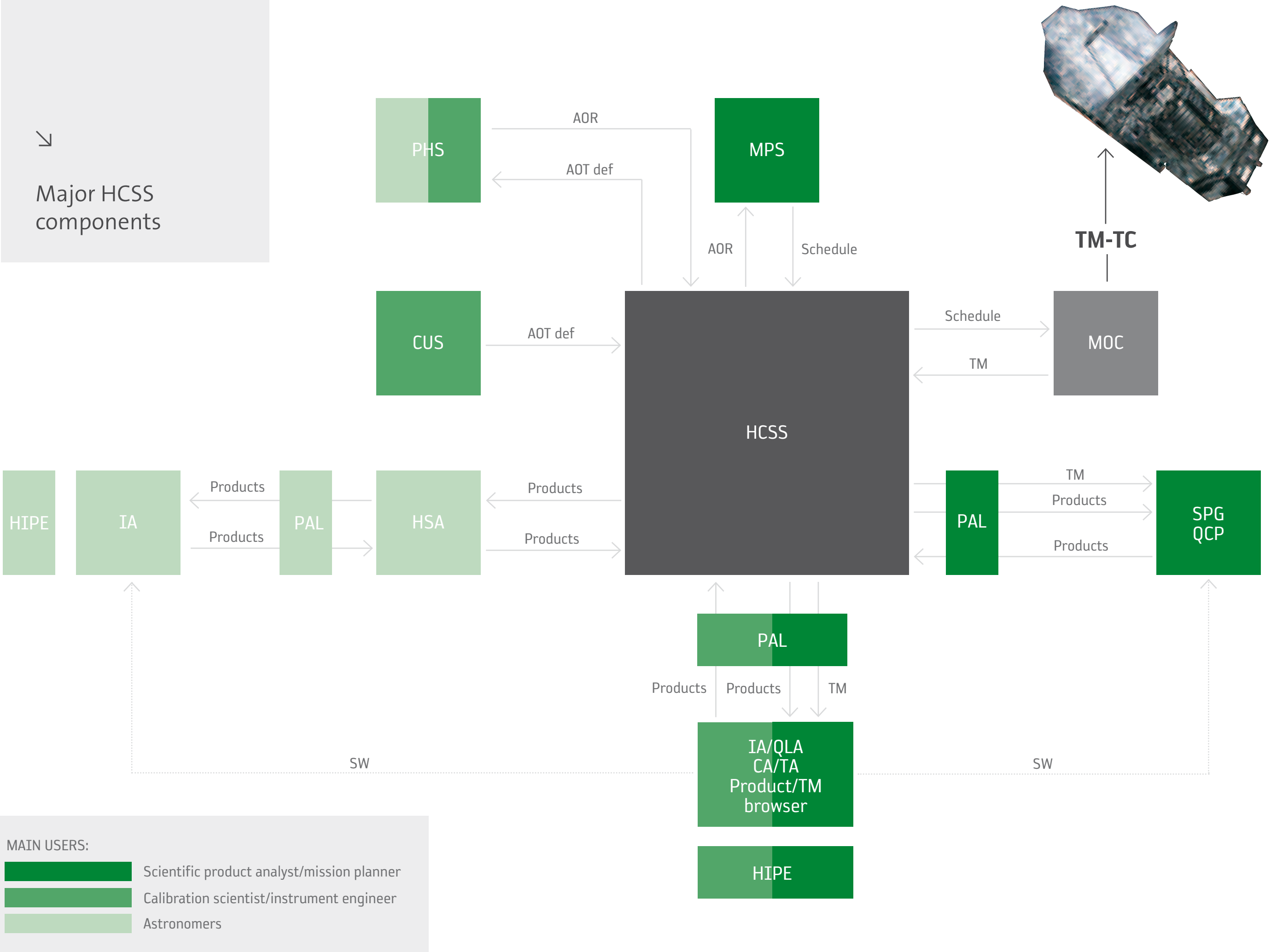
Major HCSS components

When Herschel's instruments are operated, commands are sent to the control computer inside each instrument to execute the steps needed to set it up for a measurement, read out the signals from the detectors and mechanisms and package the read-outs for transmission to the ground. On the ground, the read-outs are converted to values that astronomers can interpret and use for comparison with physical models of the observed region. The HCSS provides the necessary commanding engine, data storage, query engine, retrieval facility and analysis tools for scientific and calibration analysis.

The HCSS consists of:

- A central database that is accessed by most of the applications. As telemetry is ingested into this database at the Herschel Science Centre, these data are also propagated to the relevant ICC so that a local copy is available where the most extensive use is made of the data in terms of providing feedback on instrument health, instrument calibration, etc.
- A Proposal Handling System (PHS) to allow entering, editing and processing of observing proposals. Individual observation requests use Astronomical Observation Templates (AOTs), each of which corresponds to one of several available standard observing modes of each instrument. Entering the parameters requested

↘ Major HCSS components



for a particular observation converts the AOT into an Astronomical Observing Request (AOR) that is stored in the database.

- A 'Common Uplink System' (CUS), which is a scripting language that converts the parameters specifying an observation into a timed sequence of spacecraft and instrument commands.
- A scientific Mission Planning System (MPS), which retrieves AORs from the database, schedules them for observation at a particular date and time using selection criteria and optimisation algorithms that minimise the telescope time that is wasted in moving from one astronomical target to the next. Once the observing sequence has been determined for a given period, normally one day, the observations are expanded into command requests using the CUS and the resulting observing schedules are passed to the MOC for further processing.
- Using instrument-specific knowledge, the Standard Product Generation (SPG) and the Quality Control Pipeline (QCP) convert products – the simplest product being telemetry – into more refined products and some quality information, which reports on possible processing anomalies.
- The Herschel Science Archive (HSA) collects and stores all products and makes them available to searches and retrieval via a web-based interface. After downloading one or more products from the HSA to a local machine, an astronomer can then use interactive analysis to refine a product, e.g. by interactively masking bad pixels or by rerunning pipeline tasks with non-default parameter settings. The Herschel Interactive Processing Environment (HIPE) has been developed to facilitate this kind of work.
- Interactive Analysis is intended for the general astronomer. 'Quick Look Assessment, Calibration Analysis, Trend Analysis' (QLA/CA/TA) are the toolboxes for instrument specialists who generate and improve calibration information, establish instrument trends or update pipelines, for example, through scripts, interactive processing, or a combination of the two.

Herschel Science Centre

The Herschel Science Centre has five major 'customers'.

- The astronomical community, and its quest for scientific knowledge, is the driver for the Science Ground Segment and its development. This community has to be kept informed of relevant events, instrument health and calibration status, relevant software updates, it submits proposals and receives data and products, and it produces the scientific output for a mission which was first proposed more than 25 years ago.
- The Herschel Time Allocation Committee (HOTAC), which screens all proposals and proposes to the Director of Science and Robotic Engineering to award observing time to those programmes that promise to deliver the most relevant science. This group is the 'guardian angel' of efficient use of telescope time, which ticks away at €10 per second (a rate derived from the overall cost of the Herschel programme, divided by the expected lifetime).
- The Herschel Science Team, which has an advisory role in monitoring and guiding Herschel development and operations. Unlike the HOTAC, which directly interacts with

→ A good concept will take you a long way...

A personal view by Johannes Riedinger

About 20 years ago I had the privilege to be part of a small group of engineers and scientists who designed a chain of interfaces that would allow planning information to be passed between a Mission Operations Centre (MOC), which is in charge of all satellite operations and commanding, and a Science Operations Centre (SOC), which has an overriding interest in optimising the use of satellite time by arranging observing sequences in a particular order, especially when a mission is 'consumables limited'. The mission we were preparing was ISO, and the consumable was the onboard supply of liquid helium to cool the focal plane instruments and their detectors.

↙ ISO

This series of interfaces started with a Planning Skeleton File (PSF), in which the MOC would provide the planning rules for a particular period, e.g. identifying orbital events, blocking periods when the satellite is not available for collecting science data or reserving time for ground station activities. Next in this chain would be preparation of a Planned Observations File (POF) and associated instrument activities (Instrument Command Sequences) at the SOC, which would request astronomical observations to be executed in a particular order. This order would optimise some aspects of satellite utilisation, for example by minimising the time taken in 'slewing' from one scientific target to the next over a planning period of typically one day. This POF, once received at the MOC, would then be expanded into a timed sequence of spacecraft and instrument commands.

ISO's POF has been called 'Planned Observation Sequence' on other missions. What once used to be called an 'Instrument Command Sequence File' is on Herschel referred to as a 'Telecommand Parameter File', etc. Conceptually, however, the same series of interfaces has been in use for all ESA astrophysics missions in the Horizon 2000 programme: ISO, XMM-Newton (1999, still operational) and Integral (2002, still operational). Now, 20 years after its inception, we are still using the same concept on Herschel (launched on 14 May 2009 with an expected lifetime of about four years).

Information technology moves fast. On ISO, the programming languages for the Science Ground Segment were C for the uplink, Fortran for the pipelines generating standard products from each observation, and IDL for Interactive Analysis tasks.

At the end of 1999, when the ground rules for the Herschel Science Centre development had to be laid down, object-oriented programming languages, C++ and, in particular, Java with its promise of being (almost) independent of computer operating system and platform, had become the 'state-of-the-art'.

Two questions arose in this context that had to be answered without the luxury of being able to foretell the future: What would motivate good software engineers to join and then hopefully commit to continue working on the same project for many years? Would our customers, the astronomers and the scientists at the Principal Investigator institutes on whose contributions the success of the Science Ground Segment depends, eventually accept and adapt to changes in programming language?

Time is an important element to consider in any attempt at answering these two questions.

> What was a 'gut feeling' 20 years ago, in the absence of a 'role model', has served us truly well.

Twenty years and more can pass between the inception of a satellite and its launch, followed by at least another 10–20 years of satellite operations, exploitation, final processing and archiving of its scientific data. Digesting the still recent 'ISO experience', the first working group meetings to define Herschel operations were convened in 1996, serious Science Ground Segment software development started in January 2000, with a launch in 2009. In a rapidly evolving IT market, these are very long timescales indeed.

Unless developers feel they are given a professional challenge that allows them to further develop their skills and remain attractive in a competitive job market, the continuity of the team, and the quality of the product, may suffer severely. As is evidenced by the very limited turnover this development has seen in terms of contributing software engineers in ESA, going for an all-out Java development from the start seems to have been the right decision, because this contributed significantly to the stability of the team over many years.

In terms of acceptance of the object-oriented languages by contributing scientists at the Principal Investigatorn institutes, the picture is a little different. While acceptance by younger astronomers is becoming more widespread, a number of individuals have had, and some continue to have, significant problems with this approach. There is no doubt that parts of the Herschel community of users will export their science data as soon as possible into a format (Flexible Image Transportation System, FITS) that makes this data accessible with tools other than the Herschel Data Processing System, e.g. Class, IDL or DS9.

Indeed, we explicitly support this option of exporting the data for processing by other tools at practically every processing step. Only time will tell how large a fraction of the astronomical community will process all their data within the confines of the Herschel Data Processing System; the best we can do is to provide as powerful, flexible and attractive a system as we can to win large parts of the community over into using the tool Herschel provides free of charge and license fees.

Thus, while we are extensively re-using 'concepts' that have proven useful on previous missions, we are not re-using any of the software ESA has developed for previous missions. This is not to say, however, that some people cannot or will not apply legacy code they may have from similar missions (ISO, Spitzer) in reducing their Herschel data.

> **All these components were designed for the operational phase and their use in instrument testing shows that foresight has already paid off.**

proposed observations, the Science Team helps to optimise the mission's scientific return by making appropriate policy decisions.

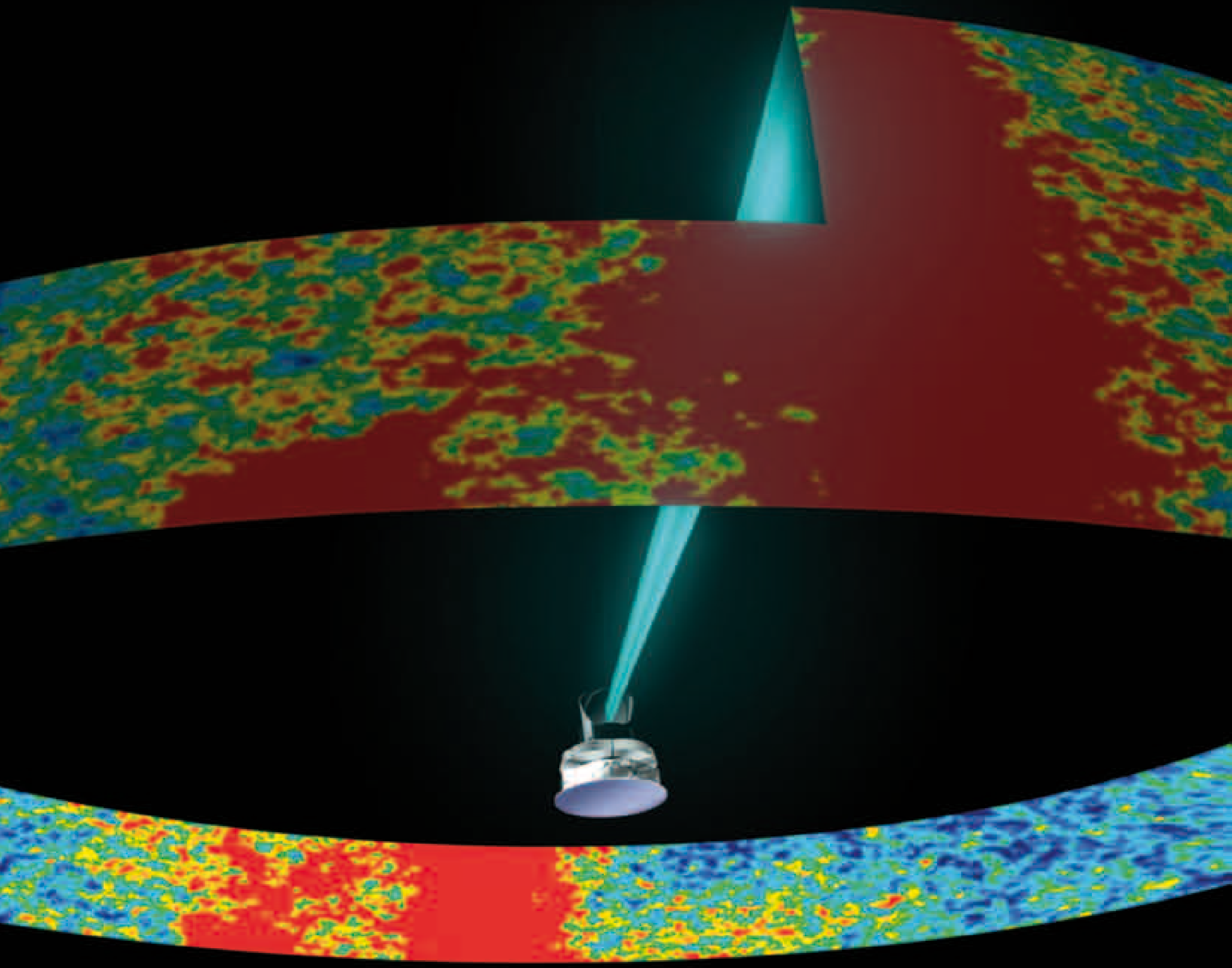
- The Mission Operations Centre at ESOC.
- The ICCs, in charge of instrument health and calibration.

Over the past years, large parts of the HCSS have been implemented by a joint team of some 50 full-time developers from the instrument teams and ESA, distributed over many locations around the world. Ten years after its original inception and at least two years before its true operational use, the HCSS and its development concepts were already proven to be successful. Instrument tests have been supported by using HCSS functionality for instrument and test support equipment commanding, for data storage and retrieval and for data processing. All these components were designed for the operational phase and their use in instrument testing shows that foresight has already paid off.

Herschel and Planck were launched from the European Spaceport in Kourou, French Guiana, on 14 May 2009. By 6 June, Herschel spacecraft and instrument commissioning activities had reached about 50% completion and, so far, not one serious anomaly has been found in either the ground segment or the spaceborne part (now 1.2 million km from Earth). With the progress we are making, we have good reason to look forward to years of scientific exploration of the Universe, in a mostly unexplored wavelength region at high resolution, obtaining insights that will significantly enhance our understanding of how the Universe came to be. ■

Acknowledgements

Many dedicated engineers and scientists, within and outside ESA, have contributed to bringing the Herschel Science Ground Segment together over almost a decade. The author thanks these colleagues. Thanks also to Peter Roelfsema, SRON Netherlands, for excerpts from his article 'Designing for Software Reuse – The Herschel Common Science System'.



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ESA's Planck satellite scanning the sky as it spins in its orbit

→ HOW WE MAP THE FIRST LIGHT

The Science Ground Segment of Planck

Damien Texier
Directorate of Science and Robotic Exploration, ESAC,
Villanueva de la Cañada, Spain

For any space mission, the 'ground segment' is vital for operating a spacecraft and processing data received from its instruments. Planck is no different, with hardware, software, telecommunications and other operations reaching from Spain to Australia.

The Planck satellite will observe the Cosmic Microwave Background (CMB), which is the cooled remnant of the light emitted around 400 000 years after the Big Bang, when hydrogen atoms combined and the Universe became transparent. It will measure the temperature variation across this microwave background with much better sensitivity, angular resolution and frequency range than any previous satellite. By observing the 'oldest' detectable radiation, Planck will be seeing the Universe as it was almost at its origin.

The ground segment of Planck is composed of the Operations Ground Segment, comprising all the elements under the responsibility of the European Space Operations Centre (ESOC), which includes the Mission Operations

Centre, the ground stations and the communications network, and the Scientific Ground Segment.

The latter is distributed between the following centres: the Planck Science Office, taking care of the scheduling of the survey strategy, and the two instrument teams' Data Processing Centres and Instrument Operations Teams, responsible for each instrument to process the telemetry and monitor the instrument operations respectively. The 35 m deep-space antenna at New Norcia in Australia is the prime ground station for Planck, with Cebreros in Spain as back-up.

DPCs and IOTs

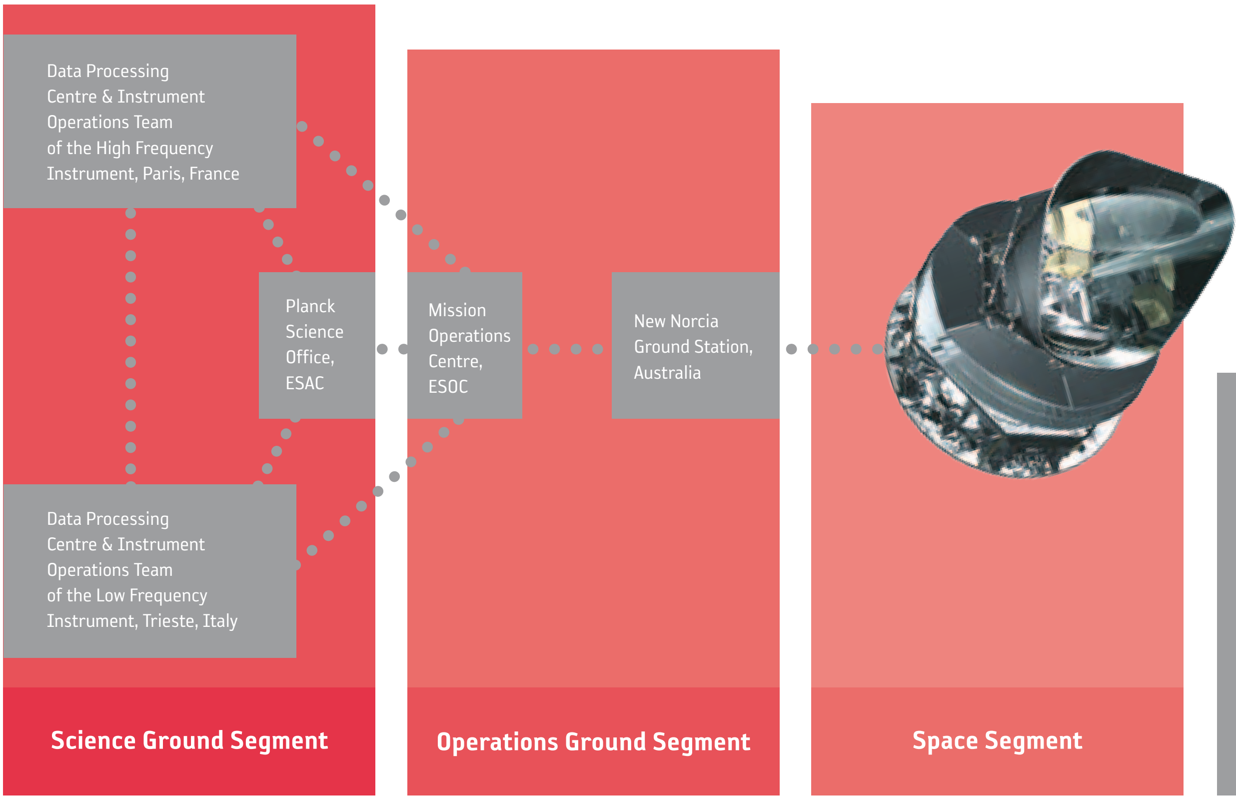
Planck carries a 1.5 m telescope which focuses radiation from the sky on two arrays of highly sensitive radiodetectors, the High Frequency Instrument (HFI) built by a consortium of scientists led by the Institut d'Astrophysique Spatiale in Orsay, France, and the Low Frequency Instrument (LFI), led by the Istituto di Astrofisica Spaziale e Fisica Cosmica (IASF) in Bologna, Italy.

For each of these instruments, two operational centres have been put in place. The first one is the Data Processing Centre (DPC), responsible for (i) taking the raw payload telemetry received at ESOC, (ii) processing the telemetry until the generation of the final scientific products to be delivered to the Planck Science Office, (iii) providing the infrastructure, tools and resources for supporting the scientific data analysis during the proprietary phase and (iv) the operation and maintenance of a software maintenance facility.

The second one is the Instrument Operations Team (IOT) responsible for (i) commanding, calibrating and monitoring the instrument to ensure the optimum payload configuration is used, (ii) daily assessment of instrument health and (iii) providing payload expertise when needed for operations.

→ The deep-space station at New Norcia in Australia is the prime ground station for Planck

For HFI, the DPC is at the Institut d'Astrophysique de Paris in France, and the IOT is at the Institut d'Astrophysique



← Elements of the Planck Ground Segment

Spatiale in Orsay. For LFI, both the DPC and the IOT are at the Osservatorio Astronomico di Trieste, Italy.

Planck Science Office

The Planck spacecraft is spinning at a constant rate of one revolution per minute, and the line of sight of the telescope is at an angle of 85° to the spin axis, so that the observed sky region will trace a large circle on the sky. As the spin axis follows the Sun, the circle observed by the instruments sweeps through the sky at a rate of 1° per day.

Planck will take about six months to complete a full scan of the sky, charting two complete sky maps during its nominal lifetime (about 15 months). To maximise the sky coverage and optimise the science output of the mission, it is possible to change the spin axis while staying away from pointing at the Sun, Earth and Moon (called the 'survey strategy').

The Planck Science Office, located at the European Space Astronomy Centre (ESAC), near Madrid, Spain, is responsible for the scheduling of the pointing to be followed by the Planck spacecraft in order to implement the agreed survey strategy. This is done using the Survey Planning and Performance Tool (SPPT) developed by the PSO. This tool can simulate a given scanning law (i.e. a set of spin axis pointings) over a period of time to plan the course of the survey.

During operations, the Planck Science Office will continuously monitor the progress of the survey by visualising the accumulated coverage and quality of the Planck survey at any time in the mission. This will allow the Planck Science Office to quickly trigger the recovery of gaps in the survey coverage before the area ceases to be visible, as well as to carry out longer term modifications in the plan geared to improve the mission output.

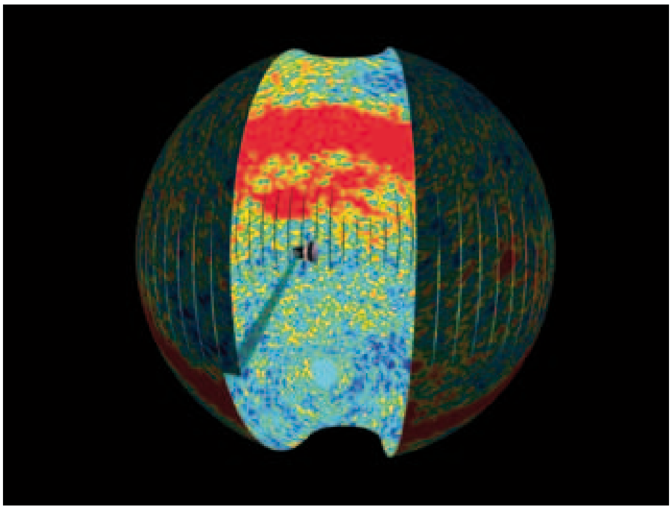
The Planck Science Office is also responsible for a number of coordination activities within the Science Ground Segment, for example, to: a) establish and maintain the scanning law in order to survey the sky is as efficient and effective a manner as possible, b) support the Instrument Operations Teams in maximising the scientific value of the data acquired by the Planck spacecraft and instrument, c) support the efforts of the DPCs to process the science data acquired by Planck and the usability of this data within the scientific community, and d) lead the preparation and execution of the calibration to be performed by the Planck payload prior to the start of the survey operation in order to tune the instruments in their optimum setups.

ESAC will also develop and host the archive system to be used during operation to exchange the data among all the groups involved in the data analysis effort (the first exchanges of data between the DPCs are planned around six months after launch with the data of the first three months), and after operations to become the Planck Legacy Archive. From here, Planck data will be made available to the worldwide scientific community (to be used at the expiration of the proprietary period of two years after the end of the nominal operations phase). These archives are developed by the Science Archive Team at ESAC based on the experience and technology used for the other science archives (ISO and XMM-Newton, for example).

Science Ground Segment operations

The nominal routine phase of the mission will last 15 months (allowing the sky to be surveyed twice) and can be extended by another 12 months. The Planck Science Office provides to the MOC in Darmstadt the sequence of pointing to be followed by the spacecraft in order to perform the surveys.

Although the Planck payload configuration is kept as stable as possible during the surveys, it is expected that some limited instrument commanding will be needed. The HFI and LFI IOTs are responsible for giving the MOC the detailed instruments commanding required. MOC will then take the pointing information from the Planck Science Office and the payload commands from the IOTs to generate the timeline to be uploaded every day to the spacecraft via the New Norcia ground station in Australia.



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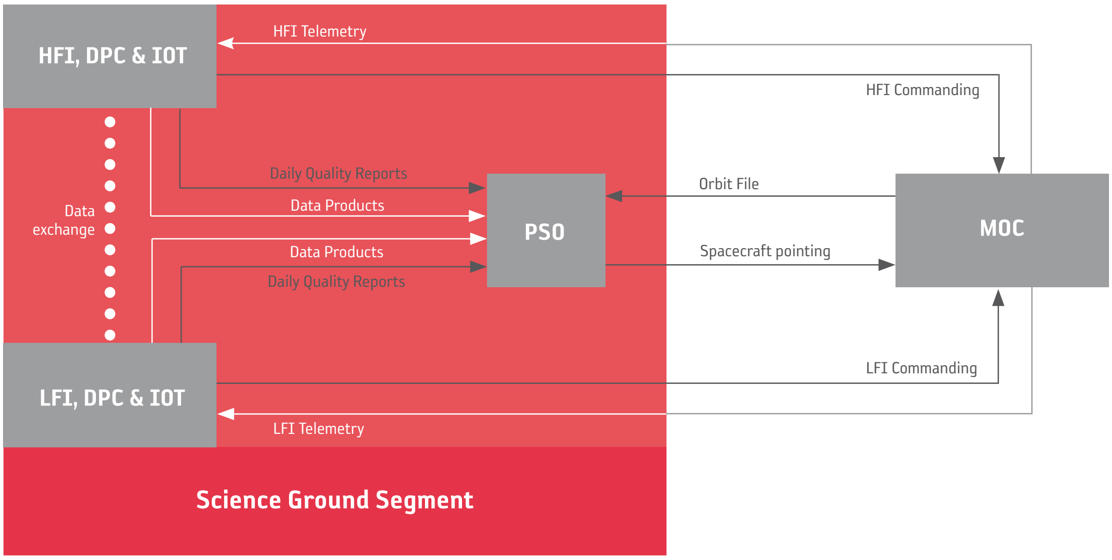
How Planck builds up its survey of the sky – completing two sky maps in 15 months (rotating 1° per day)

The telemetry downloaded each day during a ground station pass is made available at the MOC from where it is retrieved by the DPCs. The data processing is carried out by the DPCs in several steps, the first being the assessment of the performed observations. A report indicating the quality of all the performed pointings is generated every day by the DPCs and sent to the Planck Science Office.

Based on these reports, the Science Survey Planning and Performance Tool (SPPT) will be used to assess the survey quality and coverage and trigger when needed changes such as the recovery of the pointings which have not been observed. The data processing at the DPCs continues with the generation of the data products that will be ingested



Interfaces in the Planck Science Ground Segment during operations

in the Planck Archive at ESAC, from where they are made available to the scientific community.

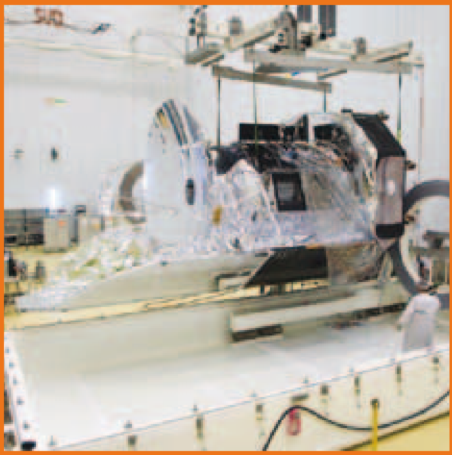
The various elements of the Planck Science Operations Ground Segment completed their development at the end of 2008, culminating in the validation of all the processes and interfaces during the System Operations and Validation Test (SOVT) and declaring it ready to support Planck mission operations.

Acknowledgements

The author would like to thank everyone involved in developing and testing the Planck Science Ground Segment in the HFI, LFI, PSO and MOC teams.

→ HERSCHEL/PLANCK AT KOUROU

→ HERSCHEL/PLANCK



12 February - Herschel: Arrival at Kourou and unpacking

15 February - Herschel: Cleaning the primary mirror with carbon dioxide snow

4 March - Herschel: Helium filling

6 March - Planck: Cleaning under ultra-violet light

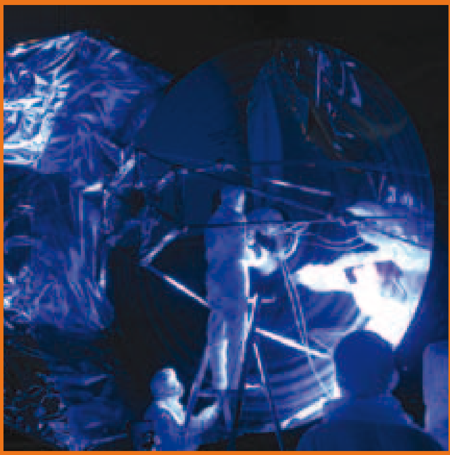
10–11 April - Herschel: Hydrazine fuelling

27 April - Planck: SYLDA support structure in place between Herschel and Planck

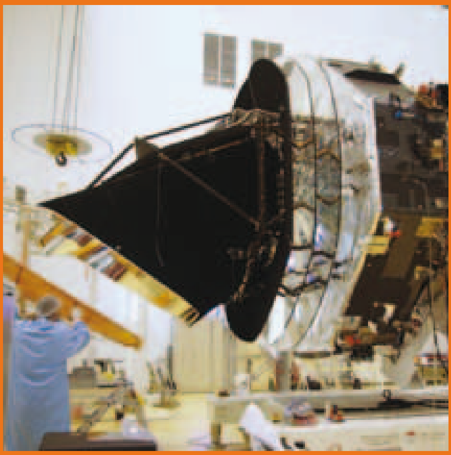
30 April - Herschel: Lowering into place on top of SYLDA

10 May - Herschel: Final view before fairing closes

The launch campaign in pictures
11 February – 14 May 2009

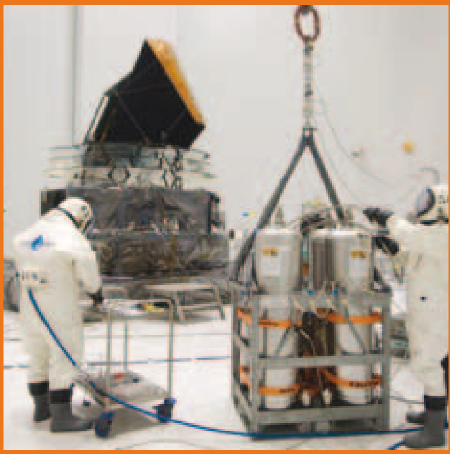


17 February - Herschel: Cleaning under ultraviolet light

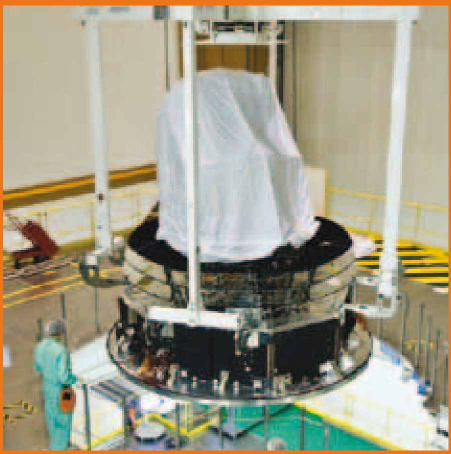


26 February - Planck: Removing the cover of the telescope

27 February - Planck: Integration of solar array



15–16 April - Planck: Hydrazine fuelling

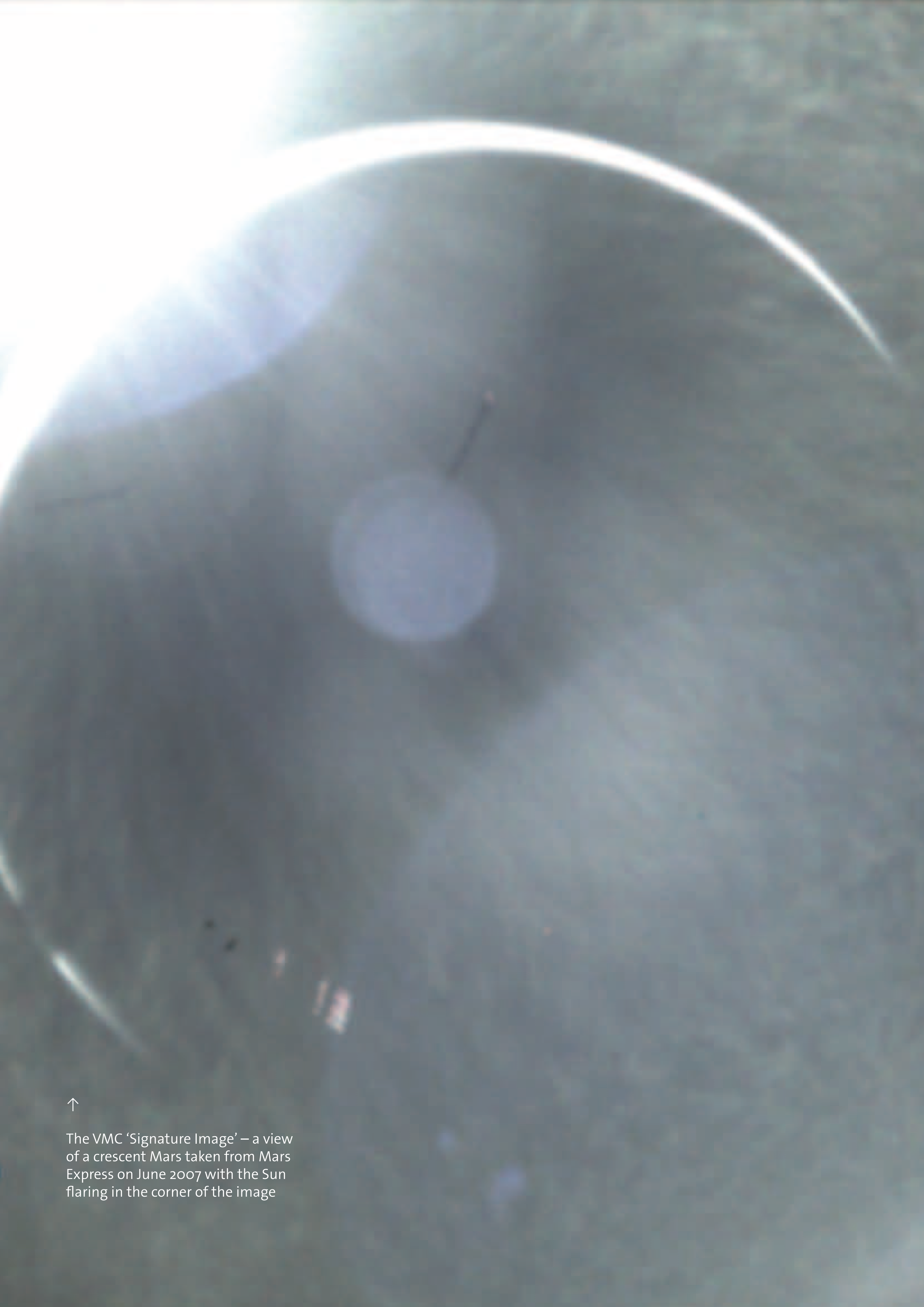


23 April - Planck: Lowering onto launcher

23 April - Planck: Integrating with launcher

13 May: Ready for roll-out to launch pad

14 May - Herschel/Planck: Launch



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The VMC 'Signature Image' – a view of a crescent Mars taken from Mars Express on June 2007 with the Sun flaring in the corner of the image

→ ORDINARY CAMERA, EXTRAORDINARY PLACES

Visual Monitoring Cameras in the ESA fleet

Michel Denis, Thomas Ormston & Daniel Scuka
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ESOC, Darmstadt, Germany

David Jameux
Directorate of Technical and Quality Management,
ESTEC, Noordwijk, The Netherlands

Olivier Witasse
Directorate of Science and Robotic Exploration,
ESTEC, Noordwijk, The Netherlands

When everything is going well on a space mission, the silent routine of a well-operated spacecraft can present a challenge to public relations and outreach activities. ESA's Mission Operations teams seem to have a solution.

ESA's Mars Express team found that the routine nature of the work not only affected outreach possibilities, but also people working in mission operations. They decided to revive the Visual Monitoring Camera (VMC), a small camera that was used to provide visual confirmation of the Beagle 2 lander separation. After this event, no further use of the camera was foreseen, but the team realised it still held potential interest for the public. By recommissioning the camera and using it to image the spacecraft's environment in orbit around the planet Mars – a dynamic, interesting and interactive new view of spacecraft operations was created and shown to the world.

History of VMCs on ESA missions

The purpose of external spacecraft monitoring is to provide feedback of spacecraft status during deployment of antennas, instrument booms or solar arrays, for example. The classical approach, using indirect information collection from sensors, becomes limited when spacecraft and space stations are getting larger and more complex, or when technical constraints prevent traditional measurements (as in the case of the Beagle, there was no telemetry link).

A new approach had to be found using visual systems for direct confirmation of spacecraft conditions to complement the classical methods. The use of visual monitoring gives additional benefits, such as detection of structural deformation, in-orbit spacecraft surface damage analysis and failure diagnostics.

Since visual information is used for monitoring the spacecraft, the same system can also be used for taking pictures of events, such as separation of spacecraft from launcher, or planetary probe from spacecraft. Pictures of the launcher and spacecraft in orbit with Earth in background are appreciated by the general public and provide the first visible results from a space mission.

VMC Project: first initiative

The first visual monitoring system that was developed for ESA was the Visual Telemetry System (VTS). It was designed for an Earth observation mission, for a spacecraft that had many antennas and booms. The VTS cameras were based on an already existing Active Pixel Sensor system dating from 1995, which was not designed with space applications in mind. Therefore, the VTS required a separate unit to interface the cameras to the spacecraft and to perform image compression.

In the end, the system was not installed on the Earth observation spacecraft due to integration and schedule difficulties. However, in 1997, a VTS acquired and transmitted near-real time images from the separation between the TeamSat satellite and the upper stage of the Ariane launcher on flight 502. The images produced were used on ground for the analysis of the launcher's upper stage behaviour.

The benefit of a visual monitoring camera was proven, but the overall system and camera size was still too big, which was not ideal for future spacecraft design. The goal for the next development was to produce a smaller standalone camera that could be directly interfaced to the communication subsystem of a spacecraft.

A view of XMM-Newton

The first application to use a new compact design, based on a CMOS sensor dedicated to space purposes, was the Visual Monitoring Camera (VMC) on board the XMM-Newton spacecraft. Its objective was to observe the deployment of the solar arrays and the sunshield, with a secondary objective to provide visual feedback for public relations purposes.

It took about a year to develop and integrate the VMC on XMM-Newton. This time though, the camera was interfaced directly to the instrument controller. To enable large images to be sent to the ground, image frames were buffered to allow low-rate readout of pixel data by the data handling system. Two cameras using different types of sensor were placed outside the spacecraft's focal plane assembly, giving two views along the telescope tube towards the service platform and the solar arrays.

On 10 December 1999, XMM-Newton was launched on the Ariane 504 flight. About five hours after launch, the cameras took pictures of the left and the right solar array assemblies. The cameras confirmed information about the status of the solar array deployment, achieving their primary objective.

During early orbit phase manoeuvres, they also took pictures of XMM-Newton's thrusters in action. Detailed analyses of

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A VMC camera, of the design flown on XMM-Newton, Cluster and Mars Express

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A plume of thruster exhaust is seen by the XMM-Newton VMC during a thrust firing

↘ The VMC of XMM-Newton captures the fully deployed arrays of XMM-Newton with a backdrop of the Earth

those pictures could help propulsion engineers to better visualise the expansion of the gas cloud at the exit of thrusters. Outgassing close to the service platform was also clearly observed as the outer skin of the telescope tube was initially inflated and gas leakage occurred as it deflated.

The new practice of placing visual monitoring cameras on spacecraft gave the opportunity to see views are not normally seen, such as spacecraft outgassing and thrusters working in space, which are very rare occurrences.

Watching Cluster's space dance

Another VMC, extended with a dedicated 27-image memory module, was integrated with the upper spacecraft of the second pair of the Cluster four-satellite fleet. After launch of the second pair in August 2000, the VMC captured the separation of the Rumba and Tango satellites. It captured a sequence of images showing first the spinning Tango against a beautiful blue-white Earth background in contrast with black of the deep space, then the 'dance' continued above the Nile delta.

→ Sequence of colour VMC images on Cluster, showing the separation of spacecraft 1 and 4, Rumba and Tango

Watching the Beagle

One of the most recent ESA missions with a VMC installed was Mars Express. It was mounted on the spacecraft to take colour snapshots of the Beagle 2 lander during separation. The VMC was located on Mars Express so that it could see through an aperture in the upper panel where it had a view of the underside of the Beagle 2 probe. It could watch the probe drift away after separation, but Sun illumination determined the exposure settings that had to be programmed to allow separation monitoring.

In December 2003, Mars Express released Beagle 2 as planned and VMC images clearly showed Beagle 2 on its journey towards the surface of Mars, where it was expected to land early in the morning of 25 December 2003.

Extended mission for the Mars Express VMC

After three years of exciting science operations with main focus on the high-range payload instruments and no VMC operations, the decision was taken to study the possibility of reviving the VMC camera in a completely different role. With its wide field of view and unique location (for a 'webcam') around the planet Mars, it provided a very attractive prospect to ESA public relations and even of interest to the science community.

However, since it had never been considered to revive the camera, it was like starting from scratch with a new instrument. No routine planning or data analysis tools existed and the ability of the camera to image anything like a planet was not known. A commissioning campaign was initiated at the end of 2006 to test the camera's abilities and the planning and data analysis processes that would be needed to successfully operate it.

The camera is relatively basic and did not have a great deal of parameters to test in the commissioning phase. The two primary parameters are the number of images to be captured and the exposure time. The exposure range of the camera runs from 0.4 milliseconds (ms) to 95.8 seconds. A spread right across these ranges was tried but it was found

↑ One of a sequence of images of Beagle 2 captured by the Mars Express VMC, showing the lander separate from Mars Express in 2003 that the planet was much brighter than expected and overexposed at all but the shortest exposure times.

From this, the team determined that the camera, which has sensitivity similar to ISO 50 film, had an optimal set of exposure times of 0.4 ms, 2.8 ms and 14 ms. The test campaign was conducted quickly and with complete success, giving the green light to routine operations.

A new and busy life

The next step was to automate the VMC observations and schedule them so as to avoid any impact on routine science. VMC observations made little impact on power and data storage. At only 3W, the VMC uses negligible power compared to other equipment. In terms of data usage, one VMC image is only about 300 Kb, although many images could still use up a significant amount of space. The numbers of images captured were therefore limited by the available downlink time.

This also limits the VMC commanding; priority in the spacecraft's command buffer must first be given to routine operations. The most limiting constraints are the spacecraft pointing and the spacecraft data bus. The VMC is not aligned with the axis of the other instruments so a special pointing type had to be created and there had to be room in the overall pointing plan to insert the VMC pointing and associated spacecraft movements (or 'slews').

On the spacecraft data bus there was a constraint too, because the VMC has a very basic data transfer mechanism and cannot interleave its data traffic with other instruments. It instead monopolises the spacecraft data bus. Because data and commands for other instruments would be blocked, the VMC could only observe when the others were off.

With all payloads in regular and intensive operation, these constraints left only a small 'window' after spacecraft thruster activities (the thruster plumes are too contaminating for the other instruments). This one-hour window is at the orbit apocentre, which limits the VMC to high-altitude full disc observations of Mars. The frequency of these windows is about once per day but, combined with other constraints like Earth communications, there are about one to three VMC observations per week.

After analysis of the timeline one or two months before the observation (in the medium-term planning cycle), the VMC pointings are scheduled and the entire mission plan is rerun to make sure there is no side-effect on other instruments. The VMC Toolkit software, developed by the operations team, produces operations request files for the approved windows.

As for all instruments, the planning system transforms the requests into command files. They are in turn loaded on board the spacecraft and autonomously executed. Each observation captures images, running a loop of four different exposure times to ensure at least one correctly exposes the planet. The planning office also plans the downlink of the data, initially stored in the onboard mass memory. After downlink, the VMC operator processes runs of the VMC Toolkit that automatically extracts the raw data and saves images as standard PNG files. The software then automatically connects to the VMC website and uploads the files for the public. For webcam use, this chain is designed to make available the most recent images of Mars.

> **"VMCs give the world a new view of Mars every week, and show intriguing properties of our spacecraft."**

New benefits from Mars Express

From the start of the recommissioning of VMC on Mars Express, the main aim was to reuse the camera as a public relations tool, to try and bring space-interested members of the public closer to the world of space science and engineering at ESA. The concept was to provide full access to the images and raw data from our 'webcam' at Mars, as soon as these could be made available.

Outreach results

Public communications, through specialised web pages on the main ESA web portal, have been another element in the 'Mars Webcam' success. The site hosts each new VMC image set and provides extensive information about the camera and the Flight Control Team's camera activities.

It also provides an open invitation to the general public to view the images, download the raw data sets and 'support the Mars Express Flight Control Team' by processing the images into animations, collages, triptychs and false-colour/true-colour outputs. Each image set is published along with the relevant Celestia data file, so that anyone can determine where Mars Express was located when the images were taken (*www.esa.int/vmc*).

The best submissions from the public are republished on the website under a special 'VMC public gallery'. Visitors are also challenged to perform their own analysis, and provide feedback and commentary on what they see, whether any surface features can be identified and if any atmospheric phenomenon can be described.

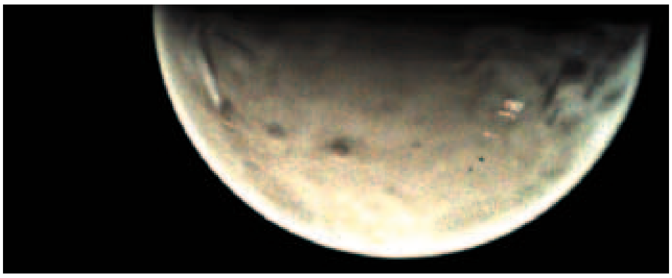
Between August 2008 and early March 2009, the VMC web site generated over 283 000 page views, second only to the ESA Careers web pages in traffic and more than one-third as much again as the main Mars Express site in the ESA portal. There are hundreds of permanent links to the site in popular search engines, and the site has attracted much positive attention from bloggers, space enthusiasts, amateur photographers and students. The VMC site is considered to be a significant success, providing excellent outreach to a often-overlooked audience of tech-savvy space enthusiasts.

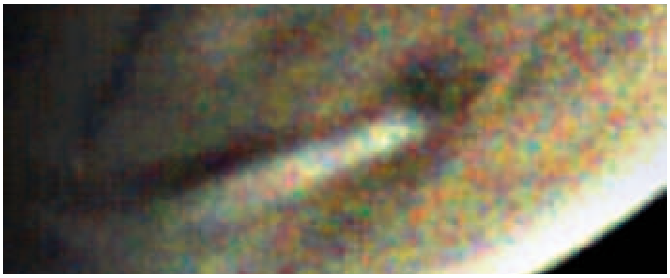
In March 2009, the VMC site was restructured to make the updated image sets more accessible, easier to find and link to, and to enable easier feedback from the general public. VMC images can now be uploaded via the Mars Express Mission Control System and automatically posted into the new site.

Science results

Besides its use as the 'Mars webcam', the VMC can also take images of interesting Martian atmospheric phenomena, potentially useful when studied with the other instruments on Mars Express in a coordinated way, the focus here being on clouds and the polar vortex. As in any planetary atmosphere, clouds represent an important feature and are a key element to understand the climate. On Mars, water and carbon dioxide clouds have been detected. New results on that topic have been brought by a number of Mars Express instruments: the imaging spectrometer OMEGA, the ultraviolet spectrometer SPICAM and the High Resolution Stereo Camera.

The VMC can provide additional information on the clouds, when the other instruments are not operating, thanks to a combination of a wide field of view (40 x 30 degrees) and operations at apocentre far from the planet. More





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The Mars Express VMC took a series of 34 images during a 30 minute observation on 2 July 2009, from a distance of 6500 km. They show what appears to be an extremely long thin cloud trailing from the peak of the volcano Arsia Mons (north pole is at top right, south pole is bottom left). The three dark spots on the left are the three Tharsis Montes, left to right: Arsia Mons, Pavonis Mons and Ascraeus Mons, and the cloud runs diagonally from Arsia Mons to the top left (see the close-up)

specifically, the VMC gives information on the cloud morphology. VMC and Rosetta images of elongated clouds on Mars at different wavelengths can be used to infer how these clouds formed from their shape.

As an example, the observation of clearly round clouds supports the hypothesis that they result from convection. Other useful pieces of information include the location of formation, frequency and the temporal evolution of a cloud. Last but not least, the observation of shadows from the VMC enable the analysis of the cloud altitude and opacity. The Mars Express OMEGA team presented scientific results including VMC images at the 'Mars Atmosphere: Modelling and Observations' workshop in November 2008.

Atmospheric polar vortices are being studied not only on Earth, but also on other planets of the solar system. These features are possible controlling factors in key climate processes. Although the scientific potential of its images is not yet fully demonstrated, VMC can provide interesting views of the polar vortex of Mars may be compared to views from on Earth, Venus, Jupiter and Saturn.

Certainly, there are other scientific areas where the contribution of the VMC can be useful. We will try in the near future to detect meteors in periods of 'meteor showers', when Mars travels through streams of cometary debris.

In-orbit visual monitoring of a spacecraft has been demonstrated successfully on four ESA missions. The VMC concept is a valid one that will hopefully be added to more and more missions as the cost, mass, size and thus design impact of such systems decrease.

These cameras, while useful for their primary purpose, can be a success in public relations, outreach or even auxiliary science data gathering. While the VMC on Mars Express takes pictures of Mars and the one on XMM-Newton showed intriguing properties of the spacecraft, other VMCs could give similar views and insights into our planet or give engineering students monitoring capabilities over space mechanisms.

To further reduce the mass of the cameras, we need to address the mechanical implementation in addition to the reduction of the number of electrical components. Combining the two approaches, mechanical and electrical miniaturisation will lead to cameras that carry a small overall cost overhead and design impact when integrated on a spacecraft.

The VMC on Mars Express follows in the traditions of the Mars Express mission, being based on design and component reuse from previous missions. VMC continues this by leaving no resource unused, from the camera itself to time on board when other instruments are not operating. The VMC operations have been implemented with largely existing tools and at no cost for the mission. Although no match for the word-class science instruments on Mars Express, the VMC gives the world a new and different view of Mars every week and encourages everyone to get involved with Europe's exploration of the 'Red Planet'. ■

→ ESA'S WINDOW TO THE UNIVERSE

The European Space Astronomy Centre

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A 'centre of excellence' for space science and ESA's hub for science operations, the European Space Astronomy Centre (ESAC) is the home of ESA's space telescope and planetary missions.

Located 30 km west of Madrid, ESAC hosts the science operation centres for all ESA astronomy and planetary missions together with their scientific archives. This is where their science operations are conducted, and where all the scientific data that they produce are archived and made accessible to the world.

Other activities are carried out at ESAC including: contributions to the ESA Tracking Stations Network (ESTRACK), with a special link to the nearby Cebreros 35 m ESA deep-space ground station; the new SMOS Earth observation satellite (expected for launch in November

2009) ground data processing and payload operations centre; a new ESAC Education Office, which is in charge of several ESA corporate education activities, with links to all ESA Directorates.

There is also the Laboratory for Space Astrophysics and Fundamental Physics (LAEFF), part of the Spanish National Institute for Aerospace Technology/Spanish National Research Council (CSIC-INTA) Centre for Astrobiology, and which is an innovative research facility aimed mainly at encouraging young Spanish scientists to enter the fields of astrophysics and fundamental physics.

The origin of ESAC dates back to 1974, when an agreement was signed between ESRO and Spain to create a satellite tracking station, Villafranca-Spain (VILSPA), and a scientific operations centre (SOC) for the International Ultraviolet Explorer (IUE). In 1994, the SOC for the Infrared Space Observatory (ISO) moved there, followed in 1999 by the XMM-Newton SOC, which became the main activity group of the centre.

In 2002 ESA launched the 'Villafranca Project', with the objective of proposing new activities to consolidate the centre, in line with an increased Spanish contribution to ESA. On 8 April 2004, following the Director General's decision, VILSPA became the European Space Astronomy Centre, ESAC, and a few months later the post of Head of ESAC was created. From 2005 to 2008 ESAC grew rapidly, increasing the number of staff and improving significantly the facilities.

Currently about 300 people work at ESAC; mostly engineers and scientists. The centre is growing both in numbers of people and activities, and has just reached (July 2009) the establishment status. One of the main future activities for the centre is the management of the new ESA Space Situational Awareness preparatory programme, recently approved during the last ESA Ministerial Council in November 2008.

Science operations: a centre of excellence

ESAC has always been at the forefront of delivering science data from space missions to the user communities, with its activities dating back to the 1970s when it was home to the IUE satellite team. Until the early 2000s, the centre usually only had one main satellite to support (initially IUE, then ISO, then XMM-Newton).

However, ESAC has now developed into a multi-satellite science development and operations centre for both astronomy and Solar System missions, as well as the home of ESA's science data archives and Virtual Observatory efforts.

It is now the pivotal location for the science operations of the Directorate of Science and Robotic Exploration missions.

The science operations are key to getting the science out of each mission. These involve most or all of the following elements together with associated software (and procedures) development, integration, test, operation and maintenance:

- User Interfaces: Calls for proposals, information flow, workshops, training, helpdesks
- Payload Operations: Scientific scheduling and optimisation, payload monitoring, quick-look data analysis
- Payload data acquisition, processing, distribution, and archiving: Payload calibration and cross-calibration, data processing (interactive tools and pipelines), archive development, population and maintenance

ESAC is responsible for the management of the overall operations and execution of the science part of operations of the Directorate's missions, following successful in-orbit commissioning. Missions in orbit are handled through the Astronomy Science Operations Division and the Solar System Science Operations Division; pre-launch development activities are the responsibility of the Science Operations Development Division.

Astronomy missions

The Science Operations Centres (SOCs) for XMM-Newton, Integral and Gaia are located at ESAC, as are the Akari European support, the Herschel Science Centre, the Planck Science Office, and the LISA Pathfinder Science and Technology Centre.

The SOCs are the main interface between the scientific community and the mission operations. Astronomers wishing to observe with, for example Integral or XMM-Newton, respond to the annual Announcements of Opportunity (AOs) for observing time that are issued by the SOCs. Their responses (observing time proposals) are reviewed by an external Time Allocation Committee; only those that make the best use of precious satellite time are selected. This can be a difficult task – in the case of XMM-Newton the annual AOs result in ESA receiving around 600 proposals requesting at least seven times more observing time than is available. Only the very best proposals are ever executed!

The selected observations are then combined into an optimised long-term plan taking into account the constraints from the spacecraft and ground segment as well as those from the proposal such as the need to observe an astronomical event at a particular time or simultaneously

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ESAC is located 30 km west of Madrid in the Guadarrama Valley, in the middle of a natural park with another space or ground-based facility. The long-term plans are then converted into the detailed list of instructions actually necessary to operate the spacecraft.

Once an observation has been performed, the scientific data are processed – in collaboration with partners in the community – to produce high-level products such as images and spectra that are immediately usable by interested scientists. Both the original data and high-level products are placed in archives for eventual release to the scientific community – all data obtained from ESA's scientific missions are placed into the public domain once the original observer's proprietary period has been concluded. For missions that are not led by ESA, such as Akari or Hubble, the role of the SOCs is often different, typically providing support to European astronomers who wish to use these missions, or other specialised activities.

Solar System missions

Science operations for the Mars Express, Rosetta, Venus Express and BepiColombo missions are hosted at ESAC. In preparing their science operations sequences and timelines, the SOCs are the main interface between the individual instrument teams and the Mission Operations Teams. The objectives and priorities for operation of the payload are defined and agreed by the Science Working Team, which is chaired by the Project Scientist. It is then the task of the SOC to build a conflict-free operations sequence from the payload operations requests (submitted by the Principal Investigator teams) that satisfies the requirements and optimises the use of resources such as power and data rate.

To support these activities a number of software tools have been developed that help to visualise the pointing of the instruments or automatically detect a violation of constraints, for example pointing too close to the Sun, or avoiding a bright star in the field of view. Usually the planning is performed in a three-step approach – long-term, medium-term and finally short-term. During each of the steps, the sequences are iterated with the instrument teams and the mission operations team to achieve an optimum result. After the science operations sequences have been uploaded to the spacecraft and executed, the science data are distributed by ESOC to the teams.

The teams have a period of six months to analyse their data and publish results. After that, all data from the observations, raw data and high-level data products have to be submitted to the Solar System Science Operations Division to be reviewed and placed in the Planetary Science Data Archive at ESAC for eventual release to the wider scientific community.

Science Archives: a scientific treasure trove

The vast amounts of scientific data obtained during a space science mission have a much longer lifetime than the satellite mission itself. The data are archived and made freely accessible online to the worldwide scientific community, and these archives are frequently a mine of unexpected discoveries. ESAC hosts the scientific archives of most of ESA's scientific missions: XMM-Newton, Integral, Herschel, ISO and Exosat for astronomy; Mars Express, Venus Express, Rosetta, Huygens, SMART-1, Giotto and SOHO for Solar System missions.

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To celebrate the International Year of Astronomy the XMM-Newton SOC produced this striking image of the starburst galaxy Messier 82 (M82) obtained with the XMM-Newton X-ray and optical/UV cameras

The Science Archives can be accessed through user-friendly interfaces from any web browser. They offer powerful query facilities with hundreds of search criteria, neatly organised by panels. Result displays offer the list of items matching the search criteria in a hierarchical manner depending of each mission, with link to preview images, visualisation tools and links to similar data in other external science archives.

The archives implement mission policies for data access control, where some data are proprietary and accessible only by privileged users and other data are fully public. Once logged in, users can download the selected data in fully automatically, without any human intervention, either through a one-click direct download for a specific item listed in the catalogue, or through a 'shopping basket' mechanism.

For the Planetary Science Archive, a map-based interface for Mars Express data gives a very easy way to access Mars data without previous knowledge of the mission. In addition to these user interfaces, archive data can also be accessed through a powerful scriptable machine interface. This has proven to be extremely useful to support mission experts in intensive and systematic instrument calibration monitoring and trend analysis, as well as allowing interoperability between ESA science archives and external archives and applications.

The Science Archives are being developed by a dedicated archive team, providing support to all missions. Each member of the group is not dedicated to one project in particular, but is working on a specific sub-system (data access, database, user interface, interoperability) across all the archive projects. This ensures permanent knowledge transfer from one project to another as people are working on several projects at the same time.

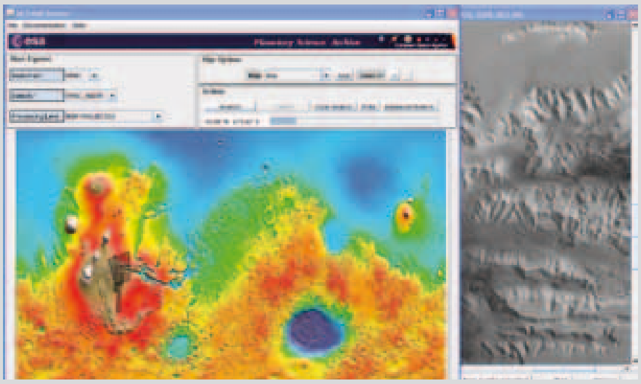
Archives have been built using a flexible and modular multi-tier architecture and modern technology (Java, XML), enabling re-use across missions and preserving efficient long-term access to the data. Over the years, this team has developed a unique expertise, enabling very reliable and cost-effective development, operations and maintenance of the archives.

The Virtual Observatory (VO) is a worldwide initiative which aims is to allow scientists to perform new science by providing them with a federation of archives and databases around the world, together with analysis tools and computational services, all linked into an integrated facility. Through the VO project within the ESAC Science Archives Team, ESA is one of the leaders of the VO, participating in the elaboration of the VO standards, ensuring all ESAC archives are accessible through the VO framework, developing VO tools and making the natural link between the VO and scientists at ESAC.

The ultimate goal is for scientists to be able to transparently access all astronomical and planetary data from their desktops, in much the same way as they currently access documents on the internet.

ESAC contributions to the ESA Ground Segment

Before ESAC became an ESA centre, the site was an ESA Telemetry, Tracking and Commanding (TT&C) station. The site still maintains some support to ESA's Directorate of Operations and Infrastructure in the operations of several ESA satellites. There are currently three antennas at ESAC belonging to ESTRACK, called VIL-1, VIL-2 and VIL-4.



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ESA's Planetary Science Archive contains data returned by ESA's planetary missions

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The XMM-Newton Science Archive. Together with all the XMM-Newton scientific data products and observation-related information, three high-level catalogues or multiwavelength datasets can be accessed through this archive

The TT&C activities are mainly performed using the VIL-2 terminal. The other terminals used in the past have mostly been mothballed, or are used for test purposes only (VIL-4). VIL-1 is currently under assessment by ESA Education Office for its use in the context of radio astronomy educational activities. The VIL-2 terminal is used to support the critical ATV docking operations to the ISS, regular support to MetOp and for back-up support to XMM-Newton, Cluster II and Integral in case of unavailability of the stations dedicated

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ESAC VIL-2 antenna is a 15 m dish for S-band reception and transmission

to these missions, (i.e. Kourou, Maspalomas and Redu). Interestingly, VIL-2 is also playing a role in ATV missions by supporting the functioning of the Proximity Communication Equipment (PCE) of the ISS, prior to each ATV launch. The ISS PCE is used to communicate with the ATV when the vessel approaches the ISS. VIL-2 is routinely controlled from ESOC, although it is operated locally for maintenance, Launch and Early Orbit Phase or during critical phases.

Cebreros

The Cebreros station, Deep Space Antenna (DSA 2), is ESA's newest tracking station and is located 77 km west of Madrid and about 12 km south of Cebreros (province of Avila). Its technical facilities comprise X-band transmission and X- and Ka-band reception, plus facilities for tracking, telemetry, telecommand and radiometric measurements.

Cebreros provides routine operations support to Venus Express, Herschel and Planck and back-up support to Mars Express and Rosetta, as well as other agencies' missions under resource-sharing agreements. The station is also equipped with Delta DOR (Differential One-way Ranging), a new technology enabling highly precise spacecraft location and tracking. Thanks to this new technology, Cebreros has also provided Delta DOR measurements for NASA's satellite Phoenix. Cebreros is routinely controlled from ESOC, although it is operated locally for maintenance, Launch and Early Orbit Phase or during critical phases.

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Cebreros Deep Space Antenna 2

SMOS Data Processing Ground Segment

ESAC host the Data Processing Ground Segment (DPGS) of the ESA's Soil Moisture and Ocean Salinity (SMOS) Earth Explorer satellite. Scheduled for launch later in 2009, SMOS is the second Earth Explorer Opportunity mission to be developed as part of ESA's Living Planet Programme. The SMOS mission has been designed to provide global observations of two key variables in the Earth's water cycle: soil moisture over Earth's landmasses and salinity over the oceans. The data acquired from SMOS will lead to better weather and extreme-event forecasting, and contribute to seasonal-climate forecasting. Soil moisture data are urgently required for hydrological studies and observations of ocean salinity are vital for improving our understanding of ocean circulation patterns.

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Artist impression of SMOS

ESAC hosts most of the activities related to the SMOS payload, the Microwave Imaging Radiometer using Aperture Synthesis (MIRAS), including the Payload Operations Centre and the Data Processing Ground Segment. These will be complemented by the long-term archive and reprocessing centre operated at Kiruna and an additional X-Band receiving station at Svalbard, to guarantee delivery of SMOS data in near-real time to operational users, the user services at ESRIN and the post-launch support office at ESTEC.

The ESAC Payload Operations Centre will also work closely with the French space agency CNES, being responsible for the satellite operations operated from the Satellite Operations Ground Segment in Toulouse. The instrument activities will be planned from ESAC, payload commands will be generated and sent to CNES for uplink, and, in return, the instrument housekeeping telemetry will be received and monitored.
The Data Processing Ground Segment (DPGS) at ESAC receives the scientific data and takes care of the generation and distribution of the SMOS data products, from Level 0 (raw data) up to Level 2 (soil moisture and ocean salinity)

as well as the Level 1 products. The DPGS will also monitor the data quality and take care of improvements on the processing algorithms.

To be able to receive the SMOS data at ESAC, an X-band antenna and the associated equipment have been installed, thus making ESAC a unique place where most of the processes involved in the operation and exploitation of the SMOS mission are collocated.

Additionally, ESAC will host the Spanish nationally funded CDTI SMOS Level 3-4 processing centre, in close coordination with the Instituto de Ciencias del Mar, University of Catalonia, Barcelona.

More than 20 people, involved at various levels in the preparations for the mission operations, are currently working on site to get everything ready for the launch. The SMOS nominal life is three years with a potential extension of a further two years, depending on the technical status and financial approval through ESA member states. The operations will be run by a variety of ESA internal and industrial teams.

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The X-band antenna recently installed at ESAC to support SMOS operations

Laboratory for Space Astrophysics and Fundamental Physics

The Spanish Laboratory for Space Astrophysics and Fundamental Physics (LAEFF) was founded in 1991 as a collaboration between INTA, CSIC and ESA, and was located at ESAC to allow for closer interaction with the ESA astronomical activities.

Research at LAEFF is carried out in different areas of astrophysics and includes the study of 'brown dwarfs', stars in different evolutionary stages, the interstellar medium and galaxies. In addition, LAEFF hosts the Spanish Virtual Observatory, with an associated astronomical archive centre and the Integral Optical Monitoring Camera analysis group. LAEFF was the Science Operation Centre for MINISAT-01, the first Spanish scientific minisatellite, and it is involved in the development of space instrumentation for Integral, JWST, BepiColombo and other future missions. Outreach activities are carried out by the PARTNeR team.

In 2009 there was a substantial change in the position of LAEFF and its liaison with its different institutions. LAEFF now should be considered as the physical site at ESAC of the Centre for Astrobiology (CAB), which is a joint CSIC-INTA institute.

Corporate Communication & Education Office

With the growing importance of ESAC, a dedicated and joint Corporate ESAC Communication and Education Office has been created.

For communication, the office is responsible for official ESA communication activities in Spain and Portugal, organisation of launch and major events at the centre and coordination of launch events in major universities and national institutions and interactions with the media. The office provides spokespersons, management of the ESAC centre image and communication and support to the Head of ESAC for high-level visits.

In education, the office supports the ESA Corporate Education Office, which is in charge of a large number of university-level educational activities involving cooperation with almost all ESA directorates.

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Aerial view of ESAC

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Their Royal Highnesses The Prince and Princess of Asturias unveil the inauguration plaque at ESAC on 7 February 2008

In coordination with ESA's Directorate of Human Spaceflight, the office manages the ESA student parabolic flight activity, called 'Fly Your Thesis!' This field of activity has recently been enlarged to include microgravity research education activities on drop towers, and the use of the ESA Large Diameter Centrifuge is being considered.

The office has also recently launched, with the Directorate of Galileo and Navigation-related Activities, the EDUNAV programme, aiming at increasing education cooperation in the field of satellite navigation at university level. ESAC education is also supporting several European masters degree programmes at universities, providing guidance, educational material and developing system engineering educational tools, in cooperation with several ESA Directorates. In 2008, the office launched the ESA PRESTIGE programme (PRogramme in Education for Space, Technology, Innovation and knowledGE) in coordination with ESA Human Resources and the Directorate of Technical and Quality Management. This programme will increase the competence of European universities in areas identified as critical for the space domain, through research collaboration with ESA. Finally, the office supports the International Space University and several ESA Education activities in the context of the International Space Education Board (ISEB), which represents the education offices of the Canadian Space Agency, ESA, JAXA, NASA and CNES.

↑

'Fly your Thesis! – An Astronaut Experience' enables university students to fly their experiments in microgravity by participating in a series of parabolic flights on an Airbus A300 Zero-G aircraft

The Communication & Education Office could be involved in the near future in supporting the definition and implementation of an ESA knowledge management policy, enlarging its 'horizontal' role within ESA.

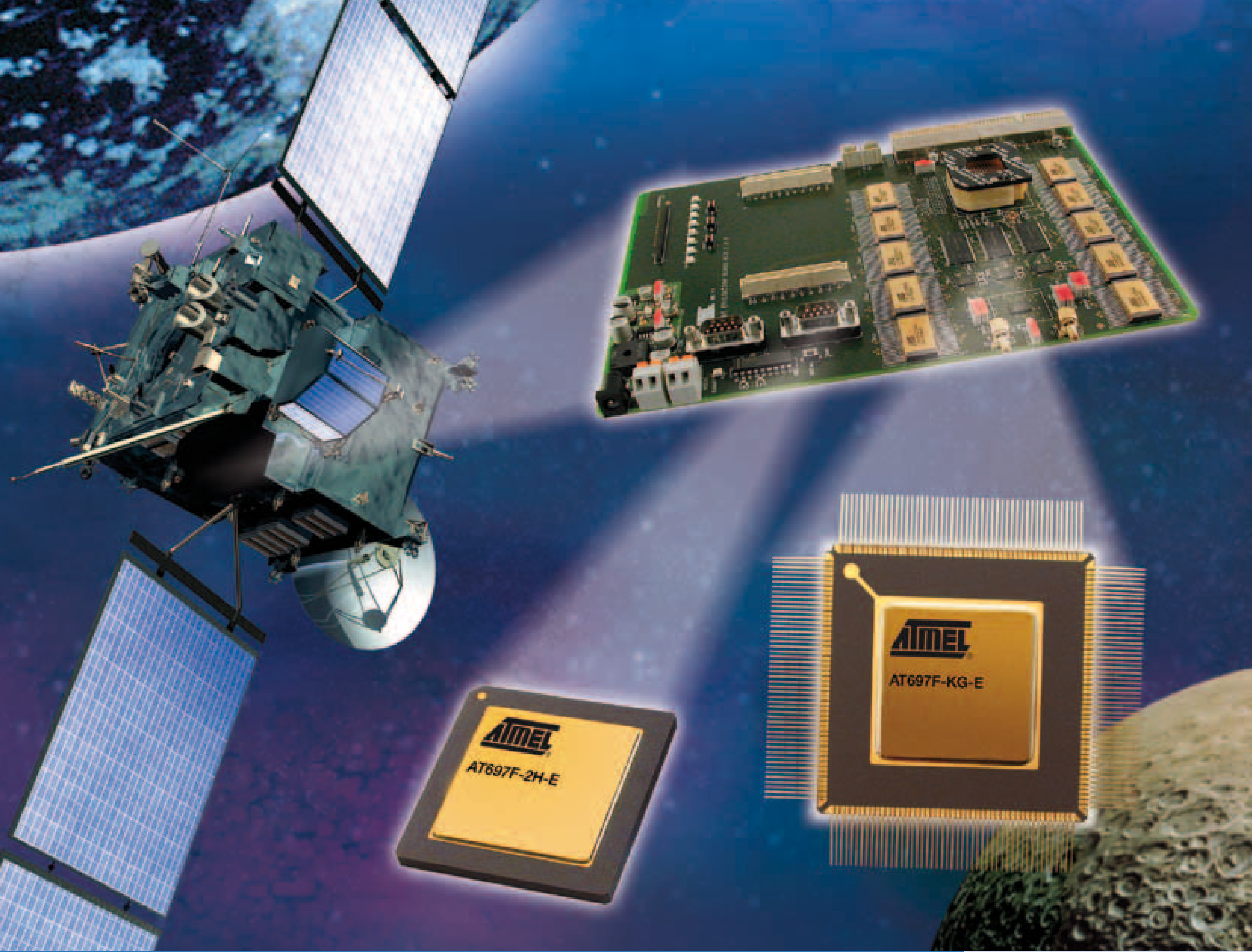
Space Situational Awareness

ESAC will soon host the Project Team of the European Space Situational Awareness (SSA) Preparatory Programme; a new initiative approved at the Ministerial Council in November 2008. SSA is a new ESA optional programme over the period 2009–11.

The purpose of the SSA initiative proposed by ESA is to provide Europe and its citizens with complete and accurate information on objects orbiting Earth, on the space environment and on threats coming from space. The SSA system proposed by ESA will operate in three specific areas. First, the surveillance of objects around Earth in various orbits, achieved by detecting, tracking and imaging these objects; second, 'space weather', addressing primarily the effect of solar activity on satellites and ground infrastructure, such as power grids and communication networks. The third is the observation, identification and assessment of asteroids and comets, known as Near-Earth Objects, which pose a potential risk of collision with Earth.

As a first step in the development of this European SSA system, ESA is initiating the SSA Preparatory Programme. During the preparatory phase, the following subjects will be addressed: architecture of the future European SSA system; governance, data policy and data security aspects; and precursor services in the areas of space surveillance, space weather and NEOs. In addition, early data centre pilots and 'breadboarding' of the future surveillance radar systems will be undertaken.

ESAC has experienced a tremendous growth in the last few years, with about 300 people working there today. The centre is still expanding, and this year the management of the new Space Situational Awareness programme adds to its responsibilities. With more than 35 years of history in various ESA activities, the site at Villanueva de la Cañada has become an important element of ESA. Without question, it is ESA's window to the Universe. ■



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Left to right: Samantha Cristoforetti, Luca Parmitano, Thomas Pesquet, Andreas Mogensen, Alexander Gerst and Timothy Peake

→ INTRODUCING EUROPE'S NEW ASTRONAUTS

ESA astronaut selection procedures and campaigns

Horst Schaarschmidt, Herve Stevenin
and the European Astronaut Selection Team
Directorate of Human Spaceflight,
European Astronaut Centre,
Cologne, Germany

The names of new ESA astronauts were announced on 20 May 2009. Originally, it was planned to select only four, but because of their high quality and the high expectations of the spaceflights to come, six were recruited to prepare for future exploration missions.

Called 'Ascans' (Astronaut candidates) until they qualify at the end of their basic training, the six newcomers report to the European Astronaut Centre in Cologne in September 2009, where they will study the basics of spaceflight for 16 months.

The 2008/9 astronaut selection

The project of a new astronaut selection had been introduced to the Member States in 2004 when it became obvious that the number of active astronauts in the European Astronaut Corps would decrease in coming years. The currently serving astronauts are ageing of course, and the group was losing an average of two astronauts per year. ESA needed to recruit new astronauts to fulfil its obligations, and also because, from May 2009, a six-person crew would permanently man the ISS.

The discussion restarted with the Member States in 2006. Concurrently, the preparation work had been started at the European Astronaut Centre to come up with a suitable work plan. In November 2007, the Director of Human Spaceflight received authorisation to continue with the preparation and contractual set-up for the selection; this process was concluded in February 2008 with the decision of the Human Spaceflight Programme Board to open the recruitment of a new group of ESA astronauts.

Setting up the process

The construction of the selection had to deal with a call to recruit highly visible positions. It was likely that the call would then attract a strong interest from potential applicants, as well as attention from the media. Therefore it was necessary to design a robust process which also had to be fair and objective.

The new selection would be performed by ESA for the first time over Europe without any national pre-selection. Several tens of thousands of applications could be expected, and measures had to be taken to allow for easy processing of an unknown number of applications, but also reduce the potentially high number of non-serious applications, even before entering the system.

It was decided to accept only online applications, with a first automatic filtering and ranking of the applications according to defined criteria. There was also the request to upload a medical certificate even before providing access to the online application in order not to overload the system with non-serious applications.

Once ranked, the best candidates were then sent to a first psychological evaluation and selection, using psychometric testing. Then there was a second psychological evaluation based on interviews, followed by a medical screening. After interviews with the Director of Human Spaceflight and the Director General, the final recruitment list was decided. Based on previous experience, part of the preparation had focused on ensuring that the available resources would not be wasted on applications that had little chance of succeeding. Education and experience criteria had been clearly set, providing an easy selection at the level of the questionnaire which could be easily verified at the first encounter.

The need for the applicants to comply with internationally defined medical criteria was a more difficult issue. Advanced medical examinations are extremely costly, meaning that the full set of test could only be performed on a limited number of candidates. However, it was necessary to maintain the highest number of candidates going through to the psychological evaluation interview. It was decided to reduce the risk of dropping out at the medical examination stage by requesting from the candidates a Civil Aviation medical certificate very early on in the process. This certificate had to be provided at registration on the application web site in order to unlock the application process.

This requirement for a medical certificate to access the application system had been advertised well in advance and local difficulties in receiving this certificate within the time limit had been clarified with the interested delegations. This requirement also presented an additional filter for personal motivation, since candidates had to make a commitment in time and money.

The selection was prepared as a phased project, including a preparation and implementation phases. This set-up was reflected in the contracts given to European service industry for the support to the European Astronaut Centre for this project, ensuring the readiness of the process without committing monies for implementation before a complete approval. Contracts were issued in three main areas: administrative support and the provision of the IT tools for the applications recording and processing; the psychological evaluation; and the medical evaluation.

The main contracts were subject to an open call, following ESA procurement rules. The administrative support contract was concluded with a Swedish consortium, the medical services and psychological services contracts were signed with a French–German consortium.

> **"Whatever level of fame our new colleagues experience, they are solid professionals – qualified for implementing space missions."**

Public interest

According to a previous decision of ESA Council and the Programme Board of Human Spaceflight, the announcement of the new selection would not take place before the docking of the Columbus laboratory to the ISS. The successful launch of Columbus followed by its attachment to the ISS and the first ESA increment as well as the exemplary rendezvous and docking manoeuvres performed by the first Automated Transfer Vehicle *Jules Verne* provided the occasion for the Director General to make the announcement.

The public interest was huge, sustained by the media in all ESA Member States. When the application period started, marked by the publication of the vacancy notice on 19 May

→ Europe's new astronauts

Samantha Cristoforetti

Jet fighter pilot, Lieutenant, Italian Air Force
Born: Milan, Italy, 1977
Studied at the Technische Universität Munich, Germany, the Ecole Nationale Supérieure de l'Aéronautique et de l'Espace in Toulouse, France, and the Mendeleev University of Chemical Technologies in Moscow, Russia. Master's degree in engineering, master's degree in aeronautical sciences, University of Naples Federico II in Italy.
Hobbies: mountaineering, diving and caving

Alexander Gerst

Geophysicist
Born: Künzelsau, Germany, 1976.
Diploma in geophysics, University of Karlsruhe, Germany; MSc in Earth Science, Victoria University of Wellington, New Zealand. He has been working as a researcher since 2001.
Hobbies: mountaineering, diving, climbing and skydiving

Andreas Mogensen

Navigation & Control Engineer
Born: Copenhagen, Denmark, 1976
Master's degree in engineering, Imperial College, University of London; PhD in engineering, University of Texas at Austin, USA. He has been working on spacecraft attitude and orbit control systems and guidance, for HE Space Operations.
Hobbies: rugby, mountaineering and diving

Luca Parmitano

Test pilot, Captain, Italian Air Force
Born: Paternò, Italy, 1976
Diploma in aeronautical sciences, Italian Air Force Academy; trained as Experimental Test Pilot at EPNER, the French test pilot school, at Istres.
Hobbies: climbing, diving and paragliding

Timothy Peake

Test pilot, Major, British Army Air Corps
Born: Chichester, UK, 1972
Degree in flight dynamics; qualified as Experimental Test Pilot at UK's Empire Test Pilots' School, Boscombe Down.
Hobbies: cross-country running, climbing and caving

Thomas Pesquet

Engineer/airline pilot
Born: Rouen, France, 1978
Master's degree from the Ecole Nationale Supérieure de l'Aéronautique et de l'Espace in Toulouse, France. Research engineer at the French space agency, CNES; then became a pilot for Air France, where he flew A320s.
Hobbies: jogging, swimming, squash and judo, with experience in diving and paragliding

2008, many of the first applicants had already registered on the web site.

During the application period, the system worked flawlessly and recorded 8341 completed and valid applications in four weeks. For the project team, this time was still busy as it gave the opportunity to validate the automated ranking system against a human evaluation by experts, to make sure it worked as expected.

After the end of the application period, the files of the 1650 top-ranked candidates were again manually reviewed and evaluated, focusing on rejecting applications which did not meet the criteria. 920 invitations were sent for the first psychological tests which took place in Hamburg, Germany, from 30 June to 1 September 2008.

The second phase of the psychological evaluation took place at the European Astronaut Centre from 15 September to 21 November for 192 applicants. This narrowed down to 45 applicants who were sent in two groups for the medical evaluation (in Toulouse and Cologne) from 12 January to 18 February 2009. The preliminary medical certificate required for applying showed its usefulness: 22 candidates still remained after the review by the ESA Medical Board.

These finalists were invited to the first interview with the Director of Human Spaceflight, and ten were further invited to the second interview chaired by the Director General. The low attrition rate in the last phases was due the quality of the candidates at these stages, and validated the design of the selection process.

Historical background

This years's list of selected candidates is the outcome of a long process which has its roots in the programmes of over three decades ago. For the first 25 years of human spaceflight, only Russians and Americans had access to space. The history of the European Astronaut Corps started in August 1973 when NASA and ESA (then ESRO) signed a Memorandum of Understanding to build a reusable science laboratory called Spacelab, which was to be launched into space inside the Space Shuttle cargo bay.

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The first ESA astronauts selected (from left): Nicollier, Merbold, Ockels and Malerba

The first laboratory module, LM1, was provided to NASA free of charge by ESA in exchange for flight opportunities for European astronauts (barter agreement). ESA started its first astronaut selection in 1977, finding four European Payload Specialist candidates for the first Spacelab mission. From this selection campaign, ESA chose its first astronauts: Claude Nicollier (CH), Wubbo Ockels (NL) and Ulf Merbold (DE). Franco Malerba (IT) was also chosen in this group, but later resigned for medical reasons (Malerba then joined ESA's Space Science Department at ESTEC, working on an ionospheric plasma physics experiment to be flown on Spacelab in 1983. Malerba eventually flew as the first Italian citizen in space on STS-46 in 1992, sponsored by the Italian space agency ASI).

Short afterwards, at the beginning of the 1980s, several European countries (also ESA Member States) started a recruitment of astronauts on a national basis in parallel

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DLR's first astronauts were chosen for the German-sponsored Spacelab D-1 mission on the Shuttle. Left, Reinhard Furrer, and right, Ernst Messerschmid. ESA's Wubbo Ockels (centre) completed the European part of the crew

with the ESA's astronaut group. Under bilateral agreements with Russia and USA respectively, these nationally recruited astronauts had opportunities to fly on Russian Soyuz to the Russian Salyut and Mir space stations or with the US Space Shuttle as 'Payload Specialists'. By 1991, there were 19 European astronauts in total; however, they were mostly members of the various national astronaut groups with only three belonging to ESA (Ockels, Merbold and Nicollier). Merbold became the first ESA astronaut to fly on a Space Shuttle mission, the 10-day STS-9/Spacelab-1 flight in 1983. Not only was this the first flight of an ESA astronaut, it was the first flight of the European-built Spacelab and the first flight of a non-US citizen on the Shuttle.

Since 1984, NASA, ESA, Japan and Canada had started preparatory work for a common space station called Alpha. In parallel, ESA Member States had decided to have autonomous access to space and started the development of the Hermes space plane, an autonomous manned transportation system, to be launched on an Ariane 5 heavy-lift vehicle. Additionally, Europe also started the Columbus programme, which consisted of three elements: a huge laboratory to be attached to the Space Station Alpha, an autonomous small space station called the 'Man-Tended Free Flyer' (MTFF), and a serviceable platform for Earth observation experiments on a polar orbit.

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Five more candidates were chosen by DLR in 1987. The group is seen here with original German astronaut Ulf Merbold: from left, Ulrich Walter, Gerhard Thiele, Merbold, Renate Brümmer, Hans Schlegel and Heike Walpot

For these upcoming programmes, ESA saw its requirement for astronauts increasing considerably (with up to 36 astronauts needed) and founded the European Astronaut Centre at Cologne in 1990. EAC would establish a centre of excellence in Europe for astronaut selection, training and medical support. In 1991/92, a new astronaut selection was carried out, but while this one was in full swing, Europe cancelled all the mentioned projects except the Columbus laboratory, which was maintained but shrank to half its original size.

Even though there was a reduced demand for the new astronauts from then on, Europe decided to go on with the selection of the astronauts, but recruiting fewer than first planned. The chosen scheme was a two-stage selection, with a national selection first under the responsibility of each ESA Member State, and then the ESA selection, in which each ESA Member State had the opportunity to present up to five candidates. More than 22 000 applications were

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In May 1991, Belgium selected its five candidates for the 1992 ESA selection. Left to right, Werner Stessens, Frank De Winne, Marianne Merchez, Vladimir Pletser, Lucien Halleux

received by the Member States in their national selections, out of which nearly 5500 were suitable candidates. Through psychological, medical and professional screening procedures at national level, 59 candidates were identified to be proposed for the second step, the final ESA selection. Some of the Member States such as Germany, France, Austria and United Kingdom had proposed candidates retained from their national selections in the 80s, and some other Member States decided for a new national pre-selection campaign applying the newly established ESA criteria.

From this final group, ESA selected the next six astronaut recruits: Thomas Reiter (DE), Christer Fuglesang (SE), Pedro Duque (ES), Jean-François Clervoy (FR), Maurizio Cheli (IT) and Marianne Merchez (BE).

Reiter, Duque, Fuglesang and Merchez started Basic Training at EAC to be later trained for Russian Soyuz flights to Mir. Clervoy and Cheli were sent to NASA to start Shuttle Mission Specialist training, being incorporated into the NASA astronaut corps. Merchez left the group in 1993 and

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The second ESA astronaut group: clockwise from left, Christer Fuglesang, Thomas Reiter, Pedro Duque, Jean-François Clervoy, Marianne Merchez, Maurizio Cheli

→ What's in store...

ESA Basic Training

Every ESA astronaut starts the training cycle by completing the 16-month 'Basic training' at the European Astronaut Centre (EAC) in Cologne, Germany. Basic training provides an overall familiarisation with the future career as an astronaut, and consists of four training blocks.

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European Astronaut Centre, Cologne, Germany

→

Sub-aqua diving training

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Sea survival training

1. Introduction

A first orientation for the newly hired astronaut candidates. They receive an overview of the major spacefaring nations and space agencies, as well as of the major manned and unmanned space programmes. Space law and intergovernmental agreements governing the worldwide cooperation in space complete this first block.

2. Fundamentals

Basic knowledge on various technical and scientific disciplines, to bring all candidates, who have different professional backgrounds and expertise, to a common minimum knowledge base in subjects relevant to their future astronaut career. Technical disciplines covered are: spaceflight engineering, electrical engineering, aerodynamics, propulsion, orbital mechanics, materials and structures. Includes an introduction to science disciplines such as research under weightlessness (human physiology, biology and material sciences), Earth observation, astronomy and others.

3. Space systems and operations

A detailed overview of all International Space Station systems (ISS structure and design, guidance navigation and control, thermal control, electrical power generation and distribution, command and tracking, life support systems, robotic systems, systems for extravehicular activities, payload systems), as well as major systems of those spacecraft which serve the ISS (e.g. Space Shuttle, Soyuz, Progress, ATV and HTV) and also includes ground systems like development and test sites, launch sites, training and control centres.

4. Special skills

Special skills include generic robotic operations, rendezvous and docking, Russian language, human behaviour and performance, and finally sub-aqua ('scuba') diving as a first preparation for Extravehicular Activities (EVA) or 'spacewalk' training.

↑ ESA astronauts André Kuipers and Frank De Winne participated in the EVA pre-familiarisation training at EAC and found that it significantly contributed to their performance during their first EVA training run in Houston

Neutral Buoyancy EVA Training

The next step comes when an astronaut is assigned to a mission, and could include full EVA training in a neutral buoyancy facility. The principle used to simulate weightlessness in a huge tank of water is called 'neutral buoyancy'. A neutrally buoyant object neither floats nor sinks. For an astronaut to be neutrally buoyant in the water, the natural tendency to float or sink is counteracted by weights or flotation devices.

Although it is not exactly the same as being 'weightless' in space, astronauts and cosmonauts can practice in neutral buoyancy how to move large objects. You can still feel the pull of gravity while neutrally buoyant, and the drag of moving about through the water slows down your movements – but it is the closest you can get to microgravity on Earth.

The full EVA training for the ISS is traditionally done at NASA's Neutral Buoyancy Laboratory (NBL) at the Johnson Space Center, Houston, Texas, and at the Gagarin Cosmonaut Training Center, in Russia.

With the assembly of the ISS in full swing, the EVA training schedule in the NBL is tight, the facility itself overbooked with operational and mission-related EVA training so the training schedule is compressed into three shifts a day. In addition, it will in future also be used for exploration related testing, which leaves little time for providing EVA skills training to ESA astronauts.

An assignment to take part in a spacewalk during a space mission depends on an EVA skills evaluation, which takes place at a very early stage of the EVA training programme in Houston. Those astronauts who handle their very first neutral buoyancy experiences in Houston well will be chosen to perform EVAs and receive the full-blown EVA training.

In this situation, EAC created an EVA pre-familiarisation training course, which is conducted at EAC's own Neutral Buoyancy Facility (NBF). This programme teaches ESA astronauts the basic EVA concepts and EVA skills, such as tethering to the ISS, use of special EVA tools, communication with an EVA crewmate as well as with the control room and how to keep full situational awareness in a complex and challenging environment.

↑ EAC's Neutral Buoyancy Facility (NBF)

↓ EVA pre-familiarisation training

was replaced on Euromir by Ulf Merbold. In the following six years, Europe would achieve many milestones in human spaceflight. In 1992, Merbold became the first ESA astronaut to undertake a second space mission (Spacelab IML-1, STS-42) and Claude Nicollier became the first European astronaut as a Mission Specialist on the Space Shuttle, taking over much more operational responsibilities than the Payload Specialists before. He was also the first European to perform an extravehicular activity (EVA, or spacewalk) with the American Shuttle EVA suit (the first European to perform an EVA was French CNES astronaut Jean-Loup Chrétien in 1988 on a mission to Mir). Later, another highlight for Europe would be marked in 1995 as Reiter started the first European long-duration mission of 180 days on Mir.

In 1993, five international partners (USA, Russia, Europe, Japan and Canada) agreed to build a common large space infrastructure: the International Space Station. Europe would attach the Columbus laboratory with its payloads to that Station and provide also a cargo spaceship (Automated Transfer Vehicle) for regular servicing missions to the ISS, together with the European Robotic Arm, the Cupola, and some other important components and experimental hardware.

In 1998, ESA Member States decided to dissolve the national astronaut groups and to integrate remaining national astronauts into a single European Astronaut Corps. These were Gerhard Thiele (DE), Hans Schlegel (DE), Reinhold Ewald (DE), Jean-Pierre Haigneré (FR), Claudie André-Deshays (now Haigneré) (FR) and Michel Tognini (FR).

Only Italy performed a separate new astronaut selection in 1998, but the two finalists, Roberto Vittori and Paolo Nespoli, joined ESA later that year together with their ASI colleague, Umberto Guidoni. Two astronauts from other Member States, André Kuipers (NL) and Frank De Winne (BE), had already qualified in the 1992 selection and were consequently recruited by ESA at that opportunity. This process was concluded in 2002 when Philippe Perrin became the last member to join, bringing the Corps up to 16 astronauts. Perrin had been a CNES 'spationaut' since 1996 and had flown as a Mission Specialist on STS-111 in 2002. After this flight, he joined ESA to work on ATV. He left the European Astronaut Corps in 2004 before he could fly in space as an ESA astronaut.

↑

The newly formed European Astronaut Corps in 1998, with members joining from national space agencies, Umberto Guidoni, Jean-Pierre Haigneré, Leopold Eyharts, Claudie André-Deshays, Paolo Nespoli, Reinhold Ewald and Roberto Vittori

Tomorrow's astronauts

Selecting the astronauts of tomorrow has been a challenging process. Both future mission profiles and human factors can vary in subtle ways throughout the years and this makes the definition of selection criteria sometimes difficult. But however tricky this could be, the selection team kept in mind that, whatever level of fame our new colleagues might experience, they should be, before all else, solid professionals, qualified for their future job of flying the space missions prepared with all their colleagues. Their successes will be ESA successes.

←

The European Astronaut Corps in 2002, with Frank De Winne, Michel Tognini, Philippe Perrin and André Kuipers

Innovative Solutions for Space Applications

Photos: ESA / EADS

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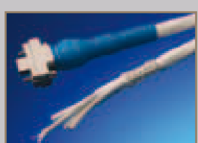

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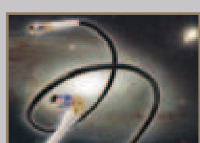

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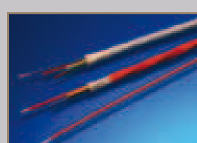

Space Shuttle *Endeavour's* crew cabin seen over Harmony Node-2 on the ISS, with ESA's Columbus (right) and the Japanese Kibo laboratories also visible. Photographed on 20 July 2009, the 40th anniversary of Apollo 11 Moonlanding, by an STS-127 crew member during the mission's second EVA

→ NEWS

In brief


esa
NASA
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Node-3 Tranquility shipped

European-built Node-3 has been named 'Tranquility' in honour of the Apollo 11 mission to the Sea of Tranquility on the Moon, 40 years ago this July.

The name was selected because of its ties with exploration and the Moon, symbolising the spirit of international cooperation embodied by the ISS.

After a European farewell ceremony on 16 May at the premises of the prime contractor, Thales Alenia Space Italy, Turin, Tranquility was shipped to NASA's Kennedy Space Center in Florida on 17 May. The shipment of Node-3 marks the completion of the development of ESA's set of permanent pressurised elements for the ISS.

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Node-3 'Tranquility' arrives at the Space Station Processing Facility at KSC, welcomed by STS-130 Commander George Zamka and his crew

Flight acceptance and transfer of Node-3 ownership to NASA is now set for October 2009. The Cupola observation module will be attached to Node-3 in July, and both modules are planned to be launched on the STS-130 Space Shuttle mission in February 2010. Tranquility contains one of the most advanced life-support systems to be flown into space, not only providing the equipment necessary to support the ISS permanent crew of six, but also crew operations functions and ISS atmospheric controls.

With the Node-3 and Cupola being the final elements of the ISS, its partners are now moving into a period of full exploitation where further international cooperation will be strengthened and work continued towards extending the life of the ISS. "We are working on the possibility of keeping our hardware certified up to 2025. The first step will be to work on an extension up to 2020," said Simonetta Di Pippo, ESA Director of Human Spaceflight.

OasISS in space

Soyuz TMA-15 (19S) was launched from Baikonur, Kazakhstan, on 27 May with ESA astronaut Frank De Winne, cosmonaut Roman Romanenko and Canadian astronaut Robert Thirsk on board. The launch starts the permanent six-crew capability on the ISS and ESA's six-month OasISS mission.

This is De Winne's second mission to the ISS after taking part in the Odissea mission in 2002. For the first four months of OasISS, De Winne will be Flight Engineer on the Expedition 20 crew with Commander Gennady Padalka. With a rotation of the six crewmembers due in October, De Winne will take over as Commander of Expedition 21 until his return to Earth in November. He is the first European to take on this role, which is a significant milestone for ESA and Europe.

As ISS Commander, De Winne will be responsible, among other things, for conducting operations on the ISS, directing the activities of the ISS

→

Canadian Space Agency astronaut Robert Thirsk, De Winne and Russian cosmonaut Roman Romanenko wave to the crowd gathered at the foot of the Soyuz TMA-15 launchpad crewmembers as a single, integrated team, and for ensuring the safety of the crew and the protection of the ISS elements, equipment and payloads.

De Winne will also undertake an extensive European programme of scientific experiments and technology demonstrations coming predominantly from scientific institutions from across Europe, as well as an extensive education programme aimed at inspiring students and young children. He will be instrumental too in operating the Japanese robotic arm and the Station's robotic arm that will be used to berth the Japanese Aerospace Exploration Agency's first H-II Transfer Vehicle (HTV) planned for launch in September 2009.

"The OasISS mission is a visible sign of the increasing role that Europe is playing through ESA in human spaceflight. The experience gained will provide a sound basis for future human exploration missions," said Simonetta Di Pippo, ESA Director of Human Spaceflight.

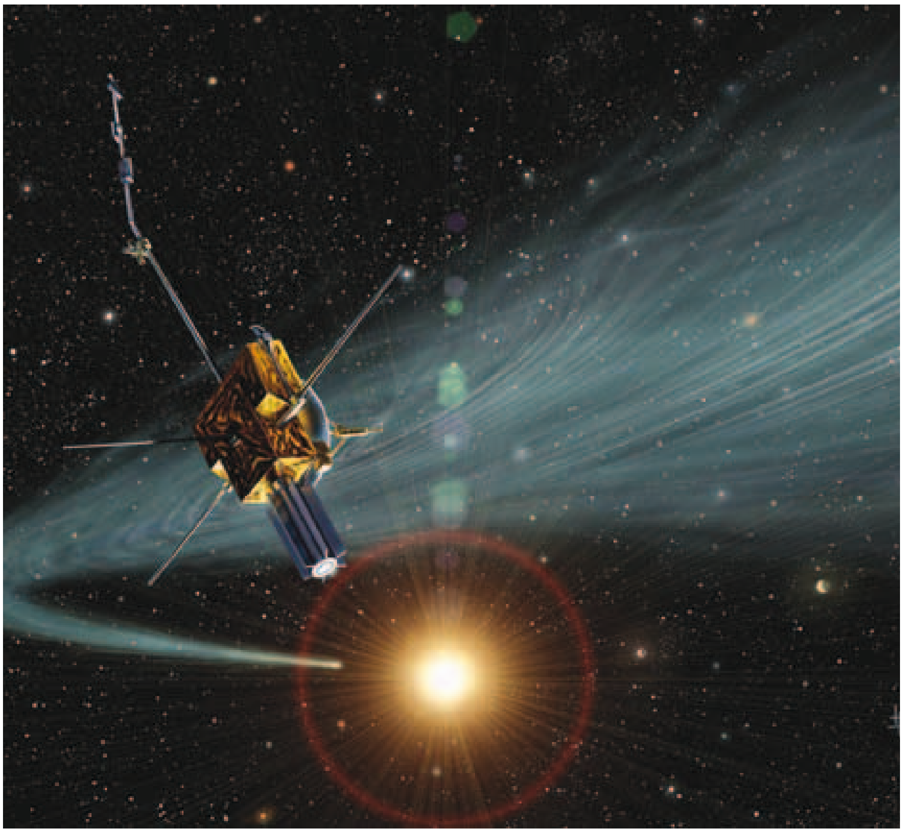
The odyssey ends

On 30 June, after 18 years, 8 months and 22 days of continuous operations, the Ulysses mission finally came to an end. A few days earlier, on 11 June, Ulysses became the longest running ESA spacecraft, breaking the previous record of 6822 days held by the International Ultraviolet Explorer.

The outstanding scientific success of the mission is indisputable, and the data provided by the instruments on board Ulysses will continue to be exploited by the heliophysics community for many years to come. Ulysses is also remarkable in the breadth of science that has been addressed, with topics ranging from solar wind physics to cosmology and serendipitous encounters with comet tails.

In addition to mapping the inner heliosphere for the first time from equator to the poles over almost two complete solar activity cycles, major discoveries have included the first in situ measurements of interstellar dust and gas, and the first measurements of rare cosmic-ray isotopes. The extended lifetime of the mission has provided key insights into the long-term behaviour of the heliosphere, in particular those processes related to the Sun's 22-year magnetic cycle.

Recent studies have focused on the effects on galactic cosmic rays of the current, extended, minimum in solar activity. Ulysses data have shown that the intensity of galactic cosmic ray protons may reach the highest level ever recorded if the lack of magnetic activity on the Sun continues. More than 1475 refereed papers using Ulysses data and two books summarising the scientific results have been published during the operational phase of the mission.



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Artist impression of Ulysses crossing the tail of Comet Hyakutake in 1996 (David A. Hardy)

As well as its scientific success, Ulysses has been an excellent example of international collaboration, both within the science and industry teams, and at the project level. After overcoming programmatic difficulties in the early days, the joint ESA/NASA project and operations teams have worked together with the science community to make the mission one of the most successful in the history of space exploration. Many individuals have contributed to this success, and all can be proud of their achievement.

The passing of a space pioneer

With the death of Derek Eaton in June, it could be said that the pioneering days of the European Space Research Organisation (ESRO) also passed with him. Derek epitomised both the spirit and strengths of the pioneers who joined ESRO in the mid 1960s.

Few engineers had a more varied career than Derek. He was the last manager of an in-house 'hands on' division – Sounding Rockets. Firing rockets from sites such as Sardinia and northern Sweden, they learned and perfected new techniques alongside the scientists whose payloads they carried. When Sounding Rockets division was closed, Derek moved for a short time to ESRO's sister organisation, the European Launcher Development Organisation, returning later to join first the Spacelab team and then the Science Directorate of the new ESA.

With such wide experience behind him, Derek was set to make his mark as a satellite project manager. His first project was the International Sun-Earth Explorer, and it set the trend of being 'on time and within budget'. His final two projects continued to illustrate his penchant for new adventures.

On Ulysses, with difficult political problems over its power supply, launch delays due to the Space Shuttle Challenger tragedy, and totally new approach in orbiting a satellite around the solar poles, the mission outlasted all expectations for 19 years, until it was shut down shortly after Derek passed away.

When new solar arrays were needed for the Hubble Space Telescope and Europe's reputation was put to the test, Derek was given the task. He and his team met the challenge and the new twin solar arrays enabled Hubble's mission to continue.

It was always a sign of his management skills that despite his often blunt and forthright manner, colleagues still say they worked 'with' rather than 'for' Derek. They recall well his humour and determination, his ability to focus on the essential details, and his flair for finding timely, if often unconventional solutions.

Much respected by NASA, with whom he worked so extensively on Ulysses, and Hubble, Derek earned by his effort and high success rate, a place among the pioneers of space of Europe and the world.

↑ Derek Eaton

Mars crew 'return' home

On 14 July, the Mars500 crew, including two ESA participants, completed their 105-day Mars mission simulation inside a special isolation facility.

Shortly after, the crew took part in a press conference attended by the Director of Human Spaceflight at the Institute for Biomedical Problems (IBMP) in Moscow, Russia. The full 520-day mission study will commence in early 2010.

→ The Mars500 crew: Oleg Artemiev, Sergei Ryazansky, Oliver Knickel, Alexei Baranov, Cyrille Fournier, Alexei Shpakov

A new space age for UK

In the week the world celebrated the anniversary of the Apollo 11 Moon landing in 1969, the new ESA facility at Harwell was formally opened at a London event on 22 July.

The ESA facility will focus on three areas: 'integrated applications', which is the combined use of different space and terrestrial technologies, data and infrastructures to create new everyday applications; climate change modelling that uses data from space; and developing technologies such as novel power sources and innovative robotics which could be used to explore the Moon and Mars.

Martin Ditter, ESA's Harwell Project Manager, said: "ESA wants to try new and innovative ways of working at Harwell, with the objective of faster and cheaper technology developments. For example, special teams of scientists and engineers from across ESA Member States may spend short periods of time working together at Harwell on 'collocated focused projects', using the skills and resources on site."

ESA Director-General Jean-Jacques Dordain said: "It is testament to the expertise and skills of the UK space workforce that ESA has chosen the UK for the location of its latest facility. This new facility will contribute to Europe's outstandingly successful space programme and cement the role of the UK within ESA and of ESA within the UK, helping us work together at international level to help the world face the challenges of the future.

"Thanks to the continuous support of all its Member States, ESA is at the leading edge of space science in the world, as demonstrated by the recent launch of the two observatories Herschel and Planck, which will bring greater understanding of the origins of the Universe. ESA is also a leader in the science of Earth and its environment, as seen in the launch this year of three satellites all dedicated to delivering data that will allow a better understanding of the mechanisms of climate change.

"Progress in science and technology provides the foundations for the delivery of new services to citizens on Earth and is a powerful factor for innovation and economic growth. It is good news for all ESA Member States that the UK is willing to be a driver of such innovation and growth in the space sector."

↑ Lord Drayson (left) receives the ESA flag from Jean-Jacques Dordain, celebrating the arrival of ESA in the UK (BIS/BNSC)

Following negotiations between ESA, the UK Department of Business, Innovation and Skills and the British National Space Centre, the facility at Harwell will initially comprise a small number of staff to be located in existing buildings. As the facility grows, additional specialised facilities may be built and included in an overall International Space Innovation Centre.

ESA astronauts named for flights

André Kuipers (NL) joins Expedition 30/31 to fly to the ISS in December 2011. He will remain on the ISS as part of the six-astronaut crew until June 2012. Kuipers, who is back-up to Frank De Winne for the current OasISS mission (Expedition 20/21), will be trained for robotic activities and possible extravehicular activity.

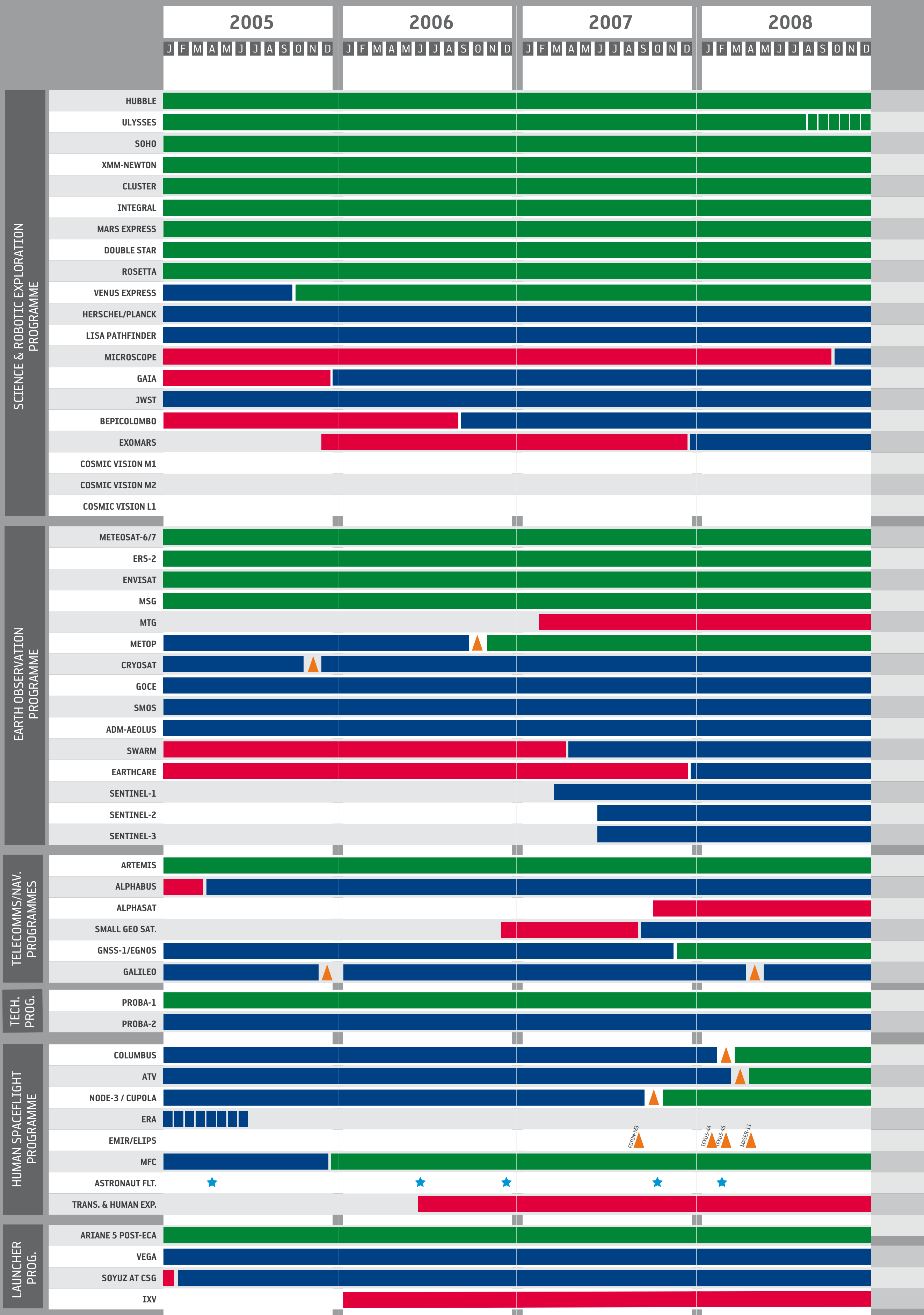
Roberto Vittori (IT) has been assigned as a Mission Specialist to the Space Shuttle STS-134 mission, scheduled for launch to the ISS in July or September 2010. This mission will deliver the Alpha Magnetic Spectrometer to the ISS. It will be Vittori's third spaceflight to the ISS, but his first on the Space Shuttle.

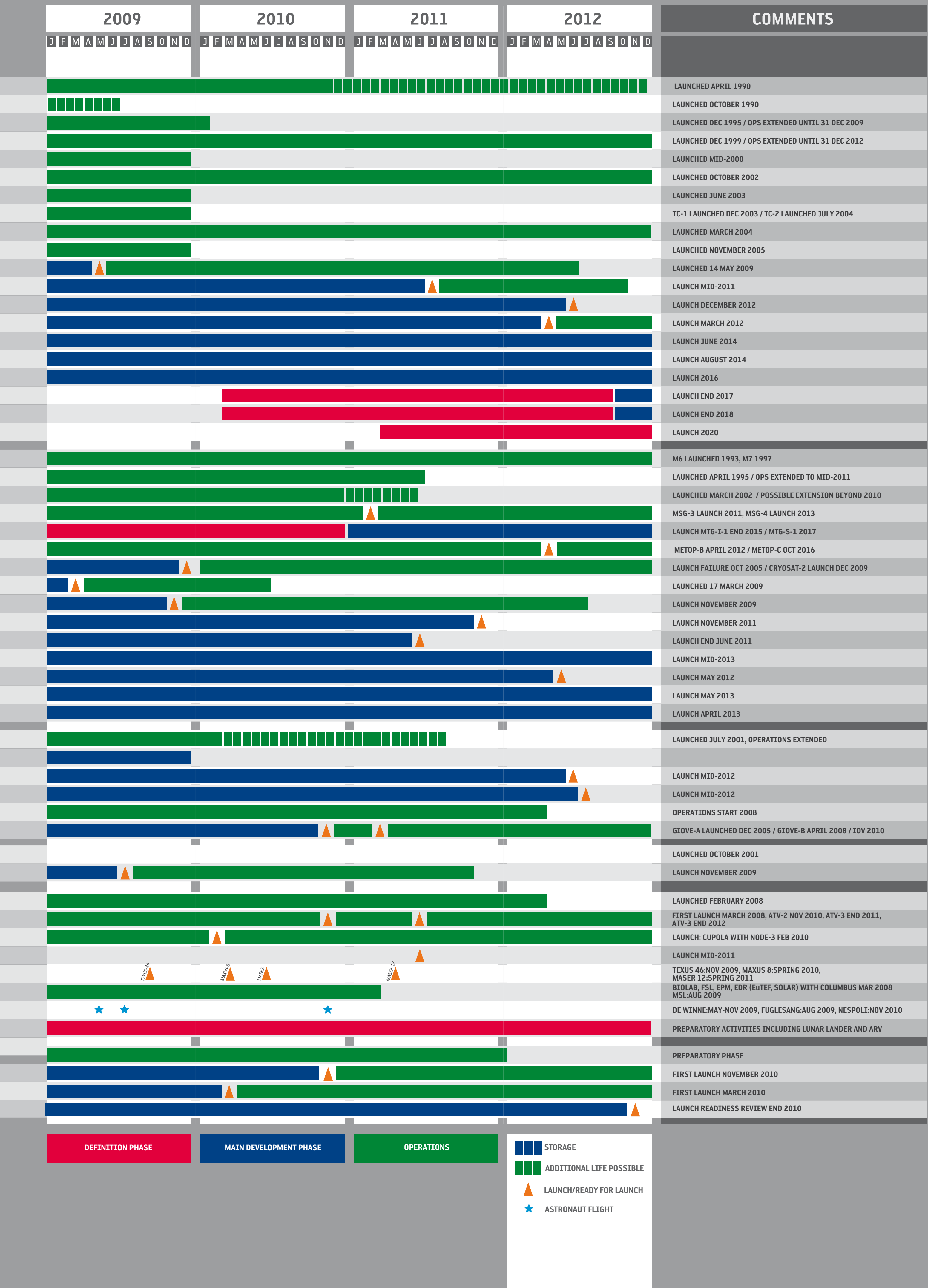
↑ A. Kuipers

↑ R. Vittori

→ PROGRAMMES IN PROGRESS

status at end July 2009


2005
2006
2007
2008
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
ULYSSES
SOHO
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
DOUBLE STAR
ROSETTA
VENUS EXPRESS
HERSCHEL/PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
EXOMARS
COSMIC VISION M1
COSMIC VISION M2
COSMIC VISION L1
EARTH OBSERVATION PROGRAMME
METEOSAT-6/7
ERS-2
ENVISAT
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
ADM-AEOLUS
SWARM
EARTHCARE
SENTINEL-1
SENTINEL-2
SENTINEL-3
TELECOMMS/NAV. PROGRAMMES
ARTEMIS
ALPHABUS
ALPHASAT
SMALL GEO SAT.
GNSS-1/EGNOS
GALILEO
TECH. PROG.
PROBA-1
PROBA-2
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS
ATV
NODE-3 / CUPOLA
ERA
EMIR/ELIPS
FOTON-M3
TEXUS-44
TEXUS-45
MASER-11
MFC
ASTRONAUT FLT.
TRANS. & HUMAN EXP.
LAUNCHER PROG.
ARIANE 5 POST-ECA
VEGA
SOYUZ AT CSG
IXV



2009
2010
2011
2012
COMMENTS
J F M A M J J A S O N D
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
LAUNCHED 14 MAY 2009
LAUNCH MID-2011
LAUNCH DECEMBER 2012
LAUNCH MARCH 2012
LAUNCH JUNE 2014
LAUNCH AUGUST 2014
LAUNCH 2016
LAUNCH END 2017
LAUNCH END 2018
LAUNCH 2020
M6 LAUNCHED 1993, M7 1997
LAUNCHED APRIL 1995 / OPS EXTENDED TO MID-2011
LAUNCHED MARCH 2002 / POSSIBLE EXTENSION BEYOND 2010
MSG-3 LAUNCH 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 NOVEMBER 2009
LAUNCH NOVEMBER 2011
LAUNCH END JUNE 2011
LAUNCH MID-2013
LAUNCH MAY 2012
LAUNCH MAY 2013
LAUNCH APRIL 2013
LAUNCHED JULY 2001, OPERATIONS EXTENDED
LAUNCH MID-2012
LAUNCH MID-2012
OPERATIONS START 2008
GIOVE-A LAUNCHED DEC 2005 / GIOVE-B APRIL 2008 / IOV 2010
LAUNCHED OCTOBER 2001
LAUNCH NOVEMBER 2009
LAUNCHED FEBRUARY 2008
FIRST LAUNCH MARCH 2008, ATV-2 NOV 2010, ATV-3 END 2011, ATV-3 END 2012
LAUNCH: CUPOLA WITH NODE-3 FEB 2010
LAUNCH MID-2011
TEXUS-46
MAXUS-8
MARES
MASER-12
TEXUS 46:NOV 2009, MAXUS 8:SPRING 2010, MASER 12:SPRING 2011
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008 MSL:AUG 2009
DE WINNE:MAY-NOV 2009, FUGLESANG:AUG 2009, NESPOLI:NOV 2010
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER AND ARV
PREPARATORY PHASE
FIRST LAUNCH NOVEMBER 2010
FIRST LAUNCH MARCH 2010
LAUNCH READINESS REVIEW END 2010
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

→ HUBBLE SPACE TELESCOPE

As Hubble prepares to start scientific operations with a full complement of instruments, installed and repaired by astronauts during the recent Servicing Mission, scientific discoveries have continued to appear, fuelled by the wealth of data in the Hubble archive. Of great interest has been a redefinition of the Hubble constant, which can help in narrowing down explanations for 'dark energy'.

The new measurement is based on Hubble's observations of Cepheid variables in a nearby galaxy, NGC 4258, and in the host galaxies of recent supernovae, directly linking these distance indicators. The use of Hubble to bridge different distance indicators has eliminated the systematic errors that are almost unavoidably introduced when comparing measurements from different telescopes. This result is consistent with the simplest interpretation of dark energy: that it is mathematically equivalent to Einstein's hypothesised cosmological constant, introduced a century ago to prevent the Universe from collapsing under the pull of gravity.

HLX-1 (blue star to upper left of galactic bulge) is located on the outskirts of the spiral galaxy ESO 243-49, is the strongest candidate to date to be an intermediate-mass black hole (Heidi Sagerud)

→ ULYSSES

On 30 June, after 18 years, 8 months and 22 days of continuous operations, the Ulysses mission finally came to an end. A few days earlier, on 11 June, Ulysses became the longest running ESA-operated spacecraft, overtaking the previous record of 6822 days held by the International Ultraviolet Explorer.

The data return for the second quarter of 2009 was 10.1% compared to 48.4% of possible data returned earlier in the year. In addition, the maximum supportable bit rate fell from 512 bps to 256 bps at the end of June. This rapid decline in mission return led ESA and NASA to decide that it was time to end spacecraft operations.

At the end of the Deep Space Network tracking pass on 30 June, both receivers were switched on and connected to the front and rear low-gain antennas, and the spacecraft S-band transmitter was then switched off, terminating the mission. At that point, Ulysses was 5.3 AU from Earth (1 Astronomical Unit is the average Sun-Earth distance) and 4.75 AU from the Sun at 18.6° north solar latitude. The event was transmitted as a live webcast from the mission operations centre in JPL, allowing team members who could not be there in person to witness the last moments of the mission.

→ XMM-NEWTON

Operations continue smoothly using the new antenna-switching concept with the spacecraft, instruments and ground segment all performing nominally. Astronomers using XMM-Newton have discovered a black hole weighing more than 500 solar masses in the distant galaxy ESO 243-49 which is about 290 million light years from Earth. The new x-ray source is called HLX-1 (Hyper-luminous x-ray source 1). This find is the best evidence yet for the long-sought for missing link between lighter stellar-mass and heavier supermassive black holes. Stellar-mass black holes (about three to twenty times as massive as the Sun) and supermassive black holes (several million to several thousand million times as massive as the Sun) have long been known to exist. However, due to the large gap in masses between these two extremes, scientists have speculated the existence of a third, intermediate class of black holes, with masses between a hundred and several hundred thousand solar masses. How these intermediate black holes form and evolve is a mystery that hopefully XMM-Newton will help to answer.

→ CLUSTER

Cluster passed through the short eclipse season early this summer and is now concentrating on magnetotail science. The Cluster Active Archive passed through its annual review with the Review Board very satisfied with its progress, in particular in the areas of cross calibration and peer review activity.

Cluster continues to reveal new aspects of space plasma physics and the interaction of the Sun with Earth. One recent study used data from all four Cluster satellites and Double Star one to reveal strong evidence for a particular configuration or manner of magnetic reconnection known as anti-parallel merging at the high-latitude magnetopause. The Cluster tetrahedron enabling detailed probing of the local plasma while Double Star provided simultaneous monitoring of magnetosheath conditions which drive magnetospheric dynamics. In another study, data from the Cluster satellites was used to estimate the magnetic energy contained in travelling compression regions (TCRs). TCRs are regions of temporarily enhanced magnetic field magnitude, and are associated with the thickening of the plasma sheet. By examining magnetic field perturbations in the TCR, the researchers were able to confirm theoretical predictions regarding the ratio of magnetic energy in the TCR to that contained by plasma energy in the associated plasma bulge. Their results show that this process transports a huge amount of magnetic energy.

→ DOUBLE STAR

Contact with Double Star TC2 has still not been re-established. TC-2 operating teams will still continue to try to establish contact with the spacecraft until the end of the mission at end of 2009.

→ INTEGRAL

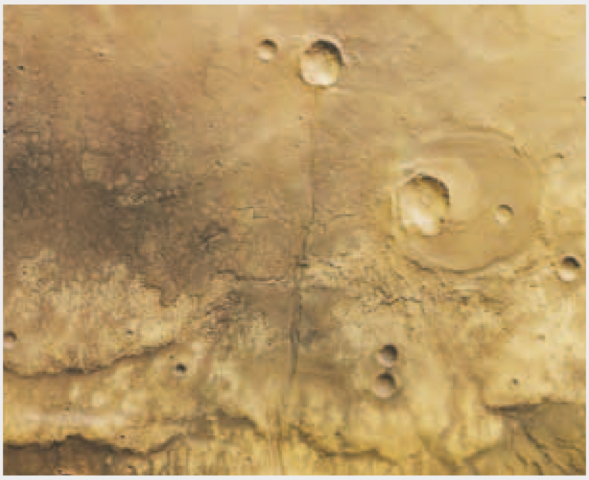
Integral operations continue smoothly with the spacecraft, instruments and ground segment all performing nominally.
The explanation for the 511 keV gamma-ray line emission arising from matter/antimatter annihilation in the direction of the centre of our galaxy has long been a feast for theorists. The spatial distribution observed by Integral does not match easily the usual suspects for the production of the antimatter, particularly that of supernovae explosions. This fact has led to about 150 publications proposing all sorts of exotic processes and 'dark matter' candidates, including 'superconducting strings', 'mirror matter', 'supermassive strangelets' or primordial black holes. Spoiling the party somewhat, astronomers and physicists now have demonstrated that the puzzle can also be explained by studying in detail how antimatter moves through the galaxy before annihilating with normal matter. In the light of these results, there is no need for exotic components to describe the unique Integral observations – maybe less exciting, but reassuring for our understanding of the Universe.

→ MARS EXPRESS

The Mars Express spacecraft is an excellent state of health with all subsystems operating nominally. A discharge test has shown that the batteries are also in a good state. For the last few months, the pericentre of its orbit has been over the mid-southern latitudes on the nightside, offering good conditions for the sounding of the subsurface by the radar instrument.

A Mars Advanced School sponsored by ESA was held in Jiaxing, Zhejiang Province, China, on 20–24 July. This intensive five-day course, with expert teaching staff from Europe and China, featured lectures on the highlights of Mars Express, archive data, Martian interior, impact cratering, geology, geodesy, atmosphere and solar wind interaction. This initiative contributes to the development of Chinese expertise in

About 40 graduate and postdoctoral students, as well as researchers, from mainland China and Taiwan, attended the Mars Advanced School in China in July



A recent HRSC image release shows Ma'adim Vallis, one of the largest canyons on Mars. The canyon is 20 km wide and 2 km deep, and is located between the Tharsis volcanic region and the Hellas Planitia impact basin. The image is centred at about 29° S and 182° E and has a ground resolution of 15 metres per pixel (ESA/DLR/FU Berlin)

planetary sciences, and fosters the excellent collaboration between China and Europe in the space science activities.

→ ROSETTA

Rosetta is preparing for its third and last Earth swingby, scheduled for 13 November 2009. A deep space manoeuvre was executed on 19 March to set the spacecraft onto the required final trajectory. The closest approach will be at a distance of 2480 km above the surface of the Earth at about 07:45 UTC (08:45 CET). This final Earth swingby will change the heliocentric velocity (and therefore the orbital energy) of the spacecraft to meet the requirements for the rendezvous with its target, Comet 67P/Churyumov-Gerasimenko in 2014, and also correctly position it for the encounter with asteroid (21) Lutetia in July 2010.

An active payload checkout takes place about two months before the Earth swingby. This 12-day checkout (21 September to 2 October 2009) is the fourth of five checkouts planned for the mission and has been allocated as preparation for the Lutetia flyby, and for comet phase payload operations. Currently the spacecraft is configured in Near Sun Hibernation Mode will be woken up in early September 2009.

→ VENUS EXPRESS

Many results from Venus Express were reported at the 43rd ESLAB symposium 'International Conference on Comparative Planetology: Venus-Earth-Mars', held at ESTEC, 11–15 May. Among the highlights was the new theory launched by the ASPERA team, that a strong magnetosphere, contrary to what is generally believed, enhances atmospheric escape rather than protecting the atmosphere from erosion. This theory is supported by measurements on board Venus Express, Mars Express and Cluster. The talk generated much discussion at the meeting and subsequent reports in the media. A number of papers arising from the conference will be published in a special issue of Planetary and Space Science. The main operations during this period were special activities to minimise the impact of the limited ground station availability owing to the Herschel/Planck launch in May.

→ AKARI

Akari continues routine operations in its post-helium phase with 501 European observations having been carried out. Calls for Proposals for the second year of the post-helium phase were issued in parallel by ISAS/JAXA and ESA in May and resulted in 18 and 5 proposals respectively. ESA's contribution to the Mid Infrared Survey catalogue is proceeding smoothly, with the first internal test version being recently released. The public release of the Far Infrared catalogue is expected in Autumn 2009 and the Mid Infrared in 2010.

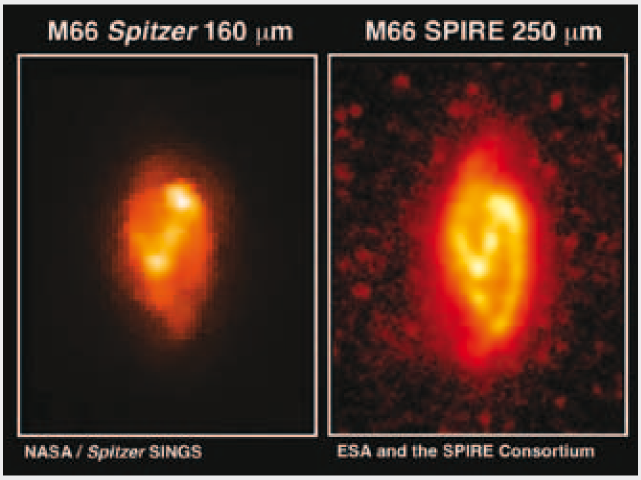
→ HERSCHEL/PLANCK

The launch campaign for Herschel and Planck was completed with the launch of both spacecraft on 14 May 2009. The launch delivered both satellites into a near-perfect transfer orbit to the second Langrangian point L2.

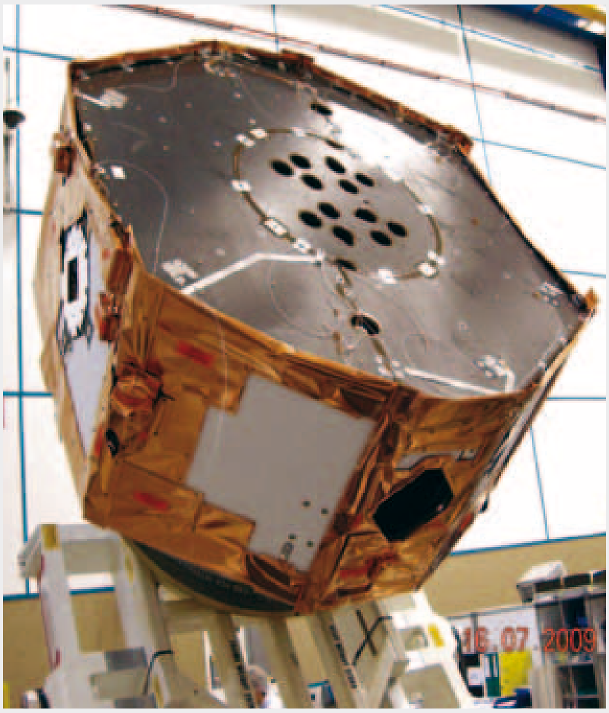
Commissioning of both spacecraft started after the early orbit phase on 19 May and was completed by mid July when the performance validation phase started. The commissioning phase ran very smoothly with only some minor anomalies that have all been corrected.

Herschel performance is well within the expectations and the highlights during the last period were the switching of the nozzle of the cryostat to set the final temperature of the superfluid helium bath and the opening of the cryostat cover on 14 June. The scientific instruments have all been functionally verified and found in perfect condition. The first scientific observations by the all instruments were carried out, demonstrating correct alignment and performance of the Herschel telescope. The detail and the quality of the first images received from the instruments significantly exceeded what was possible so far – exactly as expected from the Herschel observatory.

Planck has performed equally well within its specifications. The major part of the instrument activities was devoted to the start-up of the cryogenic cooling chain and the cooldown of the instrument. The ultimate temperature of 100 mK at the HFI detectors was achieved on 2 July and a first assessment of the data shows that both instruments, LFI and HFI, as well as the coolers are in a very good state. The



On 24 June, Herschel's SPIRE instrument was trained on two galaxies for its first look at the Universe. The pictures show Herschel's view of galaxy M66 at a wavelength of 250 micrometres (longer than any previous infrared space observatory, but still the shortest SPIRE wavelength) compared to Spitzer's shorter wavelength view



LISA Pathfinder Science Module integration at Astrium Ltd in Stevenage (EADS Astrium)

In-Orbit Commissioning Review was held on 21 July with all the requirements of the commissioning phase met.

→ LISA PATHFINDER

The LISA Pathfinder industrial team has been working on the actions arising from the system Critical Design Review (CDR) and has achieved the objectives of the CDR close-out in May. The main improvements have been concerning the software requirements consolidation, the onboard computing load and the allocation of resources to the Real-time Test Bench (RTB) verification.

The onboard computer and both spacecraft and payload harness flight models have been delivered. Integration of the Science Module flight model has started. The Propulsion Module light model structure has completed all tests (acoustic, separation and shock tests at ESTEC and static tests in IABG) and has been shipped to Stevenage (UK) for further integration with the bipropellant propulsion equipment. The verification of the onboard software is continuing on the Software Verification Facility (SVF) and on the two parallel RTBs in Astrium Ltd for the attitude control and power aspects and in Astrium GmbH for the drag-free attitude control.

The slit caesium thruster micropropulsion CDRs are being held at subsystem level. The FEEP Cluster Assembly CDR revealed that a design modification is needed to reduce the thruster degradation during endurance tests. A taskforce has been set up to thoroughly investigate the problem and evaluate the solution, and the micropropulsion system CDR has been delayed to September. Meanwhile, additional material tests are being performed in Alta (Pisa, Italy) and in the Electric Propulsion and Material Laboratories at ESTEC. The needle indium FEEP are continuing in technology development as a back-up.

The American payload DRS is ready to be shipped to Europe. The suppliers of the various European LISA Technology Package (LTP) parts have delivered all the electrical model units to Astrium GmbH for the Real-time Test Bench. The first LTP electronic flight model unit, the Laser Modulator, has been delivered to ESTEC for magnetic tests. The inertial sensor remains the most critical item, with the caging mechanism, the electrodes housing and the vacuum system. Other subsystems, such as the Phasemeter Unit, the Laser Reference Unit, the Inertial Sensor Front-end Electronics and the LTP software, are expected to be delivered before the end of the year.

The launch is not expected to take place before mid 2011.

→ MICROSCOPE

The qualification phase of the Microscope T-SAGE instrument is ongoing. All parts of the Sensor Unit qualification model were delivered to CNES, including the proof masses. On the platform, the procurements of the payload assembly structure, reaction wheels, solar sensors, magnetometers/magneto-torquers and battery are taking place and the next flight model delivery will be the On-board Computer. On the microthruster side, ESA and CNES teams are preparing an updated configuration design trade-off based on the results of the development activities. These will be presented at the next steering meeting in October, when the go-ahead for the flight hardware manufacturing of the selected system configuration will be given.

→ GAIA

The production of flight hardware for Gaia continues as planned with the first flight units of the Service Module already available (battery, low-gain antennas, one gyro, CDMU and the tanks of the chemical propulsion system). Of the 106 flight model CCDs, 90 have been accepted and are in storage waiting for the availability of the flight model front-end electronics for coupling tests.

The flight model structure of the Service Module has been delivered from the subcontractor CASA to Astrium Ltd. Integration of the chemical propulsion tanks and piping is planned for the summer. The qualification model of the 10 m diameter sunshield is nearing completion. A quarter of the size of the full sunshield, the model passed vibration tests at Sener and is now in the Large Space Simulator at ESTEC where it will undergo thermal qualification. Activities on the spacecraft avionics model are progressing, with many engineering model units integrated and first subsystem tests carried out using an advanced version of the central software.

On the Payload Module, the highlight has been the brazing of the large optical bench (the 'torus'). Ultrasonic inspection of the 17 brazed interfaces is being carried out at Boostec Industries. The torus will then be sent to Astrium SAS at the beginning of August. At Sagem, Zeiss and AMOS, several flight model mirrors are being polished. Delivery of the first mirrors for integration on the Payload Module is expected in October. The integration of the Focal Plane Assembly engineering model is progressing with the first of two CCD rows installed.

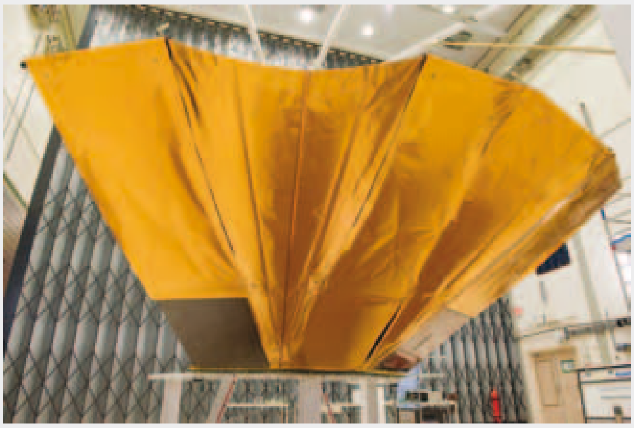
The Design Review of the Gaia Data Processing and Analysis Consortium (DPAC) took place in June. The review board concluded that the activities at DPAC are on track.

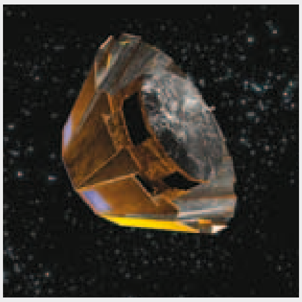
→ JAMES WEBB SPACE TELESCOPE

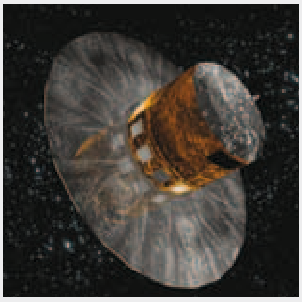
In view of critical items not yet completed, in particular elements of all science instruments, NASA has announced a one-year delay of the JWST launch date to June 2014. Cryogenic verification of the first fully assembled flight Primary Mirror Assembly segment has been completed and correction of the measured cryogenic-shape is ongoing. The conceptual baseline review of the actively cooled shroud around the Mid Infra Red Instrument (MIRI) instrument, to minimise the heat lift requirement to the coolers, has been completed.

The Near Infrared Spectrograph (NIRSpec) full-scale instrument Development Model has completed its first cryogenic thermal cycle and is now undergoing characterisation

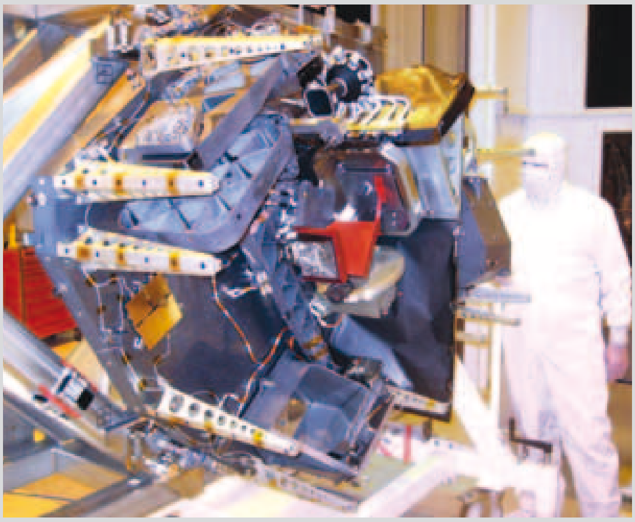
The Gaia flight model optical bench (Torus) after brazing. The hardware will undergo careful ultrasonic inspection to demonstrate suitability of the workmanship (Boostec)







Top: Qualification Model of Gaia's sunshield during deployment testing at ESTEC, Noordwijk. Bottom left: Artist impression of Gaia's sunshield deploying; right, fully deployed



JWST NIRSpec Development Model undergoing gravity test (EADS Astrium)

activities in its second cycle. NASA has now resolved the detector noise problem by trimming the detector ASICS. The Micro Shutter Assembly (MSA) shock test was passed after the initial MSA shock failure. The fight model Instrument Control Electronics (ICE) unit and software have been delivered. The flight main optics is also partly delivered and all remaining mirrors have been manufactured and are in final testing or alignment. The development of the cryogenic mechanisms remains critical.

All the MIRI filter wheel and dichroic/grating wheel mechanisms have been fully integrated. The Spectrograph Main Optics flight model has been delivered to RAL for instrument integration. The ICE flight model passed its final tests and is being prepared for delivery to RAL. A design problem in the detector electronics causing too high-level noise has now been identified by JPL. A repair of the flight boards is now required and will delay the delivery of the detector system to RAL for integration into the MIRI optical system and thus the start of the flight model test campaign.

Launcher coupled load analyses have been completed for two orientations of the JWST observatory. It has been confirmed that a rotation of JWST with respect to the upper stage will reduce the JWST centre-of-gravity offset problem identified during the mission Preliminary Design Review. The use of the Herschel-Planck launch campaign as a 'pathfinder' to upgrade the cleanliness control for JWST has been successful. Only minor adjustments will be required for JWST.

→ BEPICOLOMBO

The System Preliminary Design Review (PDR) board acknowledged the significant progress during the last year in the system design and the technology readiness status. However, concern remains on the mass budget, power availability and solar array technology readiness. Work is now progressing on the key critical issues and a report will be made to the PDR board in September. The PDR close-out meeting is expected in November.

Since the System PDR, the development of the mass is stable, which includes the completion of the PDR on the Mercury Planetary Orbiter structure. Also, the high-temperature high-UV intensity tests on solar cell assemblies continue and the development of blocking diodes is according to plan. The electric propulsion thruster has completed the 2000-hour endurance test, the result of which demonstrates that the screen grid erosion is under control and the life requirement can be satisfied. Software definition is going as planned and testing of the Onboard Computer and software test bench at the prime contractor was completed. The related hardware was delivered to the software development team. The equipment procurement process continued and 75% of the subcontractors have been selected. While some subcontracts are in final negotiation, most equipment work has started.

After the Instrument PDRs, most of the payload teams established their contracts for the C/D phase up to launch and commissioning. Payload teams are focusing on the procurement and manufacturing of the instruments, with hardware deliveries scheduled in 2010 for both structural thermal models and engineering models. The bilateral agreement between Roscosmos and ESA on the provision of the gamma-ray scientific instrument MGNS was signed in June 2009.

MMO development is progressing as planned in Japan with the completion of data management tests on the spacecraft electrical model, which includes models of the scientific instruments. The acoustic, shock and vibration tests on the structural model were completed with only minor problems identified. An extra string of solar cells will be added on the body of the spacecraft in order to account for the expected end-of-life performance in an extreme temperature and ultraviolet environment.

→ EXOMARS

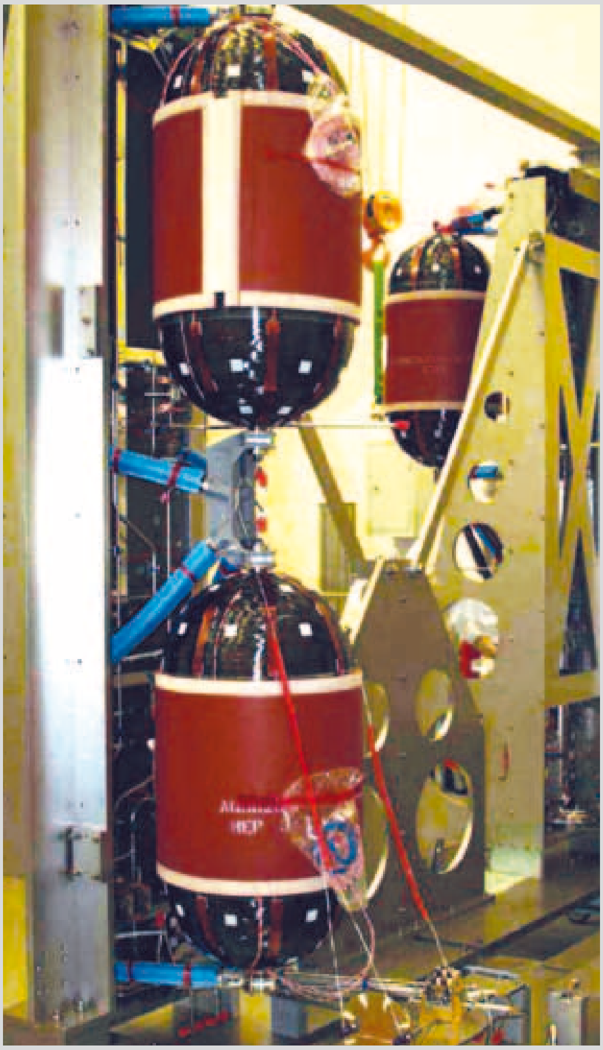
ExoMars is currently in an extended Phase B2, which started in April 2009 and will run to March 2010. As mandated by the Ministerial Council 2008, discussions with NASA on a major cooperation for the exploration of Mars have been proceeding with detailed technical and executive level meetings. The activities pertaining to international cooperation culminated in June with an ESA/NASA bilateral meeting between ESA's Director of Science & Robotic Exploration and the NASA Associate Administrator for Science in Plymouth, UK. The fruit of this historic collaboration was an agreement to create a Mars Exploration Joint Initiative that will provide a framework for the two agencies to define and implement their scientific, programmatic and technological goals towards Mars. In parallel, industry has been supporting the ongoing discussions with NASA to consider various configurations for cooperation with an objective to establish a basic system baseline to be reviewed later this year.

Decisions on the future of ExoMars will be made based on the limitation of funding declared by the participating states. The subscriptions of €850 million declared at the Ministerial Council are very restrictive for a mission such as ExoMars, and the participating states must decide on their priorities within this limit budget. A report by the Director General will be presented to ESA Council in October 2009 on the proposed way forward.

→ ALPHABUS AND ALPHASAT

Service Module

The qualification of the Alphabus Product Line equipment and subsystems is progressing well and the integration of the Alphabus Service Module protoflight model has started in April. Various structural elements are being received or manufactured in Thales Alenia Space Cannes for further preparation and integration into the Service Module. The first step is the assembly of the internal deck received from Ruag (CH) with the central tube from CASA (ES), now planned for mid July. The Chemical Propulsion System (CPS) main gas and liquid control module integration has been completed in Astrium Lampoldshausen (DE) and delivered to Thales Alenia Space Cannes where it is being equipped with thermal control hardware. The Service Module activities should lead to the delivery of the protoflight model structure, integrated with propulsion elements by the end of the year to Toulouse where it will be equipped with its avionics ready for Service Module testing. The Service Module structure and fully equipped CPS are expected to be delivered to Toulouse by the end of the year.



Alphabus chemical propulsion module built by Astrium in Lampoldshausen (EADS Astrium)

In Toulouse, pre-integration of avionics flight equipment on a mock-up of the spacecraft structure is ongoing to validate assembly procedures in advance of the completion of the flight structural items.

Repeater Module

In parallel, the Repeater Module activities have also started: the flight models of the large repeater north and south walls have been manufactured in April and are being prepared for shipment to Thales Alenia Space Turin towards end of June for thermal hardware integration and the final assembly into the two halves of the Repeater Module. Preparations are ongoing in Turin with procurement of all necessary toolings and review and approval of all the necessary processes that will be used.

Thales Alenia Space Cannes activities, which include panel and heatpipe manufacturing, are now completed. The large north Repeater Module panel has been shipped early July to Turin where it will be equipped with thermal hardware and prepared for assembly of the remaining panels into a half Repeater Module. Both halves are planned to be completed by first quarter 2010.

Launcher

The launcher contract has been signed in May 2009 between Inmarsat and Arianespace for an Alphasat launch on an Ariane 5 in the second half of 2012. A mass review of the satellite was concluded end of June confirming the compatibility of the satellite with the launcher.

Payload

The Inmarsat extended L-band (XL) 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.

Development of the Inmarsat operational payload equipment is ongoing. For most of the equipment targeted for the

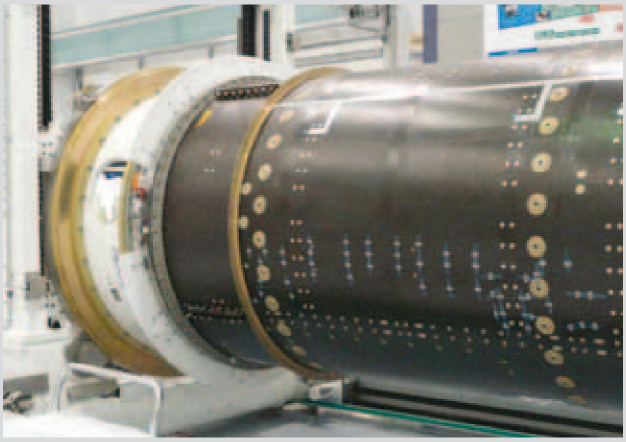
Alphabus Repeater Module 'north' panel shown here at Cannes during insert placement operations (Thales Alenia Space)

payload electrical qualification model, manufacturing is under way. While the Integrated Processor remains a priority in the programme, due to its pivotal role in the payload performance, activities have also focused on a number of new developments related to payload calibration which will be used to provide further performance improvements to the operational payload.

The Alphasat Payload Critical Design Review is planned early 2010. A first integration of payload elements to verify key performances is planned in the same period

Technology Demonstration Payloads

Work has concentrated on the preparation of inputs for the satellite Critical Design Review, foreseen towards the end of the year. For TDP8 (the environment effects facility), the breadboard manufacturing and testing is complete and Phase C/D is now in preparation.



Alphabus central tube prepared for integration at Thales Alenia Space, Cannes

Alphabus extension

The Alphabus extension programme will extend the platform's power, mass and thermal rejection capabilities. A preliminary workplan was presented to the ESA Programme Board for communication satellite programmes in May following extensive iteration with industry. During the summer, the workplan will be consolidated and bilateral meetings held with delegations to attract further subscriptions to the programme. The Alphabus extension workplan will be presented to JCB in September for approval.

Alphasat User and Application segment

The user segment and application programme will support the exploitation of the Alphasat satellite enhanced performances, developing new value-added services to mobile institutional and public users on a pan-European scale. The workplan has been approved by the ESA Programme Board for communication satellite programmes and the Industrial Policy Committee and is now being implemented. Proposals for the first two activities with Inmarsat have been received in June and are under evaluation.

→ CRYOSAT

During May and June the satellite went through the remaining environmental tests (thermal balance and vacuum) and electromagnetic and radio frequency compatibility. A few issues were found during thermal vacuum tests, requiring some units to be removed and returned to the manufacturer for investigation and repair. In one case, the unit (the main satellite computer) is scheduled to be removed at the end of July and cannot be returned until the end of August. Normal testing cannot continue without this computer, so a break in activities is imposed. In other cases, the test planning has worked around the unit repairs. The month of margin between the end of testing and the start of the Flight Acceptance Review has been consumed.

In June, the launcher Design Consolidation Meeting was held, in which all the mission specific adaptations were scrutinised. Also in June, the acceptance review for the ground segment began, to be completed at the end of July. In July, the launch adapter and separation system was brought from the manufacturer in the Ukraine to the satellite test facility in Ottobrunn, where a fit check and separation test were performed.

→ SMOS

All final satellite activities have been completed, and the project is now waiting to start packing for the launch campaign. Due to further delays announced by the Russian

Astrium Ltd team with Swarm satellite structure before shipment to IABG Munich for testing (EADS Astrium)

launcher authority, the SMOS campaign is now expected to start in mid-September at the earliest. The Flight Acceptance Review was completed in May, with a few actions still being worked on.

→ ADM-AEOLUS

The measures to reduce the susceptibility to laser-induced contamination have been implemented in the engineering model of the ALADIN laser. This included the refurbishment of all ultraviolet optics with new robust coatings. Functional tests of this model in vacuum and at low pressure are in progress and the first phase of the tests (two days of continuous laser operation) was completed with stable laser performance, fully in line with predictions.

The long-term life-test of the laser pump-diodes was completed after 16600 hours (almost two years) of continuous operation. The output energy of the laser-diodes exceeded expectations, giving good confidence in the performance of these key components over the full mission lifetime.

Steady progress has been made in the completion of the remaining platform activities and further formal test cases were executed. The completion of the nominal platform programme is foreseen in the autumn of 2009.

→ SWARM

The satellite development phase is in progress with the environmental test completed on the structural model of the satellite at IABG, and the delivery of the first flight models at unit level. The first System Validation Test (between the satellite test bed and the operating centre) was completed. The Critical Design Review of the Absolute Scalar Magnetometer is complete. This paves the way for the manufacturing of the flight models. A peer advisory group of geomagnetic specialists met at ESTEC during this quarter to advise the ESA project team about the potentiality of Level 2 geophysical products. The second Swarm international science meeting took place on 24–26 June 2009 at GFZ in Potsdam. The invitation to tender for the launcher procurement and for the Level 2 facility development is under preparation.

→ EARTHCARE

Following the System Requirements Review conclusions in February, the ESA and JAXA teams and industry have detailed and implemented solutions to all issues raised during that review. System, Instrument, Base-Platform and GDIRs (Generic Design and Interface Requirement Document) have been updated accordingly and iterated with the instrument and platform sub-contractors.

An EarthCARE Industrial Day took place in ESTEC in June to inform potential sub-contractors of the intended Phase B procurement under the Best Practices scheme. This procurement activity is ongoing and it is intended to initiate most equipment procurement and complete the industrial consortium by the end of Phase B.

In parallel with the above, industry is preparing the documentation required to organise the System Preliminary Design Review (PDR) planned after the summer break. Instrument PDRs have begun for the multispectral imager, broadband radiometer and cloud-profiling radar and are expected to be completed in the timeframe of the System PDR. The ATLID instrument PDR has been delayed to consolidate a back-up design addressing the ultraviolet laser-induced contamination issue.

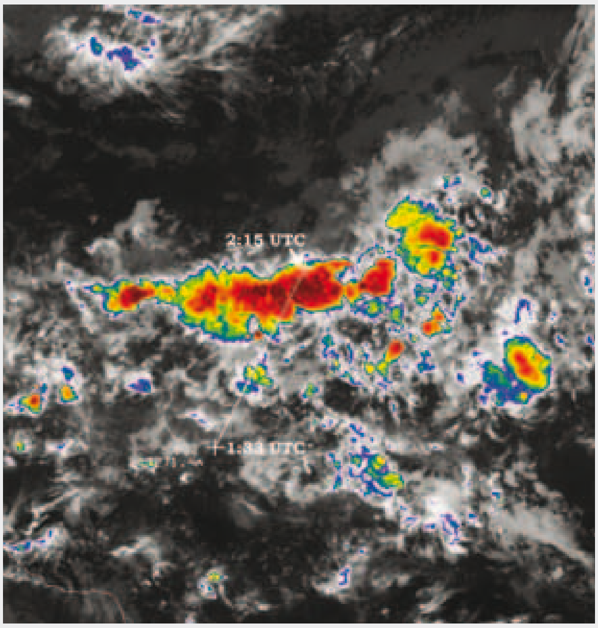
The development of the EarthCARE spacecraft in the last months confirmed the compatibility with the Soyuz and Zenit launchers and highlighted the difficulties associated with the alternative PSLV launcher – in particular performance, loads and export license issues.

→ METOP

MetOp-A

MetOp-A is in very good health and the instruments continue to perform excellently in orbit. Using radiation measurements obtained by MetOp-A, scientists have produced the first complete map of global ammonia emissions – a pollutant of key environmental concern. The map, based on observations throughout 2008, from the Infrared Atmospheric Sounding Interferometer (IASI) instrument on MetOp, shows inaccuracies in current ammonia inventories and identifies new hotspots.

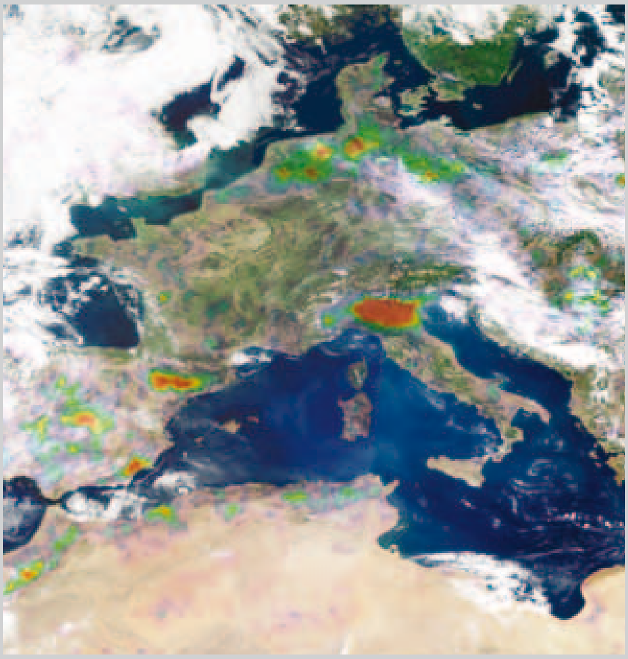
Although IASI was not originally designed to allow detection of ammonia in the atmosphere, scientists have developed a novel technique to isolate its signature from background noise. Several ammonia hotspots have been found, mainly over agricultural areas in Asia, Europe, and North America. The satellite estimates exceed the simulations, suggesting that current emissions are underestimated. Ammonia contributes significantly to the development of pollution, originating from the intensive use of agricultural fertilisers. The emission inventories are not precise or comprehensive, and systematic monitoring of this compound is difficult. Once emitted, ammonia remains in the atmosphere for a few hours and generates a cascade of environmental problems. High concentrations of ammonia affect wildlife and air quality locally



Meteosat-9 infrared image taken 1 June 2009 of major thunderstorm clusters on an extrapolated flight path of Air France flight AF447 from Rio to Paris when it was tragically lost (Eumetsat)

MetOp-B and MetOp-C

The new MetOp-B and C launch dates and the optimised Assembly, Integration and Testing (AIT) schedule have now been approved 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. With the optimised AIT planning, MetOp-C integration activities will be started, with the aim to bring the spacecraft to an integration stage that would allow for 'quick relaunch' (within 12 to 15 months) in case of MetOp-B launch failure.



Ammonia distributions over Europe in 2008 as seen by the IASI instrument on MetOp-A. The image has been superimposed over an image acquired by the MODIS instrument. The yellow to red colours indicate areas with high concentrations of ammonia (ULB/CNES/INSU-CNRS; MODIS image, LOA and Lille University)

→ MSG

Meteosat 8/MSG-1

Meteosat-8 satellite is in good health with instruments performing flawlessly. The Rapid Scan Service has been in operation for a year now. Rapid scan data complements the 15-minute High Resolution Image data generated by the operational Meteosat-9.

The scan period is five minutes, the same as European weather radars, allowing the monitoring of rapidly developing localised convective weather systems like thunder storms. The scan covers an approximate latitude range of 15° to 70°. The image data and products are based on the full 12 spectral channels available from MSG. Images are rectified to 9.5° E.

Meteosat-9/MSG-2

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

(Located at 67° E, Meteosat-6 is supporting the DCP mission over the Indian Ocean during eclipse periods. Located at 57° E, Meteosat-7 performs the Indian Ocean Data Coverage service, providing operational data and images over the Indian Ocean. Meteosat-5 was deorbited in April 2007 to approximately 500 km above the geostationary orbital ring.)

MSG-3

MSG-3 is in long-term storage in the Thales Alenia Space Cannes, awaiting the restart of the AIT campaign begin 2010, to prepare for its launch, which is foreseen for early 2011.

MSG-4

The SEVIRI Drive Unit (DU) on the MSG-4 spacecraft will be exchanged. Once a new flight DU is available and detailed performances are confirmed, dismounting activities on the satellite will be started. After reintegration of the satellite, it will be submitted to a mechanical and acoustic test sequence, including reference tests. The exchange activities and testing are due to be completed by mid 2011.

→ MTG

The Requirements Consolidation Workshops and Mid-term Reviews have been completed with both consortia, allowing appropriate adjustments to be made to the MTG requirements, and further analyses and iteration of the proposed industrial baseline design. The Interim System Requirements Reviews, scheduled for early July, are finalising these Phase A Extension activities.

In parallel with these activities, the B2/C/D ITT documentation has been finalised and is ready for release in July 2009, following agreement of the TEB. The Procurement Proposal for the MTG B2/C/D activities, and associated (modular) procurement strategy, was approved in June.

→ SENTINEL-1

With the completion of the procurement of the equipment via the Best Practices procedure, the industrial team is now complete. The System Critical Design Review will take place in the first quarter of 2010.

In order to prepare the ground for the selection of a technically suitable launcher for Sentinel-1, Coupled Load Analyses with two potential launch providers, namely Arianespace for Soyuz and Yuzhnoye for Zenit, were produced (for both launchers). Both results show full compatibility of the Sentinel-1 with both launchers (single launch configuration). The ITT for the procurement of the launcher will be issued during the third quarter 2009.

The Memorandum of Understanding for the 'in kind' provision of a Laser Communication Terminal by DLR to ESA for Sentinel-1A was signed in Bonn on 9 June. Two technical meetings between the LCT prime developer (TESAT) and the Sentinel-1A prime contractor were held in the meantime to progress towards the definition of the interfaces.

The earthquake that hit L'Aquila in Italy on 7 April 2009 has a significant and adverse effect on the Sentinel-1 schedule. Key Sentinel-1 technology, the Electronics Front-End (EFE) of the SAR antenna, was being assembled and tested in the L'Aquila plant, which is now closed. At the end of March, the EFE development was in a good state, namely: schedule-wise, the EFE was not on the critical path of the project (about two months slack time); in addition, early tests confirmed its excellent performance (better than specified); early test of the EFE with (a breadboard of) the Antenna Tile Control Unit also delivered perfect results. As a consequence of the earthquake, all equipment in the L'Aquila plant has been transported (mostly) to the Thales Alenia Space Italy plant in Rome, where – reassembled, recalibrated and after requalification of all processes – the production will restart in October.

An early radio frequency compatibility test among all antennas on board has provided excellent results and ample margin with respect to the specification. This early risk-retirement test provides the confidence that no disturbance among the antennas will occur.

The procurement of the second satellite, Sentinel-1B, has started and the offer received from industry is under evaluation.

The Sentinel-1 Ground Segment Preliminary Design Review is planned for between July and September 2009.

→ SENTINEL-2

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 early 2013. Price conversion and contractual negotiations have been completed with EADS Astrium, enlarging the baseline contract for the procurement of the second satellite model and the integration, test and in-orbit commissioning of two Laser Communication Terminals, as an option.

The Sentinel-2 Ground Segment Requirement Review and the Ground Prototype Processor System Requirements Review have been held, demonstrating the maturity and coherence of the space and ground-based elements of the Sentinel-2 system. Preparatory activities initiated with Arianespace (Vega) and Eurockot have demonstrated the satellite compatibility with the two launchers. The second half of 2009 will focus at finalising the build-up of the industrial consortium, and at consolidating the Sentinel-2 contract through a rider to be approved in September 2009.

Preparations for the embarkation of a Laser Communication Terminal are advancing with accommodation prepared on the spacecraft and agreements being finalised with the European Data Relay Satellite programme.

→ SENTINEL-3

C/D post-Preliminary Design Review (PDR) consolidation activities are proceeding and lower-level equipment PDRs are ongoing, with their completion planned for this summer. At the same time, the first equipment Critical Design Review will start.

At system level, new mission analysis simulations have been performed in the field of orbit maintenance and deorbiting, as well as micrometeoroid orbital analysis to determine possible areas that require protection. The operational concept for mission data storage and download has been frozen, following a mass-memory software PDR. At optical and topographic mission level, progress has been made in products definition, allowing the update of the relevant definition documents.

On the satellite, an alternative Attitude & Orbital Control System OCM mode has been analysed and proposed aiming to reduce the stringent requirements on thruster qualification. Feasibility has been demonstrated and finalisation of the new baseline is expected in the coming weeks. At platform level, the main technical issues are related to the battery sizing to cover safe-mode conditions, the solar array drive mechanism (SADM) design maturity and the SADM to solar array wing interfaces (mechanical loads). For this last point, the introduction of a sixth hold-down point seems now required to improve the solar array mechanical behaviour under launch loads.

On the instrument side, no major technical issues for SRAL and OLCI. The SLSTR instrument has undergone a consolidation of the new instrument development schedule following the PDR recommendations. All the lower-level PDRs are ongoing. On the MWR, the main open point is still the final assessment of the effects of the earthquake in L'Aquila on Thales Alenia Space activities, which could result in a delay of the instrument activities.

Of the 120 or so procurement contracts to be placed through competitive Invitations to Tender, 96 have been either concluded or are under final negotiation. In parallel to the Sentinel-3A activities, the procurement of the second Sentinel-3

The final qualification test of the Zefiro 9A solid rocket motor at Salto di Quirra model (B model) has started, limited to the procurement of the common equipment.

→ VEGA

On 28 April, the Zefiro 9A solid rocket final qualification test firing took place at the Salto di Quirra Interforce Test Range in Sardinia, Italy. The test verified the behaviour of the Zefiro 9A motor in a fully flight-representative configuration, and confirmed the design performance and collected information for system studies at stage level.

The AVUM liquid propulsion system firing test campaign of long-duration runs was completed except for hot-restart and depletion tests.
The P80 Ground Qualification Review began in June; the Insulated Motor Case generic qualification tests on the development model were achieved, except burst tests that are planned for September.

After in-plant qualification, the second release of the Vega Control Centre has been installed at the Vega launch site.

→ SOYUZ AT CSG

A consultation committee took place with the Russian partners at the Paris Air Show on 17 June. The main issue of this committee was the signature by all the parties of a new agreed planning. A delay by a few weeks of the first launch date was announced.

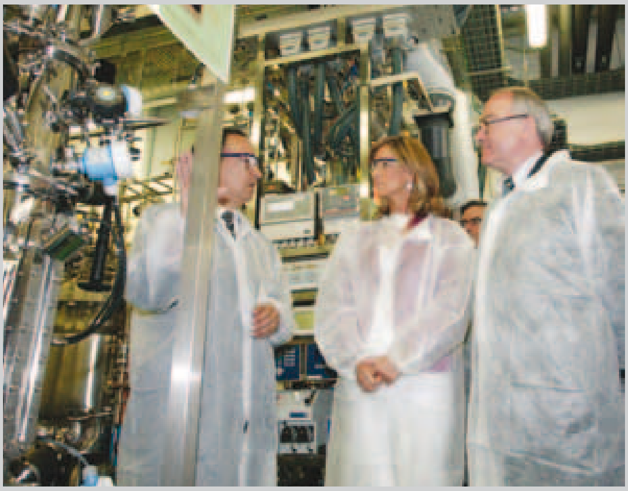
The third ship arrived in French Guiana on 26 June with the liquid oxygen and nitrogen tanks and the rail kerosene fuelling system on board. The fourth ship arrival in French Guiana has been postponed to November with the two launchers, the Fregat feeding systems and feeding mock-up on board.

The complete Mobile Gantry structure was erected and tests completed in Sergiev Posad, Russia. Dismantling of the mobile gantry structure for packing and transporting to French Guiana started on 24 June. It will be delivered to French Guiana in several batches: the first one was delivered on 20 July. The other batches will be delivered during summer, with a last delivery at the end of August. At the Soyuz Control Launch Centre, Russian equipment is being installed in the Fregat control room. In the Launcher Control Room, racks for data retransmission of launcher parameters and telemetry are being tested.

In the Soyuz Launch Vehicle and Fregat Preparation Building, the integration of launcher mechanical ground support equipment has started and the installation of electrical and hydraulic equipment on the launcher erection transport wagon is ongoing.

In the launch zone, the installation of ventilation ducts through the launch table is in progress as well as the installation of compressed gas pipelines in the technical ring. The connection of the cryogenic pipes to the control panels in the technical ring and the installation of liquid nitrogen pipes are also under way. The water cannons on the launch table have been installed.

The new Soyuz launch pad in the 'ready' position, i.e. with the four support arms closed and the two umbilical masts raised to service the Soyuz vehicle, viewed from the railtrack that will be used for the rollout of launch vehicles on their transporter/erector wagons (ESA/CNES/Arianespace/Optique vidéo du CSG/J. Guillon)



MELiSSA pilot plant inauguration at the University Autònoma of Barcelona, with Spanish Minister for Science and Innovation Cristina Garmendia (centre) and ESA Director General Jean-Jacques Dordain (right)

With the STS-127 crew joining Expedition 20 on the ISS, a total of 13 astronauts and cosmonauts were on board. From top left, Roman Romanenko, Christopher Cassidy, Doug Hurley, Tim Kopra, ESA's Frank De Winne; middle row, Koichi Wakata, Julie Payette, Robert Thirsk, Tom Marshburn; front row, Michael Barratt, Mark Polansky, Gennady Padalka and Dave Wolf

→ FLPP

For the IXV reentry demonstrator, sub-system PDRs were completed. The industrial proposal from the selected prime contractor for C2/D phase was received, and activities began in early July.

The System Requirement Review for the High Thrust Engine demonstrator started. System activities on Next Generation Launcher concepts are under way and activities on storable propulsion, as well as on hybrid propulsion, will start soon.

→ HUMAN SPACEFLIGHT

Inauguration of the second-generation MELiSSA (Micro-Ecological Life Support System Alternative) Pilot Plant was held on 4 June at the University Autònoma of Barcelona (UAB), Spain. MELiSSA is an artificial ecosystem that produces oxygen, water and food. The laboratory will help in the development of technology for a future regenerative life-support system for long-duration human space exploration missions, for example to a lunar base or to Mars.

→ INTERNATIONAL SPACE STATION

The permanent ISS crew increased to six on 29 May with the arrival of the Soyuz TMA-15 spacecraft. The new crewmembers De Winne, Romanenko and Thirsk were welcomed by the three already in residence: Russian Gennady Padalka, NASA's Michael Barratt and Japan's Koichi Wakata. It is the first time that all five ISS partners are represented on board the Space Station at the same time.

The propulsion module of ATV *Johannes Kepler* is inspected by the media at Astrium in Bremen in July (EADS Astrium)

→ SPACE INFRASTRUCTURE DEVELOPMENT AND EXPLOITATION

ATV production and cargo integration

The ATV *Jules Verne* Post-flight Review 2 was concluded in April. All consequential ATV *Johannes Kepler* modifications have been identified. The ATV-2 integration is proceeding nominally, targeting launch readiness in November 2010. The ATV-2 mission analysis has been started and the high-level cargo manifest has been received from NASA. The Production Readiness Review 2 Board was concluded on 18 June. The ATV-3 equipment procurement is running without problems and integration has started.

Operations status

The Columbus module continues to function nominally in support of the various ISS payload activities. The nine decentralised European User Operation Support Centres (USOCs) prepare and operate ESA's ISS payloads elements with the Columbus Control Centre. All ISS payloads are fully operational after corrective and preventive maintenance interventions by engineering support experts and USOCs.

→ UTILISATION

Despite a few minor technical anomalies, the ISS Increment 18 and 19 experiment programmes have been concluded. The EuTEF platform has been operated continuously with the PlegPAY experiment now also being reactivated for a final long-duration run. EuTEF will be retrieved from the external Columbus platform during an EVA to be performed by ESA astronaut Christer Fuglesang and returned to Earth on Shuttle flight 17A (scheduled for August this year) for detailed analysis and evaluation of the space samples after 1.5 years in orbit. The other external Columbus payload SOLAR has so far produced excellent scientific data during Sun observation cycles (from 23 March until 2 April, from 18 until 29 April, and from 22 May until 4 June). Based on a strong request from the science team, the long-term mission extension beyond the nominal return in spring 2010 is currently under technical feasibility assessment.

Since the arrival of the Processing Unit of the Protein Crystallisation Diagnostic Facility (PCDF) on the last Shuttle flight 15A, the European Drawer Rack is continuously active and providing power, data and cooling to the PCDF. The optical diagnostics video recording by means of microscopy, light scattering and Mach-Zehnder interferometry from the experiment reactors continued throughout several protein nucleation cycles where the final set of crystals will be returned to Earth on the upcoming Shuttle flight 2J/A for detailed x-ray analysis. The PCDF experiments will help the science team to better understand the influence of temperature on the onset of the nucleation process at various protein solubility levels and the role of depletion zones.

The Fluid Science Laboratory was activated on 29 May in order to acquire vibration measurements during the Soyuz TMA-15/19S docking. Further 24-hour measurements were taken on 3 June in support of PCDF activities. The Geoflow scientific activities, which have already produced a significant amount of excellent scientific data, are currently on hold awaiting repair and upload of the Geoflow Experiment Container.

Koichi Wakata completed his second and third (3/30 April) sessions of the 3D-Space experiment (Mental Representation of Spatial Cues During Space Flight), followed also by two sessions (20 April and 1 June) by Flight Engineer Mike Barratt who is the third test subject. The European Physiology Modules (EPM) Rack was activated on 17 June to perform the first session of the 3D-Space experiment for Frank De Winne and on 18 June to perform the first session of the experiment for Robert Thirsk.

This human physiology study investigates the effects of weightlessness on the mental representation of visual information during and after spaceflight. Accurate perception is a prerequisite for spatial orientation and reliable performance of tasks in space. The experiment has different elements including investigations of perception of depth and distance carried out using a virtual reality headset and standard psychophysics tests.

The EPM facility was activated on 3/4 June in support of the NeuroSpat experiment. On 3 June, Robert Thirsk performed his first session of the NeuroSpat experiment (Effect of Gravitational Context on EEG Dynamics: A Study of Spatial Cognition, Novelty Processing and Sensorimotor Integration) that also serves, with a combined protocol, an experiment from the European Commission within the SURE project.

The NeuroSpat experiment tests prefrontal brain functions and spatial cognition as well as the effect of gravitational context on brain processing. During this experiment, visual orientation and visuomotor tracking tasks, along with standardised electroencephalogram (EEG) tasks, are performed as a means of assessing general effects of the ISS environment on EEG signals. The involvement of five

From left: Mrs Di Pippo, Luca Parmitano, Alexander Gerst, Andreas Mogensen, Samantha Cristoforetti, Timothy Peake, Thomas Pesquet and Mr Dordain cognitive processes will be examined: perception, attention, memorisation, decision and action. The roles played by gravity on these neural processes will be analysed by measuring evoked potentials and EEG dynamics methods during virtual reality stimulation.

The EPM facility was also activated on 18 June in support of the CARD experiment with Koichi Wakata. Overnight blood pressure measurements were started with the CARD Holter device and a parallel measurement was performed with the Blood Pressure Electrocardiogram device from the US lab. CARDIOLAB Holter overnight measurements were completed and CARD data downlink activity was completed on 19 June. The CARD experiment examines increased cardiac output and lowers blood pressure (caused by dilated arteries) in the face of increased activity in the sympathetic nervous system (which normally constricts arteries) in weightlessness.

Experiment samples for the Sodium Loading in Microgravity (SOLO) experiment from ISS Commander Mike Fincke are stowed in the European-developed MELFI freezer awaiting return to Earth. SOLO is carrying out research into salt retention in space and related human physiology effects. The SOLO experiment also uses capabilities of the EPM facility. The experiment will be continued with the next subjects in Increment 20.

The Flywheel Exercise Device will be removed within the next few weeks 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 20. The Flywheel Exercise Device was launched to the ISS with Columbus in order to become an advanced exercise device for ISS astronauts and to serve human physiology investigations in the area of advanced crew countermeasures.

The maintenance activities of ESA's biology facilities Biolab and European Modular Cultivation System have been completed, ready for the next experiments.

Two plant biology experiments Polca and Gravigen, which were launched to the ISS on 26 March, performed nominally on orbit and were retrieved according to plan. The experiments were processed in the Kubik incubator between 3 and 6 April; samples were returned with Soyuz TMA-13 (17S) on 7 April. The results of the Gravigen experiment (the effect of weightlessness on gene expression in rapeseed plants (*Brassica napus*), and the Polca experiment (the effect of weightlessness on the distribution of calcium in the statocytes (gravity-sensing cells in plant root tips of rapeseed plant roots), have been examined by scientists and have delivered good results.

The Expose-R payload comprising a suite of nine new astrobiology experiments is functioning well. On 25 April and 4 May accumulated science data from this payload was copied onto a memory card in a Russian laptop PC by Gennady Padalka. The Material Science Laboratory has been integrated into the MPLM for launch on Shuttle flight 17A in August 2009, for accommodation in the Destiny laboratory under a cooperation agreement with NASA.

The Muscle Atrophy Research and Exercise System (MARES) Flight Unit has been shipped to NASA's Johnson Space Center for launch integration. MARES is scheduled to fly in March 2010 on Shuttle flight 19A.

The 50th ESA Parabolic Flight Campaign took place on 4/15 May with 14 experiments on board, 10 in physical sciences and four in life sciences.

→ ASTRONAUTS

EAC in Cologne was visited by the Czech Republic delegation on 16 April. The delegation was headed by Oldrich Vojír, Chairman of the Committee on Economic Affairs, and also included Karel Sehor and Pavel Hojda from the Subcommittee on Transport, and Karel Dobeš from the Czech Republic Space Office.

Following a stringent selection process beginning in May 2008, ESA Director General Jean-Jacques Dordain and Director of Human Spaceflight Simonetta Di Pippo presented the six new European astronauts at ESA Headquarters on 20 May: Samantha Cristoforetti (IT), Alexander Gerst (DE), Andreas Mogensen (DK), Luca Parmitano (IT), Timothy Peake (UK) and Thomas Pesquet (FR). The new recruits will join the European Astronaut Corps and start their training in September 2009 to prepare for future missions to the International Space Station, and beyond.

ESA astronaut Christer Fuglesang (SE) is preparing for the STS-128 mission (17A) in August 2009, while Paolo Nespoli (IT) is in training for Expedition 26/27 in November 2010. Roberto Vittori (IT) is in training at Johnson Space Center, Houston, under the ESA/NASA Mission Specialist Training Agreement.

→ CREW TRANSPORTATION AND HUMAN EXPLORATION

Advanced Reentry Vehicle (ARV)

The two Phase 0 industrial studies are proceeding. A Memorandum of Understanding was negotiated with NASA and approved by the ESA Council in June to progress the detailed definition of a common International Berthing Docking Mechanism interface for utilisation in the ISS and Orion and exchange of information on the man-rating design of space vehicles. The contract for the Advanced Phase A tasks was signed on 7 July. The Request for Quotation for the full Phase A was issued at the end of July by ESA's Director of Human Spaceflight.

International Berthing Docking Mechanism (IBDM)

The second technical exchange meeting to define the international standard for the future docking system for exploration was held at ESTEC in April. The meeting, involving NASA, ESA, CSA, JAXA and engineers from industry, including RSC Energia, focused on the definition of the hard docking system and resulted in an agreement to complete three trade-off studies to help define the optimum configuration.

EXPERT

Following the confirmation of additional funding from Italy and the Netherlands, the contract for the final phase of the Expert programme was signed in Rome on 20 July by ESA Director of Human Spaceflight and Thales Alenia Space, Italy.

Lunar Lander activities

To progress the design for a small mission on a shared Ariane 5 Geostationary Transfer Orbit launch, two Contract Change Notices were placed with the MoonNEXT industrial teams of OHB and Astrium Bremen. Results of the feasibility and technical definition studies of MoonNEXT Phase A activities were presented at ESTEC on 16/18 June. The MoonNEXT Preliminary Requirements Review is in progress.

A Lunar Lander Request for Information posted on the ESA Web Portal on 2 March attracted a remarkable level of interest and participation, with more than 190 proposals received by the closing date of 14 April. Delegations have been invited to nominate national experts to take part in the evaluation of the proposals.

International architecture development

The next International Space Exploration Coordination Group meeting will take place at the end of 2009, chaired by ESA Directorate of Human Spaceflight. ESA hosted a lunar architecture workshop in June.

In the frame of the ESA/NASA Comparative Architecture Assessment (CAA), meetings have been organised to consolidate the objectives and work plan for Phase 2. The joint analysis activities focus on the development of reference scenarios for collaborative missions involving the NASA Altair lunar lander and the ESA Cargo Lander; the analysis of collaboration opportunities for development, testing and deployment of the In-Situ Resource Utilisation capabilities; and the value assessment of contributions to international architecture. The ESA-JAXA CAA Phase 1 has been completed with associated reports identifying the commonalities and differences between ESA and JAXA concepts for cargo and human transportation, as well as the surface infrastructure elements, such as the pressurised rover, power and mobility systems. The possible scope and objectives for Phase 2 have also been discussed.

Human Exploration Technology

Two activities proposed for implementation, namely the development of a Water Treatment Unit Breadboard and further development of the MELiSSA Pilot Plant, were approved at the IPC meeting on 7 May. The ARES development activities continue, albeit on a reduced scale.

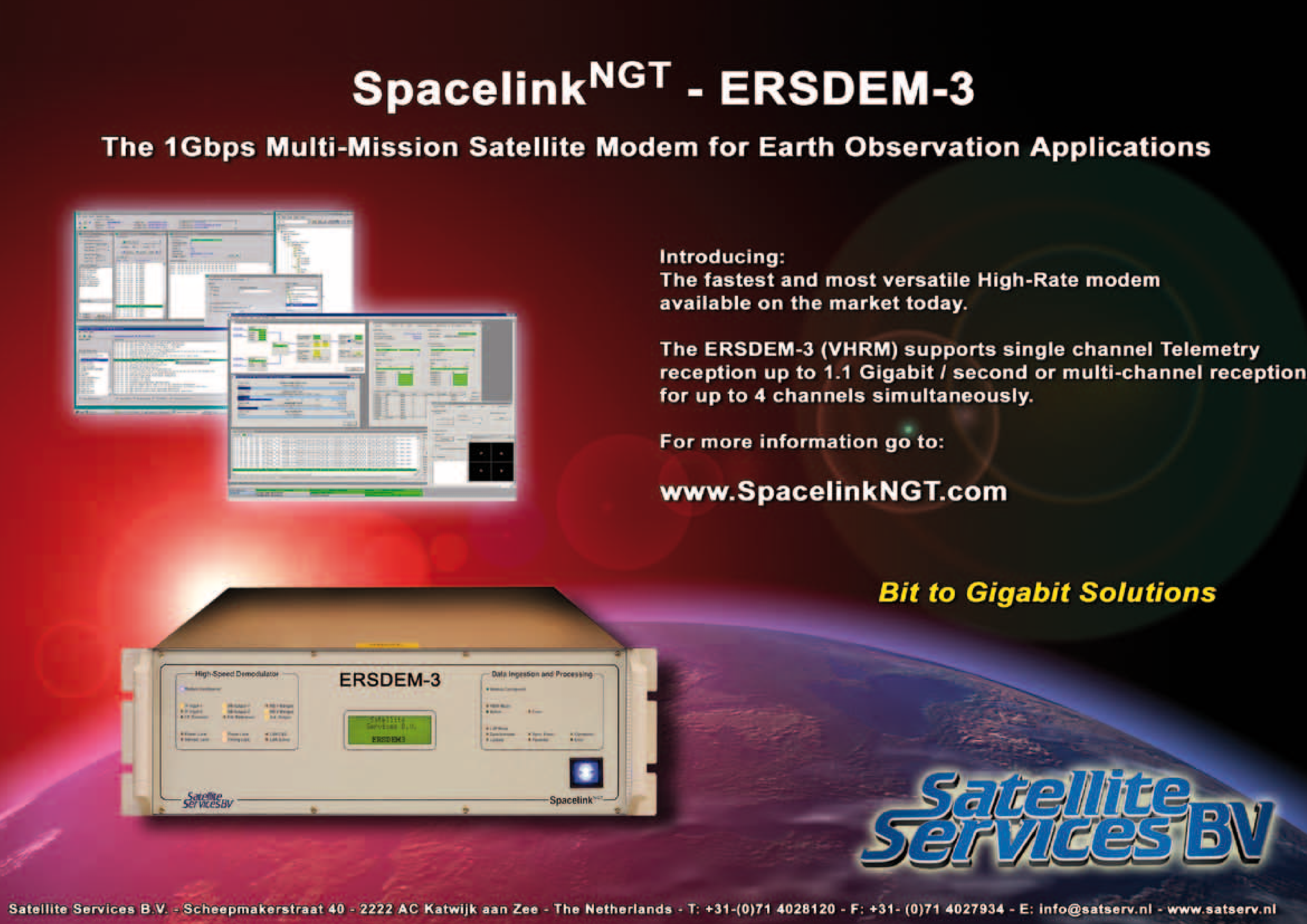
Outreach activities

Three educational DVDs produced by the Human Spaceflight Directorate have won prestigious awards at international multimedia festivals: 'ISS DVD Lesson 4 – Mission 4: Space Robotics', 'The ingredients for life: On Earth and in space' and 'Space transportation: an ATV perspective'.

Belgian student Ann-Sofie Schreurs won the SUCCESS student contest with her experiment proposal on 'Space Radiation Effects on Gene Expression'. SUCCESS is a competition for European university students to propose an experiment that could fly on the ISS.

In June, a competition was launched to select the official European name of Christer Fuglesang's mission on STS-128, open to all citizens and residents of ESA Member States. From around 190 suggestions, the winning name was 'Alissé', proposed by Jürgen Modlich, of Baierbrunn, Germany. The name refers to the trade winds used by the 15th century explorers who followed Christopher Columbus across the ocean to the New World. One of the most famous trade winds is the 'alizé', a steady north-easterly wind that blows across central Africa to the shores of America. By changing the letters 'iz' to 'iss', the destination of today's explorers is included in the mission name. This name has been included in the mission logo.

The logo for Christer Fuglesang's 'Alissé' mission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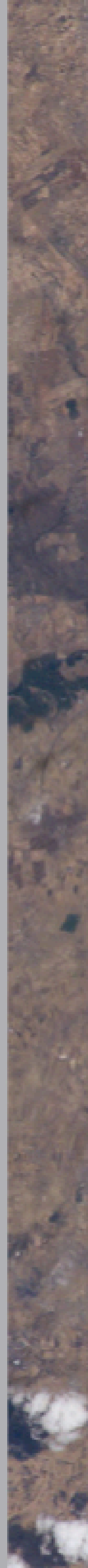

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