number 155 | August 2013

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, Poland, Portugal, Romania, 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.

EAC, Cologne, Germany.

ECSAT, Harwell, United Kingdom.

ESA Redu, Belgium.

Chairman of the Council:
Johann-Dietrich Wörner

Vice-Chairs:
Enrico Saggese and David Parker

Director General:
Jean-Jacques Dordain

←

On cover:
Alphasat I-XL, Europe's largest and most sophisticated telecommunications satellite, was launched on Ariane 5 flight VA214 into its planned orbit from Kourou, French Guiana, on 25 July (ESA/CNES/Arianespace-Optique Photo Video du CSG)

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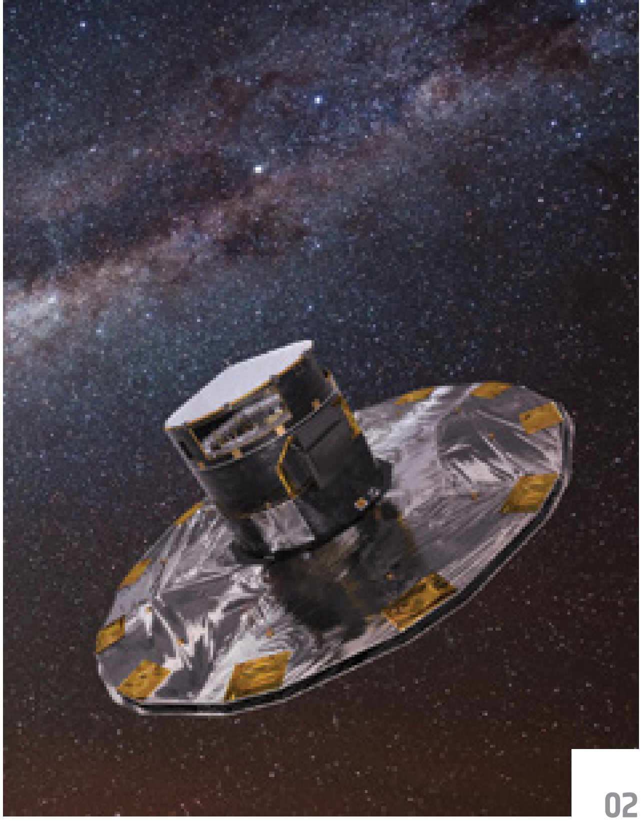
→ contents



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12

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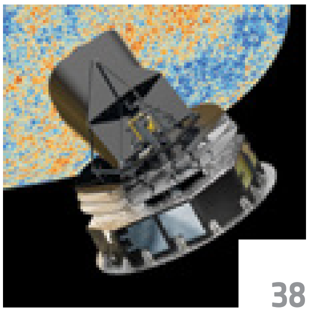
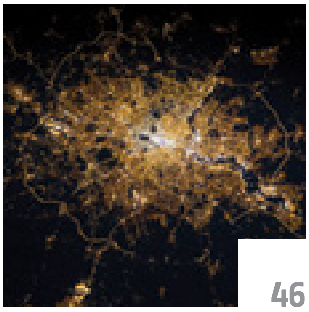
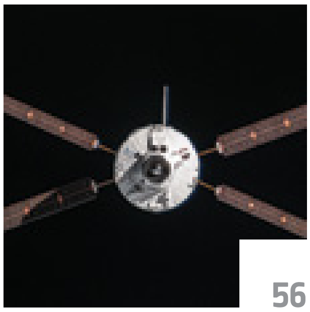


38



46

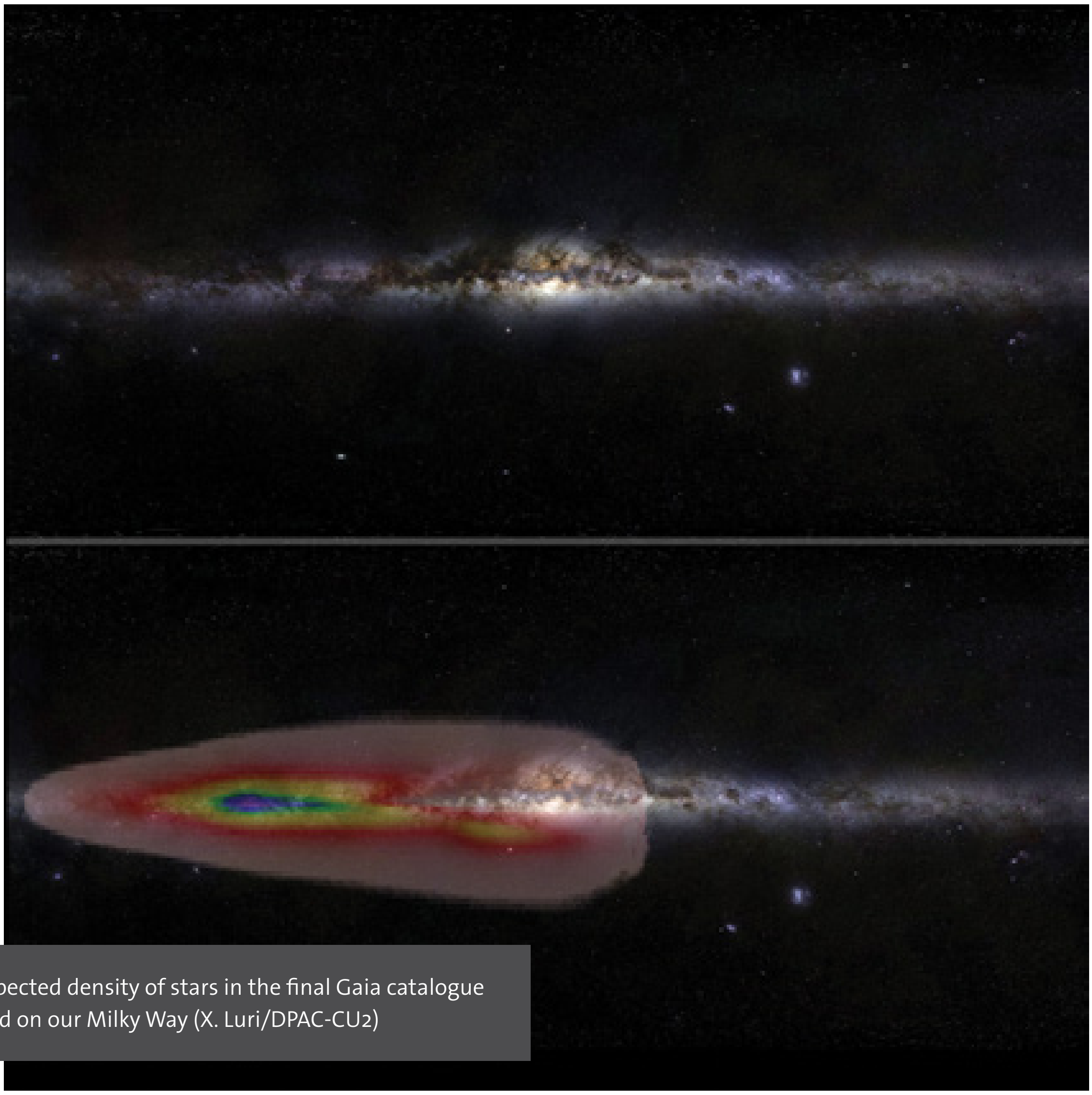


56

→ ESA'S BILLION-STAR SURVEYOR

Gaia ready for launch campaign

Giuseppe Sarri, Timo Prusti and Ared Schnorhk
Directorate of Science and Robotic Exploration, ESTEC, Noordwijk, the Netherlands



↗ The expected density of stars in the final Gaia catalogue overlaid on our Milky Way (X. Luri/DPAC-CU2)

ESA's billion-star surveyor, Gaia, has completed final preparations in Europe and is ready to depart for its launch site in French Guiana, set to embark on a five-year mission to map the stars with unprecedented precision.

Cataloguing the night sky is an essential part of astronomy. Before astronomers can investigate a celestial object, they must know where to find it. Without this knowledge, astronomers would wander helplessly in what Galileo once termed a 'dark labyrinth'. ESA's Gaia mission will create a detailed map of this labyrinth, finding clues to the origin, structure and evolution of our home galaxy, the Milky Way.

Gaia will take a census of one thousand million stars, roughly 1% of all of the stars in our Galaxy. During the satellite's expected lifetime of five years, Gaia will observe each star about 70 times, each time recording its brightness, colour and, most importantly, its position. The precise measurement of a celestial object's position is known as astrometry, and since humans first started studying the sky, astronomers have devoted much of their time to this art. However, Gaia will do so with extraordinary precision, far beyond the dreams of those ancient astronomers.

By comparing Gaia's series of precise observations, today's astronomers will soon be able to make precise measurements of the apparent movement of a star across the heavens, enabling them to determine its distance and motion through space. The resulting database will allow astronomers to trace the history of the Milky Way.

In the course of charting the sky, Gaia's highly superior instruments are expected to uncover vast numbers of previously unknown celestial objects, as well as studying normal stars. Its expected haul includes asteroids in our Solar System, icy bodies in the outer Solar System, failed stars, infant stars, planets around other stars, far-distant stellar explosions, black holes in the process of feeding and giant black holes at the centres of other galaxies. Gaia will be a discovery machine.

Origin of the Milky Way

Our galaxy is a disc of some one hundred billion stars in a spiral structure surrounding a central bulge. While many of the stars were born in our Milky Way, many others originated in small external galaxies that have subsequently merged with ours. Gaia will make it possible to discover families of stars that share peculiar motions around the galaxy or anomalous compositions. Each family could be the remnants of a once-separate galaxy that the Milky Way has consumed.

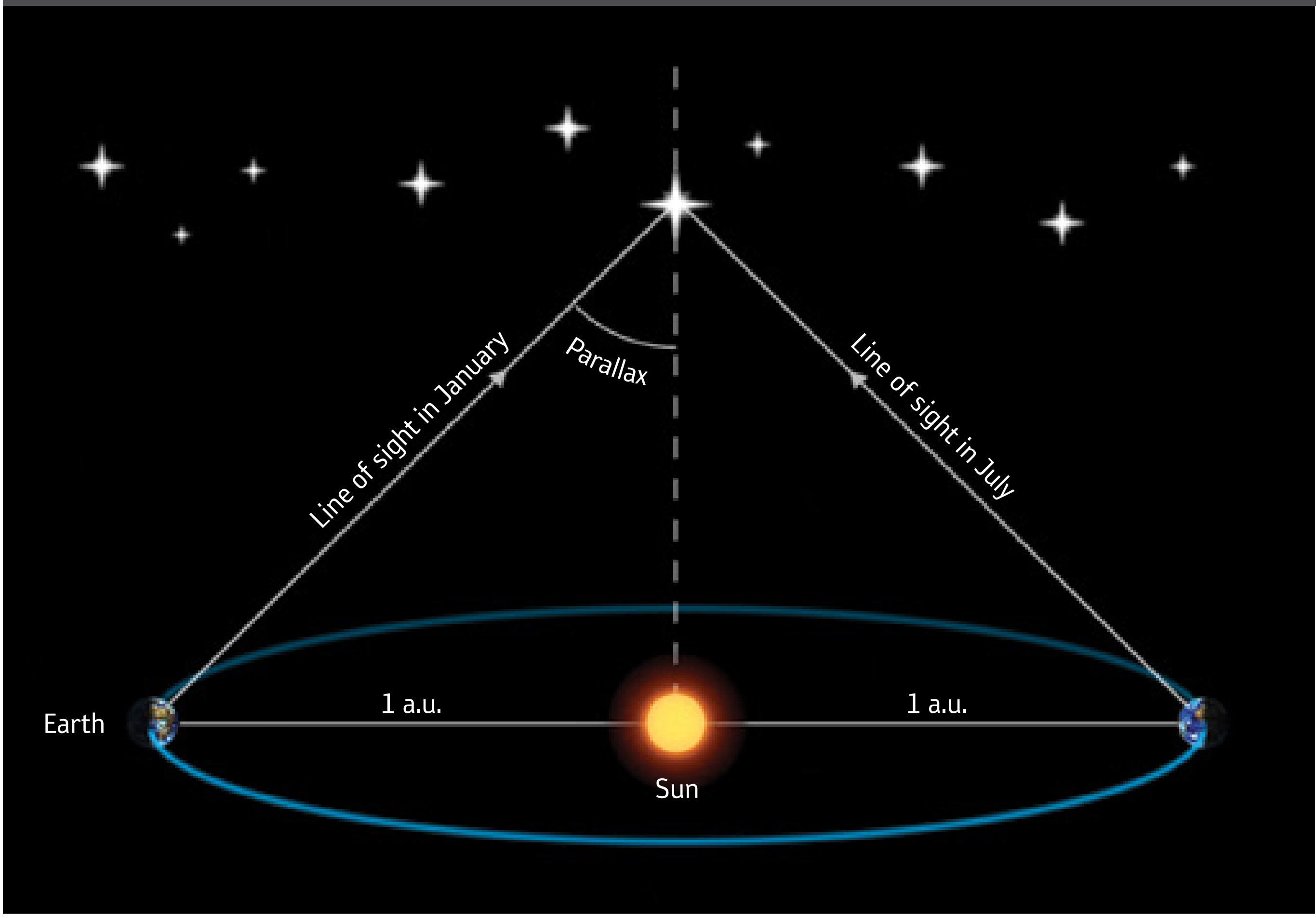
Understanding the history of our galaxy requires the measurement of stellar distances and motions for large samples of stars of different masses, ages and compositions. Gaia's survey of stars across the entire sky, down to extremely faint limits with a level of precision never accomplished before, will provide such a sample. By revealing the structure and motions of stars in our galaxy, Gaia will revolutionise our understanding of the history of the Milky Way.

Stars as individuals and collectives

To understand fully the physics of a star, its distance from Earth must be known. This is more difficult than it sounds because stars are so remote. Even the closest one is 40 trillion kilometres away, and we cannot send spacecraft out to them to measure as they go. Nor can we bounce radar signals off them, which is the method used to measure distances within the Solar System. Instead, astronomers have developed other techniques for measuring and estimating distances.

The most reliable and only direct way to measure the distance of a star is by determining its 'parallax'. By obtaining extremely precise measurements of the positions of stars, Gaia will yield the parallax for one billion stars; more than 99% of these have never had their distances measured accurately. Gaia will also deliver accurate measurements of other important stellar parameters, including the brightness, temperature, composition and mass. The observations will cover many different types of stars and many different stages of stellar evolution.

↓ Distance to a star can be calculated with simple trigonometry from the measured parallax angle. 1 a.u. is 1 Astronomical Unit, or 149.6 million km (ESA/Medialab)



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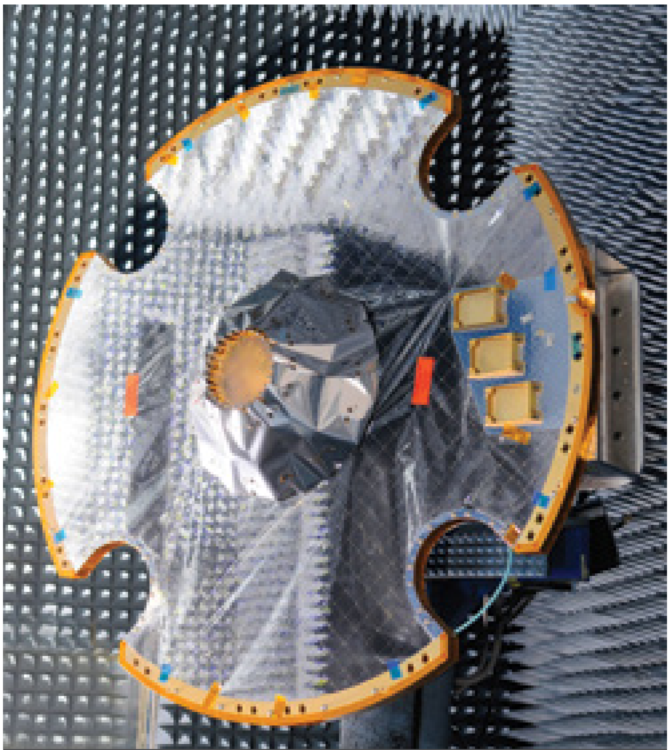
The Gaia Payload Module in its final configuration during the mechanical acceptance test at Intespace in September 2012 (Astrium)



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The 1.5m wide Gaia Antenna Panel, which contains the satellite's Phased Array Antenna, is seen here inside the EADS CASA test facility in Madrid, 2012 (Astrium)

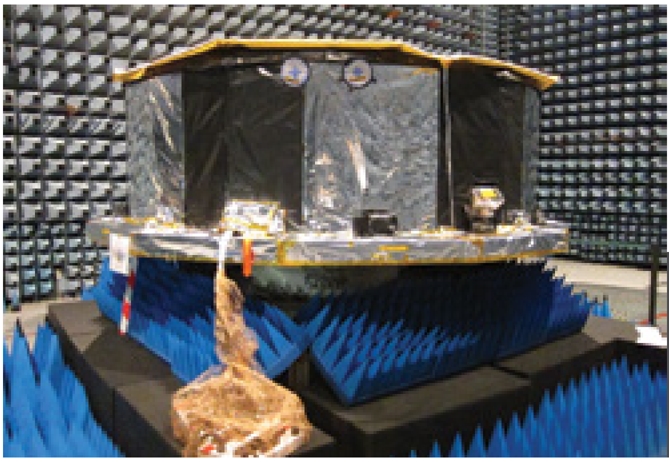
The principles of Gaia

At its heart, Gaia is a space telescope – or rather, two space telescopes that work as one. These two telescopes use ten mirrors of various sizes and surface shapes to collect, focus and direct light to Gaia's instruments for detection. The main instrument, an astrometer, precisely determines the positions of stars in the sky, while the photometer and spectrometer spread their light out into spectra for analysis.

Gaia's telescopes point at two different portions of the sky, separated by a constant 106.5°. Each has a large primary mirror with a collecting area of about 0.7 m^2. On Earth we are used to round telescope mirrors, but Gaia's will be rectangular to make the most efficient use of the limited space within the spacecraft. These are not large mirrors by modern astronomical standards, but Gaia's great advantage is that it will be observing from space, where there is no atmospheric disturbance to blur the images. A smaller telescope in space can yield more accurate results than a large telescope on Earth.

Gaia is just 3.5 m across, so three curved mirrors and three flat ones are used to focus and repeatedly fold the light beam over a total path of 35 m before the light hits the sensitive, custom-made detectors. Together, Gaia's telescopes and detectors will be powerful enough to detect stars up to 400 000 times fainter than those visible to the naked eye.

To cover the whole sky, Gaia spins slowly, making four full rotations per day and sweeping swathes across the celestial sphere. In addition the satellite rotation axis has a precession with a period of about 63 days. As it moves around the Sun, different parts of the sky are covered. Over the five-year mission, each star will be observed and measured an average of 70 times.



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The Gaia Service Module at Intespace, Toulouse, France, during launcher electromagnetic-compatibility testing in May (Astrium)

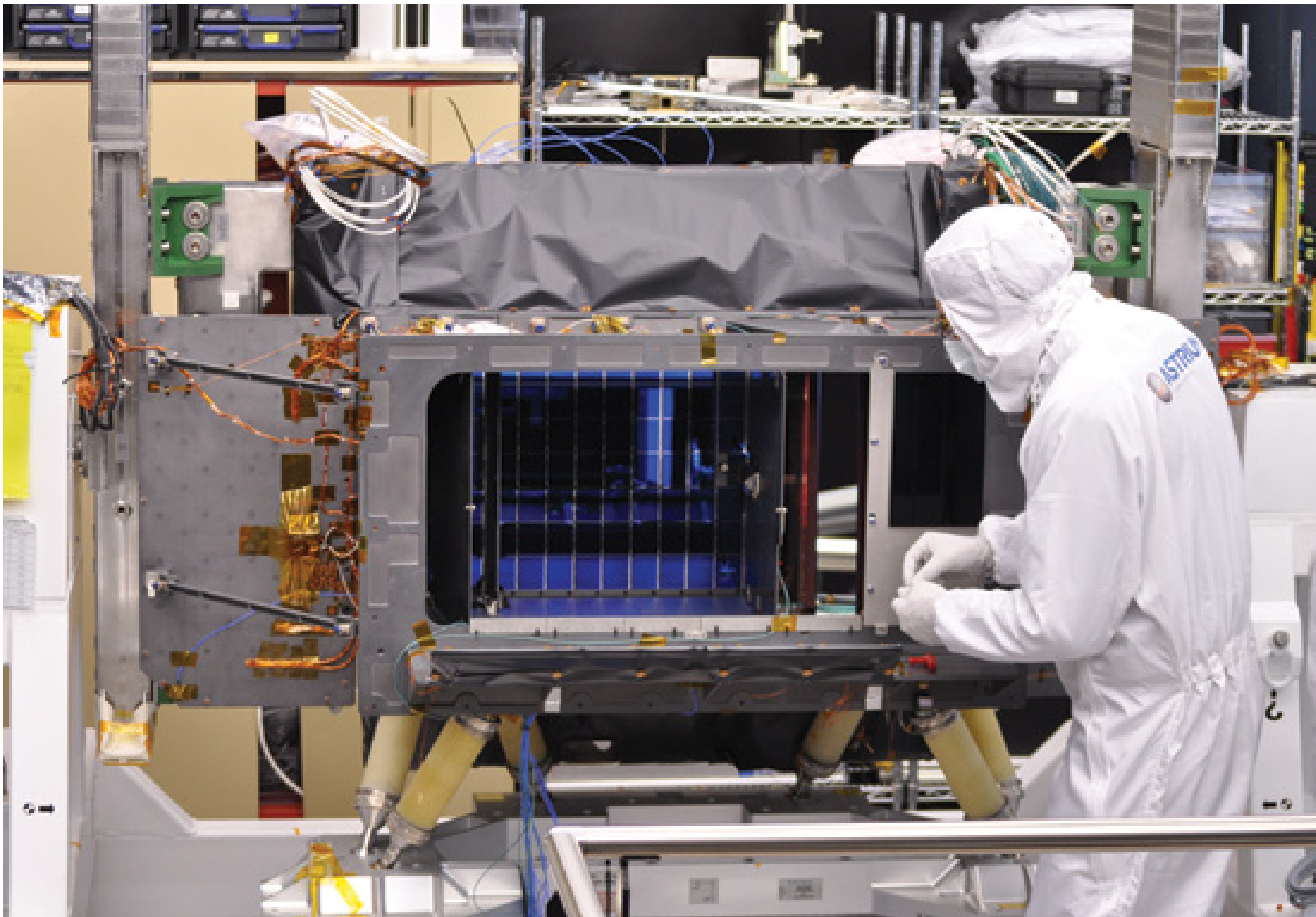
Spacecraft configuration

Gaia is composed of two sections: the Payload Module and the Service Module. The Payload Module is housed inside a protective dome and contains the two telescopes and the three science instruments. They are all mounted on a torus made of a ceramic material called silicon carbide. The extraordinary measurement accuracy required from Gaia calls for an extremely stable Payload Module that will barely move or deform once in space; this is achieved thanks to the extensive use of this material.

Underneath the Payload Module, the Service Module contains electronic units to run the instruments, as well as the propulsion system, communications units and other essential components. These components are mounted on carbon-fibre-reinforced plastic panels in a conical framework.

Finally, beneath the Service Module, a large sunshield keeps the spacecraft in shadow, maintaining the Payload Module at an almost constant temperature of around –110 °C, to allow the instruments to take their precise and sensitive readings. The sunshield measures about 10 m across, too large for the launch vehicle fairing, so it comprises a dozen folding panels that will be deployed after launch. Some of the solar array panels that are needed to generate power are fixed on the sunshield, with the rest on the bottom of the spacecraft.

Gaia is an exceptionally complex space observatory. ESA awarded Astrium SAS (Toulouse, France) the prime contract in May 2006 to develop and build the spacecraft. Together with the German and British branches of Astrium, more than 50 industrial subcontractor companies from across Europe were involved in building the spacecraft.



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Completion of the thermal hardware installation of the Gaia Focal Plane Assembly in the Class 100 cleanroom at Toulouse (Astrium)

Deployment sequence of the sun shield Assembly (Astrium)

Detection system

Three instruments will detect the light collected by Gaia's telescopes. Each one uses a set of digital detectors known as charge coupled devices (CCDs) to record the starlight falling onto them. Added together, the Gaia CCDs make the largest focal plane ever flown in space, a total of almost one billion pixels covering an area of about 0.38 m^2.

The astrometric instrument is devoted to measuring stellar positions on the sky. By combining all measurements of a given star over the five-year mission, it will be possible to deduce its parallax and thus its distance, as well as the velocity of the star as it moves across the plane of the sky.

The third dimension is provided by the Radial Velocity Spectrometer, which reveals the velocity of the star along the line of sight by measuring the Doppler shift of absorption lines in a high-resolution spectrum covering a narrow wavelength range.

The photometric instrument provides colour information for celestial objects by generating two low-resolution spectra, one in the blue and one in the red range of the optical spectrum. These data help to determine key stellar properties such as temperature, mass and chemical composition.

Launcher and launch campaign

Gaia will be carried into space later in 2013 by a Soyuz ST-B launch vehicle with a Fregat-MT upper stage, from Europe's Spaceport in French Guiana. This Soyuz is the most recent of a long line of vehicles that have proved their reliability with more than 1700 launches since launching the first satellite Sputnik in 1957. The three-stage version that will be used for Gaia was introduced 45 years ago and has been launched more than 850 times. It is by far the world's most-used launch vehicle.

After the early feasibility analyses, contact with the launcher provider has been maintained regularly in the frame of the project reviews. Detailed definition of launcher interface parameters started three years before the actual launch date. This early contact allowed the context to be set of a launch from French Guiana with a team more experienced with Soyuz launches from Baikonur and to prepare a first version of the Spacecraft Operation Plan.

Potential difficulties were identified and proper measures requiring relatively long preparation could be studied with commonly agreed solutions. The Gaia launch campaign preparation began with a visit to Europe's Spaceport in Kourou in the beginning of 2012.

In January, a second visit to Kourou verified the applicability of the chosen options. In the meantime, the definition of

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The Gaia Flight Model spacecraft undergoing final electrical tests at Astrium Toulouse in June (Astrium)

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Gaia being prepared for leak testing in June (Astrium)

the spacecraft interfaces had improved. This was reflected in the updates of the interface control documents and the Spacecraft Operation Plan. Trajectory definition, parameter exchange and verification between ESA's flight operations team at ESOC and the Russian partner NPO-Lavochkin responsible for Soyuz missions are now finalised.

Gaia mechanical and thermal peculiar verification strategies put in place to allow as much as possible a parallel development of the Service and Payload Modules also required agreement from the launcher side. Regular and clear exchanges over the progress and necessary evolutions of the verification process allowed successful implementation.

The Gaia launch campaign is organised over a period of ten weeks. Considering that almost no activity can be performed on the payload, this may seem rather long. However, after installing the deployable sun shield on the spacecraft, a deployment test is implemented to complete its final verification after transport to the launch site.

This very specific activity, already performed once at spacecraft level, will require just over a month. It will be

A Soyuz upper composite at the launchpad is lifted on top of a Soyuz rocket

↑ When moving between the different buildings and launch sites at Kourou, strict thermal, humidity and clean conditions must be maintained during the moves. Here, the CCU-3 (Container Charge Utile) is a cleanroom on wheels

performed in the S1B spacecraft integration facility at Kourou after the standard post-transport propulsion and electrical checks. In its deployed configuration, the sun shield has a diameter of 10 m; in the cleanroom, with the various stands installed, the sun shield requires a 12 m diameter surface to be kept free.

Following sun shield deployment, the spacecraft will be moved to the S5B facility for final pressurisation and propellant fuelling. In the same cleanroom, the launcher adaptor system will be ready to receive the satellite on top. This set-up will then be taken to another building, the S3B, for the mating on top of the fuelled Fregat-MT upper stage and for fairing installation. These operations are performed on a special scaffold that allows full access around the spacecraft at different levels.

The launcher fairing has been adapted to fit Gaia inside with sufficient margin. Once under the fairing, contact with the spacecraft will only be visual or via the electrical support equipment through umbilical lines. Four days before launch, the complete upper composite will be transferred to the launch pad, where the three lower stages of the Soyuz launcher await. Overnight, the upper composite is then lifted on top and connected to the launcher third stage. The last activities take place in the Soyuz gantry protecting the launcher from the Guianese weather conditions until launch day. ■

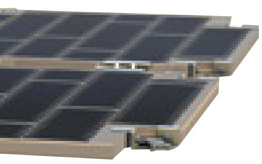
↑ The scaffolding used to prepare the upper composite. A Fregat upper stage, attached to a section of the launcher, is inside the scaffolding. The halves of the fairing are shown on the left

The 2018 ExoMars rover

→ EXOMARS

ESA's next step in Mars exploration

Jorge Vago, Olivier Witasse, Pietro Baglioni, Albert Haldemann, Giacinto Gianfiglio, Thierry Blancquaert, Don McCoy, Rolf de Groot and the ExoMars team
Directorate of Science and Robotic Exploration, ESTEC, Noordwijk, the Netherlands



Establishing if life ever existed on Mars is one of the outstanding scientific questions of our time. To do this, ESA is launching two missions to Mars, in 2016 and 2018.

ESA and Russia's space agency Roscosmos have signed an agreement to work in partnership to develop and launch two ExoMars missions. The first mission will study Mars' atmospheric composition and deliver a lander. The second mission will land, operate a static surface platform and put a large rover on the surface with the objective of searching for signs of life.

Both missions will use novel technologies needed to accomplish their goals and extend Europe and Russia's planetary exploration capabilities.

The missions

The first ExoMars mission consists of two elements: the Trace Gas Orbiter (TGO) and the Entry, descent, and landing Demonstrator Module (EDM). The TGO will first deliver the EDM, which will land on Mars to validate key technologies for the 2018 mission. The orbiter will then begin an aerobraking

↑ The 2016 ExoMars Trace Gas Orbiter

campaign. On reaching its science orbit, the TGO will search for evidence of methane and other atmospheric gases and investigate the surface, looking for possible active geological or biological processes. The TGO will also serve as a data relay for surface missions until the end of 2022.

The second mission will deliver the ExoMars rover and a platform to the surface of Mars. The rover will search for signs of life, past and present. It will have the capability to drill to depths of 2 m to collect and analyse samples that have been shielded from the harsh conditions prevailing on the surface, where radiation and oxidants can destroy organic materials. The surface platform will be equipped with instruments to study the martian environment.

ESA and Roscosmos have agreed a well-balanced share of responsibilities for the different mission elements. ESA will provide the TGO and EDM in 2016, and the Carrier Module and rover in 2018. Roscosmos will be in charge of the 2018 Descent Module (DM), will furnish launchers for the two missions and Radioactive Heating Units for the rover. Both agencies will contribute scientific instruments. NASA will also deliver important elements to ExoMars, including the Electra Ultra-High Frequency radio package for TGO and Mars surface proximity link communications, engineering support to EDM, and a major part of MOMA, the organic molecule instrument on the rover.

Establishing whether life ever existed on Mars is one of the outstanding scientific objectives of our time and constitutes the highest scientific priority of the ExoMars programme.

The 2016 ExoMars Mission

The 2016 mission has the science objectives to study martian atmospheric trace gases and their sources, and to contribute to the search for signs of possible present life on Mars. The latter will be pursued through a careful analysis of the association among minor atmospheric constituents and isotope ratios. This mission will also achieve the first of the programme's technological objectives with the EDM – to land on Mars.

There are four TGO investigations. NOMAD groups two infrared and one ultraviolet channel, while ACS has three infrared channels. Combined, these two instruments will provide the most extensive spectral coverage of martian atmospheric processes so far. To achieve the very high sensitivity required to allow NOMAD and ACS to detect species existing in very minute abundances, these instruments need to operate in 'Solar Occultation' mode.

Twice per orbit, at local sunrise and sunset, they are able observe the Sun as it shines through the atmosphere. In other words, they use our star as a very bright infrared lamp. The Sun is so luminous that the signal-to-noise ratio is very high. Detection of atmospheric trace species at parts-per-billion level will be possible.

NOMAD and ACS can also operate in 'Limb Scanning' mode and in 'Nadir Pointing' mode. The latter mode is interesting, but very challenging. The instruments can look directly down at the planet. However, here they must observe infrared light reflected off the surface as it shines through the atmosphere. In this case, the signal is very weak. The strategy to achieve an acceptable signal-to-noise level is to reduce the noise. This requires cooling the detector and some of the optics, which is the difficult part. On the other hand, this mode allows the study of the atmosphere draped over the surface, and hopefully it will help to identify sources and sinks for interesting species.

One gas species that has elicited much interest is methane (CH_4). On Earth, it is methanogenic bacteria that produce most of our methane. Alternatively, it can be exhaled as the result of certain subsurface hydrothermal processes. The PFS instrument on Mars Express made a first possible detection in 2004.

Contemporary observations from Earth, using infrared spectrometers in association with ground telescopes, have provided similar information.

But because the Mars Express result was close to the detection limits of the instrument, and since the ground observations were obtained looking at Mars through Earth's atmosphere, which itself has a sizeable methane component, the scientific community would like to see this methane signature verified.

Recently, NASA's Mars Science Laboratory/Curiosity searched for a methane signal with its SAM instrument, but did not find any. It could be that Curiosity is not in the right location, or it is the wrong season, or that methane is not present on the ground but higher up in the atmosphere. With NOMAD and ACS, the TGO will be able to conduct a planet-wide observation campaign across a full martian year. It will be possible to detect methane and many other hydrocarbon species.

If the presence of methane is confirmed, its association with other gases, as well as a careful analysis of isotopic ratios, will help us to determine whether its origin is biological or geological, or perhaps a combination. In either case, this would indicate that Mars remains an active planet.

Two other instruments will also be observing the martian surface. CaSSIS is a high-resolution (4.5 m/pixel), colour stereo camera. Its innovative design allows obtaining co-registered image pairs, such that every photograph is stereo. This is very important for building accurate digital elevation models of the martian surface. CaSSIS will be used to study geological formations that may be associated with trace gas detections of interest. It will also be an important tool for characterising candidate landing site locations for future missions.

Finally, FREND is a neutron detector that can provide information on the presence of hydrogen, in the form of water or hydrated minerals, in the top metre layer of the martian surface. A similar instrument flew on NASA's 2001 Odyssey mission, providing a first map of global surface water distribution. FREND will be capable of improving significantly the ground coverage resolution of the existing subsurface water map.

Following the release of the EDM from the hyperbolic Mars arrival trajectory, the TGO will first settle into an intermediate orbit. From there it will conduct a roughly nine-month aerobraking campaign to achieve its science orbit: approximately circular, altitude about 400 km and 74° inclination. The orbit's inclination has been selected to maximise the number of Sun occultations during the mission, while still providing a good seasonal and latitude coverage. The EDM has been conceived as a technology demonstration platform, with the objective of achieving Europe's first landing on Mars. It will enter the martian atmosphere from the hyperbolic arrival trajectory and use its heatshield to slow down sufficiently to deploy a supersonic parachute.

> **"Establishing whether life ever existed on Mars is one of the outstanding scientific objectives of our time and constitutes the highest scientific priority of the ExoMars programme."**

↑ ExoMars Entry, descent, and landing Demonstrator Module being prepared for vibration tests at ESTEC in March 2013

The final stages of the landing will be performed using pulse-firing liquid-fuel engines. About a metre above ground, the engines will turn off. The platform will land on a crushable structure, designed to deform and absorb the final touchdown impact. Throughout the descent, the Entry and Descent Science Team will perform investigations using various ensors to recover a number of atmospheric parameters, including density.

The EDM will land during the statistical 'dust storm' season. No entry profiles yet exist obtained during this time of the year when Mars' atmosphere is dust loaded. This will be very important information for designing future landed missions. Finally, the EDM also includes a small environmental station, DREAMS, that will operate for a few days using battery electrical energy. DREAMS will measure a number of atmospheric parameters:

ExoMars 2016 mission information

Spacecraft	Trace Gas Orbiter / Entry, descent and landing Demonstrator Module
Launch	January 2016, from Baikonur, Kazakhstan
Launcher	Proton M
Mars arrival	October 2016
Wet mass	4332 kg, including 600 kg EDM
TGO orbit	Circular, 400 km altitude, 74° inclination, approx. 30-sol repeat pattern (achieved after aerobraking by November 2017
EDM landing	Direct entry, Meridiani Planum (1.82° S, 6.15° W), uncertainty ellipse 100 x 15 km
Lifetime	TGO: until end 2022 (nominal science lifetime is 1 martian year). EDM: 2–3 days

temperature, pressure, wind speed and direction, optical depth and, for the first time, atmospheric electrical charging. The EDM will also include a camera.

The 2018 ExoMars Mission

The 2018 mission will address the programme's two top science objectives. The ExoMars rover will carry a comprehensive suite of instruments dedicated to exobiology and geology research named after Louis Pasteur. The rover will be able to travel several kilometres searching for traces of past and present signs of life. It will do this by collecting and analysing samples from within rocky outcrops and from the subsurface – down to 2 m depth. The very powerful combination of mobility with the ability to access locations where organic molecules could be well preserved is unique to this mission. It is also planned to include instruments on the landing platform with the goal of studying the martian surface environment. However, these sensors have not been selected yet.

The search for life

The term 'exobiology', in its broadest definition, denotes the study of the origin, evolution and distribution of life in the Universe. It is well established that life arose very early on the young Earth. From the analysis of fossil records, we know that by 3.5 billion years ago life had attained a large degree of biological sophistication. Since then, it has proven extremely adaptable, colonising the most disparate ecological habitats, from the very cold to the very hot, spanning a wide range of pressure and chemical conditions.

Today, Mars is cold and dry. Its surface is highly oxidised and exposed to sterilising/degrading ultraviolet light and ionising radiation. Low ambient temperature and pressure preclude the existence of liquid water, except in very localised environments, and then only episodically. Nevertheless, numerous features such as large channels, dendritic valley networks and sedimentary rock formations signal the past action of surface liquid water on Mars: lots of it.

The size of martian outflow channels implies immense discharges, exceeding any known flood flows on Earth. Mars' observable geological record spans approximately 4.5 billion years. From the number of superposed craters, the oldest terrain is believed to be about 4 billion years old, and the youngest possibly less than 100 million years of age. Most river valley networks are ancient (3.5–4 billion years old). Presently, water on Mars is only stable as ice, either at the poles as permafrost, or widespread underground deposits or in trace amounts in the atmosphere.

From a biological perspective, the existence of past liquid water in itself motivates the question of life on Mars: though the planet as a whole may have been prevalently cold, during its first 500 million years some surface environments were warm and wet. Perhaps life may have independently arisen on Mars, more or less at the same time as it did on Earth.

An alternative pathway may have been through the transport of terrestrial organisms, embedded in meteoroids, delivered from Earth to Mars. Yet another hypothesis is that life may have developed within a warm, wet subterranean environment. In fact, given the discovery of a flourishing biosphere a kilometre below Earth's surface, a similar vast microbial community may be active on Mars, having long ago retreated into that ecological niche, following the disappearance of a more benign surface environment.

The possibility that life may have evolved on Mars during an earlier period when water existed on its surface, and that organisms may still exist underground, marks the planet as a prime candidate to search for life beyond Earth.

If life ever arose on Mars, it probably did so during the planet's first half to one billion years. Conditions then were similar to those on early Earth: active volcanism and hydrothermal activity, meteoritic impacts, large bodies of liquid water (which may have been largely ice covered) and a mildly reducing atmosphere. Nevertheless, there is inevitably a large measure of chance involved in finding convincing evidence of ancient, microscopic life forms.

↑ View of Mars from NASA's 1976 Viking mission

On our planet's surface, the permanent presence of running water, solar ultraviolet radiation, atmospheric oxygen and life itself quickly erases all traces of any exposed, dead organisms. The only opportunity to detect them is to find their biosignatures encased in a protective environment – for example, within a suitable rock horizon. However, since high-temperature metamorphic processes and plate tectonics have resulted in the reforming of most ancient terrains, it is very difficult to find rocks on Earth older than three billion years in good condition.

Mars, on the other hand, has not experienced widespread tectonic activity like Earth. This means that rock formations from the earliest period in martian history exist, that have not been exposed to high-temperature recycling. Consequently, well-preserved ancient biomarkers may still be accessible for analysis. So why have we not found them yet? Possible answers to this question lie on where and how we have explored Mars.

In 1976, the twin Viking landers conducted the first in situ measurements focusing on the detection of organic compounds and life on Mars. The Viking biology package contained three experiments, all looking for signs of metabolism in soil samples. One of them, the labelled-release experiment, produced very provocative results. If other information had not been also available, these data could have been interpreted as proof of biological activity. However, theoretical modelling of the martian atmosphere and regolith chemistry hinted at the existence of powerful oxidants, which could more-or-less account for the results of the three biology package experiments.

The biggest blow was the failure of the Viking gas chromatographer mass spectrometer to find evidence of organic molecules at the parts-per-billion level. With few exceptions, the majority of the scientific community concluded that the Viking results did not demonstrate the presence of life. Numerous attempts were made in the laboratory to simulate the reactions observed by the Viking biological package. While some have reproduced certain aspects of the data, none succeeded entirely.

The next incremental step in our understanding of the martian surface was entirely unexpected. It came as a result of measurements conducted by the 2009 Phoenix lander in the northern subpolar plains. Phoenix included, for the first time, a wet chemistry analysis instrument that detected the presence of the perchlorate anion in soil samples collected by the robotic arm. Perchlorates are interesting molecules. For example, ammonium perchlorate is regularly used as a powerful rocket fuel oxidiser. Its salts are chemically inert at room temperature, but when heated beyond a few hundred degrees, the four oxygen atoms are released, becoming very reactive oxidation vectors.

↑ The rover and drill on the surface of Mars. The Rover will monitor and control torque, penetration depth and temperature of the drill bit. The drill's full 2 m extension is achieved by assembling four sections: one drill tool rod, with an internal shutter and sampling collection capability, plus three extension rods

It did not take long for investigators to recall that Viking had relied on thermal volatilisation (in other words, heat) to release organics from soil samples. If perchlorate had been present in the soil at the two Viking lander locations, perhaps heating could explain the results obtained? A review of the Viking findings showed that some simple chlorinated organic molecules had been detected. At the time, these compounds were interpreted to be remnants of a cleaning agent used to prepare the spacecraft.

More recently, the 2011 Mars Science Laboratory has looked for organic molecules on samples drilled out of surface rocks. They have obtained the same chlorinated compounds as Viking. Hence, also the MSL results are consistent with the presence of perchlorate. We must take these results into account for preparing our mission.

The need for subsurface exploration

For organisms to have emerged and evolved, liquid water must have been present on Mars. Without it, most cellular metabolic processes would not be possible. In the absence of water, life either ceases or slips into a quiescent mode. Hence, the search for extinct or extant life automatically translates into a search for long-standing water-rich environments, past or present.

The strategy to find traces of past biological activity rests on the assumption that any surviving signatures of interest will be preserved in the geological record, in the form of buried or encased remains, organic materials and fossil communities. Similarly, because current martian surface conditions are hostile to most known organisms, also when looking for signs of extant life, the search methodology should focus on investigations in protected niches: in the subsurface and within surface outcrops.

The same sampling device and instrumentation can adequately serve both types of studies. The ExoMars rover's surface mobility and the 2 m vertical reach of its drill are both crucial for the scientific success of the mission.

The rover will search for two types of life-related signatures: morphological and chemical. This will be complemented by an accurate determination of the geological context. Morphological information related to biological processes may be preserved on the surface of rocks. Possible examples include the microbially mediated deposition of sediments, fossilised bacterial mats or stromatolitic mounds. Such studies can only be accomplished with mobility and an imaging system capable of covering from the metre scale down to submillimetre resolution (to discern microtextural information in rocks).

Effective chemical identification of biosignatures requires access to well-preserved organic molecules. Because the martian atmosphere is more tenuous than Earth's, three important physical agents reach the surface of Mars with adverse effects for the long-term preservation of biomarkers:

1. The ultraviolet (UV) radiation dose is higher than on our planet and will quickly damage potential exposed organisms or biomolecules.

2. UV-induced photochemistry is responsible for the production of reactive oxidant species (like the perchlorates mentioned earlier) that, when activated, can also destroy biomarkers; the diffusion of oxidants

→ Mission strategy to achieve ExoMars rover scientific objectives

1. To land on an ancient location possessing high exobiological interest for past (and/or present) life signatures, i.e. access to the appropriate geological environment.

2. To collect well preserved scientific samples (free from radiation damage and surface oxidation) at different sites with a rover equipped with a drill capable of reaching well into the soil and surface rocks. This requires mobility and access to the subsurface.

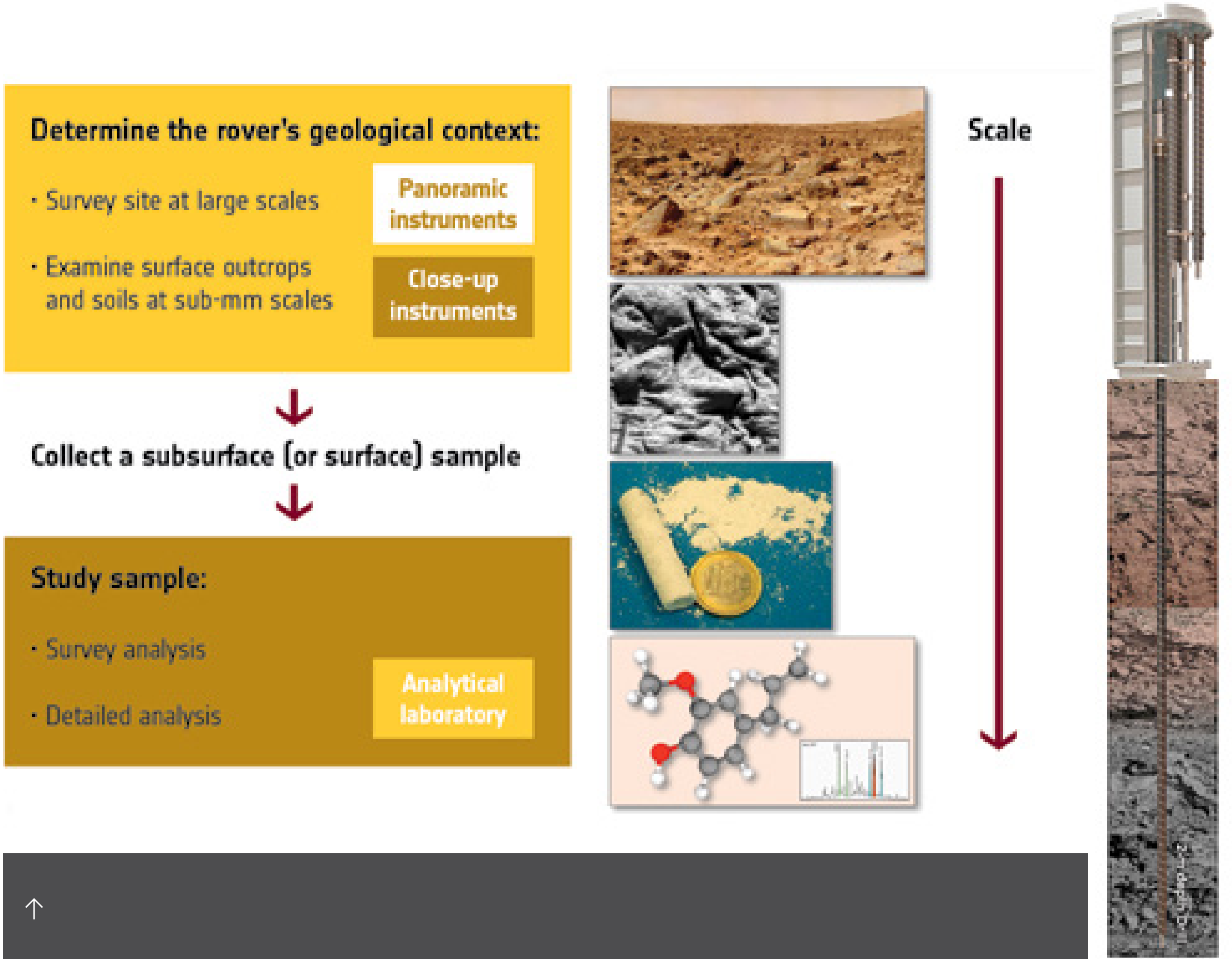
3. At each site, to conduct an integral set of measurements at multiple scales to achieve a coherent understanding of the geological context and thus inform the search for biosignatures: beginning with a panoramic assessment of the geological environment, the rover must progress to smaller-scale investigations of surface rock textures, and culminate with the collection of well-selected samples to be studied in its analytical laboratory.

The rover's Pasteur payload must produce self-consistent sets of measurements capable to provide reliable evidence, for or against, the existence of a range of biosignatures at each search location.

For the ExoMars rover to achieve high-quality scientific results regarding the possible existence of biosignatures, the rover must be delivered safely to a scientifically appropriate setting: ancient (older than 3.6 billion years, dating from Mars' early, more life-friendly period), having abundant morphological and mineral evidence for long-term water activity, including numerous outcrop targets distributed in the landing ellipse (to be sure the rover can get at least to some of them), and with little dust coverage.

ExoMars 2018 mission information

Spacecraft	Carrier Module and Descent Module (including Rover and Surface Platform). Data relay function to be provided by TGO
Launch	May 2018, from Baikonur, Kazakhstan
Launcher	Proton M (back-up in Aug 2020)
Mars arrival	Jan 2019 (back-up in Apr 2021)
Landing	Direct entry, from hyperbolic trajectory, after the dust storm season Landing site to be defined: must be safe/appropriate for 'search for life' science objectives. Latitudes between 5°S and 25°N, all longitudes. Uncertainty ellipse: 100 x 15 km.
Rover mass	310 kg, including drill/SPDS and instruments
Lifetime	220 sols (solar days on Mars)



↑

The ExoMars rover surface exploration scenario. The rover will conduct measurements at multiple scales. Starting with a panoramic assessment of the geological environment in its vicinity, it will then perform more detailed investigations of surface rock textures to try to decipher their depositional history and search for biosignatures. The rover will also scrutinise the subsurface to complete the geological picture, and to help decide where to drill. Samples can be collected from outcrops or from the subsurface (0–2m depth). Once a sample has been obtained, it will be imaged and analysed further, at mineral grain and molecular scales, in the analytical laboratory

into the subsurface is not well characterised and constitutes an important measurement that the mission must perform.

3. Ionising radiation penetrates into the uppermost metres of the planet's subsurface. This causes a slow degradation process that, over many millions of years, can alter organic molecules beyond the detection sensitivity of analytical instruments. Note that the ionising radiation effects are depth dependent: the material closer to the surface is exposed to a higher dose than that buried deeper.

The best opportunity for life to have gained a foothold on Mars was during the planet's very young history, when water was more abundant. It is therefore imperative that the rover is able to land in an ancient region (older than 3.5 billion years) that includes water-related deposits.

However, the record of early martian life, if it ever existed, is likely to have escaped radiation and chemical damage only if trapped in the subsurface for long periods. Studies show that a subsurface penetration in the range of 2 m is necessary to recover well-preserved organics from the very early history of Mars.

Additionally, it is essential to avoid loose dust deposits distributed by the wind. While driven by the wind, this material has been processed by UV radiation, ionising radiation and potential oxidants in the atmosphere and on the surface of Mars. Any organic biomarkers would be highly degraded in these samples.

For all these reasons, the ExoMars drill will be able to penetrate and obtain samples from well-consolidated (hard) formations, such as sedimentary rocks and evaporitic deposits, at various depths from zero down to 2 m. The drill's infrared spectrometer will conduct mineralogy studies inside the borehole.

On Earth, microbial life quickly became a global phenomenon. If a similar explosive process occurred in the early history of Mars, then the chances of finding evidence of past life may be good. Even more interesting would be the discovery and study of life forms that have successfully adapted to modern Mars. However, this presupposes the prior identification of geologically suitable, life-friendly locations where it can be demonstrated that liquid water still exists – at least episodically throughout the year. None have been identified so far.

For these reasons, the ESA Exobiology advisory team recommended that ESA focus mainly on the detection of extinct life; but also, build enough flexibility into the mission design to allow identifying present life.

The ExoMars Rover

The ExoMars rover will have a lifetime of 220 sols (around six months). During this period, it will ensure a regional mobility of several kilometres, relying on electrical power from solar arrays. The Pasteur payload contains: panoramic instruments (cameras, an infrared spectrometer, a ground-penetrating radar and a neutron spectrometer); contact instruments for studying rocks and collected samples (a close-up imager and an infrared spectrometer in the drill head); a subsurface drill capable of reaching a depth of 2 m and to obtain specimens from bedrock; a sample preparation and distribution system (SPDS); and the analytical laboratory (a visual/infrared imaging spectrometer, a Raman spectrometer and a Laser Desorption, Thermal Volatilisation Gas Chromatograph Mass Spectrometer).

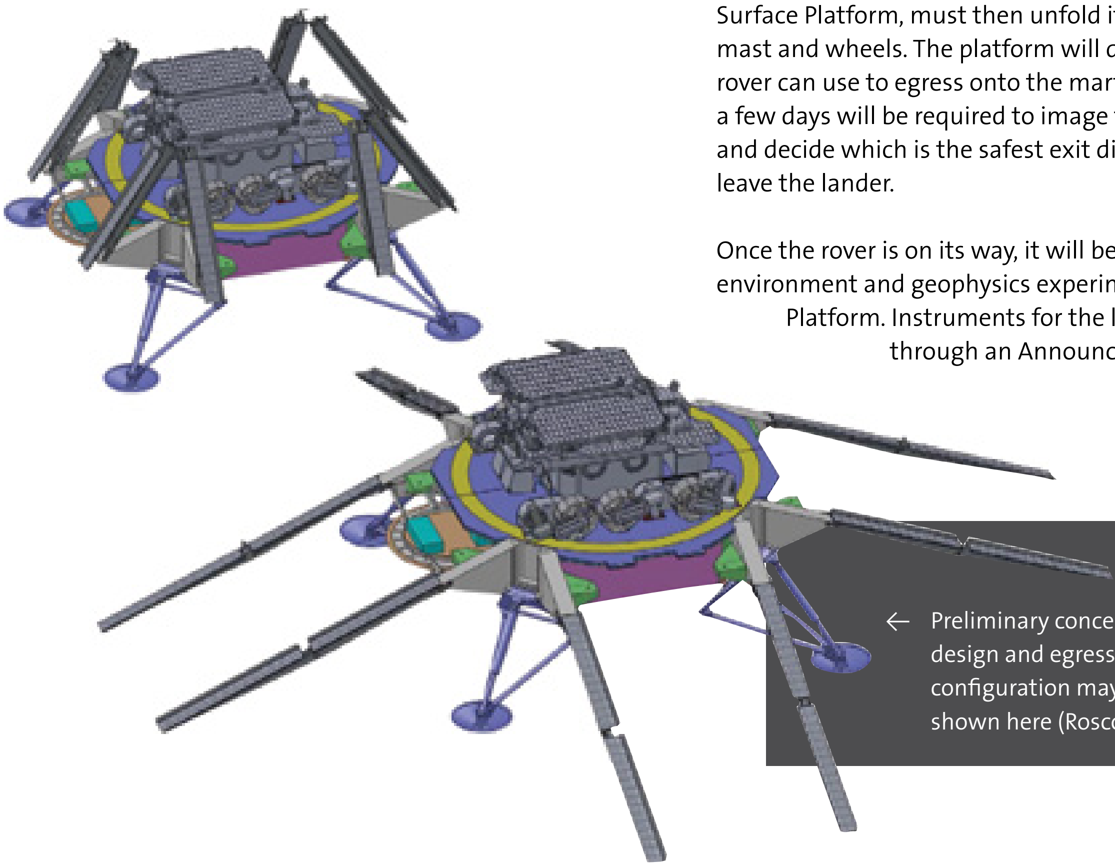
The ExoMars lander

The ExoMars Descent Module (DM) is the part of the spacecraft composite that enters the atmosphere to achieve a controlled descent and landing. The Carrier Module (CM) will take the DM to Mars and deliver with a very precise entry angle. The DM will hit the top of the martian atmosphere at approximately 20 000 km/h. A thermal shield at the bottom of the capsule will be used to decelerate to roughly twice the speed of sound. Thereafter, the parachute system will take over.

However, even after the main parachute has reached its terminal speed, the DM will be still travelling at more than 300 km/h. The last stage will involve using of throttled liquid-fuel engines. A multibeam radar will measure the distance to ground and the horizontal speed over the terrain. The DM's computer will receive this information and combine it with its knowledge of the DM's attitude to decide how to fire the engines and achieve a controlled landing. Legs will be used for the final touchdown.

If all goes according to plan, the rover, sitting on top of the Surface Platform, must then unfold its solar panels, camera mast and wheels. The platform will deploy ramps that the rover can use to egress onto the martian surface. Most likely, a few days will be required to image the lander surroundings and decide which is the safest exit direction for the rover to leave the lander.

Once the rover is on its way, it will be possible to conduct environment and geophysics experiments from the Surface Platform. Instruments for the lander will be selected through an Announcement of Opportunity.

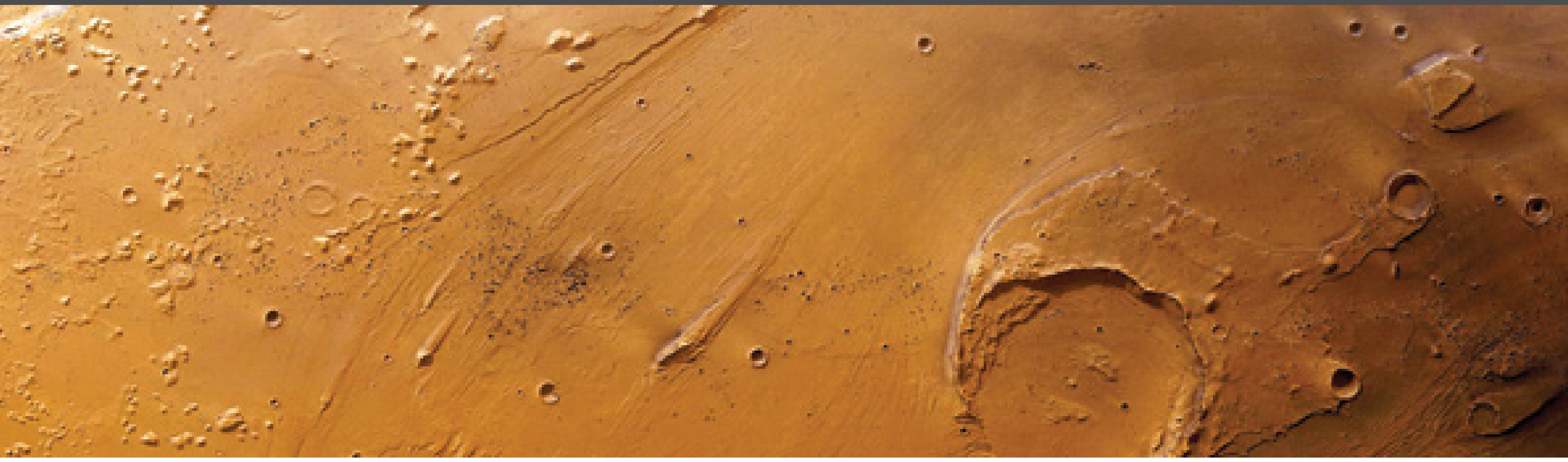


← Preliminary concept for the rover platform design and egress system. The final configuration may differ from the one shown here (Roscosmos/Lavochkin)

ExoMars Rover Pasteur exobiology instruments

Instrument	Scientific rationale
Panoramic instruments	**To characterise the rover's geological context, both on the surface and on the subsurface. Typical scales span from panoramic to 10 m, with a resolution of approx. 1 cm for close targets.**
PanCam	Panoramic camera system with two wide-angle stereo cameras and a high-resolution camera; to characterise the rover's environment and its geology. Very important for target selection.
ISEM	Infrared Spectrometer, for bulk mineralogy characterisation, remote identification of water-related minerals and for aiding PanCam with target selection.
WISDOM	Ground Penetrating Radar, to establish subsurface stratigraphy down to 3 m depth and to help plan the drilling strategy.
ADRON	Neutron Spectrometer, to determine the level of subsurface hydration, and the possible presence of ice.
Contact instruments	**To investigate outcrops, surface rocks, and soils. Among the scientific interests at this scale are: macroscopic textures, structure and layering. This information will be fundamental to understand the local depositional environment and to search for morphological biosignatures on rocks.**
CLUPI	Close-Up Imager, to visually study rock targets at close range (50 cm) with sub-mm resolution. This instrument will also investigate the fines produced during drilling operations, and image samples collected by the drill. The close-up imager has variable focusing and can obtain high-resolution images at longer distances.
Ma_MISS	IR spectrometer in drill, for conducting mineralogical studies in the drill borehole's walls.
Support subsystems	**These essential devices are devoted to the acquisition and preparation of samples for detail investigations in the analytical laboratory. The mission's ability to break new scientific ground, particularly for 'signs of life' investigations, depends on these two subsystems.**
Subsurface drill	Capable of obtaining samples from 0–2 m depth, where organic molecules can be well preserved from radiation and oxidation damage. It contains temperature sensors and an infrared spectrometer.
SPDS	Sample Preparation and Distribution System, receives a sample from the drill system, prepares it for scientific analysis, and presents it to all analytical laboratory instruments. A very important function is to produce particulate material while preserving the organic and water content fractions.
Analytical laboratory	**To conduct a detailed analysis of each collected sample. Following crushing of the sample, the first step is a visual and spectroscopic investigation. Thereafter follows a first search for organic molecules. In case interesting results are found, the instruments are able to perform more detailed analyses.**
MicrOmega	Visual/IR Imaging Spectrometer, will examine the crushed sample material to characterise structure and composition at grain-size level. These measurements will also be used to help point the laser-based instruments, Raman and MOMA.
RLS	Raman Laser Spectrometer, to determine the geochemistry/organic content of minerals in the crushed sample material.
MOMA	Mars Organic Molecule Analyser, the rover's largest instrument. Its goal is to conduct a broad-range, very-high sensitivity search for organic molecules in the collected sample. It incudes two different ways for extracting organics: Laser Desorption and Thermal Volatilisation with or without derivatisation (Der) agents, followed by separation using four gas chromatograph columns. The identification of the evolved organic molecules is performed with an ion trap mass spectrometer.

↓ A Mars Express image of the Ares Vallis region, showing evidence of ancient and vast water discharges. This immense channel — 1400 km long — empties into Chryse Planitia, where the Mars Pathfinder mission landed in 1997 (ESA/DLR/FU Berlin)



ExoMars TGO instruments

Instrument	Scientific rationale
Trace gases	**To provide a detailed characterisation of the martian atmospheric composition, including trace species at parts per billion level. Map the distribution of trace gases, identifying sources and sinks, and study geographical distribution and temporal variability. These two instrument suites will work in partnership to maximise the science results.**
NOMAD	Suite of two IR and one UV spectrometers The two IR channels cover the 2.2–4.3 µm band (for trace gases and atmospheric escape), whereas the UV and visible channel spans the 0.20–0.65 µm range (to investigate aerosols, ozone and sulphuric acid).
ACS	Cluster of three IR spectrometers covering respectively the bands 0.7–1.7 µm, 2.3–4.6 µm and 1.7–17.0 µm. ACS will study trace gases, profile isotope ratios and contribute to atmospheric escape studies.
Camera	**To perform photo-geological investigations on zones deemed interesting as possible sources of important trace gases. To characterise candidate landing sites for future missions.**
CaSSIS	High-resolution stereo camera (4.5 m/pixel), capable of obtaining coregistered colour, stereo image pairs.
Subsurface	**To obtain improved coverage of subsurface water and hydrated minerals in the top 1 m layer of the martian surface with the objective to achieve ten times better resolution than previous measurements.**
FREND	Neutron Spectrometer with a collimation module to significantly narrow the instrument's field of view, thus allowing the creation of higher resolution maps of hydrogen distribution.

ExoMars EDM investigations

Investigation	Scientific rationale
Descent science	**To study the martian atmosphere and obtain images throughout the EDM's descent.**
AMELIA	Utilising the EDM's engineering data (accelerometers and heatshield sensors) to reconstruct its trajectory and determine atmospheric conditions, such as density and wind, from a high altitude to the surface. Use the results to improve atmospheric models.
Surface science	**To characterise the surface environment in the presence of a dust-rich atmosphere.**
DREAMS	Environmental station that will conduct a series of short observations to establish temperature, pressure, wind speed and direction, optical opacity (dust loading), and atmospheric charging (electric fields) at the EDM's landing location.

Great expectations

The TGO mission will provide fundamental new science about the martian atmosphere. By measuring trace gases with unprecedented sensitivity, this mission will help scientists to determine whether Mars is still alive today – either from a geological or biological perspective.

NASA's very successful 2004 Mars Exploration Rovers were conceived as robotic geologists. They have demonstrated the past existence of wet environments on Mars. In 2009, Phoenix provided important new results about the oxidation environment. But perhaps it is ESA's Mars Express together with NASA's Mars Reconnaissance Orbiter mission of 2005 that have advanced most our understanding of past Mars. They revealed multiple, ancient deposits containing clay minerals that can only have formed in the presence of liquid water. This reinforces the hypothesis that ancient Mars may have been wetter than it is today. Mars Science Laboratory is studying geology and seeking organics on the martian surface with the goal to identify habitable environments. The ExoMars rover constitutes the next logical step.

ExoMars will have instruments to investigate whether life ever arose on the Red Planet. It will also be the first mission combining mobility with the capability to access locations where organic molecules can be well-preserved, thus allowing, for the first time, the investigation in situ of Mars' third dimension: depth. This alone is a guarantee that the mission will be able to break new scientific ground. The rover results will be complemented by those obtained with the Surface Platform instruments.

With a longer-term perspective, understanding the scientific importance of subsurface material is fundamental prior to deciding which types of samples to return to Earth for further analyses. The ESA and Roscosmos ExoMars rover's findings constitute a key milestone for a future international Mars Sample Return campaign.

Following on the accomplishments of Huygens and Mars Express, ExoMars provides Europe and Russia with a new challenge, and a new opportunity to demonstrate their capacity to perform world-class planetary exploration science. ■

With global population rapidly rising, the world will need to feed 9 billion people by 2050, which will require a 50% increase in food production (IFAD/Mwanzo Millinga)

→ GREEN GROWTH

Earth observation for international development projects

Anna Burzykowska, Torsten Bondo and Stephen Coulson
Directorate of Earth Observation, ESRIN, Frascati, Italy

Earth observation information provides a key contribution to the planning, implementation and monitoring of large international development projects. ESA has been collaborating with multilateral development banks since 2008 to demonstrate the value of such information to their investments taking place in developing countries.

ESA's current and planned technological capabilities place Europe at the forefront of Earth observation. In the next decade, ESA plans to launch more than 25 new Earth observation satellites, which will provide an enormous wealth of new data to be exploited by the scientific as well as operational user communities.

This includes launching the most ambitious operational Earth observation programme in the world: Global Monitoring for Environment and Security (or GMES/Copernicus, see **http://copernicus.eu**). This programme will combine data from the world's biggest fleet of Earth observation satellites and from thousands of *in situ* sensors to provide timely, reliable and operational information services covering land, marine and atmospheric environments and emergency response.

Preparations for adapting to this vast amount of information are in place in Europe for public sector users, but the data will be available globally. The potential for new applications with new user communities in the international development and private sectors is evident.

This year, ESA broadened the initial scope of working with the multilateral development banks. New initiatives have been started to demonstrate the benefits of Earth observation information for major international development projects with the major banks (World Bank, European Investment Bank, UN International Fund for Agricultural Development, Asian Development Bank and the European Bank for Reconstruction and Development).

These initiatives are being carried out through ESA programmes, together with the European and Canadian Earth observation services industry (mainly small companies) that are in a world-leading position in terms of diversity and maturity of products and services. ESA can therefore be a key partner to international development institutions seeking innovative solutions to address the sustainable development challenge.

Why 'green growth'?

Many areas of sustainable development are facing their defining moments. Today's urban population of about 3.6 billion people is projected to reach 5 billion by 2030, with more than 90% of the urban population growth expected to occur in the developing world. This increasing concentration of population and assets will intensify their exposure to natural disasters. In 2011 the world experienced the highest disaster losses ever recorded and this trend will continue, exacerbated by the effects of climate change and variability, which are likely to affect the poorest and most vulnerable communities.

Moreover, with global population rapidly rising, the world will need to feed 9 billion people by 2050, which will require a 50% increase in food production. At the same time, the World Bank estimates that by 2025, nearly two-thirds of countries will be water-stressed and 2.4 billion people will face absolute water scarcity, posing challenges to agricultural productivity and food security.

Other major global issues related to natural resources depletion, such as deforestation, soil degradation, desertification and loss of biodiversity, also reveal alarming trends. Deforestation and degradation of 2 billion hectares of forest landscapes affects not only Earth's environment and the balance of greenhouse gases (GHG), but also the livelihoods of 350 million people who live within or close to dense forests and depend on them for their subsistence and income.

Similarly, healthy biodiversity and economically productive oceans are essential for food security, jobs and the sustainable quality of life on Earth. An estimated 61% of the world's total Gross National Products (GNP) comes from areas within 100 km of the coastlines. The oceans as a whole provide 16% of the global population's animal

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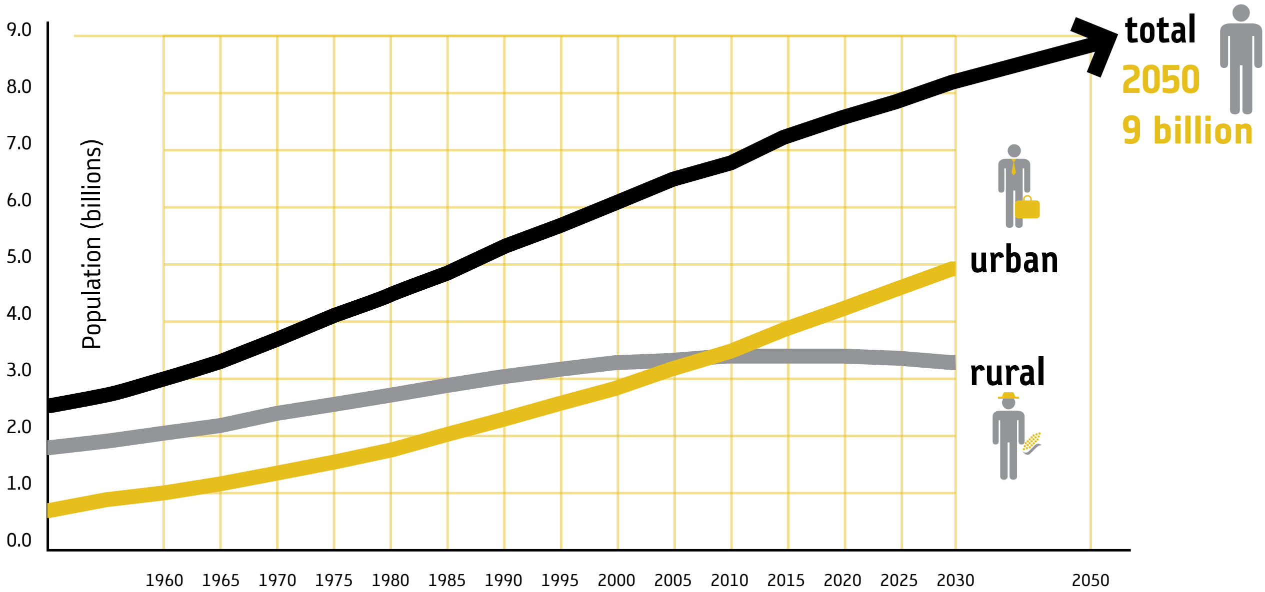
Today's urban population of 3.6 billion people is projected to reach 5 billion by 2030 (www.un.org)

Urban and rural population growth



2025

← 2/3 of the all countries will be water-stressed meaning 2.4 billion people will face water scarcity

esa

protein intake. However, over-exploitation is undermining the socio-economic performance of these resources.

As much as 85% of the world's ocean fisheries are fully exploited, over-exploited or depleted. More than 60% of global coral reefs are under direct threat from land- and ocean-based activity. Taken together, they are creating an annual global economic loss of some $US 50 billion, not taking into account the disruptive effects of sea-level rise and other effects of climate change.

Counteracting all these challenges requires targeted, focused and result-driven development programmes. These are actively exploring practical paths of action to ensure that natural resources are used sustainably, while meeting the demands of growing global population, managing disruptive impacts of climate change and preparing for increased frequency and intensity of natural disasters. Many of these programmes are defined, developed, financed and/or led by the key multilateral development banks.

Given the major trends outlined above, there is increasing pressure (indeed necessity) that these major development programmes ensure economic growth in an environmentally sustainable manner, or put simply: 'green growth'.

In support of this, financial approaches are being developed to put an economic value on the environment. Examples include: the Natural Capital Project led by Stanford University and World Wildlife Fund (see **www.naturalcapitalproject.org**), and the Wealth Accounting and Valuation of Ecosystems Services (WAVES) initiative, recently launched by the World Bank itself (see **www.wavespartnership.org**).

Led by ESA and in cooperation with the major development banks, new knowledge products and services, innovative ideas (including the potential of the next-generation Earth observation tools) and techniques are being customised and tailored to help achieve the sustainable development objectives of specific development projects.

←

Swordfish dead in tuna-fishing net. Swordfish are sometimes caught by accident (BJ Skerry/Nat. Geo./WWF)

Earth Observation in support of 'green growth'

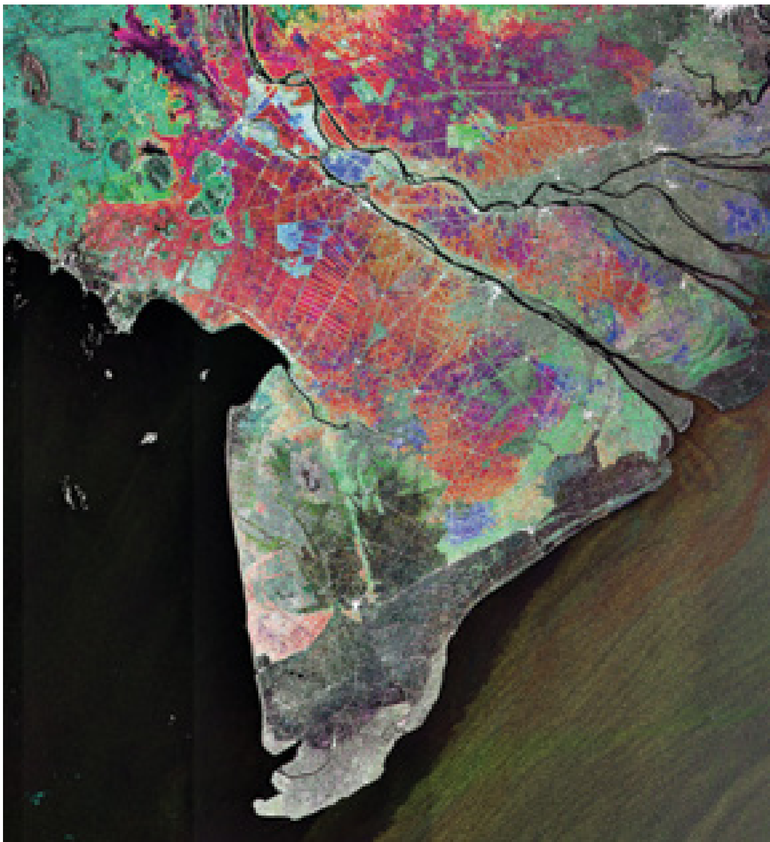
Earth observation by satellite can address a number of areas of environmental sustainable development, or green growth. It is a valuable source of information for management and protection of key ecosystems to counteract over-exploitation resources, desertification and land degradation, and to support sustainable agriculture and biodiversity conservation. In the same way, Earth observation capabilities extend to marine and coastal ecosystems to mitigate negative impact of both natural and human-induced changes on sensitive habitats.

Earth observation is also used extensively to support risk assessment, as well as crisis mapping including post-disaster recovery, rehabilitation and reconstruction. In addition, Earth observation is used for operational monitoring of urban development with comprehensive, accurate, up-to-date geographical information to understand how cities are evolving over time at local, regional and global levels.

ESA partners with main user communities to ensure that Earth observation services and products can be used to respond to sustainability needs and studies of the environment. The key ongoing activities are: TIGER, the initiative supporting African institutions in managing water resources; and the GLOB projects, delivering a range of global satellite information in support of international environmental treaties and conventions.

ESA is also a leading organisation within the Committee for Earth Observation Satellites (CEOS), where, along with other space agencies, it supports the Forest Carbon Tracking system and the Global Forest Observing Initiative. Within CEOS, ESA was a founding member of the International Charter 'Space and Major Disasters', which has provided over the last ten years rapid access to Earth observation data and information in support of aid relief from natural disasters to national and international disaster relief organisations worldwide.

The challenge now is to establish a stable connection between existing and upcoming European Earth observation capabilities and the leading institutional players in sustainable development to exploit synergies with funding programmes behind them. The existing partnerships with the multilateral development banks are a start to building a comprehensive approach toward this new user community, taking advantage of ESA's three decades' of experience in developing Earth observation-based applications.



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An Envisat radar image of the Mekong Delta In Vietnam, where such an enormous amount of rice is produced it makes Vietnam the world's third biggest rice exporter. Radar sensors are particularly suited for monitoring rice cultivation because they are able to detect waterlogged ground and penetrate the humid cloud coverage typical of Asian rice-cultivating regions

ESA and the multilateral development banks

The multilateral development banks provide support to developing countries to reduce poverty and stimulate economic growth. This involves dealing with the complex challenges of climate change, rapid urbanisation, threats to food security, natural resource depletion and the risk of natural disasters. The provision of accurate and consistent geospatial information is a key component and the world is looking at the development banks to bring the best available datasets to support strategic planning and to deliver quality solutions to the countries around the world.

Over the last couple of years, some of the banks have gained significant experience in utilising new technologies, including satellite Earth observation tools and other geospatial technologies in addressing a variety of development challenges. For example, the World Bank has developed partnerships with external organisations, including national space agencies (such as ESA, NASA, NOAA and JAXA), and private sector satellite operators and services providers to improve its access to the range of available Earth observation data, information services and knowledge products.

ESA began exploring this potential through three small-scale technical assistance demonstration projects for the World Bank in 2008. The trials demonstrated the use of Earth observation-based services to support climate change adaptation projects in Belize (coral reefs), Bangladesh (coastal dynamics) and North Africa (land subsidence).

The success of the early pilots resulted in the scaling up of the collaboration with the World Bank in 2010 to include 12 larger-scale activities and the launch of a joint 'Earth Observation for Development', or 'eoworld' initiative (see **www.worldbank.org/earthobservation**). The 12 activities were spread across the bank's sustainable development network and carried out in over 20 countries in Latin America, Africa, South and East Asia in the following thematic areas:

- climate change adaptation
- disaster risk management
- urban development
- water resources management
- coastal zone management
- marine environment management
- agriculture
- forestry

In parallel (and building on the experiences with the World Bank), ESA began further collaboration with more multilateral development banks. A further ten demonstration projects are being completed with the European Investment Bank, and eight demonstration projects have been started with UN International Fund for Agricultural Development. In addition, strong interest is being shown by Asian Development Bank and European Bank of Reconstruction and Development to initiate collaboration with ESA.

All these activities aim to demonstrate the value of Earth observation to support targeted international development programmes. The long-term objective is to promote the use of Earth observation as a standard reference technology and a component of 'best-practices' in the definition of future programmes, projects and other development initiatives, and to establish this technology as a standard tool in planning, implementation, monitoring and assessment of international development investments.

Practical examples of the application of Earth observation information include establishing baselines, results monitoring, impacts assessment and auditing, identifying 'hot spot' locations, and supporting dialogue with local partners by putting development issues in a spatial context.

"Not only wetlands, but also rangelands, grasslands, forests, deserts and coastal areas – all our natural reserves – provide valuable assets to society in terms of measurable and accountable services."

The impact of Earth observation in development projects

The initial projects to demonstrate the utility of Earth observation information have confirmed that the availability of factual, evidence-based information is a unique tool. This is not only for practical management of ongoing international development activities, but also for transparency and raising awareness to develop an informed community of stakeholders and to engage them effectively in a dialogue on the common issues.

Many of the bank project managers highlighted their fundamental need for quality data and information to

Peru/Bolivia
Satellite monitoring of water quality and land cover of Lake Titicaca demonstrated that between 2003 and 2010 the size of the lake decreased by 7% and that important wetland and breeding ground for endemic species are facing unprecedented degradation.

Liberia
Earth observation-based forest mapping provided independent verification of contradictory reports concerning available forest resources and discovered that deforestation rates in the investigated areas had been kept to a minimum.

Jakarta
The problem of urban subsidence is particularly disturbing. Pumping of water from deep wells causes the land to sink by as much as 10 cm a year. Earth observation accurately and efficiently identified the subsidence problem in the metropolitan area, revealing trends with millimetre precision and on the level of single infrastructure elements.

Papua New Guinea
Satellite-based land-cover monitoring helped to involve local government, industry and civil society in setting a transparent baseline for the future biannual environmental audits.

↑ Examples of benefits obtained by integrating Earth observation information into specific World Bank projects

guide their decisions, especially in view of multimillion-dollar investments in new infrastructure, forest stocks, environmental conservation or water resources.

From the perspective of planning, this type of tested and validated geo-information with known accuracies and limitations was useful, particularly in cases where there was a need to upgrade the reliability of available datasets to mitigate the possibility of making poor decisions (based on inaccurate or out-of-date data that can be locked into a project in the early stages).

From the operations perspective, the use of Earth observation information for project implementation and evaluation was regarded as essential to managing a range of operational risks, as well as to strengthening of strategic relevance and technical quality of the proposed or ongoing projects.

These initial activities also helped identify the potential of further exploiting Earth observation information within new World Bank global programmes and partnerships (GPPs).

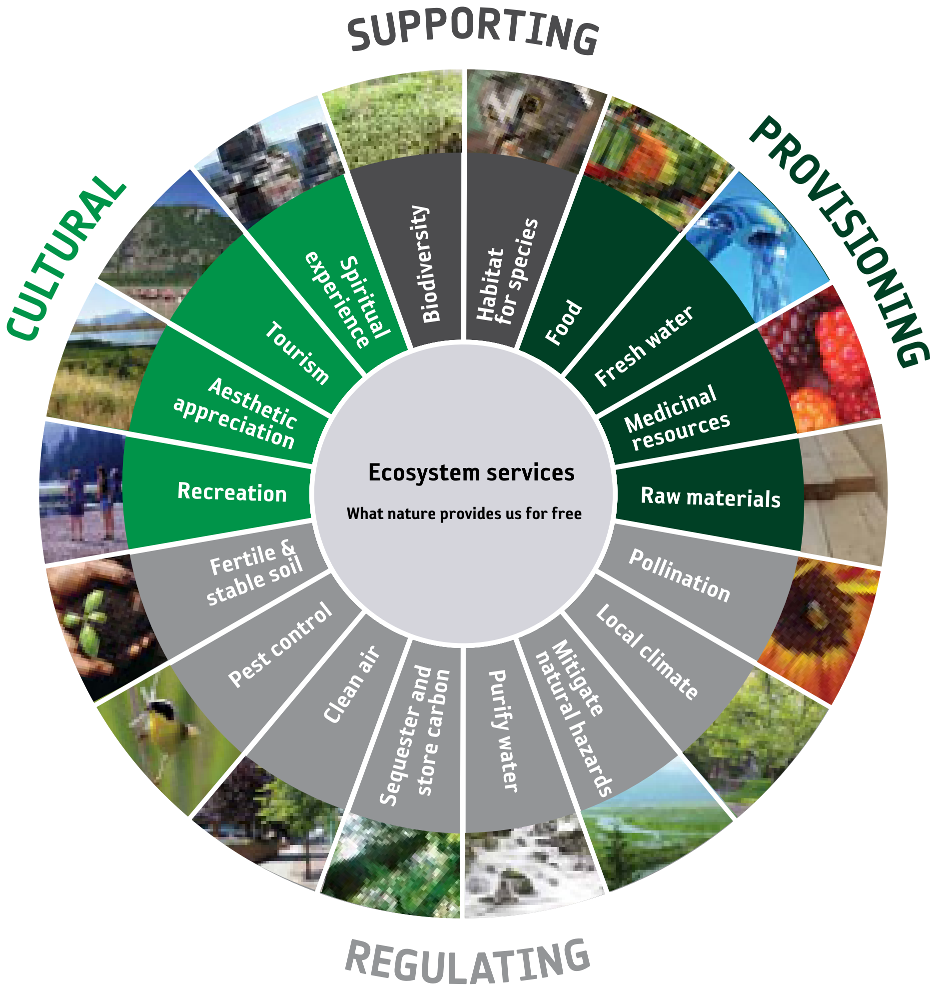
GPPs are important because they play a key role in creating and sharing of knowledge, and in mobilising financial and technical resources of a larger community of donor organisations, as well as public and private stakeholders, particularly on environmental issues. Discussions are in progress to explore the potential of Earth observation with the two new World Bank initiatives: the Global Partnership for Oceans (GPO), see **www.globalpartnershipforoceans.org**, and the Wealth Accounting and the Valuation of Ecosystem Services (WAVES), see **www.wavespartnership.org**.

Latest developments: ecosystems services

The value that nature brings to countries and societies is often taken for granted or not well understood. Consider a wetland on which a government plans to build a new department store. People who appreciate the natural beauty of this wetland want to preserve it. But how can these people argue against the clear numbers demonstrating economic growth and new jobs if this department store is erected?

The beauty of the wetland is often not enough to change government decisions, especially not in times of financial crisis. Government and policy makers need firm arguments and most often these must be supported by financial information. In order to secure protection of this wetland as well as its beauty, for example, its economic value to society must be quantified and communicated to decision-makers.

It is surprising to most people that the economic value brought to society by a wetland more often than not outweighs the economic gain of destroying it. A wetland provides clean water for drinking and agriculture, it refills groundwater stocks, it works as flood-prevention agent, it prevents erosion and damage from storms, as well as being



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An ecosystem service is defined as the benefit that people derive, either directly or indirectly, from a natural reserve. Earth observation can provide input to the valuations of ecosystem services by establishing baselines, monitoring the compliance of standards, spot checks of sustainable management practices and support environmental reporting (MetroVancouver)

a habitat for wildlife and a carbon store. Putting a price on all these values of a wetland may convince decision-makers to keep the land rather than developing it with building (see *'The economic value of the world's wetlands'* by L. Brander and K. Schuyt, 2010, available at TEEBweb.org).

Not only wetlands, but also rangelands, grasslands, forests, deserts and coastal areas – all our natural reserves – provide valuable assets to society in terms of measurable and accountable services. This is leading to a new concept of natural capital accounting or 'ecosystems service' (ES) assessments.

These financial approaches to quantifying the economic value of the environment were introduced in the Millennium Assessment report on Ecosystems, and further defined and globally mainstreamed through initiatives as the Economics of Ecosystems and Biodiversity (TEEB), the System of Environmental Economic Accounting (SEEA) by the UN Statistical Division and WAVES.

Working with the ecosystems service community

European traditions in environmental monitoring are very strong. The EU is a world leader in environmental and ecosystems monitoring through programmes and initiatives led by the Joint Research Commission and the European Environmental Agency. ESA's Earth Observation Directorate has been involved in environmental monitoring through climate variability and risk assessments, 'Reduced Emissions from Deforestation and Forest Degradation' (REDD) activities, coastal monitoring, global wetlands monitoring, biodiversity mapping, assessments of renewable energies, water management and certification of sustainable forest management.

As part of these European environmental traditions, ESA is increasing its activities in ecosystems service assessments. These will also support new global strategic safeguards for biodiversity and ecosystems, for example, Convention on Biological Diversity targets and the EU Biodiversity policy.

ESA is working with a consortium of experts from five specialist Earth observation service companies in Austria, UK and Sweden to understand needs and requirements of the ES community and improve the capacity to measure natural capital around the world. Two lines of activities have been initiated: demonstration of the benefits of Earth observation-based information for selected ES projects and users, and broader studies of how the Earth observation information can be used in ES assessments to expand this potential market.

The production and processing sectors are estimated to have negative environmental costs not accounted for on a global scale, in the order of $7.3 trillion or 13% of the global economy (2009). This includes air pollution, greenhouse gas emissions and bad land and water use. Coal power production is a sector where the estimated health costs and other damages exceed the production value of the sector.

- Example of economic value of sustainable use of nature resources and ecosystems services (TEEB for Business Coalition, P. Suhkdev, TEd Talk 2011 and E. Barbier, 2007)

These demonstration trials include forest studies in Vietnam, Indonesia and Peru, and coastal studies in Australia and Yucatan. The aim of these activities is to derive the economic value of specific ecosystems addressed in each area for a selected group of users whose natural resources are threatened by industrialisation and bad land-use management.

The market expansion studies target the whole ecosystems domain, including a wide range of users and stakeholders from European and UN organisations, international environmental convention secretariats, manufacturing companies, the private insurance sector, specialised NGOs and SMEs, environmental certification organisations, research institutions, industry-wide groups and the international development banks. Together with the WAVES team at the World Bank, ESA hosted a user workshop targeting US ecosystems stakeholders in May. Similarly the global law company Linklaters hosted a workshop with ESA targeting European ecosystems stakeholders in April 2013 in London.

The messages from these user consultation workshops were clear: there is a need for better geospatial data with higher spatial resolution, delivering accurate and validated information. There is a need for long-term consistency in delivery of these data, enabling capabilities for tracking changes in ecosystems services using the same datasets. There is a need for data sources that support not only local and regional studies, but also national accounting programmes.

The ES community have a long list of initial requirements: improved and specialised land use and land-cover mapping, forest inventories, crop yield for the provisioning ES services, improved models for flows of surface-water mapping, better nutrient and sediment retention models, sediment retention and soil retention for regulating services. In addition, there is strong interest in indirect proxies for population density for the cultural services and improved life cycle assessments, hazard/erosion and risk mapping for the supporting ES services. ■

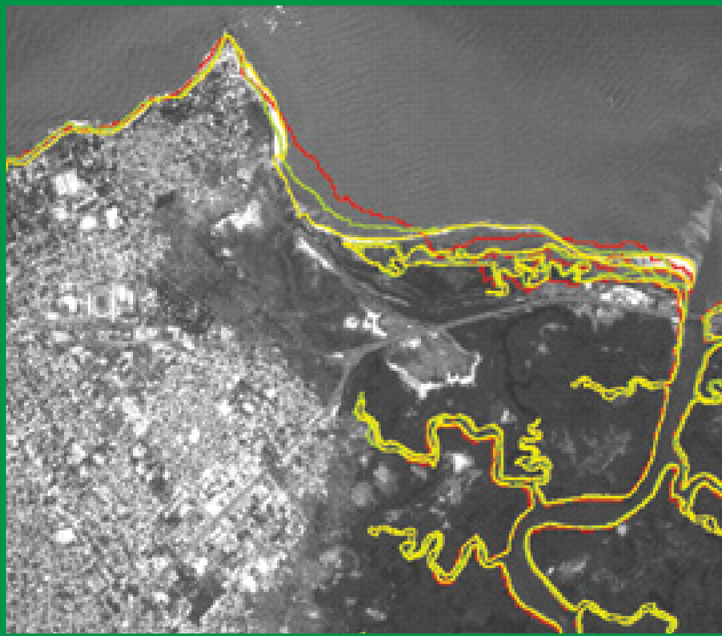
For smallholders in Thailand, cutting down the mangrove forests may lead to short-term profits in shrimp farming. However, when all ecosystems services provided by the mangroves are accounted for, the economic gain to society is larger if the mangroves are kept rather than removed, because of their erosion and coastal storm protection ability. The incentive for governmental accounting of the value of nature is present

- Example of economic value of sustainable use of nature resources and ecosystems services (TEEB for Business Coalition, P. Suhkdev, TEd Talk 2011 and E. Barbier, 2007)

Case Study 1

→ MONITORING COASTLINE CHANGE IN WEST AFRICA FOR WORLD BANK

WHY	West Africa, countries are lacking long-term, harmonised records of the evolution of coastal environment. Historical satellite data analysis has allowed the assessment of long-term trends in coastal change and sea-level rise.
WHAT	Satellite coastline change maps, sea-level, currents and wind data
RESULTS	The ESA study carried out by Geoville confirmed that coastline is decreasing along the entire length of West Africa and that there is a need to support a range of preventive actions in collaboration with national governments. Coastline monitoring became an integral part of the bank-financed project focused on adaptation to climate change in São Tomé and Príncipe.
OUTLOOK	São Tomé and Príncipe is also experiencing illegal logging in the pristine rainforest covering most of the island. ESA is now working together with UN-IFAD in an activity to map changes and type of the forest.



← Remote Sensing Training course for government office employees, local World Bank and UN IFAD staff in São Tomé and Príncipe (Geoville)

↑ Coastline change of the city of Bakau, Gambia (Geoville)

2010
2000
1988

Case Study 2

→ AGRICULTURAL MAPPING IN GAMBIA FOR UN-IFAD

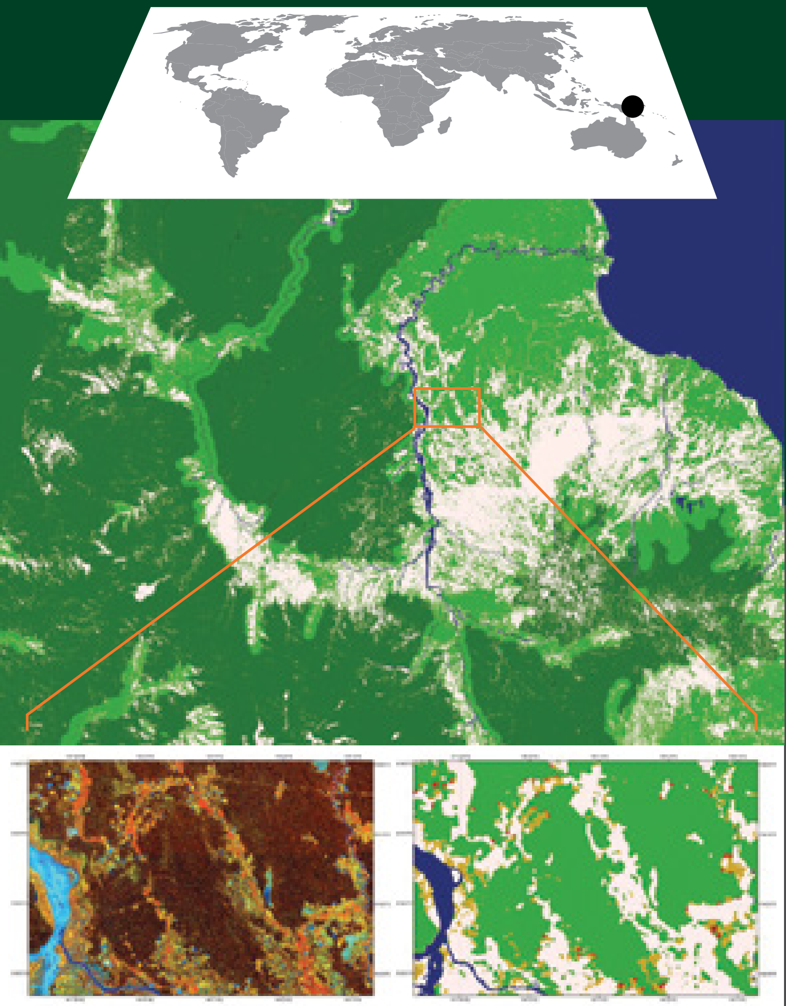
WHY	Gambia is 300 km by 50 km in size and heavily influenced by the Gambia river that crosses the country from east to west. It is one of the poorest countries in the world with soil erosion, land degradation, seawater salt intrusion, poor infrastructure and extreme poverty. UN-IFAD is working with the Gambian government on development projects that will focus on the poor rural population and their participation in local government and rural communities to implement strategies to improve agricultural production.
WHAT	ESA is working with the Swiss company Sarmap in mapping Gambia from space with radar. The aim of this is to establish baselines, understand current agricultural practices and document interannual changes.
RESULTS	Land-cover maps and maps of rice crop production patterns are in production.
OUTLOOK	Sarmap, ESA and UN-IFAD are also working with local communities. The local people are involved in collecting crop information for validation of the space-based maps. This will greatly enhance the accuracy of the maps as well as educate local people, a natural element of most bank development activities.

↗ A colour composite using both Envisat ASAR and ALOS PALSAR (yellow indicates permanent vegetation/settlements, blue shows changing land cover (agriculture) (Sarmap)

→ Gambia land-cover map from ALOS (Sarmap)

Case Study 3

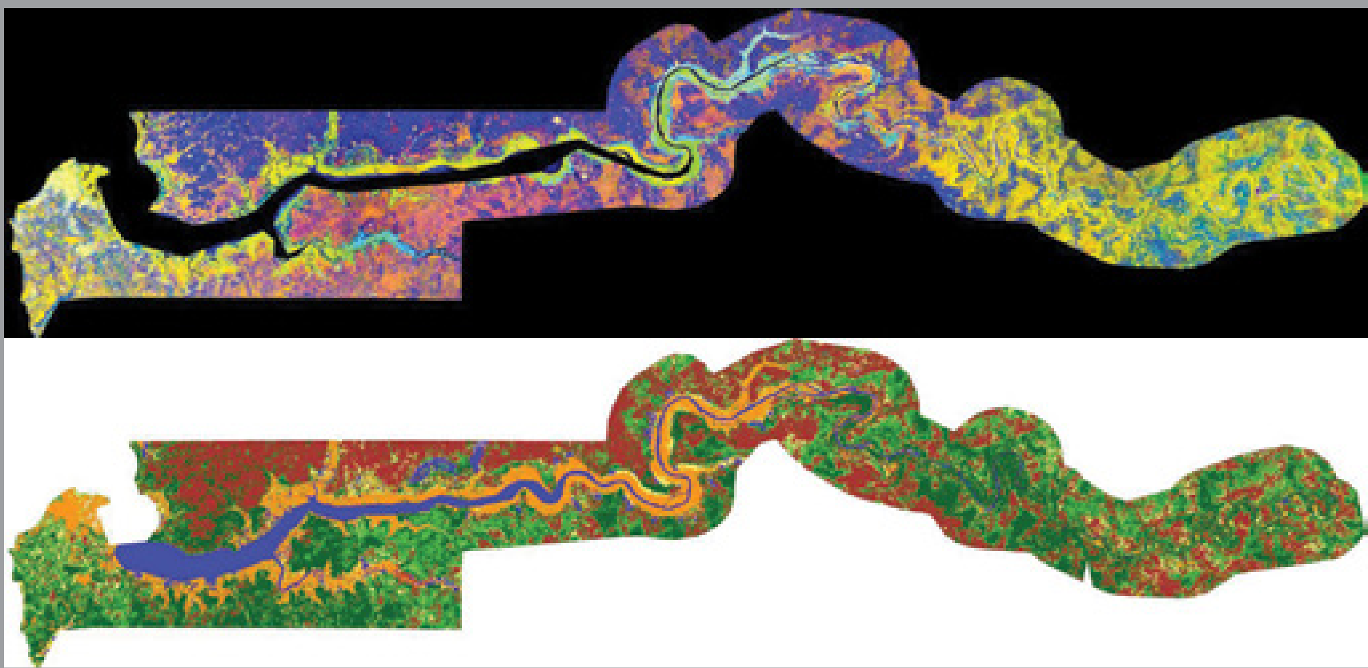
→ ASSESSING THE IMPACT OF OIL PALM PRODUCTION IN PAPUA NEW GUINEA FOR WORLD BANK



WHY	Papua New Guinea face problems with unsustainable extraction practices in the palm oil and forestry section and growing industrialisation.
WHAT	Land cover and forest type mapping.
RESULTS	Earth observation services provided in Papua New Guinea documented that the World Bank-supported development of smallholder's plantations are compliant with oil palm sector sustainability criteria, such as the Roundtable on Sustainable Palm Oil, and do not result in negative effects on the environment.
OUTLOOK	The ESA project with SarVision demonstrated new opportunities for managing operational risks associated with palm oil production and other agricultural practices causing conflicts with existing natural habitats.

←

Small clearings for food gardens/subsistence agriculture in Oro. The RapidEye 5 m satellite image mosaic (left) shows recent small clearings in 2011 (blue spots), secondary forest (dark brown), smallholder oil palm (dark orange) and other land cover types. The forest cover change map product at 30 m resolution (right) shows deforestation of secondary forest during 2005–9 (orange), deforestation of secondary forest during 2009–11 (red), in addition to secondary forest (green), rivers (blue), and non-forest including oil palm (white) (SarVision, RapidEye)



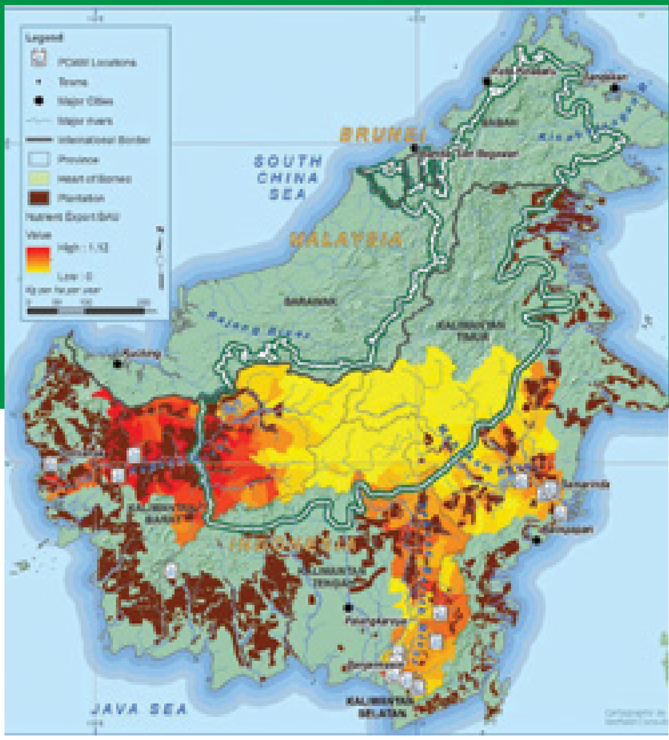
Case Study 4

→ EO FOR GREEN GROWTH ANALYSIS IN BORNEO FOR WWF

WHY	Borneo's tropical forests are among the most diverse and beautiful on the planet. Faced by threats from expansion in the palm oil extraction industry, forestry and mining and growing industrialisation, the governments of Indonesia, Malaysia and Brunei joined forces in assessing the economic value of the island's nature reserves in a large reporting activity: Heart of Borneo (www.heartofborneo.org). The main aim of the project was to assess business-as-usual scenarios against sustainable development scenarios taking ecosystems services into account.
WHAT	ESA worked with the World Wildlife Fund for ES assessments. Watershed functions, soil erosion, biodiversity and carbon stocks were carefully assessed using models and Earth observation data.
RESULTS	Services delivered for the World Wildlife Fund were key to the success of the Heart of Borneo project. Careful addressing of the value of all ecosystems was effective in changing policymaker views on land use in Borneo to include more sustainable practices.
OUTLOOK	ESA is launching more demonstration trials including forest studies in Vietnam, Indonesia and Peru, and coastal studies in Australia and Yucatan. The aim of these activities is to derive the economic value of the specific ecosystems addressed in each area for a selected group of users whose natural resources are threatened by industrialisation and bad land use management.

↑ Water yield and water supply intakes for Kalimantan, Indonesia, using land cover information, slope and elevation data from satellites

↓ Projected nitrogen export associated with business as usual for 2020, Kalimantan, Indonesia (Hatfield Consultants)



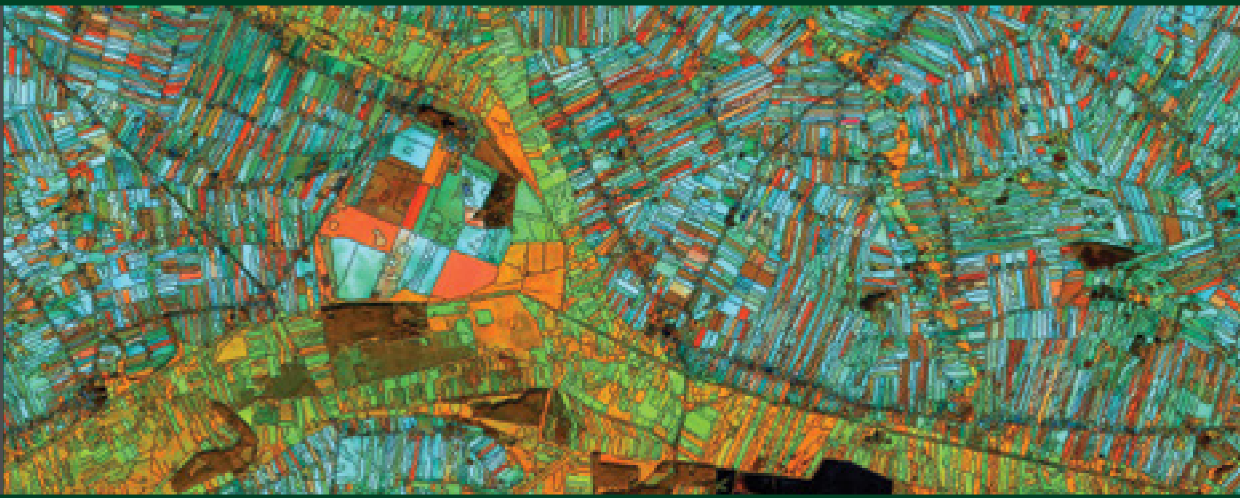
"All these activities aim to demonstrate the value of Earth observation to support targeted international development programmes."

Case Study 5

→ ECOSYSTEMS CHARACTERISATION FOR EEA

Agricultural landscape of łęczyca, Poland, classified with the purpose of finding small hedges, bio-corridors and natural fences for example that protect biodiversity (GISAT)

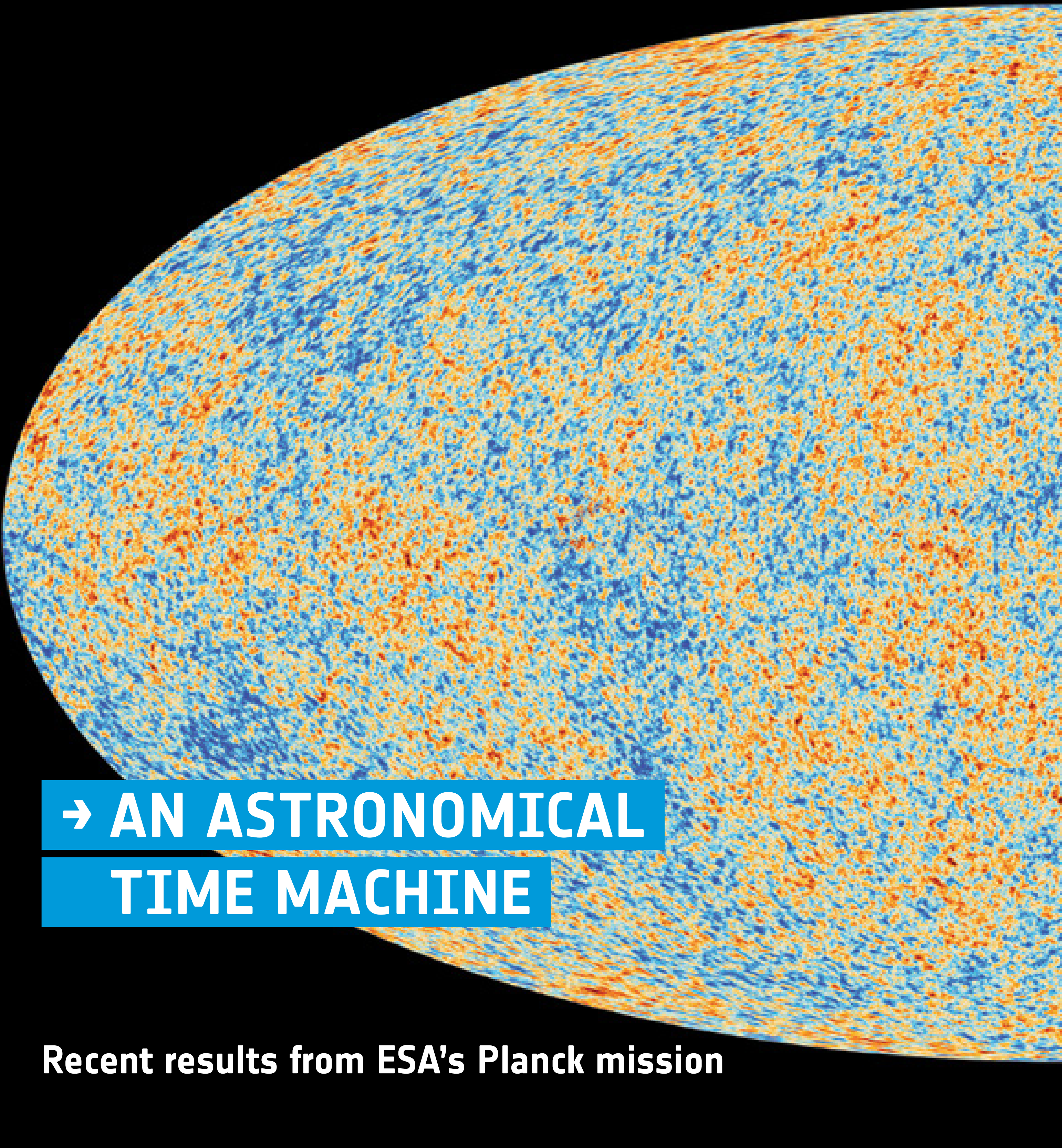
→



WHY	Small linear landscape features serve as natural habitats or bio-corridors and provide provisioning (genetic, wood), regulating (climate, soil erosion protection, water purification) and cultural (landscape character) ecosystem services.
WHAT	A ESA project carried out by Geoville and GISAT assessed the ability of Earth observation analysis techniques to support the European Environmental Agency (EEA) needs related to ecosystem mapping and assessment, land and ecosystem (capital) accounts, green infrastructures and regional environmental characterisation.
RESULTS	It is possible using high-resolution satellite data to map almost all linear features of relevance to the EEA.
OUTLOOK	EEA and ESA are looking into the possibility for expansion of the trials on a pan-European scale.

←

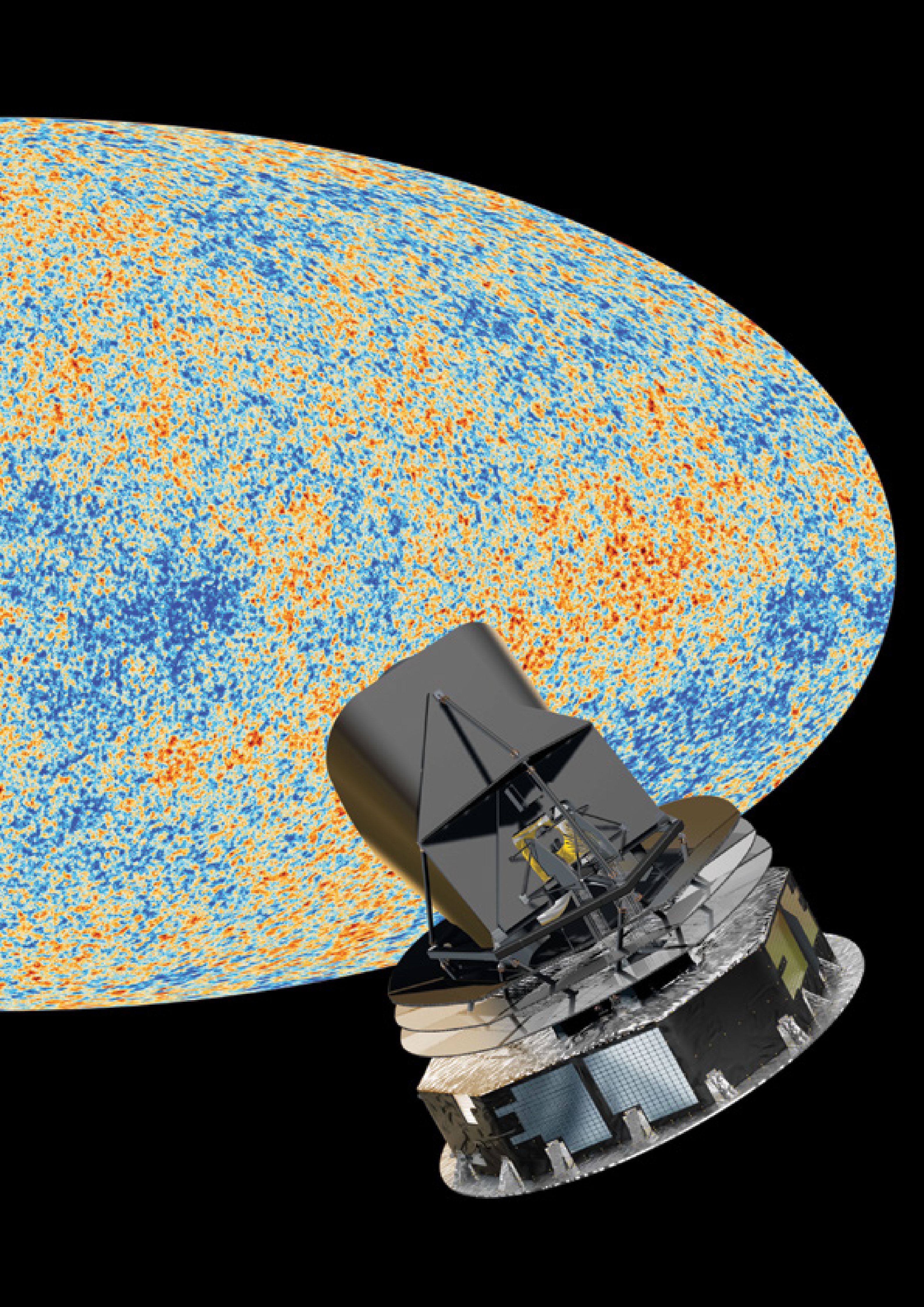
Detailed mapping of high resolution land use and land cover is crucial to assess changes in ecosystems. This detailed satellite based map of building footprints and land cover types supports Water Resource Management and exposure mapping of urban infrastructure and agriculture along the Mekong River in Cambodia. (GeoVille for ESA/WorldBank; KARI (Korea Aerospace Research Institute)

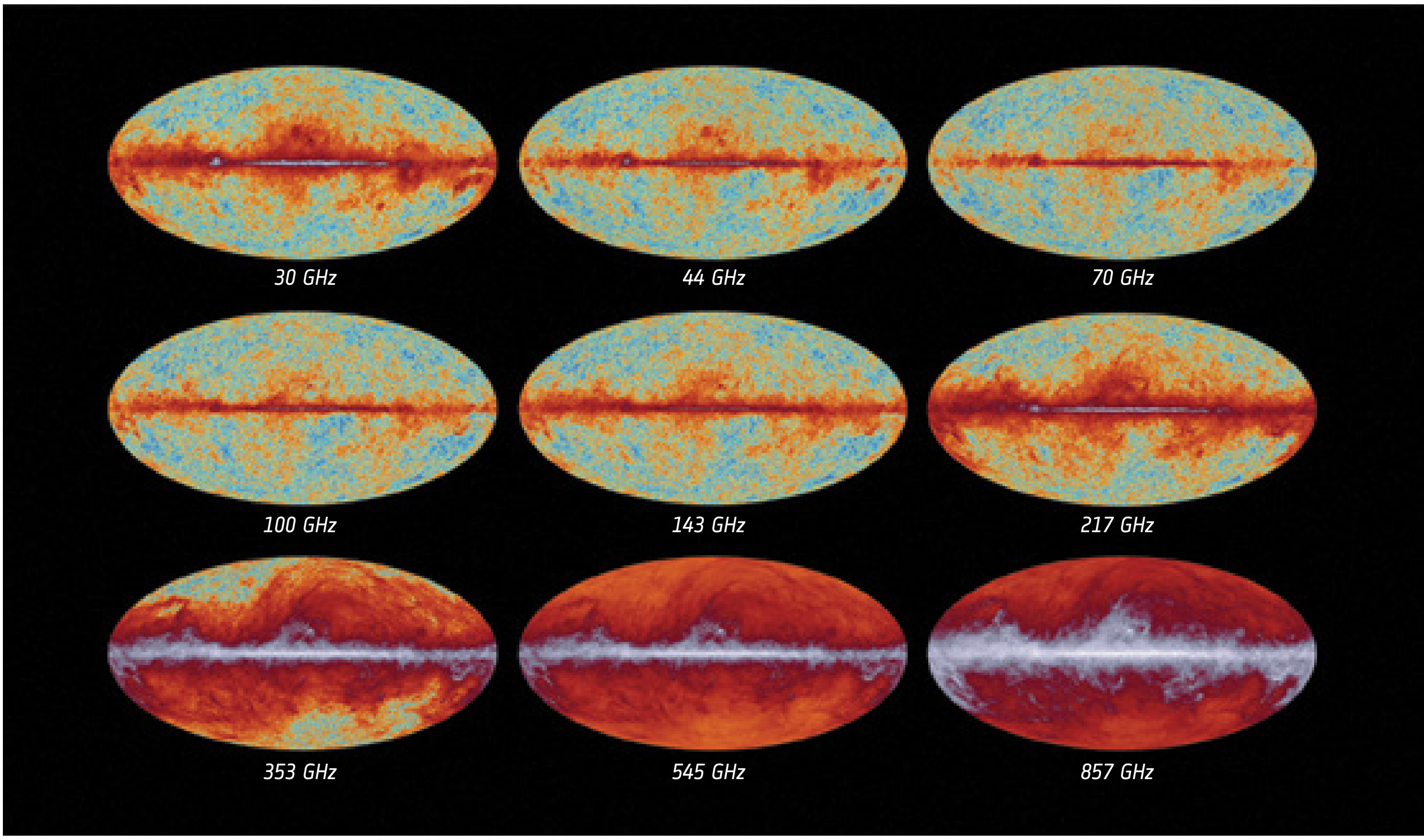


→ AN ASTRONOMICAL TIME MACHINE

Recent results from ESA's Planck mission

Jan Tauber (on behalf of the Planck Collaboration)
Directorate of Science and Robotic Exploration, ESTEC, Noordwijk, the Netherlands





Planck is designed to measure and analyse, with the highest accuracy ever achieved, the remnants of the radiation that filled the Universe immediately after the Big Bang – 13.8 billion years ago – literally looking back to the dawn of time.

Observed today as the Cosmic Microwave Background (CMB), this 'fossil' radiation, the farthest and earliest that any telescope can see, is the first light that could ever travel freely throughout the Universe, and therefore it can be thought of as the 'echo' or 'shockwave' of the Big Bang.

This primeval light can be characterised by a temperature, which corresponded initially to that of the Universe at the time that it was released (approximately 3000 degrees). As the Universe expanded, the temperature of the CMB decreased, and it has already been measured to be approximately 2.7K (close to –270 °C) or about 1000 times lower than its initial value.

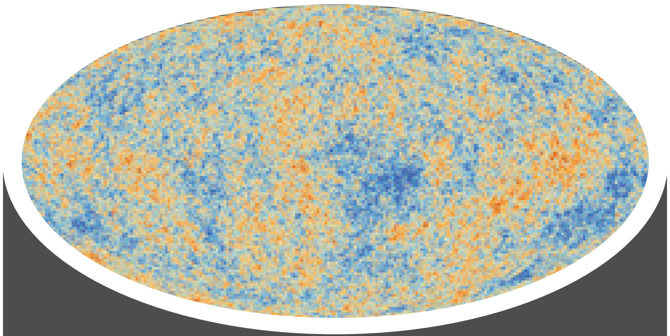
The 'colour' of the CMB radiation was also changed by the expansion of the Universe; nowadays it has shifted entirely out of the range of light that we can observe with our own eyes. Its wavelength (a measure of colour) has by now grown into the regime of microwaves and to detect it, we must use appropriately tuned radio instruments.

Although the CMB radiation looks almost identical no matter in which direction we look, it is known from previous observations that its temperature is actually slightly warmer or cooler in different parts of the sky. These differences in temperature are tiny – typically one part in 100 000 – and theory tells us that they are the imprints left in the CMB

↑ Dust structures within 500 light-years of our Sun as seen by Planck (ESA/LFI & HFI Consortia)

→ Planck all-sky maps

All-sky maps recorded by Planck at nine frequencies during its first 15.5 months of observations. Each of the panels is a projection that unwraps the spherical sky around us onto a flat image. The bright horizontal feature traversing each image is light from the galaxy surrounding us (Milky Way). At the longest wavelengths (upper left, equivalently lowest frequencies), the images are affected by radio emission from the interstellar material in the Milky Way, which is mostly made of 'synchrotron' radiation emitted by electrons that spiral along magnetic field lines, but also comprises 'bremsstrahlung' radiation, emitted by electrons that are decelerated in the presence of protons. At the shortest wavelengths (lower right, equivalently highest frequencies), the images show the emission of heat from interstellar grains of dust in the Milky Way (warmed by surrounding stars). The Cosmic Microwave Background is visible as an irregular pattern above and below the Milky Way, most evidently in the middle (microwave) frequency bands (between 70 GHz and 217 GHz) (ESA/Planck Collaboration)



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Anisotropies in temperature of the Cosmic Microwave Background as observed by Planck. Tiny temperature differences correspond to regions of slightly different densities, representing the seeds of all future structure: the stars and galaxies of today. Reddish spots correspond to warmer (less dense) areas and bluish spots to cooler (denser) areas. The reddest spots are about 50 millionths of a degree warmer than the average temperature across the whole sky, and the bluest spots cooler by the same amount (ESA/Planck Collaboration)

by the primeval 'seeds' of today's huge concentrations of matter, galaxies and galaxy clusters, for example.

The measurement of these point-to-point temperature differences, called 'anisotropies', enables scientists to learn more about the evolution of structure in the Universe. The objective of Planck can be simply described as measuring these temperature differences over the whole sky, and assembling them into a 'map of the anisotropies of the CMB'.

Planck provides the most precise measurements so far of the anisotropies, the accuracy of which is set by fundamental astrophysical limits. To carry out these highly sensitive measurements, Planck carries a telescope that gathers light from the sky and focuses it on a camera. This camera contains 74 detectors (or pixels), each of which is able to measure light only within a narrow range of colours (or more technically speaking, wavelengths). Planck's camera is sensitive to nine such colour bands, spanning the wavelength range from one centimetre (radio bands) to one third of a millimetre (the very far infrared).

In the middle of this range are the microwaves, where the CMB shines the brightest. Each of Planck's detectors is cooled to very low temperatures (some very close to absolute zero) otherwise their own heat emission would spoil the measurements. Planck rotates on itself in such a way that the camera is swept across the sky in a circle, and Planck's orbital motion carries it around the Sun in one year.

Since Planck's camera acquires images continuously, the combined circular and orbital motions allow it to observe all parts of the sky within a period of about six months. Therefore, each year, Planck can produce two independent images of the whole sky, in each of the nine bands ('colours') that it is sensitive to. These images were released for the first time to the public in March.

Unfortunately, the all-sky maps made by Planck contain many more sources of light than just the CMB. For example, the Milky Way galaxy in which we live produces itself radiation in the colours that Planck is sensitive to. So in fact Planck observes the CMB through a 'curtain of light'. In order to make a picture of the CMB *only*, we first have to 'remove' this curtain. To do this, scientists make use of previous observations, which have measured the CMB's spectrum to great accuracy. In this process, the combination of data collected in all of Planck's nine maps is crucial to achieve an optimal reconstruction of the underlying CMB. The result is a map of the whole sky, which shows by how much the temperature of the CMB deviates from its average value at any direction that we may observe it.

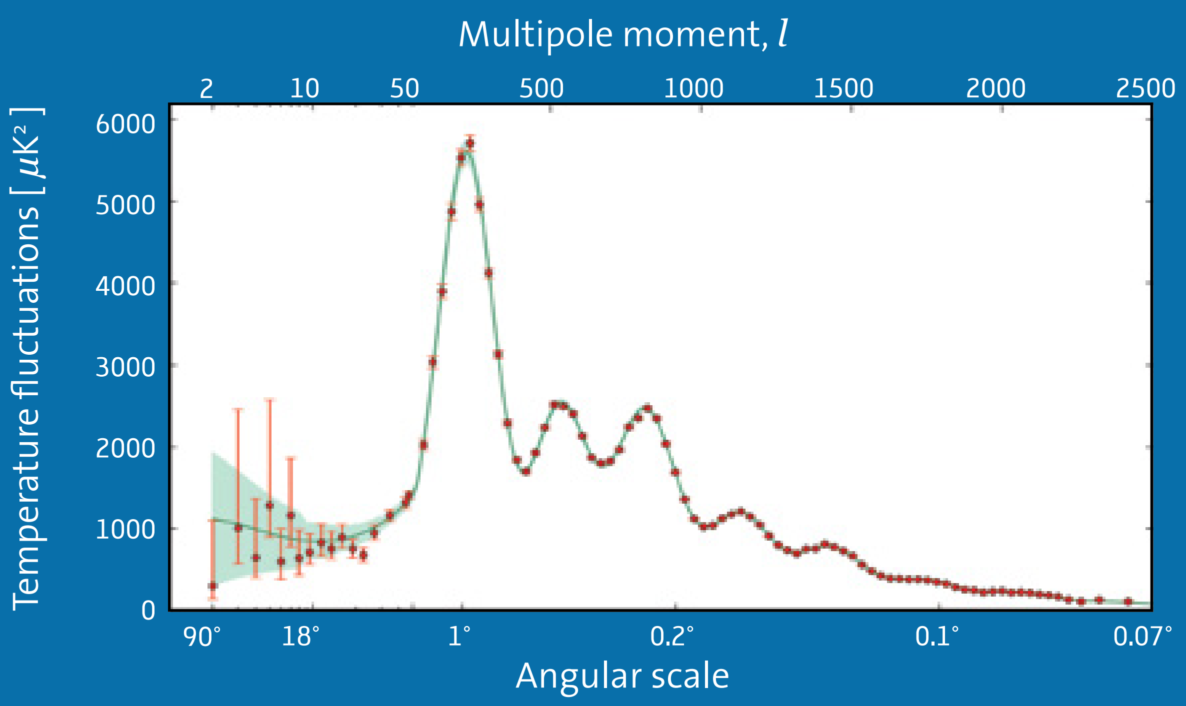
Planck's image of the CMB anisotropies is therefore a picture of the Universe when it was only about 380 000 years old (if we compare the Universe to the typical human lifetime of around 80 years, the CMB was generated when that person was about 20 hours old). At that time, the Universe consisted of a hot soup of matter and radiation with almost no structure.

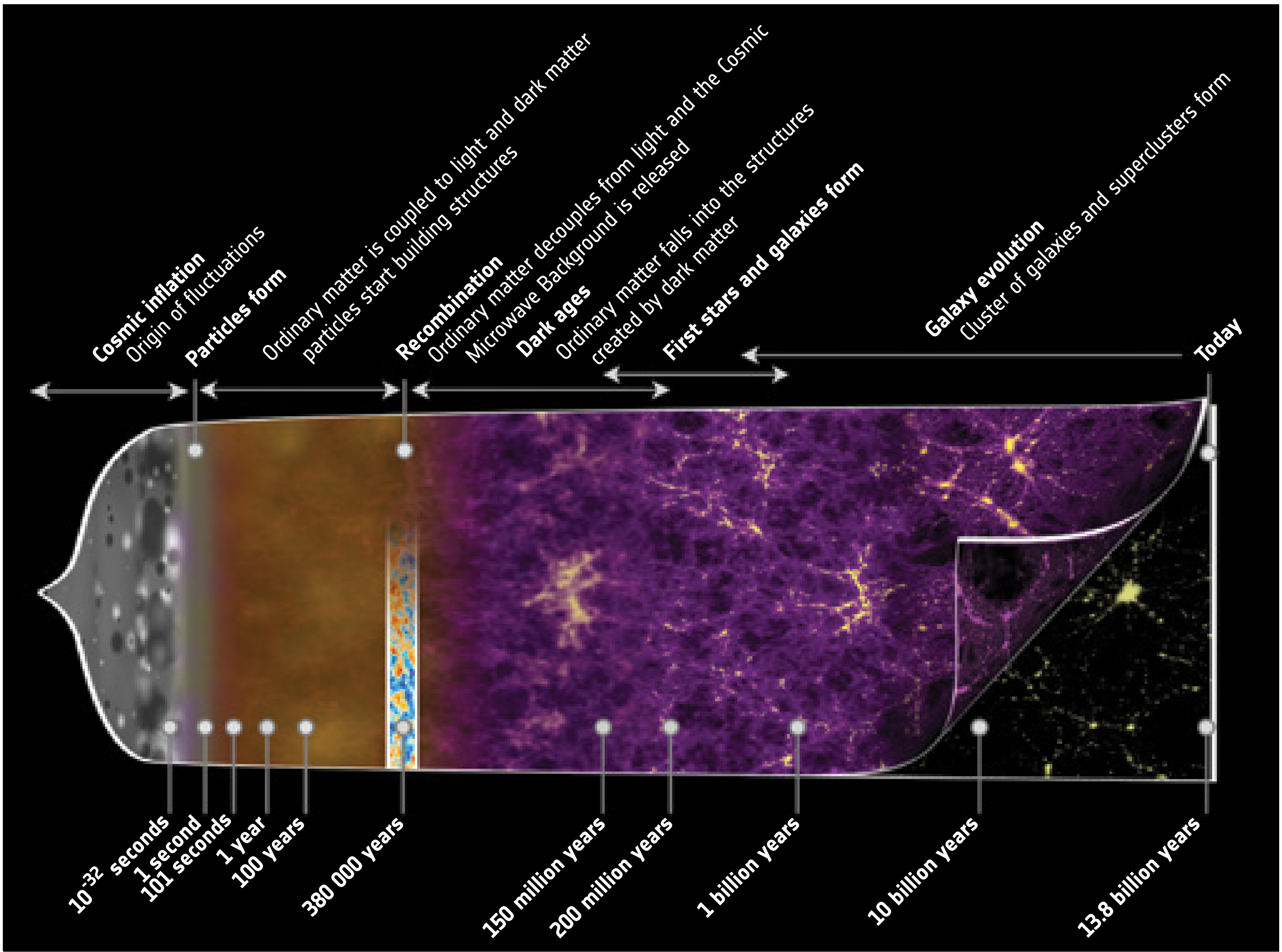
The tiny irregularities that we see in the image correspond to similarly tiny enhancements or deficits in the density of matter, which would later grow by the effect of gravity into all the structures that we see today (such as stars, galaxies, clusters of galaxies). The early soup behaved very similarly to the 'plasma' that we find today on the surfaces of cool stars. In particular, we know that acoustic waves of many frequencies ran back and forth within the primeval plasma (as happens also on the surface of a star). These acoustic waves leave very characteristic and prominent signatures in the 'angular power spectrum' of the image of the CMB anisotropies, which are analogous to those left by individual harmonic tones in the sound spectrum of a musical piece.

The angular power spectrum of the CMB is the (statistical) quantity that is predicted by theory and therefore the one from which we extract most of the scientific information contained in the all-sky image of the CMB. The amplitude and spacing of all the bumps and wiggles in the curve depend on the physical parameters that we have assumed when making a prediction. For example, the precise location of the prominent peak at a scale of about one degree depends on the exact time at which the CMB was released with respect to the Big Bang, and on the sound speed in the plasma.

→ Temperature fluctuations in the CMB

The angular power spectrum of the Cosmic Microwave Background shows the strength of the temperature fluctuations in the CMB detected by Planck at different angular scales on the sky. The largest angular scales, starting at angles of ninety degrees, are shown on the left side of the graph, and increasingly smaller scales are shown towards the right. For comparison, the diameter of the full Moon measures about half a degree from Earth. The red dots are measurements made by Planck, shown with error bars that account for measurement errors as well as for an estimate of the uncertainty that is due to the limited number of points in the sky at which it is possible to perform independent measurements. This so-called 'cosmic variance' is an unavoidable statistical effect that becomes most significant at larger angular scales and limits the amount of information that can be extracted from the data. The green curve represents the best fit of the 'standard model of cosmology' – currently the most widely accepted scenario for the origin and evolution of the Universe – to the Planck data. The pale green area around the curve shows the predicted level of cosmic variance around the best-fit model Universe





↑ The history of the Universe, according to Planck

Other parameters – though not the only ones – that have a significant influence on the shape of this curve are:

- The relative amounts of the two kinds of matter that we know are present in the Universe: 'ordinary' matter (out of which we are made) and 'dark' matter (which we cannot observe directly but whose existence we can sense by the gravitational pull it exerts on the rest of the Universe)
- The time at which the first stars started to form in the Universe
- The relative amount of 'dark energy' that produces a repulsive force causing the expansion of the Universe to accelerate at the present time
- The properties of quantum fluctuations at the instant in which our Universe was formed, which provide the seeds of later structure formation

The way in which scientists extract scientific information from the data is by comparing the angular power spectra predicted by models to the measurements, varying the parameters which characterise the physical phenomena that are included in the model, until an acceptable fit is found. It is fortunate that, although the model of the Universe could be made arbitrarily complex, only a limited number of physical phenomena have a significant influence on the shape of the angular power spectrum of the CMB.

In fact it is quite surprising – and an important result from the Planck data – that *a very simple model of the early Universe (based on only six free cosmological parameters) is sufficient* to explain the very accurate measurements of the shape of the angular power spectrum. This amazing convergence indicates that any exotic physical phenomena operating at the time that the CMB was released must have very little influence on the properties of our Universe. This is good news for our understanding – though maybe disappointing to theorists who would like to find evidence for new physics.

The new 'recipe' of the Universe as found by Planck contains the three components that we already knew about: ordinary and dark matter together make up about a third of the total, and dark energy about two thirds. The relative amounts of these components have been established by Planck with extremely low uncertainty, between 1% and 2%, which explains why scientists have heralded the coming of the era of 'precision cosmology'. On the other hand, it is sobering to note that we can see directly only a very small fraction (about 5%) of the total contents of the Universe, whereas the remaining 95% is indirectly inferred.

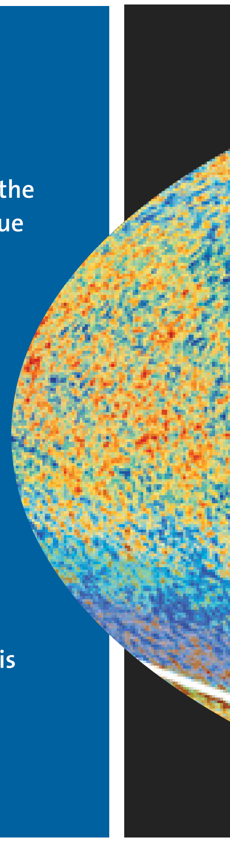
The Planck recipe also tells us that the Universe is around 13.8 billion years old, and that the CMB was released about 380 000 years after it began. But what does Planck say about the very beginning of our Universe? Current theory says that our Universe came into being through a period of accelerated expansion referred to as 'cosmic inflation', which lasted about a trillionth of a trillionth of a trillionth of a second, at the end of which our entire (expanding) Universe had the approximate size of a grapefruit.

During this period, quantum fluctuations were hugely expanded in size and became the seeds of later structure in matter. The imprint of some of those initial fluctuations is still visible in the CMB, and can be observed by Planck. In fact, two of the parameters in the basic six-variable recipe relate directly to those fluctuations, and Planck allows us to glimpse for the first time what must have happened during the end phases of cosmic inflation. What we have learned is first, that inflation is still the best explanation for what we see, and second, that inflation ended gently rather than abruptly. This information has allowed scientists to discard a wide range of possible ways in which inflation could have developed.

Although Planck's discoveries uphold very firmly the currently favoured understanding of the Universe, this is not where the story ends. For some time there have been hints of the existence of some 'anomalous' statistical properties of the CMB's anisotropies; however, they were not taken very seriously as there were lingering doubts about their origin. The extraordinary quality of the Planck data now confirms without a doubt that the anomalies, which might challenge the very foundations of cosmology, are really of cosmic origin.

→ Anomalous features

Two anomalous features in Planck's map of the CMB have been enhanced with red and blue shading to make them more clearly visible. One is an asymmetry in the average temperatures on opposite hemispheres of the sky (separated by the curved white line), with slightly higher average temperatures in the southern ecliptic hemisphere and slightly lower average temperatures in the northern ecliptic hemisphere. This runs counter to the prediction made by the standard model that the Universe should be broadly similar in any direction we look. There is also a cold spot that extends over a patch of sky that is much larger than expected (circled) (ESA/Planck Collaboration)



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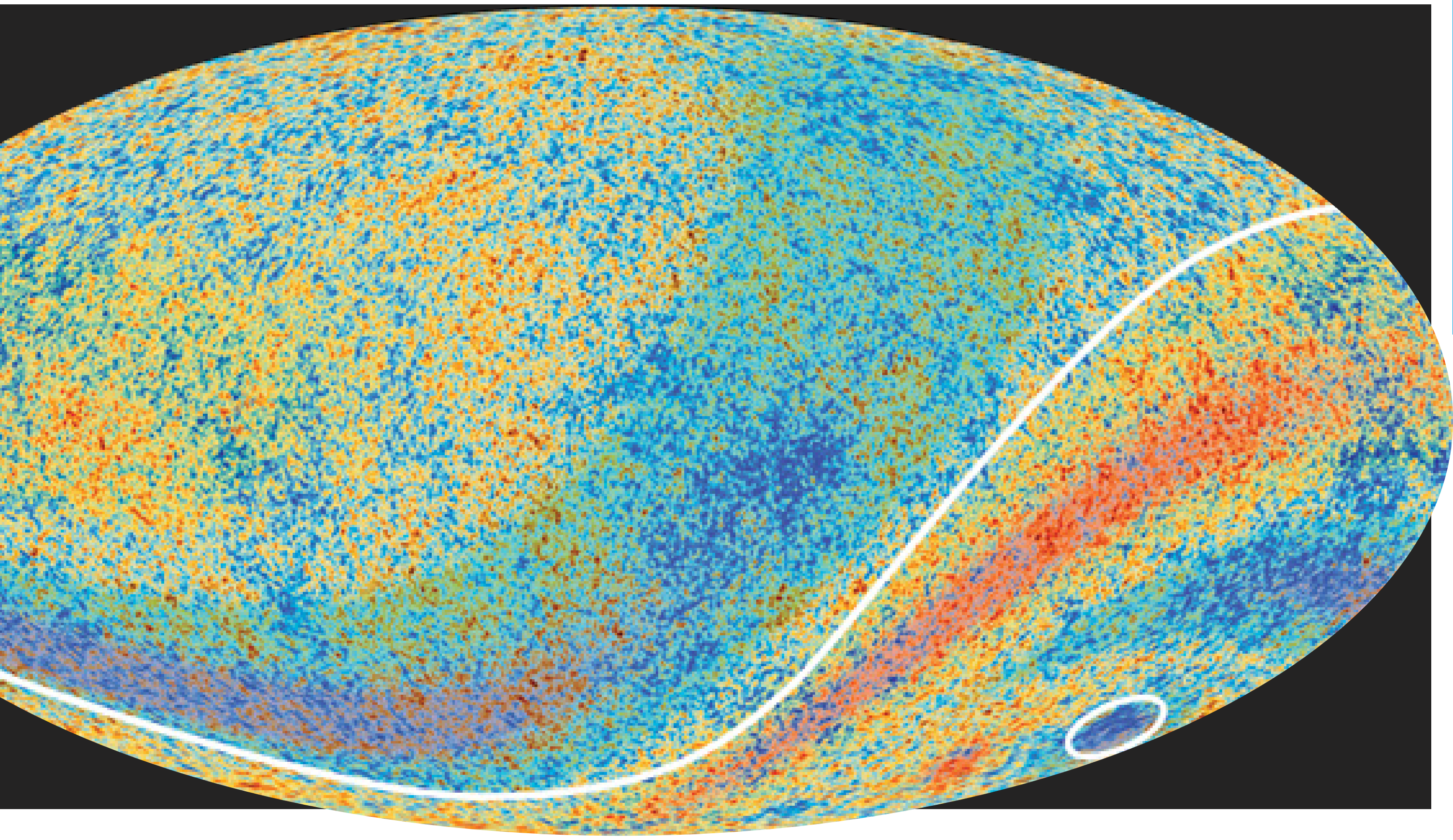
ESA Director General Jean-Jacques Dordain presenting the first results of Herschel and Planck to David Willetts, UK Minister of State for Universities and Science, at the Farnborough Airshow in 2010



What are these anomalies? While the observations on small and intermediate angular scales agree extremely well with the model predictions, the fluctuations detected on large angular scales on the sky – between 90° and 6° – are about 10% weaker than the best fit of the standard model to Planck data would require them to be. Another, perhaps related, anomalous signal appears as a substantial asymmetry in the CMB signal observed in the two opposite hemispheres of the sky: one of the two hemispheres appears to have a significantly stronger signal on average. An additional peculiar element in the data is the presence of a so-called 'cold spot': one of the low-temperature spots in the CMB extends over a patch of the sky that is much larger than expected. And there are more of these curious features.

Although any of these anomalies could – when seen on its own – simply be a statistical fluke, the existence of an *ensemble* of anomalies is remarkable, and therefore their cosmological significance is not negligible.

Theory tells us that when the Universe was born its texture was highly homogeneous and isotropic, meaning that its properties were almost exactly the same in every point and that there were no preferential directions in space. This extremely uniform background was punctuated only by minuscule, almost random fluctuations, which would later give rise to cosmic structure. In spite of the rich variety of structure that currently populates it, the Universe has remained remarkably homogeneous and isotropic on very large scales.

But the new CMB image delivered by Planck suggests that some aspects of this model might need revision: in particular, the large-scale isotropy might not hold when considering really large scales. Planck's new image of the CMB suggests that some aspects of the standard model of cosmology may need a rethink, raising the possibility that the fabric of the cosmos, on the largest scales of the observable Universe, might be more complex than we think.

Thus, Planck's results stimulate cosmologists to face an interesting tension: on the one hand, the 'standard model of cosmology' is still the best way – and a remarkably simple one – to describe the CMB data, even though it includes elements that still lack solid theoretical understanding and experimental support such as dark matter, dark energy and cosmic inflation. On the other hand, the anomalies seen by Planck hint towards the possibility that the model should be at the very least extended, if not radically modified.

The Planck results are certain to move cosmology in interesting and possibly new directions. And the bounty of data that Planck is contributing to the field is not yet at an end: in 2014, a new set of data will be released which will include the determination of the polarisation of the CMB's anisotropies, and which promises to bring new information on all the current discoveries.

London seen at night from ISS
(NASA/ESA)

→ NIGHTPOD

Capturing Earth by night from space

Massimo Sabbatini and Luigi Castiglione
Directorate of Human Spaceflight and Operations, ESTEC, Noordwijk, the Netherlands

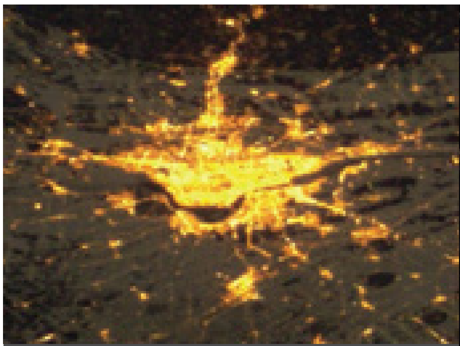
Julien Harrod
Communication Department, ESTEC, Noordwijk, the Netherlands

The International Space Station offers a unique view of Earth and snapping photographs is a favourite pastime of many astronauts. Images sent back from space are not only inspiring and beautiful, but can also be used for scientific and educational purposes.

Astronaut photography began with the first manned spaceflights in 1961. Every US manned mission since 1962, for example, from Mercury through Gemini, Apollo and Skylab to the Shuttle, has included a look back at Earth by film photography, generally with hand-held cameras.

From both American and Russian platforms, astronauts and cosmonauts have acquired innumerable photographs as part of their scientific tasks, or as 'just plain tourists', looking out of the window at the landscapes below.

For astronauts and cosmonauts staying on the first US and Soviet space stations in the 1970s, taking pictures of Earth was one of their main roles – mostly for Earth observation, but sometimes also for military reconnaissance and not necessarily for public benefit. Mission objectives have moved on since the 'Cold War' and astronaut photos are now being used in many other areas.



↑ →

The image above is the best-resolution picture that ISS astronauts have taken of Montreal, Canada, by hand. The exposure time coupled with orbital motion created the blur. On the right, the same city as snapped with Don Pettit's home-made tracker (NASA/ESA)

However, humans do not have ultraviolet or infrared vision like Earth observation satellites do, and so we are limited to taking pictures of Earth during the day. Given that half of the surface of Earth is in darkness at any time, the scope for astronaut pictures is reduced. In the daytime, human constructions tend to blur into the surrounding landscapes.

At night, however, humankind's footprint becomes fully visible from above. Artificial lights bloom, revealing where humans have colonised coastlines, created towns, cities and road systems, even in the remotest areas.

Night-time views of some cities and countries can reveal much about their infrastructure. After his first space mission in 2002, NASA astronaut Don Pettit noticed that

→ NightPod tech specs

Material: aerospace-grade aluminium
Turning circle: –20 to +20 degrees with around 50 cm movement
4-axis movement
Tracking accuracy: 7 arcsec
Best ground resolution: 10 m/pixel
Tracking range: +/– 18 degrees

→

←

Barcelona at night taken by ESA astronaut Paolo Nespoli in 2011 by hand using an exposure time of 0.067 sec (1/15) at 12800 ISO (NASA/ESA)

each city shows a characteristic 'signature' at night. ESA astronaut André Kuipers also noticed this, taking many photographs during his six-month stay on the International Space Station in 2012.

André described the 'wonders of Earth at night' during his PromISSe mission: "Lightning, oil-field fires and the auroras are always visible, as well as the extremely bright lights used by fishing boats and of course the cities, villages and roads that all light up in a golden glow."

But how can astronauts share these views with us on Earth?

Forget the flash

A common problem for amateur photographers is that pictures taken without adequate lighting result in blurry images, because of the long exposure times that are needed for a camera to collect enough light. While the camera shutter stays open to allow in enough light, shakes from a photographer's hand can distort the final picture.

← **Swim to the light.** Usually concentrated lights at night are a tell-tale sign of human habitation. Here an unidentified village in Asia is outshone by lights of fishing boats in the China Sea. Lights are used by fishermen to attract fish to their nets (NASA/ESA)

→ Human sentinels

The International Space Station flies in a relatively low orbit over many countries and cities. It only takes 90 minutes to fly around the world so astronauts are often 'first at the scene' after geological events or natural disasters. Using handheld digital cameras, astronauts can easily recognise sunlight glinting on water, enabling them to report on the extent of floods. Their pictures can even be analysed to see if water has been contaminated with surface oil, for example.

The Space Station travels over areas at different times of day. Most Earth observation satellites fly over Earth in fixed orbits that revisit the same areas at the same time each day. This is good for collecting easily comparable data but leaves scientists in the dark if they want to observe specific phenomena that happen at different times, such as morning fog.

Astronaut photography is helping the work of marine biologists in protecting and preserving coral reefs in our oceans. Astronauts can identify coral reefs from orbit, and often take pictures because of their unusual and striking appearance. Their cloud-free high-resolution images are proving valuable for experts to survey and monitor the reefs.

To overcome this problem, there are a couple of solutions. One is to use a single flash of light to illuminate the scene, allowing sufficient light to reach the camera such that a shorter exposure time can be used. The second is to mount the camera on a stable fixture, such as a tripod, to keep the camera still.

A flash only works if the subject is within 5 m of the camera, and for the tripod to work the subject must stay in view. For astronauts circling Earth at an altitude of 400 km and a speed of 7 km/s, obviously both solutions are impractical.

Another way would be to track the subject, like astronomers who slowly move their telescopes at the same rate of Earth's rotation in order to make steady long exposures of stars and other distant objects.

A typical photograph taken by an astronaut during daytime has an exposure time of 1/1000 second, fast enough to take sharp and detailed pictures without blurring. At night though, exposure times of 1/15 second are needed and blurring is impossible to avoid.

> **"Lightning, oil-field fires and the auroras are always visible, as well as the extremely bright lights used by fishing boats and of course the cities, villages and roads that all light up in a golden glow."**

←

A coral reef seen by the crew of Expedition 5 from the International Space Station in 2002. Such images are very helpful in conducting underwater surveys (NASA)

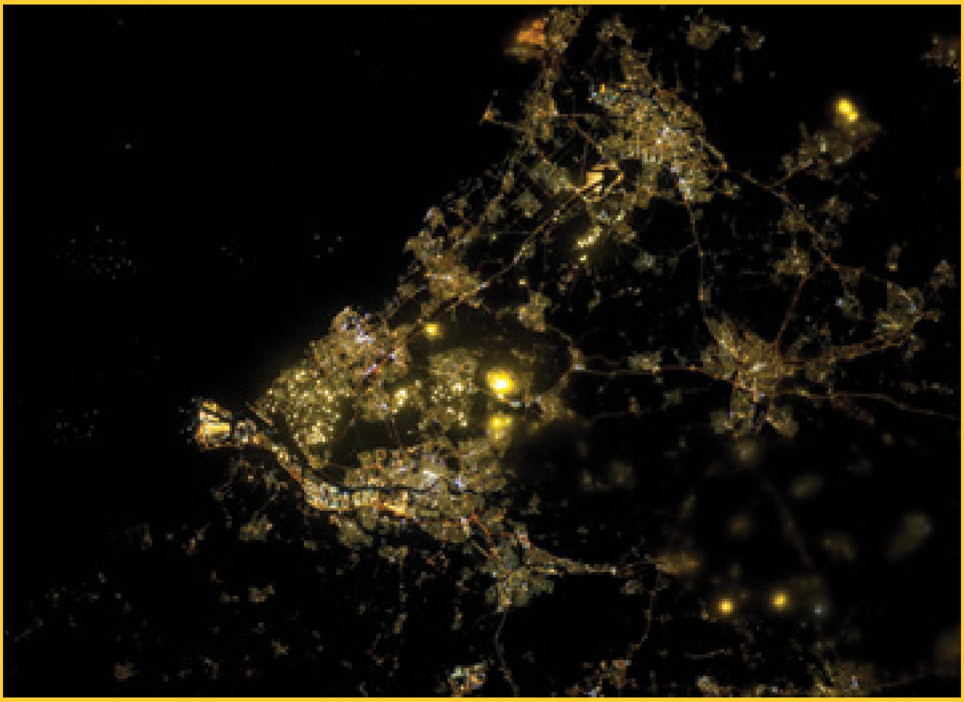
The only way to take clear picture of Earth at night is for an astronaut to steadily follow a subject on the surface as it speeds past. Much of this is guesswork, because it is not easy to look through the camera's viewfinder for the time taken to get a picture from space at night.

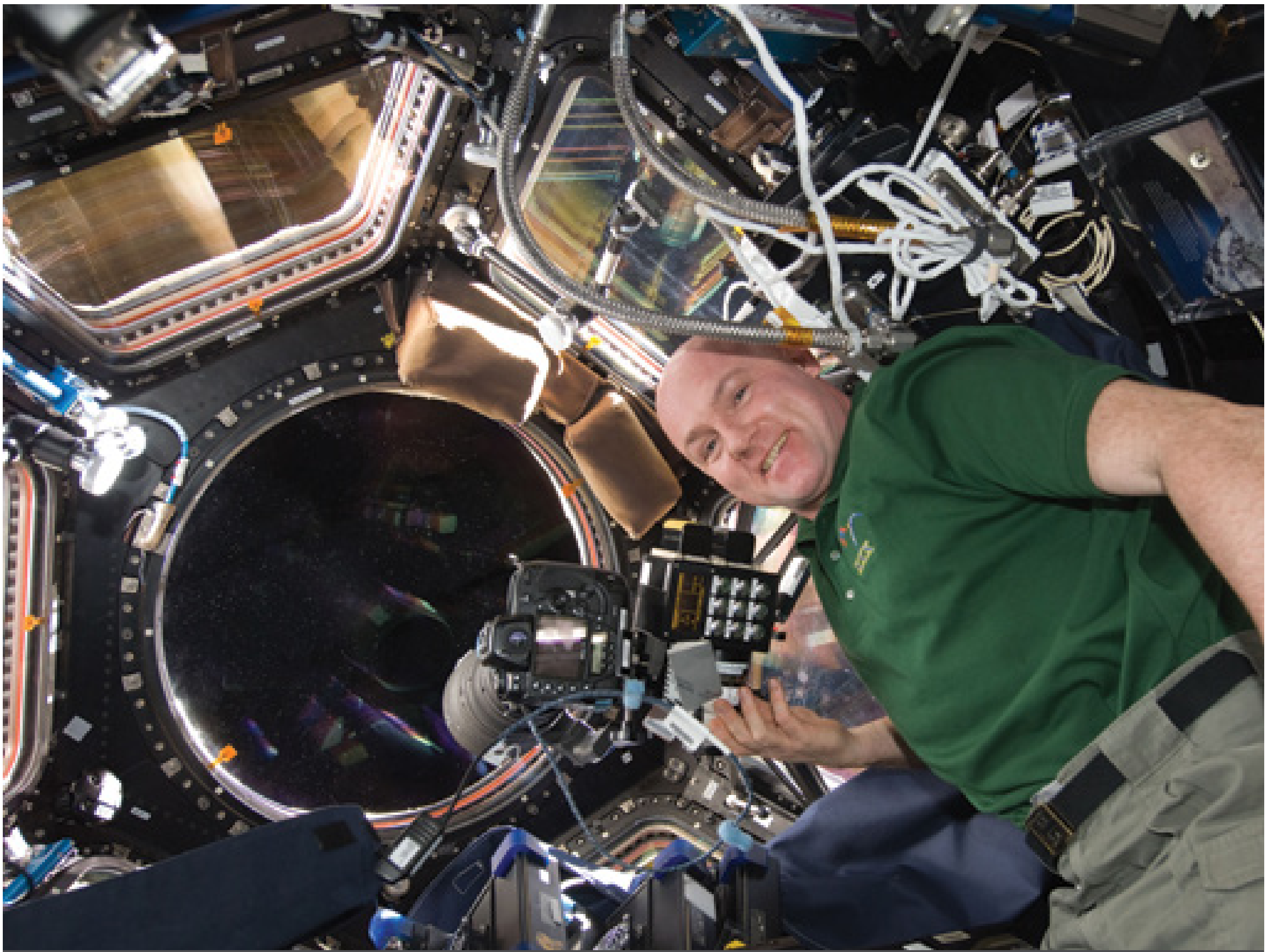
ESA astronaut Paolo Nespoli was exceptionally good at estimating the speed at which to turn his camera and keep a steady hand, but it is almost impossible for most photographers to stop the slightest movements from showing in the end results.

Another problem is tracking. If astronauts see an area of interest, they can wait for another pass on the next orbit to ready their camera again. But on the next orbit, the Space Station will have moved 2200 km farther on in

← **Bright lights, big city.** The wide expanse of Shanghai at night, the old centre at the river's bend with the bright white light is surrounded by sprawling suburbs built in a more modern, straighter pattern. The bright band of lights at the top right is Pudong international airport (NASA/ESA)

→ **Grow west.** Not all artificial lights are to help humans find their way on roads. The bright white lights here are in Westland, an agricultural district in the Netherlands. The Netherlands is the second-largest exporter of fresh produce in the world. Today, the Westland and the area around Aalsmeer have the highest concentration of greenhouse agriculture in the world (NASA/ESA)





↑ ESA astronaut André Kuipers with NightPod installed in Cupola (NASA/ESA)

→ Don Pettit showing his scavenged 'barn-door' tracker. The drill is used to move the device at a constant speed. The tracker required no permanent modifications of the scavenged parts (NASA) relation to the point they were waiting for. A city will rarely be directly under the Space Station, so an astronaut needs not only to point and track the area of interest, but also while viewing at an angle.

Scavenging parts for barn-door solutions

NASA astronaut Don Pettit is an amateur astronomer and well known for his engineering skills and 'do-it-yourself' approach. During his first stay on the Space Station as part of Expedition 6 in 2002, Don was keen to take pictures of auroras at night but came across the same problem of blurred images.

Don was inspired by homemade 'barn-door trackers', used by amateur astronomers to take clear pictures of the night sky, and decided to tackle the problem. To compensate for the rotation of Earth, he mounted a camera on a piece of hinged wood, like a barn door but placed horizontally. By opening the door at a steady rate the camera would move in an opposite direction to Earth and stay in the same position relative to the starry sky.

What works on Earth for looking up at stars should work just as well looking down from space, even though our planet moves much faster under the Space Station than stars appear to revolve around Earth. Don managed to create a 'barn-door'-type tracker using spare parts found on the Station.

The 'hinged planks' were fashioned from camera mounts left over from making an Imax film. By using a nut and screw scavenged from a Progress vehicle, Don found that he could position and move the camera. To ensure a smooth and steady rate of turning, he used an electric screwdriver to slowly turn the screw.

With some practice, Don managed to estimate the speed correctly and his pictures of cities at night were a lot sharper than those taken previously by hand.

The 'signatures' of cities became more apparent as Don shared his pictures. He commented, "European cities show a characteristic network of roads that radiate outwards like glowing spider-webs."

→ **East versus west.** Berlin is known for being divided during the Cold War by the Berlin wall. At first sight, this picture seems to show the historical division in the type of lights used in each half of the city. It is still not clear as to what causes the difference in colour; it could be a difference in street lighting used by different authorities, or it could be reflections from trees or simply cloud cover over part of the city (NASA/ESA)

↑

NightPod installed on a mock-up of the European Cupola observatory during testing. The camera aid can be moved and stowed or fastened to the side windows of the observatory module (NASA/ESA)

Professionalising the proof of concept

Ten years later, Don was scheduled to return to space with ESA astronaut André Kuipers on Expedition 30/31. By this time, the International Space Station had grown to include a dedicated observatory module called Cupola that offered panoramic views, helping astronauts to see areas of interest in advance.

André was eager to show the public the beauty of our planet by night, as well as by day. He asked colleagues at ESA whether it would be possible to send a more professional 'barn-door tracker' to the Space Station in time for their mission.

ESA saw potential in this idea and looked for a new solution. "We tackled the problem from both a software angle, looking at digital processing of pictures, and from a hardware angle, looking at a mechanical aid as a solution," said principal investigator Massimo Sabbatini, Head of ESA's Erasmus Centre at ESTEC in Noordwijk.

In just under six months, the payload was designed, tested and approved to the strict space safety levels – in fact, an incredibly short time in space hardware development terms.

ESA's lead developer for the project, Luigi Castiglione, explained: "Given the short time we had, a motorised mechanical solution was chosen because it was a proven technology and offered better resolution."

Dubbed 'NightPod', the motorised space-tripod was built by Cosine BV in the Netherlands and Astrofein GmbH in Germany. Lightweight and compact, the package used as many off-the-shelf components as possible to speed up production and safety qualification. It was designed to incorporate as many different types of cameras as possible and had to be under 10 kg at launch, including packaging.

The end design consists of four parts: the structure's 'legs' that fix to Cupola, an interface control box, the camera mount and the motors to move the camera over four axes. The unit was tested at the Johnson Space Center, USA, in a full-size mockup of the Cupola module. The package hitched a ride to the Space Station on Soyuz TMA-03, together with André, Don and cosmonaut Oleg Kononenko.

Point and click

Once installed, NightPod was easy to set up and could be operated with one hand. To calibrate the motors, an astronaut enters the relevant data, such as the height at which the Station is orbiting and its yaw, pitch and roll parameters. These are standard values that change over time but can easily be looked up.

After calibration, the astronaut points the camera at whatever is of interest, releases the shutter and NightPod will automatically compensate for the movement of the Station. The subject will be kept steady in the camera's viewfinder during its exposure time.

More functionality is available in 'automatic mode', where NightPod takes pictures with different exposure times of the same target while it is in view. NightPod does this automatically without further intervention by an astronaut, freeing their time for other scientific experiments. By stitching the images together digitally, it is possible to create views of Earth with unprecedented resolution.

More than a million pictures have been taken from the International Space Station since the launch of its first component modules over ten years ago, and NightPod just celebrated its first year in orbit. Many scientists have expressed interest in using NightPod and expanding its scope.

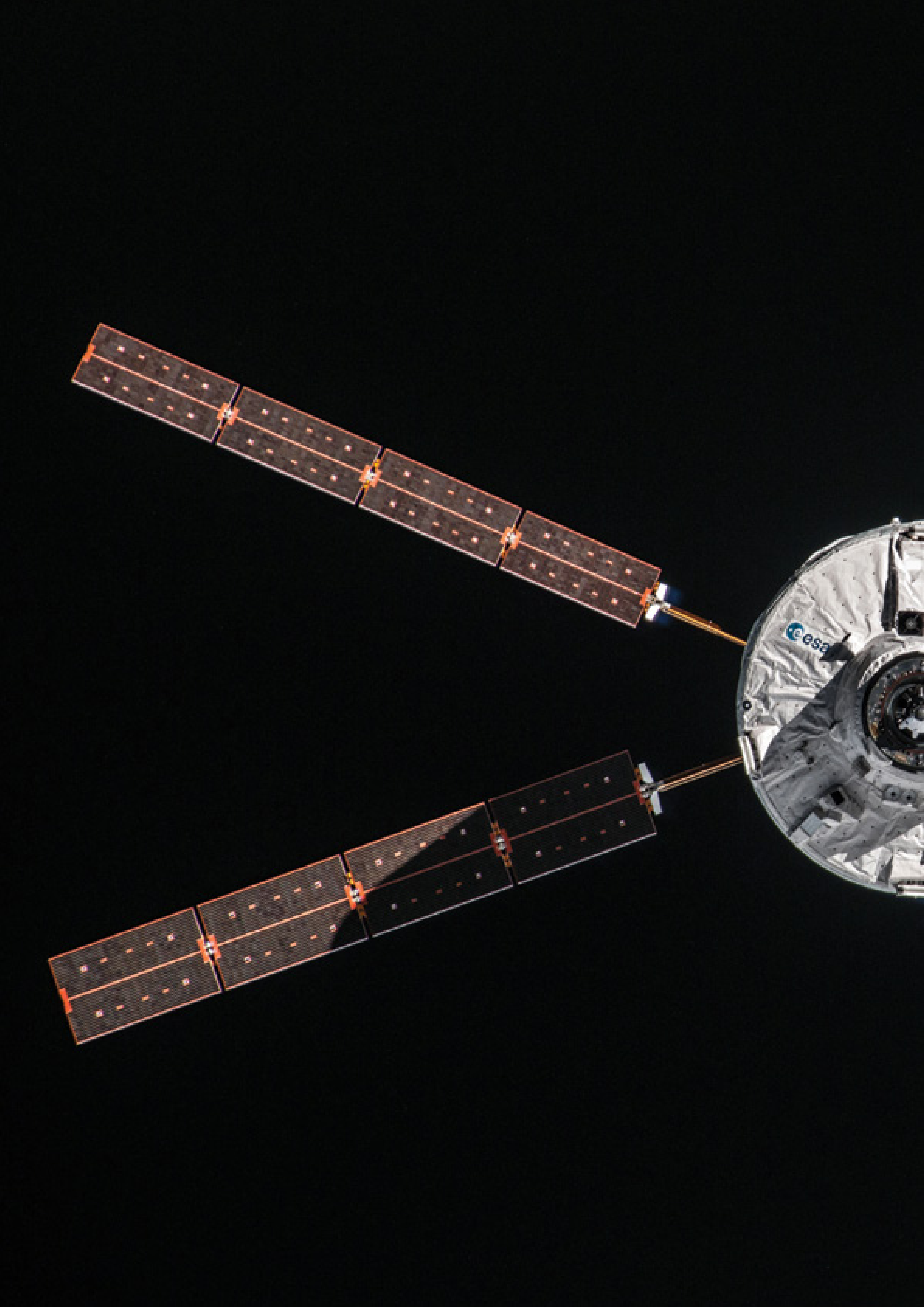
In the meantime, people on Earth continue to marvel at the beauty of these night-time shots. André wrote in his blog, "I hope you are happy with the images I take. It is quite a challenge, especially during the night cycle of Earth. Night-time photography is not as easy as counting to three."

Canadian astronaut and International Space Station commander Chris Hadfield became a fan of NightPod and took over 200 pictures using the system.

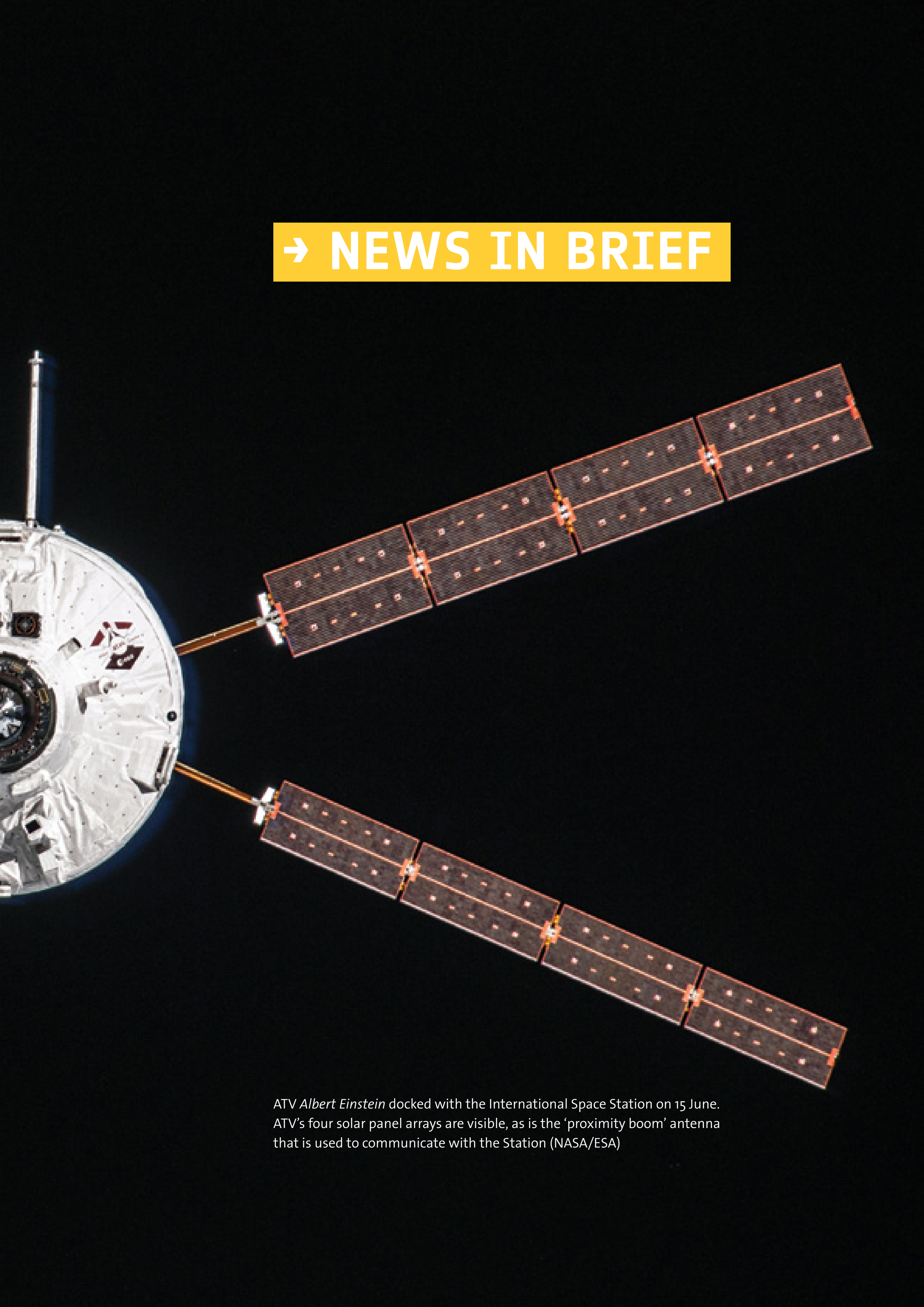
NightPod has made night-time photography easier and all astronauts visiting the Space Station are trained to use it. Now the results are left to the ingenuity and creativity of the astronauts and scientists.

← **Tokyo lights and San Francisco Bay.** The vast metropolises of Tokyo, Japan, and San Francisco in USA are interrupted by the blackness of the bays they surround. Note the difference in street lighting used by the two cities. The bluish hue of Tokyo is characteristic of Asian cities, whereas western cities are generally illuminated by yellow/orange-coloured lighting (NASA/ESA)

→ **Dark and light.** The darkness of the water at the Port Phillip Bay is in contrast with the streetlights of Melbourne city in Australia (NASA/ESA)


esa

→ NEWS IN BRIEF



ATV *Albert Einstein* docked with the International Space Station on 15 June. ATV's four solar panel arrays are visible, as is the 'proximity boom' antenna that is used to communicate with the Station (NASA/ESA)

↑ ESA astronaut Timothy Peake

Timothy Peake set for ISS

ESA astronaut Timothy Peake (UK) will fly to the International Space Station in 2015. He will be the first British citizen to live and work on the Space Station and it will be the eighth long-duration mission for an ESA astronaut.

Tim was born in Chichester, UK, in 1972. He completed a degree in flight dynamics and qualified as an experimental test pilot at the UK's Empire Test Pilots School. A former helicopter test pilot and Major in the British Army, Tim will join the crew of Expedition 46/47 for six months.

Tim is thrilled with his assignment: "I am delighted to be proposed for a long-duration mission to the International Space Station. This is another important mission for Europe and in particular a wonderful opportunity for European science, industry and education to benefit from microgravity research."

The two remaining astronauts of the 2009 group, Andreas Mogensen and Thomas Pesquet, will be assigned before mid-2015 for flights at the latest in 2017.

Luca Parmitano in orbit

A Soyuz spacecraft launched from Baikonur Cosmodrome in Kazakhstan on 28 May, delivering ESA astronaut Luca Parmitano (IT) and his crewmates to the International Space Station where they will live and work for five months.

Luca is flying on board the Space Station for the Italian Space Agency (ASI) under a bilateral agreement between ASI and NASA.

With Luca were Russian Soyuz commander Fyodor Yurchikhin and NASA astronaut Karen Nyberg. All three will be part of the Station's Expedition 36/37. Luca's own mission is named 'Volare' – 'to fly' in Italian – to symbolise the search for new frontiers and opportunities for discovery.

This is only the second flight to arrive in such a short time, eight times faster than the previous two-day procedure. Luca is the first European flight engineer to co-pilot the Soyuz spacecraft on this fast-track approach.

← Expedition 36 Flight Engineer Luca Parmitano meets fellow Flight Engineer, NASA astronaut Chris Cassidy, on arrival at the Space Station on 29 May (NASA/ESA)

↗ The Skylon spaceplane, which could be powered by a European-designed SABRE air-breathing rocket engine (Reaction Engines Ltd)

ESA test opens way to UK spaceplane engine investment

The UK government has announced plans to invest in the development of an air-breathing rocket engine – intended for a single-stage-to-orbit spaceplane – following the ESA-managed feasibility testing of essential technology.

The £60 million investment, provided through the UK Space Agency, will back technical improvements leading to construction of a prototype Synergistic Air-Breathing Rocket Engine, or SABRE.

Designed by UK company Reaction Engines Ltd, this unique engine will use atmospheric air in the early part of the flight before switching to rocket mode for the final ascent to orbit. The concept paves the way for true spaceplanes – lighter, reusable and able to fly from conventional runways.

Reaction Engines plans for SABRE to power a 84 m-long pilotless vehicle called Skylon, which would do the same job as today's rockets while operating like an aeroplane, potentially revolutionising access to space.

The investment decision followed the success of ESA-managed tests of a key element of the SABRE design, a precooler to chill the hot air entering the engine at hypersonic speed, in Reaction Engines' Oxfordshire headquarters back in November 2012. The idea has been around since the 1950s but this is the first time a working system has been achieved, giving Europe a real technological lead.

Last year's tests stemmed from a research project funded by ESA and Reaction Engines to examine key technologies. The project spanned the ESA's Basic Technology Research Programme, which supports promising new ideas, and the follow-on General Support Technology Programme for maturing the resulting technologies.

The next four years will see progress made on the SABRE's technical design, including improvements to the lightweight heat exchanger and manufacturing. The significant part of the programme – supported by further commercial investment – will be the construction and ground testing of a complete prototype SABRE engine.

ESA will continue its current technical consultancy role on behalf of the UK Space Agency, advising on the feasibility of Reaction Engines' technology, designs and future plans. ESA first made contact with Reaction Engines while working on the European Commission-funded LAPCAT project, looking into a derivative SABRE engine design called Scimitar to propel an aircraft halfway around the world in 4.6 hours.

"Einstein-a-go-go"

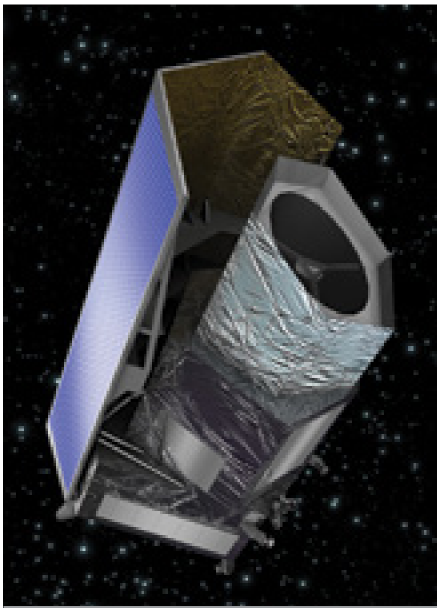
ESA's fourth Automated Transfer Vehicle, *Albert Einstein*, was launched on 5 June from Europe's Spaceport in Kourou, French Guiana. Europe's supply spacecraft performed a series of manoeuvres to dock with the International Space Station on 15 June.

The rendezvous and docking were performed autonomously by ATV's own computers, closely monitored by flight controllers from ESA and France's CNES space agency at the ATV Control Centre in Toulouse, France, and by ESA astronaut Luca Parmitano and his crewmates on the Station.

The 20-tonne ferry, the heaviest spacecraft ever launched by Europe, was loaded with 2580 kg of propellant to perform regular reboosts of the Station's orbit. It also carried 860 kg of propellant, 100 kg of oxygen and air, and 570 kg of drinking water, all to be pumped into the Station's tanks. In its pressurised cargo module, it carried more than 1400 items packed into 141 bags, including 2480 kg of dry cargo such as scientific equipment, spare parts, food and clothes for the astronauts.

At the end of its mission, scheduled for 28 October, ATV-4 will separate from the Station, packed with waste bags. It will be directed to burn up safely in the atmosphere during reentry over the South Pacific Ocean.

↑ View of ATV *Albert Einstein* as it approach the ISS on 15 June (NASA/ESA)



↑ Euclid

Thales Alenia begins Euclid construction

The construction of ESA's Euclid mission to explore the 'dark Universe' will be led by Thales Alenia Space Italy as prime contractor, beginning the full industrial phase of the project, it was announced in July.

In June, Astrium Toulouse was confirmed to build the payload module – the telescope and optical bench carrying the science instruments. The Euclid Consortium will provide the mission's two state-of-the art scientific instruments: a visible-light camera and a near-infrared camera/spectrometer. Together, these instruments will map the 3D distribution of up to two billion galaxies spread over more than a third of the whole sky.

The Euclid Consortium comprises nearly 1000 scientists from 100 institutes in 13 European countries: Austria, Denmark, France, Finland, Germany, Italy, Netherlands, Norway, Spain, Switzerland, Portugal, Romania and the UK. It also includes a US NASA team of scientists.

Euclid will be launched in 2020 to explore the roles played by dark energy and dark matter in the evolution of the Universe since the Big Bang and, in particular, in its present accelerating expansion.

Safe splashdown for experimental reentry vehicle

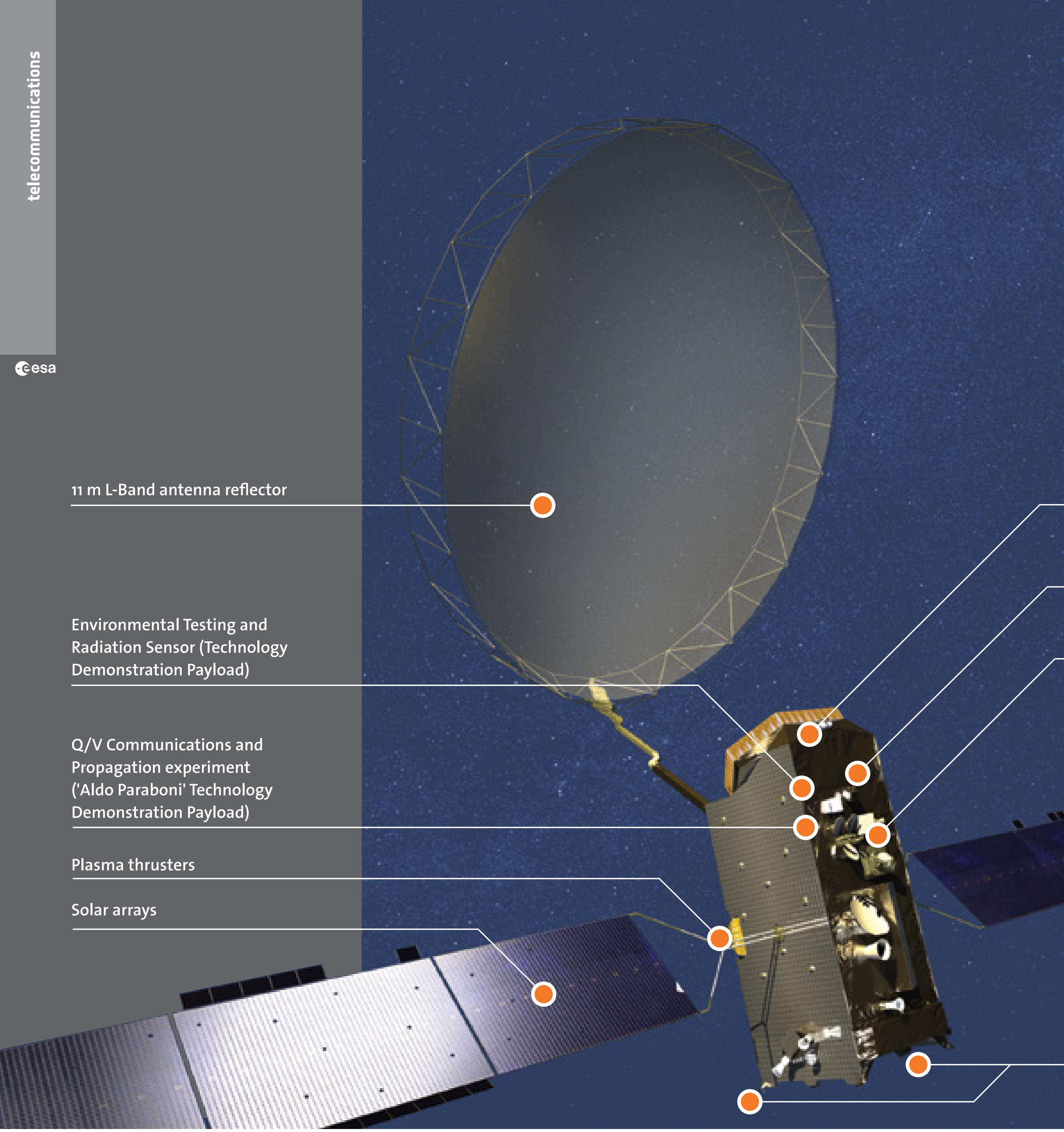
ESA's experimental reentry vehicle passed its milestone descent and landing test on 21 June at the Poligono Interforze Salto di Quirra range off the east coast of Sardinia in Italy.

The full-scale Intermediate eXperimental Vehicle (IXV) prototype was released from an altitude of 3000 m by a helicopter, falling to gain speed to mimic a space mission before parachute deployment. The parachute slowed IXV for a safe splashdown at a speed below 7 m/s.

This was the last step in a series of tests that shows IXV can be recovered safely after its mission into space. It will be launched next year on Vega, Europe's new small launcher, into a suborbital path. It will reenter the atmosphere as if from a low-orbit mission, testing new European reentry technologies during its hypersonic and supersonic flight phases.

The IXV project is developing and flight-testing the technologies and systems for Europe's future autonomous atmospheric reentry vehicles.

← IXV recovered from the sea by helicopter after safe splashdown



There are times when size really does matter, especially when it comes to satellite telecommunications. Larger and more complex satellites are required by a demanding market.

European citizens, along with telecom users all over the world, want to be able to connect to others at all times and at a reasonable cost – whether by video, voice or email – from any location, whether on a train, in a car, on a boat, or on top of a mountain. They want to receive more high-definition television channels or radio stations, and soon they will want to watch their favourite sporting events in 3D.

This demand requires more power, capacity and size from our telecommunication satellites.

Launched on 25 July, Alphasat is the largest European telecom satellite ever built. As the biggest public–private space project ever made in Europe, Alphasat was primarily designed to expand

→ ALPHASAT LAUNCH SPECIAL

ALPHASAT FACTS & FIGURES

Launch mass	6.6 tonnes (3.5 tonnes dry mass)
Solar array span	40 m
Electrical power	12 kW
Chemical propulsion	500 N apogee engine / 16 10 N bipropellant thrusters
Electric propulsion	4 Snecma PPS 1350 plasma thrusters
Payload	Inmarsat L-Band payload, Advanced LCT, Q/V-band experiments (2), Advanced startracker, Environment effects facility
Geostationary location	25° East
Launch vehicle	Ariane 5 VA214
Launch site	Europe's Spaceport, Kourou, French Guiana
Operational lifetime	15 years

telecommunications provider Inmarsat's existing global mobile network.

ESA partnered with Inmarsat for the commissioning of Alphasat, which was built by Astrium. Alphabus is a joint development by Astrium and Thales Alenia Space under ESA/CNES contract. Its new-generation advanced geomobile communications payload provides access to the extended L-band spectrum and enables deployment of a wide range of high data rate services for aeronautical, land and maritime users across Europe, Asia, Africa and the Middle East.

Alphasat is also the first flight opportunity for the Alphabus platform, a high-power platform that gives European industry a unique position in the world telecom market.

It also hosts four Technology Demonstration Payloads developed through ESA's Advanced Research in Telecommunications Systems (ARTES) programme.

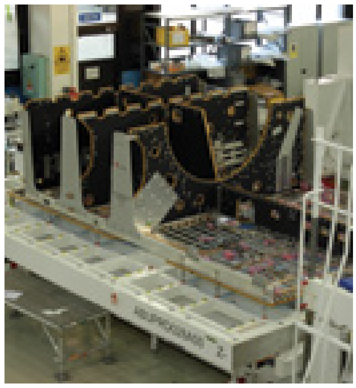
→ ALPHASAT'S ROAD TO ORBIT

2002	Start of ESA/CNES cooperation
2002–5	Early Alphabus system design and critical technology developments
May 2005	Alphabus Preliminary Design Review
Sep 2005	Alphabus platform Phase-C/D starts
Jan 2006	Alphabus Hardware Design Review
Nov 2007	Start of Alphasat satellite programme
2008	Alphasat Critical Design Review
Feb 2008	Alphabus Qualification Review

KEY MILESTONES

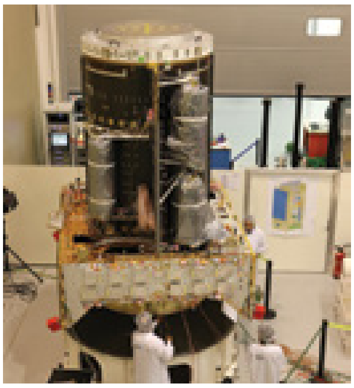
2009

Construction of Alphasat begins. Service Module Central Tube Protoflight Model at CASA, Spain



August

Repeater Module construction at Thales Alenia Space Italy

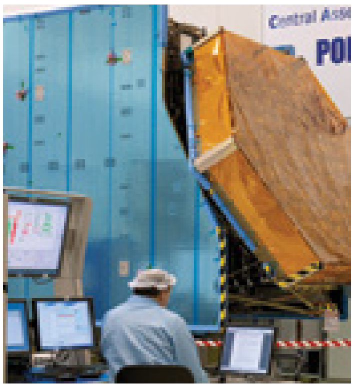


June

'Shogun' shock test of Service Module, at Intespace, Toulouse

December

Service Module assembly complete

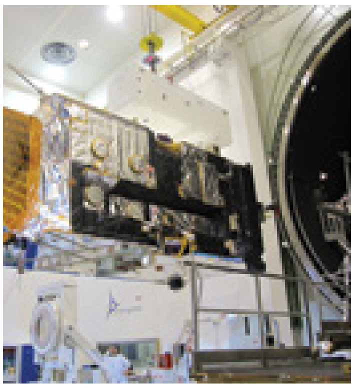


February 2011

Repeater Module antenna feed integration at Astrium UK

March

Service Module and Repeater Module mating at Astrium Toulouse

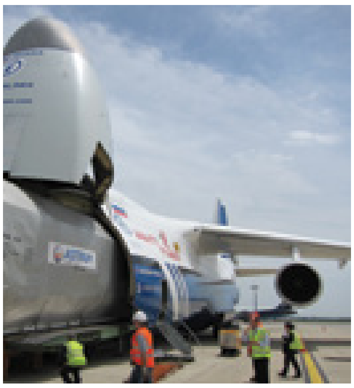


January 2013

Thermal vacuum test, Toulouse

May

Final System Functional Test campaign, including testing the Inmarsat payload, the four ESA Technology Demonstration Payloads and the platform



June

Prepared for shipment to Kourou

5 July

Alphasat fuelling operations complete

> Alphasat is the successful combination of different partnerships, opening doors to many more in the near future.

> Alphasat is an excellent example of how ESA is boosting Europe's competitiveness and growth.

October

Chemical propulsion system and fuel tanks integrated on Service Module

December

Mechanical integration of Service Module completed at Thales Alenia Space Cannes

January 2010

Service Module shipped from Thales Alenia Space Cannes to Astrium Toulouse

February

Service Module powered up for the first time

June

First integration of solar array, prior to mechanical testing. Mechanical test campaign begins

August

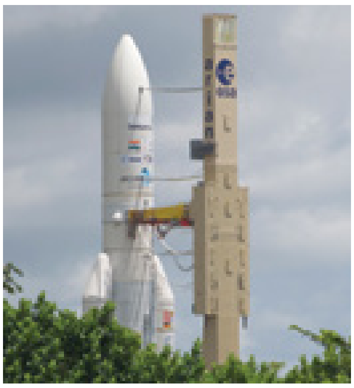
Mechanical test campaign complete

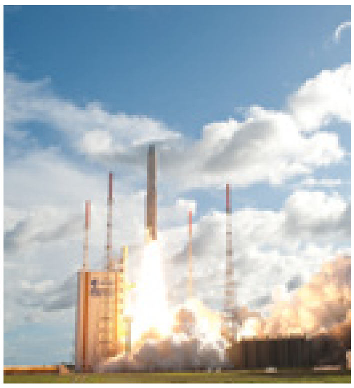
May 2012

Payload testing, Toulouse

August

Electromagnetic Compatibility testing complete. All Technology Demonstration Payloads integrated on spacecraft





15 July

Alphasat satellite encapsulated in the Ariane 5 fairing

17 July

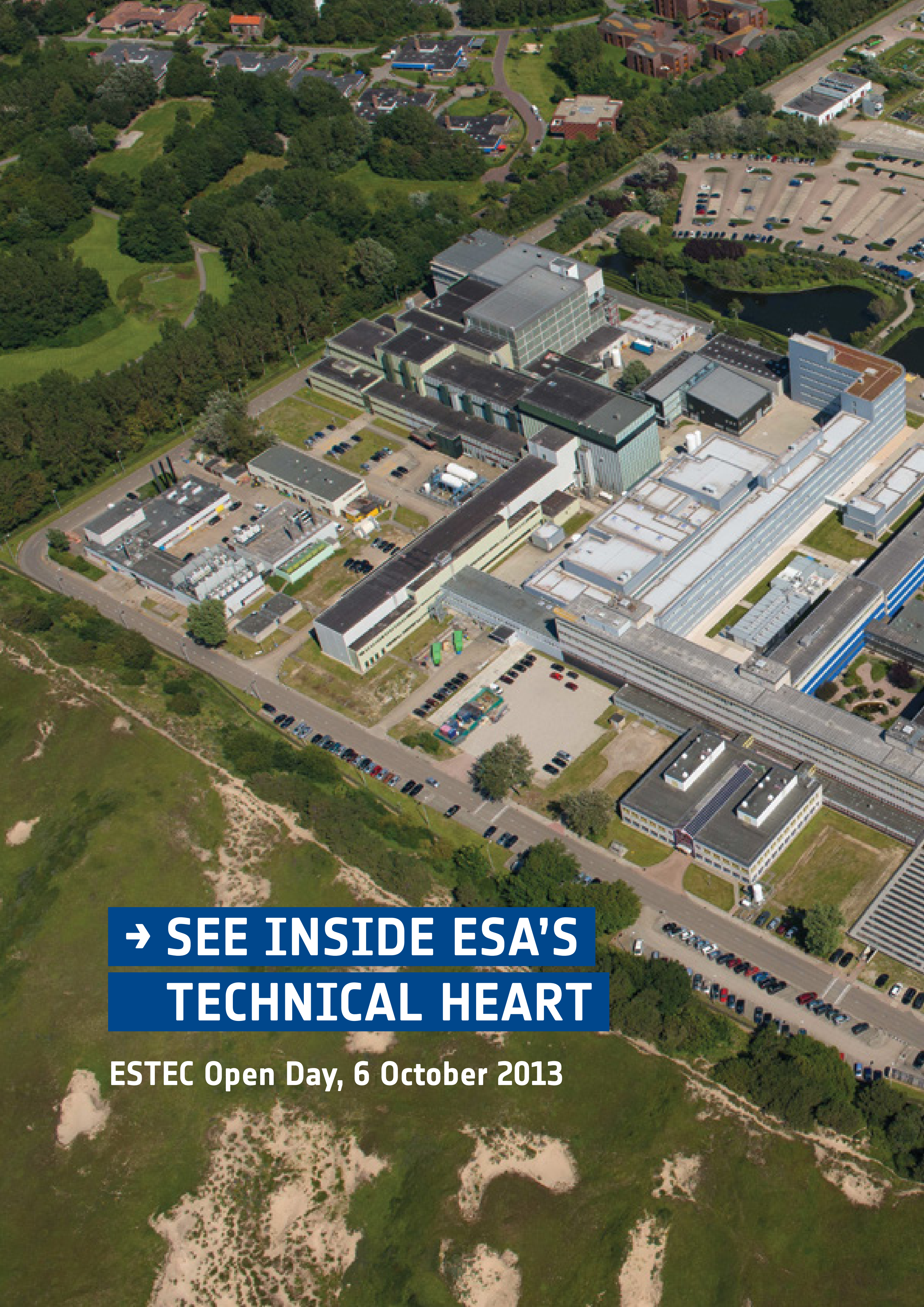
Fairing containing Alphasat is fitted on top of the co-passenger satellite (Insat-3D)

24 July

Rollout of the launcher to the launch site at Kourou, French Guiana

25 July 2013

Launch!



→ SEE INSIDE ESA'S TECHNICAL HEART

ESTEC Open Day, 6 October 2013

ESTEC from the air

At ESA's ESTEC Open Day, we hope to inspire all ages

From the latest ATV space ferry to the very first Alphasat, Europe has never been more active in space. But where were all these space missions born? See for yourself on 6 October, as ESA's ESTEC space research and technology centre opens its doors to the public.

No sooner had Luca Parmitano arrived at the International Space Station than ESA's latest space truck was resupplying the orbital outpost. In June, Proba-V was returning its first maps of global vegetation, while the high-power Alphasat telecoms satellite was being prepared for launch in July. The Gaia satellite will soon begin charting a billion stars in 3D in our galaxy, while the next batch of Galileo navigation satellites will also fly this year.

All very different space missions with diverse goals, but their origins can all be traced back to a single location: the European Space Technology and Research Centre, ESTEC – ESA's largest establishment, nestling beside the sand dunes of Noordwijk in the Netherlands.

In place for half a century, ESTEC is the incubator of the European space effort, where most ESA projects are born and where they are guided through development. Involvement may start with initial mission planning, research projects or laboratory support, extending to the testing of entire spacecraft in the ESTEC Test Centre, the largest facility of its kind in Europe. And ESTEC's Erasmus Centre is one of the leading European repositories of human spaceflight expertise.

Our Space Expo visitor centre is open year-round but, on 6 October this year, for one day only from 10:00 to 17:00, the entire ESTEC establishment is being opened to the public – you can register to visit at http://www.esa.int/estecopenday2013

This will be your chance to meet ESA astronauts, talk to space scientists and engineers, and view laboratories and test facilities equipment that simulate every aspect of the space environment.

You'll be able to see satellites being tested for flight and touch hardware that has already flown in space.

ESA astronaut André Kuipers meets the public at Open Day 2012

At Space Expo, check out a piece of real moon rock returned by Apollo 17

→ 8 ESTEC FACTS

- Planning of the ESTEC site began in Delft on 1 January 1963.

- When ESTEC construction began in 1965, foundations had to be sunk 25 m down to ensure sufficient stability for precision engineering tests. Even so, modern instruments used in ESTEC laboratories are so sensitive that the tides of the nearby North Sea can be detected.

- ESTEC's Large Diameter Centrifuge can spin objects continuously for up to six months at a time, subjecting them to up to 20 times Earth gravity, eight times higher than Jupiter's gravity field.

- Entire spacecraft will fit inside the ESTEC's Large Space Simulator, a vacuum chamber big enough for a double-decker bus. It is used for 'thermal vacuum' testing of the very largest spacecraft.

- For the ESA/JAXA BepiColombo spacecraft, 12 giant xenon lamps were used to recreate the sunlight encountered around Mercury – 11 times more intense than Earth's and producing temperatures over 450°C.

- The largest shaker in Europe is ESTEC's Multi-Axis Shaker, called Hydra. It recreates the force of a major earthquake to simulate rocket launch conditions.

- ESTEC's Large European Acoustic Facility is the largest sound system in Europe, producing noise of up to 154 decibels, which is like standing near a jet aircraft taking off. This noise is contained by 50 cm-thick steel-reinforced epoxy-coated concrete walls.

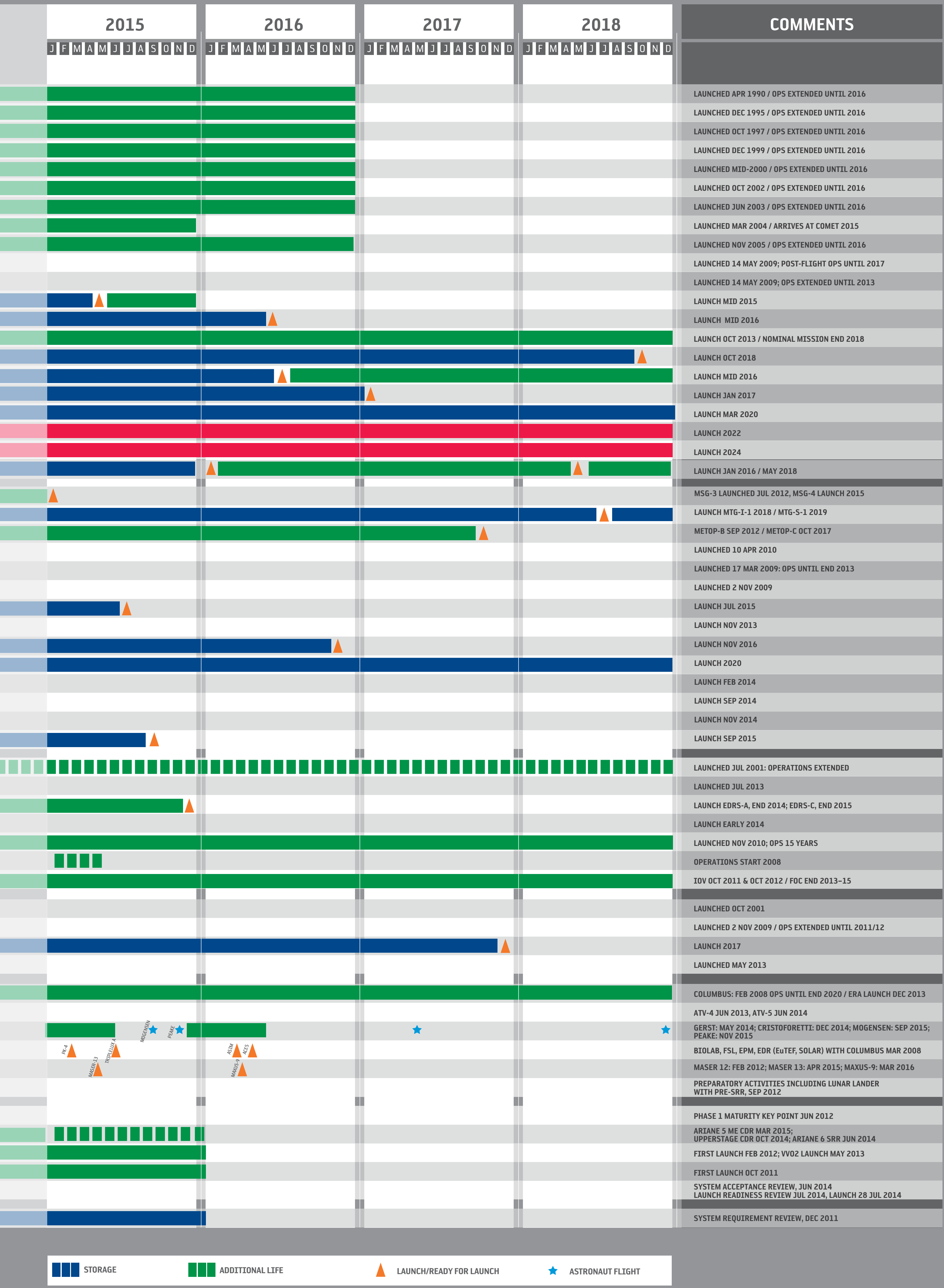
- Over 80 000 visitors come annually to ESTEC's visitor centre, Space Expo. Attractions include all kinds of European space relics – such as Andre Kuipers' spacesuit and an authentic Foton capsule still showing the scorch marks from reentry. There's a life-size Apollo Lunar Module on a mock-up lunar surface and an actual Ariane 4 first-stage engine that performs regular 'lift offs'. Experience spaceflight in a Soyuz simulator and see a piece of iron meteorite and moonrock for yourself!

→ PROGRAMMES IN PROGRESS

Status at end of July 2013

Luca Parmitano and NASA astronaut Chris Cassidy (right) exit the Quest airlock on the International Space Station for their first six-hour spacewalk on 9 July (NASA/ESA)

2011
2012
2013
2014
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
SOHO
CASSINI-HUYGENS
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
ROSETTA
VENUS EXPRESS
HERSCHEL
PLANCK
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
SOLAR ORBITER (M1)
EUCLID (M2)
JUICE (L1)
COSMIC VISION M3
EXOMARS
EARTH OBSERVATION PROGRAMME
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
AEOLUS
SWARM
EARTHCARE
BIOMASS
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
TELECOMMS/NAVIGATION PROGRAMMES
ARTEMIS
ALPHASAT
EDRS
SMALLGEO
HYLAS
GNSS-1/EGNOS
GALILEO
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS / NODE-2 / NODE-3 / CUPOLA / ERA
ATV
ASTRONAUT FLIGHTS
ELIPS ISS UTILISATION
ELIPS NON-ISS PAYLOADS
TRANSPORTATION & HUMAN EXPLORATION
VITTORI
KUIPERS
PARMITANO
GERST
CRISTOFORETTI
FASES
FASTER
EML
TRIPLELUX B
CYTOSKEL
MASER-12
LAUNCHER PROGRAMME
ARIANE 5 POST-ECA
ARIANE 5 ME & ARIANE 6
VEGA
SOYUZ AT CSG
IXV
SSA
PREPARATORY PROGRAMME
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2015
2016
2017
2018
J F M A M J J A S O N D
COMMENTS
LAUNCHED APR 1990 / OPS EXTENDED UNTIL 2016
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2016
LAUNCHED OCT 1997 / OPS EXTENDED UNTIL 2016
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2016
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2016
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2016
LAUNCHED JUN 2003 / OPS EXTENDED UNTIL 2016
LAUNCHED MAR 2004 / ARRIVES AT COMET 2015
LAUNCHED NOV 2005 / OPS EXTENDED UNTIL 2016
LAUNCHED 14 MAY 2009; POST-FLIGHT OPS UNTIL 2017
LAUNCHED 14 MAY 2009; OPS EXTENDED UNTIL 2013
LAUNCH MID 2015
LAUNCH MID 2016
LAUNCH OCT 2013 / NOMINAL MISSION END 2018
LAUNCH OCT 2018
LAUNCH MID 2016
LAUNCH JAN 2017
LAUNCH MAR 2020
LAUNCH 2022
LAUNCH 2024
LAUNCH JAN 2016 / MAY 2018
MSG-3 LAUNCHED JUL 2012, MSG-4 LAUNCH 2015
LAUNCH MTG-I-1 2018 / MTG-S-1 2019
METOP-B SEP 2012 / METOP-C OCT 2017
LAUNCHED 10 APR 2010
LAUNCHED 17 MAR 2009: OPS UNTIL END 2013
LAUNCHED 2 NOV 2009
LAUNCH JUL 2015
LAUNCH NOV 2013
LAUNCH NOV 2016
LAUNCH 2020
LAUNCH FEB 2014
LAUNCH SEP 2014
LAUNCH NOV 2014
LAUNCH SEP 2015
LAUNCHED JUL 2001: OPERATIONS EXTENDED
LAUNCHED JUL 2013
LAUNCH EDRS-A, END 2014; EDRS-C, END 2015
LAUNCH EARLY 2014
LAUNCHED NOV 2010; OPS 15 YEARS
OPERATIONS START 2008
IOV OCT 2011 & OCT 2012 / FOC END 2013–15
LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH 2017
LAUNCHED MAY 2013
COLUMBUS: FEB 2008 OPS UNTIL END 2020 / ERA LAUNCH DEC 2013
ATV-4 JUN 2013, ATV-5 JUN 2014
MOGENSEN
PEAKE
GERST: MAY 2014; CRISTOFORETTI: DEC 2014; MOGENSEN: SEP 2015; PEAKE: NOV 2015
PK-4
TRIPLELUX A
ASIM
ACES
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MASER-13
MAXUS-9
MASER 12: FEB 2012; MASER 13: APR 2015; MAXUS-9: MAR 2016
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER WITH PRE-SRR, SEP 2012
PHASE 1 MATURITY KEY POINT JUN 2012
ARIANE 5 ME CDR MAR 2015; UPPERSTAGE CDR OCT 2014; ARIANE 6 SRR JUN 2014
FIRST LAUNCH FEB 2012; VV02 LAUNCH MAY 2013
FIRST LAUNCH OCT 2013
SYSTEM ACCEPTANCE REVIEW, JUN 2014
LAUNCH READINESS REVIEW JUL 2014, LAUNCH 28 JUL 2014
SYSTEM REQUIREMENT REVIEW, DEC 2011
STORAGE
ADDITIONAL LIFE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

KEY TO ACRONYMS

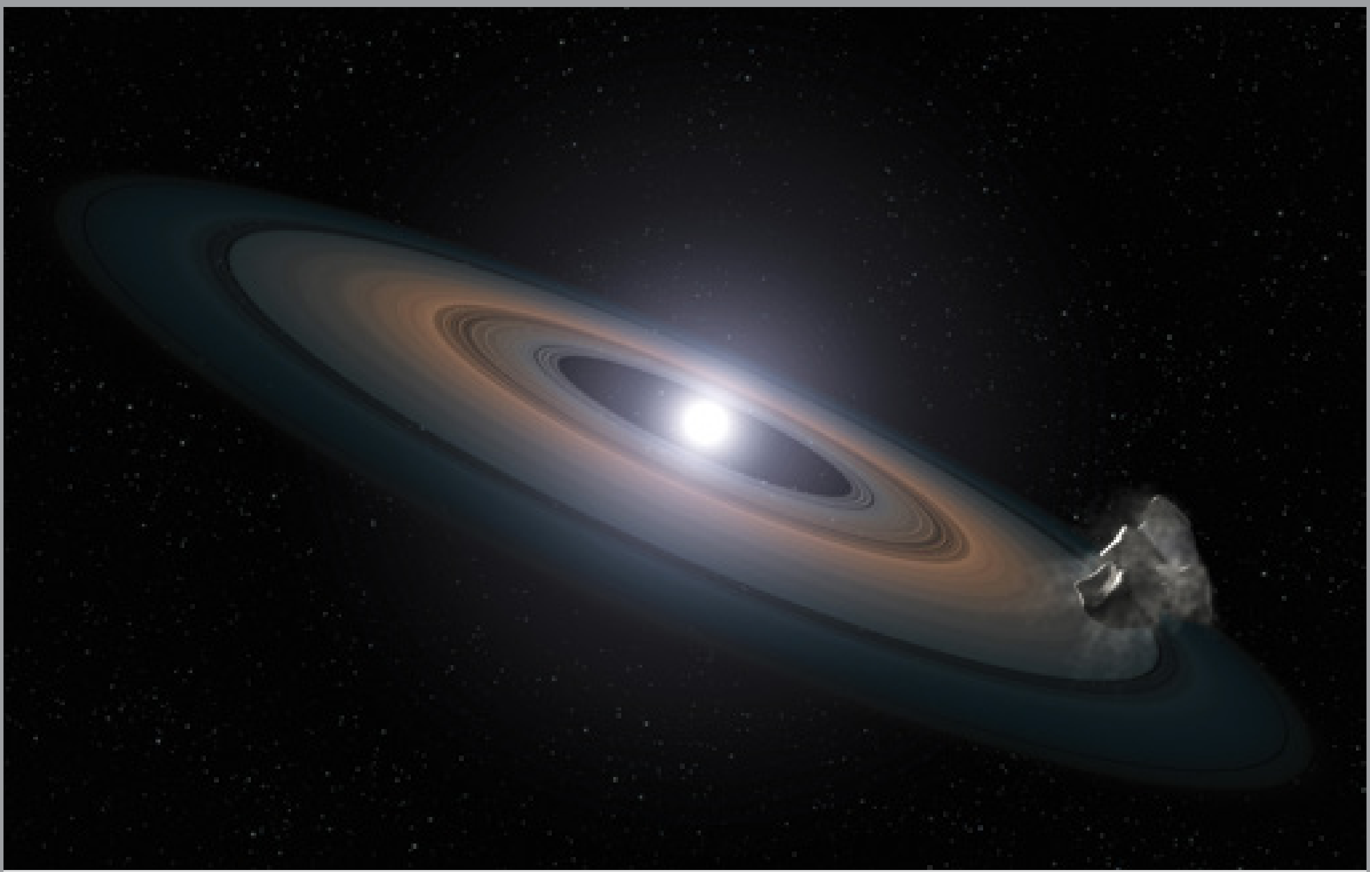
AM - Avionics Model	ITT - Invitation to Tender
AO - Announcement of Opportunity	LEOP-Launch and Early Orbit Phase
AIT - Assembly, integration and test	MoU- Memorandum of Understanding
AU - Astronomical Unit	PDR - Preliminary Design Review
CDR - Critical Design Review	PFM- Proto-flight Model
CSG - Centre Spatial Guyanais	PLM- Payload Module
EFM - Engineering Functional Model	PRR - Preliminary Requirement Review
ELM - Electrical Model	QM - Qualification Model
EM - Engineering Model	SM - Structural Model
EMC - Electromagnetic compatibility	SRR - System Requirement Review
EQM - Electrical Qualification Model	STM- Structural/Thermal Model
FAR - Flight Acceptance Review	SVM- Service Module
FM - Flight Model	TM - Thermal Model

→ HUBBLE SPACE TELESCOPE

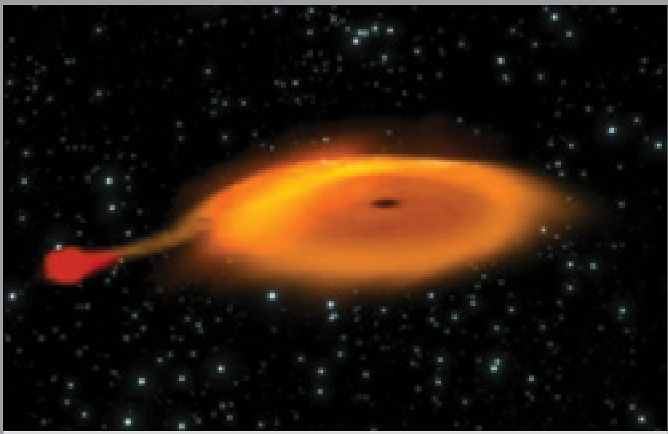
Hubble has found signs of Earth-like planets in the atmospheres of a pair of white dwarf stars in a nearby cluster. The stars are 150 light-years away in the Hyades cluster, in the constellation of Taurus. Searches for planets in these clusters have not been fruitful – of the roughly 800 known exoplanets, only four are known to orbit stars in clusters. This scarcity may be because of the nature of the cluster stars, which are young and active, producing stellar flares and other outbursts that make them difficult to study in detail.

A new study instead observed evolved cluster stars to hunt for signs of planet formation. Hubble's spectroscopic observations identified silicon in the atmospheres of two white dwarfs, a major ingredient of the rocky material that Earth and other terrestrial planets in the Solar System are made of. This silicon may have come from asteroids that were shredded by the white dwarfs' gravity when they veered too close to the stars. The rocky debris likely formed a ring around the dead stars, which then funnelled the material inwards. The debris detected whirling around the white dwarfs suggests that terrestrial planets formed when these stars were born. After the stars collapsed to form white dwarfs, surviving gas giant planets may have gravitationally nudged members of any leftover asteroid belts into star-grazing orbits.

Besides finding silicon in the Hyades stars' atmospheres, Hubble also detected low levels of carbon. This is another sign of the rocky nature of the debris, since astronomers know that carbon levels should be very low in rocky, Earth-like material. Based on the silicon-to-carbon ratio in the study, astronomers concluded that this material is basically Earth-like. This discovery suggests that rocky planet assembly is common in clusters.



Debris around white dwarf star (NASA/ESA/STScI)



MAXI J1659-152 is a rapidly spinning binary system comprising a black hole and a red dwarf companion

→ XMM-NEWTON

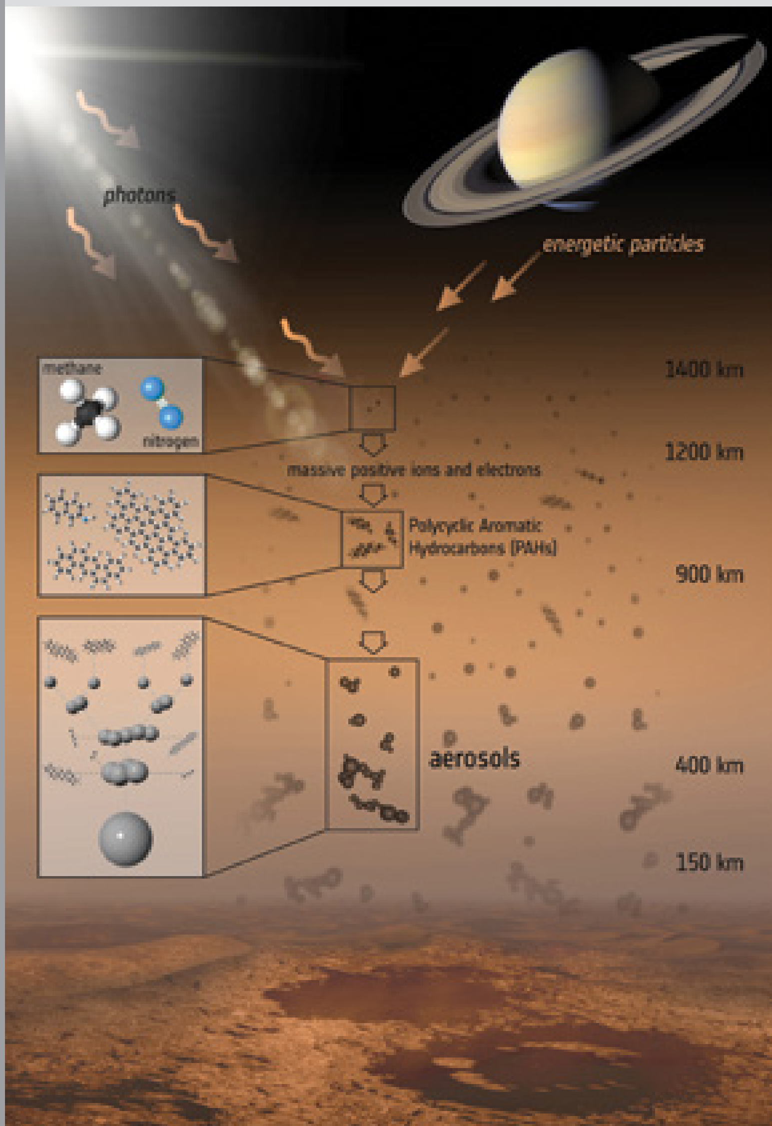
Operations have been extended to the end of December 2016, subject to a mid-term review in late 2014. Caging of the reaction wheels remains an area of concern. Several mitigation measures are being investigated, one of these being the use of a four-reaction wheel control mechanism. Its implementation in 2013 will also be an important tool to achieve further reduction of fuel usage.

XMM-Newton has helped to identify a star and a black hole that orbit each other at the dizzying rate of once every 2.4 hours. The black hole in this compact pairing, known as MAXI J1659-152, is at least three times more massive than the Sun, while its red dwarf companion star has a mass only 20% that of the Sun. The duo are separated by roughly a million kilometres, similar to the distance between Earth and the Moon, and were discovered in 2010 by NASA's Swift space telescope. Further observations from ground and space telescopes, including XMM-Newton, revealed that the X-rays come from a black hole feeding off material ripped from a tiny companion. Several regularly spaced dips in the X-ray intensity were seen in an uninterrupted 14.5-hour observation with XMM-Newton. These dips are almost certainly caused by the irregular rim of the black hole's accretion disc briefly obscuring the X-rays as the system rotates. From these dips, an orbital period of just 2.4 hours was measured, setting a new record for black hole X-ray binary systems, beating the previous record by nearly an hour.

→ CASSINI-HUYGENS

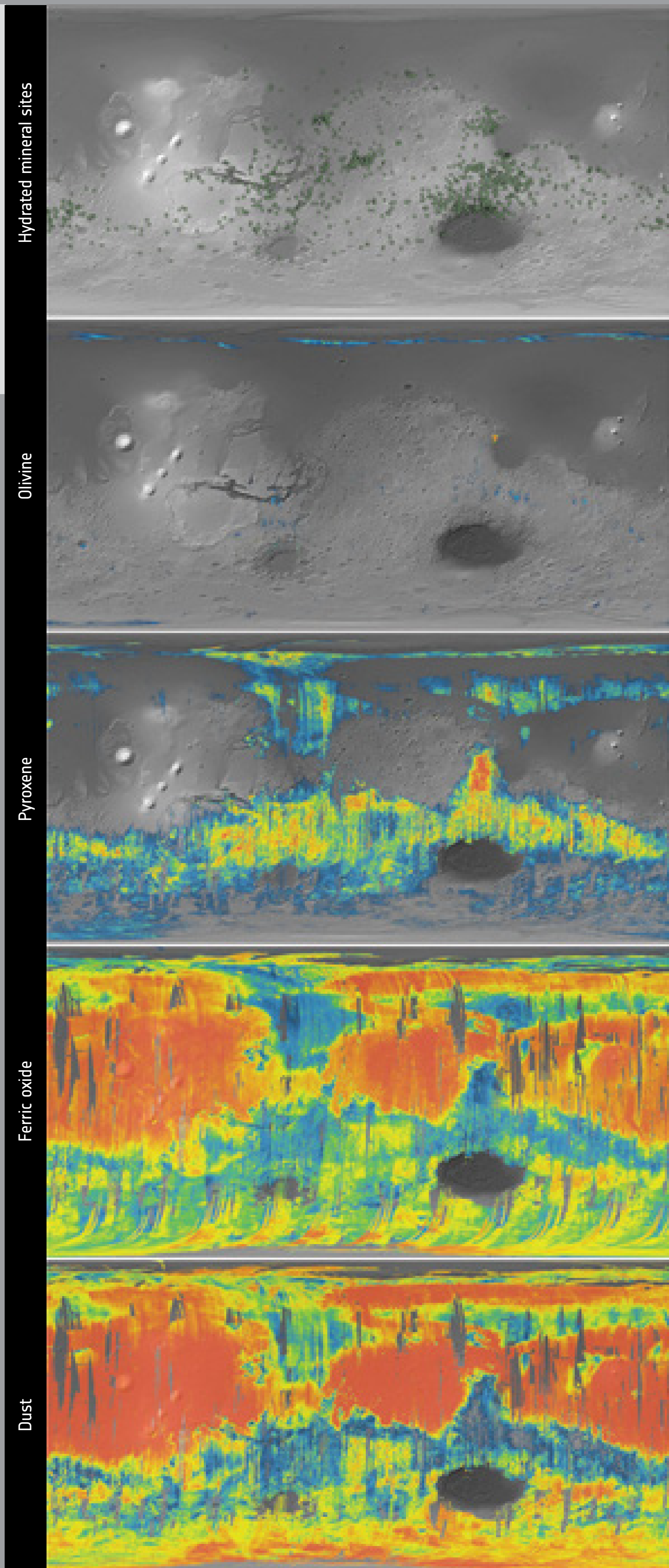
Scientists working on VIRTIS data (near-infrared and visible wavelengths) found the signature of infrared emission of complex polycyclic aromatic hydrocarbons (PAHs) in Titan's atmosphere for the first time. A wide range of hydrocarbon molecules is known to be produced in the atmosphere, starting from the photo-dissociation of nitrogen and methane. The production of heavier carbon molecules with decreasing altitude ultimately led to the formation of aerosols (forming the typical haze layer at lower altitude) that 'snow' down and cover the surface of Titan. However, the direct link between PAH and aerosols remained theoretical so far. This new analysis of VIRTIS data demonstrates that these complex organic molecules are precursors in the formation of aerosols.

The atmosphere of Titan



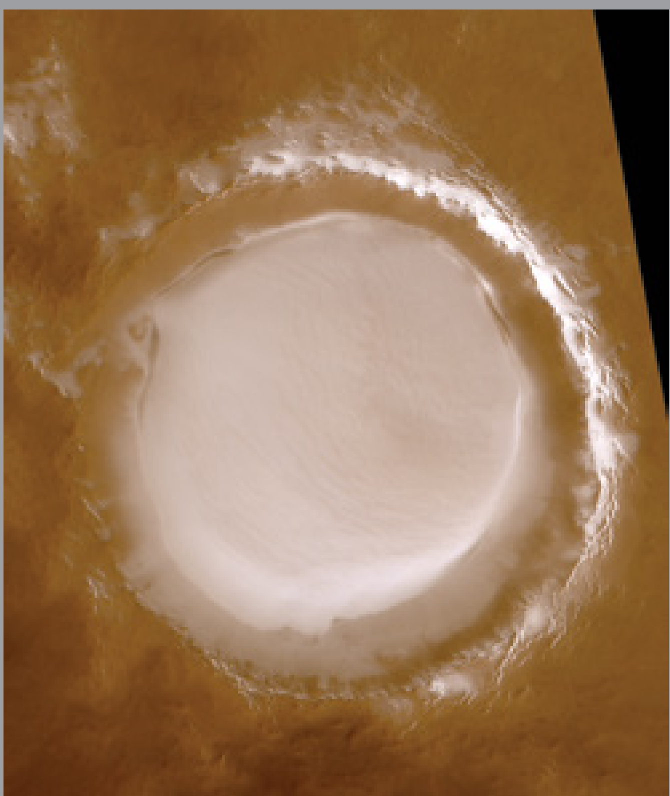
→ MARS EXPRESS

Spacecraft and payload are in excellent health. After leaving solar conjunction on 2 May, Mars Express resumed normal operations. The tenth anniversary of the launch was celebrated in ESA establishments. At a media briefing in ESOC, global mineralogical maps derived from the OMEGA



Maps from the OMEGA instrument on Mars Express show near-global coverage of key minerals that help plot the history of Mars. The hydrated minerals map shows individual sites where minerals that form only in the presence of water were detected. The olivine and pyroxene maps tell the story of volcanism and the evolution of the planet's interior. Ferric oxides are present everywhere on the planet: within the bulk crust, lava outflows and the dust oxidised by chemical reactions with the martian atmosphere, causing the surface to 'rust' slowly over billions of years, giving Mars its distinctive red hue (ESA/CNES/CNRS/IAS/Univ. Paris-Sud, Orsay/NASA/JPL/MOLA)

instrument were released. These maps, an important legacy of the mission, trace the history of water and volcanic activity on Mars, and identifies sites of special interest for the next generation of lander missions, in particular for the ExoMars rover mission.



A Mars Express image of Korolev crater. At 80 km in diameter, the crater contains a smooth-surfaced, roughly circular fill deposit predominantly of frozen water, 1.5–1.8 km thick. The top of the deposit is about the same altitude of the plains surrounding the crater. It is believed that this ice feature was built up by atmospheric deposition triggered by microclimate effects inside the crater (ESA/DLR/FU Berlin/G. Neukum/F. Jansen)

→ ROSETTA

Preparations are continuing for the spacecraft wake up on 10 January 2014. At that time the spacecraft will 5.39 AU from Earth and a distance of 4.49 AU from the Sun. Science and mission operations preparation for the rendezvous, landing and escort phase continue, including support from ground-based observatories.

→ VENUS EXPRESS

Records of cloud motion in the atmosphere of Venus as captured by the VMC camera have revealed that the planet's winds have become faster over the last six years. While the strong 'super-rotation' of the atmosphere has been known for some time, these findings showing a continuously increasing windspeed during the duration of the mission, which is very surprising.

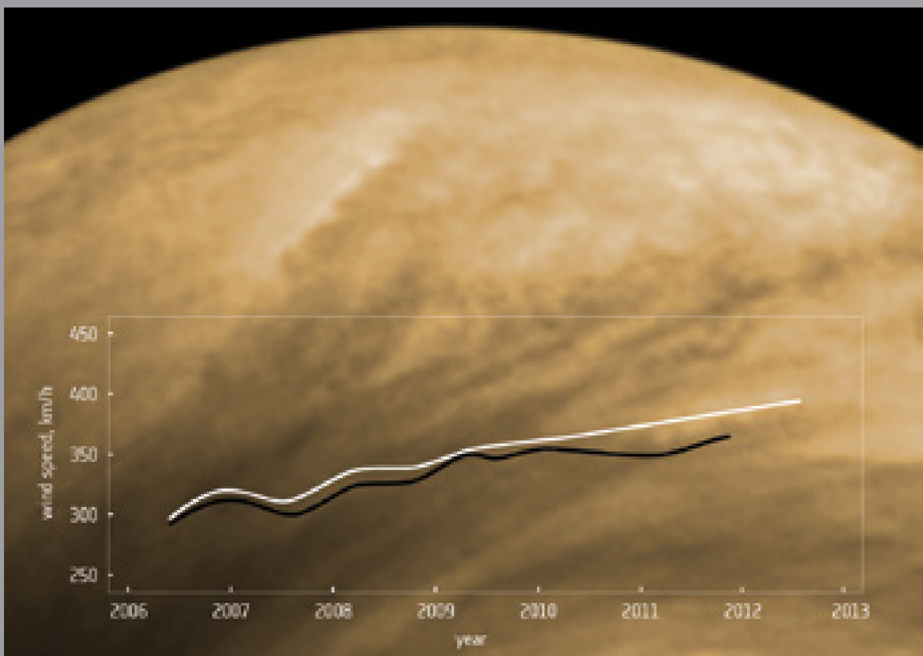
The cloud cover of Venus is opaque and structureless at visible wavelengths but in ultraviolet light there is sufficient contrast to enable tracking of cloud features in the cloud-tops, some 70 km above the planet's surface, and so measure the winds. Such features have been tracked since the beginning of the orbital phase of Venus Express over a period of ten Venusian years (six Earth years). Over 45 000 features have been tracked by hand and more than 350 000 more features were tracked automatically using a computerised method. This has enabled characterisation of patterns in the long-term global wind speeds.

When Venus Express arrived at the planet in 2006, average cloud-top wind speeds between latitudes of 50 degrees on either side of the equator averaged roughly 300 km/h. The results of two separate studies have now revealed that these already remarkably rapid winds have increased to almost 400 km/h over the course of the mission. This is a very significant increase and such a large variation has never before been observed on Venus. The reason for this is not yet understood, but it might be because of the exchange of momentum between different layers in the atmosphere. It might also be caused by an exchange of momentum with the solid planet itself.

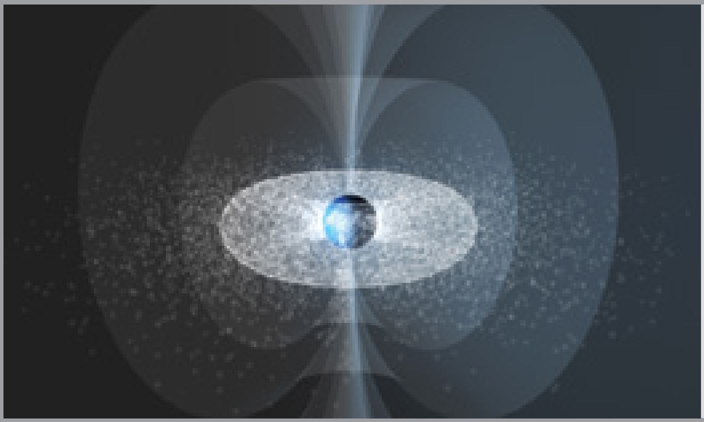
Indeed, other measurements by Venus Express have revealed that the rotational speed of the solid planet has become reduced during the last 20 years. In addition to this long-term increase in the average wind speed, regular variations linked to the local time of day and the altitude of the Sun above the horizon have also been found. A regular oscillation occurs roughly every 4.8 days near the equator. This is thought to be connected to atmospheric waves at lower altitudes.

→ CLUSTER

The environment that surrounds Earth, beyond the outermost layers of the atmosphere, is strongly shaped by the magnetic field of our planet. The interaction between Earth's magnetic field and the solar wind produces the complex topography of the magnetosphere. The innermost part of the magnetosphere is a doughnut-shaped region called the plasmasphere, which is centred around Earth's equator and rotates along with it. This plasmasphere, whose toroidal shape is forged by the magnetic field of Earth, exchanges mass and energy with the outer layers of the magnetosphere, and scientists have been studying the details of the interaction between these two regions.



Studies of the atmosphere of Venus show that average wind speeds at low latitudes have increased over the first six years of the Venus Express mission. The white line shows data derived from manual cloud tracking, and the black line is from digital tracking methods



The plasmasphere, the innermost part of our planet's magnetosphere, exchanges mass and energy with the outer layers of the magnetosphere. While earlier observations had only shown the plasmasphere sporadically supplying mass to the outer magnetosphere, Cluster has revealed another source of the supply. A steady wind continuously transfers material from the plasmasphere into the magnetosphere, releasing about 1 kg of plasma every second – almost 90 tonnes a day – into the outer magnetosphere (ESA/ATG Medialab)

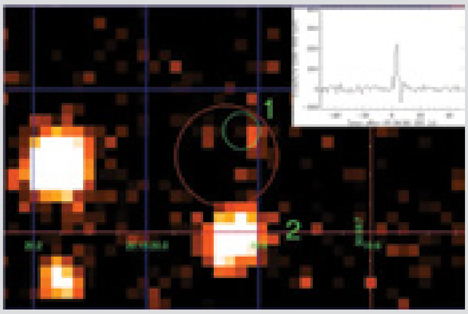
A recent paper reported for the first time the observation of a wind blowing continuously out of the plasmasphere. The outflow amounts to almost 90 tonnes a day. This was predicted by theory two decades ago but could only be observed with the unique capability of the Cluster ion instrument, which measures the ion distribution function down to a few electron volts. These results have implications for atmospheric loss and plasmaspheric wind that will now need to be taken into account in future models.

The spacecraft will reach their closest separation since launch, around 5 km in Autumn. Special instrument modes will be used to study electromagnetic waves in the radiation belts in collaboration with the NASA Van Allen probes. Science and operations planning continues in anticipation for the launch of ESA's Swarm mission. Cluster and Swarm will combine measurements to make unparalleled measurements of the complex coupling between the Earth's magnetosphere and inner magnetic field.

→ INTEGRAL

Operations have been extended to the end of December 2016. Integral observed high-energy emission from a gamma-ray burst, GRB 061122, that occurred in a distant galaxy on 22 November 2006. Thanks to the polarimetric capabilities of Integral's IBIS imaging telescope, the polarisation of the prompt emission of the gamma-ray burst could be determined. Using an eight-second time interval of IBIS data from 22 November 2006, the polarised fraction of the prompt emission was found to be greater than 60% (at a 68% confidence limit) in the 250–800 keV energy band. The GRB has been associated with a distant host galaxy. Multi-wavelength data have been obtained from follow-up observations of the GRB field, using the Canada-France-Hawaii Telescope and the Telescopio Nazionale Galileo.

The J filter image of GRB- 061122 taken with the Canada-France-Hawaii Telescope. The object labelled as '1' is the GRB host galaxy, and the two circles represent the best GRB error boxes derived from X-ray (green) and optical (red) observations of the GRB afterglow. IBIS data are inset (D. Götz et al)

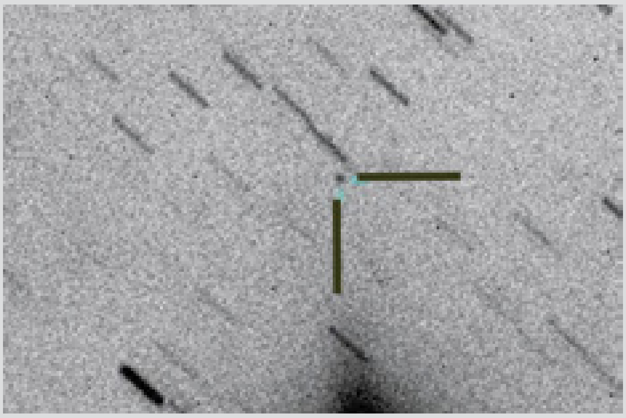


→ HERSCHEL

Herschel continued to make science observations until 29 April when its supply of superfluid liquid helium coolant was finally exhausted. This event makes further observing impossible, and marked the definitive end of operations as an astronomical observatory. Since the start of science observing in 2009, Herschel performed around 23 500 hours of science observations selected by the time allocation committee. This is almost 19% more than the 'nominal' amount foreseen before launch and, in addition, Herschel performed over 2000 hours of calibration observations that will also be useful for science.

Employing a series of three orbit-changing manœuvres (in March, May and June), the spacecraft has now been injected into a heliocentric orbit where it will remain indefinitely. After the final manoeuvre on 17 June, which emptied the thruster propellant tanks, the spacecraft was 'turned off' by manual commands from ESOC.

Although Herschel is no longer performing observations, it is important to keep in mind that the mission is far from over. The number of astronomers using Herschel data has never been larger than it is now, and is still growing. The number of scientific publications is on track to make this year the most productive so far. Herschel is now in the 'post-operations phase' with support continuing to be provided to



This fuzzy 'dot' is Herschel, seen on 27 June, using the 2 m Faulkes Telescope North in Hawaii. The stars are elongated because the apparent motion of the spacecraft relative to the stars was tracked during the exposure. These observations serve to refine our knowledge of the orbit of Herschel, and may help in the future to avoid mistaking Herschel for a possible asteroid or near-Earth object (N. Howes/E. Guido/Remanzacco Obs.)

the astronomical community, and the data, tools and archive are being continuously refined to make the data as valuable and productive as possible for many years to come. This is particularly important for Herschel, since there is no future far-infrared space observatory firmly planned.

→ PROBA-2

The spacecraft and instruments continue to provide an uninterrupted stream of data to the scientific as well as the space weather community. As time passes, more data products are added and made available, i.e. the Carrington Rotation movies are now produced regularly from the SWAP imager and available at http://proba2.sidc.be (a Carrington Rotation is the full rotation of the Sun that takes approximately 27 days). Mission management was transferred to the Space Situational Awareness Programme on 1 July.

→ GAIA

The environmental acceptance test campaign finished in April. The last functional tests were completed in June. The Flight Acceptance Review will be completed in July.

The development of the ground segments progressed with major system-level tests completed. The System Validation Test campaign with the spacecraft took 36 days and validated all flight operation procedures. The test of the software modules necessary to perform the scientific part of the in-orbit commissioning is on track. The Ground Segment Readiness Review was concluded in May.

The activities with Arianespace progressed nominally and they are now focused on the preparation for the launch campaign. The Final Mission Analysis Review with the launcher authorities was concluded in June. The originally planned launch in September is not possible any more due to priority being given by Arianespace to another customer. Launch is planned for 25 October. The spacecraft will be shipped to Kourou on 5 August.

Final touches made to the Gaia solar panels in the Toulouse clean room (Astrium SAS)

→ LISA PATHFINDER

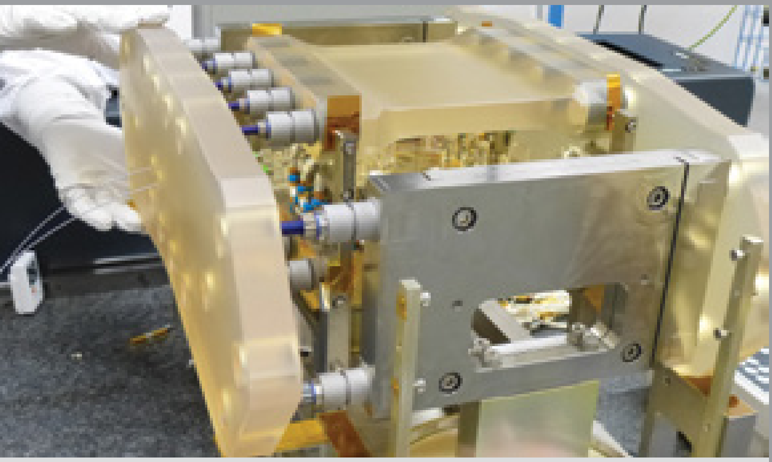
The Science Module was taken out of storage to fit panels kitted with the various components of the cold-gas micro-propulsion system. The Propulsion Module, unaffected by the change of micro-propulsion, remains in storage. The cold-gas micro-propulsion engineering and procurement activities proceed, with acceptance tests being performed on flight equipment for panels, tanks, valves and regulators. The micro-thrusters and drive electronics are under production by Selex ES (IT).

RUAG (CH) delivered the launch lock mechanism flight units in May. In the meantime, the QM of this mechanism was integrated in the inertial sensor head QM that under environmental testing.

The optical interferometry ultra-stable bench is being integrated onto its supporting frame within the LTP instrument. This frame is made of the same material as the bench and will provide the interface to the two inertial sensor heads, each carrying a free-floating test mass, and to the spacecraft structure.

ESAC performed a simulation of several key scientific experiments. These included measurements of tiny accelerations of the test masses when free-floating within the spacecraft. Simultaneously, a team of scientists based at the AstroParticle and Cosmology Laboratory in Paris, supported the simulation with near-real time data evaluation.

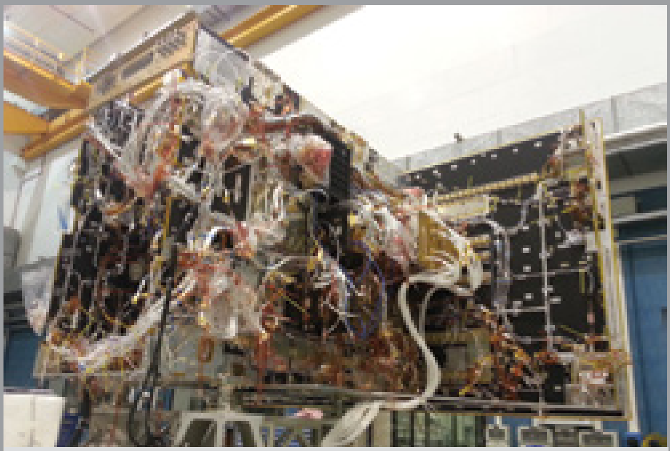
Launch will be on a Vega, the third VERTA flight, with Rockot as the back-up launcher.



An integration engineer works on the LISA Pathfinder interferometry bench in the clean room (Astrium GmbH)

→ BEPICOLOMBO

Harness integration on the Mercury Planetary Orbiter (MPO) was completed and electrical integration of the first units began. Thermal balance results on the Mercury Transfer Module (MTM) TM match overall well with predictions. The functional verification testing using the Engineering Test Bench is progressing. The MTM FM has completed its propulsion integration (proof pressure testing is next, with delivery to Turin in August). The solar cell technology was selected. Procurement of flight cells will be initiated as soon as initial qualification results allow.



BepiColombo Mercury Planetary Orbiter Protoflight Model integration

A first set of instrument FMs have completed acceptance testing and calibration. Instrument delivery and integration onto the MPO structure will take place during the second half of 2013. The scientific payload will be partially substituted by QMs during system-level thermal vacuum test because of late availability. These units will be exchanged for FMs before the mechanical stack testing.

The Japanese MMO FM was integrated at JAXA. Functional verification of the scientific payload at system level was completed. The environmental test campaign is scheduled for mid 2013.

Ground segment development is ongoing, with the second delivery of the Mission Control System and the Mission Planning System under final acceptance. The first delivery of the simulator was accepted. A series of compatibility tests with the Deep Space Transponder were completed.

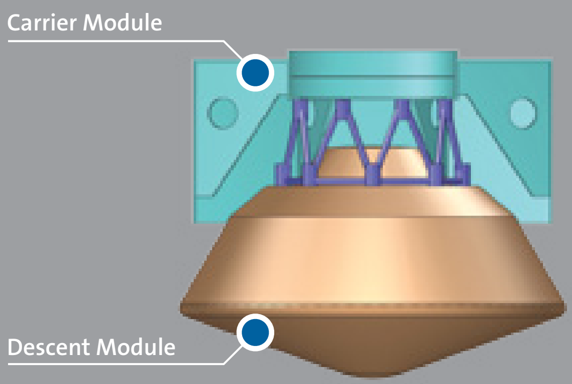
→ MICROSCOPE

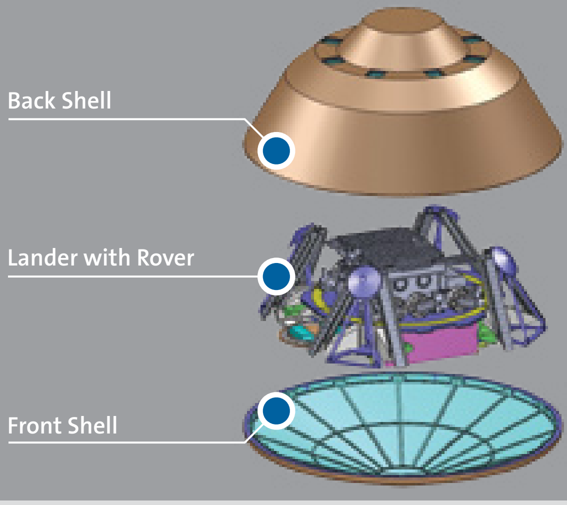
The ESA-provided cold-gas micro-propulsion system is being procured. The first hardware delivery will be the electronic controller EQM, planned in December.

→ EXOMARS

A Joint Management Plan for the combined project teams of ESA, Roscosmos, Lavochkin and Thales Alenia Space Italy was formally signed as well as a document describing the basic contributions of ESA and Roscosmos to the ExoMars cooperation. A special ad hoc working group of ESA and Roscosmos experts was formed to consolidate the working understanding of the respective agency technical standards to be applied in the cooperation.

Manufacturing is nearing completion for the 2016 Trace Gas Orbiter (TGO) Entry, descent and landing Demonstrator Module (EDM) flight hardware. Deliveries to the system integrators at Thales Alenia Space France for the TGO and in Italy for the EDM have started. The EDM SM tests were completed and the EDM SM is being prepared for Planetary Protection test procedures at Thales in Italy. For both modules, the Avionics Test Benches (ATB) are proceeding with software testing. Spacecraft interfaces for TGO instruments are being





Left, the ExoMars 2018 mission concepts for the spacecraft composite, and right, the Russian-provided Descent Module showing the ESA Rover

tested using a TGO spacecraft simulator to ensure that the delivered instruments will function normally once integrated with the spacecraft hardware.

A major ESA-level SRR for the 2018 mission was completed with the Russian partners. The review results will be assessed by both agencies in the next quarter to endorse the architecture and responsibilities of each partner for the subsequent design activities.

Mars environment testing of the Rover's 2 m Drill and the Sample Preparation and Distribution System was completed, including rarefied carbon dioxide atmosphere, low temperature and soils characteristic of Mars. The next steps in these developments will lead to QMs as precursors for FMs.

The ExoMars Ground Segment Mission Control System development started in the period. Discussions with the Russian partners have taken place on the upgrade of the Russian Bear Lake deep space antenna for ExoMars. With this additional antenna and the ESA ground stations already baselined for the mission a substantial volume of scientific data can be achieved providing the ExoMars scientists with a large data return.

→ SOLAR ORBITER

Design reviews were held for a number of units. The PDR of the Attitude and Orbit Control Subsystem was also completed. Solutions have been found at system level for the initial performance issues of one of the five Stood-Off Radiator Assemblies.

The initial Software Validation Facility is being built up at prime contractor's premises. The configuration of the High Gain Antenna boom will be modified to improve the quality of the science data return. Implementation of EMC requirements, including test facility identification for spacecraft and payload units, is making progress; a facility has been identified in Berlin Instrument Boom tests.

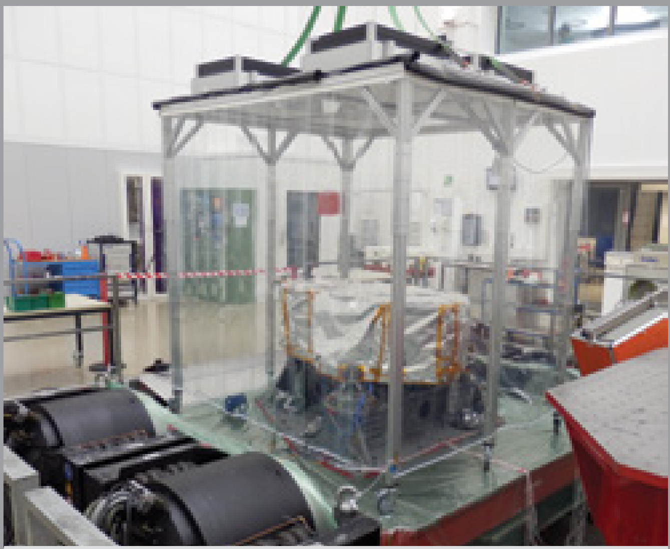
Tests of surface-treated materials at ESTEC under simultaneous high temperature and high ultraviolet flux have been completed. More tests will verify their behaviour under electron and proton fluxes, to investigate their suitability for High Temperature Multi-Layer Insulation for the back of the antennas, heatshield front shield and feed-through coatings. The facility commissioned to use this technology is producing titanium sheets for the STM front layer of the heatshield.

ASI has selected the contractor to complete the development of the METIS coronagraph development. The SWA-HIS (Heavy Ions Spectrograph of the Solar Wind Analyser instrument suite) STM suffered a failure during random vibration test. Investigation is ongoing. The SWA-EAS sensor STM completed vibration testing. Instrument CDRs will be run from August (starting with the SPICE instrument) to February 2014. Instrument STMs are being readied for shipment to the prime contractor in Summer and Autumn. The Science Ground Segment Requirements Review was completed.

The Atlas V launch vehicle interface technical definition with NASA is progressing towards agreement of the Launch Vehicle Interface Requirements Document.

→ JAMES WEBB SPACE TELESCOPE

The first two flight instruments, the Mid-Infrared Instrument (MIRI) and the Fine Guidance Sensor (FGS), have been integrated. Preparations for the first Integrated Science Instrument Module (ISIM) cryogenic vacuum risk reduction test are ongoing. The acoustic and sine vibration tests of the NIRSpec FM have been completed. The NIRSpec Acceptance/Pre-Shipment Review began in June.



NIRSpec Flight Model FM2 vibration test in a class 100 clean tent (IABG)

NASA completed the manufacturing of the first new spare microshutter arrays with slightly adjusted geometry to mitigate the observed high number of sticking shutters in the present FM. The new array samples have also been acoustically tested and no stuck closed shutters were seen. Preparations are ongoing to upgrade the MIRI STM to a Thermal Optical Model that will be used for the upcoming end-to-end verification of the MIRI cooler system at JPL.

→ EUCLID

The prime contractor offers were received in March and evaluated by ESA. The contract went to Thales Alenia Space Italy, Turin. The procurement of the Near Infrared Spectrophotometer (NISP) detectors is proceeding with Teledyne Imaging Sensors (US). Various grades of EMs and STMs have been produced and are under test at Teledyne and NASA. The procurement of the CCD detectors of the Visible Imager (VIS) is also proceeding with e2v (UK).

Phase-B2 activities for VIS, NISP and the Science Ground Segment developed by the Euclid Consortium have started. The VIS SRR was held, while the NISP SRR is running with a Science Ground Segment Preliminary Requirements Review. Work started with Arianespace to support Soyuz launcher interface activities until the system CDR.

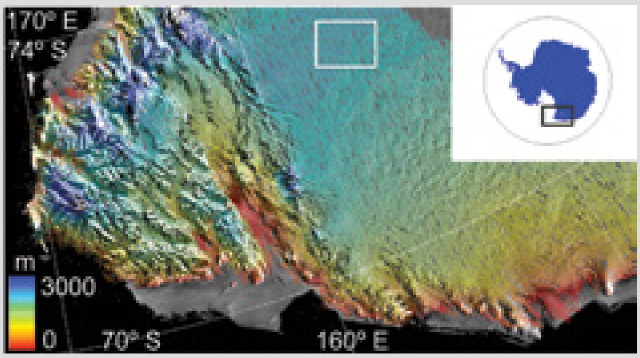
→ GOCE

Having already lowered its orbit by 20 km in the past year to maximise the gravity field signals captured by the satellite, a further lowering by 10 km was completed. In doing so, the equatorial altitude has (at the time of writing) reached an unrivalled 223.88 km, in a 143-day repeat cycle. Note that GOCE was already and by far the lowest-orbiting research satellite worldwide, a feat made possible by the satellite's unique accelerometer sensor and air drag compensation system.

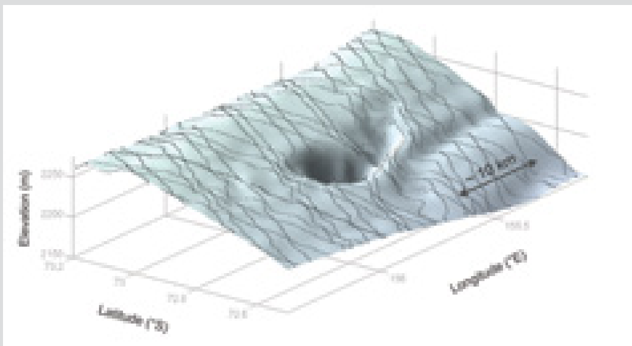
The present measurement cycle will be the last. Having analysed all the available data on the xenon gas consumption by the electric propulsion system, as well as the updated air density predictions for the coming period, it is predicted that the mission will come to a natural end in late 2013. In an orbit as low as GOCE's, this will be followed swiftly by reentry into Earth's atmosphere.

→ CRYOSAT

Over the coming months, CryoSat data will reveal the effect of the 2012 summer record minimum on sea-ice thickness on the overall winter sea-ice volume. An important CryoSat result, just published by UK scientists, has shown evidence



Location of the crater in Victoria Land, East Antarctica at about 73° and 156°. The crater is located within the white box (ESA/M. McMillan)



3D view of the crater created using CryoSat data. The satellite can measure both area and depth, allowing scientists to calculate the total volume of the crater: 6 cubic km (ESA/M. McMillan) of one of the largest-ever floods beneath Antarctica ice sheets that has drained several billion tonnes of water from a sub-glacial lake, possibly into the ocean. CryoSat mapped a vast crater in Antarctica's icy surface left behind when the lake, lying under about 3 km of ice, suddenly drained.

→ ADM-AEOLUS

The laser transmitter FM has passed the opto-mechanical stability test and in July underwent the environmental qualification campaign. The ultraviolet endurance test of the Aladin optical bench has also been completed. Preparations for the satellite test campaign, planned from mid-July to mid-September at Interspace in Toulouse, are under way. The campaign will characterise the micro-vibration and Vega launcher shock environment.

→ SWARM

The three Swarm satellites are stored within their transport containers waiting for a Rockot launch slot. The launch date was delayed until November because of the ongoing investigations on the Rockot launcher upper stage anomaly.

Integration fit-check of the Cloud Profiling Radar Structural Model on the EarthCARE Protoflight Model (Astrium/JAXA)

→ EARTHCARE

The integration fit-check of the Cloud Profiling Radar STM with the spacecraft structure was completed, with the test of the large antenna deployment using the Japanese zero-G device. The EarthCARE PFM structure was shipped to Astrium Ltd (UK) in preparation of the satellite propulsion sub-system integration.

Delivery and integration test of the Cloud Profiling Radar electrical simulator with the spacecraft EFM took place. All of the Broadband Radiometer FM and flight spare micro-bolometer detectors have been dispatched by INO Canada. The ATLID instrument Housing Structure Assembly PDR was held. Following the qualification of the Cloud Profiling Radar EM, JAXA and NTS have initiated the Protoflight CPR activities in Japan.

→ METEOSAT

Meteosat-8/MSG-1

Meteosat-8 is located at 3.9°E longitude and operating normally. Meteosat-8 is the operational back-up for Meteosat-9 and 10.

Meteosat-9/MSG-2

The satellite is in good health and performance is excellent. Meteosat-9 is located at 9.5°E longitude and provides the Rapid Scan Service, complementing the full-disc mission of the operational Meteosat-10.

Meteosat-10/MSG-3

Meteosat-10 is Eumetsat's operational satellite located at 0° longitude, performing the full-disc mission (one image every 15 minutes in 12 spectral channels), as well as the data collection, data distribution and search and rescue missions.

MSG-4

The new Mirror Scan Drive Unit for the SEVIRI instrument was reintegrated on the scan assembly by Astrium GmbH, Friedrichshafen. After mechanical and functional tests at Astrium in Ottobrunn, the scan assembly was delivered to Astrium Toulouse for reintegration in SEVIRI. The repaired SEVIRI instrument should be back at Thales Alenia Space, Cannes, for reintegration on MSG-4 in September. Launch is planned for 2015.

MTG

MTG-I PDR was closed in April, confirming a robust satellite design from which the detailed implementation activities can proceed. The first full analysis loop relating to the satellite microvibration performances and impacts on instrument pointing stability was completed. Results indicate that the mitigation measures proposed, such as reaction wheel isolators, will ensure disturbance levels for the instruments that are below those originally budgeted. The closure of all other PDRs relating to the MTG-S satellite and the associated main elements (platform and instruments) are progressing.

In Best Practice Procurement activities, over 90% (by value) of the subcontractors are now selected, including almost all space hardware suppliers. Residual activities in this area relate mainly to the Ground Support Equipment definition and procurement. The predicted Flight Acceptance Reviews for MTG-I and MTG-S protoflight satellites are now July 2018 and 2020 respectively.

→ METOP

MetOp-A

All instruments continue to perform excellently. MetOp-A will be operated in a dual MetOp operations scenario with MetOp-B initially until 2015.

MetOp-B

MetOp-B Level 1 calibration/validation activities were completed and MetOp-B became operational on 24 April. Level 2 activities are continuing.

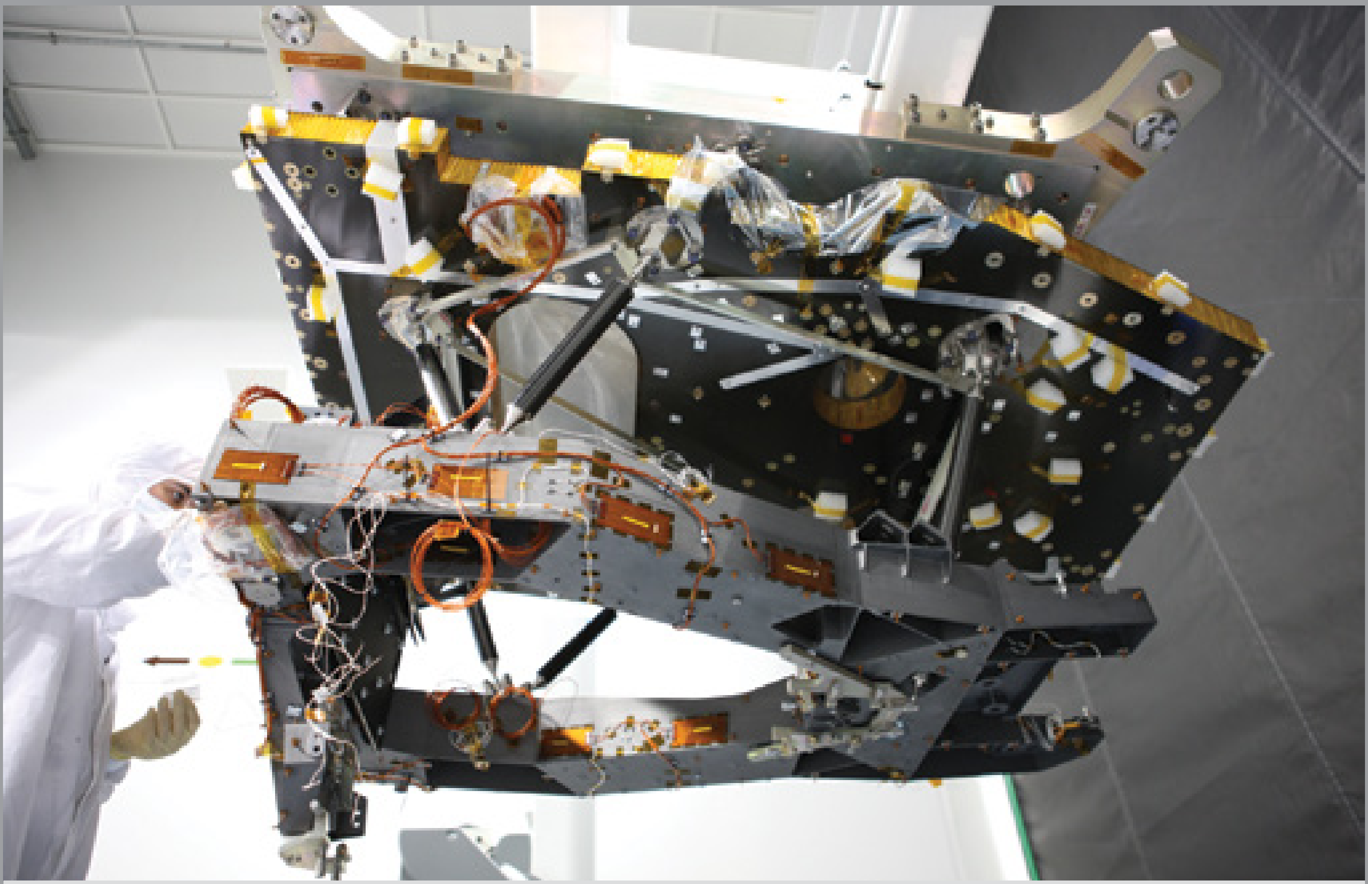
MetOp-C

The satellite is stored as three separated modules (platform, payload, solar array). Some equipment and instruments have been dismounted for repair or calibration. Launch is planned for 2017.

→ SENTINEL-1

AIT for Sentinel-1A is in progress with the spacecraft undergoing thermal vacuum and thermal balance tests at Thales Alenia Space Italy, Rome. Integration of the Synthetic Aperture Radar (SAR) antenna, currently at the payload prime contractor facilities at Astrium GmbH, Friedrichshafen, will take place early September. It will be followed by the radio-frequency compatibility tests at Thales Alenia Space, Cannes. The Optical Communication Payload was already integrated on Sentinel-1A. However, an anomaly

Sentinel-1A ready to start the thermal vacuum tests in Rome (Thales Alenia Space)



Sentinel-2 Multispectral Instrument Protoflight Model telescope (Astrium SAS)

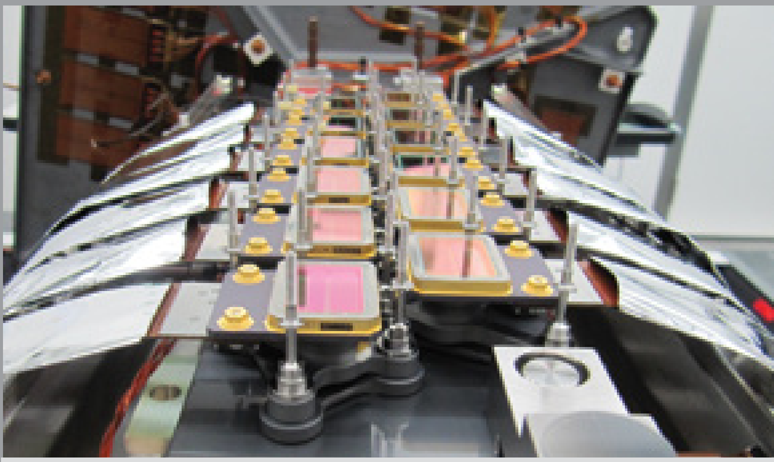
found during qualification means the Sentinel-1A flight unit must be modified. This reworking will take place between the thermal and mechanical vibration tests. Launch is now planned for February 2014 from Kourou, on a Soyuz.

→ SENTINEL-2

The payload instrument PFM including its Visible (VNIR) focal plane was characterised with excellent performance for radiometry and geometry. A recent SWIR focal plane contamination by hydrocarbons is now fully resolved and the PFM instrument AIT is back on track. In the meantime, equipment for the second instrument FM was delivered to Astrium.

Protoflight satellite AIT is ongoing. The launch service contract with Eurockot for Sentinel-2A concluded its Preliminary Mission Analysis Review. A similar preparatory phase was initiated with Arianespace for Sentinel-2B using Vega.

Image quality activities progressed with the Ground Prototype Processor delivered and installed at ESTEC and CNES. The Ground Segment CDR is ongoing with emphasis on prelaunch system validation tests and in-orbit commissioning preparations.



Sentinel-2 Multispectral Instrument Protoflight Model short-wave infrared focal plane at Astrium (Astrium SAS)

→ SENTINEL-3

Sentinel-3A AIT is ready to start instrument integration in June. DORIS (Doppler Orbitography and Radio positioning Integrated by Satellite) flight equipment for both A and B models was delivered by CNES, ready for integration. The SAR Radar Altimeter PFM testing was completed and the antenna was integrated on the satellite. Microwave Radiometer delivery is planned in August. Sub-assemblies for the OLCI (Ocean and Land Colour Instrument) and the SLSTR (Sea and Land Surface Temperature Radiometer) are being delivered for integration within the instruments.

The central software Qualification Review took place in June, with the latest version being released both to the Sentinel-3A AIT and the Functional Chain Validation on the Virtual-EM model. At system level, the Ground Segment CDR was completed.

→ SENTINEL-4

It is anticipated to close the PDR by the end of June, finalising Phase-B2 and starting Phase-C/D. The Best Practice Procurement process for the instrument continues with more than 95% (by value) of anticipated ITTs/RFQs being released by June. Astrium GmbH and Kayser-Threde GmbH are working to complete the industrial teaming with their subcontractors by Autumn. Ground segment activities are progressing, supported by regular coordination with Eumetsat on mission implementation.

→ SENTINEL-5 PRECURSOR

The platform CDR started in June. In parallel, platform AIT started at Astrium Ltd., Stevenage, UK. Delivery of the majority of platform electronic units is scheduled in July. Dutch Space completed integration of the basic EFM for the TROPOspheric Monitoring Instrument (TROPOMI) payload. The EFM can then be used for electrical interface verification, FM test procedure checkout and Electromagnetic Compatibility (EMC) testing.

All Charge Coupled Device FM detectors from E2V for the Ultraviolet/Near-infrared module of TROPOMI were delivered in May. The Short-Wave Infrared (SWIR) FM detector from Sofradir completed full characterisation testing at SRON and was returned to SSTL for integration into the SWIR FM. SWIR FM integration started at SSTL in March.

The combined Flight Operations Segment/Payload Data Ground Segment PDR concluded in April. A Rockot launcher study concluded in March and the final presentation of the Vega study will take place in July.

→ PROBA-3

This mission involves two platforms and a formation-flying system. Phase-B was completed in 2012. Post-PDR activities are ongoing. The scientific coronagraph payload PDR was completed this Spring. Requests for Quotation for the mission and the payload have been released and industry is preparing Phase-CDE1 proposals.

The last time Alphasat is seen before launch, as the Ariane 5 fairing is lowered to encase the satellite and the Sylda dual-launch pod (ESA/CNES/Arianespace/Optique Photo Video du CSG)

→ ALPHASAT

Alphasat left the Intespace test facilities in Toulouse in June after completion of its final integration and test campaign. The satellite arrived at the launch site in Kourou, French Guiana, on 21 June. Alphasat's Ariane 5 ECA launcher was moved to the Final Assembly Building where the satellite is joined to the launcher. Fuelling operations began on 27 June.

On 12 July, Alphasat was mated with its launcher adaptor in preparation for installation on the Ariane 5. The satellite was encased in the fairing on 15 July, after being placed on the Sylda dual-launch pod. The Sylda stack and fairing were lifted onto the rocket on 17 July and secured to the launcher. Finally, Alphasat was switched on and its batteries charged.

Alphasat was launched on 25 July and delivered into the target geostationary transfer orbit. By 5 August, the satellite had reached a temporary position in geostationary orbit, where it deployed its 11 m-diameter main antenna over the course of a day – marking ten days in orbit and completing one of the final steps towards starting services. It will stay in this slot for several weeks while Inmarsat together with ESA continue testing the telecom payload, the backup units on the Alphabus platform and ESA's four hosted payloads.

→ ADAPTED ARIANE 5 ME & ARIANE 6

Negotiation for the frame contract and three work orders related to specific activities (WO1), Common Upper Stage (WO2) and Ariane 6 (WO3) carried on into June. The final evaluation board took place on 11 June and assessed the results for WO1 and WO2. For WO3, it is planned to place a Work Order covering Phase-A only until the end of September and selected Phase-B1 activities. The contract proposals for placing the three WOs were approved in June.

Adapted Ariane 5 ME

The Ariane 5 ME ground segment contract is in preparation. A procurement proposal for fairing industrialisation activities was approved in June.

Upper Stage and Commonalities

Commonalities assessment synthesis meetings took place in May, freezing the list of eligible elements common to Adapted Ariane 5 ME and Ariane 6. At the same time, anticipation of Ariane 6 requirements to achieve commonalities objectives were identified and the relevant cost assessed during a workshop in June.

Ariane 6

Industry presented results of the Ariane 6 Concept Choice study. After complementary analysis, the final Ariane 6 concept (the 'Multi P Linear') was selected early July. This concept is based on a lower 'composite' of four motors, each loaded with around 135 tonnes of solid propellant, providing also synergies with the Vega evolution. An 'in-line' arrangement of three will serve as the first stage, while the fourth will be mounted above as the second stage, topped by a cryogenic third stage based on the Vinci engine.

On the Lower Composite demonstrators, work for the three demonstrators is progressing, while a contractual proposal for avionics demonstrators is expected in July.

The Ariane 6 'Multi P Linear' concept

→ VEGA

Vega performed its first demonstration flight (VV02) on 7 May. This mission confirmed the launcher's flexibility to ensure complex flight strategies: the introduction of a multi-payload capability allowing the release of three satellites (Proba-V, VNREDSat and ESTCube-1) in different orbits and with several engine reignitions. The payload altitude injection accuracy was extremely high (less than 1 km with respect to the prediction and user requirements).

This flight also introduced the new Flight Programme Software and the VESPA structure designed for carrying the main satellite in the upper part of the fairing and one or several payloads underneath.

Following the positive decision by Member States, the next Vega flight will be an exploitation flight carried out by Arianespace, using the second launcher currently procured from ELV within the VERTA frame contract. Its payload will be DZZ, with a launch planned for April 2014.

In parallel to the ongoing exploitation, and following the decision taken during the last Ministerial Conference, Vega evolution has started to better respond to market demand, with an increase of performance, in the frame of the VECEP programme.

→ IXV

Phase-D/E1A and E1B are progressing, including the manufacturing and qualification of the flight segment and ground segment deliveries. Preliminary mission analysis activities should be complete by June. On 19 June, IXV passed its milestone Descent and Landing System test at the Salto di Quirra range off the coast of Sardinia, Italy. FM vehicle integration activities began.

Phase-D/E1A and E1B activities are progressing with the elaboration of the scenarios for the implementation of the Phase-E/F. The Request for Quotation for Phase-E2A/F activities (incl. transportation, logistics, flight segment launch campaign, ground segment launch campaign, mission operations, recovery operations and post-flight analysis) was issued, and following an additional request of extension of the submission deadline, the industrial proposal is now expected within the second half of July.

The VERTA Work Order for Phase-E2B (including Vega mission and launch services) will be signed with Arianespace. The procurement proposal for the PRIDE-ISV Phases-A/B1/B2 was approved. The Request for Quotation to industry was issued in June.

Close-up view of Vega VV02 liftoff on 7 May

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

In solid propulsion, Pressure Oscillation Demonstrator (POD-X) activities progressed with the delivery of three CPC segments (loaded motor case). Integration readiness Key Point was held on 3 July. The first hot firing test will be in October at CAEPE test centre in France. In hybrid propulsion, manufacturing and testing is progressing as planned, and the industry proposal negotiation for the next rider was finalised at the end of June. On the Expander Cycle Thrust Chamber, the first technology phase for the Thrust Chamber Assembly was concluded in July with concept choice Key Point. The Request for Quotation for the main contract for the subsequent phase was sent to industry in June.

→ HUMAN SPACEFLIGHT

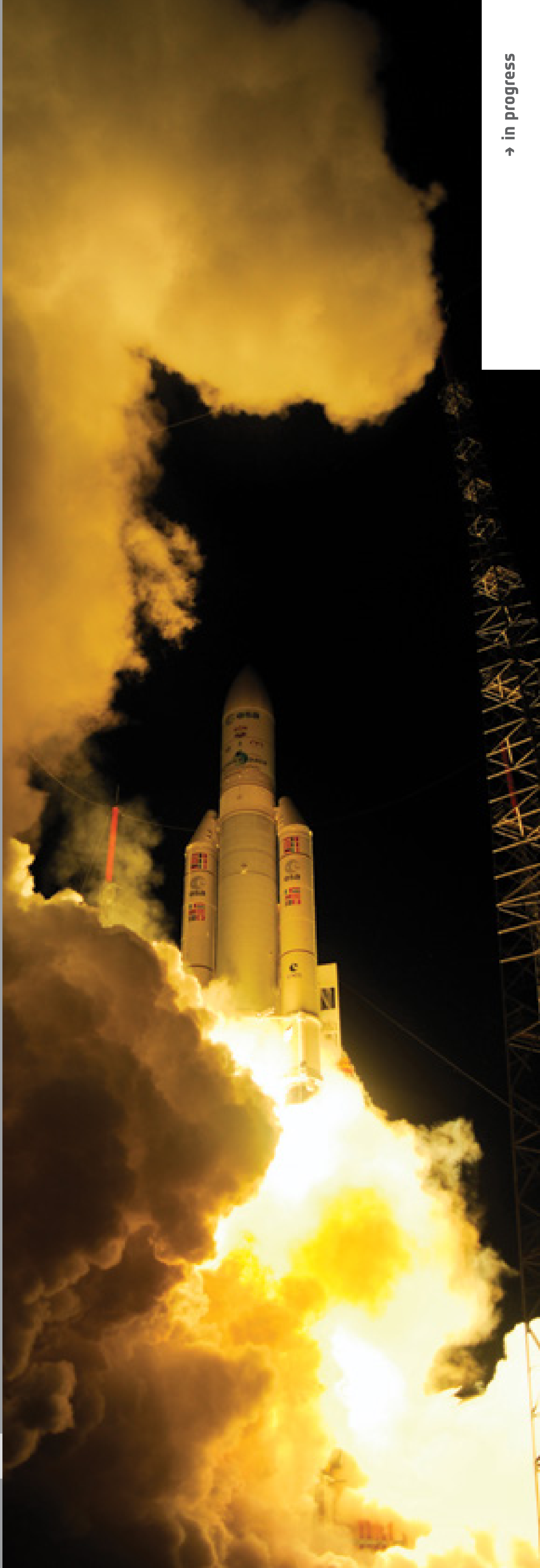
Three spacewalks were carried out on the ISS between March and June. During the first Russian spacewalk on 19 April, a faulty retro-reflector needed for the docking of ESA's ATV Albert Einstein was replaced. A US spacewalk on 11 May identified and repaired an ammonia leak from the Photovoltaic Thermal Control System. A second Russian spacewalk on 24 June prepared the ISS for the arrival of the 'Nauka' Multipurpose Laboratory Module. Nauka will be the final ISS module launched to the ISS, together with the European Robotic Arm.

→ ISS TRANSPORTATION

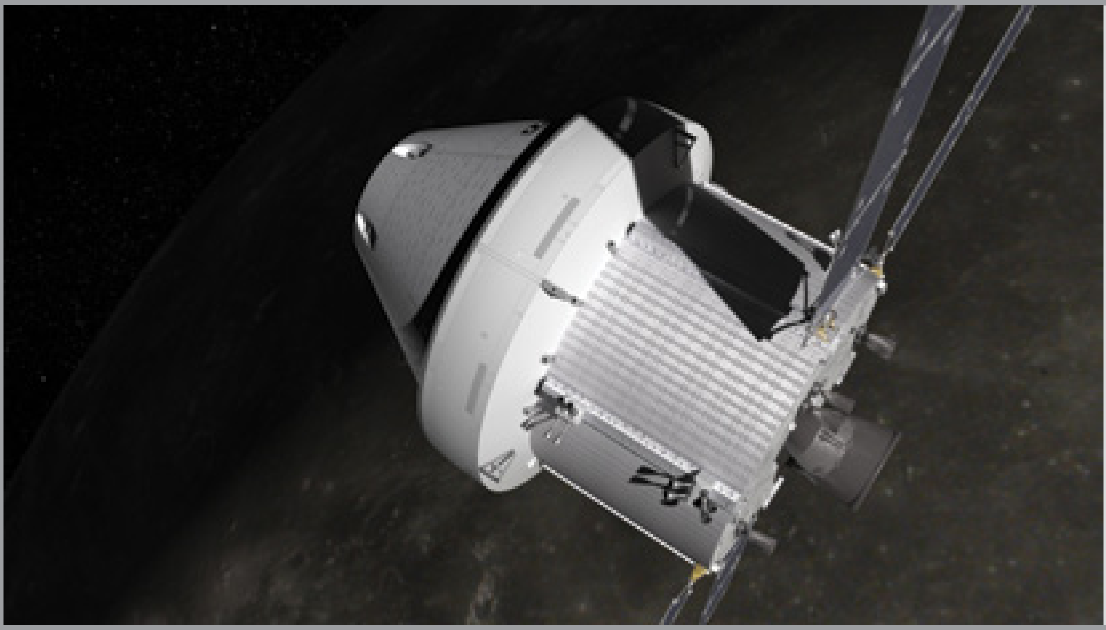
ATV *Albert Einstein*
ESA's fourth Automated Transfer Vehicle (ATV-4) was launched on 5 June on an Ariane 5 from Europe's Spaceport. After a 10-day journey, ATV docked automatically with the ISS on 15 June, closely monitored by flight controllers from ESA and CNES at the ATV Control Centre in Toulouse, and by ESA astronaut Luca Parmitano (IT) and his crewmates on the Station.

ATV-4 delivered 100 kg of oxygen and air, 570 kg of water, 2580 kg of propellants (for reboosting the Station's orbit and undertaking debris avoidance manoeuvres) and an additional 860 kg to refill the tanks of the Zvezda Service Module, and 2.48 tonnes of dry cargo. ATV-4 performed its first reboost of the ISS on 19 June. ATV-4 will spend four months attached to the Station.

ATV *Georges LeMaître*
ATV-5 will be shipped to Kourou in September for launch in June 2014.



Lift of Ariane 5 VA213 with ATV *Albert Einstein* on 5 June



The ATV-derived European Service Module for NASA's Orion spacecraft (NASA)

Multi-Purpose Crew Vehicle (MPCV)

The contract proposal for Phase-B2 of the MPCV European Service Module (ESM) was approved until close of the PDR. The full contract proposal will be presented at the end of 2013. The ESM system PDR will be conducted at the beginning of November.

→ ISS DEVELOPMENT/EXPLOITATION

European Robotic Arm (ERA)

The ERA control centre is being installed at ESTEC. The Multipurpose Laboratory Module and ERA will arrive in Baikonur in December, so a new launch date is needed. This will have an impact on the spacewalks and operations to be carried out by ESA astronauts Alexander Gerst (DE) and Samantha Cristoforetti (IT) during their upcoming missions.

Multipurpose End-to-End Robotic Operation Network (METERON)

Eurobot was tested at ESTEC in preparation for the OPSCOM2 experiment (tele-operation of the Eurobot at ESTEC from the ISS).

→ ISS UTILISATION

Human research

The Vessel Imaging experiment (in conjunction with NASA's Integrated Cardiovascular experiment) was concluded for all astronaut test subjects on 2 May. The joint experiments will help to quantify the cardiovascular response to fluid shifts in the body during long-term exposure to weightlessness, with the aim of optimising countermeasures to the adverse effects of spaceflight.

Cosmonaut Roman Romanenko completed his second and final session of activities for ESA's Immuno experiment on 8 May. Romanenko's blood and saliva samples, as well as those of earlier test subjects Oleg Novitsky and Yevgeny Tarelkin, will be returned on Soyuz TMA-08M (34S) in September. The samples are currently stored in the European-built MELFI freezer.

Canadian astronaut Chris Hadfield and NASA's Tom Marshburn carried out their fourth and final sessions as subjects of ESA's Reversible Figures experiment before returning to Earth. This experiment investigates the adaptive nature of the human neuro-vestibular system in the processing of gravitational information related to 3D visual perception. They also completed the Circadian Rhythms experiment. Luca Parmitano became a new subject for the experiment and had his first two 36-hour sessions in June.

Marshburn and Hadfield completed their last questionnaires for the 'Space Headaches' experiment before departing the ISS. Parmitano began filling in daily and weekly questionnaires after his arrival on the ISS. He will continue this until his return in November. The questionnaires are being analysed to help determine the incidence and characteristics of headaches occurring for astronauts in orbit.

Parmitano started the first sessions of ESA's Skin-B experiment on 7 and 24 June. Each session included three different non-invasive measurements made on the inside of the forearm. Skin-B will help to develop a mathematical model of aging skin and improve understanding of skin-aging mechanisms, which are accelerated in weightlessness. It will also provide a model for the adaptive processes for other tissues in the body.

Luca Parmitano installs the Fundamental and Applied Studies of Emulsion Stability (FASES) experiment container into the Fluid Science Laboratory in Columbus

Luca Parmitano working with the Circadian Rhythms experiment in June (NASA/ESA)

Biology research

The first runs of the new joint ESA/NASA Seedling Growth biology experiment were completed in zero g. Three additional runs were undertaken in the European Microgravity Cultivation System (at three different gravity levels, 0.1, 0.3 and 0.7g) in April and May. The research will provide insight into the cultivation of plants during long-term missions.

Fluids research

The Geoflow-2b experiment in the Fluid Science Laboratory (FSL) completed its final run on 23 April. Data from the final Geoflow runs had to be downlinked directly to ground due to a video date recording issue on orbit. The issue is being resolved.

The new Experiment Container for the new Fundamental and Applied Studies of Emulsion Stability (FASES) experiment was sent to the ISS on ATV Albert Einstein. Parmitano installed the experiment container in the FSL on 19 June, and the first science run was then carried out. The FASES experiment investigates the effect of surface tension on the stability of emulsions. Thin emulsions of different compositions are stored in 44 individual sample cells through which the emulsions will be optically and thermally characterised. Results of the FASES experiment are important for applications in oil extraction processes, and for the chemical and food industries.

Materials research

Following testing, the Batch 2a solidification experiments (CETSOL-2, MICAST-2, SETA-2) restarted in the Materials Science Laboratory (MSL) in the US laboratory. However, experiments had to be put on hold temporarily after the processing of a sample cartridge for SETA-2 was stopped on 22 May (because MSL's associated Standard Payload Computer experienced a random reboot during the solidification phase). Unfortunately the sample cannot be melted again (due to safety regulations). The computer reboot must be investigated before the experiment can start again.

Radiation research

The Tri-Axis Telescope (TriTel) experiment was concluded on 10 May with a total of 139 days worth of data gathered using its active cosmic radiation detector hardware and passive detectors located in Columbus. The TriTel instrument was transferred to the Russian segment where it will continue to operate with another similar detector.

Solar research

ESA's SOLAR facility carried out three additional data acquisition periods during Sun visibility windows from April to June.

Non-ISS Research

The 58th ESA Parabolic Flight Campaign (27 May – 7 June) was concluded with a research envelope that included 12 experiments: nine in physical sciences, three in life sciences. The preparation of the 59th flight campaign, foreseen for early November, is under way with the final list of experiments.

The second campaign of the medium-duration (21-day) bed rest study was carried out at Medes from 9 April to mid-May. The third campaign will take place in Autumn. The study builds on previous campaigns, testing nutritional supplements as a countermeasure for the effects of (simulated) weightlessness on the human body. The campaign tests a nutritional supplement (potassium bicarbonate plus whey protein) together with resistive vibration exercise to determine if the supplement improves the effect of the exercise.

As part of the continuing Drop Tower Utilisation programme, 22 'drops' were carried out in June at the ZARM facilities in Bremen for the Liquid Jet Injection and Impingement (LiqJet) experiment. That experiment is studying the formation in microgravity of two liquid jets at various flow rates, sprayed into an experiment chamber, as well as their interaction.

→ ASTRONAUTS

Luca Parmitano (IT) and his crewmates Fyodor Yurchikhin of Roscosmos and NASA's Karen Nyberg were launched on a Russian Soyuz rocket from the Baikonur Cosmodrome

ESA astronauts Andreas Mogensen and Thomas Pesquet (right) during spacewalk training at NASA's Neutral Buoyancy Lab, in Houston, USA (NASA/ESA)

Luca Parmitano pictured during his second extravehicular activity (EVA) on 16 July, just before he reported water floating behind his head inside his helmet. The water was not an immediate health hazard for Parmitano, but Mission Control decided to end the spacewalk early (NASA/ESA)

in Kazakhstan on 28 May. They docked to the ISS 5 hours and 49 minutes after launch. This was the second time an ISS crew made a four-orbits-to-docking manoeuvre, rather than taking the usual 34 orbits, which requires two days. Parmitano's mission includes a full research programme in life and physical sciences, as well as an additional complement of educational and public relations activities and a key role in docking/robotics procedures for visiting vehicles (including ATV-4). He is scheduled to make two spacewalks during his mission, on 9 and 16 July. He will remain on the ISS until mid-November.

Alexander Gerst (DE), Expedition 40/41, and Samantha Cristoforetti (IT), Expedition 42/43, continued their mission-assigned training. Timothy Peake (UK) has been assigned to fly to the ISS on a long-duration mission at the end of 2015, as a member of Expedition 46/47. This will be the eighth long-duration mission for an ESA astronaut.

Andreas Mogensen (DK) and Thomas Pesquet (FR) underwent pre-assignment EVA training at the Neutral Buoyancy Laboratory at NASA's Johnson Space Center in April and May. A number of ISS partner crews trained at EAC. Expedition 38/39 crewmembers Koichi Wakata (JAXA) and Richard Mastracchio (NASA) underwent Columbus System, Payload and ATV training. Expedition 41/42 astronaut Barry Wilmore (NASA) completed Columbus User and Operator training.

→ TRANSPORTATION/EXPLORATION

International Berthing and Docking Mechanism (IBDM) and International Docking System Standard (IDSS)

Design work for the Evolved Engineering Development Unit is progressing. The Test Readiness Review for the IBDM push-off and lock-down mechanisms took place in June. The first model of the Linear Electromechanical Actuator underwent functional tests in June.

A proposal for cooperation on the IDSS was received from NASA, with special emphasis on the Block II version of the mechanism, tailored for exploration missions. An initial

ESA's Luca Parmitano waits for a photo opportunity in Cupola during Expedition 36 in June (NASA/ESA) breakdown of the activities between NASA and ESA was agreed.

Sierra Nevada Corporation (US) confirmed its interest in using the IBDM on their Dream Chaser vehicle. The work could be shared between European industry (which would develop the actively controlled Soft Docking System) and Sierra Nevada (which would manufacture the Hard Docking System in accordance with the NASA design). An agreement for the formalisation of this cooperation is in preparation.

Interim Technology Phase for Reusable Systems and Reentry (GSTP)/ European Experimental Reentry Testbed (EXPERT)

Orbital Sciences (US) has completed its assessment of alternative launch systems that could be used for EXPERT. Technical and financial data have been provided and are under analysis. Discussions with NASA and Lockheed-Martin (US) are also ongoing for other launch vehicles.

→ LUNAR EXPLORATION ACTIVITIES

New Lunar Exploration Strategy

The ESA and Roscosmos signed the protocol for the New Lunar Exploration Strategy at the Paris Air Show, Le Bourget, on 18 June. Meetings were held with Russian counterparts on 17/18 June to discuss the way forward. Five joint European/ Russian working groups were established to address specific elements of future lunar exploration cooperation.

Lunar Lander Phase-B1

The mission documentation and system study were finalised in July.

→ SPACE SITUATIONAL AWARENESS (SSA)

SSA Architectural Design

Phase 2 of the first SSA Architectural Design contract (Astrium) for the Space Surveillance and Tracking (SST) and Near-Earth Object (NEO) segments was initiated in March. Phase 2 will detail further the design selected at the Mid-Term Review (MTR). Because of the very large footprint of the Space Weather (SWE) system, the extent of the work to be performed for the SWE Phase 2 is being discussed between ESA and Astrium.

The second SSA Architectural Design contract (Indra) passed the SST and NEO segment MTR. Phase 2 will start in July/ August. Negotiation of a second SSA Architectural Design contract for the SWE segment was concluded in June.

SSA/SST

Development for the new Conjunction Prediction System and Re-Entry Prediction System is on schedule. The list of enhancements made to the system following suggestions made by the user community was agreed with GMV, the prime contractor for the consortium performing these tasks.

Development of the data processing chain will provide the automated ability for the system to ingest data from both optical and radar sensors in order to generate a catalogue of Earth-orbiting objects. In parallel, the development of systems able to task sensors to perform specific duties is also ongoing.

In addition, the Conjunction Data Message, a standard developed through the frame of the Consultative Committee for Space Data Systems, was approved as an international standard.

SSA/SWE

The development of the SSA SWE Segment is progressing as planned. The SSA Space Weather Coordination Centre (SSCC) is managing the SWE Data Centre in Redu, Belgium, and providing support to the SWE end users through the helpdesk. Provision of the federated SWE services is ongoing from: the Solar Influence Data Centre/Royal Observatory of Belgium, the Tromsø Geophysical Observatory, the Space Weather Application Center – Ionosphere at DLR, the Kanzelhöhe Observatory, the University of Graz and the Seibersdorf Laboratories GmbH. New services from National Observatory of Athens, the Norwegian Mapping Authority, CLS, IEEA and the Finnish Meteorological Institute are in development. These new services will address end-user services in the domains of ionospheric weather and geomagnetic services.

SSA/NEO

The NEO Coordination Centre in ESRIN was officially inaugurated on 22 May. The initial web services at http://neo.ssa.esa.int/ are updated daily. Work to set up an international decision process on NEO impact threat mitigation is continuing in coordination with the Action Team 14 of the UN Committee on the Peaceful Uses of Outer Space. A meeting of AT-14 on 17/18 June prepared the establishment of a Space Mission Planning Advisory Group for potential future NEO deflection missions. An Industry Day was held on 11 June at ESOC.

SSA/Ground Segment Engineering

The monostatic breadboard radar was integrated at the site of Santorcaz, near Madrid. The radar final acceptance is pending the accreditation of the site as a secure zone by the national authorities from Spain. All subsystems of the bistatic breadboard radar (Onera) are planned to be complete by the end of 2013. The components for the transmitting subsystem, receiving subsystem and signal and data processing subsystem have been procured.

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