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bulletin

European Space Agency

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

Chairman of the Council: D. Williams

Director General: J.-J. Dordain

←

ESA astronaut Samantha Cristoforetti (IT) during training for spacewalks in NASA's Neutral Buoyancy Laboratory in Houston. In July, she was assigned to fly to the International Space Station in November 2014 as part of Expedition 42/43 (ESA/NASA)

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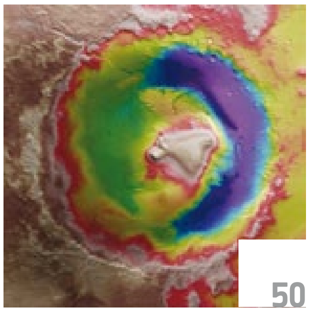
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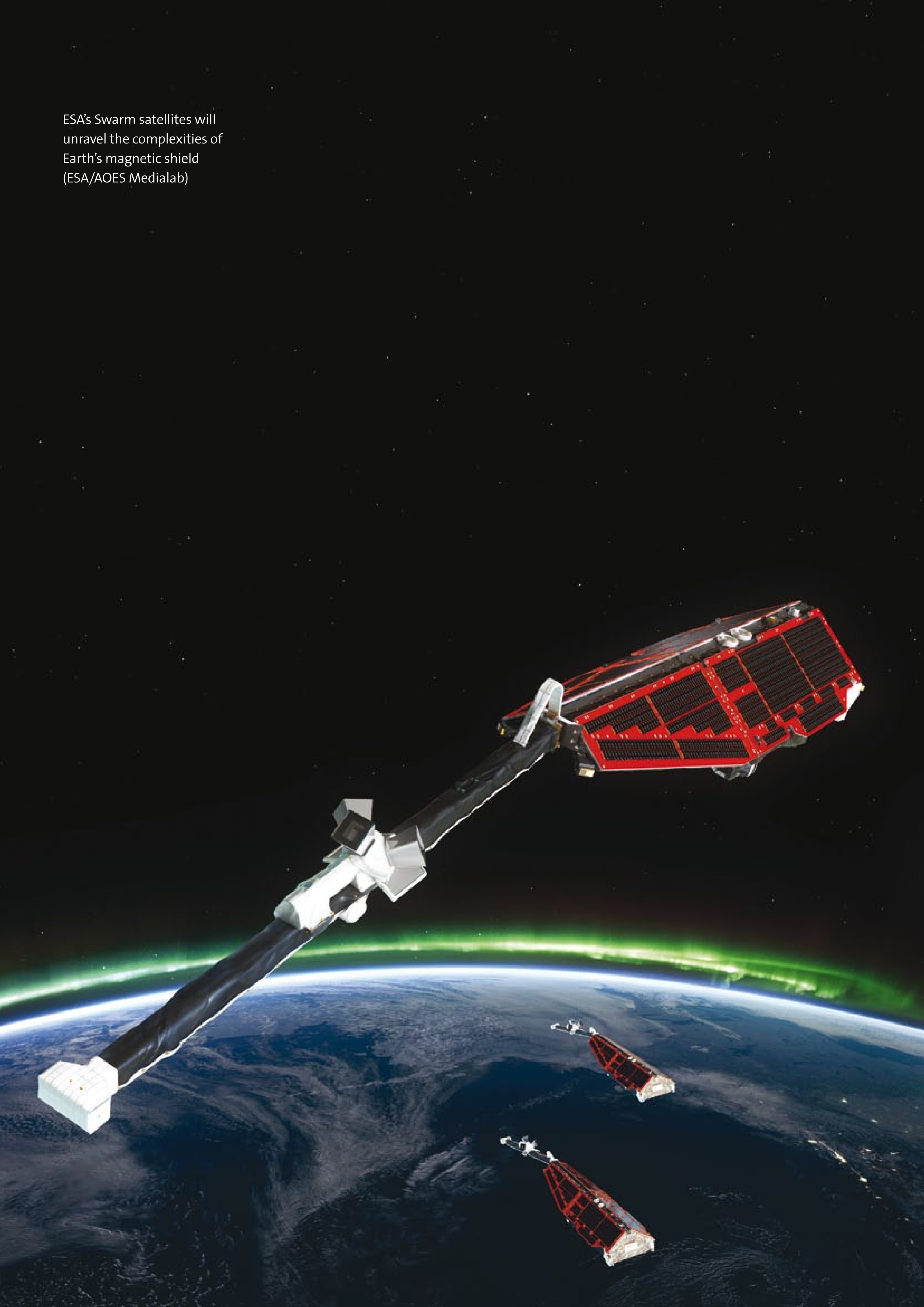

ESA's Swarm satellites will unravel the complexities of Earth's magnetic shield (ESA/AOES Medialab)

→ A JOURNEY TO EARTH'S CORE

Swarm: ESA's magnetic field mission

Yvon Menard, Roger Haagmans and the Swarm Project Team
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Directorate of Earth Observation, ESRIN, Frascati, Italy

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Directorate of Human Spaceflight and Operations, ESOC, Darmstadt, Germany

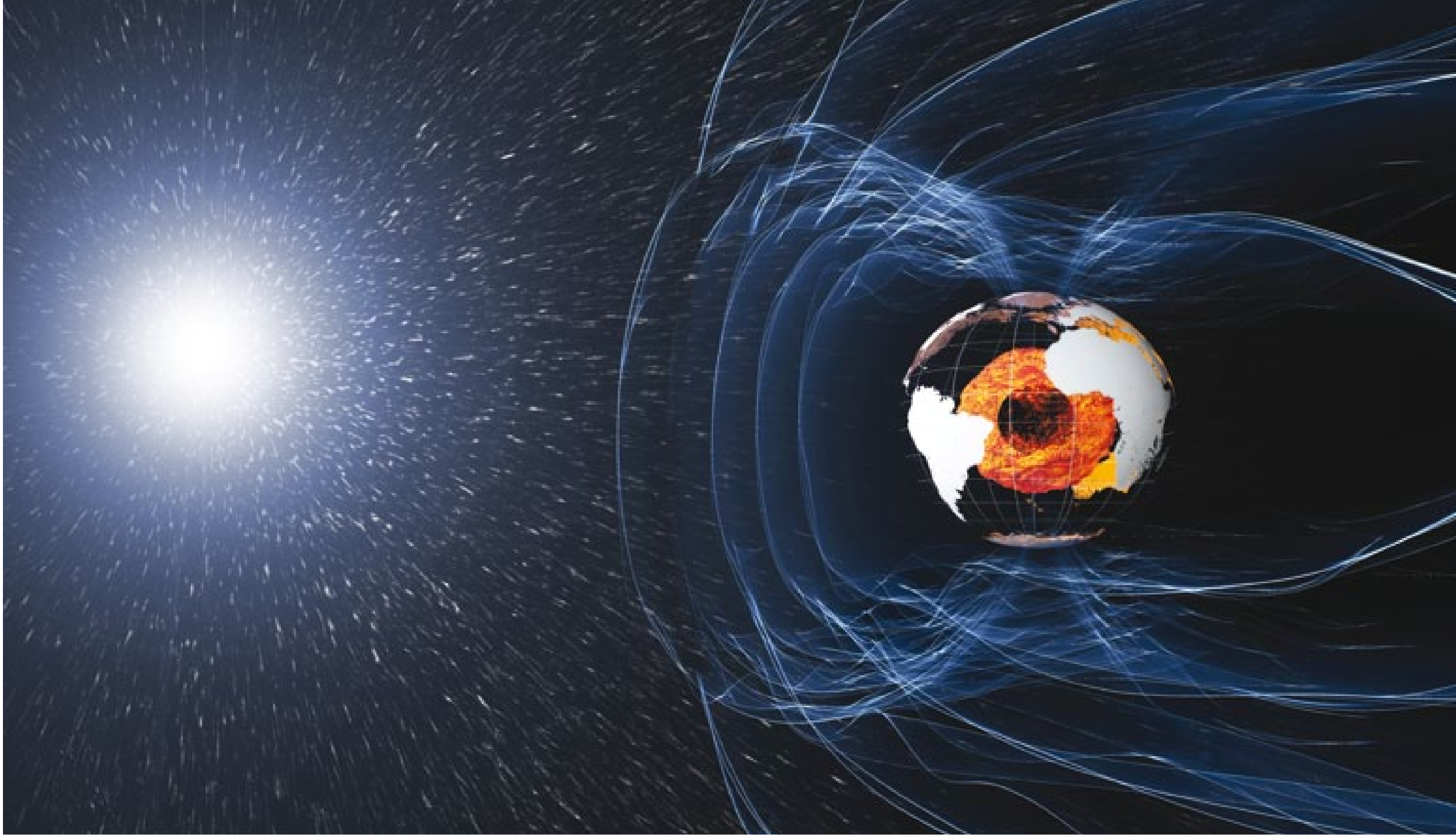
Essential for life on Earth, our planet's protective magnetic shield is weakening. ESA's Swarm mission, a constellation of three state-of-the-art satellites to be launched later this year, will help us understand what is happening to this vital shield.

ESA's Earth Explorer missions are developed in direct response to pressing Earth-science issues raised by the scientific community. They are designed to improve our understanding of how Earth works as a system and the impact human activity is having on natural processes.

Swarm will be the fourth Earth Explorer mission in orbit, following GOCE, SMOS and CryoSat. The mission was proposed by a consortium led by Eigil Friis-Christensen (DTU Space, Denmark), Hermann Lühr (GFZ Potsdam, Germany) and Gauthier Hulot (IPGP, France).

Carrying novel technologies, Swarm sets out to identify and measure precisely the different magnetic signals that stem from our world's core, mantle, crust, oceans, ionosphere and magnetosphere.

By unravelling the mysteries of Earth's magnetic field, Swarm will provide new insights into many natural processes, from those occurring deep inside the planet to the near-Earth electromagnetic environment and the influences of the solar wind.



The force that protects our planet

Although invisible, the magnetic field and electric currents near Earth are responsible for generating complex forces that have an immeasurable impact on our everyday lives. Earth's magnetic field is largely generated deep inside our planet's liquid outer core. This is a huge 'ocean' of swirling molten iron, driven by convection currents. Acting like the spinning conductor in a bicycle dynamo, it generates electrical currents and thus, the continuously changing electromagnetic field. This magnetic field can be likened to that of a powerful bar magnet at the planet's core, which is currently tilted about 11° to Earth's axis of rotation.

The field acts as a shield, protecting the planet from charged particles that stream towards Earth in solar winds. This complex force, however, is in a constant state of flux. Magnetic north wanders and occasionally reverses direction, so that a compass would point south instead of north. Moreover, the magnetic field varies in strength, and it is currently showing signs of significant weakening.

Although the field has been sustained over billions of years, exactly how this happens and its irregular behaviour are still poorly understood.

The continuous changes in the core field that result in motion of the magnetic poles and reversals are important for the study of Earth's lithosphere field (also known as the 'crustal' field), which has induced and remnant magnetised parts. The latter depend on the magnetic properties of the sub-surface rock and the history of Earth's core field. For example, most oceanic crust is generated as a result of volcanic activity.

When the magma hardens, it locks in the direction of the prevailing magnetic field at the time. The seafloor actually acts as a geological 'tape recorder' so that pole reversals are visible in magnetised rock as the seafloor spreads over time. Analysing the magnetic imprints of the ocean floor allows the past core field changes to be reconstructed, and also helps investigate tectonic plate motion.

→ A history of magnetic discovery

1st century AD

Earliest known magnetic compass invented by the Chinese.

11th century

Chinese author Zhu Yu first reports a compass being used for navigation at sea.

12th century

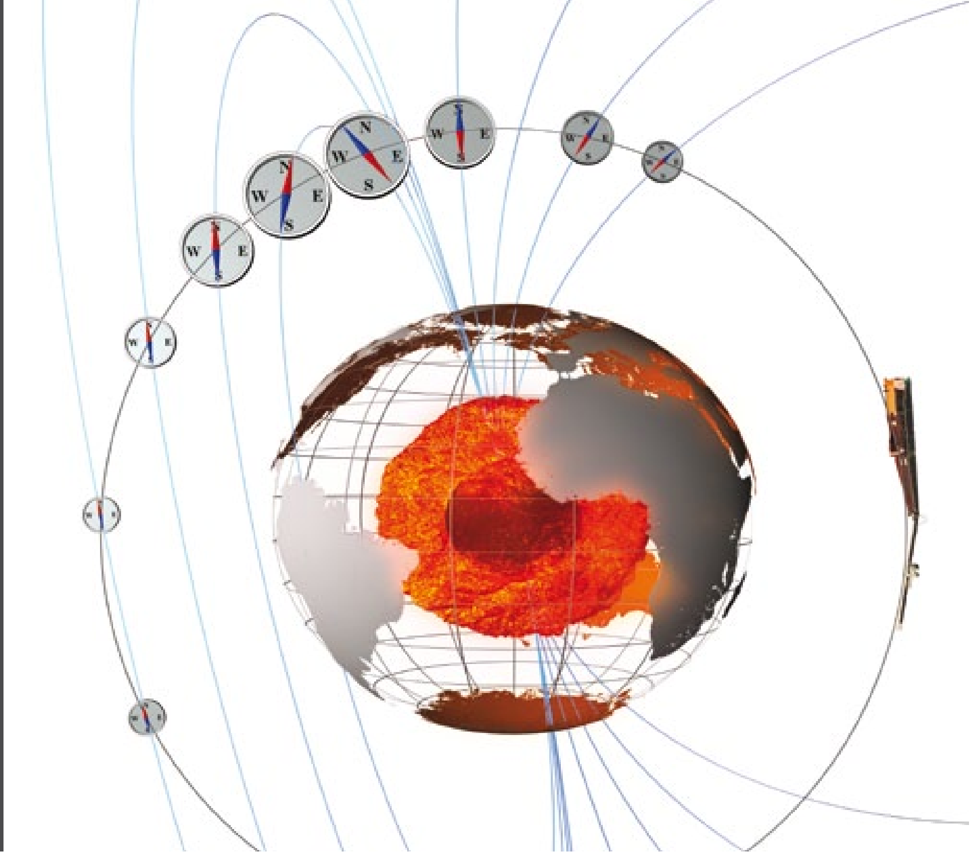
Compass probably introduced into Europe by the Arabs.

1187

English scholar Alexander Neckam reports use of magnetic compass for crossing English Channel.

← Swarm's measurements will further our understanding of space weather and radiation hazards caused by particles from the Sun interacting with our magnetic field (ESA/AOES Medialab)

→ Earth's magnetic field is largely generated deep inside our planet's liquid outer core, and it is continuously changing. Each Swarm satellite aims to measure the strength and direction of the magnetic field (ESA/AOES Medialab)



Other induced sources of magnetism can be found between the thin crust and the outer core and in the ocean. Electrical conductivity variations in the silicate mantle generate minute signals that can be detected in space when electrical currents in the magnetosphere vary in time. These variations can be related to mantle composition, such as temperature, water content and melt processes.

There is also thought to be a weak contribution to the electromagnetic field from oceans. Because seawater is conductive, it generates electrical currents in response to changing electric currents off Earth.

The magnetosphere is the region in space about 10–20 Earth radii from Earth. This region comprises complicated current systems, similar to the ring current around the magnetic equator relative to the magnetic poles on Earth. The magnetosphere protects us from charged particles streaming from the Sun in solar winds. In general, these particles cannot penetrate the magnetosphere.

The ionosphere, a region in the upper atmosphere 50–600 km from Earth, contains ionised atoms resulting from the effect of ultraviolet light from the Sun. Strong electric currents flow in the sunlit hemisphere, which is much more conductive than the night side. The magnetic field of these currents can be detected in magnetic field measurements. Irregular solar activity, known as magnetic storms, results in energetic processes on top of diurnal variations. For example, the aurora borealis and aurora australis are formed when charged particles in solar wind are channelled by Earth's magnetic field into the atmosphere near the poles.

When these particles collide with atoms and molecules (mainly oxygen and nitrogen) in the upper atmosphere, some of the energy in these collisions is transformed into visible light, the green–blue patterns that characterise these auroras.

Swarm will contribute to a better scientific understanding of many of these processes, also in relation to global change and improve our knowledge of how Earth works as a system.

1269

Petrus Peregrinus of Maricourt described a floating compass and writes about the polarity of magnets.

1600

'On the Magnet and Magnetic Bodies, and on the Great Magnet the Earth' published by William Gilbert (who concluded that Earth itself was magnetic and this was why compasses point north, he was also the first to argue that the centre of Earth was iron).

1634

Henry Gellibrand was the first to document that Earth's magnetic field changes with time.

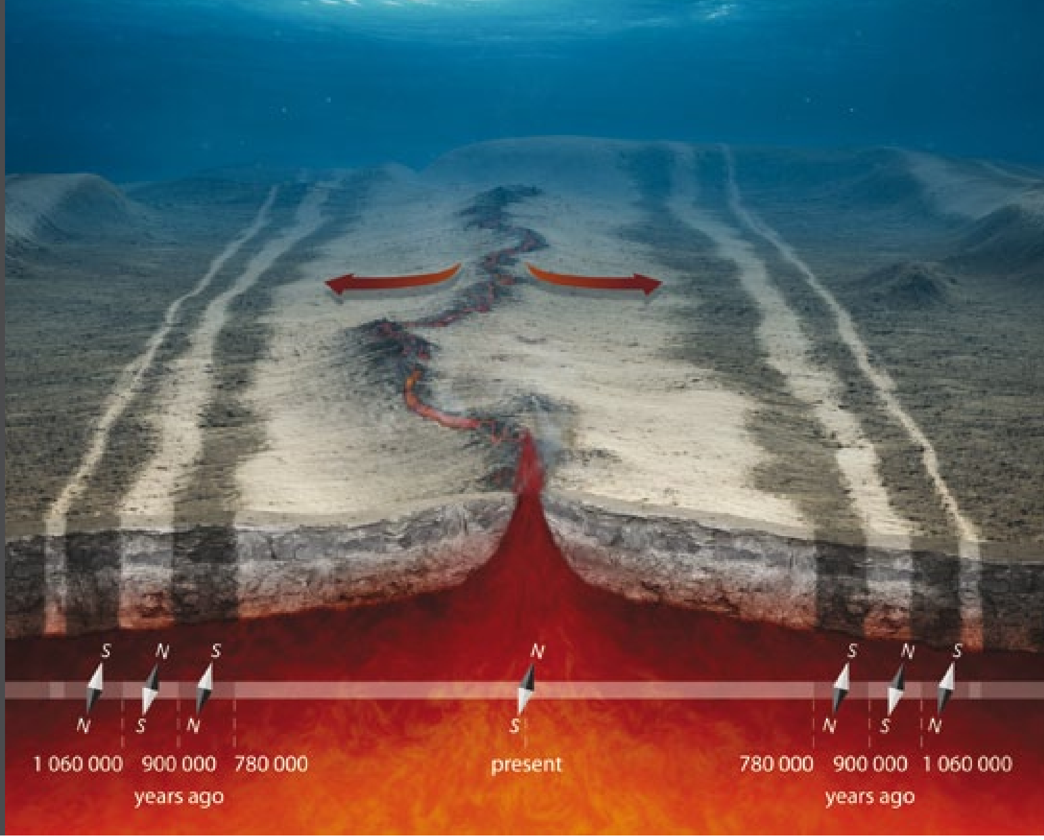
1700

Edmund Halley carried out magnetic surveys over the Atlantic Ocean and publishes the first map showing lines of equal declinations of the magnetic field in the Atlantic.

1798

German explorer Alexander von Humboldt makes magnetic measurements on his voyages through Europe, Latin America and Russia.

→ The direction of magnetic grains laid down successively in Earth's crust, particularly the sea floor, are primary evidence for magnetic field reversal. When the rock is new and molten, its grains are free to align themselves with the prevailing magnetic field. As the rock cools, the grains are frozen in time. As the sea floor expands (in the Atlantic), it is striped with rock oriented in different directions, indicating that the magnetic poles have reversed many times throughout Earth's history (ESA/AOES Medialab)



Space compasses and their bearing on Earth

The three Swarm satellites will provide precise and detailed measurements of the strength and direction of the magnetic field. Magnetic sensors measure a combination of the core field tangled with others from magnetised rocks in the crust, electrical currents flowing in the ionosphere, magnetosphere and oceans, and currents induced by external fields inside Earth. The challenge is to separate the individual magnetic field sources, each with their own characteristics in space and time. GPS receivers, an accelerometer and an electric field instrument will deliver supplementary information to study the interaction of Earth's magnetic field with the solar wind.

The main areas of focus are:

The core

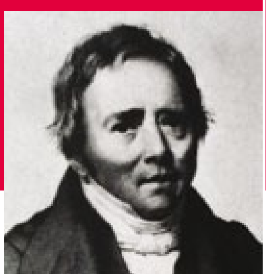
Measuring the core field and, in particular, how it changes over time are two of the very few means of probing the Earth's liquid core. Variations with time directly reflect the fluid flows in the outermost core and provide a unique experimental constraint on geodynamic theory. Progress in geomagnetic research calls for moving beyond simple extrapolation of the field with time to forecasting that field through a better understanding of the underlying physics. A serious limitation on investigating internal processes over months to years is the effect of external magnetic sources that contribute on timescales up to the 11-year solar cycle. All this clearly shows the need for a comprehensive separation and understanding of external and internal processes which Swarm addresses.

The crust

Magnetism of the lithosphere tells us about the history of the global field and geological activity. This needs to be determined from space with much higher resolution than currently exists. By complementing the spatial scales observed from Swarm with aeromagnetic surveys, the gap in our knowledge about Earth's crust will be filled. The crust also holds information on how the changing field may have affected the climate historically, through the escape of atmospheric gases to space.

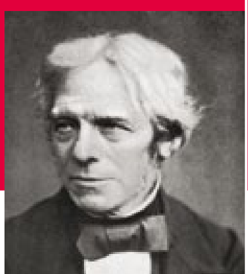
1819

Danish physicist Hans Christian Ørsted discovers relationship between electricity and magnetism when he sees that an electric current can influence a compass needle.



1821

Michael Faraday establishes first basis for the magnetic field concept in physics.



1832

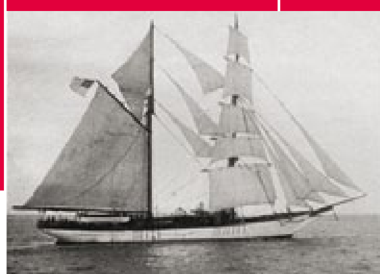
Carl Friedrich Gauss and Wilhelm Weber begin investigating the theory of terrestrial magnetism.

1840

Carl Friedrich Gauss publishes the first geomagnetic field model demonstrating the dipolar nature of Earth's magnetic field.

1909

The *Carnegie*, a yacht made almost entirely of wood and other non-magnetic materials, starts voyages to gather oceanic magnetic data.



The mantle

The constellation of satellites makes it possible, for the first time, to image the mantle's electrical conductivity globally in three dimensions. This will yield clues to its chemical composition and temperature, which are fundamental to understanding mantle properties and dynamics. This will complement seismic analysis and gravity observations made, for example, by GOCE.

The ocean

The conductive ocean produces a relatively weak magnetic signature, which contains independent data on tides and ocean circulation, i.e. the total effect from the ocean. This information is unique and complementary to other satellite techniques. However, it is also very challenging to isolate this signal from all the other contributing sources of the magnetic field.

Two Swarm satellites will orbit close together at the same altitude - initially about 460 km - while the third will be higher at about 530 km. These different near-polar orbits, along with the various Swarm instruments, improve the measurement sampling in space and time (ESA/AOES Medialab)

1919

Irish physicist Joseph Larmor suggests that dynamos could naturally sustain themselves in conducting fluids (this theory explains how the geomagnetic field originates deep inside Earth).

1979

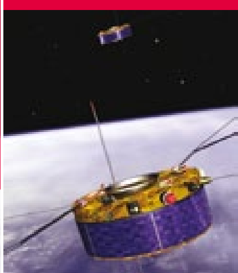
NASA launches Magsat satellite to map Earth's magnetic field.

1999

Denmark launches Ørsted satellite to measure Earth's magnetic field (based on data from this mission, scientists confirmed that the magnetic poles are moving).

2000

ESA launches Cluster mission to study the interaction of solar wind with the magnetosphere.



2000

Germany launches CHAMP satellite to study variations in magnetic and gravity fields.

↑ One of the Swarm satellites, with boom deployed, undergoing tests at IABG's Magnetic Field Simulation Facility in Ottobrunn, Germany. The tests are carried out in a magnetically clean environment – hence the wooden floor (ESA/IABG)

The upper atmosphere

The magnetic field is also of primary importance for Earth's external environment, providing information about the Sun–Earth connected system, which can be studied in detail through Swarm. While there are indications that air density in the thermosphere is related to geomagnetic activity, this is still not well understood. Furthermore, the magnetic field acts as a shield against high-energy particles from the Sun and deep space. It controls the location of radiation belts, and also the path of incoming cosmic ray particles, which reflect the physical state of the heliosphere.

Swarm complements ESA's Cluster mission, which has been in orbit since 2000. Cluster observes the interaction of solar wind with the magnetosphere while Swarm's observations are made closer to Earth. The interplanetary medium controls the energy input into the Earth's magnetosphere and the development of magnetic storms, or 'space weather'. A deeper understanding of the weather in space from Swarm is relevant to satellite technologies, radio communications, navigation systems and power infrastructures. Widely reported, but still largely unknown, are possible correlations between solar activity and climate variations.

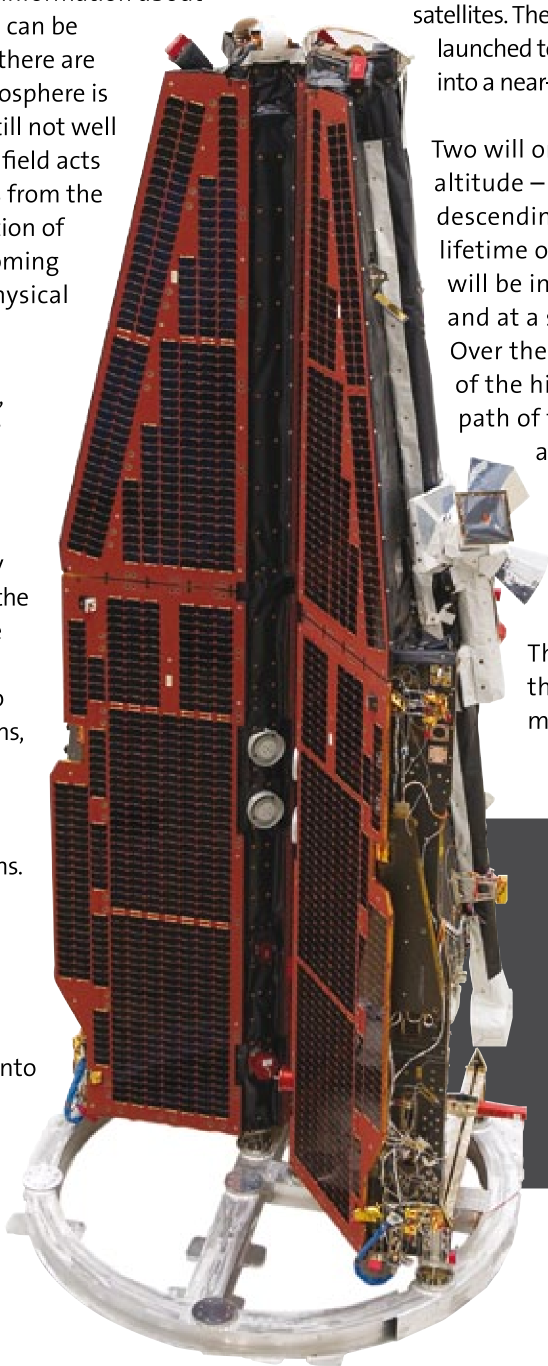
No other single physical quantity can be used for such a variety of studies related to our planet. Highly accurate and frequent measurements of the magnetic field will provide new insight into our planet's formation, dynamics and environment, stretching from Earth's core to the Sun.

The first Earth Explorer constellation

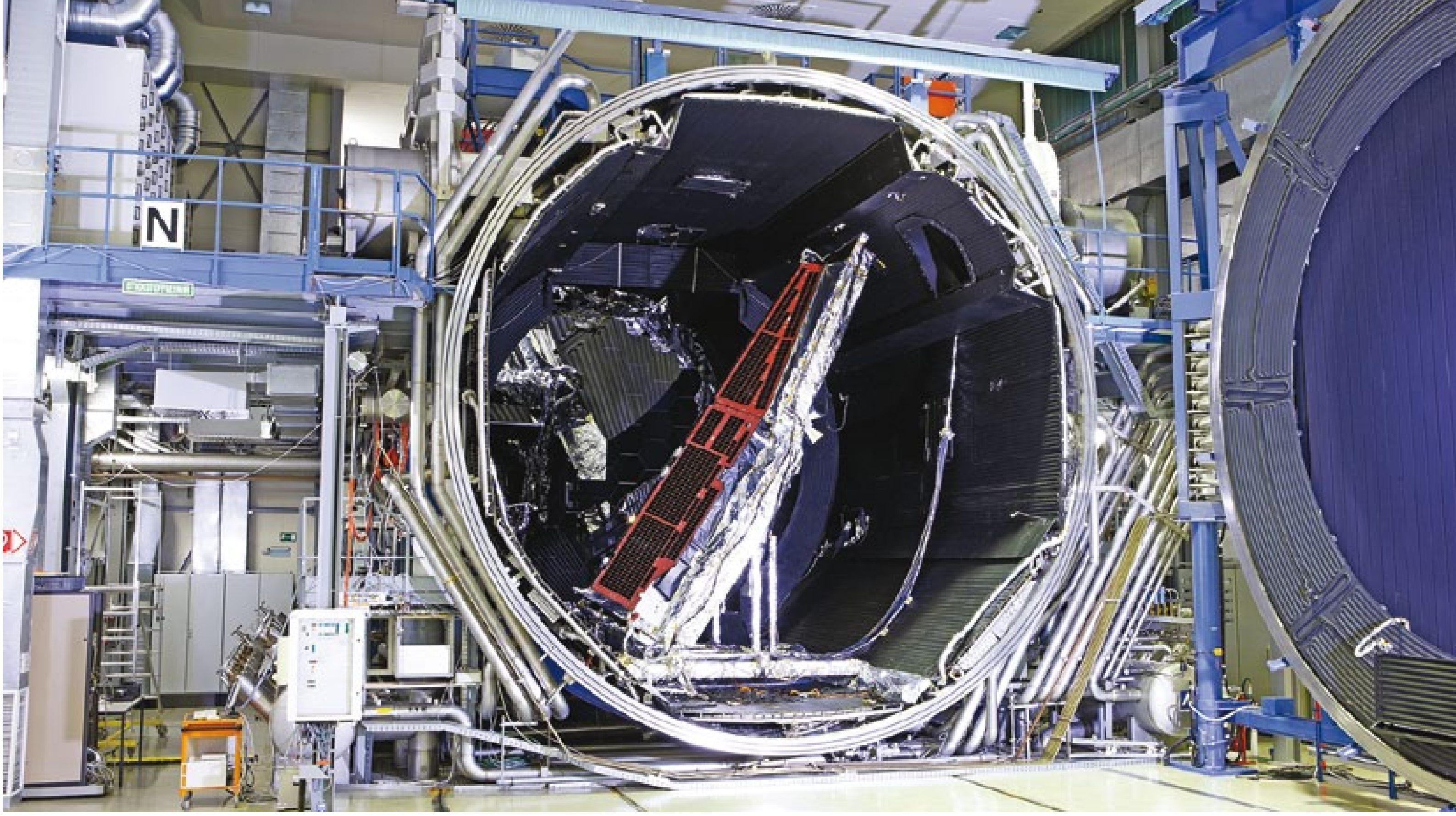
Swarm will be ESA's first constellation of Earth observation satellites. The three identical satellites will be launched together on one rocket from Russia into a near-polar, low-Earth orbit.

Two will orbit in tandem at the same altitude – initially at about 460 km, descending to around 300 km over the lifetime of the mission. The third satellite will be in a higher orbit, initially 530 km, and at a slightly different inclination. Over the course of the mission, the orbit of the higher satellite drifts to cross the path of the two lower satellites at an angle of 90°.

Essentially, the two different orbits, along with the various Swarm instruments, optimise the sampling in space and time. This helps to distinguish between the effects of different sources of magnetism.

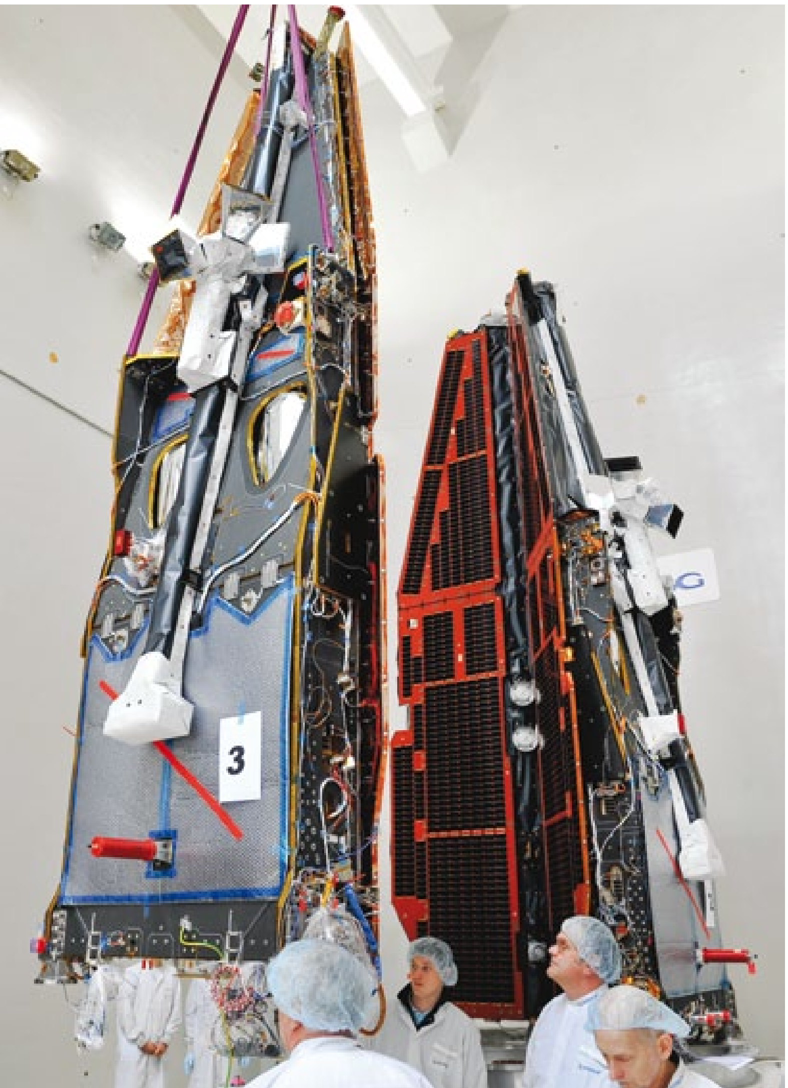


← Two of the trapezoidal Swarm satellites mounted together vertically as they would be under their launcher fairing, with space on the left for the third (ESA/IABG)



↑ A Swarm satellite in the Space Simulation Chamber at IABG, Ottobrun (ESA/IABG)

↓ IABG's centre in Ottobrunn opened its gates on 17 February, when international media representatives were granted access to see the three Swarm satellites (ESA/IABG)



Technological excellence

Swarm had to be designed to cope with a number of highly demanding constraints: a non-Sun-synchronous low Earth orbit, fitting three satellites within one rocket fairing, accommodation of instruments, a small and defined cross-section for reducing air drag (fuel is limited for orbit maintenance), provision of sufficient solar array area, accommodation of units including propellant tanks, 'magnetic cleanliness' near the magnetometers, and avoidance of micro-vibrations to ensure a quiet environment for the accelerometers.

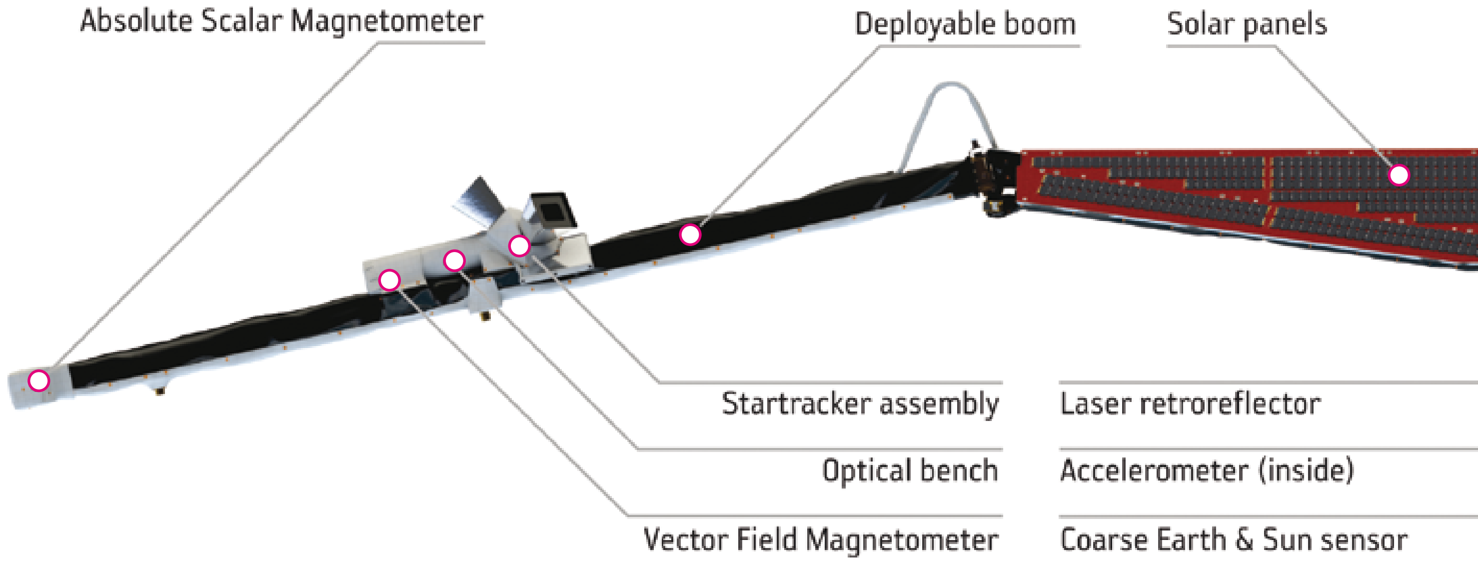
These requirements led to a set of particular design features: a long deployable magnetometer boom, an ultra-stable optical bench, a high ballistic coefficient and body-mounted solar arrays to cover the range of solar aspect angles expected.

To get good magnetic measurements from the magnetometers, the satellites have to be as magnetically clean as possible. Therefore, the magnetometers are placed at the ends of long booms away from the satellite body because their own magnetic fields reduce in proportion with the cube of the distance from the satellite.

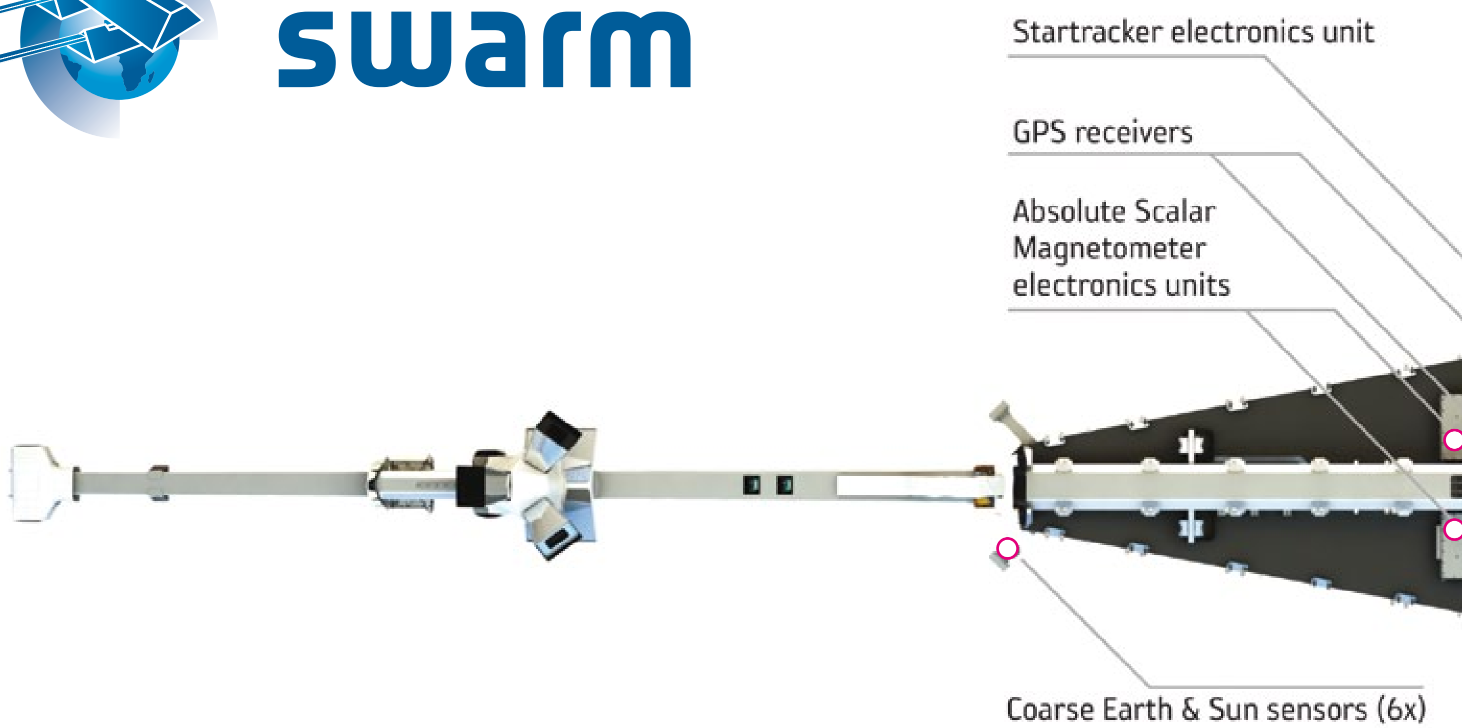
Magnetic disturbance is minimised by using appropriate materials, a well-proven electrical grounding concept, self-compensating wiring for power harnesses, batteries and solar arrays, and careful calibration and assembly/integration processes.

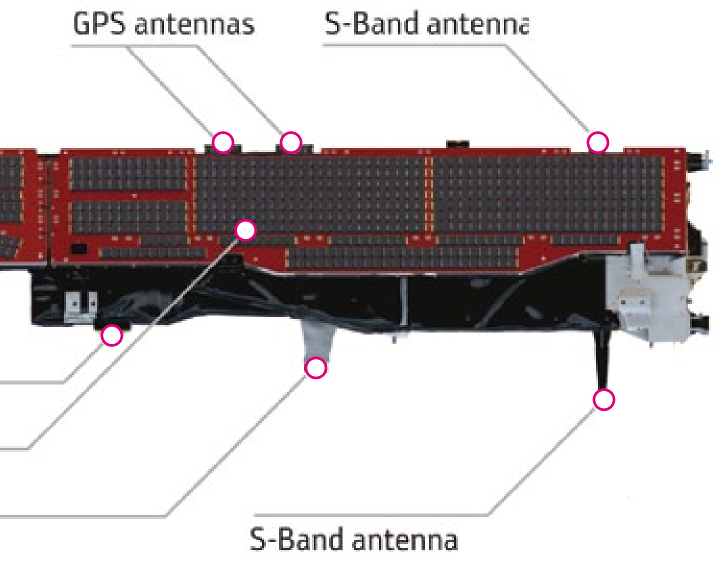
Specific focus has been placed on the design of the optical bench carrying the Startracker assembly and Vector →

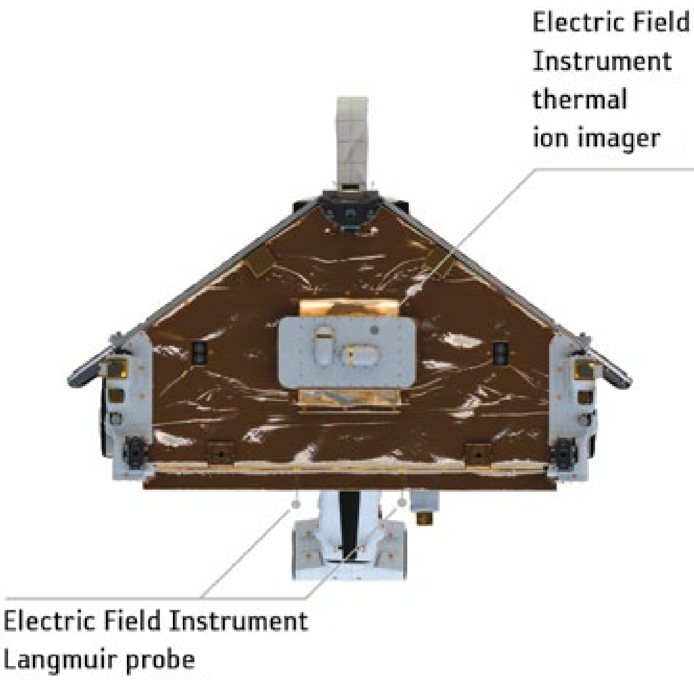
→ ESA'S MAGNETIC FIELD MISSION

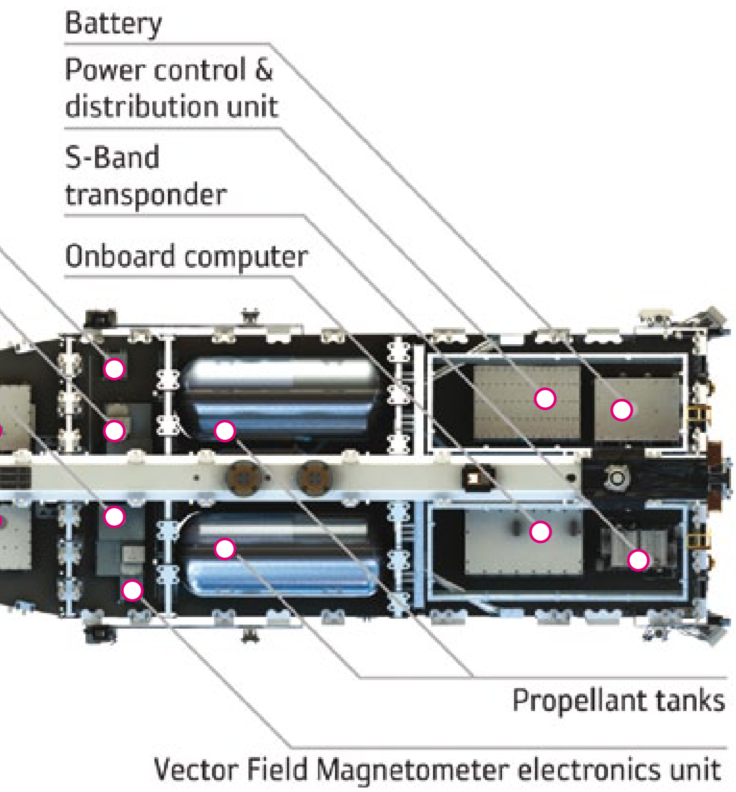


swarm









→ Facts and figures

Dimensions: length (boom deployed) 9.26 m, (boom stowed) 5.04 m, width 1.5 m, height 0.85 m

Mass: 473 kg

Power: two body-mounted solar arrays (two panels per array), gallium arsenide cells in series delivering 608 W; a set of 48 Ah lithium ion batteries

Onboard computer: 6 MB memory, allowing autonomy of satellite for more than three days

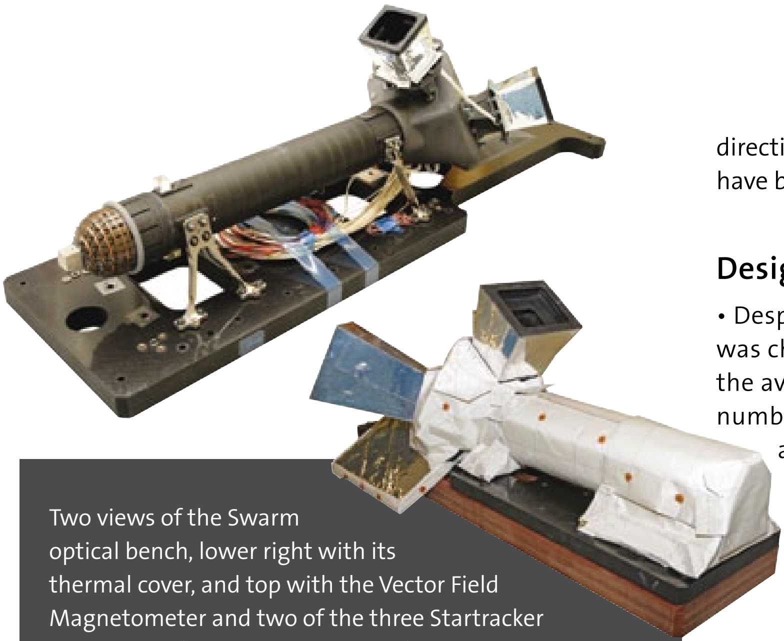
Attitude and orbit control:
magneto-torquers (10 Am^2 moment) and cold-gas thrusters (20 and 50 mN) actively control and maintain attitude on all three axes

Science data downlink:
6 Mbit/s (to Kiruna ground station)

Data processing, distribution and archiving: ESRIN

Mission life: four years (plus three-month commissioning period)

Prime contractor: EADS/Astrium GmbH



Two views of the Swarm optical bench, lower right with its thermal cover, and top with the Vector Field Magnetometer and two of the three Startracker units visible (EADS/Astrium GmbH)

→ Field Magnetometer. The stability of the bench greatly influences the quality of the magnetic data product. The proposed design is based on best technology available.

To receive optimum ionospheric and magnetic signals, Swarm has been designed to fly in a particularly low orbit, between 530 km and 300 km above Earth. The shape of the satellite minimises aerodynamic drag effects and torque, and therefore propellant gas consumption. The mass and volume of the satellites were also limited by the capacity of the small low-cost launchers such as Vega, Rockot or Dnepr.

In turn, this compatibility limited the length of the boom, and meant coming up with a new design of lightweight structure. Orbit definition for the constellation was also a factor in the design, because the three spacecraft need to reach different orbits. Only indirect orbit injection was possible with this class of launcher, which justifies the large quantities of propellant gas carried by each satellite.

The result is three slim, trapezoidal satellites, each about 9 m in length (with boom deployed) and weighing 473 kg, using the maximum available volume under the Rockot fairing. The satellites are symmetrical about their flight direction. The sides of the satellites that face the Sun each have body-mounted solar panels.

Design features

• Despite its low specific impulse, cold-gas propulsion was chosen for the reaction control system because of the availability of low-force thrusters qualified for the number of times they would be fired. 'Freon' was chosen as the propellant gas over the standard nitrogen to reduce the volume of the tank in order that fitted inside the spacecraft and launcher fairing. Reaction wheels were not an option because of magnetic and vibration effects.

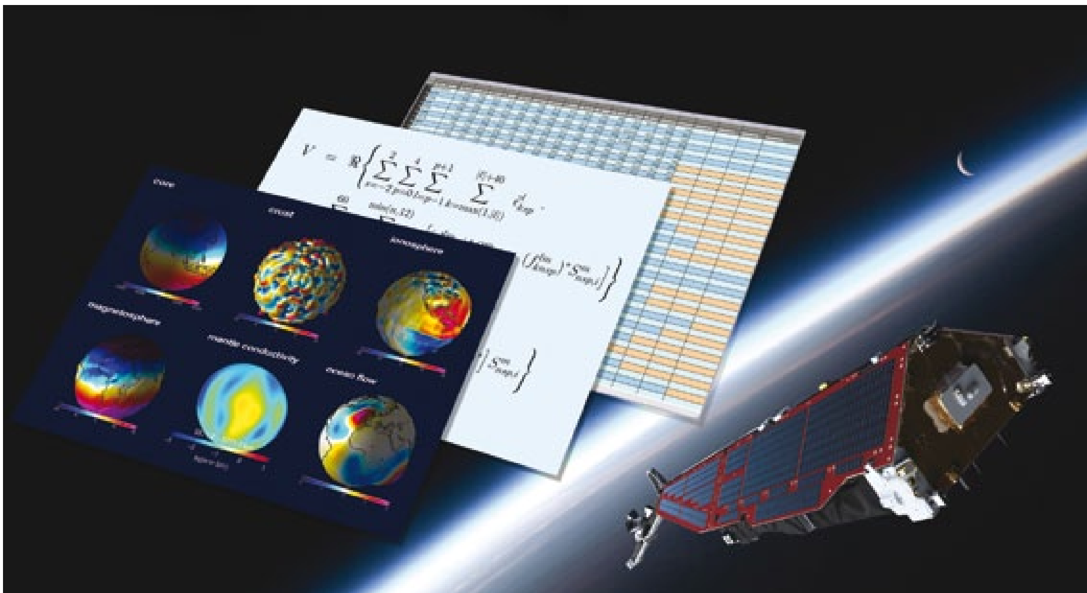
• The micro-accelerometer has to be within 5 mm of the centre of mass of the satellite. For this, the two tanks full of propellant gas are positioned on each side of the micro-accelerometer connected by a pipe. As gas is consumed after a satellite manoeuvre, the level of gas in each tank is the same and the centre of mass remains in the same position. This design allows the measurement of non-gravitational forces.

• The main structure of the satellite is made of carbon-fibre reinforced plastic. This material offers thermal stability, savings on mass and the avoidance of eddy current effects that can be encountered with large aluminium sheets.

• The power system is optimal for electromagnetic compatibility and magnetic cleanliness. The configuration of the solar arrays was optimised to take into account the single launch requirement of limited fairing space.

The launcher

The launcher selected for placing Swarm into orbit with a single launch is the Rockot-KM, procured by ESA through a dedicated contract with Eurockot GmbH based on the experience gained through other ESA missions. The three Swarm satellites will be installed on a Breeze-KM upper



←

Swarm will deliver products to study Earth's magnetic field and its interaction with the Sun, which will benefit a broad range of applications in Earth sciences and space weather (ESA/AOES Medialab) stage using an adapter/dispenser system specifically designed for this mission by Khrunichev Space Centre and Salyut Design Bureau of Moscow.

Constellation operations

The Flight Operations Segment is responsible for operating Swarm in orbit. It is in charge of communications with the satellites, ensuring their good health, maintaining orbits, executing payload activities requested from mission management and delivering the science data and housekeeping telemetry to the processing centre.

This segment comprises the mission control centre at ESOC (Darmstadt, Germany), the primary ground station at Kiruna (Sweden), and reinforcement stations for critical mission phases at Svalbard (Norway), Troll (Antarctica) and Perth (Australia). The most critical mission phase is the launch and early orbit phase. Lasting about three days, this phase will be handled by the large mission control team. During this period, an exciting moment will be the first acquisition of signal following the separation of the satellites from the launcher, and checking the successful activation of all essential units. Several hours after launch, the 4 m booms are deployed on each of the satellites.

Next comes a three-month orbit acquisition and commissioning phase, in which a complex sequence of manoeuvres and drifting periods are carried out to gradually reach the correct orbits for operations. The payloads of each satellite are activated, checked and characterised.

In the routine mission orbits, operations will be largely automated, with a reduced number of contacts and a relatively simple planning of science-related activities. During the operational phase of four years, the orbits of the satellites are left in free decay, except for manoeuvres on the lower pair of satellites to avoid collision when satellites cross each other at the poles or for constellation maintenance. This ensures adequate space and local time sampling of the magnetic field to support the separation of the different magnetic field contributions to advance science.

→ 'A Journey to the Centre of the Earth'

Classic science-fiction writer Jules Verne imagined an exciting expedition to the centre of Earth, but the reality is less romantic. The heart of our planet remains inaccessible to direct observation. While Verne's story describes a passage to the Earth's core through an extinct volcano in Iceland, in fact the deepest hole ever drilled by humans is located on the Kola Peninsula in Russia.

Called the 'Kola Superdeep Borehole', this dig was started in 1970 with the aim of reaching the 'Mohorovičić discontinuity', or 'moho', which is where the crust and mantle intermingle. This was never completed and the hole is currently 12 km deep, a mere scratch in thin surface of our planet. But even if it was possible to dig a hole to Earth's centre, 6350 km deep, we would not be able to survive the high temperatures and pressures that exist there: 6000°C and 360 gigapascals!

So the core is inaccessible, but not completely invisible – because it is possible to explore the centre of Earth virtually, using seismology. Data captured by seismographs all over the world allow us to map the structure of Earth. Scientists now believe Earth has a liquid iron external core and a central solid iron nucleus.

There are other ways to penetrate the depths of our planet, to explore this ultimate 'terra incognita' despite the impossibility of venturing there. Scientists have a number of solutions, such as studying Earth's 'polar wander' (the small wobbles in its axis of rotation) or the variations of acceleration due to gravity for example. All these phenomena offer a lot of information on deep Earth dynamics and especially on the convection movements in the iron ocean around the core, confirmed after over 400 years by magnetic observatories or more recently by Ørsted and CHAMP satellites.

But no other single physical quantity can be used for such a variety of studies related to our planet as the variation of its magnetic field. Highly accurate and frequent measurements of the magnetic field will provide a unique map of mantle conductivity and a new view of the core field.

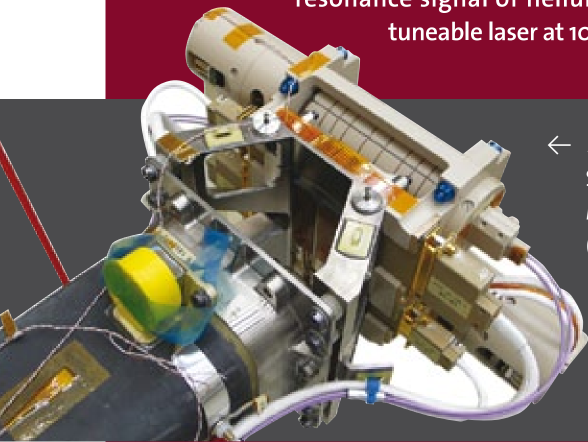
This virtual picture of Earth can be compared to the rich imagination of Jules Verne, more than a century ago. Swarm will contribute to this virtual picture by providing new insights into our planet's formation, dynamics and environment, from the Sun to the centre of the Earth.

→ Instruments

Swarm takes advantage of a new generation of magnetometers. An electric field instrument, an accelerometer and GPS receivers will deliver supplementary information to study the interaction of Earth's magnetic field with solar winds, electric currents and radiation, and their effects on the Earth system.

Absolute Scalar Magnetometer (ASM)

This novel instrument will measure the magnetic field to an accuracy greater than any other magnetometer. The ASM is an 'optically pumped metastable helium-4 magnetometer', developed and manufactured by CEA-LETI in Grenoble (France) under contract with CNES Toulouse. It provides scalar measurements of the magnetic field for the calibration of the vector field magnetometer using a technique based on enhancing the magnetic resonance signal of helium atoms with a tuneable laser at 1083 nm.

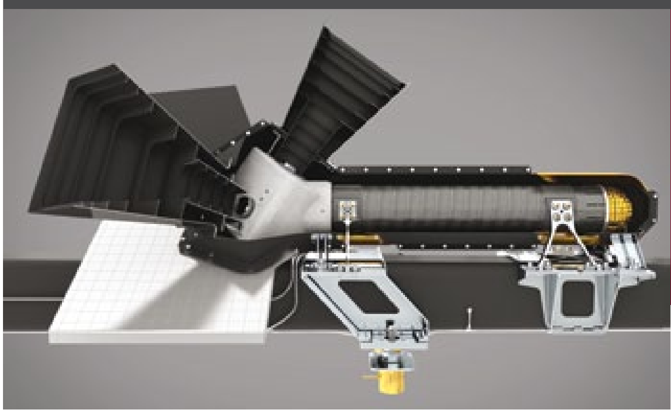


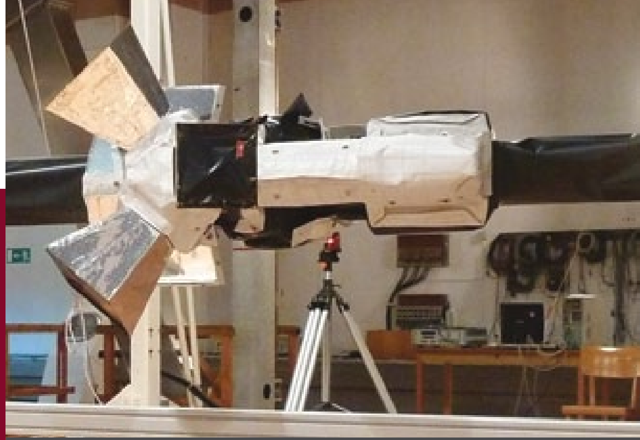
← Absolute Scalar Magnetometer (EADS/Astrium)

Vector Field Magnetometer (VFM)

This core instrument will make high-precision measurements of Earth's magnetic field vector components. It was developed and manufactured at the Technical University of Denmark based on heritage from many previous satellite missions as well as sounding rockets and stratospheric balloons.

↓ Vector Field Magnetometer on the right (ESA/AOES Medialab)





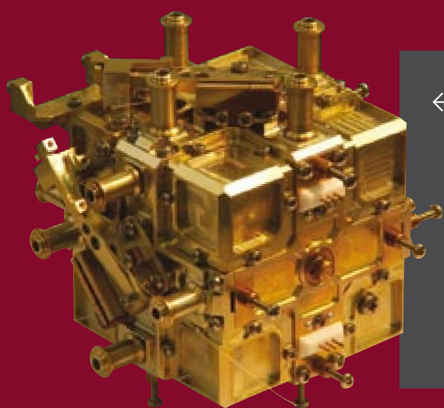
↑ Startracker assembly (at left of VFM) (ESA/IABG)

Startracker assembly

This unit provides high-precision attitude data, primarily needed to determine the orientation of the magnetic field vector measured by the Vector Field Magnetometer. The attitude information is also used by the satellite's attitude and orbital control system to establish a fine-pointing mode during normal operations and the orientation of other instruments. This latest generation of startracker was developed and manufactured at the Technical University of Denmark, based on heritage from many previous satellite missions.

Micro-accelerometer

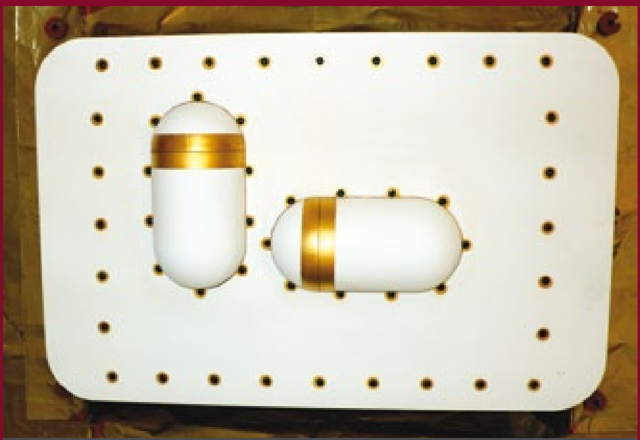
These units will measure the satellites' non-gravitational accelerations in their respective orbits, which in turn will provide information about air drag and solar wind forces. Air density models will be derived from these products and will be used together with magnetic data to obtain new insights on the geomagnetic forcing of the upper atmosphere. The instrument was designed and manufactured by VZLU (Czech Republic) supported by Czech subcontractors – the first time that ESA has contracted an instrument of this complexity to Czech industry.



← Accelerometer sensor (VZLU)

Electrical Field Instrument (EFI)

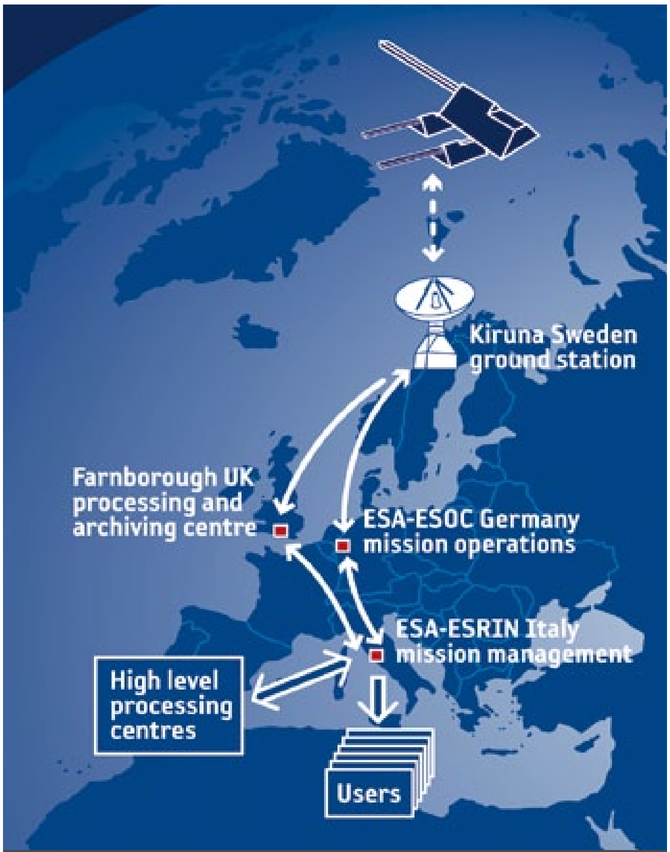
To characterise the electric field around Earth, this instrument will measure plasma density, drift and acceleration at high resolution. It is the first ever three-dimensional ionospheric imager in orbit, with an ingenious thermal ion imager design from the University of Calgary (Canada) and a unique concept for the sensors of the Langmuir probe from IRFU, Uppsala (Sweden). The instrument was developed by ComDev (Canada) with scientific support of the University of Calgary for the thermal ion imager sensors. The power supplies were developed by CAEN SpA (Italy). A Langmuir probe assembly is included with the instrument to provide measurement of electron density, electron temperature and spacecraft potential.



↑ Electrical Field Instrument thermal ion imagers (EADS/Astrium)

GPS and laser retroreflector

The precise orbit determination of the Swarm satellites will rely on the data of the GPS receiver. Each satellite is equipped with a laser retroreflector to validate the GPS system. Swarm is supported by the International Laser Ranging Service that provides satellite laser-ranging observation data from a network of stations around the world. The GPS receiver (RUAG, Austria) is used firstly as the orbit sensor to provide a real-time navigation solution (position, velocity and time) to the attitude and orbit control system and secondly as a sensor generating raw measurements data (code and carrier phases) as required for precise orbit determination and total electron content measurements. The laser retroreflector for Swarm was procured as a rebuild of existing ones from the GeoForschungs Zentrum Potsdam, that have been used on previous satellite missions such as CHAMP, GRACE and TerraSAR-X.



↑ Swarm's ground segment (ESA/AOES Medialab)

Products and user community

The Swarm Product Data Ground Segment at ESRIN (Frascati, Italy) is the point of access for the scientific community to collect the scientific data from all the instruments on each satellite (Level-1b) and advanced products either per satellite or from a constellation analysis (Level-2).

Typically, for studies of Earth's interior, global models of the core and crust and conductivity maps of the mantle (Level-2) are made available. These are produced for ESA by a consortium of specialists from six European academic institutes with support from consultants in the USA and Czech Republic. For example, for studies of the upper atmosphere, which are usually of a more local nature, magnetic field measurements are provided, and also products per each satellite that contain information about the atmospheric conditions such as ion velocity and direction, ion and electron temperature (all Level-1b), neutral density and winds (Level-2).

The unique combination of local and global products will allow users to address today's scientific open questions. Swarm will deliver products to study Earth's magnetic field and its interaction with the Sun, which will benefit a broad range of applications in Earth sciences and space weather. ■

→ ALL THE SPACE YOU CAN USE

The next decade of the International Space Station

Nadjejda Vicente
Directorate of Human Spaceflight and Operations,
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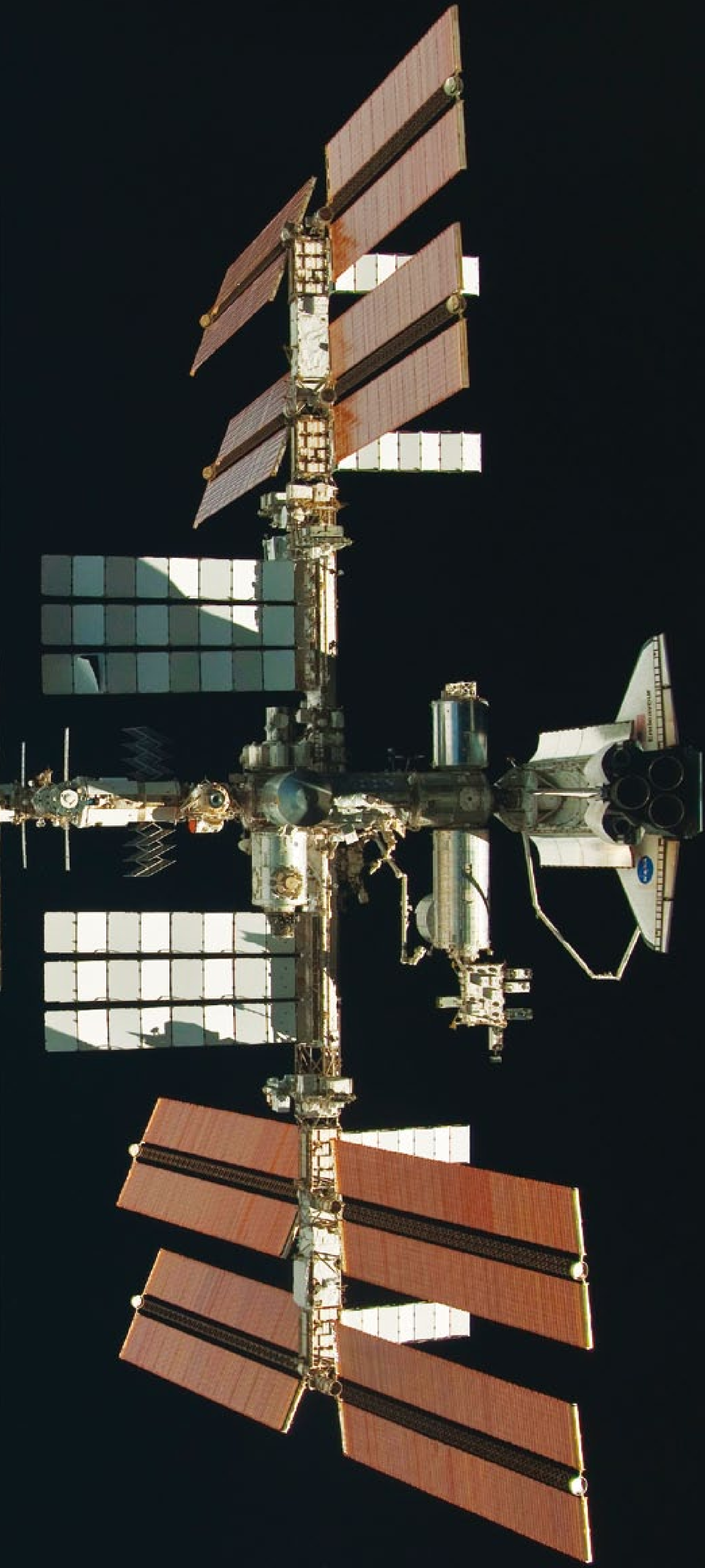
Julien Harrod and Carl Walker
Communication Department,
ESTEC, Noordwijk, The Netherlands



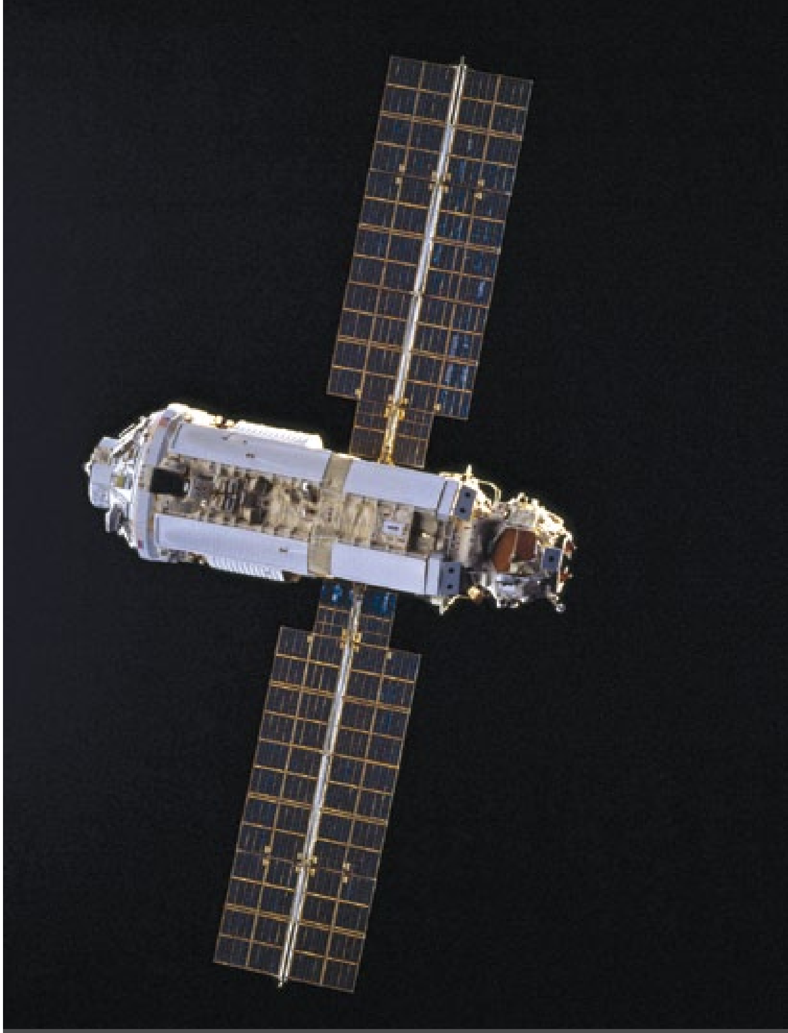
The ISS with both ATV *Johannes Kepler* and Space Shuttle *Endeavour* docked, as seen by ESA's Paolo Nespoli from Soyuz TMA-20 in May 2011 (ESA/NASA)

One of the most ambitious space projects ever undertaken, the International Space Station has been crewed for over a decade, but more importantly, its five partner space agencies still have many years of ISS use ahead of them.

Scientific research on the ISS is increasing our knowledge of the Universe and creating tangible benefits for people on Earth – today. The first results from this amazing structure are now coming to light, but this is only the beginning, because the ISS will continue to operate for at least another eight years. We may not know yet what will be the most important discoveries gained from the Space Station, but we already have some fascinating breakthroughs.

For decades, experiments in space have answered numerous scientific questions and inspired technological development. Last year, the ISS was completed after nearly 13 years of construction, and the number of scientific activities relating to the effects of long-term microgravity on the human body reached a record high.

This long-awaited utilisation phase has been the dream of the ISS project since its beginnings in the 1990s. However, during construction, assembly and maintenance activities would take priority over scientific experiments. Now the opposite is true, meaning more crew time is available for science. In this utilisation phase, a minimum of 35 hours of ISS crew time per week is devoted to scientific activities, and several crews have exceeded that requirement.



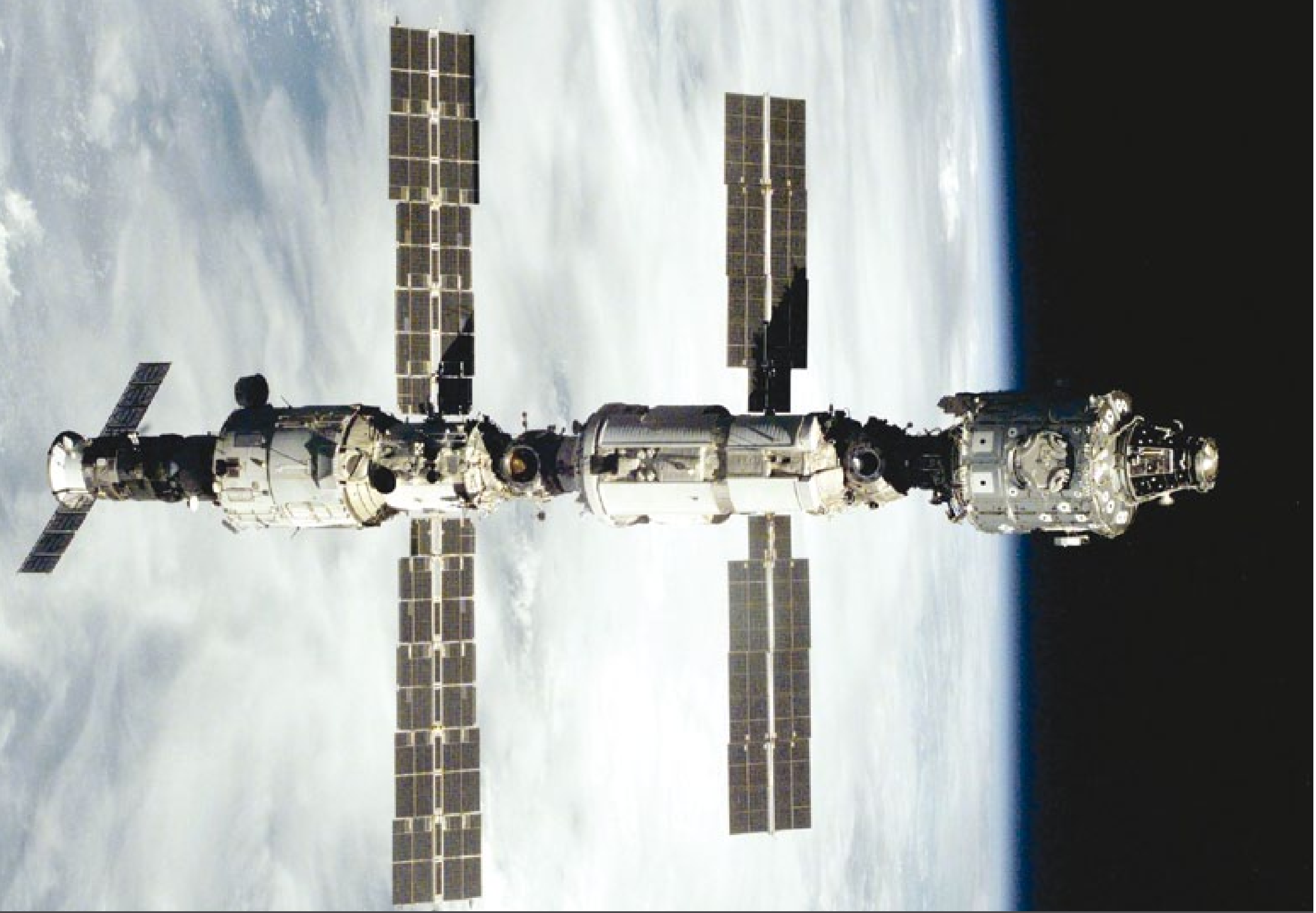
↑ Construction of the ISS began in 1998, when the first module Zarya was launched on a Russian Proton rocket (NASA)

When science meets space

The ISS is a unique environment: it is the only permanent 'weightless' laboratory available to scientists and a platform to conduct research that cannot be performed in any other way. Gravity affects almost everything we do on Earth. In orbit, its effects virtually disappear and are replaced by microgravity conditions, or 'weightlessness'. Here, scientists are conducting pioneering investigations in many fields, testing and modifying existing theories, and pushing the boundaries of our knowledge.

Compared with earlier space stations, the ISS provides substantially more opportunities for carrying out experiments, either on scientific 'racks' inside the Station or at special attachment points outside. This is because the ISS has a larger internal volume, more computing power, more electrical power and an extended lifetime that allows scientists to conduct experiments over longer periods with a continual flow of data.

> **“If we stop investing in space, we will harm our economies.”**
>
> Dr Julie Robinson, ISS Programme Scientist at NASA



↑ Two weeks after Zarya's launch, the STS-88 Shuttle mission carried Unity, the first of three node modules, and connected it to Zarya. This two-module core remained unmanned until the Russian module Zvezda was added in 2001, allowing a crew of two astronauts to be on the ISS permanently. Here are Zvezda, Unity and Zarya seen from STS-106 (NASA)

This long-term aspect means that studies can be performed over many years. For example, living on the ISS for longer periods gives researchers insights on how the human body changes when it is exposed to weightlessness over more time. These data are important to study phenomena with high latency, such as bone loss and osteoporosis, that are very relevant to public health. This will also help us to understand how astronauts cope on longer trips, possibly to other celestial bodies or planets.

Model for cooperation

The ISS is one of the most important projects of mankind in space today, not only in terms of its science, but also because of what it represents in international cooperation.

ESA's Director General, Jean-Jacques Dordain, said that after the ISS programme, the world would never be the same again. The global partnership of 14 nations has not changed since 1998, and has overcome major financial, political and technical difficulties.

"The ISS partnership is a model for whatever we as humans want to do in the future," said Berndt Feuerbacher, President of the International Astronautical Federation and chair of ESA's Human Exploration Science Advisory Committee.

Certainly one of the triumphs ascribed to the ISS is the spirit of solidarity and cooperation in operating it jointly, and its influence on the peaceful interaction of nations on Earth cannot be underestimated.

What is planned for the future?

The ISS has been operational for nearly three years, with a permanent six-person crew and all international partnership laboratories deployed. "All partners have invested a lot in the build-up of this fantastic infrastructure and we are looking into almost a decade of intensive and effective use of the ISS," said Thomas Reiter, ESA's Director of Human Spaceflight and Operations and himself a former ISS astronaut.

Now looking at a broad range of utilisation ideas and objectives, all five partners have agreed on making the ISS as attractive as possible to the widest range of research studies. A fruitful competition among European scientists to get their experiments on the ISS is already taking place.

← Cosmonaut Sergei Krikalev uses a camera in the Zvezda module a few days after the arrival of the ISS's first crew, Expedition 1 (Krikalev, William Shepherd and Yuri Gidzenko) in November 2000 (NASA)

According to Jean-Jacques Dordain, "In Europe, the ISS utilisation demand is much higher than the available resources, but a world without competition is not an interesting world."

Many agencies are using the ISS to research further space exploration technologies. The Russian space agency Roscosmos is looking at improving space systems, such as airlocks as well as developing new inflatable modules. The Japanese space agency JAXA is focusing on the field of biomedicine at progressively larger scales: from microbes and plants, to humans. NASA is allowing commercial companies to take on the transportation role, to focus on science and using the ISS as a platform for exploring beyond low Earth orbit.

Different plans, different paths, but working all together on a unique permanent platform in space. Space agencies may not want to explore the same areas at the same time, but as Jean-Jacques Dordain says, "The Space Station is a start of cooperative endeavours to explore further. Each step we are making in space is a step for the future of planet Earth. Now the key question is how we should extend the current partnership. The future is cooperation with more international partners and no one is excluded."

Return on investment

All ISS partners stress the challenging budgetary situation, which demands coordinated efforts to maximise return and benefits. To make the ISS and space in general a sustainable activity, there is an urgency to have short-term benefits and a long-term exploitation vision.

"Space is not a cost, but an investment," says Jean-Jacques Dordain. A unique opportunity rather than an unjustified waste of resources, the ISS is advancing frontiers of research and development, a key factor for economic growth on Earth.

The ISS is increasing our knowledge and boosting industrial growth by creating business cases with new

"Our future is open. What happens depends on us, on our ability to fight for our own ideas, as well as our ability to cooperate with everybody."

Prof. Heinz Riesenhuber, Member of the Federal German Parliament and former Research Minister applications for the market. A common ambition is to open up competitively the ISS facilities to the best brains of the world, whose experiments promise radically new technologies that can have a substantial economic impact.

So all agencies are committed to decreasing operational costs and shortening the time between submitting research proposals to flying experiments on the ISS. All organisations, from universities and industry research groups to commercial companies, are invited to submit proposals and, by using an open invitation model, as many communities as possible can benefit from ISS research.

From space to your doorstep

Scientific results or samples from experiments on the ISS may not directly save a life or cure a disease, but they can be a crucial step on the way to achieving these goals. The ISS is offering its laboratories to diverse research that ultimately translates into new applications and benefits for people on Earth.

Researchers are queuing to conduct research in the Station's weightless environment, but they know that developing concrete applications based on science is not easy. Protocol barriers and timescales can be an issue. "Often scientists and engineers do not talk to each other in detail about their objectives and problems. An experiment usually needs a different set up from real casting processes in industry. Hence close collaboration is essential to achieve maximum impact," says Robert Guntlin, Managing Director of Access, an independent research centre associated with the Technical University of Aachen in Germany.

By understanding what the scientists need on the experimental side and linking it to engineers' demands for industrial processes and products, different timescales can be matched. "A healthy amount of patience is a good ally, especially in fundamental research," says former astronaut Christer Fuglesang, now Head of Science and Applications in ESA's Human Spaceflight and Operations Directorate. "Research takes time. The reward for humankind will be tremendous if we can take the time to wait for the results to come."

Multidisciplinary research teams are a functional way to link engineers and scientists to produce optimum results, relying on better exchange of information across research fields. Making research data available in a common format is seen as a great way to speed advancements and promote new ways to use results obtained.

Exploration is not fast, nor is it cheap or easy. But ultimately, it is worth it. "Exploration holds high risk, but a lot of economic benefits come from it. We can't even

↑ The ISS provides opportunities for carrying out experiments on scientific 'racks', one of which here seen during installation by Expedition 20 crewmember Bob Thirsk (NASA)

↓ ESA astronaut Christer Fuglesang aboard Shuttle *Discovery* in 2006, now Head of Science and Applications in ESA's Human Spaceflight and Operations Directorate (NASA)

> **As soon as space benefits become available to the public, people forget that space did it. Just as they forget that their car satnav system needs satellites to be launched and maintained, they do not realise how important the ISS was in creating modern appliances**
>
> Prof. Mike Cruise, Chair of the ESA Physical Sciences Working Group

→ ISS Symposium 2012

The ISS Symposium was held in Berlin in May. Nearly 300 international scientists, politicians, media and representatives of industry, national agencies and all five ISS partner agencies gathered together to review the main achievements of the orbital outpost.

Space experts had the opportunity to look at case studies in fundamental and applied research and the latest spin-offs for the benefit of humankind. They also indicated the way forward with research objectives that broke new ground.

Keynote speaker, NASA Administrator Charles Bolden, "We are all trying to make life better for people here on Earth, and by doing so we also enhance our ability to explore beyond low Earth orbit and, one of these days, proceed further into our Solar System."

↑ Jean-Jacques Dordain addresses the ISS Symposium 2012 in Berlin (ESA/J. Mai)

← The ISS Symposium was a unique occasion to showcase results of scientific research from the ISS. The 'ISS Utilisation Exhibition' displayed experiments and instruments used in space, that lead to spin-offs for the benefit of people on Earth. Commercial companies presented state-of-the-art products and technologies whose scientific foundations were laid on the ISS. Here ESA's Paolo Nespoli (right) and Alessandro Donati (second from left) take delegates on a tour.

imagine the benefits that will come out of future space exploration," says Nicole Buckley, the Canadian Space Agency's Chief Scientist for ISS and Life Sciences.

Global cooperation in the human exploration of space has already started. Economic progress, innovation, inspiration and increased knowledge await all who join the endeavour. In the years to come, when humankind conquers new frontiers in space, the value of such a versatile and complex platform will be fully appreciated.

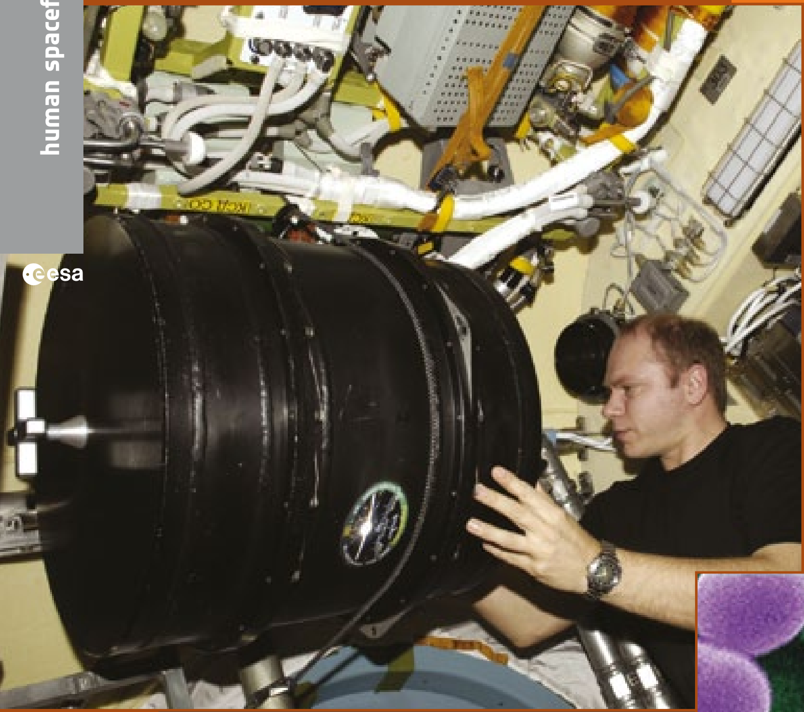
In Thomas Reiter's words, "For planet Earth and our journey beyond, let's keep researching to better understand our world, and to utilise and explore space." ■

- Nadjejde Vicente is an HE Space writer for ESA
- Julien Harrod is an EJR-Quartz writer for ESA

→ MADE IN SPACE

Many impressive results are already flowing from Space Station research, increasing our knowledge and creating tangible benefits on Earth – right now

→ Health care



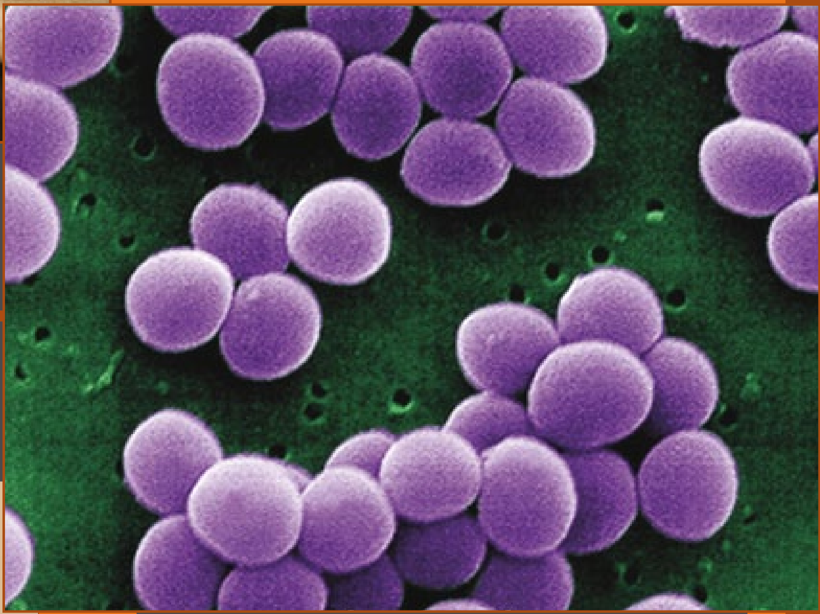
↑ Cosmonaut Oleg Kotov with the PK-3 Plus plasma experiment system on the ISS (NASA)

↓ Plasma therapy demonstrated at the ISS Symposium in May

From 3D crystals to reinventing hygiene

Over 30 different experiments have been carried out on the ISS to study 'cold plasma'. This research has found that this plasma can kill bacteria in a form closer to room temperature, and therefore not damage human tissue. As a technology spin-off, applications using cold plasma sterilisation are being tested today in clinical trials.

Using this electrically charged gas, plasma therapy may save many lives with the touch of a button. Such a breakthrough could become vital to medical science in the struggle to fight superbugs that are increasingly resistant to antibiotics. In just 30 seconds, plasma irradiation can kill 20 million resistant bacteria without harming human beings.



↑ Experiments on the ISS have been instrumental in developing plasma-based tools that can be used to kill bacteria in hospitals, such as potentially deadly strains of resistant *staphylococcus aureus*, also known as MRSA (CDC/M.J. Arduino/DRPH/J.H. Carr)

This revolution in healthcare can also be used to sanitise plants and cure symptoms of genetic disorders, and we can even expect to see commercial sanitisers for use in our homes. Worldwide agriculture will benefit too: chickpea seeds exposed to cold plasma treatment show 50% faster growth.

↑ ESA astronaut André Kuipers and his NASA colleague Dan Burbank ate a special diet for ESA's SOLO experiment (NASA/ESA)

Battle against bone loss

Osteoporosis is a harsh disease that reduces the quality of life for millions and costs Europe around €25 billion each year. It typically affects the elderly, so the rise in life expectancy in developed countries means the problems inflicted by osteoporosis are increasing. Astronauts experience accelerated osteoporosis because of weightlessness, making them the ideal guinea pigs for osteoporosis research. Scientists are looking at salt as a possible cause for this bone loss, a finding that some believe will change current thinking. ESA's recent SOLO, or 'Sodium Load in microgravity', experiment studied this aspect.

Immune cell death tracked down

New results are offering clues to why astronaut immune systems weaken in space. In 2008, ESA flew the ROALD experiment to the ISS, confirming that the 5-LOX enzyme is partly responsible for immune cell death. This enzyme can be blocked with existing drugs, so improving health in people with reduced immune response could be soon a reality.

Former NASA Shuttle astronaut Millie Hughes-Fulford, who flew on STS-40, the first dedicated medical mission, explained in a very graphical way the role of new drugs: "If you think about the immune system as a small river turning into a big river going to a waterfall, the drugs we are using now are treating the waterfall. With MicroRNA drugs, we treat the raindrops in the mountains, so we could potentially regulate our whole immune system."

↑ "Where the robot entered my head," says 21-year old Paige Nickason, the first patient to have brain surgery performed by NeuroArm, the world's first robot capable of performing surgery inside an MRI scanner. NeuroArm uses technology born from the Canadarm, as well as Canadarm2 and Dextre, the Canadian Space Agency's family of space robots used for maintenance on the ISS (CSA/J. Stang)

→ NASA astronaut Millie Hughes-Fulford during STS-40 in 1991 (NASA)

Brain surgery or rocket science?

Expertise in robotic arms developed for the ISS and spin-off technology is being used in hospital operating theatres. A robot as dexterous as the human hand, but even more precise and tremor-free allows for more accurate microsurgery operations, making neurosurgery possible even while the patient is in a magnetic resonance machine. Autonomous life support systems and telemedicine are being widely tested in space and will be indispensable on future interplanetary exploration missions.

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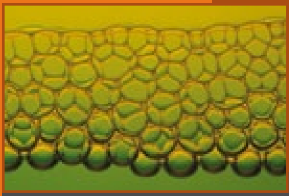
→ Industrial applications

Coffee, cars and cranes

Research in microgravity has led to advances in metallurgy, particularly the production of metallic foams – blocks of metal that contain bubbles – that are strong, light and provide a cushioning effect on impact.

"Foams are unstable, and therefore harder to study in gravity," said Prof. John Banhart from the Technical University of Berlin. The automotive industry is excited by these developments and lightweight crane lifting arms are already using this technology.



↑ Study of foams in space can benefit the food industry (GRASP/Uni. Liège/D. Terwagne)

The behaviour of bubbles in microgravity has also caught the attention of Nestlé, the world's largest packaged food company. The Swiss group is hoping to continue its microgravity research on the ISS to enhance the taste and shelf life of a range of its products from chocolate mousse to coffee.

← Research on alloys in space is being used to develop jet engines that can operate at even higher temperatures and hence use fuel more efficiently (Rolls-Royce plc)

Super alloys to fly further and save energy

High-performance turbine blades made from titanium/aluminium alloys could lead to a 50% reduction in the weight of a typical jet engine, which would reduce fuel consumption and emissions from air travel. This is especially relevant for the aviation industry where, in the next four years, over one million blades need to be made for new aircraft.

→ Fundamental Physics

The Station's crown jewel

Space is the ultimate laboratory for high-energy particles detection. The Alpha Magnetic Spectrometer (AMS-02) is a huge, state-of-the-art cosmic-ray detector, designed to examine fundamental properties of matter and antimatter and explain the origin of the Universe. The machine measures quantum particles and has already collected 13 billion measurements in its first 10 months of operation. By the middle of this decade, AMS-02 will be able to quantify the entire spectrum of extragalactic cosmic rays in low Earth orbit. Weighing around 8 tonnes, AMS-02 is not only the largest and most complex scientific instrument on the ISS, but also the largest international collaboration on a single experiment in space, with over 600 scientists from 60 institutes working on the project.

↑ The Alpha Magnetic Spectrometer (AMS-02) seen on the ISS during the STS-134 Shuttle mission in 2011: a state-of-the-art cosmic-ray detector, the largest and most complex scientific instrument on the ISS (NASA)

← ACES seen here attached to the Columbus laboratory, lower right

What time is it?

Currently, atomic clocks are the most precise way of keeping time and are used to test laws of quantum physics with extreme precision. The Atomic Clock Ensemble in Space (ACES) is an ESA experiment in fundamental physics based on a new generation of atomic clocks – an active Space Hydrogen Maser and the PHARAO cold-atom clock provided by the French space agency CNES.

In the second half of this decade, the most precise measurement of time yet – in space – will be used to probe our knowledge of the fundamental laws of physics governing the Universe. ACES will test Einstein's general relativity and alternative theories of gravitation. Taking full advantage of the microgravity environment and worldwide coverage provided by the ISS, ACES will establish a stable and accurate onboard timepiece that will be used to perform space-to-ground and ground-to-ground comparisons of best available atomic frequency standards.

The combination of high-temperature resistant, high-strength and lightweight alloys makes these materials ideal for jet turbine blades. By observing how these metals solidified in microgravity, scientists and industry are able to understand better the physical process and developed advanced casting techniques for complex blade shapes, relying on centrifuges to spread the liquid alloy in its mould. "Without the research in space, this type of turbine blade would never have been made," said Jean-Jacques Dordain, ESA Director General.

To help further refining industrial casting processes and products, the Electromagnetic Levitator facility (a joint ESA/DLR development) will soon operate in the Columbus laboratory. It can be used for the melting and solidification of conductive metals, alloys or semiconductors, in ultra-high vacuum, or in high-purity gaseous atmospheres. Thanks to the weightless environment and the electromagnetic fields generated by a coil system, melting and solidification can take place without containers.

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→ Earth and space monitoring

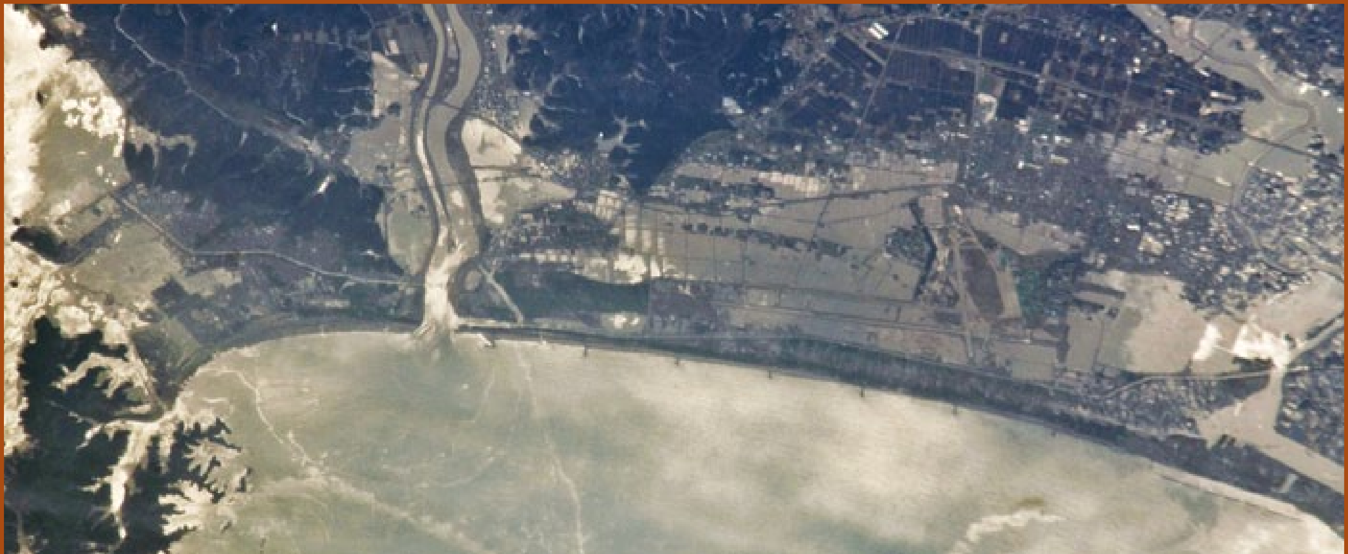
Night watch

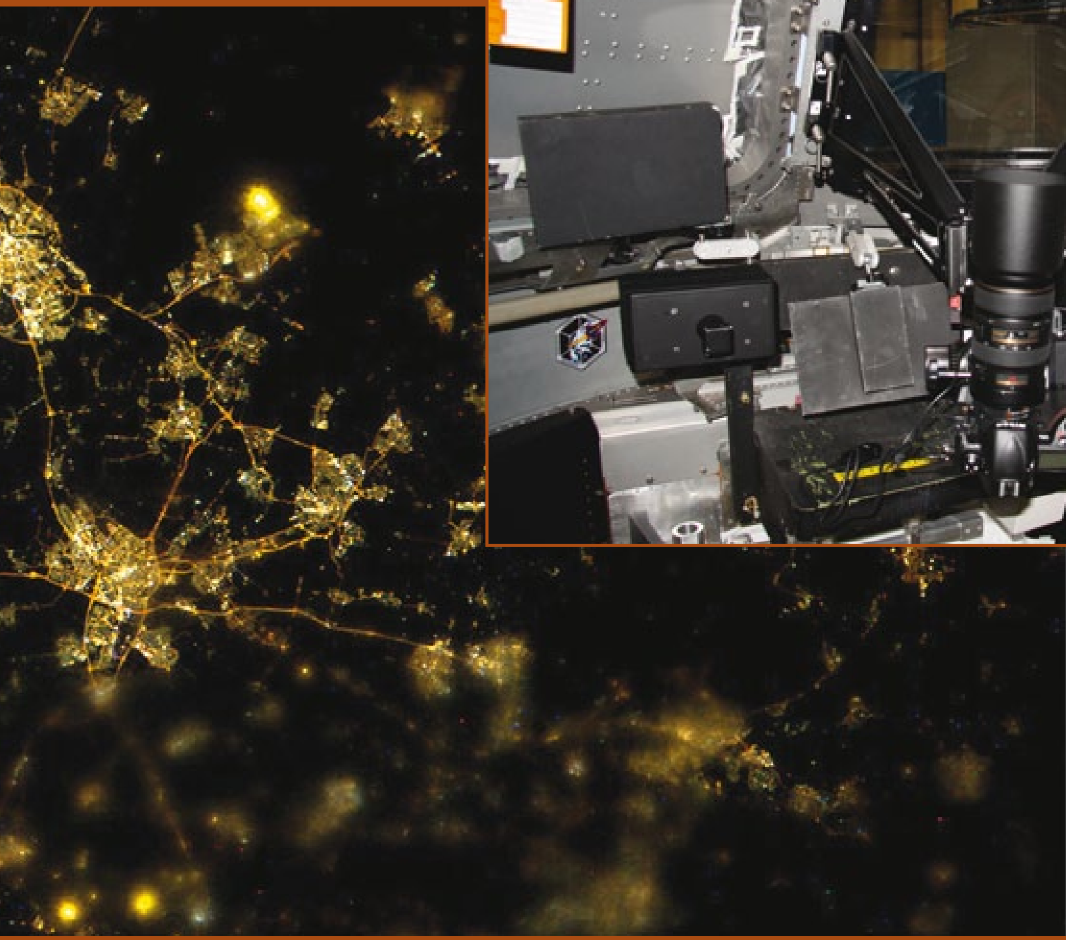
ESA astronaut André Kuipers installed a tracking device called 'NightPod' on the ISS, an aid for taking night-time pictures of Earth. This motorised tripod compensates for the motion of the ISS – orbiting the planet at 7 km/s – by tracking single points on Earth automatically. The first results are sharper photos with more detail than earlier pictures. These stunning images of cities at night are not only for art and entertainment, they are also used to model spatial distribution of population density, carbon emissions and even economic activity.

This is planet Earth

The ISS is a permanent human eye-in-the-sky. Astronauts can see what is happening on the ground in human terms, often before other satellites. The ISS orbits at a low altitude compared to most Earth observation satellites, only 400 km above Earth, lending itself well to observing surface activity. Astronauts can monitor disaster situations, such as hurricanes or the tsunami that hit Japan in 2011, when the crew of the ISS responded to the crisis and acquired useful images of the flooding.
For two years, a dedicated antenna and receiver on Columbus allows to the tracking of ships on the world's oceans in real time. A global ship traffic control system could seriously hamper marine piracy, illegal dumping, illegal fishing and provide an early warning for collisions.

↓ This view of the coast of Japan just after the tsunami of 2011 illustrates unique aspects of the ISS for Earth observation and disaster response. Using handheld digital cameras, the crew has the capability to capture 'sunglint' on water surfaces with greater frequency and control than most satellite-based systems, meaning they can detect and map standing water and may also indicate areas of particular environmental and health concern. True-colour images such as these can be transmitted to aid workers on the ground and are readily understandable with little or no post-processing (ESA/NASA)





↑ ESA's NightPod photographic aid installed in the Cupola (ESA/NASA)

← The Dutch cities of Rotterdam, The Hague, Leiden, Amsterdam and Utrecht stand out in this view from the ISS taken by André Kuipers in 2012 (ESA/NASA)

Staring at the Sun

How is the Sun influencing our planet? To understand our star's effects, the Sun's cycles must be studied over a long period of time. The SOLAR payload facility, on the outside of ESA's Columbus laboratory, is measuring total solar irradiance with unprecedented accuracy across most of the spectral range. Its data provide a valuable contribution to understanding the interaction between the solar energy flux and Earth's atmosphere. This is important for Earth climate predictions, helping scientists improve long-term climate models and forecasts.

→ View of the SOLAR experiment mounted outside ESA's Columbus laboratory since Expedition 16 (NASA)

An Ariane 5 night launch
from Europe's Spaceport in
French Guiana

→ A BOOST FOR EUROPE

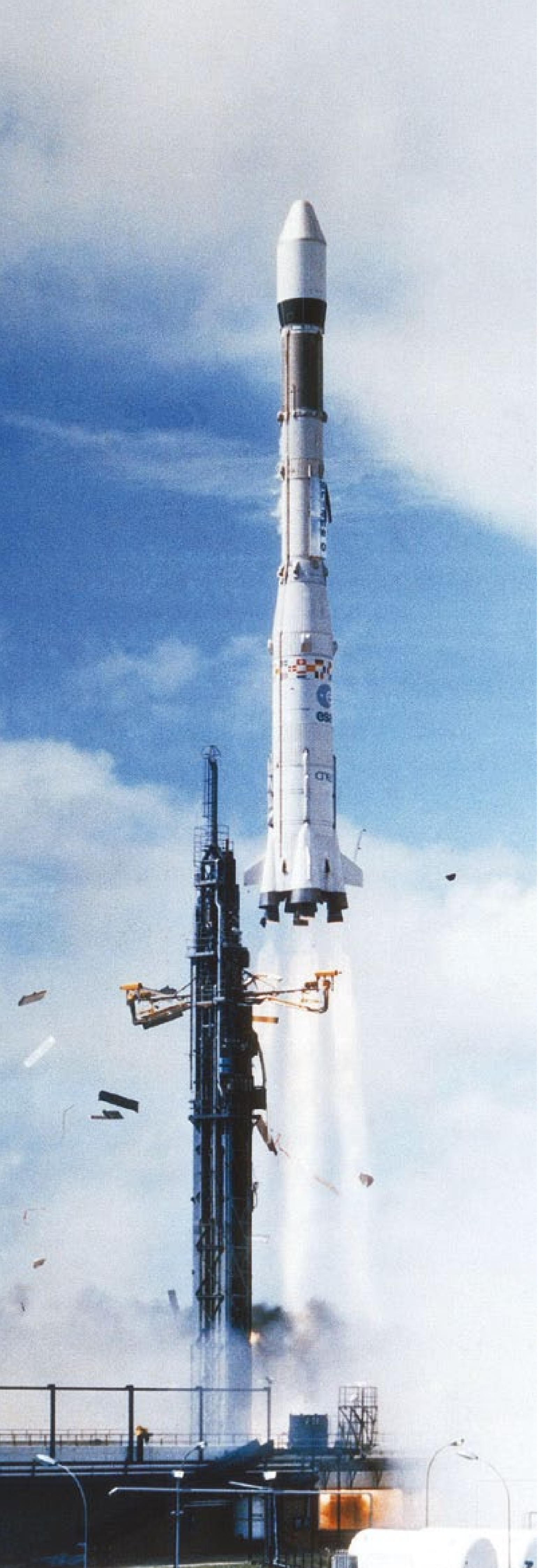
The evolution of the European launcher sector

Lucía Linares and Nida Rosa Baierl
Directorate of Launchers, ESA Headquarters, Paris, France

Although Europe has independent access to space and a leading position in the world launch services market today, a strategy to ensure that both can be maintained sustainably in future is being developed by ESA.

Europe has guaranteed access to space and offers services to customers worldwide through a versatile family of launchers: Ariane 5, Vega and Soyuz from Europe's Spaceport in French Guiana. But while this approach has been successful so far, the risk is that it becomes less sustainable economically later down the line.

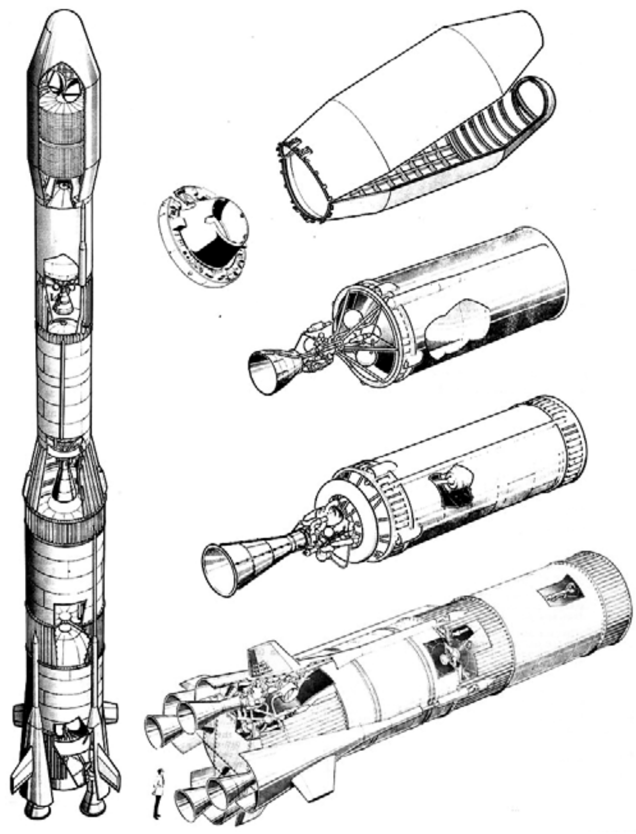
Despite continuing work to reduce the cost of launch services, the dependence of the current European family of launchers on a volatile commercial launch service demand and an increasingly fierce international competition, coupled with evolving performance needs, make it likely that public money will be required on a continuous basis to fund the costs of maintaining assets in operational conditions to preserve this autonomous European access to space.



So ESA has started investigating the feasibility of a new approach for European space access, aimed at making Europe's launch services fully self-sufficient in the long term. The idea behind the 'New European Launch Service' (NELS) is to deliver competitive launch services to both governmental and private European customers, without the need for public funding in exploitation, while keeping pace with the rapidly changing worldwide launch market.

European access to space

Because the strategic importance of access to space is well recognised in all space-faring nations, the space transport sector is generally supported through law, policies and practices in those countries. Governments retain a high degree of freedom of action exemplified, at international level, by the absence of stringent international restrictions to public procurement in space transport and to the international trade in launch services.



↑ Blueprint of the first Ariane: work on the launcher began as early as 1973, when the project was then called Lanceur à Trois Etages de Substitution (LIIIS) or L3S

← The first Ariane launcher blasted off into space on Christmas Eve, 1979

The development of launch systems and their subsequent exploitation is invariably funded by the public sector to a large extent and no single launch service provider in the world has been able so far to sustain itself solely on the basis of commercial launch service revenues, even in the case of an institutional captive launch service market.

A stable launch rate guaranteed by the captivity of national institutional payloads to domestic launch systems continues to be the common basis on which most launch systems are exploited. Only in a very few cases, where domestic launch capability for a certain payload category is not available, are institutional payloads launched by foreign launch vehicles.

While benefiting from a stable, predictable institutional launch business base, largely outnumbering the commercial share (except in the case of Europe), launch service providers can, in addition, access the commercial market.

Guaranteed access to space has been a strategic choice for Europe since 1973 and is today generally recognised as a key European asset, by both EU and ESA Councils. It encompasses elements pertaining to both the development and exploitation phases. Defined by the ESA Ministerial Council in 2005, these elements are the availability of (i) operational launch systems, (ii) European relevant industrial capabilities for research and technology, development and subsequent exploitation, (iii) an operational launch range and (iv) a launch service provider.

Since the beginning of European access to space, it has had the characteristic feature of a heavy dependence on commercial market demand and therefore an induced sensitivity to competitors' behaviour. Sustainability of this sector is critical, in particular because its competitiveness is a key factor in the development of space applications.

↑ The current European launcher family: Vega, Soyuz at CSG, Ariane 5 and Ariane 5 ECA

After more than 30 years, Europe has recently opened a new chapter by bringing into service a complete family of launch systems. Now, to ensure a long-term sustainable and competitive European launch service, important decisions about the way ahead are to be taken at the Ministerial Council in November 2012.

Access to space to serve space applications

Space applications have become an integral part of our daily lives, both for national governments and the general public. Their development has evolved hand in hand with that of access to space, because actual accessibility of launch services is a first enabler in making space services available. Access to space has always been, and continues to be, critical in the development of the space sector.

This means that all spacefaring countries have developed their domestic access to space, generally considered as foundation of national security, civil and commercial space efforts and a key element in safeguarding and fostering domestic industrial capabilities.

Access to space has evolved from solely a means to respond to a domestic strategic demand to serving also non-institutional missions with the growth of commercial uses for communication satellites. Capturing a share of the competed market is of interest to all launch service providers, and this competitiveness has become a factor in the competitiveness of satellite operators.

History of launch commercialisation

Competition among launch service providers to secure accessible non-institutional payloads began in the late 1970s, marked by the first launch service agreement between Arianespace and Intelsat in 1978. The commercial launch services market was initially disputed only between Europe and the USA.

Towards the end of the Cold War, in 1985, China began attempts to enter the commercial launch services market, followed by Russia with ex-Soviet launchers a few years later. As a first reaction, to protect the US launch vehicles from this new competition, bilateral agreements were put in place with China, Russia and the Ukraine, regulating launch service prices and imposing launch quotas.

Nevertheless, to provide a means to access the demand for commercial launch services, Russian and Ukrainian players reverted to the creation of international joint ventures that would not only allow for an easier access to the market, but also provide an opportunity to acquire hands-on commercialisation knowhow.

↑ Launch of Ariane L7 of Intelsat V in 1983

The US decision to abandon launch quotas for Russian launchers in December 2000 was a first step towards change. With the large number of ex-Soviet launchers no longer subjected to quotas and still being able to profit from low production costs, serious competitors for the European and US launch vehicles started to appear.

During the 1990s, Russian competition came mainly in the form of the Proton vehicle, but an expansion of the launch services offered took place with the use of converted intercontinental ballistic missiles and the maturation of Sea Launch. At the same time, a contraction of the launch service demand led to serious strains on the market.

With this important launch service offer becoming available and driving the price level, US launch providers could not continue capturing a share of the commercial market demand in economically viable conditions. This led to the withdrawal of US launch vehicles (Atlas V and Delta IV) from the commercial launch services market in the late 2000s to concentrate almost exclusively on the captive institutional market.

The European launcher sector today

In 2010, Europe secured about 40% of the global commercial market both in launch services and telecommunication satellites, although public space investment in Europe represents only about 10% of the total public space investment worldwide. Launchers represent the one of the major areas of space manufacturing activity in Europe, second only to satellites for space applications.

During the days of Ariane 1 to Ariane 4 operations, each euro invested in development yielded more than €4 in industrial turnover in European industry. Today, Ariane 5 is successfully positioned in the commercial geostationary transfer orbit (GTO) market and generates €1 billion industrial turnover per year. Over the last 10 years, owing to the success of Ariane, the market share of Arianespace has been about half of the accessible GTO launch service market demand and, on average, 45% of the entire accessible market.

A historic period for Europe

The last months have seen a turning point in Europe's access to space. After more than 30 years of relying on Ariane, both Soyuz and the new Vega launchers made their maiden flights from Europe's Spaceport in French Guiana, in October 2011 and February 2012, respectively.

European access to space is now ensured through a family of launch vehicles consisting of the ESA-developed Ariane 5 and Vega launchers, complemented by the Russian Soyuz vehicles, launched from Europe's Spaceport. This family covers the entire range of performance needs: Ariane 5 for the injection of heavy payloads into GTO, escape missions and serving the International Space Station, Soyuz for medium payloads and Vega for small payload missions to low-Earth and Sun-synchronous orbits.

ESA is the 'procuring entity' of ESA launchers in development, while the exploitation phases of Ariane, Vega and Soyuz have been entrusted to a launch service provider, Arianespace, by the governments of ESA Member States. Arianespace acts as the procurer in exploitation following completion of the qualification process that ends the development phase. On the industrial side, Astrium and ELV SpA act as launcher system prime contractors for Ariane 5 and Vega. For Soyuz, the Russian federal space agency Roscosmos acts as prime supplier, with TsSKB Progress as launch vehicle authority and NPO Lavochkin as upper stage provider.

← A Russian Proton rocket was used to put ESA's Integral observator y into its orbit in 2002. Russia provided the launcher in return for observation time on Integral

Dependence on the commercial market

While the industries of other countries (for example, USA, Russia and China) have benefited from a steady, sizeable and captive civilian and military institutional demand, European space industry finds itself on less solid ground because it lacks both the institutional captive market and, to a certain extent, a significant institutional demand. Its economical viability is therefore dependent on the securing a large share of the worldwide accessible market of launch services.

Indeed, Ariane has been the only launch vehicle to carry more commercial than domestic payloads over the past years when institutional launches represented about 80% of the total launches worldwide. This is evidence of its success in the market, but it also shows its forced reliance on a highly volatile, non-protected market share. European industry and Arianespace have to be extremely resilient to changes driven both by satellite operators and by competitors in the worldwide market. This situation renders the sector particularly vulnerable to commercial market variations, in conditions that differ from those of its competitors.

While the dual-launch configuration of Ariane 5 (launching two satellites) allows for cutting launch service prices for satellite operators, it also has its drawbacks. These could be the unavailability of one of the two satellites to be launched, or the inability to pair up two satellites for reasons related to Ariane performance.

Matching suitable satellites as pairs will become more difficult as the mass distribution of accessible payloads is expected to grow towards the upper limits of the small and medium-large payload mass categories (i.e. towards 3.5 and 6.5. tonnes) and there is a decrease in the number of payloads under 3.5 tonnes.

Upcoming challenges

Today's situation is likely to become more challenging, and is already in the medium term because competition in the launch services market is increasing with a wider choice of providers. There has been the return of Sea Launch after its exit from bankruptcy, an increased availability of Chinese launchers and the attempts of SpaceX to capture a commercial market share in addition to its institutional core business.

This situation may even worsen by the end of the decade when new generations of Russian and Chinese modular launch vehicles are expected to become available. They are expected to offer increased flexibility at reduced cost, possibly augmenting the GTO launch service capacity to a point where an overcapacity

↑ Soyuz at CSG: a Soyuz launcher took off from Europe's Spaceport in French Guiana on 21 October 2011, the first time that a Soyuz was launched from a spaceport other than Baikonur or Plesetsk

in the market could appear. Low Earth orbit services are expected to continue, focusing mainly on domestic institutional demand, but some additional capacity could nevertheless become available on the launch services market.

Costs of the European launch system

Although successful in the commercial market, exploitation of the Ariane 5 launch system has required public funding over the past years to cover certain costs related to the maintenance of infrastructure in operational conditions, like all other space-faring nations in their domestic launch systems.

Despite several measures, including those that are currently being taken in a review of the procurement process for exploitation, the need for Ariane exploitation costs to be covered in part by public funding is expected to continue, in both short and medium terms with Ariane 5 ECA, and in the long term with Ariane 5 ME, although at a reduced level. The reduction of costs has therefore become an essential element in reflecting on the future evolution of European launch service provision.

Taking this into account, and to safeguard competences, the future of European launcher systems has to be decided beyond the lifetime of the currently used family of vehicles to face the challenges of the future.

↓ New generations of Russian and Chinese modular launch vehicles are expected to become available by the end of the decade. This is the Chinese Shenzhou-9 manned spacecraft atop a Long March 2F vehicle in June (Reuters)

↓ The Sea Launch service uses a mobile sea pl commercial payloads on Russian/Ukrainian This is the launch of Koreasat 5 in 2006 (Sea

↑ ESA's small launcher Vega, single-body with three solid propulsion stages and an additional liquid propulsion upper stage. The maiden flight of Vega was carried out on 13 February 2012

Prospects and drivers

The environment in which the European launcher sector operates today is different to that of the early days of the European launcher programme. Back then, it benefited from a favourable environment that allowed Ariane to remain dominant in the commercial market, against the background of a very small and non-captive European institutional market, unlike the cases of USA, Russia and China. This allowed a large part of the economic burden to be offset by Member States.

However, competition has increased in recent years and is bound to get tougher in the near future. It is likely that the position of Ariane, Vega and Soyuz will be challenged within the next few years, meaning that the European launcher sector could become less and less sustainable. A sector of key significance for both European governments and commercial operators seems therefore at the mercy of a volatile worldwide commercial demand.

The current model for guaranteeing access to space for Europe, although successful so far, may no longer be economically sustainable. Efforts to make this model sustainable by reducing the costs have their limits, since exploitation costs are driven by, among others, the industrial organisation in development, which is derived from Member States' contributions.

atform for equatorial launches of Zenit 3SL rockets. Launch)

↓ Falcon 9 is a US launcher system manufactured by SpaceX. The first Falcon 9 was launched in 2010, and the second carried the first SpaceX Dragon spacecraft later that year. SpaceX has been awarded a number of contracts from the US DoD and NASA over the years (NASA/SpaceX)

→

Europe’s Spaceport in French Guiana covers an area of 750 km², almost as much as the city of New York

↓

Two of the concepts of a Next Generation Launcher, being examined in ESA’s Future Launchers Preparatory Programme

The New European Launch Service

In view of this, ESA is investigating the feasibility of a novel approach for access to space, aimed at achieving a self-sustained exploitation phase, i.e. economically self-sufficient, without the need for public funding for launch service exploitation, and with the sole provision of the infrastructure of Europe’s Spaceport in French Guiana. To that end, ESA has issued a request for proposals for a feasibility study for a New European Launch Service (NELS).

The NELS approach represents a turnaround in past and current practices worldwide. It aims at delivering competitive launch services to both government and private European customers, as its core customer base, including a competitive presence on the worldwide launch service market.

The NELS development shall therefore be driven by the end goal of providing an enabling service with the best product (in terms of availability and reliability) at the best price to European customers and responding to their exploitation needs, rather than by a technology-focused approach. No development constraints are being imposed on industry,

so as to allow freedom in proposing the best technical and organisational solutions.

Proposals from industry on the NELS should produce preliminary study results by September, which can be taken into account for the best possible course for the future of Europe's launcher family to be decided at the next Ministerial Council.

In defining the future of European access to GTO, two scenarios are being assessed. The first is the development of Ariane 5 ME (Mid-life Evolution) with significant postponement of Next Generation Launcher activities, and the second is the direct development of the Next Generation Launcher with no Ariane 5 evolutions beyond the current Ariane 5 ECA performance-increase activities.

Ariane 5 ME is a more powerful and versatile version of the current Ariane 5 ECA. It responds to the need for heavier payloads and includes reignition capabilities (a versatile cryogenic upper stage using the new Vinci engine). This should allow Ariane to handle a wider range of missions: injection of satellites into a higher geostationary and supersynchronous orbits, wide range of combinations and pairing of different types of institutional missions, such as Earth-escape, GTO-escape, geostationary and Moon or Mars missions, and a guaranteed deorbiting and/or injection into graveyard orbits to address space environment issues.

The development of a Next Generation Launcher is being pursued as a goal of the ESA Future Launchers Preparatory Programme. System studies and technology activities, including ground and inflight tests, are conducted to foster new technology capabilities within Europe so as to enhance the reliability and competitiveness of European launchers.

The selected scenario to be proposed at the ESA Ministerial Council in November will therefore depend on an in-depth analysis of these two scenarios, industrial proposals received, especially on NELS, affordability for ESA Member States in the short and medium term and development activities of the chosen scenario.

Whichever scenario is selected, it must enable Europe to guarantee future access to space for its missions, to be competitive on the launch services market and to be adaptable to evolving performance requirements and competition. ■

IAP Ambassadors are involved in a great many face-to-face meetings in their target communities, connecting people from these sectors with the space industry

→ MAKING THE CONNECTION

Ambassadors for the use of space-based applications

Alan Brunstrom
Directorate of Telecommunications and Integrated Applications,
ESA Harwell, Oxfordshire, United Kingdom

Pierluigi Mancini
Directorate of Telecommunications and Integrated Applications,
ESA Headquarters, Paris, France

Tony Sephton, Ralf Huber, Andreas Schoenenberg, Amnon Ginati and Magali Vaissiere
Directorate of Telecommunications and Integrated Applications,
ESTEC, Noordwijk, The Netherlands

A growing network of 'IAP Ambassadors' is convincing new users from many different sectors that space-based services can help to meet their needs.

IAP stands for Integrated Applications Promotion, and when ESA Director General Jean-Jacques Dordain initiated this programme, it meant taking on several new kinds of challenges. ESA is justly renowned for its ability to resolve technical problems and to manage complex, multi-national projects successfully. The central purpose of IAP, however, is to engage with new user communities who neither know nor care much about space technology.

Success depends upon persuading people from these sectors that the space industry can do something useful for them. This in turn requires the creation of a local presence, everywhere, without increasing costs or dissipating the critical mass of existing ESA centres: a challenge indeed.

ESA has risen to this challenge by setting up a network of Ambassador Platforms (APs), each dedicated to opening up one or more user communities. There is no standard model for an AP and indeed no two are exactly alike – exactly because they have to reflect the different characteristics of the communities they are addressing. Some are specialists in a particular industry, others in a broad theme such as health or transport, while still others have a regional focus.

Their technical knowledge of space systems is equally varied. But what they have in common is a remit to find ways of integrating different space-based services, thereby creating solutions that meet the needs of their target markets.

The first AP was inaugurated in 2009. Three years later, and there are now nine APs in operation. Several others are in the pipeline, reflecting a growing recognition of how this innovative approach can build awareness not only of user needs, but also of how well the space industry can meet them. That mutual awareness is critical: it helps to drive the demand for services upon which most of the space industry ultimately depends for its survival.

Similar – and yet different

Rather than look at each AP in turn, it is more illuminating to look at what they have in common and their differences in how they have approached their respective roles. One of the activities common to all the APs is the organising of conferences and workshops, where their target communities can exchange information with the space industry. Yet the character of these events varies greatly.

Far above the Arctic Circle, Leif Erik Nohr manages the AP for E-Health in Inaccessible Regions (eHIR), which is hosted by the Norwegian Centre for Telemedicine in Tromso (NST). Leif is a lawyer, reflecting the legal complexities of providing potentially life-saving medical services to people who have no other access to them. That is not limited to the sparsely populated Arctic region: NST is a World Health Organisation collaborating centre for telemedicine and as such the AP provides a focal point for these applications worldwide, including the maritime sector and developing countries.

Leif Erik Nohr, based at the Norwegian Centre for Telemedicine in Tromso, AP for E-Health in Inaccessible Regions

Hosting a workshop in the Arctic, for users in remote locations, is rather different to hosting one in Rome. Massimo Cavaliere manages the AP for Dual-Use Space-based Services (APDUSS), hosted by the Italian Defence Ministry. Leif and Massimo are as alike as chalk and cheese but both have been very successful in using this method of building awareness among their respective user communities.

The APDUSS inauguration workshop was opened by the Italian Defence Minister and attracted 250 experts from the wide-ranging security and civil protection communities. The inauguration workshop held by eHIR involved fewer participants, but arguably had even greater geographical reach. In both cases, the level and quality of those participants, in terms of their professional qualification and influence, led directly to the submission of proposals for integrated application projects.

Fostering project proposals is the primary objective of every AP and it is noteworthy that when ESA challenged each of them to come up with at least one proposal in time for a recent meeting of the Joint Communications Board, they all delivered. Given that the APs are voluntary, self-funded operators and that none of them can exercise control over their user communities, this is a remarkable validation of the effectiveness of the concept.

If a further endorsement is needed, ESA has noticed a clear correlation between the countries that have APs and those that generate the most interesting IAP proposals (there has for instance been a strong resurgence of proposals from Italy since Massimo Cavaliere opened the APDUSS).

Honest brokers

Being an ‘honest broker’ is one of the most important qualities of an AP. Although mandated to encourage user communities to engage with the IAP programme, they are prohibited from participating in project consortia. The ideal AP is therefore a rather special kind of entity: expert, involved and respected in their particular field, yet working for the common good rather than for their own financial benefit. The European Space Policy Institute (ESPI) in Vienna is one such example, hosting the AP for Central and

“ **Our central purpose is to engage with new user communities**

Eastern Europe (APCEE). This is one of the few APs with a primarily regional focus.

A regional aspect is combined with a thematic interest by the AP for the Baltic Sea Region (APBSR) in Helsinki, hosted by the Foundation for a Living Baltic Sea, commonly called the Baltic Sea Action Group. The AP's focus is on the marine environment, maritime safety and transport applications, with special attention to the characteristics of the Baltic Sea and winter conditions.

Nevertheless, most APs do in practice have some measure of geographical focus, if only out of a natural tendency for their contact networks to radiate from their physical location and to be strongest in their home country. Sometimes an AP's contact networks are its strongest asset. Thus Marie-Laure Germain has been able to take advantage of the virtual networks developed by Pôle Risques, which absolutely requires such capabilities in order to function as a distributed 'excellence cluster in risk management'. Based in Aix-en-Provence, Pôle Risques hosted the AP for Environmental Risks and Hazards in the Mediterranean (ERHM). Good networking facilitated some very well attended workshops for the civil protection and emergency management sector, where fragmentation of the agencies involved is a major problem.

Marie-Laure has now moved the AP role to a new host – Eurisy in Paris. Eurisy is a non-profit association of space agencies in Europe, of which ESA is a founding member, working closely with professional end-user communities to raise awareness of operational satellite-based services, and so stimulate demand.

Marie-Laure will maintain a certain focus on French user communities, while also benefiting from Eurisy's pan-European outreach. This will be ever more important as the IAP programme matures and more of its projects move into a pre-operational phase, creating an interface with Eurisy's activities, which are aimed at informing end-user communities about what space can do for them right now.

What makes an IAP Ambassador?

The professional and academic background of the Ambassadors is as varied as everything else about them. Erich Klock joined ESPI from an Austrian scientific research institute, with an MBA, an MSc in space sciences and a first degree in electronic engineering.

Erich Klock, based at ESPI in Vienna, AP for Central and Eastern Europe

Both Marie-Laure and Antti Jokinen (from the Baltic Sea Action Group) moved into the environmental sector two or three years ago: Marie-Laure came with a degree in political sciences and a background in the international defence and security sector, while Antti brought 20 years' experience in the product marketing of mobile networks.

Marie-Laure Germain, based at Eurisy, Paris, AP for Environmental Risks and Hazards in the Mediterranean

Antti Jokinen, based at the Baltic Sea Action Group in Helsinki, AP for the Baltic Sea Region

who neither know nor care much about space technology ”

ESA's Alan Brunstrom, who recently managed the AP for Enhanced Mobility in the UK

Alan Brunstrom, who until recently managed the AP for Enhanced Mobility in the UK (eMOB), spent more than 25 years on the commercial side of the satellite communications industry and has a first degree in geography, a foundation he shares with his replacement, Ian Downey, who has a similar depth of experience in the development and promotion of satellite-based services.

Ian Downey, based at the Harwell Science and Innovation Campus near Oxford, the new AP for Enhanced Mobility in the UK

The AP for eMOB is based at the Harwell Science and Innovation Campus near Oxford and is supported by the UK's Technology Strategy Board. As such it reflects that organisation's emphasis on promoting innovation, with a broad remit across the UK that includes but is not limited to transport and associated safety and environmental issues.

The newest Ambassador, Dr Mathias Link, works at Luxinnovation, Luxembourg's National Agency for Innovation and Research. He manages an AP focused on the 'Space for Med' initiative, jointly proposed by ESA and the European Investment Bank (EIB). In fact, the AP is hosted within the EIB, less than 500 m from Luxinnovation.

Dr Mathias Link, based at Luxinnovation, Luxembourg's National Agency for Innovation and Research, manages an AP focused on the 'Space for Med' initiative

An engineer and physicist with previous experience in various European high-tech companies, Mathias's role at Luxinnovation includes responsibility for development of the country's space sector, giving advice on European research and development programmes and dealing with Luxembourg's Space Cluster.

The 'Space for Med' initiative aims to bring economic growth to the southern and eastern Mediterranean regions, by bridging the digital divide with satellite-based applications in the areas of energy, water management, transport and logistics. It is a good example of how the IAP approach is attracting innovative, third-party funding partnerships that are helping to develop space-based services in different regions across the globe.

Other Ambassadors also hold a professional position that is directly aligned with their AP role. Ignacio Martí Pérez is Deputy Technical Director at CENER, the National Renewable Energy Centre of Spain, an internationally recognised centre of expertise that hosts the AP for the European Adoption of Renewable Energy (EARE).

Ignacio Martí Pérez, Deputy Technical Director at CENER, the National Renewable Energy Centre of Spain, hosts the AP for the European Adoption of Renewable Energy

Dr Joris van Enst heads the newly inaugurated AP for Water Management. With a degree in geology, Joris was head of the sciences department for the Ministry of Education, Culture and Science in the Netherlands. He has taken on management of an AP that is hosted by 'Het Waterschapshuis', which coordinates information and communications technology for the Dutch water authorities.

Dr Joris van Enst, based at 'Het Waterschapshuis' in the Netherlands, heads the newly inaugurated AP for Water Management

> **We are persuading people that the space industry can do something useful for them**

There are 25 regional authorities in addition to the national organisation and they have world-leading expertise in most aspects of water management, as is to be expected from a country that has 40 per cent of its land below sea level. Joris's AP role is in addition to a heavy workload in other areas: a situation familiar to many of the Ambassadors.

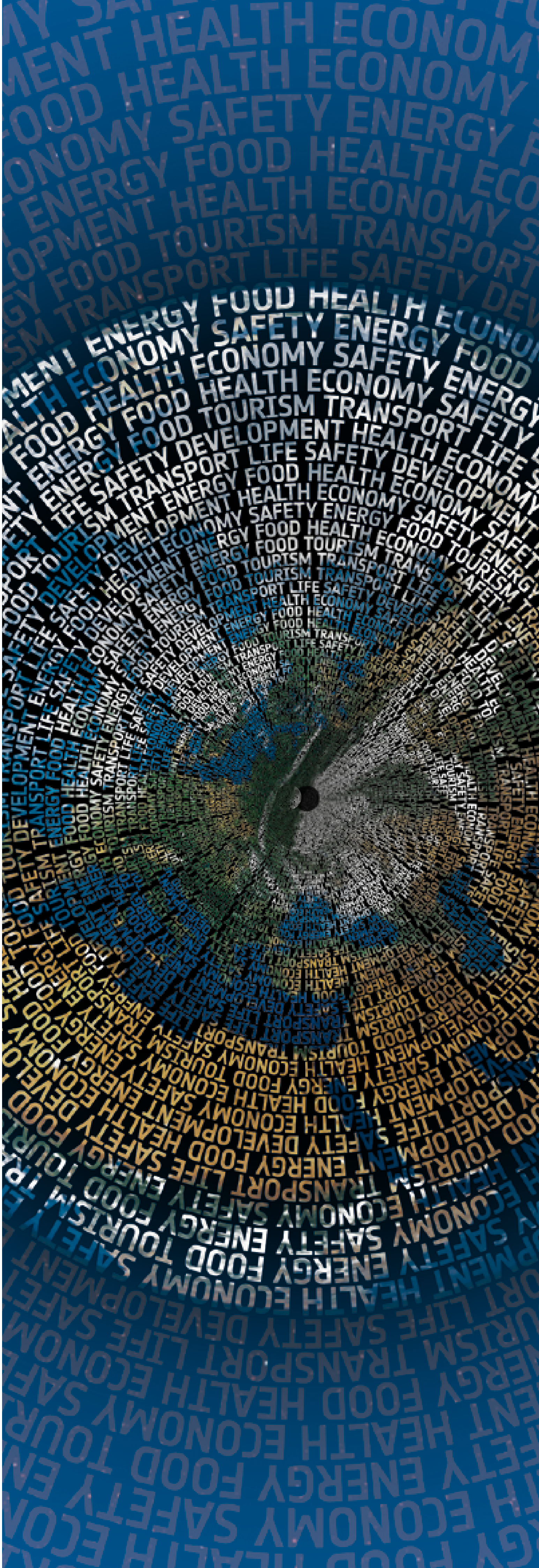
Indeed, the amount of time dedicated to the AP role varies from one day a week to more than five days a week. Some APs deploy more than one person to the role, albeit on a part-time basis. Thus the water management task is shared between Joris and his right-hand man, Piet Reijers. A similar arrangement is in place at CENER between Ignacio Marti and Andrea Hercsuth. In other cases, the Ambassadors simply work more hours than any one person probably should: an indication of their commitment and the strength of their motivation.

Given that the Ambassadors are focused on outreach activities, it is perhaps surprising that their personalities are no more alike than anything else about them. If they were a sales team, they would mostly be notable for a 'soft sell' and a focus on substance rather than slick presentation – but otherwise they are definitely a collection of individuals rather than a unified team.

This raises an obvious question: is this a real network pursuing a coherent strategy, or an ad hoc collection of entities each pursuing their own interests? At least part of the answer lies in the sharing of a common goal, namely the generation of innovative space-based services that will turn potential users into customers.

A confederacy, not a federation

The issue of how far things should be federated and directed from the centre, or decentralised and driven by varying levels of common interest, lies at the heart of the



evolution of the AP network. It clearly tends more to the latter, with an emphasis on developing regional presences that provide access to international opportunities.

The APs are coordinated via the IAP Awareness Activities section, headed by Tony Sephton. They come together formally two or three times a year at one of the ESA establishments, timed to coincide with the meetings of the IAP Advisory Committee (IAPAC). This enables the network to take direction from the enormous collective knowledge and experience of the IAPAC members, who have helped the programme to address several market sectors that were previously barely touched by the space community.

Some of the Ambassadors also meet as occasion demands, although most of their collaborations are done remotely. For instance, a recent open competition on services for the wind energy sector was developed jointly by EARE in Spain and eMOB in the UK, based on the user requirements identified in workshops convened in their respective countries by Ignacio Marti and Alan Brunstrom. They spoke with each other and emailed, but never physically met during the process.

In a way, this is typical of how the AP process works. Ignacio and Alan's efforts were coordinated by one of the Technical Officers from the IAP team, who carried out a dual role.

One of these roles was as mentor or handler to a particular AP, in this case EARE. An ESA handler is generally assigned to each AP, based on language and personal interest in particular regions or topics.

↓

IAP is very active in precision agriculture. Led by VISTA, the TalkingFields project has evolved into a pre-operational service after successful demonstrations with large farms in Germany and Russia, while the FruitLook service is now aiding the irrigation of vineyards and orchards in South Africa (ESA/S. Kill)

↑

The pre-operational telemedicine service AMAZON is now in use with International SOS for remote users in Africa, following an IAP project to extend the capabilities originally developed by RDT for the TEMPUS aeronautical solution seen here (RDT)

The last of these was also the basis for the second part of the Technical Officer's role in this case, namely to incorporate all the user requirements identified by the APs into the Statement of Work for the resultant Invitation To Tender (ITT). Once such an ITT for an open competition has been released, the APs promote it through their networks, to ensure the widest possible awareness among interested parties and to increase the number and quality of bids.

A user-driven approach

The IAP programme prides itself on being 'user-driven'. Yet putting users in the 'driving seat' is not a straightforward matter: first you have to find them, then persuade them that they want to get on board and finally, as an analogy, teach them how to 'drive' this complicated 'space vehicle'.

The APs spend most of their time on this part of the process. Besides the conferences and workshops already mentioned, the Ambassadors are all involved in a great many smaller face-to-face meetings (the eMOB Ambassador in the UK conducted over 100 such meetings in the first year and still felt that he was only scraping the surface of the target communities). How to reach the whole of their potential audience is the fundamental problem affecting all the APs. Together with ESA, they have come up with a couple of highly effective solutions.

One especially effective tool is the 'Call for User Ideas', whereby ESA and the AP network use all of their outreach mechanisms to stimulate the market into submitting ideas on a particular topic or theme. More than 40 potentially attractive ideas and several subsequent projects were generated by such a call for the Baltic Sea region; an operation in which Antti Jokinen and his then-nascent APBSR were involved.

The latest call is on critical infrastructure, which includes monitoring, management and protection of infrastructures that are classified as essential for the provision of vital services (for instance within utilities, transport and information communications technology networks.) The call has been managed via the APs, in an acid test of their ability to identify and pull out solid project ideas from a topic so large that it would otherwise be hard to know where to begin.

Another mechanism for this kind of outreach are the web sites run by each AP. Accessible both via the main IAP web site and as a standalone portal, the AP sites are characteristically varied in their level of use, although they all conform to a standard developed by ESA. For some APs the portal is their main tool for building networks and gathering and sharing information. For others, direct personal contact is more important. Either way, the number of contacts built up by the APs now runs into the thousands and this has actually become the biggest source of contacts for the IAP programme as a whole.

How many APs are enough?

It is not yet certain how large the AP network will become, or how exactly their organisation will evolve. Evolution is

↓

The latest AP 'Call for Users Ideas' is on critical infrastructure: the monitoring, management and protection of infrastructures that are essential for vital services (for example, transport or communications technology networks)

↑ Testing the TEMPUS telemedicine unit (TATRC)

the right term, for this is certainly an organism in the early stages of rapid growth. What is certain is that the needs of the market and the level of success achieved by the APs will determine how far the network is enlarged.

In this context, it is necessary to consider all the following factors: the endless range and variety of user communities and potential markets for space-based applications; the multi-dimensional nature of the AP's role (geographical, thematic and sectorial); the cross-cutting nature of integrated applications (involving combinations of satellite communications, navigation, Earth observation, human spaceflight technologies and terrestrial systems); the very limited market penetration that has been achieved in many sectors; the growing number of ESA Member States; the newness of the IAP programme; and the fact that many of these things also cut across each other (for instance an AP may have a thematic focus that is particularly relevant in one country but which can subsequently be applied in many, such as is the case with the AP for Water Management in the Netherlands).

Given all these considerations, it becomes clear that the AP network is not randomly distributed. In fact, their distribution is a reflection of demand. A key factor has been the willingness of countries and host organisations to participate, so in this sense the network has been largely self-selecting. That in turn reflects the current IAP strategy, which is still very much aimed at achieving rapid growth in order to realise a vast, untapped potential.

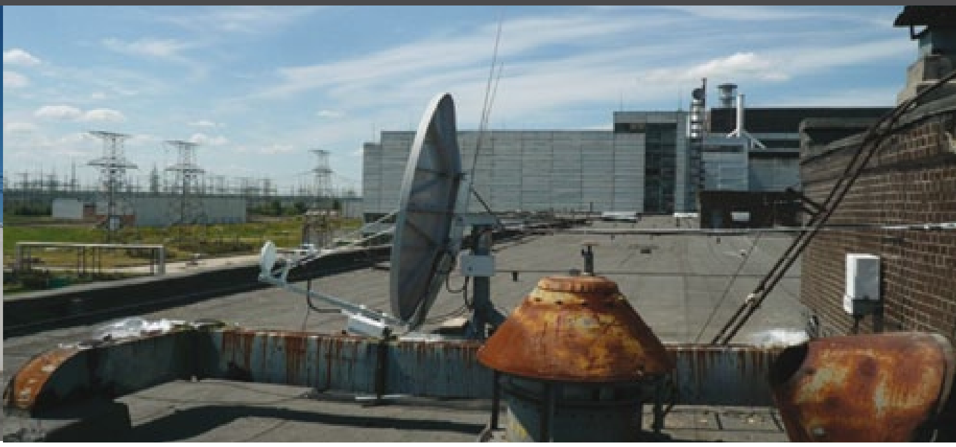
The IAP strategy for growth is definitely bearing fruit. In terms of throughput, the programme aims to achieve an annual activity level of 21 feasibility studies and 18 demonstration

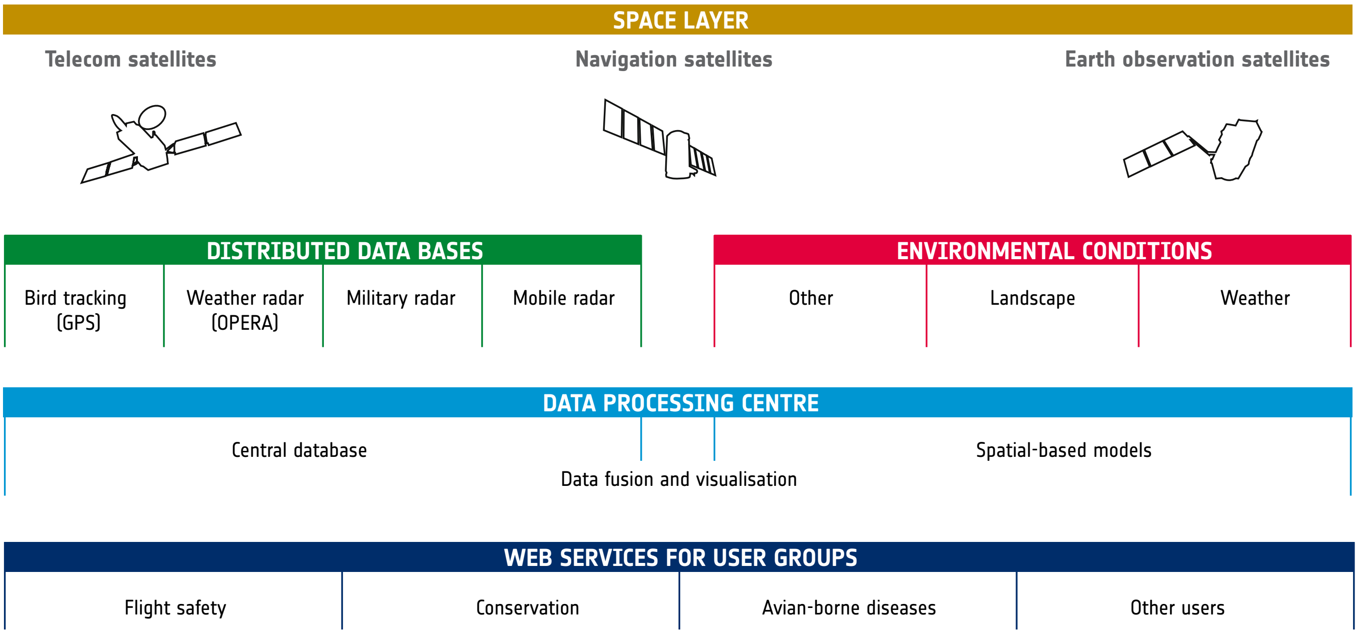
↑ Attendees of the ESA IAP Ambassador Platform meeting held at ESTEC, Noordwijk on 13 June 2012

projects, with three to five new services reaching a sustainable or viable operational status each year. If you examine the current situation, these targets are already close to fulfilment (as of May there were 20 ongoing feasibility studies, 14 demonstration projects and five new services that had reached operational or pre-operational stages).

An impressive proportion of the activities has been prompted, reinforced or otherwise facilitated by the APs. A few statistics may help to illustrate this. Four of the seven IAP open competitions running in May 2012 were initiated by the APs, while four of the next five competitions planned for release had received substantial input from APs in terms of identifying users, engaging them in the programme and defining their requirements. Two earlier open competitions, that between them led to three contracts, were also initiated by an AP. The majority of IAP open competitions have been either initiated by, or received major input from, one or more of the Ambassadors.

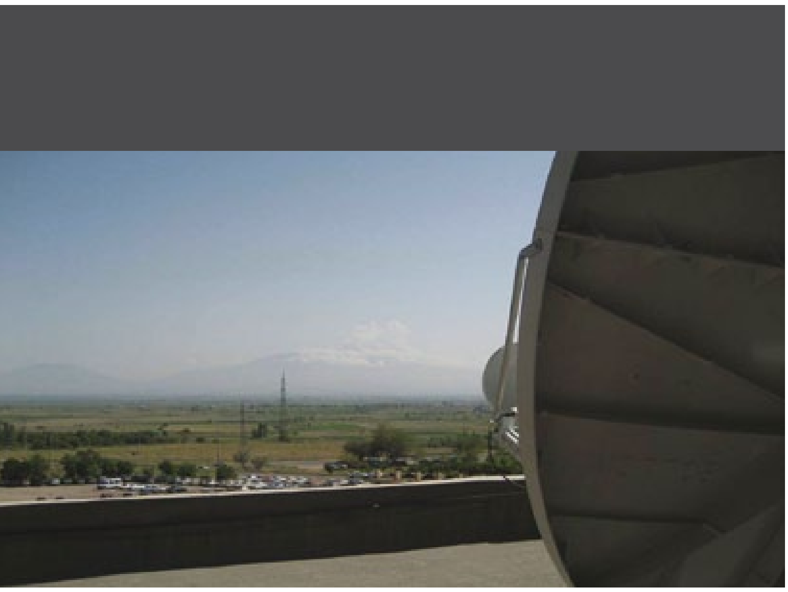
↓ The International Atomic Energy Authority is using a service developed with ESA to enable secure, remote monitoring of safeguard data at eight locations (including those here at ANPP in Armenia and Chernobyl), from its HQ in Vienna (left)





↑ The bird avoidance service FlySafe is now in operation with the Dutch and Belgian air forces and provided by the Royal Netherlands Meteorological Institute. This is an example of how space and non-space systems can be combined to deliver an integrated application

It is more difficult to quantify the impact of the APs on activities that are received in response to the IAP continuously open calls for proposals. This is because the APs are required in such cases to limit their involvement to providing encouragement in the early stages and perhaps to facilitating contacts and communications subsequently. Nonetheless, of the 14 such studies current in May, at least five have engaged in significant contact with an AP and the same is true of at least five more that are in the pipeline.

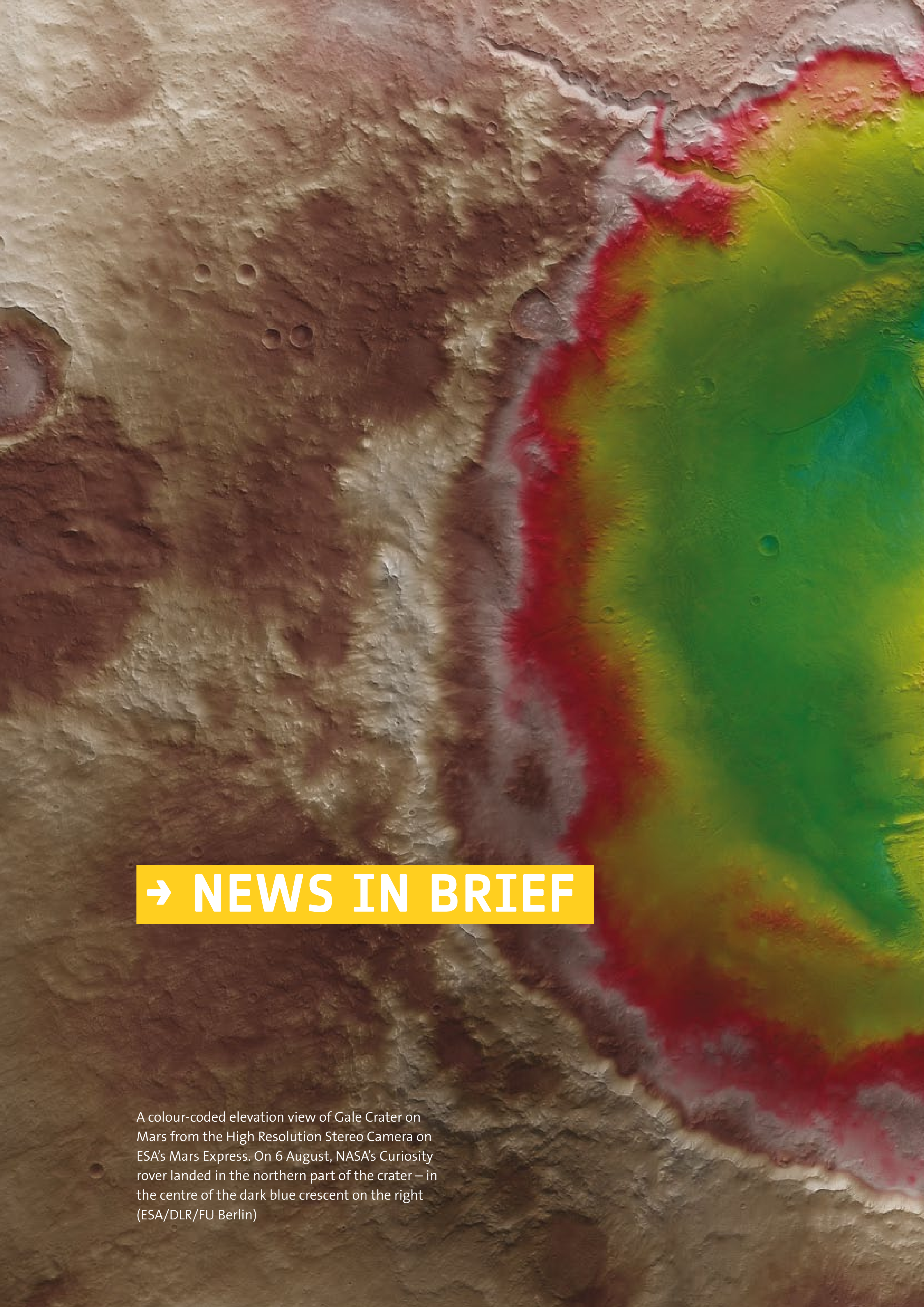


If the Ambassadors sometimes feel a little isolated and commonly express a desire for closer and more frequent interaction, this is a reflection of the reality that they are there to change. When they start touching the boundaries of each other's activities, it may be time to pause for reflection and reorganisation. It will also be a sign of success: and since space services are known to generate a large economic multiplier effect, that success will benefit user communities and members of the space industry far beyond the immediate confines of the IAP programme.

For this reason, the AP network is in the process of being reinforced through measures that have been proposed by interested IAP Member States and which will be brought to the ESA Ministerial Council this year for approval. There is every reason to be optimistic that a growing number of 'Ambassadors for space' will soon be conveying the benefits of space-based services and applications to an even wider audience. ■

With thanks to:

- Massimo Cavaliere, Ian Downey, Joris van Enst, Marie-Laure Germain, Antti Jokinen, Erich Klock, Mathias Link, Leif Erik Nohr and Ignacio Marti Perez.



→ NEWS IN BRIEF

A colour-coded elevation view of Gale Crater on Mars from the High Resolution Stereo Camera on ESA's Mars Express. On 6 August, NASA's Curiosity rover landed in the northern part of the crater – in the centre of the dark blue crescent on the right (ESA/DLR/FU Berlin)

ESA records crucial signals from Mars rover

ESA's Mars Express acquired signals from NASA's Mars Science Laboratory on 6 August as it delivered the car-sized Curiosity rover onto the Red planet's surface.

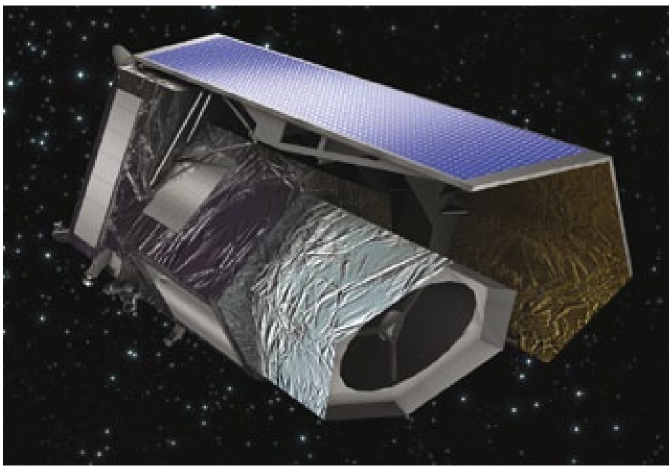
↑ A Mars Express image of Gale Crater, showing the planned landing site of Curiosity marked as an ellipse (ESA/DLR/FU Berlin)

This completed a key step in ESA's ongoing support to NASA's Mars Science Laboratory (MSL) mission. Signals recorded by Mars Express during MSL's entry and descent were received at ESA's European Space Operations Centre (ESOC), Darmstadt, Germany. ESA's New Norcia tracking station also picked up signals directly from the NASA mission, 248 million km away at Mars.

The recorded signals were transferred to NASA's Jet Propulsion Laboratory, Pasadena, California, for analysis immediately on receipt at ESOC. Similar direct-to-Earth recordings made at ESA's New Norcia ground station in Australia were also sent to NASA.

These data recorded by Mars Express and New Norcia include information on MSL's velocity and direction, and also sequential critical events during descent such as parachute deployment, heat shield separation and rover separation. They will prove valuable to scientists as they reconstruct MSL's descent profile, helping to improve and refine models of the martian atmosphere and assess landing accuracy.

Dark Universe mission blueprint complete



← The Euclid spacecraft

ESA's Euclid mission to explore the hidden side of the Universe – 'dark energy' and 'dark matter' – reached an important milestone in June that will see it head towards full construction.

Selected in October 2011 alongside Solar Orbiter as one of the first two medium-class missions of ESA's Cosmic Vision 2015–25 plan, Euclid received final approval from ESA's Science Programme Committee to move into the full construction phase, leading to its launch in 2020.

The sky at the end of the Earth

A photo of the Milky Way taken by Dr Alexander Kumar (UK), who is serving as the ESA-sponsored Expedition Doctor and Chief Scientist at Concordia Base, Antarctica.

Concordia is a joint French-Italian inland Antarctic research station run by the French Polar Institute and Italian Antarctic Programme. Every year it hosts a human research studies coordinated by ESA with universities and research institutions from across Europe.

This is the most extreme and remote environment on the planet. Enduring four months of 24-hour complete darkness, the world's lowest temperatures (regularly dropping below -80C) and the effects of hypoxia (the base is 3200 m above sea level), the winter-over crew of 13 Europeans are living in complete isolation.

No supplies can be delivered during the winter and nobody can leave the base, no matter what the emergency. Life here, high up on the Antarctic Plateau in the world's largest desert, is the closest thing on Earth to interplanetary exploration.

Studying the effects of isolation here is preparing ESA for the real thing: a mission to Mars
(ESA/IPEV/PNRA/A. Kumar)

MSG-3 first Earth image

Europe's latest geostationary weather satellite, MSG-3, captured its first image of Earth on 7 August.

ESA was responsible for the initial operations of MSG-3 after launch on 5 July and handed over the satellite to Eumetsat on 16 July.

For its mandatory programmes, Eumetsat relies on ESA for the development of new satellites and the procurement of recurrent satellites like MSG-3.

This cooperation has made Europe a world leader in satellite meteorology by making best use of the respective expertise of the two agencies. MSG-3 will become Meteosat-10 and continue providing Europeans with high-quality observations of weather from space, being especially valuable in rapid detection and warning of extreme weather situations.

↑ The first image from the Spinning Enhanced Visible and Infrared Imager (SEVIRI) instrument on MSG-3, taken on 7 August, is a joint achievement by ESA, Eumetsat and the European space industry (Eumetsat)

Alpbach summer school looks to future

For 10 days each summer, about 60 science and engineering students and post-graduates from ESA Member States and Cooperating States descend on the Austrian Alps for a unique educational experience.

↑ Members of the Theseus team of the 2011 Alpbach Summer School (FFG)

Held almost every year since 1975, the Alpbach Summer School has a long tradition of providing in-depth teaching and practical experience through an intensive programme of lectures and workshops given by top-level space experts. A different theme is chosen every year, encompassing many different aspects of space science and technology.

The 2012 Summer School (24 July to 2 August) focused on the theme 'Exploration of the giant planets and their systems' and addressed innovative concepts for missions to the giant planets of the outer Solar System (Jupiter, Saturn, Uranus and Neptune).

The participating students are divided into teams and are asked to design their own space mission by applying the knowledge derived from their lecture programme. They are encouraged to use their creativity and organisational skills, and to learn to work together as a team.

The student projects are judged by an independent panel of experts in various categories: the best science case, the best technical case, the best competitiveness and the best overall presentation. "The Summer School has inspired hundreds of students to follow space careers and to see space as an exciting and challenging endeavour," said Michaela Gitsch from the Austrian Research Promotion Agency (FFG), Director of the Alpbach Summer School. "It provides an excellent and realistic introduction to what they can expect if they follow a career in space."

The theme of the 2011 Summer School was 'Star formation across the Universe', and the most highly rated mission proposal, Theseus, was a study of pre-main sequence stars. Volunteer students from the proposing team continued working on their concept during an ESA-sponsored post-Alpbach event last November, which resulted in a modified mission concept named Low and Intermediate Mass star Explorer Satellite.

The Alpbach Summer School is organised by the Aeronautics and Space Agency of the FFG. It is co-sponsored by ESA and the national space authorities of its Member and Cooperating States, with the support of the International Space Science Institute and Austrospace. The 2012 Summer School included participation of the Europlanet Research Infrastructure, a project funded by the European Community.

To apply for next year's Summer School, look at the web sites for ESA Education and the Alpbach Summer School. Full details can be found at: **www.summerschoolalpbach.at**

Fiftieth Ariane 5 flight

Ariane 5 flight VA208 on 2 August marked the 50th successful Ariane 5 launch in a row.

This was Ariane 5's fourth launch of 2012, continuing a line of launch successes unbroken since 2003. Ariane 5 VA208 launched from Europe's Spaceport in French Guiana to deploy two telecommunications satellites, Intelsat 20 and Hylas-2, into their planned transfer orbits.

← Ariane flight VA208 (ESA/CNES/Arianespace/Optique Video du CSG)

A night in the Argentine desert

ESA's 35 m tracking station under construction near the town of Malargüe in Argentina. Starting in this year, it will join ESA's network receiving data from missions like Mars Express, Venus Express, Herschel and Planck.

The station completes the deep-space coverage needed to ensure full telecommunications during mission-critical events and enhance the return of scientific data. This photo was taken in March, just after the 600 tonne dish was installed.

Cosmic collision?

↑ Overlapping galaxies NGC 3314A and NGC 3314B (NASA/ESA/STScI/AURA/Univ. Alabama)

The Hubble Space Telescope has produced a highly detailed image of a pair of overlapping galaxies: NGC 3314, apparently as if they are in the midst of a collision.

This is in fact a trick of perspective: the two just appear to be close from our observation point. NGC 3314A and B are in fact separated by tens of millions of light years. How do we know this? The biggest clue is the shape of interacting galaxies. The immense gravitational forces involved in galactic mergers are enough to pull a galaxy out of shape long before it actually collides.

Deforming a galaxy like this does not just warp its structure, but it can trigger new episodes of star formation, usually visible as bright blue stars and glowing nebulae.

Studies of the motion of the two galaxies indicate that they are both relatively undisturbed, and that they are moving independently of each other. This indicates in turn that they are not, and indeed have never been, on any collision course. NGC 3314A's warped shape is likely due instead to an encounter with another galaxy, perhaps nearby NGC 3312 or another nearby galaxy.

The chance alignment of the two galaxies is more than just a curiosity though. It greatly affects the way the two galaxies appear to us. NGC 3314B's dust lanes, for example, appear far lighter than those of NGC 3314A.

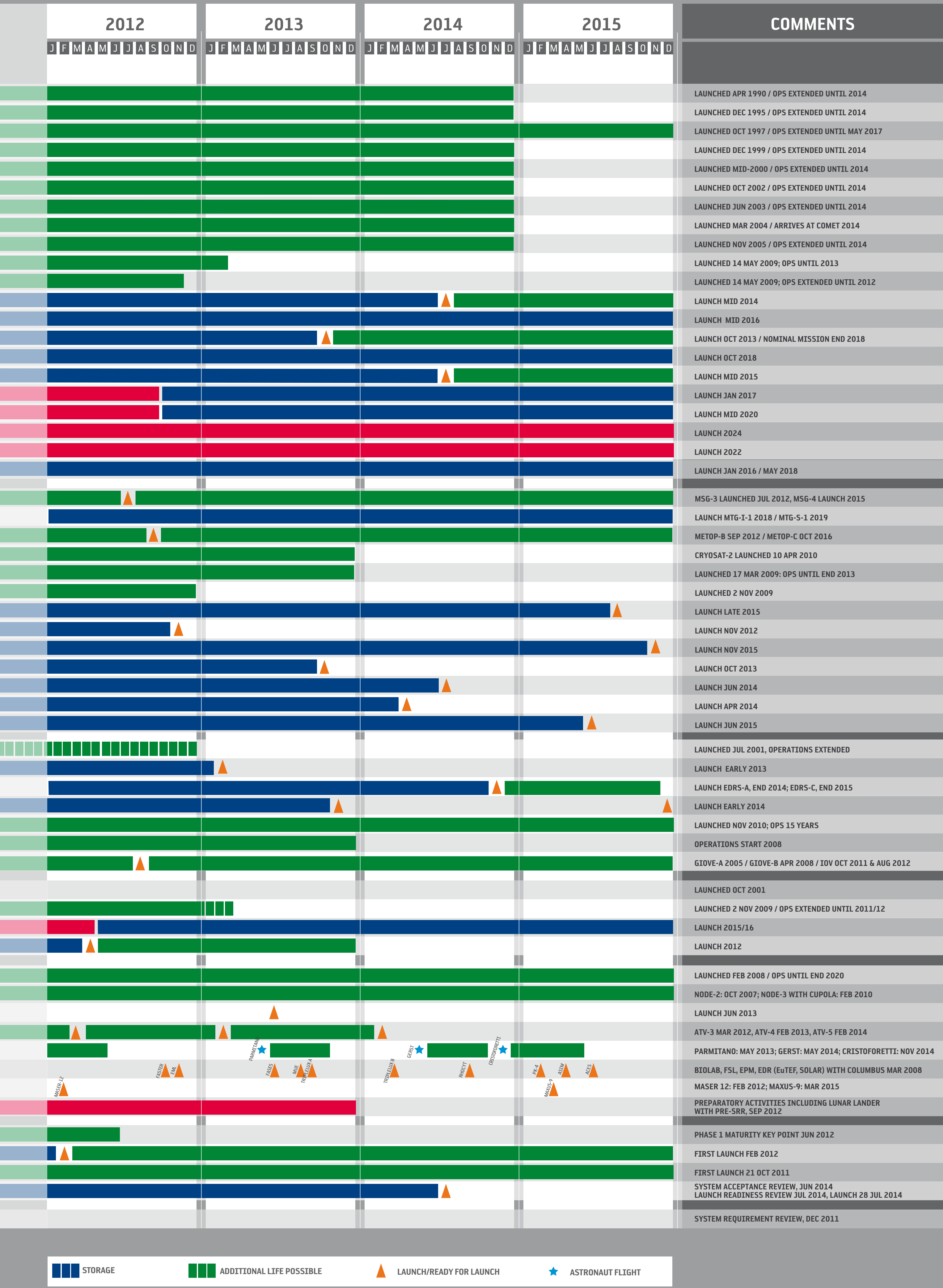
This is not because that galaxy lacks dust, but because they are illuminated by the bright stars in the foreground. NGC 3314A's dust, in contrast, is backlit by the stars of NGC 3314B, silhouetting them against the bright background. Such an alignment of galaxies is also helpful to astronomers studying 'gravitational microlensing'.

→ PROGRAMMES IN PROGRESS

Status at August 2012

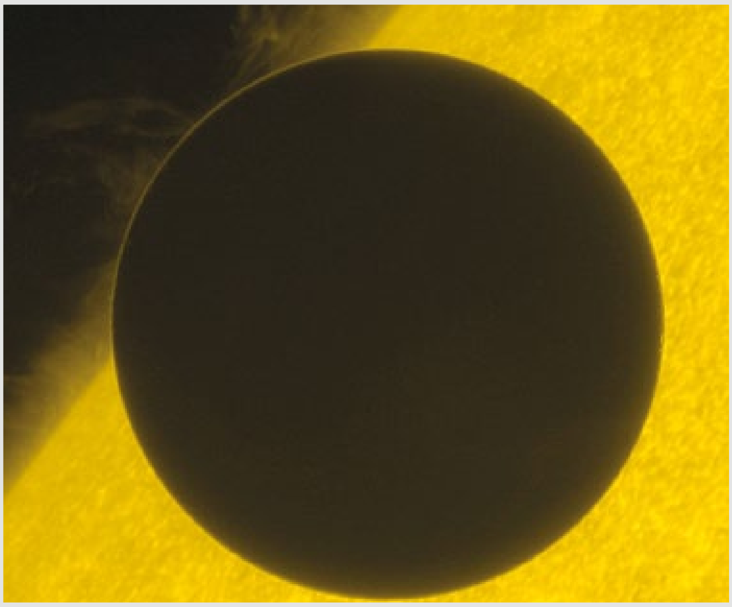
After more than ten years of work by European scientists and engineers, the Mid Infrared Instrument (MIRI) was declared ready in May for delivery from the UK to NASA's Goddard Spaceflight Center for integration on the James Webb Space Telescope (STFC/RAL)


2008
2009
2010
2011
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)
COSMIC VISION M3
JUICE (L1)
EXOMARS
EARTH OBSERVATION PROGRAMME
MSG
MTG
METOP
CRYOSAT
GOCE
SMOS
AEOLUS
SWARM
EARTHCARE
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
LAUNCHER PROGRAMME
ARIANE 5 POST-ECA
VEGA
SOYUZ AT CSG
IXV
SSA
PREPARATORY PROGRAMME
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2012
2013
2014
2015
COMMENTS
J F M A M J J A S O N D
LAUNCHED APR 1990 / OPS EXTENDED UNTIL 2014
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2014
LAUNCHED OCT 1997 / OPS EXTENDED UNTIL MAY 2017
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2014
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2014
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2014
LAUNCHED JUN 2003 / OPS EXTENDED UNTIL 2014
LAUNCHED MAR 2004 / ARRIVES AT COMET 2014
LAUNCHED NOV 2005 / OPS EXTENDED UNTIL 2014
LAUNCHED 14 MAY 2009; OPS UNTIL 2013
LAUNCHED 14 MAY 2009; OPS EXTENDED UNTIL 2012
LAUNCH MID 2014
LAUNCH MID 2016
LAUNCH OCT 2013 / NOMINAL MISSION END 2018
LAUNCH OCT 2018
LAUNCH MID 2015
LAUNCH JAN 2017
LAUNCH MID 2020
LAUNCH 2024
LAUNCH 2022
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 2016
CRYOSAT-2 LAUNCHED 10 APR 2010
LAUNCHED 17 MAR 2009: OPS UNTIL END 2013
LAUNCHED 2 NOV 2009
LAUNCH LATE 2015
LAUNCH NOV 2012
LAUNCH NOV 2015
LAUNCH OCT 2013
LAUNCH JUN 2014
LAUNCH APR 2014
LAUNCH JUN 2015
LAUNCHED JUL 2001, OPERATIONS EXTENDED
LAUNCH EARLY 2013
LAUNCH EDRS-A, END 2014; EDRS-C, END 2015
LAUNCH EARLY 2014
LAUNCHED NOV 2010; OPS 15 YEARS
OPERATIONS START 2008
GIOVE-A 2005 / GIOVE-B APR 2008 / IOV OCT 2011 & AUG 2012
LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH 2015/16
LAUNCH 2012
LAUNCHED FEB 2008 / OPS UNTIL END 2020
NODE-2: OCT 2007; NODE-3 WITH CUPOLA: FEB 2010
LAUNCH JUN 2013
ATV-3 MAR 2012, ATV-4 FEB 2013, ATV-5 FEB 2014
PARMITANO: MAY 2013; GERST: MAY 2014; CRISTOFORETTI: NOV 2014
BIOLAB, FSL, EPM, EDR (EuTEF, SOLAR) WITH COLUMBUS MAR 2008
MASER 12: FEB 2012; MAXUS-9: MAR 2015
PREPARATORY ACTIVITIES INCLUDING LUNAR LANDER
WITH PRE-SRR, SEP 2012
PHASE 1 MATURITY KEY POINT JUN 2012
FIRST LAUNCH FEB 2012
FIRST LAUNCH 21 OCT 2011
SYSTEM ACCEPTANCE REVIEW, JUN 2014
LAUNCH READINESS REVIEW JUL 2014, LAUNCH 28 JUL 2014
SYSTEM REQUIREMENT REVIEW, DEC 2011
PARMITANO
GERST
CRISTOFORETTI
MASER-12
FASTER
EML
FASES
MUE
TRIPLELUX A
TRIPLELUX B
RHOCYT
PK-4
ASIM
ACES
MAXUS-9
STORAGE
ADDITIONAL LIFE POSSIBLE
LAUNCH/READY FOR LAUNCH
ASTRONAUT FLIGHT

KEY TO ACRONYMS

AM - Avionics Model	LEOP- Launch and Early Orbit Phase
AO - Announcement of Opportunity	MoU - Memorandum of Understanding
AIT - Assembly, integration and test	PDR - Preliminary Design Review
AU - Astronomical Unit	PFM - Proto-flight Model
CDR - Critical Design Review	PLM - Payload Module
CSG - Centre Spatial Guyanais	PRR - Preliminary Requirement Review
EFM - Engineering Functional Model	QM - Qualification Model
ELM - Electrical Model	SM - Structural Model
EM - Engineering Model	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
ITT - Invitation to Tender	



Like a scene from the Danny Boyle film ‘Sunshine’ (2007), this Hinode image of the Venus transit is really spectacular (NAOJ/JAXA)

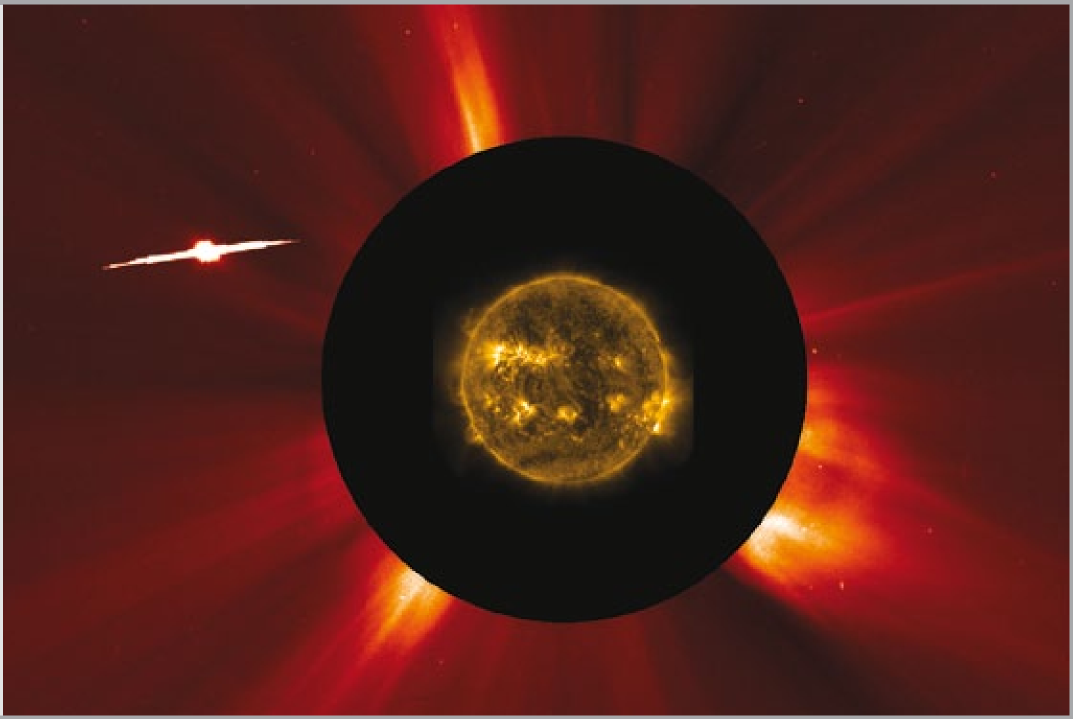
→ SOHO

Astronomers around the world looked to the sky in June to observe Venus as it passed across the face of the Sun for the last time this century. ESA’s Sun-watching space missions also tuned in for the solar spectacular. Along with SOHO, Venus Express, Proba-2 and Hubble monitored Venus and the Sun during the transit.

“The most spectacular images and movies should come from Hinode’s Solar Optical Telescope, which has by far the highest resolution of any solar instrument in space,” says Bernhard Fleck, ESA’s Hinode and SOHO project scientist. Hinode is a Japanese-led mission with ESA participation to study the mechanisms of the solar atmosphere.

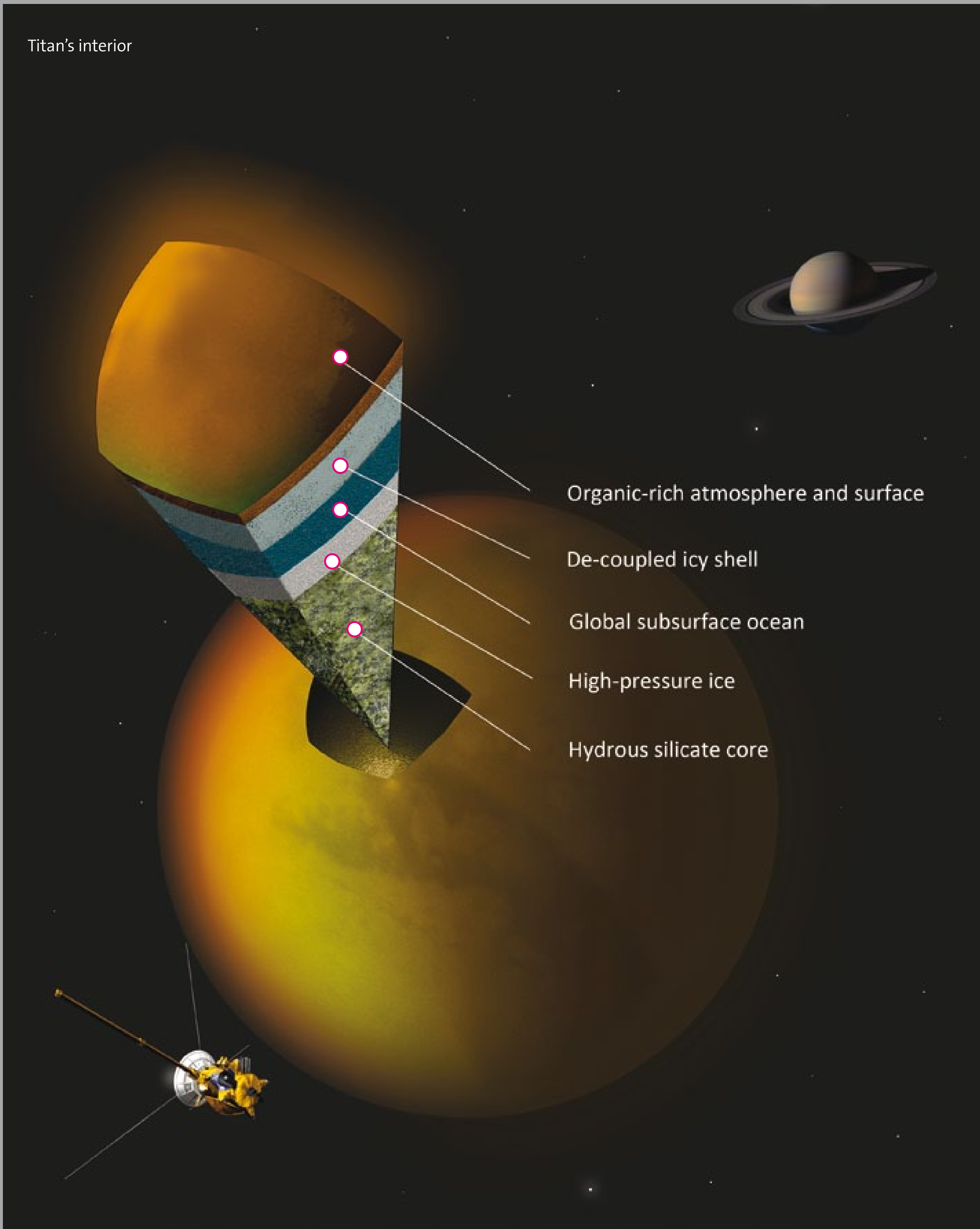
Unfortunately, SOHO was not well placed to observe the transit. However, it did something that no other spacecraft could do: provide views of Venus as it approached the Sun before the actual transit, and as it moved away for several days afterwards.

SOHO’s LASCO instrument captured this view of Venus approaching the Sun on 5 June.



→ CASSINI-HUYGENS

Cassini has detected large tides on Saturn's moon Titan that point to a liquid ocean (most likely composed of water) below its surface. On Earth, we are familiar with the combined gravitational effects of the Moon and Sun creating the twice-daily tidal rise and fall of our oceans. On Titan, the eccentricity of the moon's orbit results in varying gravitational pull from Saturn, which excites similar tides in Titan's crust, resulting in variations of about 10 m in height. Such an amount of crust deformation is only possible if the rigid part is floating on a global sub-surface liquid layer. Thermodynamic models and the relative abundance of chemical species in Titan's interior suggest the liquid layer to be liquid water-ammonia mixture.



→ XMM-NEWTON

Astronomers using data from XMM-Newton have found a long-sought after X-ray signal from NGC 4151, a galaxy that contains a supermassive black hole. Observations by XMM-Newton have revealed X-rays emitted and then reflected by ionised iron atoms very close to the central black hole. By measuring the time delays occurring in these 'reverberation' events, scientists have been able to map the vicinity of this black hole in unprecedented detail. The discovery promises a new way to unravel what is happening in the neighbourhood of these powerful objects.

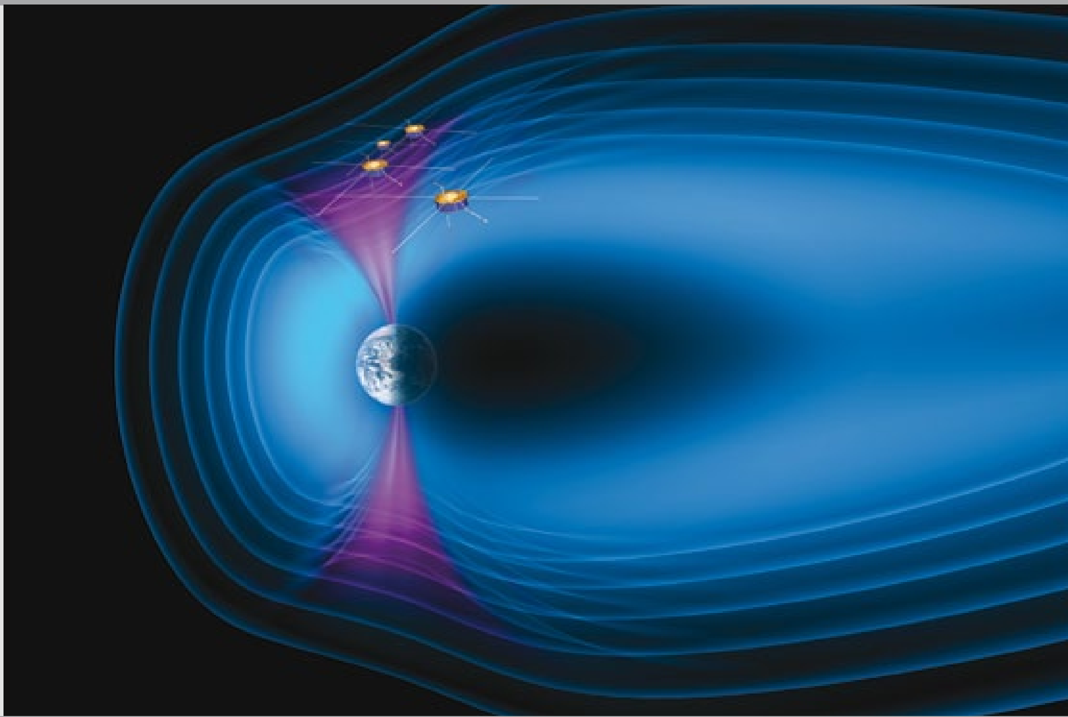
Supermassive black holes are enormous concentrations of matter, weighing millions to billions of times the mass of the Sun, that reside at the centre of most large galaxies, including the Milky Way. A small fraction of these supermassive black holes feed on material from their surroundings, giving rise to intense emission that may even outshine the entire radiation output of their host galaxies, and are known as Active Galactic Nuclei.

→ CLUSTER

Cluster continues to output great science. A recent science highlight focused on the magnetic cusp regions of the magnetosphere, two regions above the planet's magnetic poles where the magnetic field is extremely weak. This region was a key aspect of the original mission goals because it allows solar wind particles to access the upper layer of Earth's atmosphere – the ionosphere – and thus impact on modern technologies such as GPS positioning accuracy.

The observation of energetic particles has triggered an intense debate regarding the nature of such particles: exactly where and how are they being accelerated to such high energies, with several acceleration mechanisms suggested. Cluster has provided strong evidence that the particles are accelerated locally, in parts of the cusp with very low magnetic fields called 'diamagnetic cavities'. These regions are threaded by a magnetic field originally solely linked to Earth but which are snapped open through a process called reconnection, directly connecting the solar magnetic fields

The spiral galaxy NGC 4151, located about 45 million light years from us. NGC 4151 is a Seyfert galaxy and hosts one of the brightest Active Galactic Nuclei known at X-ray wavelengths. The supermassive black hole lying at the centre of NGC 4151 has a mass of about 50 million solar masses (D.W. Hogg/M.R. Blanton/Sloan Digital Sky Survey)



The magnetic environment of Earth with polar cusps in purple and the four Cluster spacecraft shown entering the northern cusp from the magnetosphere as they did in February 2003 (a very favourable crossing event to study the properties of high-energy particles in the cusp)

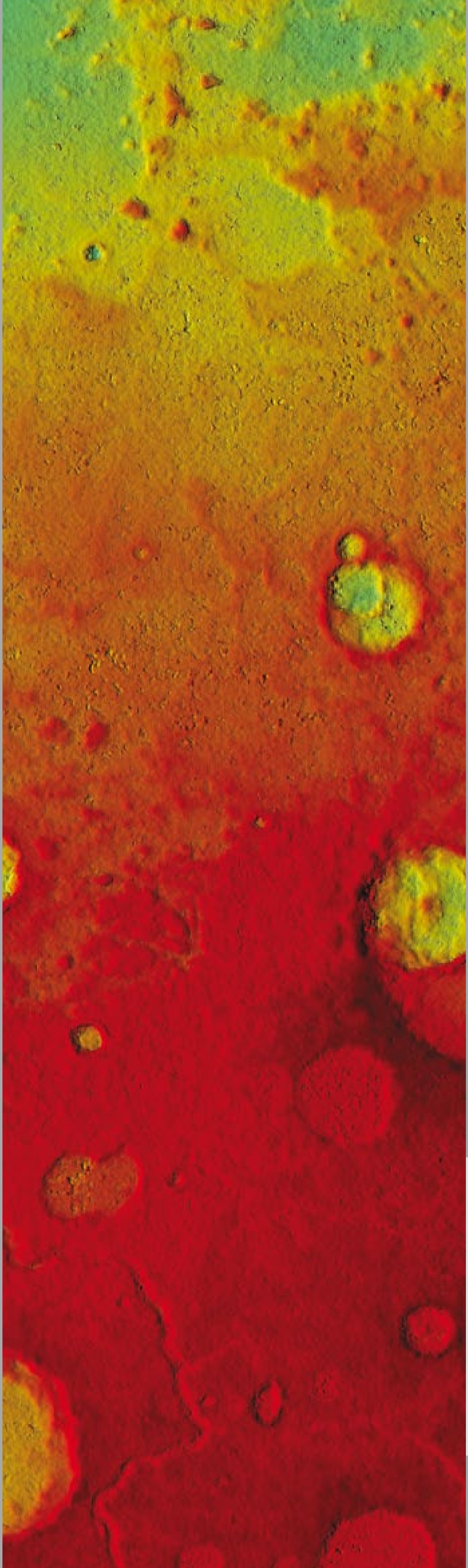
to those of Earth. These results have implications for other environments in the Universe with such magnetic geometry, such as regions below the Sun's corona.

Cluster has been implementing Guest Investigator (GI) operations. The aim of the GI Programme is to identify new and compelling use of the scientific payload and spacecraft configuration by requesting proposals from the scientific community. During the summer, Cluster will implement the next phase of these GI operations with a multiscale formation to investigate flow breaking on the night side of Earth, where large volumes of plasma impinge on the dipolar field lines of the magnetosphere. Cluster is also targeting the high-latitude regions of the magnetosphere linked to the aurorae, to continue its unique multi-spacecraft investigation of this region. These high-latitude regions will also be key for upcoming conjunctions with ESA's Swarm mission, which is due for launch in autumn this year, and there are activities examining the synergies between Cluster and Swarm.

→ INTEGRAL

The 9th Integral workshop 'An Integral view of the high-energy sky (the first 10 years)' will take place on 15–19 October in Paris, at the Bibliothèque Nationale de France 'François Mitterrand'. The workshop is sponsored by ESA, CNES and other French and European institutions. During this week, Integral celebrates its 10th anniversary, being launched on 17 October 2002. More details at http://IntegralWorkshop2012.in2p3.fr

Poster for the 9th Integral workshop



→ MARS EXPRESS

The Flight Dynamics team at ESOC, now using more precise astronomical position data for the martian moon Phobos, predicted that Mars Express would be occulted by the moon on 30 April for about 10 seconds. Seen from Earth, Mars Express would be about 10 000 km behind the moon. The occultation was measured to be actually a little shorter than predicted. By measuring the occultation entry and exit times while monitoring the Mars Express communication signal, Phobos's position was confirmed and possibly its accuracy could be improved even further. The next occultation will occur on 2 April 2013.
A recent published article, 'Characterization of hydrated silicate bearing outcrops in Tyrrhena Terra, Mars: Implications to the alteration history of Mars', reports a large number of detections of hydrated minerals, in the cratered highlands of the southern martian hemisphere. The presence of these minerals, altered by underground water during the planet's early history, indicates that subsurface water and fluids persisted for prolonged periods of time during the first billion years of the planet's existence.

→ ROSETTA

On its way to rendezvous with Comet 67P/Churyumov-Gerasimenko, Rosetta had a close flyby with main-belt asteroid (21) Lutetia, providing a valuable dataset for investigating this peculiar asteroid in great detail. The latest results have been published in a special issue of *Planetary and Space Science*. The part of Lutetia that was visible during the flyby – about half of its entire surface, mostly coinciding with the asteroid's northern hemisphere, was closely inspected by Rosetta's four remote-sensing instruments covering visible, infrared, microwave and ultraviolet wavelengths. Accurate to a few hundred metres, the close-up images obtained show regions characterised by very distinct geological properties. By tracing craters and other features on Lutetia's surface, it is possible to produce a geological map of the asteroid and to date the epochs when the various craters were produced by collisions with

A topographic map made up of images taken by the High Resolution Stereo Camera on Mars Express, showing part of the 'dichotomy boundary' between the southern highlands and the lower northern hemisphere on Mars. A valley network runs between large craters in the lower part of the image: this branching network is believed to have formed by the erosion of liquid water flowing at the surface, due to rain or snow melt. The topography and morphology show that water flowed from south to north. Such evidence of fluvial features is a big help in quantifying water action at the surface throughout martian history (ESA/DLR/FU Berlin) smaller bodies. For the largest craters, it was even possible to reconstruct details of the impacts that created them. Lutetia's surface has regions that range widely in age, and each reveals a chapter in this asteroid's long and tumultuous history, which is also reflected in its unusual surface composition determined from spectral analysis.

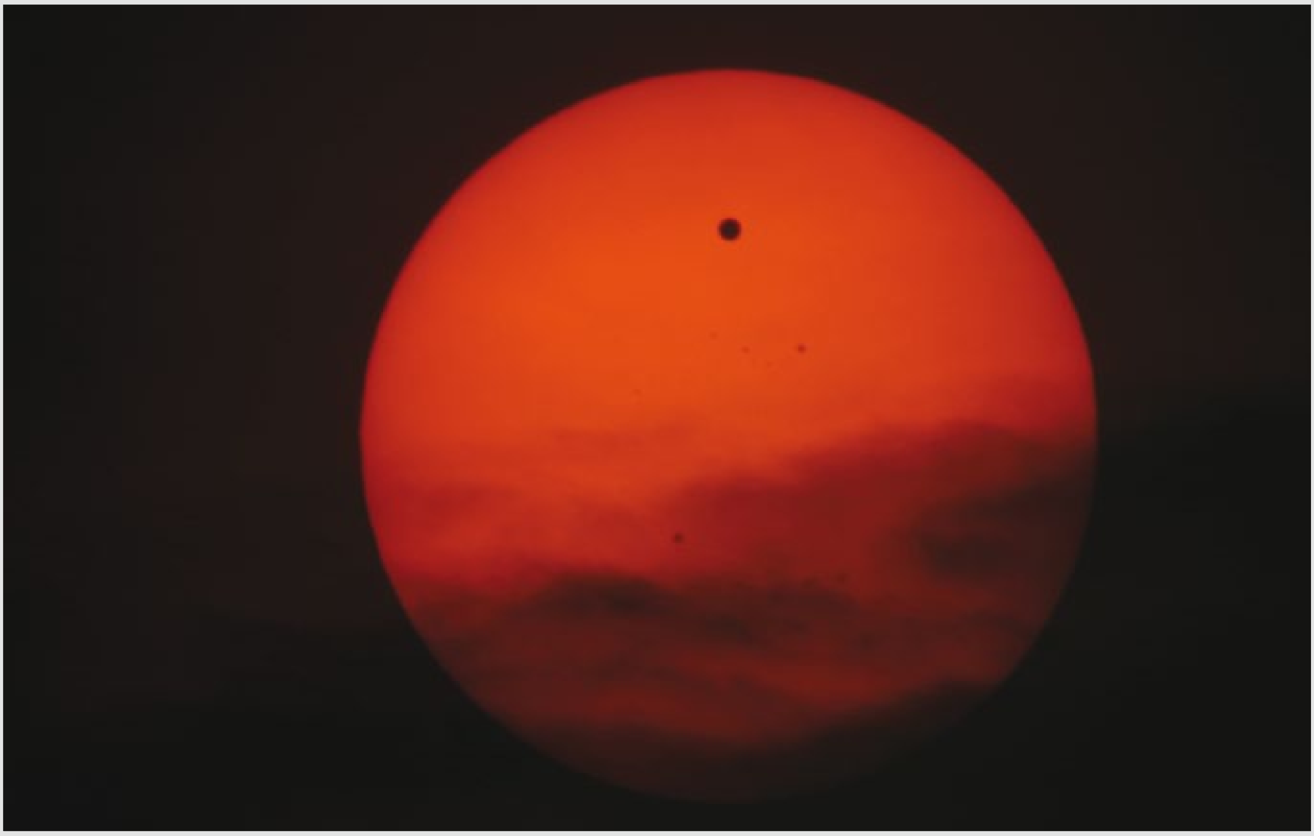
→ VENUS EXPRESS

The Solar Occultation in Infrared (SOIR) channel of the SpicaV instrument measures composition, density and temperature of the upper atmosphere of Venus with a solar occultation technique. The team analysing these data has discovered that a very cold layer exists at about 125 km altitude, in the 'mesosphere'. The temperature goes down below –173°C. This is surprisingly low; such low temperatures are not even found in Earth or Mars atmospheres and these planets are farther away from the Sun than Venus.

Preliminary tests of atmospheric models show that it may be possible to get such low temperatures if certain conditions are met. SOIR always takes its measurements at the terminator (the border between day and night) either on the morning or on the evening side. The team is now investigating if these low temperatures also occur on other places on the planet and what are the implications for atmospheric circulation and chemistry.

On 6 June, Venus passed between the Sun and Earth (making a 'Venus transit'). From Earth, Venus could be seen as a small black disc moving across the disc of the Sun for about seven hours. This is a very rare event, taking place only twice on average every 122 years. The reason for this is that the orbital plane of Venus is slightly tilted with respect to that of Earth's, and a transit can only occur when the planets line up near the intersection of the two orbital planes. Historically such transits have been important for determining the scale of the Solar System, following a method first proposed by Edmund Halley in 1691. Several dramatic attempts at various locations over Earth were made in the centuries following Halley's proposal and a reasonable estimate of the 'astronomical unit' of measurement (AU) was determined.

Nowadays these observations are more of historical interest, but recently it was realised that a Venus transit offers excellent opportunities for refining methods for searching and characterising atmospheres of exoplanets. The principle of studying an atmosphere of an exoplanet,



In Europe, because the event took place at night, the full transit could only be observed at latitudes north of the Arctic circle. This photo was taken against the midnight Sun in the middle of the transit from Svalbard, Norway, at latitude 78° N. In addition to Venus, several sunspots can be seen. Some low clouds near the horizon partly dim the image

In a study of regions where massive stars are forming, Herschel captured this stunning image of a part of the Cygnus nebula, a rich star-forming region about 4500 light years from us. The image combines data at 70 µm (blue), 160 µm (green) and 250 µm (red) wavelengths and shows the famous 'swan'. Exploiting the unique capabilities offered by Herschel in this portion of the spectrum provides astronomers with new observations, helping us to understand how massive stars form and influence the formation of lower-mass stars in their surroundings (ESA/Herschel/PACS/SPIRE/HOBYS)

by looking at how the starlight is modified by being partly filtered through a planetary atmosphere, is more or less identical to how sunlight is modified by transmission through the atmosphere of Venus. Venus Express is making detailed observations of the regions of the atmosphere that can be observed from Earth during a transit and so is providing 'ground truth' for the simulated exoplanet observations. The next Venus transit will take place in 2117.

→ HERSCHEL

Herschel and its ground segment continue to perform well, and the stream of data containing new information and discoveries about the 'cool Universe' is uninterrupted. Images and spectra will continue to be received until all superfluid helium on the satellite has been exhausted. The prediction for 'end-of-helium' date is regularly refined and has been updated to March 2013, providing a couple of more weeks of observing.

Although the end of observations is a very important milestone, it is not the end of the Herschel mission. The science ground segment will continue to support Herschel observers for years to come. The final 'disposal' of the spacecraft is under consideration, and placing it in heliocentric orbit is the current plan, but the possibility of a lunar impact providing an unplanned bonus for scientists interested in the Moon is also being investigated.

→ COROT

COROT has now spent more than 2000 days operating normally in orbit. The process of extending the mission for a second time, now beyond 2013, is continuing and detailed planning for operations during this extension is being finished. COROT continues to deliver high-quality data and aging effects are small and have not impacted any of the data. Analysis of tens of thousands of exoplanetary light-curve results indicates that solar-type stars are more active in general than previously assumed. Our Sun appears to be among the least active among such stars; NASA's Kepler team reached a similar conclusion. What the impact of such a result will be, for example on the issue of life on habitable planets, is too early to say, but it is interesting that the Sun is special in at least this respect.

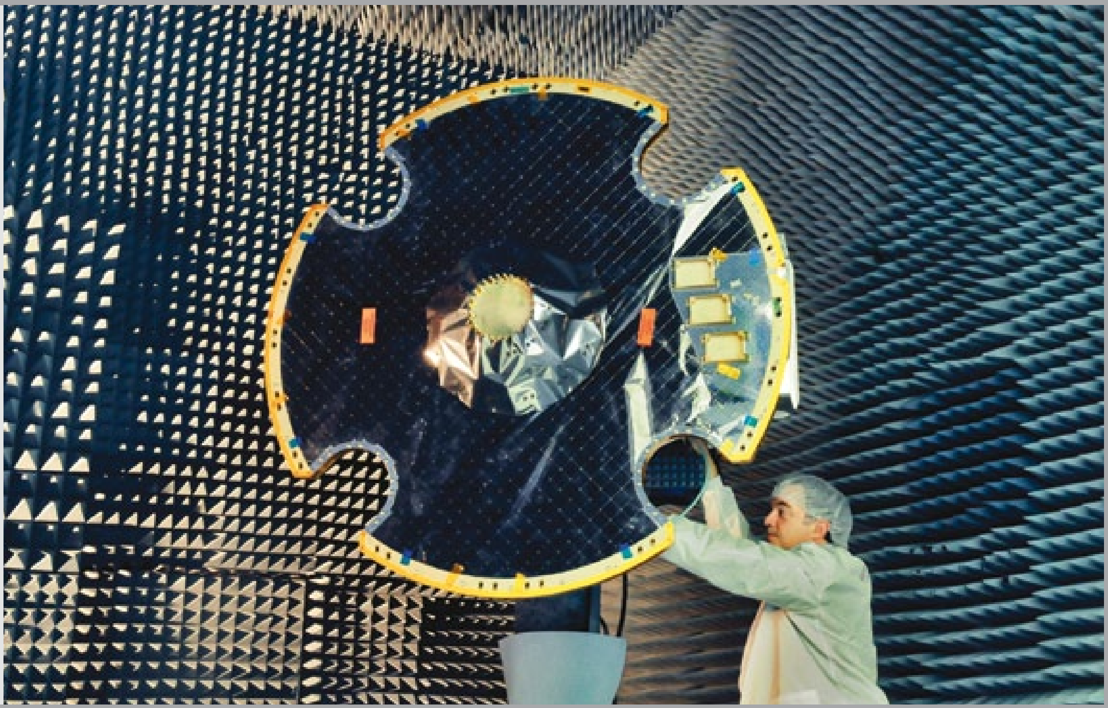
This summer, COROT is observing two fields in the sky, in the direction towards the galactic centre. One of the primary targets of the asteroseismological observations is a bright solar-type star already known to be host to one planet. This planet was discovered in 2009 through radial velocity observations from the ground, and has a mass of about 25 Earth masses. It is not a transiting object, but there are reasons to believe that the orbital plane of the system is close to be transiting. With a period of 14.5 days, this leaves plenty of room for other potential (smaller) planets in this system to be transiting and therefore could be discovered by COROT.

It is also expected to detect the variations in the reflected light from the planet itself as it orbits its host star, as well as the solar-like oscillations ('pressure modes' or p-modes) from the star itself. The latter observation will allow a proper (accurate to within 1%) determination of the stellar mass and radius. Apart from observing this important object, COROT will also observe more than 1200 red giant stars, as well as around 500 very hot stars.

Another primary task is the detection of solar-like oscillations in both components of an eclipsing binary already observed once by COROT. This object is the brightest eclipsing binary – containing a red giant and a B-type star – that COROT can access in the sky. The observation of the secondary eclipse of this system, occurring in July, is very exciting and allows a unique identification of p-modes in the light curve.

→ GAIA

The Gaia procurement phase is formally closed. All flight hardware is with the prime contractor Astrium SAS. The last deliveries were the Basic Angle Monitor and the Focal Plane Assembly for the PLM, the Phased Array Antenna and the last micropropulsion thrusters for the SVM.



The Gaia Phased Array Antenna in the Radio Frequency test chamber at Astrium CASA ESPACIO (Astrium)

The alignment of the two telescopes has been accomplished.

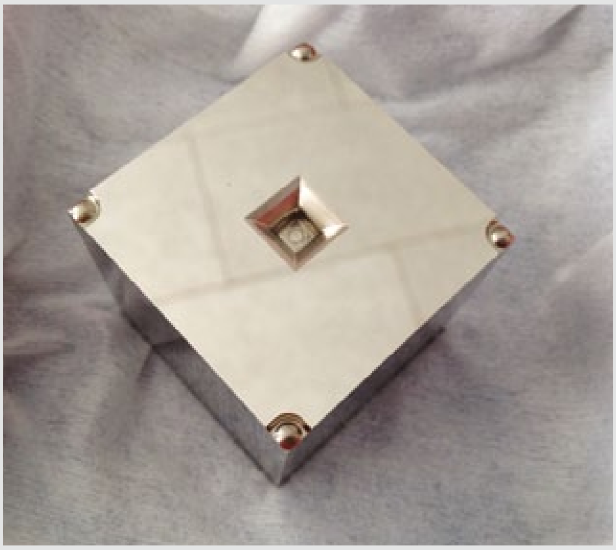
A high spatial frequency defect has been found on the filter of the Radial Velocity Spectrometer during the optical system tests on the PM. The defect arose from a very specific coating process, which was necessary because of the large size of the filter. The problem is understood and a new set of filters will be manufactured. The SVM is being finalised for thermal balance/thermal vacuum test.

Work with the operations and science ground segments is progressing. Dates of the System Validation Tests (on the AM and FM spacecraft) are set after summer. The Science Operation Centre (SOC) and, to a limited extent, the Gaia Data Analysis and Processing Consortium (DPAC) will participate to one of the tests. An end-to-end operational test is running at the SOC in ESAC (including all key ground software elements required for the spacecraft commissioning phase, connected in a single environment).

Work with Arianespace continues. The launch vehicle assigned to Gaia is a Soyuz 2.1b (three stages) and a Fregat MT upper stage.

→ LISA PATHFINDER

The Lisa Technology Package (LTP) units, needed for the completion of the LTP Core Assembly (LCA), have been dismounted from the spacecraft; notably, the Optical Bench FM, which took part in the thermal vacuum and thermal balance test at system level, is currently at the University of Glasgow for further verification at unit level.



One of the two accepted flight test masses for LISA Pathfinder: at the core of this mission, these two gold/platinum test masses are 46 mm in width and weigh about 2 kg

During April and May, the Qualification Review Part 1 took place for the system environmental testing. At the outset, the major technical issue related to the qualification of a significant number of units to the shocks generated by the Vega launcher. Through a dedicated effort by ESA and industry in close cooperation, most units were qualified for the shock environment and only a very limited set of actions are needed to remove residual risk.

The better-than-specified performance of the attitude off-pointing allowed an increase in the number of launch opportunities from about 70 days to more than 200 days per year, now fully adequate.

Since the launch lock mechanism concept for the inertial sensor head was chosen last year, industrial development is proceeding and the CDR was held April. This was followed in May by a 'delta-CDR' of the Inertial Sensor Head itself, which needed some redesign to accommodate the new mechanism.

The baseline launch vehicle is Vega, on the third VERTA launch. The PDR for the back-up launcher, Rockot, was held in 2011 and all related actions were closed in May.

→ BEPICOLOMBO

The Science Working Team defined the strategy for possible Mercury Planetary Orbiter (MPO) orbit adaptation for best scientific return in view of the uncertainty of Mercury's gravitational field as measured by the NASA Messenger spacecraft. Definition of thermal design modifications to reduce heat leaks into the spacecraft and improve heat transfer capability to the radiator was completed. Associated new procurements were initiated and the integration of the thermal hardware and chemical propulsion system on the FM spacecraft is proceeding.

The three spacecraft module STMs and the sunshield were integrated into the launch composite and the mass properties tests were completed. The launch composite was transferred to the vibration table for testing. The Electric Propulsion subsystem's first coupling test of the thruster, power supply and flow control valve was completed. The Solar Array CDR is in progress, as is the parallel qualification of two solar cell options. The development schedule of equipment remains critical in view of the qualification in parallel to FM development.

The MPO payload teams began qualification of their instruments in support of the delivery of FMs in early 2013.

BepiColombo in integrated launch configuration on the mass properties table at ESTEC, Noordwijk

Preparations were ongoing for the first System Functional Test on the spacecraft Engineering Test Bed, with parallel operation of the payload, and for electromagnetic compatibility testing in September.

JAXA has completed an additional thermal vacuum test of the Mercury Magnetospheric Orbiter (MMO) at 1 Solar Constant to validate improvements on the thermal hardware. The environmental acceptance test campaign of FM units is ongoing, allowing the start of the final MMO spacecraft integration in autumn 2012.

Work on the Ariane 5 launch services is proceeding. The ground segment supported the first end-to-end test between the control centre and the Engineering Test Bed. An extensive test between the deep space transponder and the ground station equipment to demonstrate radio frequency compatibility has been performed.

→ MICROSCOPE

The new ITT for the procurement of the cold-gas micropropulsion system was released in March. Selex-Galileo (IT) was selected as industrial contractor. In June, ESA endorsed the participation in the CNES Microscope programme and approved the start of procurement.

→ EXOMARS

Work continued on the Trace Gas Orbiter (TGO) and Entry, Descent and Landing (EDL) Demonstrator Module, to be launched in 2016, as well as study work on a Mars surface science mission with an ESA rover and a Russian lander platform to be launched in 2018.

The ESA/Roscosmos bilateral cooperation was consolidated through a Declaration of Intent for Joint Mars Exploration Missions and agreements on a cooperation plan. Meetings between ESA and Roscosmos, including European industry and several key Russian companies such as Lavochkin, Tsniimash, Krunichev and Tsenki, looked at a broad international cooperation and advanced technical understanding.

Roscosmos confirmed their commitment to launch the 2016 mission on a Proton rocket and to provide two important instruments for the 2016 TGO, consolidating the 2016 mission cooperation. ESA and Roscosmos continued discussions on the 2018 mission and agreed to start a Phase-B study with all parties later this year.

Development progress on the 2016 mission continues apace with the schedule need and a number of key events were successfully achieved. The TGO instruments, including two Russian instruments (ACS and FREND) and two European instruments (NOMAD and CASSIS), were accommodated in the orbiter payload area.

TGO software development has started and the main orbiter spacecraft structure was fixed at the Manufacturing Readiness Review. For the EDM, the landing platform was designed and proven with a series of landing tests to demonstrate the capabilities of the crushable structure. Several tests of the aeroshell components and materials have also passed development testing. A DREAMS instrument STM was delivered for integration into the EDM surface platform STM.

For the 2018 mission, ESA and Roscosmos have studied the mission architecture and arrived at a design for a spacecraft composite consisting of a compact Carrier Module provided by ESA, a large Descent Module (about 1.6 tonnes) from Roscosmos with some contributions by ESA, and a 300 kg ESA Rover with some scientific instrument contributions

The ESA EDM Surface Platform crushable structural test model (SENER)

from Roscosmos. Roscosmos presented a first design for the Descent Module, which will land on retractable legs that are subsequently used to level the surface platform to ease the Rover's egress onto the martian surface.

Payload accommodation studies on the Rover have continued along with technological developments for the Sample Processing and Distribution System and the 2 m Sub-Surface Drill.

→ SOLAR ORBITER

All sub-system level procurement activities are complete. Activities continue with some lower-tier items and several sub-system PDRs are ongoing. The Heat Shield PDR was conducted and will be closed out exercise in September 2012.

To reduce project risk, a new process development and qualification has been started for surface treatment of high-temperature materials (multilayer insulation on antennas, Heat Shield front, feedthrough coatings) as a back-up to the baseline design. Eight instrument PDRs have now been conducted, with two more scheduled for later this year.

Agreements have been reached to procure a European-led SPICE instrument (with involvement of US institutes) to replace the originally NASA-funded instrument, and a European-led Suprathermal Ion Sensor (part of the Energetic Particle Detector instrument suite).

NASA is considering whether to select a more powerful Atlas V-411 launch vehicle, allowing an additional launch opportunity in late 2017. If this is approved, ESA and the prime contractor have to verify the system compliance with this opportunity.

→ JAMES WEBB SPACE TELESCOPE

NASA activities continue in the new project plan for launch in October 2018. All milestones have been completed on schedule. The cryogenic facility for the Integrated Science Instrument Module (ISIM) is in final test runs, including its optical system simulating the main telescope. The cryogenic facility for the testing of the combined ISIM and 6.5 m main telescope is being built.

The re-integration of NIRSpec onto the flight spare optical bench is under way. The first main optical assemblies and two mechanisms have been integrated. The standalone detector system and micro-shutter system tests are being carried out in parallel to reduce risk for the main integration. The NIRSpec Engineering Test Unit is also being prepared for delivery to NASA for the first ISIM cryogenic test.

The MIRI FM Acceptance/Pre-Shipment Review was concluded, so it could be shipped to Goddard Spaceflight Center. MIRI is the first JWST flight instrument delivered.

JWST's MIRI Optical System incoming inspection at NASA's Goddard Spaceflight Center (NASA)

The instrument sensitivity issue will be solved in parallel to the instrument integration and test by using a detector test bed at NASA's Jet Propulsion Laboratory.

→ PROBA-2

The LYRA radiometer continued its 'solar flare hunting' campaigns. During these campaigns, the instrument team tries to acquire data during a solar flare with one of the instrument back-up units. Because the filters for extreme ultraviolet radiometers degrade considerably when exposed to solar radiation, the team want to minimise their use (to extend the detector's lifetime). They predict possible flare eruptions and switch on the back-up units only during these predicted times. Because solar activity was moderate in the last three months, not too many flares were caught. Despite this, the hunt goes on, because potential findings in especially the Lyman-Alpha channel may provide important insights into the flaring mechanism.

There were two noteworthy astronomical events in the last months: the solar eclipse on 20/21 May, observed by both solar instruments on Proba-2, as well as the Venus transit in June. The eclipse was visible from Earth as an annular eclipse, but the imager on Proba-2 only saw it as a partial eclipse (because of the spacecraft altitude at 720 km).

Venus transit observations began when Venus moved into view between the spacecraft and the solar corona.

The scientific campaign to make a possible Lyman-Alpha observation ended some 30 hours after the end of the actual transit. Proba-2 was pointed off several degrees towards Venus after the transit with the Sun out of the field of view. Lyman-Alpha emission occurs in the atmosphere of Venus, but was not detected by LYRA because of the weak signal arriving at the detector.

→ ENVISAT

Just weeks after celebrating its tenth year in orbit, communication with the Envisat satellite was suddenly lost on 8 April. Attempts to re-establish contact with the satellite were immediate, using a widespread network of ground stations.

Because there were no signs of degradation before the loss of contact, the investigation team has been collecting external information to help understand the satellite's condition. These include images from ground radar and the French Pleiades satellite.

Having investigated all areas suspected of causing such an anomaly, there were several failure scenarios. Two were the coherent with the collected information:

– Scenario 1: The loss of the Regulated Power Bus through a double failure (i.e., a 'silent first failure' could have happened in the past) would stop telemetry and telecommand capabilities while the carrier continues transmitting until the batteries are depleted. The satellite is without attitude control but no transition to Safe Mode occurs.

– Scenario 2: The satellite was triggered into Safe Mode in response to a short circuit of a Telecommand Coupler in the Central Communication Unit. Entering Safe Mode was unsuccessful because of a subsequent failure, e.g. a gyro converter failure, a thruster failure or a failure in the safe mode electronics (noting that Safe Mode has never been entered since launch).

Envisat appears to be completely unpowered, with the batteries empty and the solar array not providing any or not enough power to restart any functions. The hydrazine in the pipes and probably other liquids are likely to be frozen.

The outstanding performance of Envisat over the last decade led many to believe that it would be active for years to come, at least until the launch of the follow-on Sentinel missions. However, Envisat had already operated for double its planned lifetime, making it well overdue for retirement.

With ten sophisticated sensors, Envisat has observed and monitored Earth's land, atmosphere, oceans and ice caps, delivering over a thousand terabytes of data. An estimated 2500 scientific publications so far have been based on this information, furthering our knowledge of the planet.

During those ten years, Envisat witnessed the gradual shrinking of Arctic sea ice and the regular opening of the polar shipping routes during summer months. Together with other satellites, it monitored the global sea-level height and regional variations, as well as global sea-surface temperatures with a precision of a few tenths of a degree. Years of Envisat data have led to a better understanding of ocean currents and chlorophyll concentrations.

Envisat

In the atmosphere, the satellite observed air pollution increase in Asia and its stability in Europe and North America, and measured carbon dioxide and methane concentrations. It also monitored the Antarctica ozone hole variations. Over land, it mapped the speed of ice streams in Antarctica and Greenland.

Envisat's images were used regularly to update the global maps of land use, including the effects of deforestation. Using its imaging radar, Envisat mapped ground displacements triggered by earthquakes and volcanic eruptions, improving understanding of tectonics and volcanic mechanisms.

Envisat provided crucial Earth observation data not only to scientists, but also to many operational services, such as monitoring floods and oil spills. Its data was used for support civil protection authorities in managing natural and man-made disasters. It also contributed valuable information to the services within the framework of Europe's Global Monitoring for Environmental Security (GMES) programme, paving the way for the next generation of satellites.

Now with the end of the mission, the launch of the upcoming GMES Sentinel satellites has become even more urgent to ensure the continuity of data to users, improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

→ GOCE

GOCE continues to deliver top-class gravity field data in the form of gravity gradients, satellite-to-satellite tracking data as well as gravity field models and derived quantities.

The reprocessing campaign of all Level 1b data is complete, following an improvement of the gradiometer data processing algorithm chain. Release 4 of GOCE-based gravity field models is expected in 2013.

ESA is preparing for operations beyond 2012. Having reached all its objectives, the mission offers a unique opportunity to find ways of significantly improving the spatial resolution of gravity field data, in a way no other mission will be able to do. This would mean operating at a 15–20 km lower altitude. A decision on the operating altitude for 2013 will be made in September. Note that GOCE is already and by far the lowest orbiting research satellite worldwide.

Having collected all data on the xenon gas consumption by the drag-free control system, as well as air density predictions for 2013, it is expected that the mission will come to a natural end late next year.

→ CRYOSAT

Both the space and the ground segment continue to operate flawlessly, acquiring and generating science data systematically. The reprocessing of the first 18 months of data has started and will be completed in 2013.

→ ADM-AEOLUS

The endurance test of the first flight laser in near-vacuum conditions has revealed laser damage on the ultraviolet optics. A programme for optimising the optical coating processes has been started and new substrates for all ultraviolet optics are being procured.

The infrared sections of the laser transmitters are being refurbished because of a common anomaly in their optical amplifiers. During the refurbishment of the transmitting and receiving optics, an anomaly was discovered in one of the beam expander's optical elements. With the overall unit alignment almost complete, a solution was found.

→ SWARM

The three satellites have completed their FARs and are being prepared for storage before the launch campaign. Launch is planned for 10–13 November.

→ EARTHCARE

The industrial contract rider for Phase-C/D was signed by ESA and Astrium GmbH. Satellite system-level test plans are being reviewed for the second Verification Control Board. The spacecraft EFM is being prepared for testing.

The Power Laser Head STM of the ATLID laser instrument is being manufactured and procurement of parts for the transmitter and receiver is ongoing. PDRs of several key units in ATLID have started.

The Boot Software CDR of the Instrument Control Units for the European instruments was performed. The Application Software CDR of the Broadband Radiometer instrument has also started.

JAXA and its industrial partners are integrating the Cloud Profiling Radar EFM. The CPR Electrical Interface Simulator is being assembled to allow representative testing of this instrument as part of the EFM programme.

A CALIPSO/CloudSat/EarthCARE science workshop was held in June in Paris, underscoring the importance of this

MSG-3 launch on 5 July (ESA/CNES/Arianespace/Photo-Optique Video CSG)

mission, which is expected to provide significant scientific breakthroughs in the understanding cloud and aerosols related processes.

→ METEOSAT

MSG-3

The spacecraft completed all its tests and fuelling at Kourou. It was integrated on the launcher on 25 June, ready for launch on 5 July. The launch was originally planned for 19 June but was postponed because of issues related to the co-passenger satellite EchoStar 17. All simulation campaigns at ESOC took place to prepare for LEOP. MSG-3 was launched on 5 July. After 11 days of LEOP, Eumetsat took control of MSG-3 operations on 16 July.

→ MTG

The Flexible Combined Imager instrument PDR concluded in June. The satellite PDR is ongoing, covering both the MTG-I (Imager) and MTG-S (Sounder) satellites. The Infrared Sounder and the Common Platform PDRs are both planned for September/October.

The Best Practice Procurement process continues with about 80% (by value) of anticipated ITTs/RFQs released. For 65% of these procurements, the preferred suppliers have been selected, with negotiations either ongoing or completed. Of particular note was the selection and negotiation of the Lightning Imager supplier, which allows a formal start of this critical and very challenging instrument development in July.

→ METOP

MetOp-A

The satellite is performing very well, even though it exceeded its planned five-year life on 19 October 2011. Extended operations are now confirmed, at least up to the end of MetOp-B commissioning in 2013.

GOME-2 is producing very good scientific data, but the unexpected throughput loss behaviour can still lead to some science limitation, during the extended mission. GOME-2 throughput has been stable over the last 18 months with very small degradations for specific frequency ranges.

MetOp-B

The satellite has been at Baikonur since February. Just before filling the satellite tanks with hydrazine, Russian launcher authorities informed ESA that Kazakhstan had not provided launch authorisation. This was because the launch would be in a northerly direction, required for MetOp's Sun-synchronous orbit. The satellite went into storage for seven weeks and needed some intervention for items with limited lifetime. This issue was resolved and launch rescheduled for 19 September.

EADS/Astrium team training for the fuelling of MetOp-B (Astrium GmbH)

Launch preparations have resumed with satellite hydrazine filling in August and integration inside the fairing and with the launcher in September. The Soyuz launcher, fairing and Fregat upper stage are in storage at Baikonur.

→ SENTINEL-1

Integration is progressing: the external structure panels, once equipped with the thermal hardware, are being fitted with the different platform subsystems at Thales Alenia Space Italy. The propulsion subsystem and the batteries are already integrated on their respective panels. The electrical integration of the avionics subsystem is completed and undergoing tests with the flight software. The AIT campaign of the two large solar array panels is also completed.

At Astrium GmbH, Germany, the SAR instrument is in the final phases of the antenna integration. The SAR electronics EM testing at Astrium Ltd., UK, is complete and the assembly and integration of the flight unit is ongoing. On the Optical Communication Payload (TESAT, Germany) the telescope assembly is complete.

Activities with the launch service provider, Arianespace, continue towards a launch in October 2013.

→ SENTINEL-2

Two launch service contracts have been signed with Eurockot (Rockot for Sentinel-2A) and with Arianespace (Vega for Sentinel-2B). The Rockot Preliminary Mission Analysis Review began in June. The first Sentinel-2 Satellite Validation Test campaign during which the Satellite EFM was remotely operated by the flight control team at ESOC was completed in March. The Optical Communication Payload development activities conducted under the responsibility of DLR intensified at TESAT to meet the date needed for Sentinel-2 in Spring 2013.

The last procurement actions of the Payload Data Ground Segment are being finalised to support the Ground Segment CDR in March 2013. A Sentinel-2 preparatory symposium in April at ESRIN gathered more than 300 research and development users in all aspects of mission applications including land cover, forestry and agriculture.

→ SENTINEL-3

Phase-C/D manufacturing and AIT are under way. At spacecraft level, platform integration activities are continuing. Virtual EM testing is proceeding and the validation of the flight software version 2 is almost complete, with a delivery planned in July, in preparation of the first System Validation Test between the satellite virtual EM and the flight operations segment in September.

Testing of the OLCI FM key elements (Focal Plane Assembly, Video Acquisition Module and Electronics Unit) is ongoing. The SRAL PFM instrument TRR took place in June. SLSTR virtual EM testing was completed. The FM structure is ready for delivery to the Optical Mechanical Enclosure contractor and the integration of the PFM should start shortly. Final confirmation of the achieved good performance of the redesigned infrared detectors is expected, allowing this critical design element to be fixed.

Activities leading to the Preliminary Mission Analysis Review (PMAR) with Rockot towards the end of this year are ongoing. Similar activities are also ongoing with Arianespace, with a slightly shifted planning to allow completion of the Vega PMAR by the end of the year. Rockot is the baseline launcher for Sentinel-3A, while Vega is the baseline launcher for Sentinel-3B.

→ SENTINEL-5 PRECURSOR

The satellite/system-level PDR began in May. A Ground Segment Requirements Review is covering the Flight Operations Segment and Payload Data-processing Ground Segment. In addition, a Software Reuse File review has started for existing satellite central software to identify all components to be incorporated in the specific Sentinel-5 Precursor software.

CDRs for the Tropospheric Monitoring Instrument (TROPOMI) started in June, for the payload sub-systems, and will continue to the end of the year, with an instrument-level CDR in 2013. A new launch date was set for 30 June 2015.

→ EUROPEAN DATA RELAY SYSTEM

A public–private partnership contract has been signed with Astrium. The first EDRS payload – a laser communication terminal and a Ka-band inter-satellite link – will be carried on the Eutelsat-9B satellite, built by Astrium and positioned over 9°E. The first of the two EDRS nodes will be launched in 2014. The second EDRS node will be launched in 2015 on a dedicated satellite built by OHB that will use the SmallGEO platform, and will also embark Avanti's Hylas-3 satellite as a 'hosted payload'.

→ ALPHABUS AND ALPHASAT

The Inmarsat-led Alphasat Final Design Review was held in June. The satellite completed its first full electromagnetic compatibility test with the payload. The satellite thermal vacuum test is being prepared for September. The four Technology Demonstration Payloads supplied by ESA and national space agencies are now all fully integrated on the spacecraft and are also ready for the thermal vacuum test. Launch will be in early 2013.

The Alphabus Extension programme is on track to significantly increase the mass of embarked payloads by, among other things, making extended use of electric propulsion.

The Alphasat team after integration of the Laser Communication Terminal on the satellite (TESAT)

Alphasat Technology Demonstration Payload 1, the Laser Communication Terminal

→ ARIANE 5 POST-ECA

The Steering Committee for the Maturity Key Point of June noted that the project was now proceeding in Phase-C and declared the closure of the Launch System PDR, confirming consistency of subsystem specifications and launcher performance figures. The performance requirement for a geostationary transfer orbit (with deorbit) mission at 11.5 tonnes was set, considering Vinci idle mode as the baseline. The Mission Requirements Document change proposals were approved.

→ VEGA

After the successful VV01 flight, the Vega Qualification Flight Level 1 exploitation was completed in June, followed by the start of the Flight Qualification Review. The analysis confirmed the excellent results in terms of robustness of the launcher, margins and predictions. The Radio Frequency working group completed its analysis of the perturbation of the RF link during the qualification flight and the conclusions and improvements were proposed in June.

The VV01 Return of Experience exercise, organised to perform a detailed review of the VV01 campaign data and to optimise the ground operations for future launches, began in March and closed in June.

Investigations have been made for the complementary telemetry to be introduced on the VERTA 1 flight to provide the necessary information related to the multi-payload separations as well as the adapter. The Flight Software code review was completed, and the adapter Manufacturing Review was performed. The VERTA 1 Preliminary Mission Analysis Review was held in May, and preparation for this flight is on schedule.

→ FUTURE LAUNCHERS PREPARATORY PROJECT

Intermediate eXperimental Vehicle (IXV)

The second IXV Industrial Workshop was held at ESRIN, 31 May/1 June.

→ NEXT GENERATION LAUNCHER

In system studies, after the first main milestone (KP1), the second phase has been completed with a down-selection of the concepts: the file associated to CH concept will be updated, and the activities will continue on the HH Boosted configurations (both in Staged Combustion and Gas Generator variants) as well as on the PPH. The third phase, which will include an update of the documentation for each retained concept, is close to completion.

Phase-B of SCORE-D (Stage COmbustion Rocket Engine Demonstrator) is progressing towards the PDR in October. The development Key Point was completed in June, defining a reference Demonstration Logic for SCORE-D testing and associated back-up, including the necessary level of subsystem tests before defining a full demonstrator campaign. The sub-system Feasibility Reviews are progressing. The Test Readiness Review for new Pre-Burner & Main Combustion Chamber technologies, based on Astrium GmbH technology, has authorised as a test campaign now in progress on the P8 test bench at DLR Lampoldshausen.

In Cryogenic Upper Stage Technologies (CUST), industrial activities are progressing, with the post-flight analysis of the in-flight demonstration of the Propellant Management Device (flown on a Texus sounding rocket in November). Several other technology development are progressing, such as the development of Jettisonable Ground Fluid Connector (SRR complete) and the Versatile Thermal Insulation developed by Thales Alenia Space Italy (CDR in progress).

A CUST workshop was organised with industry in June in ESA HQ in Paris.

→ HUMAN SPACEFLIGHT

ISS highlights included the undocking of the Russian Progress 46P logistics spacecraft on 19 April, and launch and docking of Progress 47P (with 2.6 tonnes of ISS cargo) on 20 and 22 April respectively.

In May, the new logistics vehicle SpaceX Dragon began serving the ISS and providing additional means to return samples and equipment from orbit. This spacecraft is the first commercial unmanned cargo spacecraft under NASA contract. Launched from Cape Canaveral Air Force Station in Florida on 22 May on the new Falcon-9 launcher, it delivered about 520 kg of cargo on its final demonstration flight. After berthing to the ISS's Node-2 and a few days of cargo transfer activities, the Dragon undocked on 31 May, splashing down off the California coast some five hours later with around 660 kg of samples and cargo from orbit.

In the run up to the arrival of Dragon, ESA's André Kuipers and NASA's Don Pettit (and Joe Acaba) had extensive simulated and actual robotics training on the ISS, including practicing malfunction scenarios. On 25 May, Kuipers assisted Pettit in capturing the Dragon using the ISS Canadarm 2. Dragon was then moved to a hold position before finally being berthed at Node-2 with Kuipers as the

The new logistics vehicle SpaceX Dragon berthed on Node-2 of the ISS (ESA/NASA)

André Kuipers' close-up of Dragon approaching the ISS (ESA/NASA)

main robotic arm operator. Kuipers and Acaba were principal arm operators for undocking Dragon.

Systems and payload activities by Kuipers included replacing the failed GPS1 receiver of the Attitude Control System/Global Positioning System in the US laboratory on 4 April with Dan Burbank; assembling a radiation detector (Tissue Equivalent Proportional Counter) on 23 April and deploying it in the Russian service module; troubleshooting on the Japanese Ryutai fluids research rack and replacing a power supply to resolve a trip in its Image Processing Unit; inspection and maintenance on Water On/Off Valves in ESA's Columbus laboratory; and standard sampling and maintenance on the Water Recovery System racks in Node-3. Kuipers also took surface and atmospheric samples in Columbus (and other areas of the ISS) and was involved with crew handover activities on arrival of three new crewmembers.

Kuipers was also involved in public affairs/education and outreach events in different countries, ranging from live links with Dutch TV broadcasters, Artis Planetarium in

André Kuipers and Don Pettit seen during a session of simulated and actual robotics training on the ISS in April (ESA/NASA)

Amsterdam and the Google YouTube SpaceLab competition finalists in Cologne, Germany. He also sent messages, for example, to the ISS Symposium in Berlin, the World Wildlife Fund Annual Global Conference in Rotterdam and to Queen Beatrix on the Queen's Day national holiday in the Netherlands. Kuipers also took part in ham radio sessions and an ESA public affairs event with Twitter participants at ESTEC, Noordwijk.

→ ISS DEVELOPMENT/EXPLOITATION

ATV *Edoardo Amaldi* (ATV-3)

ESA's third Automated Transfer Vehicle, ATV *Edoardo Amaldi* has been docked with the ISS since 29 March. Up to June, ATV thrusters boosted the ISS five times to higher orbital altitudes, to set up phasing for the Soyuz TMA-22 landing and Soyuz TMA-04M and Progress 47P launches. The five reboosts increased ISS altitude by 16.5 km in total. Cargo transfer activities have included water from ATV tanks and using the ATV's gas supply to repressurise the ISS cabin atmosphere. Undocking is tentatively scheduled for 29 September.

ATV *Albert Einstein* (ATV-4)

System integration tests in Bremen are ongoing. ATV-4 is on target for the Pre-shipment Review by the end of July, however the launch campaign is delayed because of late availability of facilities at Kourou, leading to launch no earlier than 11 April 2013. With a very tight launch manifest from Kourou (five Ariane 5 and two Soyuz launches before ATV-4), the launch date will be closely monitored.

ATV *George Lemaitre* (ATV-5)

The Integrated Cargo Carrier will be shipped to Bremen in December. Some equipment had to be used as replacement units for ATV-4, but refurbishment or reprocurement has started. An analysis is being made for using ATV-5 as an experiment carrier for two new technology optical sensors.

A team of ESA engineers and trainers were in Bremen to review progress of ATV-4 construction, here seen inside the cargo area (ESA/L. Ferra)

→ ISS UTILISATION

European research on the ISS

The PromISSe mission was completed with André Kuipers as a focal point for much of the European research, as well as undertaking or supporting numerous experiments for ESA's ISS partners. Various facilities in the Columbus laboratory underwent functionality testing in April following the transition of the Columbus Data Management System from Cycle 12 to Cycle 13 software, with Kuipers supporting the transition activities including upgrading two Portable Work Station laptops.

Human research

During cardiopulmonary research from March to the end of May, four astronauts (Kuipers and NASA astronauts Dan Burbank, Pettit and Acaba) were subjects of ESA's Vessel Imaging experiment in conjunction with NASA's Integrated Cardiovascular experiment, consisting of echography scans with ECG and heart rate measurements.

The CARD experiment was completed by Kuipers in April after he repaired a faulty connector on the ESA/NASA Pulmonary Function System (PFS) in Human Research Facility 2 in Columbus. The PFS is used in the CARD experiment for measuring cardiac output.

Blood pressure and heart rate data were also taken over a 24-hour period and the related blood samples were returned to ground on Soyuz TMA-22 in April. The CARD experiment examines increased cardiac output and lower blood pressure (caused by dilated arteries) in the face of increased activity in the sympathetic nervous system (which normally constricts arteries) in weightlessness.

The broken connector for the ESA/NASA Pulmonary Function System. With a repair by André, all five measurements sessions for the CARD experiment were completed in time for return to Earth (NASA/ESA)

The next experiment using the Pulmonary Function System was 'Energy', which determines energy requirements of astronauts during long spaceflights. Kuipers made oxygen uptake measurements using the Pulmonary Function System on 8 May. A double-labelled water isotope was consumed by Kuipers and tracked through the ISS Water Recovery System to determine levels of the isotope excreted. His activity was measured using an Actimeter armband, and he provided urine samples for analysis.

Additional experiments used the Portable Pulmonary Function System to record a variety of pulmonary measurements during exercise on the CEVIS Cycle Ergometer. This formed part of ESA's Thermolab and EKE experiments in conjunction with NASA's Maximum Volume Oxygen (VO2 Max) experiment. Different sessions were carried out by Burbank, Kuipers and Pettit between March and June.

Blood and urine samples for Kuipers, Burbank and Ron Garan were returned to Earth on Soyuz TMA-22 concluding all on-orbit activities for the Sodium Loading in Microgravity (SOLO) experiment. SOLO consisted of astronaut subjects undertaking two different six-day diets, one with low salt and the other with higher salt level. During each session, the astronauts logged what they ate, measured their body mass and provided blood and urine samples.

Russian cosmonauts Anton Shkaplerov and Anatoly Ivanishin were again subjects of ESA's Immuno experiment in April, providing blood and saliva samples to check for hormones associated with stress response and for carrying out white blood cell analysis in addition to filling in a stress test questionnaires.

Kuipers also continued the 'Space Headaches' experiment, filling in weekly questionnaires that are analysed on ground to help determine the incidence and characteristics of headaches experienced by astronauts in orbit.

Biology research

The processed experiment containers for the ROALD-2 (Role of Apoptosis in Lymphocyte Depression 2) experiment were returned to Earth and handed over to the science team.

Fluids research

The Geoflow-2 experiment in the Fluid Science Laboratory (FSL) completed activities in April. All related data has been downlinked. A test campaign is now under way with the FSL, before the Fundamental and Applied Studies

André Kuipers ate two special diets for the SOLO salt retention experiment (NASA/ESA)

of Emulsion Stability (FASES) experiment starts in 2013. Results of FASES will be significant for oil extraction processes, and the chemical and food industries.

Two flash disks, one each for the SODI-DSC (Diffusion and Soret Coefficient Measurements for Improvement of Oil Recovery) and SODO-Colloid-2 experiments, were returned to Earth on Soyuz TMA-22. The SODI-Colloid-2 experiment studies the growth and properties of advanced photonic materials within colloidal solutions, with emphasis on nano-structured, periodic dielectric materials, known as 'photonic' crystals, which are promising candidates for new types of optical components. SODI-DSC is supporting research to lead to more efficient extraction of oil resources.

Materials research

Three processed sample cartridge assemblies for the Materials Science Laboratory (MSL) Batch 2a experiments (MICAST-2, CETSOL-2, SETA-2) were returned to Earth on SpaceX Dragon. Three more samples are still in orbit awaiting processing. The science programme for these MSL Batch 2a experiments is on hold, pending launch of a furnace cleaning tool along with additional samples for the Batch 2a experiments. Using the cleaning tool to remove any graphite foil inside the Solidification and Quenching furnace insert of the MSL is the first step before restarting processing of Batch 2a sample cartridges.

Radiation research

On 21 May, Kuipers installed active DOSTEL radiation detectors for the dose distribution inside the ISS 3D (DOSIS 3D) experiment in the European Physiology Modules facility, as well as 10 passive radiation packages at different points inside the Columbus laboratory. The passive detectors are used for 'area dosimetry', i.e. to measure the spatial radiation gradients inside Columbus, while the two active detectors make time-dependent radiation measurements. DOSIS-3D builds on the DOSIS experiment by combing data gathered in Columbus with data gathered in other modules of the ISS.

Kuipers loaded new application software on the EXPRESS Rack 3 laptop in Columbus on 10 May for the continuation of ESA's ALTEA-Shield experiment with new objectives. Radiation shielding tiles for the experiment were transported to the ISS on ATV-3. He relocated the ALTEA (Anomalous Long Term Effects in Astronauts) hardware to Columbus from the US laboratory on 8 June and reconfigured the hardware to the 'shielding' configuration and installed it in the EXPRESS rack where it started immediate data acquisition. The shielding part of the ALTEA-Shield experiment is testing two different types of materials (and different thicknesses of each material) as shielding against cosmic rays.

Solar research

ESA's SOLAR facility carried out three additional data acquisition periods during 'Sun visibility windows' between 19 March and 26 May, each lasting just under two weeks. During the window in May, simultaneous measurements were taken in coordination with ESA's Venus Express mission.

André Kuipers waves outside his Soyuz TMA-03M capsule in Kazakhstan on 1 July (NASA/Bill Ingalls)

→ ASTRONAUTS

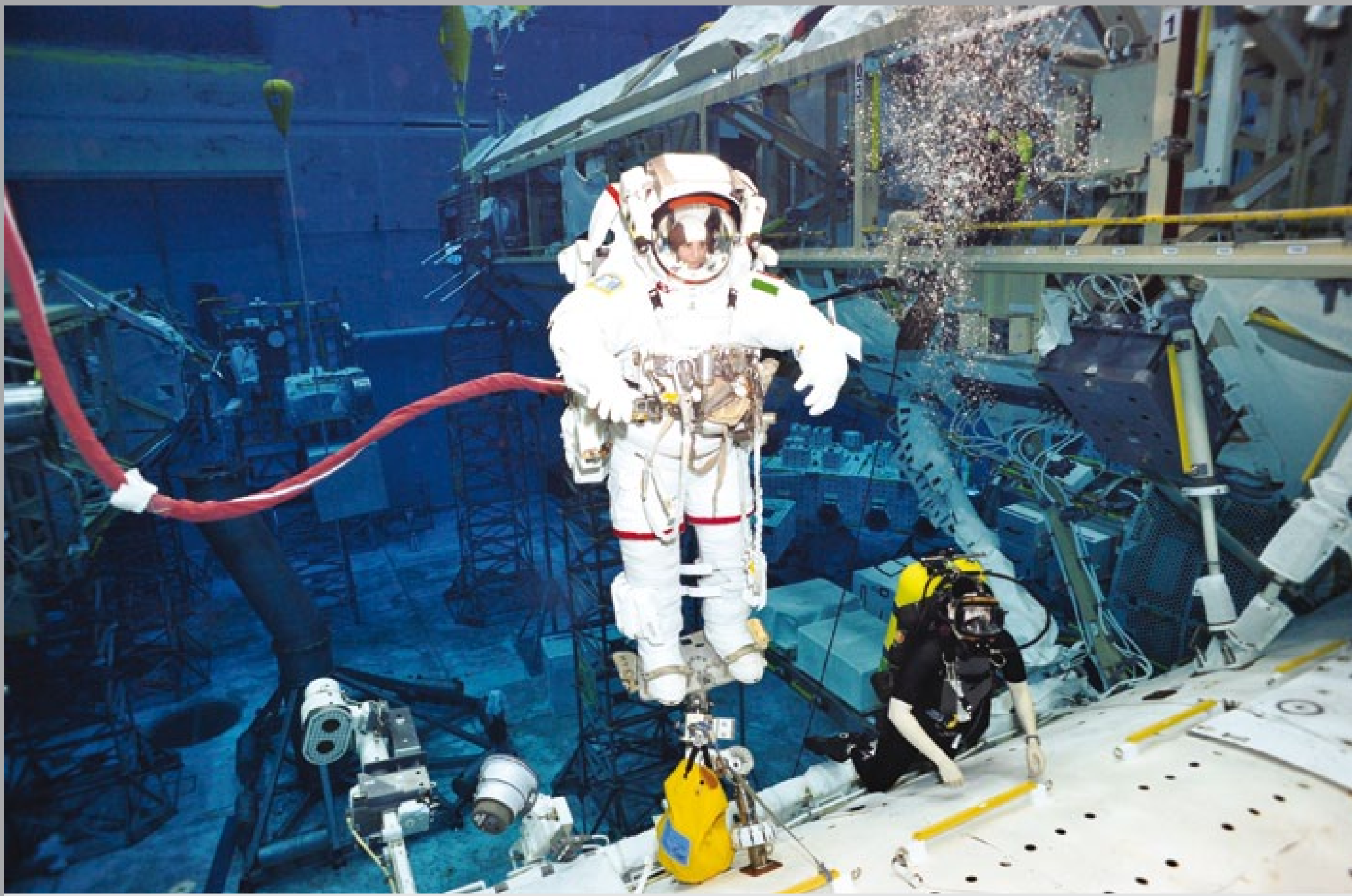
André Kuipers, together with Russian Oleg Kononenko and NASA's Donald Pettit, landed in Kazakhstan on 1 July in Soyuz TMA-03M. Kuipers and Pettit flew to Houston, Texas, where they had medical checks before meeting the media on 6 July. They performed a series of Baseline Data Collection (BDC) tests in support of ESA and NASA life science investigations that were part of the PromISSe mission, as well starting a rehabilitation programme. The BDC, medical activities and rehabilitation continued until 20 July when Kuipers returned to Europe. He will continue rehabilitation and start mission debriefings in Russia, USA and Europe throughout August and September.

Samantha Cristoforetti, assigned to an ISS expedition in 2014

Samantha Cristoforetti has been assigned to a long-duration mission on the ISS, the eighth such mission for an ESA astronaut, starting at the end of 2014. Cristoforetti completed basic training in 2010 and is now training on the Russian Soyuz spacecraft, ISS systems, robotics and spacewalks. A captain in the Italian air force, Cristoforetti has logged more than 500 hours of flying time on six types of military aircraft.

→ NON-ISS RESEARCH

The 56th ESA Parabolic Flight Campaign was held in May, with a total of twelve experiments, four in physical sciences, seven in life sciences and one technology experiment. This included three Mars500-related experiments that marked the end of this human exploration preparation project with the last measurements made six months after the end of the actual 520-day isolation.



Samantha Cristoforetti during spacewalk training in NASA's Neutral Buoyancy Laboratory water tank in Houston, USA (NASA/ESA)

Samantha Cristoforetti with Canadian astronaut David Saint-Jacques and a real-size Canadarm2 mock-up during robotics training in Canada (CSA/ESA)

→ CREW TRANSPORTATION

International Berthing and Docking Mechanism (IBDM) IBDM dynamic testing was completed at SIRRIS in Leuven, Belgium. The results confirmed the feasibility of a design compatible with both NASA and Russian designs.

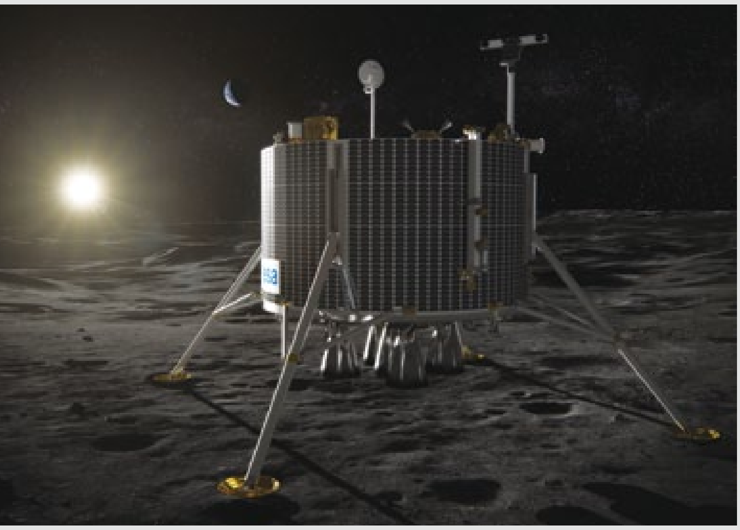
International Docking System Standard (IDSS)

Docking standardisation discussions continued with representatives of the Chinese Manned Space Engineering Office (CMSEO) at ESTEC in May. The Chinese have shown interest in discussing possible adaptations of their docking system to an international standard and to the joint definition of a new large-diameter mechanism, capable (like the IBDM) of docking and berthing, for the permanent connection of major modules of their Space Station. The exchanges on the development of docking systems with the Chinese showed that also China identified the need for a docking system that could work for space vehicles of various masses and deliver moderate impact loads.

An International Docking Systems Workshop at ESTEC in May involved about 30 experts (from USA, Europe, Canada, Russia, China and Japan), bringing together for the first time the IDSS partners from the ISS countries and new participants, offering an opportunity to enlarge the docking standardisation discussions to a new set of international partners (for example, China).

The need for a standard docking interface was reconfirmed and the design of ESA's IBDM system appeared as a very promising candidate for such a standard. ESA was asked to organise a follow-up workshop at the IAF Conference in October. Discussions with NASA and the Canadian Space Agency looked at the possible joint development of a new docking system based on the IBDM.

ESA's Lunar Lander is a robotic explorer that will demonstrate key European technologies and conduct science experiments on the Moon (ESA/AOES Medialab)



Advanced Return Vehicle (ARV)

The System Concept and Programmatic Review of the ARV took place with the industrial team in Bremen in May.

→ HUMAN EXPLORATION

Scenario studies

ESA participated in the Global Exploration (GLEX) Conference in May in Washington DC, presenting various papers related to interim results of the ESA Scenario Studies as well as the International Space Exploration Coordination Group (ISECG) Global Exploration Roadmap and Benefit Assessment.

Lunar Lander

A Call for Declarations of Interest for payloads on the Lunar Lander was released on 25 May. The spacecraft design has progressed, with the 220 N thruster hot-firing test and the hydraulic flow test completed. The navigation breadboard was ready to start testing the precision landing and guidance system. The separation analysis by Arianespace has provided positive results, confirming acceptable spacecraft clearance at separation and the Soyuz performance in lunar transfer orbit.

Lunar Polar Sample Return (LPSR)

Lunar exploration has been declared a top priority in Russia, with the LPSR as the next major mission (launched after 2020) after the ongoing Luna-Glob and Luna-Resource missions. In a broad cooperation agreement on exploration, encompassing Moon, Mars and Jupiter, Roscosmos has invited ESA to participate in LPSR and to provide flight hardware for the Luna-Resource lander mission in 2017.

Meteron

The Meteron project is testing the control of robots on Earth from a man-machine interface on the ISS. The first communication tests (Disruption Tolerant Networking) were delayed and are planned to be performed by NASA astronaut Sunita Williams from August to October.

A communication test was run between the S-band antenna in the Russian segment of the ISS (Kontur2) and the ESA ground stations at Villafranca and ESOC.

→ EDUCATIONAL ACTIVITIES/OUTREACH

A very successful live link with André Kuipers on the ISS was held on 24 April as part of the Spaceship Earth education project (over 1600 children participated in the events throughout Europe with each site having scientific demonstrations and hands-on activities).

ESA's 'Mission X – Train Like An Astronaut' is a worldwide educational initiative supported by ESA and national space agencies to encourage healthy and active lifestyles among children. A special event was coordinated with the UK Space Agency in London on 27 April, featuring ESA astronaut Paolo Nespoli and three Olympic athletes. André Kuipers recorded a video message from the ISS, announcing the winners of the participating teams, completing this activity.

→ SPACE SITUATIONAL AWARENESS

An agreement with Spain for the deployment, test and validation of the monostatic breadboard radar at the Santorcaz Naval Radio Communication Station is being finalised and the site is being prepared for installation.

The breadboard radar project aims at demonstrating the potential technologies for future SSA radar capabilities.

A contract with ONERA for the development of the bistatic breadboard radar has been signed and began on 26 June.

A Programme Proposal for a cooperative Kua Fu Space Weather mission (with China) was discussed in July. This cooperation with China represents a unique opportunity to secure the availability of essential data required for operational space weather predictions.

The substantial contribution of China, including the launch of three spacecraft, will make it possible for Europe to implement this mission at a fraction of the cost of a non-cooperation mission. The costs of the European contribution will be shared between the Science and SSA Programmes because the mission is of interest from both space weather and science perspectives.

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