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esa

bulletin

→ space for europe

European Space Agency

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

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

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

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

The ESA headquarters are in Paris.

The major establishments of ESA are:

ESTEC, Noordwijk, Netherlands.

ESOC, Darmstadt, Germany.

ESRIN, Frascati, Italy.

ESAC, Madrid, Spain.

EAC, Cologne, Germany.

ECSAT, Harwell, United Kingdom.

ESA Redu, Belgium.

Co-Chairs of the Council:
Bo Andersen and Jean-Yves Le Gall

Vice Chair:
Klaus Pseiner

Director General:
Jan Woerner

←

On cover:
Tim Peake is an ESA astronaut assigned to fly to the International Space Station as part of Expedition 46/47 for six months in December 2015. He will be the first British ESA astronaut to visit the Space Station (NASA)

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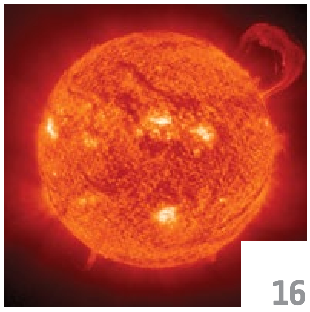
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Tim is seen here with one of Newton's original *Principia* works (M. Alexander)

→ ON THE SHOULDERS OF GIANTS

The Principia mission of Tim Peake

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ESA astronaut Tim Peake will be the first Briton to live and work on the International Space Station, spending over five months off the planet, when he makes ESA's eighth long-duration space mission.

"If I have seen further, it is by standing on the shoulders of giants," wrote the renowned scientist Sir Isaac Newton to Robert Hooke in 1676. This quote is particularly apt, because that is exactly what Tim Peake will be doing – building on the work of previous European astronaut missions, while being supported by a huge team of scientists and engineers on the ground.

Also fittingly, Tim's mission is called Principia, after Newton's book, *Philosophaie Naturalis Principia Mathematica*, describing the principal laws of motion and gravity. Science is an important part of the Principia mission, and Tim will conduct a wide range of experiments on the International Space Station.

The 43-year-old former army helicopter pilot will serve as a flight engineer for Expeditions 46 and 47. Launched from Baikonur Cosmodrome in Kazakhstan in December, he will share the trip with Russian cosmonaut Yuri Malenchenko and NASA astronaut Timothy Kopra, returning to Earth half a year later.

↑ The Soyuz TMA-19M crew: Tim Peake, Tim Kopra and Yuri Malenchenko (NASA)

↓ The logos of Expeditions 46 and 47, Tim's Soyuz flight patch and the ESA Principia mission logo

Tim acknowledges sharing a very similar army background and temperament with his counterpart Kopra, and praises the experience of Malenchenko, who will be logging his sixth spaceflight.

Tim will fly on Soyuz TMA-19M, a modernised version of Russia's legendary manned space vehicle, travelling in the right-hand seat of the capsule.

Tim and his crew will arrive just before Christmas at a busy Space Station. Tim will share the last leg of the one-year mission for US astronaut Scott Kelly and Russia's Mikhail Korniyenko. These two spacefarers will be in the ninth month of their space marathon, a first in the history of the Space Station. Tim hopes that their arrival will give the resident crew a boost during the last three months of their record-breaking mission.

Major Tim

Tim was born in 1972, the same year that the last person walked on the Moon. His interest in space has been a lifelong passion. It started in his childhood, gazing at the stars and wondering about the Universe. But although he has kept his curiosity since then, he had not actually dreamed of becoming an astronaut.

> I have a huge respect for the ground control teams and everything they do for our missions.

↑

Tim meets the mission control teams at the Columbus Control Centre at Oberpfaffenhoffen who will be supporting him during the Principia mission

"I hadn't seriously thought about becoming an astronaut before the ESA selection in 2008. Before then I had just assumed that there was no easy path for a British citizen to become an astronaut," said Tim.

"I'd been working as a military test pilot in the five years before I applied to ESA, so I had already had an interest in the space sector – aviation and space are linked and share many similar technologies. But it was only when ESA announced they were selecting new astronauts, that I thought 'Wow, this is too good an opportunity to miss.'"

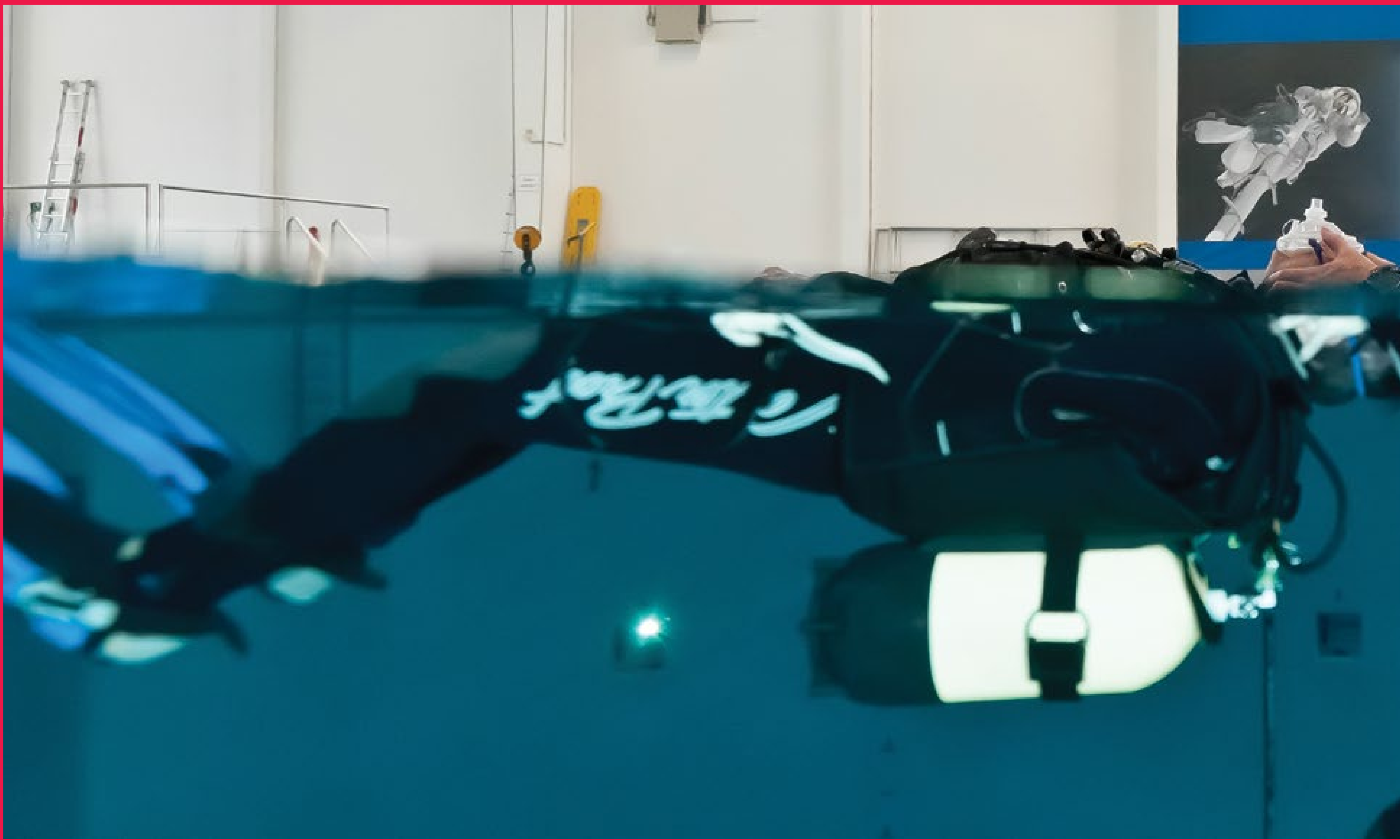
Tim considers himself very fortunate to have been inspired by great teachers and leaders along the way. He graduated in the British Army Air Corps at the age of 20, starting a successful career as a pilot that would take him across the globe. He served for 18 years in the British Army, including tours in Bosnia and Afghanistan. He received a science degree in flight dynamics from the University of Portsmouth in 2006.

Previous life and work experiences have provided him with notable strengths for his spaceflight adventure. Tim is used to dealing with international partners and respecting cultural differences.

"In preparing me for being an astronaut, I think a lot of the skills that you learn along the way while being a test pilot or a pilot in general are fundamental to the astronaut role.

Not just in terms of getting on as a team, but also in emotional character and stability in emergency situations," said Tim. As a test pilot, Tim has logged over 3000 hours' flying time on more than 30 types of helicopter and aircraft. Danger and emergency situations have been part of his career.

→ Views from Tim's training over the last six years



↑ Tim rehearsing his rescue diver skills in EAC's Neutral Buoyancy Facility in Cologne, 2012

→ In June 2012, Tim spent 12 days under the sea off the coast of Florida on a NASA NEEMO mission (NASA)

↑ Water egress and survival is an important part of Soyuz mission training. When a Soyuz spacecraft returns to Earth there is always the possibility that it could land in water (GCTC)

↓ Tim prepares for a spacewalk training session in the Neutral Buoyancy Laboratory (NBL) pool at NASA's Johnson Space Center (NASA)

← Tim endures winter survival training in Russia with crewmates Tim Kopra and Sergei Zalyutin (GCTC)

↓ Tim inside the Soyuz simulator, a full-scale mockup of a Soyuz capsule, at the Gagarin Cosmonaut Training Centre, Moscow, in October 2014 (GCTC)

Wearing his Sokol spacesuit, Tim Peake walks to the Soyuz simulator for final exams at Star City, Moscow (M. Alexander)

"There have been a couple of hair-raising moments in my career and I think you would be hard pushed to speak to a helicopter pilot with 3000 hours who hasn't had one or two emergencies. It's the nature of the job really. You explore the limits of aircraft performance, but before you make any flights, you spend a lot of time analysing the risks and making sure everything is safe.

"In simulations and training situations, I've found that my earlier training really does take over, which is a bit of a cliché, but simply it means that you stay calm, analyse the problem and find a solution as quickly as possible," added Tim.

Tim was selected as an ESA astronaut in May 2009 after completing the year-long selection process. He described the moment as a wild mix of emotions – elation, shock and trepidation. With no guarantee of even getting a spaceflight, Tim put his career as a test pilot to one side.

Since then, though, his life has radically changed. Besides becoming a parent of two little boys, he has been travelling the entire time, living in Germany and the United States. The gamble of choosing space paid off when, in 2013, he was assigned to fly to the International Space Station on a long-duration mission.

European science in space

"And all this science I don't understand, it's just my job five days a week," sings Elton John, about an astronaut in his classic 1972 song Rocket Man. But Tim does understand the science. In fact, he is fascinated by quantum physics and cosmology, and he is very excited about being involved in research that brings real benefits to people back on Earth.

"The science being studied on board the Station is incredibly exciting and has the potential to deliver major breakthroughs in several areas, such as medical treatments, new materials and our fundamental knowledge of the Universe," said Tim.

His set of 30 European experiments will cover human research, biology and radiation, as well as demonstrating new technology on the Space Station.

He will take full advantage of the Station's scientific facilities and perform valuable science for Europe in the European Columbus laboratory.

His contribution is not limited to European science. During Principia, Tim will play a role in about 15 other human research experiments from the US, Canadian and Japanese space agencies.

Life sciences and biology in space

Astronauts have experienced problems in their muscles, bones and heart after long stays in orbit. In weightlessness, the internal machinery of the human cell is affected in ways that cannot be mimicked on ground. The Cytoskeleton and Spheroid experiments will look at cell proliferation and their life cycle in space, as well as how space affects their genes.

These investigations could not only help improve astronauts' health and performance, but also find its way into clinical medical research to treat common diseases in the elderly such as atherosclerosis, hypertension, diabetes and thrombosis.

↑ Tim during his MSS Robotic Arm course at the Canadian Space Agency headquarters near Montreal in 2013. The MSS, or Mobile Servicing System, is better known by its main component called Canadarm2 (CSA)

While constant exercise and a proper diet help astronauts minimise the effects of weightlessness, all sort of changes affect their bodies. Human research is vital to understand the causes and to help develop countermeasures.

Understanding how the neural processes of perception adapt to weightlessness is the focus of the Brain-DTI experiment. Tim's brain will be examined in detail on ground before and after his mission. This research could lead to new

↑ Blood draws will be regular occurrences for many of Tim's experiments

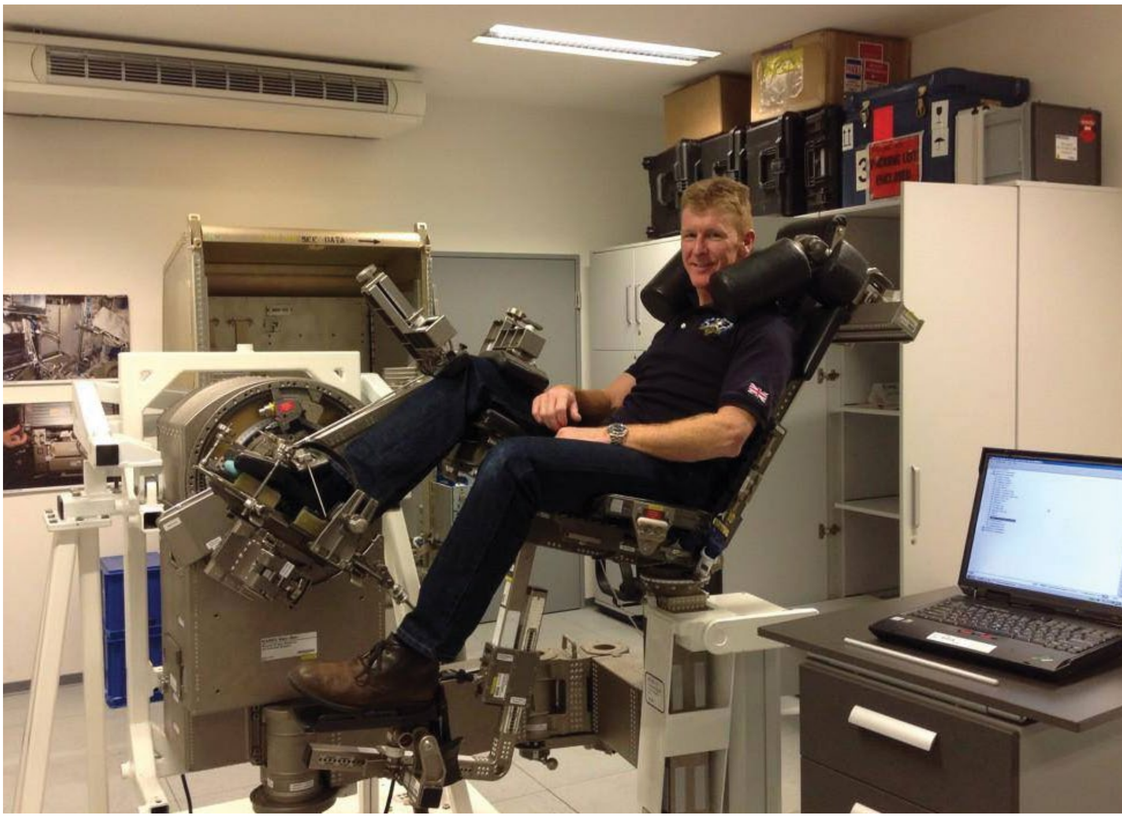
↖ Using Transcranial Doppler Ultrasound to scan Tim's brain

↙ Temperature monitoring for the Circadian Rhythms experiment

tools for further research on spatial cognition. He will also register any headaches and other symptoms while in orbit. The results of the Space Headaches experiment will help develop measures to reduce migraines.

Dust particles float in the Station's atmosphere and often irritate eyes and lungs. The Airway Monitoring experiment will monitor Tim's lungs and airways to test their reaction as a tool to monitor lung inflammation. More than 300 million people suffer from asthma, so patients on Earth could benefit from the quick and simple lung test developed for this research.

The Energy experiment will contribute to planning the right amount of food on long-duration missions to the



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To get a better insight on unused muscles, Tim will use the Mares facility, an adjustable chair that can measure the range of motion of around seven joints in the human body

International Space Station and beyond. Tim will measure changes in energy expenditure to derive an equation for an astronaut's needs in weightlessness.

The Circadian Rhythms experiment will look at how long-duration spaceflight affects Tim's biological clock. We all have an inner clock – the circadian timing system – that tells us roughly what time of day it is, and makes us sleepy at night. That cycle is disrupted in orbit, where astronauts experience 16 sunrises and sunsets every day on the Space Station. The findings will help future missions but also people working irregular hours on Earth, such as doctors and emergency workers.

Scientists think that reduced stress on bones may be responsible for the progressive cartilage loss seen in long-term space residents. The results of this Cartilage experiment are expected to help develop technologies to counteract bone loss for space travellers and bedridden patients on Earth. Astronauts lose up to 1% of their bone mass each month in space.

The Early Detection of Osteoporosis in Space experiment will look at changes in cosmonaut's bone structure. This research will help detect and hopefully prevent osteoporosis in large population segments, especially those over 55 years old. Living in microgravity leads to the loss of muscle mass, function and motor control. By taking samples of Tim's soft tissue, the Muscle Biopsy experiment looks for the root of the problem of maintaining muscle mass in space. The European astronaut will provide feedback on how his muscles perform before and after his flight.

Technology demonstrations

The International Space Station offers a unique environment to demonstrate new technology. Remote operations and interactive tools for a better performance in orbit will not only help make the planet a better place, but will also pave the way for future space exploration.

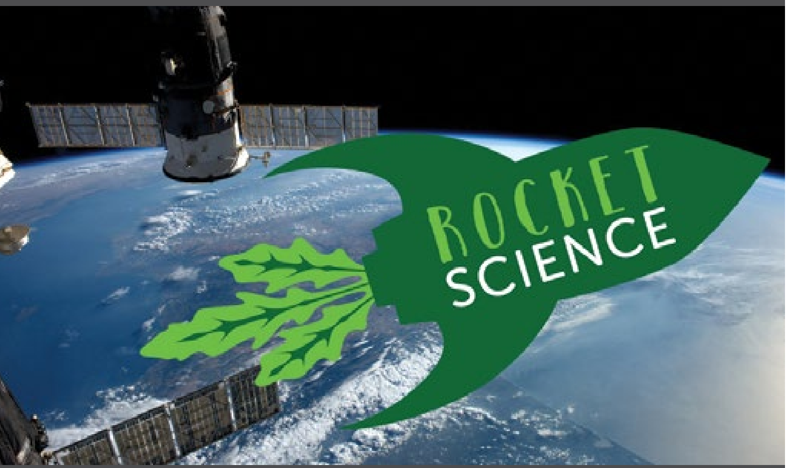
Tim will test novel ways for training on board. ESA has developed a system with 3D animations and augmented reality features that will allow the astronaut to perform new tasks without previous training. He will use a tablet to run the 3D Visual Training (3D ViT) tool, and follow instructions. The system has already proved to be helpful for spacecraft operations during the last visit of Europe's Automated Transfer Vehicle to the Station.

ESA is investigating the limits of human perception and ability to apply fine forces with their limbs and hands in space. Tim will use a force-reflecting joystick in space (Haptics/Interact). The tests will help improve the equipment to support robotic and human interaction in weightlessness. To help turn robotics and remote operations into a standard tool for space missions, ESA is linking the Space Station with Earth. Tim will operate ESA's Eurobot in the Netherlands

An astronaut needs to be a jack of all trades: required to do tasks such as fixing the plumbing, repairing a damaged solar array or troubleshooting much of the technical equipment on board

Tim Peake

↑ The designer of Tim's ESA mission patch, Troy, with Tim and Blue Peter presenter Lindsey Russell (M. Alexander)



↑ In the 'Rocket Science' activity, 2 kg of rocket seeds will be exposed to space and brought back for school experiments

↑ HM Queen Elizabeth II visits the RHS 'Rocket Science' exhibition at the RHS Chelsea Flower Show. In collaboration with ESA, the UK's Royal Horticultural Society Campaign for School Gardening and the UK Space Agency launched the Rocket Science project at the show (RHS)

while orbiting Earth using a laptop and a joystick. The Meteron SUPVIS-E activity is the continuation in a series of experiments of increasing complexity.

Materials science

On Earth, a number of gravity-driven phenomena often lead to unwanted effects when processing materials. Buoyancy, convection and sedimentation can hamper creating the 'perfect' alloy or compound. To improve the quality, reliability and reproducibility of products made on Earth, European scientists are experimenting in weightlessness. Tim will be operating a number of materials processing facilities and running a set of experiments to investigate the effects of microgravity on metal microstructures, especially on liquid metals when forming alloys.

Inspiring the next generation

Tim is determined to make Principia an exciting adventure for the younger generation too. Thousands of schoolchildren in the UK were invited to design the logo for Tim's mission on the BBC's Blue Peter children's TV show. The winning entry came from 13-year-old Troy, who designed a patch that included many references to the mission.

As an ambassador for science and space-based careers, Tim is inviting students of all ages to share the trip and the excitement of his space adventure, and he is involved in an intensive outreach programme.

Principia school activities running alongside Tim's mission have some elements of science or technology in them, from computer coding and growing plants, to maths, fitness and nutrition.

When ESA astronaut Andreas Mogensen flew to the International Space Station in September, he carried a very special cargo for Tim's 'Rocket Science' activity: 2 kg of rocket seeds, also known as rucola, a popular ingredient in salads. These seeds will be exposed to the weightlessness and radiation of space.

After several months, the seeds will be returned to Earth and distributed across 10 000 schools in the UK, along with another batch of seeds that did not leave our planet.

Schoolchildren will plant both types of seeds and compare their growth. The pupils will learn whether space travel impacts growth and whether humans could one day produce their own food in space.

Primary and secondary schools in the UK are turning to the 'Raspberry Pi' mini computer to take advantage of its flexibility. Two of these credit card-sized computers called Astro Pi will go to the Station equipped with a host of

Tim takes part in an emergency scenario training session in the ISS mock-up trainer at Johnson Space Center (NASA/ R. Markowitz)

↑ A space-rated version of 'Raspberry Pi' mini computer that Tim will use to run code written by students

sensors and gadgets. Students can devise and code their own apps or experiments to run in space.

During his mission, Tim will place these tiny computers in different locations. He will load the winning codes, set them running, collect the generated data and then send the results back to Earth. Five themes are set to stimulate the students' creativity and scientific reasoning: spacecraft sensors, imaging and remote sensing, environmental measurements, data fusion and space radiation.

Tim will also join the efforts of teachers on Earth in the quest to explain physics to their pupils. He will record videos from the International Space Station demonstrating the phenomena that mentors find hard to show during their earthbound lessons. Some lucky students and teachers will also have the chance to see and talk to the astronaut through live video calls with the International Space Station. Tim will connect with the pupils for a few minutes to answer the pupils' questions

Space technology is not all high-tech. Radios operated by amateur enthusiasts can be used to communicate with the International Space Station. As he flies above the UK, Tim will talk to students using handheld-radios over ARISS, the Amateur Radio on the International Space Station. An ARISS conversation usually lasts for about 10 minutes, which is the window when the Station flies over a certain area and radio contact is possible from orbit. Tim will use the amateur radio callsign GB1SS.

'Mission-X: Train like an astronaut' is an educational programme in which thousands of schoolchildren aged 8 to 12 years old from more than 25 countries do science activities and learn how to get fit. Tim will kick off the 2016 worldwide challenge by talking about regular exercise and nutrition, both on Earth and in space.

← Tim will kick off 'Mission-X: Train like an astronaut 2016', an educational programme for kids to stay healthy and keep fit

Teachers can access a special package of teaching resources prepared for Tim's mission. The European Space Education Resource Office (ESERO), together with the UK Space Agency and British partners, are providing tools to inspire students throughout the space adventure.

Throughout his mission, Tim will be interacting with the wider public and sharing his experiences. He is already active on social media, such as Twitter, Facebook and Flickr, and he will be posting images, videos and comments about his life in space. He will also be running one of the most exciting competitions to be held in space – with the help of some very special guest 'crew members' along the way. Look out for his music-based #spacerocks competition on Twitter.

→ One of the limited-edition patches that Tim Peake will take to the Space Station as prizes for his #spacerocks competition

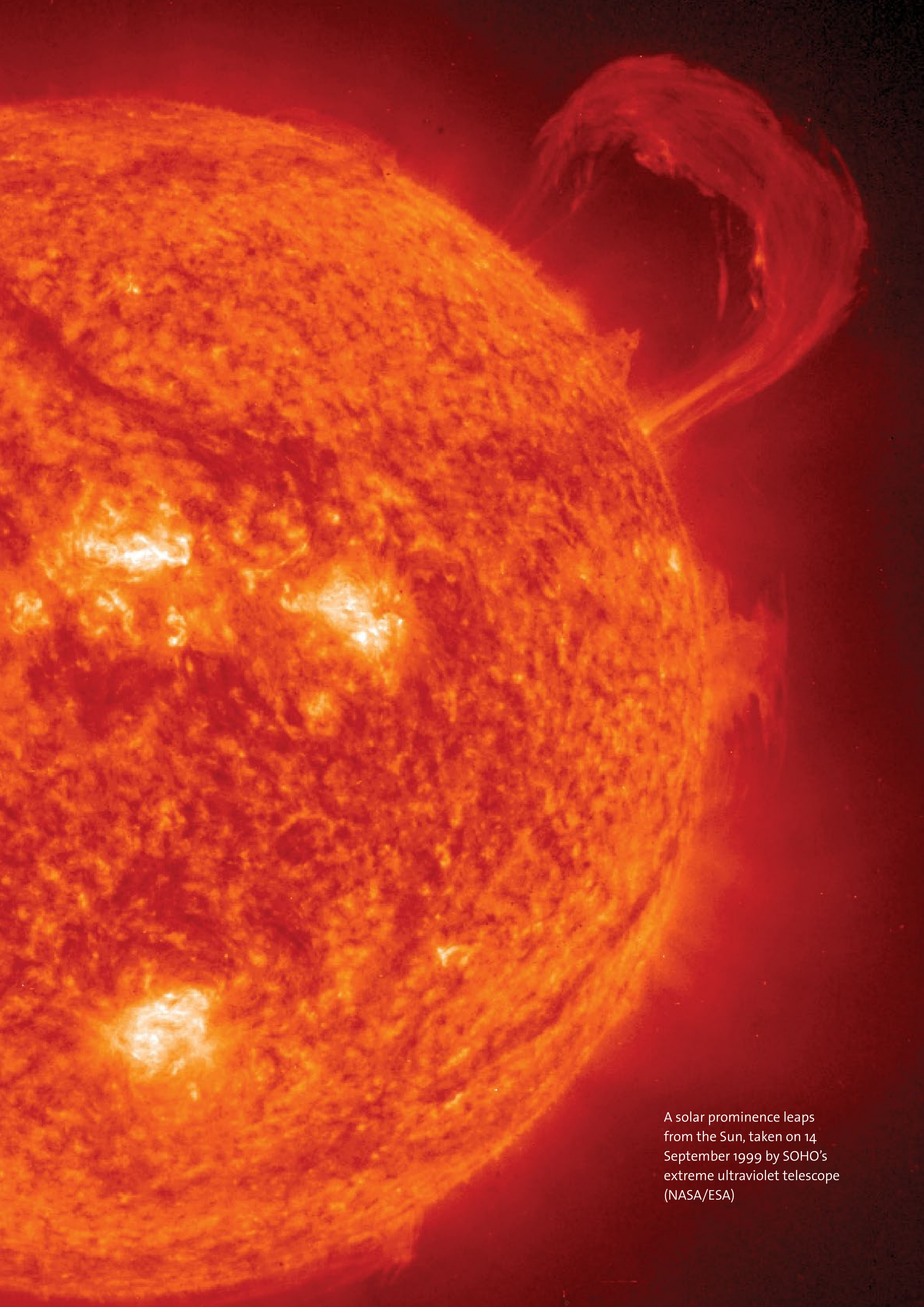
↑ Michelin-star chef Heston Blumenthal has prepared food for Tim's mission to the International Space Station. Heston's journey to create the best dining experience for the astronaut relied on the help of schoolchildren joining 'The Great British Space Dinner' competition in the UK

Returning to gravity

After living and working on the Space Station for six months, Tim will return to Earth in the Soyuz capsule with his crewmates. Closing the Soyuz hatch will signal the end of his Principia mission, and the astronauts will land on Earth in less than four hours later.

Once back to Earth, Tim will fly straight to the European Astronaut Centre, the home base of all ESA astronauts in Cologne, Germany. This early access to Tim allows ESA's medical team to monitor his health very closely and to start his fitness and rehabilitation programme quickly. Scientists also benefit from continuing with their scientific examinations soon after landing. ■

Nadjejda Vicente is an HE Space writer for ESA



A solar prominence leaps from the Sun, taken on 14 September 1999 by SOHO's extreme ultraviolet telescope (NASA/ESA)

→ SOHO

Two decades of observing the Sun

Emily Baldwin
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Daniel Müller
Directorate of Science and Robotic Exploration, ESTEC, Noordwijk, the Netherlands

Originally planned as a two-year mission, the ESA/NASA space-based observatory SOHO has been studying the Sun for 20 years, each day sending thrilling images from which research scientists learn about the nature and behaviour of our star.

SOHO, standing for 'Solar and Heliospheric Observatory', is stationed 1.5 million km out, on the sunward side of the Earth, where it enjoys an uninterrupted view of the Sun. Experts around the world use SOHO images and data to help them understand the workings of the Sun's core, its hot and dynamic outer atmosphere, the solar wind and its energetic particles.

Crucially, we also rely on the mission to monitor the impact of space weather on our planet, with a vital role in forecasting potentially dangerous solar storms. In addition to investigating how the Sun works, SOHO is the most prolific discoverer of comets in astronomical history, with the destinies of more than 3000 comets tracked as these icy worlds endure fiery encounters with the Sun.

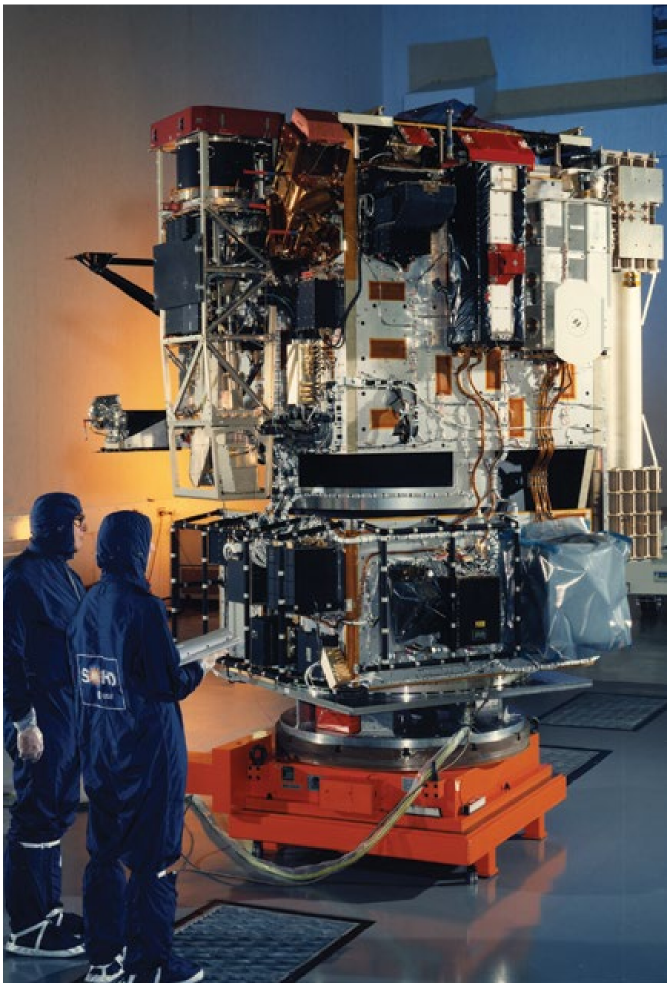
SOHO is a joint project of international cooperation between ESA and NASA. The spacecraft was built for ESA by Europe's aerospace industry, in a consortium led by Matra Marconi Space (now Airbus Defence & Space), and was launched on a US Atlas launch vehicle on 2 December 1995. It began operations in May 1996.

The longest Sun-watching mission

Originally planned for a two-year mission, its numerous extensions have allowed it to cover nearly two 11-year solar cycles – the complete cycle 23 and already a large fraction of cycle 24. SOHO is thus the longest-lived Sun-watching mission.

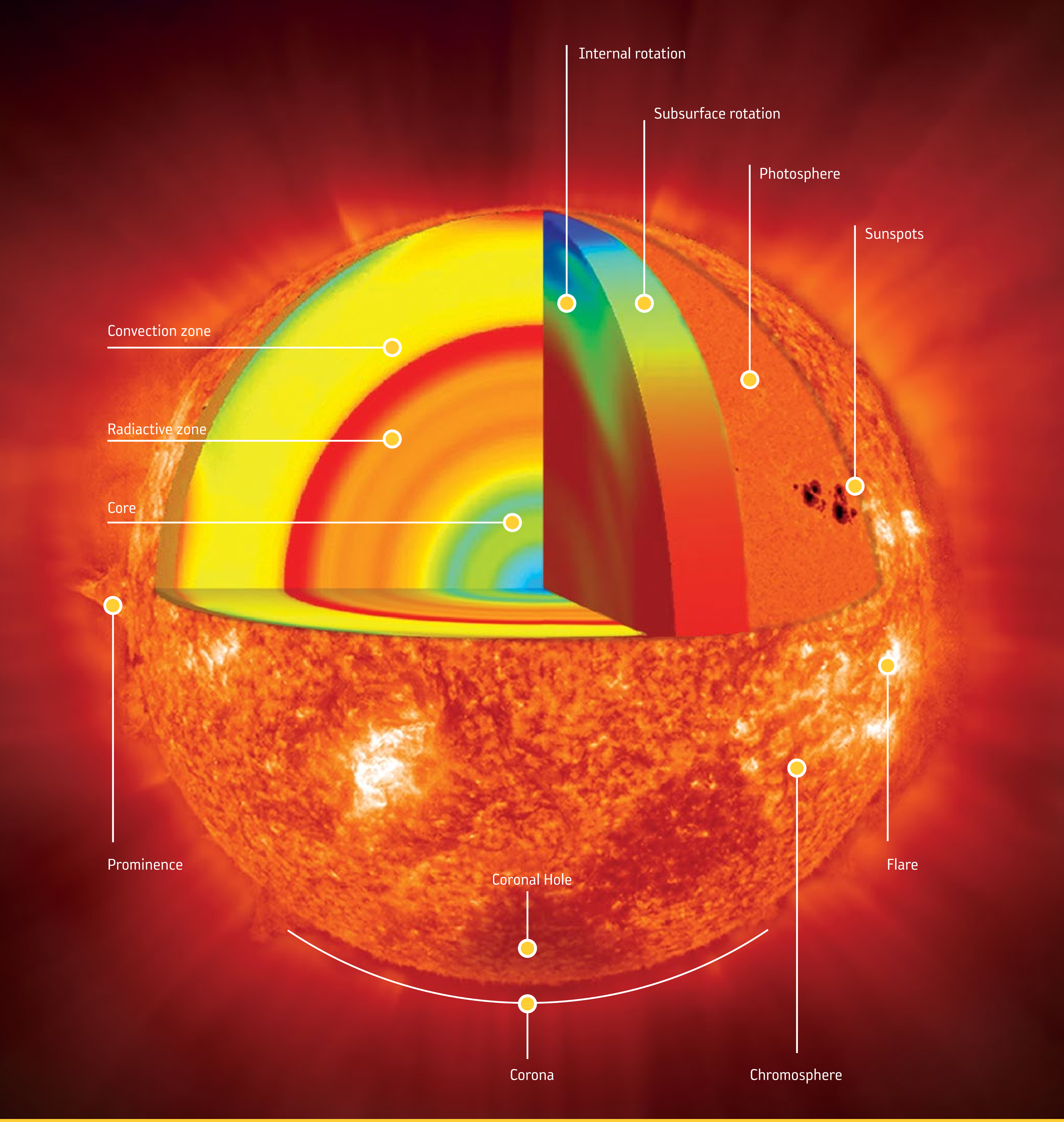
Of the satellite's 12 science instruments, nine come from multinational teams led by European scientists, and three from US-led teams. More than 1500 scientists in 20 countries are directly involved in SOHO's instruments and research programmes. NASA launched SOHO and is responsible for communications and daily operations.

Although four of the original 12 science instruments are no longer used – they were superseded by the next generation of sensors on newer missions – SOHO continues to provide unique and important measurements of our star.



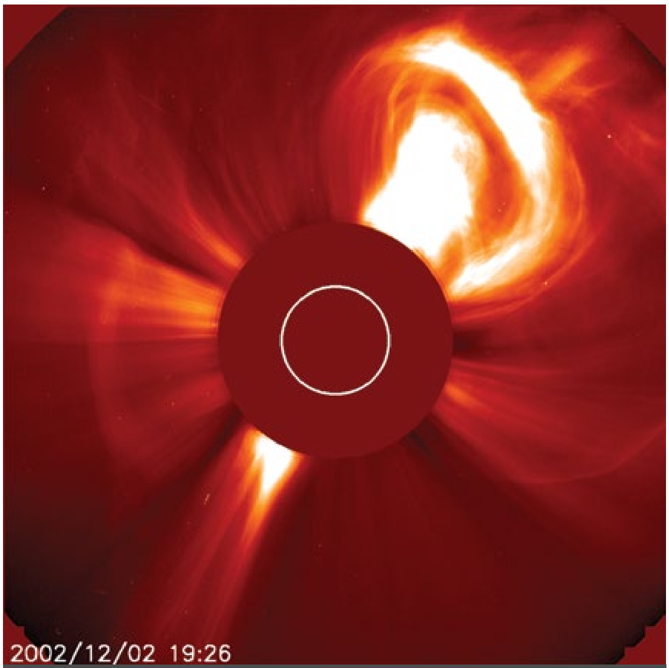
↑ ESA engineers inspect SOHO during assembly at the Matra Marconi Space facility (ESA/NASA)

↑ Launch of SOHO on an Atlas II-AS (AC-121), from Cape Canaveral Air Station on 2 December 1995 (NASA)

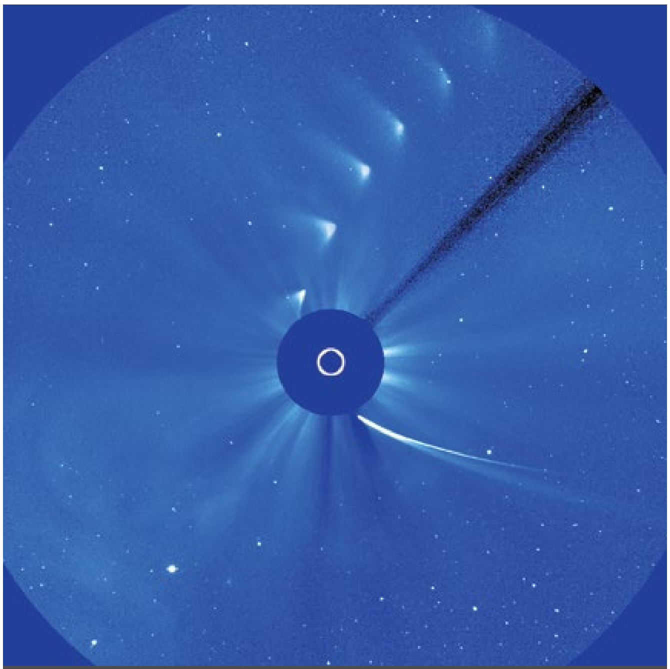


→ The anatomy of our Sun

Left cutaway: The Sun's interior explored with sound waves. Red depicts layers where sound travels faster than predicted by theory, implying that the temperature is higher than expected, while blue indicates slower speeds and lower temperatures. The prominent red layer marks the transition between the turbulent outer convection zone and the more stable inner radiative zone. Right cutaway: The Sun's internal rotation, where red depicts fast rotation and blue slower rotation. Outer layers: Visible light images show sunspots, cool dark features in the photosphere, which lies below the chromosphere. Flares, resulting from the release of a buildup of magnetic energy, and coronal mass ejections (CMEs, giant clouds of electrically charged atomic particles launched into space) often occur in magnetically active regions around sunspot groups.



↑ This LASCO C2 image shows a very large coronal mass ejection (CME) blasting into space on 2 December 2002. It has the classic shape of a CME: a large bulbous front with a more compact, inner core of hot plasma. This material erupts away from the Sun at speeds of over a million km/h (ESA/NASA)



↑ The demise of Comet ISON as it came within 1.2 million km of the Sun on 28 November 2013, fading from view in the following days. The small white circle in the middle indicates the position and size of the Sun behind the occulting disc of the LASCO coronagraph (ESA/NASA)

Seeing inside the Sun

Just as seismology reveals Earth's interior by studying seismic waves from earthquakes, solar physicists use 'helioseismology' to probe the solar interior by studying the frequency and oscillations of sound waves reverberating through it.

SOHO opened and pioneered the new field of 'local area helioseismology', providing the first images of structures and gas flows below the Sun's surface and even images of activity on the far side.

It discovered 'sunquakes' and a slow subsurface current of gas flowing from the equator towards the poles. Deeper inside the Sun, about a third of the way towards the centre at the transition between its turbulent outer shell – the convection zone – and the more orderly radiative zone, SOHO found that the speed of the rotating gas changes abruptly.

The measurements indicated that, near the equator, the outer layers rotate faster than the inner layers, while at mid-latitudes and near the poles the situation is reversed. This boundary region is of particular interest because it is where the solar dynamo that creates the Sun's everchanging magnetic field is believed to operate. SOHO also shed light on the 'solar neutrino problem' – a major discrepancy between the rate at which neutrinos were predicted to be created by nuclear fusion in the deep solar interior and the rate measured at Earth.

SOHO confirmed that the standard model of the Sun is correct, ruling out that possible explanation. Instead, the discrepancy had to be explained by the physics of the neutrino, as confirmed by better neutrino measurements a few years later.

The solar heating mystery

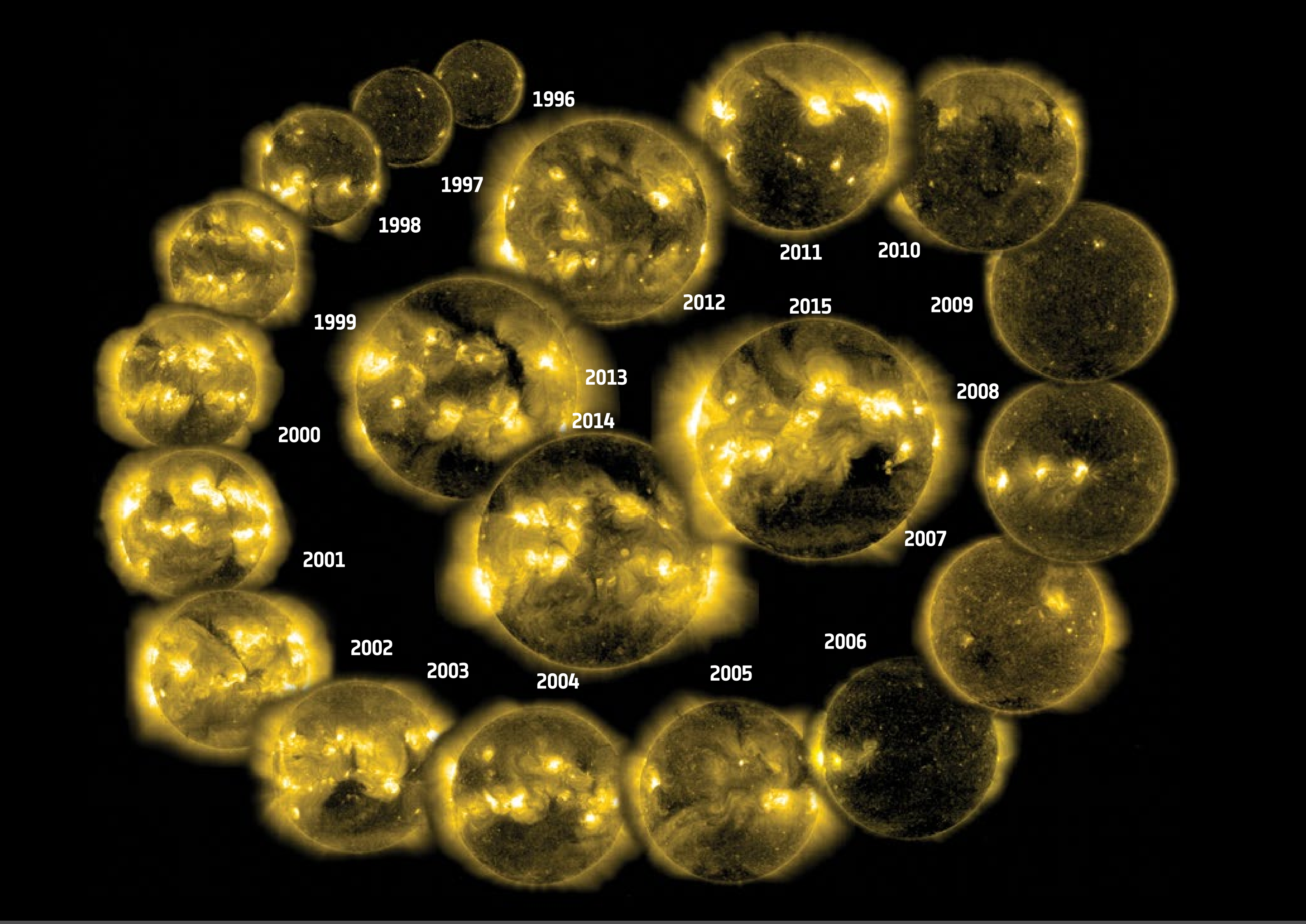
The question of why the Sun's outer atmosphere is heated to the extremely high 1–2 million degrees when the visible surface is 'only' about 5500°C has long been a mystery of solar physics.

SOHO has revealed an extremely dynamic atmosphere where plasma flows and small-scale transient events play

↑ Aurora borealis over an Icelandic lake (C. Gauna)

→ Members of the SOHO recovery team at NASA Goddard Space Flight Center in September 1998, including staff from ESA, NASA, Matra Marconi Space, Allied Signal Technical Services Co., Computer Sciences Corp. and Space Applications Corp. (NASA/ESA)

an important role. They also discovered new dynamic phenomena such as solar tornadoes and global coronal waves – disturbances associated with coronal mass ejections that can travel around the entire solar globe – and provided evidence for the upwards transfer of magnetic energy from the surface to the corona through a magnetic carpet, a weave of magnetic loops extending above the Sun's surface.



↑ The changing face of the Sun seen through SOHO's Extreme ultraviolet Imaging Telescope from 1996 (small, most distant disc) to 2015 (largest, central disc). The images were taken each northern spring and show the waxing and waning of activity during the 11-year solar cycle (ESA/NASA)

Gone with the solar wind

A prime goal was to observe where the solar wind – electrically charged atomic particles streaming from the Sun – is produced and how it is accelerated to beyond 3 million km/h. Scientists have made great strides in answering this fundamental question. They measured the acceleration profiles of both the 'slow' and 'fast' solar wind and found that the fast solar wind streams into interplanetary space by 'surfing' on waves produced by vibrating magnetic field lines.

Mapping the outflow of the plasma from coronal holes – darker, cooler and less dense areas of the Sun's corona where the Sun's magnetic field reaches into space, allowing hot gas to escape – revealed a clear connection between the flow speed and the structure of the chromosphere.

SOHO also revealed that heavy solar wind ions in coronal holes flow faster and are heated hundreds of times more strongly than protons and electrons.

The Sun–Earth connection

With its near-continuous monitoring of the Sun, SOHO has revolutionised our understanding of the Sun–Earth connection and dramatically boosted space weather forecasting.

The major driver of space weather are CMEs, the most powerful eruptions in the Solar System, which propel billions of tonnes of electrified gas into space at millions of kilometres per hour. If CMEs hit Earth, in addition to causing intense auroral displays in polar regions by electrically charging atoms in our upper atmosphere, they can cause major geomagnetic storms, which can damage satellites, disrupt telecommunications, endanger astronauts, lead to corroded oil pipelines and cause current surges in power lines.

SOHO is a pioneer in detecting when such a solar storm is incoming. It has studied more than 20 000 CMEs to date, pinpointing their sources on the Earth-facing hemisphere of the Sun, and determining their speed and direction to provide up to three days' warning – sufficient to take mitigating action on Earth. From its vantage point matching Earth's orbit, the observatory can also make *in situ* measurements when a CME and its energetic particles arrive.

Star bright

The Sun's surface brightness is an important part of SOHO's long-term studies, because changes could influence Earth's climate. SOHO monitors the total brightness as well as variations in the extreme ultraviolet flux, both of which are which are important for understanding the effect of solar variability on climate. The measurements show that the Sun's total brightness changes by only 0.1% between the minimum and maximum of a cycle.

A prolific comet-hunter

Besides watching the Sun, SOHO is also a prolific comet discoverer: more than 3000 comets have been found, the majority by amateurs accessing realtime data via the Internet. While many of these sungrazing comets perish in the Sun's heat, some survive, albeit in various states of degradation: SOHO has watched many comets lose their heads and tails during their solar encounter.

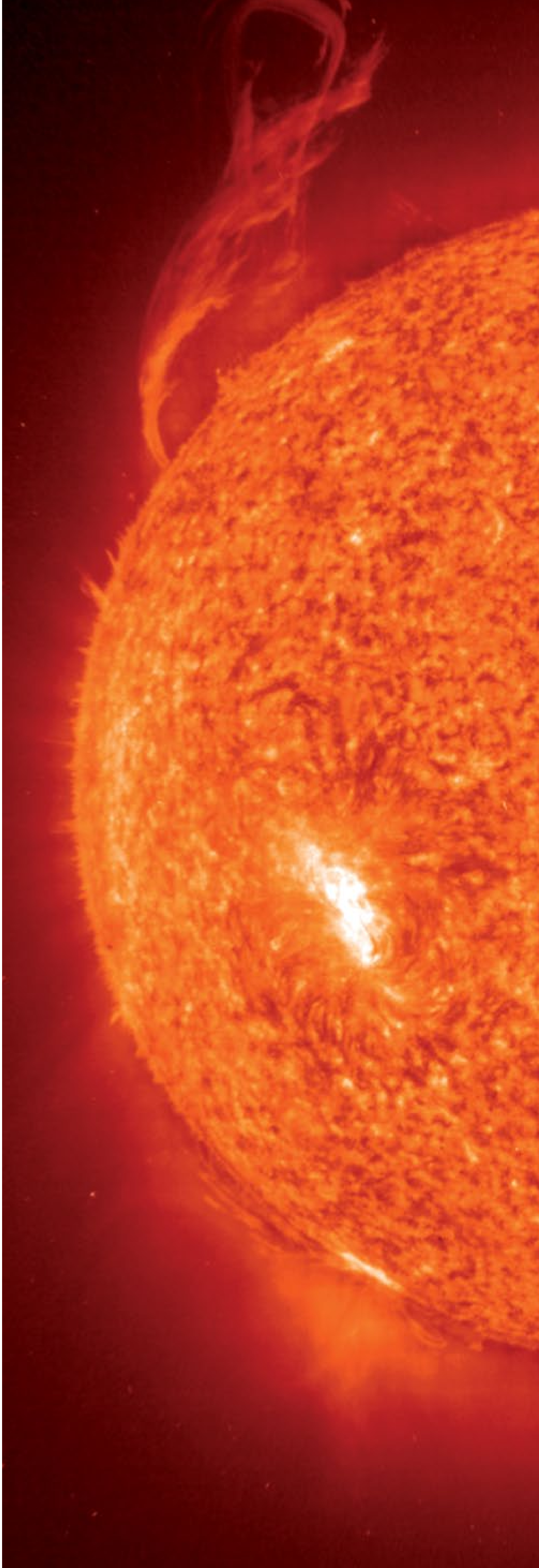
Near-loss and dramatic recovery

The mission almost ended on 25 June 1998 when control was lost during a routine spacecraft manoeuvre. It took three months to restore operations in one of the most dramatic recovery operations in space history, including just over two weeks to thaw frozen hydrazine propellant in the tank and pipes. Unexpectedly, all 12 instruments survived despite the extreme temperatures they suffered during the time that contact was lost.

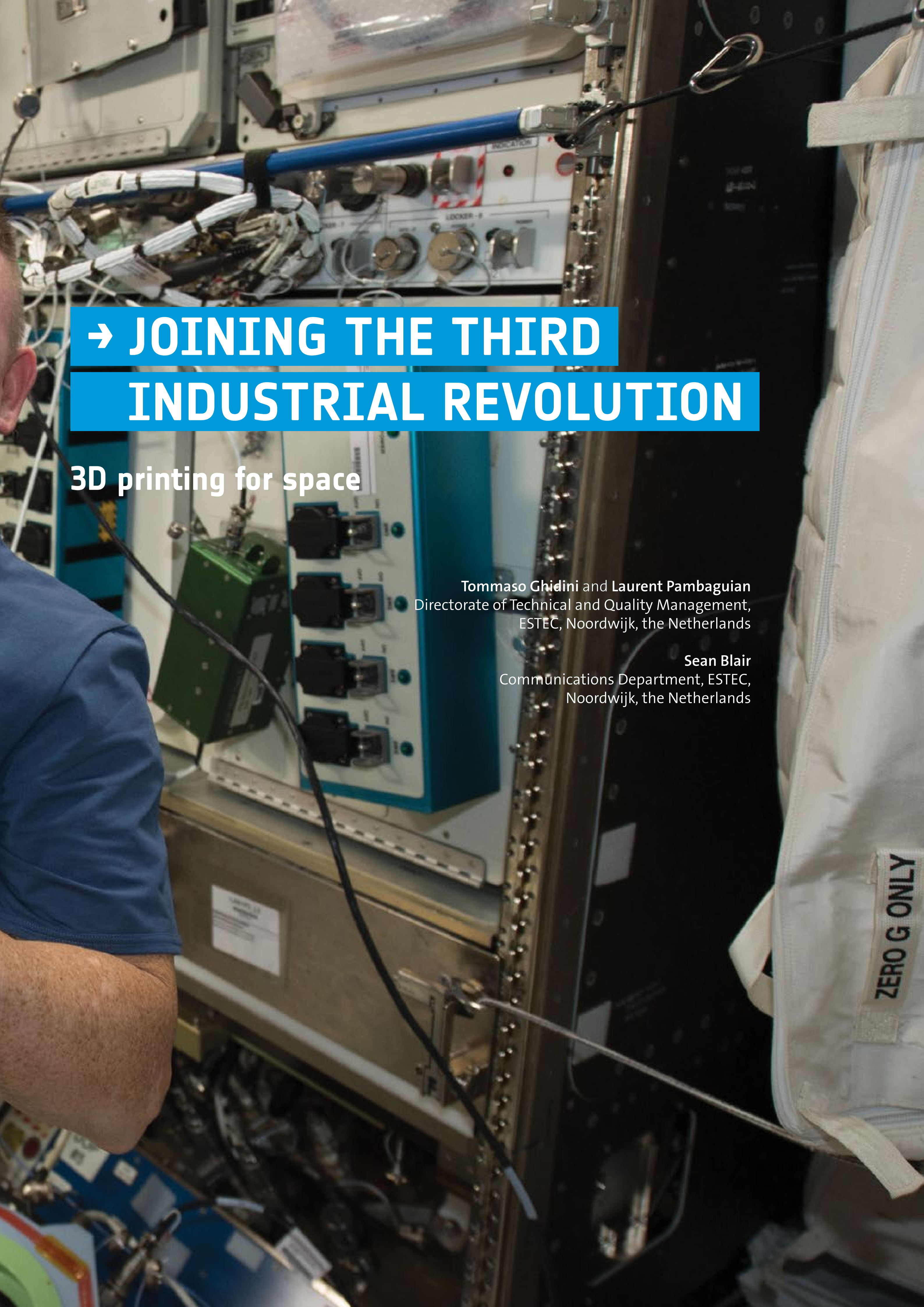
But the drama was not over yet: all three gyroscopes later failed, the last in December 1998. New control software that no longer relied on gyros was developed and installed in February 1999, allowing the spacecraft to return to full scientific operations. This made SOHO the first spacecraft to be stabilised in three axes without gyros. Despite these problems, engineers have kept SOHO functioning with all its instruments performing well.

After it went into space in 1995, SOHO was meant to operate until 1998, but the mission is so successful that it has already seen several extensions. It currently has approval until end 2018 (subject to a mid-term review in 2016). These extensions enable SOHO's scientists to compare the Sun's behaviour (for example, sunspot activity) not only at different times in one solar cycle, but also during different solar cycles.

Emily Baldwin is an EJR-Quartz writer for ESA



NASA astronaut Butch Wilmore holds a 3D printed ratchet wrench from a new 3D printer on the International Space Station in 2014 (NASA)



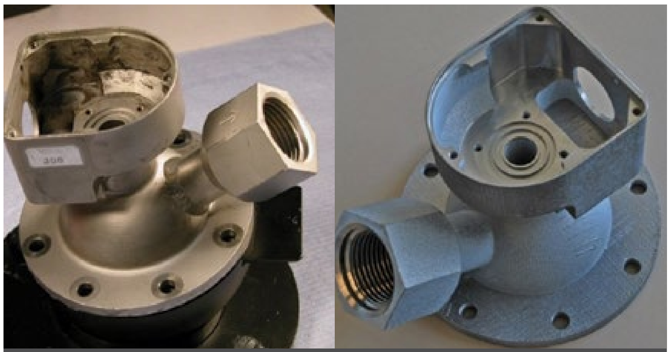
→ JOINING THE THIRD INDUSTRIAL REVOLUTION

3D printing for space

Tommaso Ghidini and **Laurent Pambaguian**
Directorate of Technical and Quality Management, ESTEC, Noordwijk, the Netherlands

Sean Blair
Communications Department, ESTEC, Noordwijk, the Netherlands

On Earth, 3D printing has been called 'the third industrial revolution'. Almost anything that can be designed can then be built up layer by layer – with cheaper, faster production cycles that yield tailor-made, optimally performing parts. But ESA is already finding out how the space industry can benefit.



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Original and 3D-printed 'water on/off valves' for the European Columbus laboratory on the ISS

Like many innovations, ESA's research into 3D printing began with how to solve a problem – namely a malfunctioning component in the plumbing of Europe's Columbus laboratory on the International Space Station.

Columbus is a complete research lab squeezed into a 75 cubic metre can. It uses a system of valves to pump hot and cold water to its various experiments, as well as to cool module avionics and control cabin humidity. The problem was that one of these 'water on/off valves' (WOOVs) that regulated that flow got stuck in the open position in September 2009, while another failed while closed the following year.

The WOOVs could be replaced, but this required following a 28-page procedure that included tilting bulky experiment racks away from the walls. Meanwhile, down on the ground, it became clear a redesign was required. At which point, the idea was pitched: "Well, we could always try 3D printing…"

"Back in 2009, this was very first item of hardware we decided to replicate with 3D printing: a titanium copy of the stainless steel core of the WOOV," recalls Laurent Pambaguian of ESA's Materials Technology section, coordinating ESA's research into 3D printing.

"The work was done with Germany's Fraunhofer Institute of Laser Technology. The WOOV was interesting because it possesses both thick and thin walls, multiple interfaces and a very delicate weld that represents a potential point of failure. We were indeed able to reproduce it, and at the same time, by changing its material we reduced the mass of the item by 40%."

In the event, a conventionally manufactured replacement WOOV was selected for orbital service instead, and has been gradually swapped with its predecessor during subsequent years. But the initial experience of designing and printing this item made it clear that 3D printing did indeed hold huge potential for space.

On the ground, 3D printing – also known as additive manufacturing (AM) – has been described as 'the third industrial revolution'. These days everything from aircraft turbines to jewellery, surgical instruments to office buildings, is being 3D-printed. The AM sector experienced a compound annual growth rate of 35.2% to $4.1 billion in 2014 reports AM consultants Wohlers Associates, and the sector is predicted to quadruple by the decade's end.

Instead of standard 'subtractive manufacturing' – where material is cut away from a single piece – AM involves building up a part from a series of layers, each one printed on top of the other. It is the difference between digging out a bunker and building up a house, reducing the amount of raw material needed to make a part by 40–90%.

The process starts with a computer-aided design (CAD) model, which is then sliced apart to plan its layer-based physical printing. Anything suitable for the printing process can be designed by computer then printed as an actual item, typically by melting powder or wire materials, in plastic, metal or even ceramic.

"ESA has been actively investigating AM. It offers the opportunity to lower the mass and cost of parts across a wide variety of scales, while being well suited to the kind of low production runs typical of the space sector, while delivering very high performance and reliability," says Tommaso Ghidini, head of ESA's Materials Technology section.

"The question might be asked, why not stand aside, and leave AM development to the open market?" commented Mikko Nikulainen, head of ESA's Component Technology and Space Materials Division.

"The answer is that because the benefits of AM are so apparent, qualification work needs to be carried out to ensure the space sector – with its stringent and highly specific requirements – can indeed reliably utilise it as soon as possible. We need to turn it into a repeatable,

→ Solving problems on the WOOV

The first 'water on/off valve' (WOOV) got stuck open during Columbus's second year of operation. Initial theories on its malfunction focused on some kind of leak due to mechanical failure. But actually the first clue was that only the cold water WOOVs had failed, while valves regulating hotter or mixed water kept working.

"The cold water was beneath the dew point temperature," explains Stephan Hinderer, Columbus systems engineer. "So condensation began to pass beyond imperfectly closed seals, helped by a non-optimal combination of materials, to trigger corrosion in the valve's motor."

One WOOV was returned to Earth on the Space Shuttle in March 2011 so that a full failure investigation could be performed by ESA's Materials and Electrical Components Laboratory. The WOOV had already been flagged for a more robust redesign, bearing in mind the likely need for replacements during Columbus's 10-year design life.

"As a result of the lessons learned, countermeasures were added to the Mk 2 design, with enhanced insulation around the cold valves and better material compatibility with humidity," added Stephan.

The Mk 2 WOOV was swapped over on a corrective maintenance basis – three out of six cold water WOOVs have needed to be replaced so far, with the remaining ones exhibiting no degradation, while the four hot or mixed water WOOVs stayed functional.

↓ A failed 'water on/off valve' (WOOV) being replaced by Canadian astronaut Chris Hadfield (NASA)

reliable process, with set pre- and post-processing and follow-up inspection: all the work done to turn a given part into an useable product for space."

The broad potential of AM, as highlighted by the work ESA has already performed, has led in turn to it becoming an important element of the agency's new Advanced Manufacturing cross-cutting initiative.

"From that first WOOV replication, the cost and mass benefits were already apparent. But the real lesson we learnt was that to take the maximum benefit out of AM, we needed to change the initial design – and our way of thinking," said Tommaso.

That prospect was explored with follow-up test items, including an antenna support strut, where mass was reduced by 46% and a radio-frequency filter possessing an internal silver coating – normally produced by bolting halves together – had its mass reduced by 50% and its manufacturing time slashed by several weeks. Its internal geometry was also made more wavy: the silver coating required to optimise its radio-frequency performance is far easier to apply than when dealing with sharp corners encountered in today's state-of-the-art hardware.

↑ Holding what looks like an alien lifeform, ESA's Tommaso Ghidini demonstrates what he terms a 'bionic' part, an example of a 3D-printed bracket for a satellite, designed based on rules of biological evolution (ESA)

“Traditional design rules are often based around giving a cutting tool access to the bulk part. But with AM we can move away from the standard practice of ‘design for manufacturing’ and progress towards ‘design for need’. Much more complex shapes, incorporating precise internal geometries, can be built up freely, layer by layer,” continued Tommaso.

As a next step, ‘topology optimisation’ software can be employed during the design phase, placing material in response to the loads borne by the item. The resulting items can be radically different to conventional designs, often weirdly organic in appearance because of following similar design rules to biological evolution – but prove robust in practice.

Following various research projects in recent years, AM is now the subject of a European Harmonisation programme. ESA has come together with other European actors, including the European Commission and European Defence Agency, national space agencies, universities and research institutions and the private sector to agree a common European research and development ‘roadmap’ – effectively a shared ‘to-do list’, noting all the work needed to bring AM technology to a level where it can be used in space.

↑

Evolving designs: using ‘topology optimisation’ software, items produced can be radically different to conventional designs, often weirdly organic in appearance because they have material placed in response to the loads borne by the item mimicking the process of biological evolution

→ The rise and rise of 3D printing

Where did 3D printing come from? Like many new technologies, it actually arose from the mating of previously disparate technologies – the coming together of computer aided design, inkjet nozzles and automated machine tool systems. Plastic printing arrived first but various metals came after, typically involving powder or wires being melted into place via powerful lasers. And the open source RepRap movement is making 3D printing available to domestic enthusiasts.

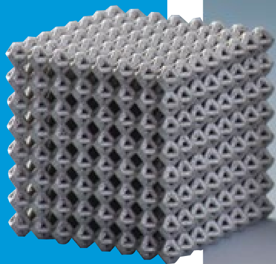
Almost anything that can be designed can be printed with far fewer parts and manufacturing steps, with the next technical challenge being to blend the printing of different materials using a single printer. On the largest of scales military jets are already flying with 3D-printed parts, printed furniture is on sale and 3D printed bridges and artificial reefs are enlivening the human landscape. But the most interesting application might be down at the nanoscale: as printing precision grows ever-more sharper, the prospect arrives of printed composites with specially tailored material properties.

“The AM Harmonisation process began with a workshop last year, progressing to a mapping of needs for onward planning. The enthusiasm this particular harmonisation has met with has really been unprecedented, with around 700 experts getting involved, representing 26 countries and 390 companies. In fact, 62 new companies, predominantly small-to-medium enterprises joined the industry body Eurospace in order to participate,” recounted Tommaso.

The resulting roadmap is being finalised for publication, covering around 30 types of parts that would strongly benefit from being manufactured using AM and the entire end-to-end AM process, from initial modelling and design of items to material supply and processing and post-processing stages to qualification and standardisation. This latter element is all-important for space. To give space mission managers sufficient confidence in 3D-printed parts, methods need to be in place to ensure that these items perform to a benchmarked, repeatable standard.

“The eventual aim is to put a dedicated European Coordination on Space Standardisation (ECSS) standard in place, for common use by all European space projects.

→ Advanced Manufacturing: march of the makers

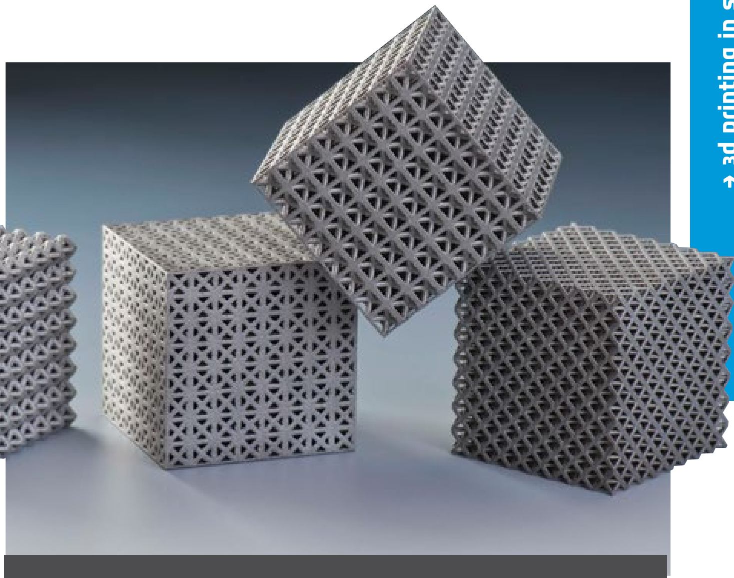


Recent decades have seen a gradual de-industrialisation of the European economy, as manufacturing jobs and in some cases entire industrial sectors have been exported overseas. But new manufacturing techniques may help mitigate this trend: these are now being explored through ESA's Advanced Manufacturing cross-cutting initiative, so called because its activities extend across several agency directorates and programmes.

As Mikko Nikulainen, head of ESA's Component Technology and Space Materials Division, explains: "Through this initiative we aim to home in on emerging manufacturing technologies which open up new industrial possibilities in terms of design freedom, streamlined production stages and reduced cost, along with enhanced performance from the final product. The opportunity is there to change the way we work, revising and rebuilding industrial supply chains, and, in the process, regaining lost manufacturing capabilities. Accordingly, the initiative is attracting strong interest from European industry."

The new possibilities opened up by computer-based concurrent engineering is an important part of the initiative, enabling teamwork focused on a common design model that evolves iteratively in real time as the different subsystem experts make their contributions. Computer-aided design techniques are also being optimised to take advantage of innovations in the subsequent production stages. The various varieties of additive manufacturing are an important part of the new initiative.

But in order to prepare these standards, we need to understand and assess the various different AM production methods, and have full traceability on the parts, powders or other substrates being used – we will need to be sure that equivalent 3D printers using different batches of material will produce items of sufficient quality, able to meet mission requirements. And then we'll also need to establish standardised ways of testing that this is indeed the case," adds Tommaso.



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Examples of 3D-printed honeycomb lattices, which could potentially be used in future for combustion chambers or catalyst beds, combining reduced mass with enhanced thermal performance

What kinds of spacecraft elements are being considered for 3D printing? High on the list are intricately patterned hardware, such as structural brackets, instrument housings and antenna signal filters. Spacecraft thrusters, possessing complicated internal shapes, are also a priority. Early testing by ESA's Propulsion Engineering section replicated complex showerhead injectors and honeycomb lattices to serve as combustion chambers or catalyst beds, offering reduced mass coupled with enhanced thermal resilience.

In May, the world's first thruster incorporating a 3D-printed platinum–rhodium combustion chamber and nozzle was test-fired. The prototype thruster was produced and tested at the Airbus Defence & Space facility in Lampoldshausen, Germany, through an ESA project called Additive Manufacturing Technologies for Advanced Satellite Thrust Chamber (AMTAC).

The 10 N hydrazine thruster made a series of firings lasting more than an hour and with 618 ignitions, including a single burn of 32 minutes, during which a maximum nozzle throat temperature of 1253°C was reached.

"This demonstrates that performance comparable to a conventional thruster can be obtained through 3D printing. Considering that platinum currently costs €40 a gram, 3D printing offers considerable future savings," explains Dr Steffen Beyer of Airbus Defence & Space, managing the project.

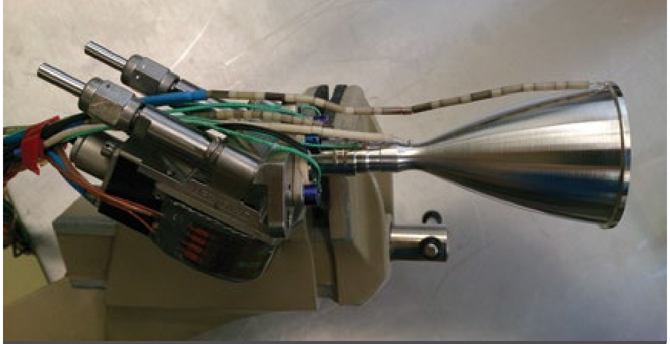
Airbus Defence & Space produce around 150–200 thrusters in this class per year for different customers. “Platinum–rhodium was chosen for this first phase as the most mature platinum alloy for additive manufacturing. Then, in AMTAC’s next phase, we will attempt to print using a new alloy, platinum–iridium, which has performance advantages. This alloy cannot easily be manufactured by traditional techniques like casting and forging, so printing is the only way it can be harnessed for space use,” added Dr Beyer.

The AM roadmap sets out a clear path ahead for the next five years, but with the rapidly advancing nature of the technology involved, the plan is to revisit and revise it within the next two to three years. And then, once AM does become a mainstream element of the European space industry, what will be the likely consequences on the shape of spacecraft to come?

A pair of complementary system engineering studies, currently being run from ESA’s Concurrent Design Facility (CDF), are seeking to assess the follow-on impacts of 3D-printed parts. One, being managed by Laurent and performed by Thales Alenia Space in Cannes is based around a top-down approach. “If the mass of a given mission can be shrunk down significantly, then perhaps it could be launched on a cheaper launcher, or even – if bespoke items of equipment can be printed at a similar cost to a single item today – then perhaps multiple spacecraft can be economically flown. It’s about shifting our way of thinking,” said Laurent.

The other study, undertaken by OHB in Bremen, follows a bottom-up approach, aiming to assess each and every part of a spacecraft, to assess which items would be suitable for AM as a means of reducing their mass and cost while maintaining or enhancing performance.

↑ ESA’s Concurrent Design Facility already makes routine use of 3D printing, producing plastic-printed spacecraft models from CAD files



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The 3D-printed platinum thruster seen with thermal instrumentation after firing on 5 May 2015 (ESA/Airbus Defence & Space)

←

Test-firing of world’s first 3D-printed thruster with platinum combustion chamber and nozzle (ESA/Airbus Defence & Space)

“The team are setting up an evaluation methodology, to screen all the parts to rank their suitability for 3D printing. Lots of possibilities open up, in particular the concept of combining different subsystems together – such as to print heat pipes through satellite panels, to produce structural elements that also perform thermal roles,” explained system engineer Ilaria Roma, overseeing this study.

“When we review the initial results, we’ll have a multidisciplinary team on hand, because every time a subsystem is touched, there can be follow-on changes elsewhere, which might end up as drawbacks. Then, in the next stage, the team will select four to five parts to redesign for AM.”

The CDF allows concurrent engineering, meaning different specialists can interact simultaneously on the same virtual spacecraft. The facility already makes routine use of 3D printing. “We can produce plastic-printed spacecraft models from our CAD files. It can be very helpful to hold something tangible in your hands, for instance to figure out how a mission needs to be oriented, with its solar panels towards the Sun and communication antenna towards Earth,” added Ilaria.

In practical terms, the first majority-3D-printed mission is likely to be a miniature CubeSat; AM production of CubeSats is set out as part of the roadmap. Also in the planning stage are on-orbit 3D printers for both plastic and metal (NASA has a plastic 3D printer on the ISS today, with Italian space agency ASI preparing its own test prototype for the Station).

→ Setting the standards for Advanced Manufacturing

Wolfgang Veith heads ESA's Product Assurance and Safety Department within the Directorate of Technical and Quality Management, which is tasked with managing project risk by ensuring hardware, software and product reliability, and the setting of common industrial standards for the space sector. It is this Department – internally referred to as 'TEC-Q' for short – that will oversee the new Advanced Manufacturing initiative.

"Advanced Manufacturing will bridge different programmes, technical disciplines and technology levels to focus on a common theme, so the underlying purpose of TEC-Q is to ensure that the fundamental technologies, materials and processes selected for a given mission are fit for purpose for that mission – which can vary enormously in practice, but are always extremely stringent because of the inescapable rigours of the space environment: hard vacuum, temperature extremes, radiation, vibration, shock and so on," said Wolfgang.

"This involves much more than simply testing candidate parts, but really to have a complete overview and traceability of the full production chain that created them, to gain a full understanding of the technologies used, its limitations and margins, and therefore the ability to anticipate any potential problems that might arise at any point.

"This method used for validating and qualifying existing processes, is also a very good fit when it comes to appraising new and evolving manufacturing techniques. We need to be able to fully master and hone the quality of the entire chain. Taking the case of AM, that would extend from the parameter settings and variations of the actual printers to the raw materials – wires or powder – and their physical properties – in terms of composition, powder size and distribution – to monitoring the ongoing process stability and the fundamental properties of the printed parts. Are these items reproducible to a set quality benchmark over time? And if not, why not?"

In addition, Wolfgang's department also oversees the European Coordination on Space Standardisation (ECSS), an initiative established to produce and promote a coherent, single set of user-friendly standards for all European space activities. So to really bring these new manufacturing techniques to a point where they can be taken up by European space projects, dedicated ECSS standards will need to be created for each one. Such standards would dictate the production and testing methods to be used. Understandably, space can be a conservative business, but an ECSS standard would represent a commonly known stamp of quality that will hasten market acceptance greatly.

Manned missions could carry 3D printers with them to ensure full self-reliance as they fly many months or years distant from Earth. Any broken item could be quickly and easily replaced. This approach has already been validated by ESA by manufacturing and functionally testing parts that have required fixing during past manned missions, including screws, clamps and even plastic gloves.

On-orbit printers present the prospect of designing mission parts specifically for microgravity, including delicate elements that could never otherwise survive the ascent out of Earth's gravity well. Or, to hasten the sustainability of deep space missions, to print with other materials – advanced polymers and composites for a start, progressing to food and eventually even human cells and organs, currently being demonstrated on the ground. Effective in situ resource utilisation beyond Earth would be another revolutionary step forward – already being investigated as part of the roadmap, starting with Earth's Moon.

The cratered lunar face can grow much hotter than might generally be imagined. At lower latitudes, soaking up uninterrupted sunlight throughout the two-week lunar day, the temperature of sunlit rock surfaces creeps up above 100°C. Small wonder then that Apollo EVA suits required sophisticated cooling systems, and overheating would remain an occupational hazard of future manned Moon missions. But a new ESA research project treats the rocky, sun-drenched lunar environment as an opportunity rather than an obstacle.

"The idea is to harness the lunar regolith as a raw material, along with endlessly available solar power, to make it possible to 3D print a Moon base. By focusing sunlight very precisely we would perform 'sintering' – melting successive layers of regolith into structural elements, to build up a habitat," explained Laurent.

This new project, being carried out through ESA's General Support Technology Programme – which brings promising


ESA's concept of a 3D-printed lunar base design

technologies up to a level where they could be taken up by future missions – represents a progression from a previous lunar 3D-printing activity.

"The previous approach we investigated was based on a binder 'ink' which would have to be imported from Earth. But with solar sintering all that would be needed is to fly the 3D printer itself, and then manufacture the base using in situ resources, making the logistics of lunar settlement much more feasible. What is important for this study is the capability of focusing solar energy for manufacturing, to find out what would be required in practical terms," added Laurent.

→ Europe's Harmonisation process: mapping the technological way forward

Every year, around €1 per citizen is invested on your behalf into future space technologies – you and the other half a billion Europeans. ESA plays a critical role in this process, coordinating with research partners across the continent to ensure the maximum effectiveness of this investment.

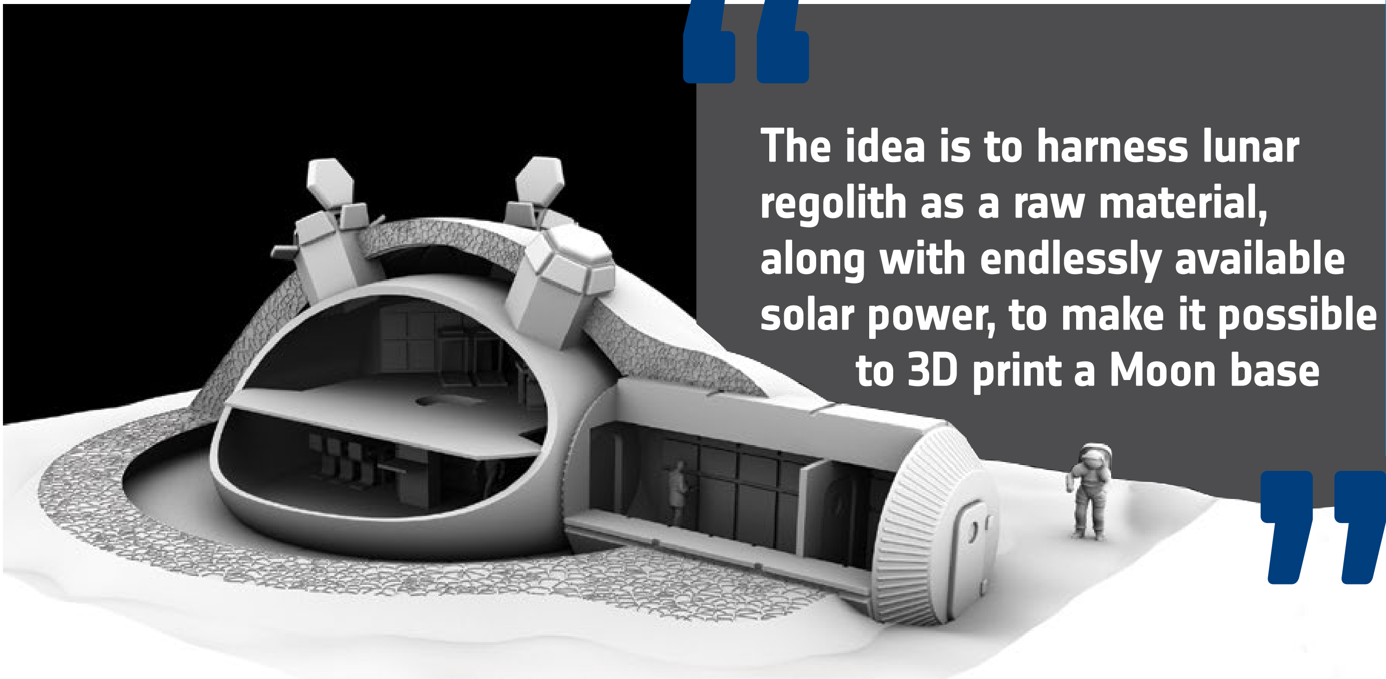
Just over half is spent directly by ESA's technology programmes in its Member States. The remainder is invested by various bodies, including the national space agencies, research institutions and the European Commission. Such spending extends across beyond the borders of ESA's Member States to the whole of Europe, but the agency plays a crucial wider role by facilitating an ongoing process called Technology Harmonisation.

By bringing together key participants in European space technology R&D, a full overview of the activities is achieved, serving to fill technology gaps, maximise efficiency and agree on common 'roadmaps' for the subsequent development of key technologies. This allows different R&D projects to tackle different aspects of common problems, building for success.

Continuously evolving, the Harmonisation process began back in 2001. Faced with global rivals able to outspend Europe by several orders of magnitude – or else put to work an order of magnitude more engineers – it became clear that every euro invested in R&D must maximise Europe's return on investment in order to maintain its lead.

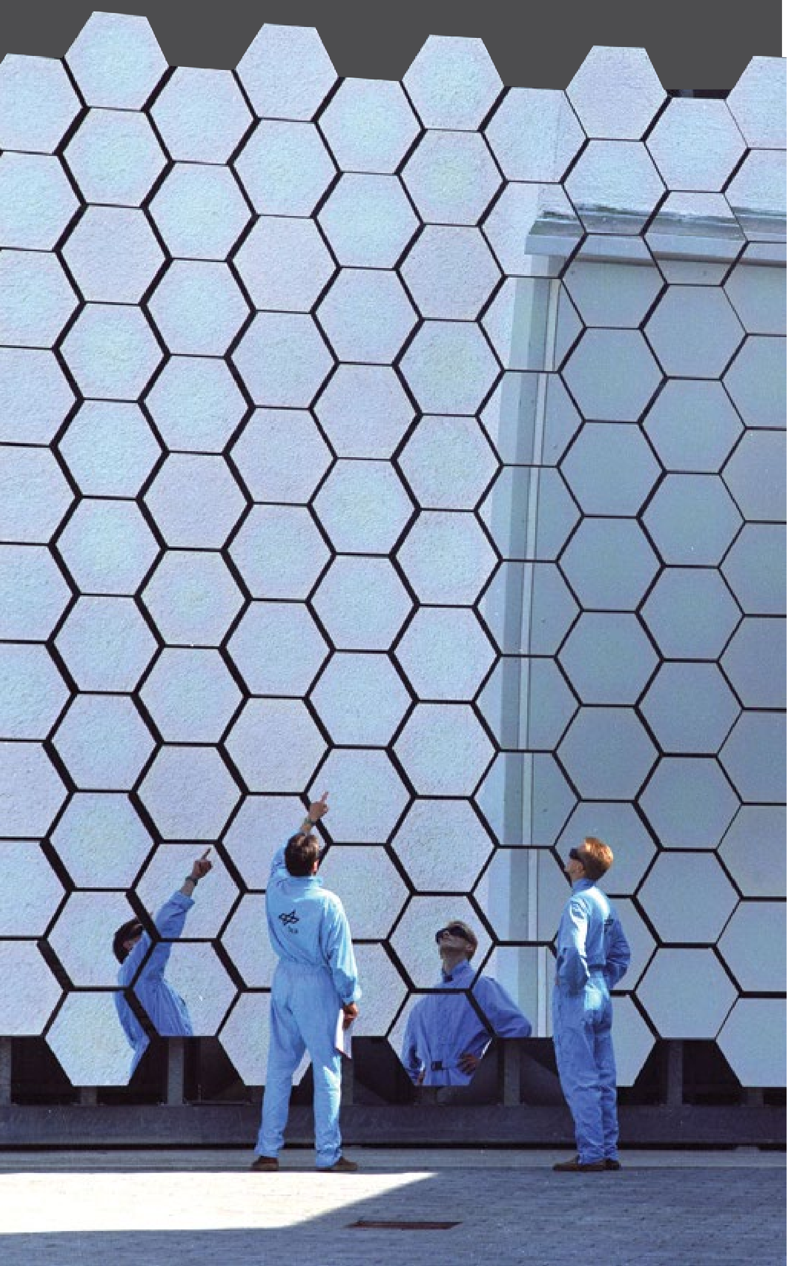
Around eight topics are chosen for Harmonisation annually, involving a pair of Harmonisation cycles. Each cycle begins with a 'mapping meeting', where all stakeholders meet to agree a consensus on the current status and technical landscape of the technology to be harmonised, followed up by the preparation of a roadmap, taking into account all the data prepared during the mapping meeting.

Each roadmap covers all European R&D from ESA, the European Commission, EDA and national agencies, along with industrial entities where data are available. Along with AM, other recent Harmonisation subjects have included satellite formation-flying techniques, electric propulsion and optical communications.



> **The idea is to harness lunar regolith as a raw material, along with endlessly available solar power, to make it possible to 3D print a Moon base**

↓ The concentrator mirrors of the high-flux solar furnace operated by the German Aerospace Center DLR in Cologne, Germany



To produce the necessary temperatures of over 1100°C needed to liquefy simulated lunar regolith, the project is harnessing a high-flux solar furnace operated by the German Aerospace Center DLR in Cologne, Germany. “Solar furnaces are normally employed for high-temperature materials testing, so this represents a quite new application,” says Laurent.

“It’s still at an early stage but there could be additional advantages to regolith sintering as well; useful gases should also be liberated from the high-temperature rock for colonists, most notably oxygen.”

The ability to ‘glassify’ the vicinity of the lunar base might also help with controlling Moon dust, which has been demonstrated to clog up and erode spacesuits and equipment, and can even trigger allergic reactions.

The study is a good example of the role of ESA’s Materials and Processes domain, developing and qualifying novel technical capabilities to enable previously impossible missions. And what works on the Moon could also work back on Earth – the team is also considering investigating 3D printing for the rapid construction of post-disaster emergency shelters here as well as for airless surfaces farther out in space.

The real tipping point, no doubt decades ahead, would be the production of 3D printers capable of printing other 3D printers – a development which would enable rapid industrialisation of the Solar System. ■

Sean Blair is an EJR-Quartz writer for ESA

European Student Earth
Orbiter, a microsatellite
mission to low Earth orbit

→ FOR STUDENTS, BY STUDENTS

The European Student Earth Orbiter

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The European Student Earth Orbiter, a micro-satellite mission to low Earth orbit, is providing students with unparalleled hands-on experience to help prepare well-qualified space engineers for Europe's future workforce.

The European Student Earth Orbiter (ESEO) is being developed, integrated, and tested by European university students. The satellite will orbit Earth taking pictures, measuring radiation levels and testing technologies for future education satellite missions.

ESA's Education and Knowledge Management Office, responsible for ESA's corporate education programme, is bringing together young people from Member and Cooperating States, aged from six upwards, and encouraging them to gain and maintain an interest in science and technology.

The office helps those who perform studies at university level to acquire a real hands-on experience in space programmes. ESA's long-term objective is to contribute to sustaining Europe as a knowledge-based society, by increasing the skills and motivation of the next generation of European space professionals.

During the last two years, the office's Tertiary Education Unit has been working on Phase-C of ESEO, with the technical coordination of the programme assigned to ALMASpace (now SITAEL SpA) as prime contractor.

The 45-kg ESEO microsatellite should be ready for launch in the second half of 2016, with mission duration of around six months, extendable up to 18 months. Eleven university student teams from eight different countries are involved in the project.

The complete payload complement is educational: designed, built, tested and operated by university student teams. The only exception is the instrument developed by AMSAT-UK, whose educational outreach is targeted more towards primary and secondary school pupils.

ESEO will be launched as a secondary payload, its target orbit is Sun-synchronous, at altitude of about 523 km and a nadir-pointing attitude. During its mission, pictures of Earth's surface will be taken, and measurements of plasma and radiation will be made and transmitted down to the ground.

Just as in ESA space projects implemented by professional industrial teams, formal project reviews are conducted at key project milestones. On 22 May, the Review Board chaired by ESA's Inspector General, declared the successful achievement of the ESEO Critical Design Review, and now the project is moving towards the manufacturing, assembly integration and testing of the Flight Model.

Spacecraft bus

The spacecraft bus has been developed by SITAEL in Italy, and includes full redundancy. The electronics are based on Commercial Off-The-Shelf (COTS) components, and the onboard software provides housekeeping, Attitude and Orbit Control, Fault-Detection, Fault-Isolation and Recovery, and payload mission management services.

The power distribution and protection module is developed by a team of students from the Budapest University of Technology and Economics (BME), guided by the group of researchers and lecturers who already provided the tried-and-tested electrical power system of the Rosetta lander, Philae.

For the protection of the essential loads of the spacecraft bus, the power distribution and protection module incorporates a new generation of Integrated Current Limiter (ICL) chips. These have been developed under ESA's Basic Technology Research and General Support Technology Programmes, which thanks to the ESEO mission are expected to have their first in-orbit demonstration.

Payload and student contributions

A technical challenge for the project consists in the large number and variety of payload instruments, all developed by university student teams, which overall lead to demanding accommodation constraints, when considering the limited mass and size of the microsatellite bus.

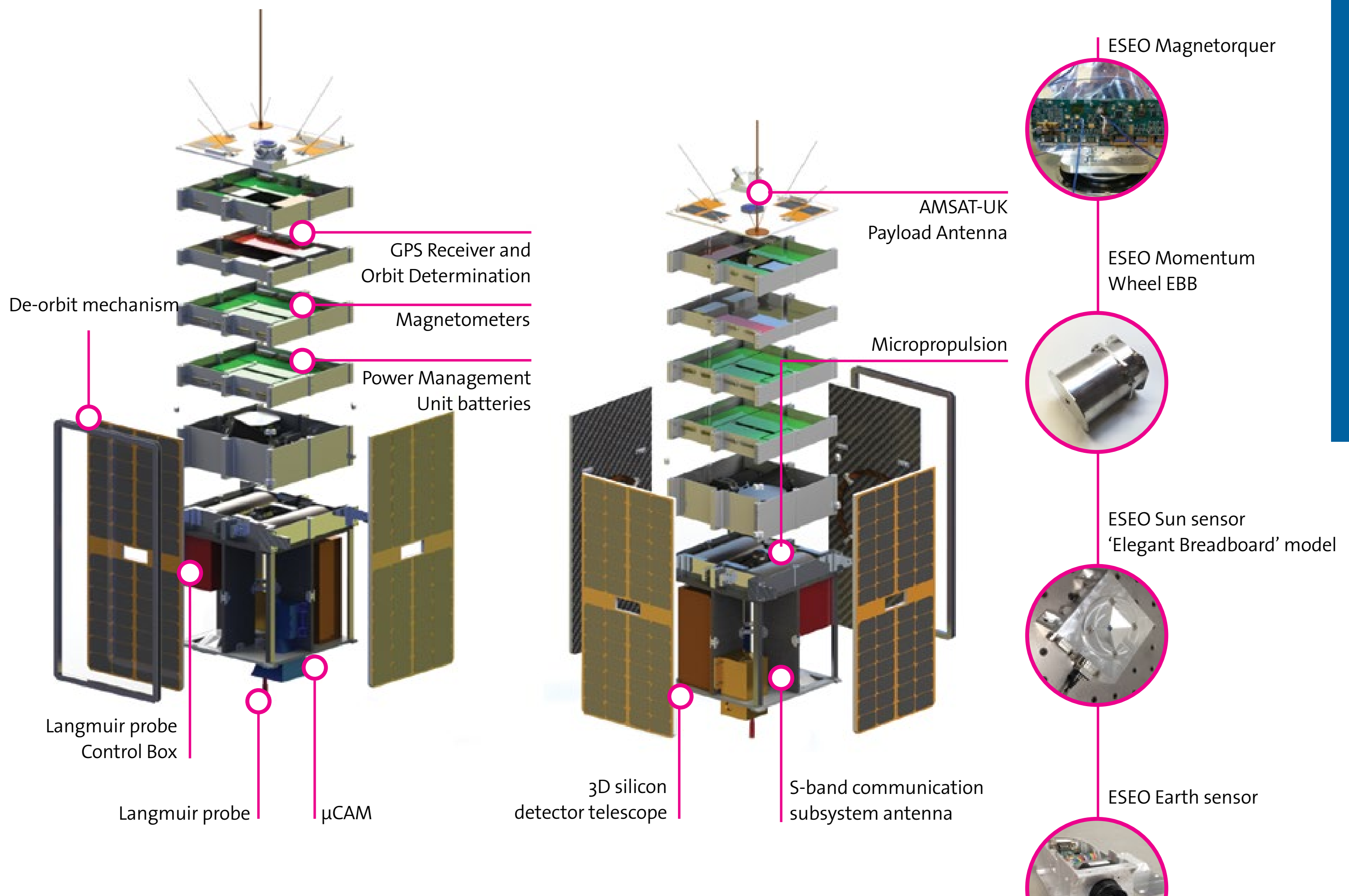
Education achievements

About 200 students are collaborating in ESEO's Phase-C/D, at different levels of involvement; most of them are involved on the premises of the different university teams participating in the project.

A series of ESEO project lectures, training courses and internships have been organised and conducted at the University of Bologna and at the prime contractor premises. Lectures are given by experts from ESA and other space organisations, and are offered to about 80 students

→ EDUCATIONAL PAYLOAD INSTRUMENTS AND CONTRIBUTIONS FROM UNIVERSITY STUDENT TEAMS

CONTRIBUTION	UNIVERSITY
Digital Camera (two independent optics)	Tartu Observatory and University of Tartu, Estonia
Langmuir Probe	Budapest University of Technology and Economics (BME), Hungary
Three-axis dosimeter (TRITEL)	MTA Centre for Energy Research, Budapest, Hungary
S-band Transmitter (HSTx)	Technology University of Wroclaw, Poland
Attitude Determination Experiment (ADE) **software**	Technology University of Delft, the Netherlands
De-Orbiting Mechanism (DOM)	University of Cranfield, United Kingdom
VHF transmitter and L-band receiver	AMSAT-UK, United Kingdom
Mission Control Centre, primary UHF Ground Station, secondary S-band Ground Station, and onboard GPS receiver and navigation unit	University of Bologna, Italy
Primary S-band Ground Station	Technology University of Munich, Germany
Secondary UHF Ground Station	University of Vigo, Spain



↑ ESEO systems and payloads

(60 selected from the whole ESEO university teams network, and 20 selected by the ESA Education Office).

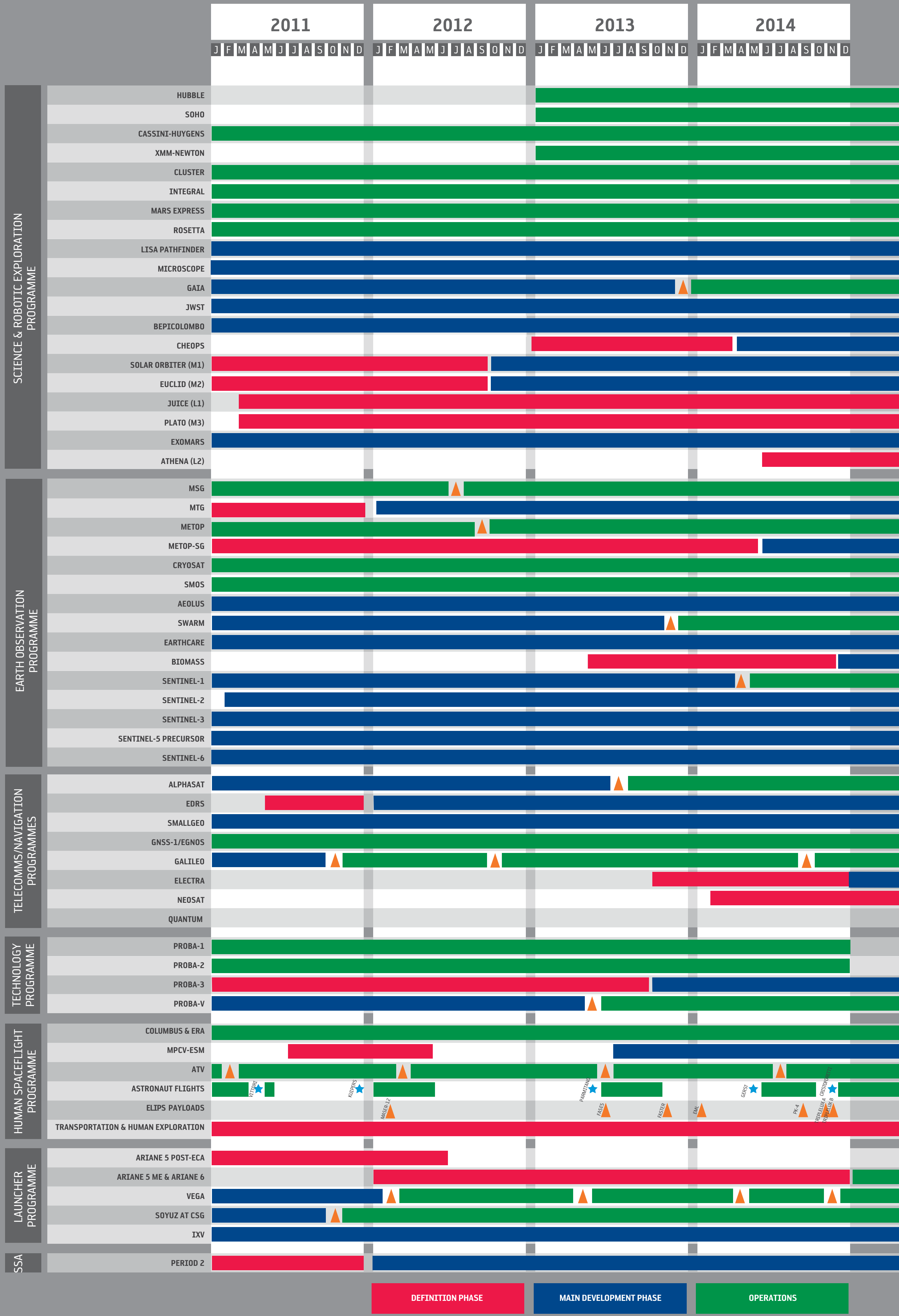
The University of Bologna grants European Credit Transfer and Accumulation System credits to the students that pass proficiently the related exams. Such initiative allows the participating students to gain the basis for a common background on spacecraft engineering, and to acquire practical experience in space system design, spacecraft assembly, integration, verification and testing, and it also facilitates the networking among the different university teams. ■

← Participants of ESEO training course in 2014

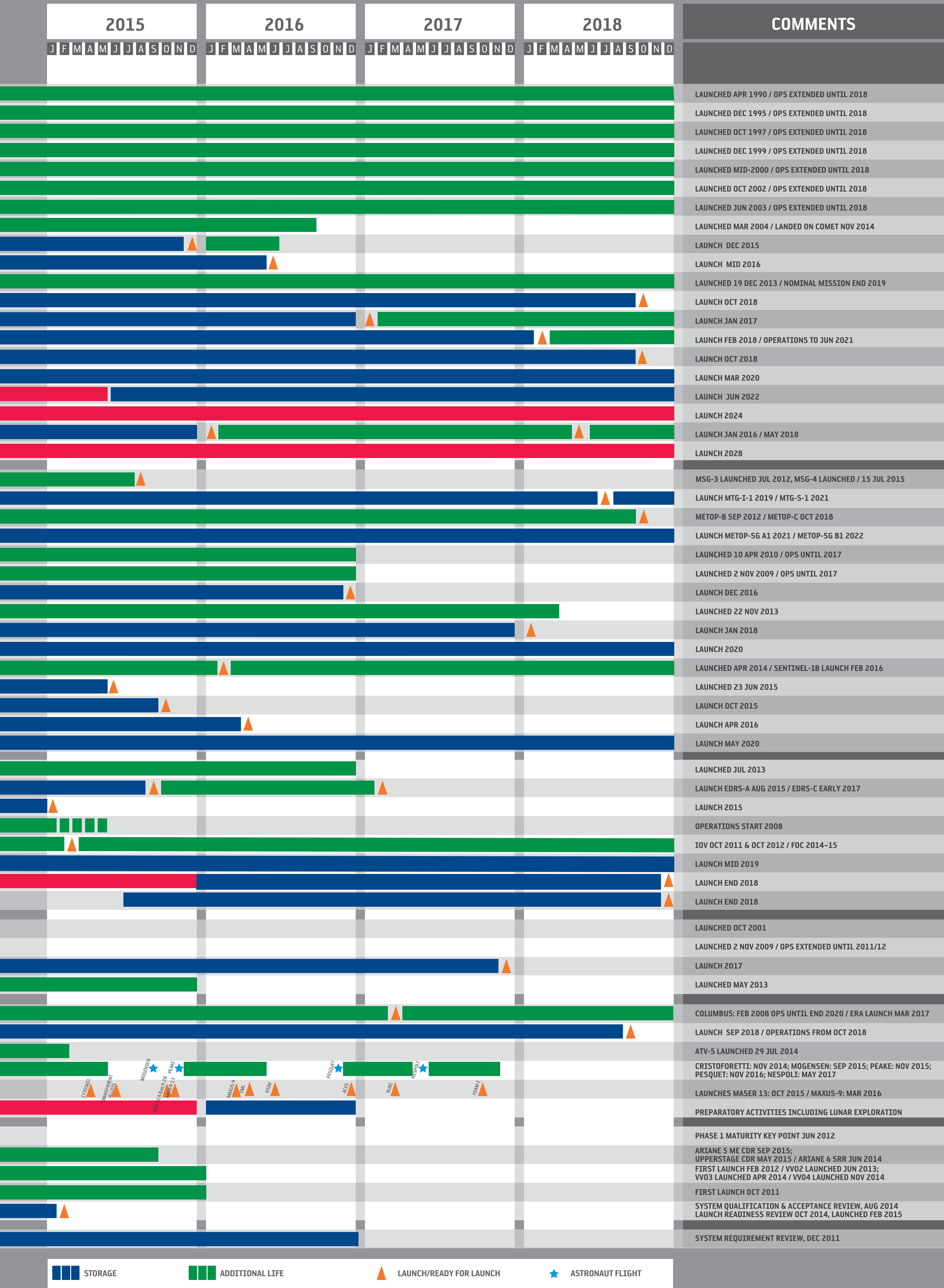
MSG-4, the last weather satellite in Europe's highly successful Meteosat Second Generation (MSG) series, was launched on Ariane 5 flight VA224 on 15 July from Europe's Spaceport in Kourou, French Guiana (ESA/CNES/Arianespace-Optique Video du CSG)

→ PROGRAMMES IN PROGRESS

Status at end July 2015



2011
2012
2013
2014
J F M A M J J A S O N D
SCIENCE & ROBOTIC EXPLORATION PROGRAMME
HUBBLE
SOHO
CASSINI-HUYGENS
XMM-NEWTON
CLUSTER
INTEGRAL
MARS EXPRESS
ROSETTA
LISA PATHFINDER
MICROSCOPE
GAIA
JWST
BEPICOLOMBO
CHEOPS
SOLAR ORBITER (M1)
EUCLID (M2)
JUICE (L1)
PLATO (M3)
EXOMARS
ATHENA (L2)
EARTH OBSERVATION PROGRAMME
MSG
MTG
METOP
METOP-SG
CRYOSAT
SMOS
AEOLUS
SWARM
EARTHCARE
BIOMASS
SENTINEL-1
SENTINEL-2
SENTINEL-3
SENTINEL-5 PRECURSOR
SENTINEL-6
TELECOMMS/NAVIGATION PROGRAMMES
ALPHASAT
EDRS
SMALLGEO
GNSS-1/EGNOS
GALILEO
ELECTRA
NEOSAT
QUANTUM
TECHNOLOGY PROGRAMME
PROBA-1
PROBA-2
PROBA-3
PROBA-V
HUMAN SPACEFLIGHT PROGRAMME
COLUMBUS & ERA
MPCV-ESM
ATV
ASTRONAUT FLIGHTS
ELIPS PAYLOADS
TRANSPORTATION & HUMAN EXPLORATION
LAUNCHER PROGRAMME
ARIANE 5 POST-ECA
ARIANE 5 ME & ARIANE 6
VEGA
SOYUZ AT CSG
IXV
SSA
PERIOD 2
DEFINITION PHASE
MAIN DEVELOPMENT PHASE
OPERATIONS


2015
2016
2017
2018
COMMENTS
J F M A M J J A S O N D
LAUNCHED APR 1990 / OPS EXTENDED UNTIL 2018
LAUNCHED DEC 1995 / OPS EXTENDED UNTIL 2018
LAUNCHED OCT 1997 / OPS EXTENDED UNTIL 2018
LAUNCHED DEC 1999 / OPS EXTENDED UNTIL 2018
LAUNCHED MID-2000 / OPS EXTENDED UNTIL 2018
LAUNCHED OCT 2002 / OPS EXTENDED UNTIL 2018
LAUNCHED JUN 2003 / OPS EXTENDED UNTIL 2018
LAUNCHED MAR 2004 / LANDED ON COMET NOV 2014
LAUNCH DEC 2015
LAUNCH MID 2016
LAUNCHED 19 DEC 2013 / NOMINAL MISSION END 2019
LAUNCH OCT 2018
LAUNCH JAN 2017
LAUNCH FEB 2018 / OPERATIONS TO JUN 2021
LAUNCH OCT 2018
LAUNCH MAR 2020
LAUNCH JUN 2022
LAUNCH 2024
LAUNCH JAN 2016 / MAY 2018
LAUNCH 2028
MSG-3 LAUNCHED JUL 2012, MSG-4 LAUNCHED / 15 JUL 2015
LAUNCH MTG-I-1 2019 / MTG-S-1 2021
METOP-B SEP 2012 / METOP-C OCT 2018
LAUNCH METOP-SG A1 2021 / METOP-SG B1 2022
LAUNCHED 10 APR 2010 / OPS UNTIL 2017
LAUNCHED 2 NOV 2009 / OPS UNTIL 2017
LAUNCH DEC 2016
LAUNCHED 22 NOV 2013
LAUNCH JAN 2018
LAUNCH 2020
LAUNCHED APR 2014 / SENTINEL-1B LAUNCH FEB 2016
LAUNCHED 23 JUN 2015
LAUNCH OCT 2015
LAUNCH APR 2016
LAUNCH MAY 2020
LAUNCHED JUL 2013
LAUNCH EDRS-A AUG 2015 / EDRS-C EARLY 2017
LAUNCH 2015
OPERATIONS START 2008
IOV OCT 2011 & OCT 2012 / FOC 2014–15
LAUNCH MID 2019
LAUNCH END 2018
LAUNCH END 2018
LAUNCHED OCT 2001
LAUNCHED 2 NOV 2009 / OPS EXTENDED UNTIL 2011/12
LAUNCH 2017
LAUNCHED MAY 2013
COLUMBUS: FEB 2008 OPS UNTIL END 2020 / ERA LAUNCH MAR 2017
LAUNCH SEP 2018 / OPERATIONS FROM OCT 2018
ATV-5 LAUNCHED 29 JUL 2014
MOGENSEN
PEAKE
PESQUET
NESPOLI
CRISTOFORETTI: NOV 2014; MOGENSEN: SEP 2015; PEAKE: NOV 2015; PESQUET: NOV 2016; NESPOLI: MAY 2017
CYTOSKEL
MAXUS-9
EML
ASIM
ACES
RUBI
LAUNCHES MASER 13: OCT 2015 / MAXUS-9: MAR 2016
PREPARATORY ACTIVITIES INCLUDING LUNAR EXPLORATION
PHASE 1 MATURITY KEY POINT JUN 2012
ARIANE 5 ME CDR SEP 2015; UPPERSTAGE CDR MAY 2015 / ARIANE 6 SRR JUN 2014
FIRST LAUNCH FEB 2012 / VV02 LAUNCHED JUN 2013; VV03 LAUNCHED APR 2014 / VV04 LAUNCHED NOV 2014
FIRST LAUNCH OCT 2011
SYSTEM QUALIFICATION & ACCEPTANCE REVIEW, AUG 2014 LAUNCH READINESS REVIEW OCT 2014, LAUNCHED FEB 2015
SYSTEM REQUIREMENT REVIEW, DEC 2011
STORAGE
ADDITIONAL LIFE
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		
ELM	Electrical Model	QM	Qualification Model
EM	Engineering Model	SM	Structural Model
EQM	Electrical Qualification Model	SRR	System Requirement Review
FAR	Flight Acceptance Review	STM	Structural/Thermal Model
FM	Flight Model	SVM	Service Module
IPC	Industrial Policy Committee	SVT	System Validation Testing
ITT	Invitation to Tender	TM	Thermal Model

→ CASSINI-HUYGENS

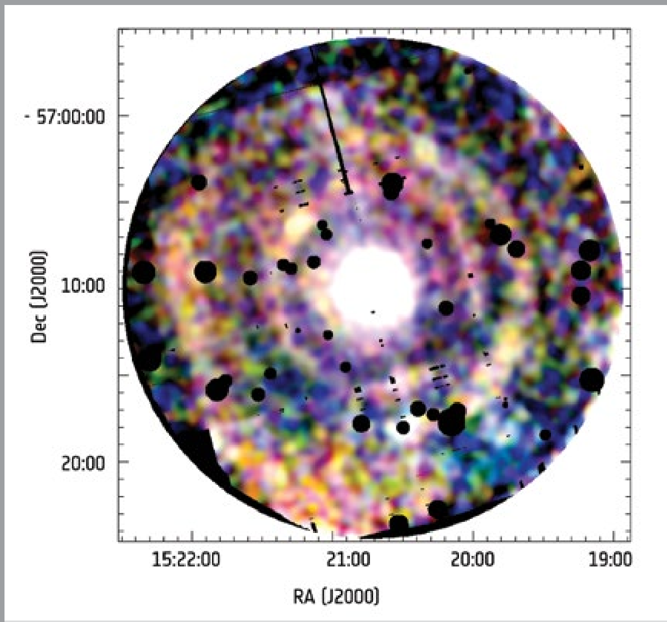
Hydrocarbon lakes were first observed in Titan's polar regions in 2006. However the formation process of the depressions in which liquid accumulates remains unknown. Chemical dissolution is believed to play a role in landscape development, in the same way that terrestrial salts (halite, gypsum) or carbonates (limestones, where terrestrial karsts develop) are soluble in liquid water on Earth. On Titan various organic solids, such as acetylene, butane or benzene, would be soluble in Titan's methane and ethane.

In a recent paper, the dissolution hypothesis on Titan was tested qualitatively and quantitatively for the first time. An algorithm initially applied to Earth to compute dissolution rates of minerals in liquid water was adapted. The strength of this technique is that it allows the inference of the timescale for dissolution to develop depressions of a given depth. The timescales produced by the model suggests that dissolution would be a very efficient mechanism to shape landforms quite rapidly in geological terms, usually within less than one hundred million years, depending on the amount of methane rain reaching the ground. The age determination is consistent with ages inferred from crater counting, accumulation times of organics to form the equatorial dune fields or possible methane outgassing events in Titan's past.

→ XMM-NEWTON

Astronomers combining data from XMM-Newton and NASA's Chandra X-ray Observatory have discovered a bright X-ray light echo in the form of four well-defined rings around Circinus X-2 (an X-ray binary in the plane of our galaxy containing a neutron star and evolved companion star).

In 2013, the neutron star underwent an enormous outburst lasting about two months, during which time it became one of the brightest sources in the X-ray sky. Follow-up



A set of four rings around Circinus X-1 can be seen in this image where X-rays measured by XMM-Newton are shown in red, green, and blue corresponding to low, medium, and high-energy X-rays, respectively. Point sources have been removed

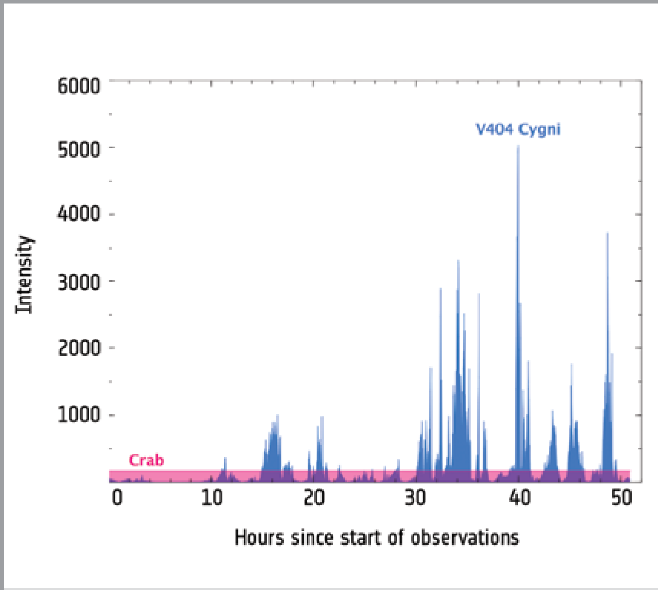
observations with XMM-Newton revealed a set of four rings that appear as concentric circles around Circinus X-1. These rings are almost certainly 'light echoes' originating from the 2013 outburst and then reflected back from interstellar dust, similar to sound echoes experienced on Earth. Just as bats use sonar to triangulate their position in flight, these X-ray light echoes have been used to pinpoint Circinus-X1's location, 30 700 light years from Earth. Previous distance estimates were very uncertain and inconsistent. But knowing the distance to this system is important because it will allow many of the other properties of Circinus X-1 to be better understood.

→ CLUSTER

For the first time two ESA space missions, Cluster and Swarm, joined forces to simultaneously measure the properties of Earth's magnetic field at two different altitudes. They found a number of striking similarities in the behaviour and structure of the field-aligned currents they detected, despite their vastly disparate locations – Cluster being 15 000 km above Earth and Swarm at just 500 km. Field-aligned currents (FACs) flow along Earth's magnetic field lines, transferring energy between the magnetosphere and ionosphere at high latitudes. Their intensity is highly variable, much more intense during magnetic substorms when colourful auroras light up the sky. What this joint activity delivers is the ability to characterise FACs in the ionosphere and magnetosphere at the same time – particularly their intensity.

The three satellites of ESA's Swarm mission have the main goal of probing the strength, properties and dynamics of Earth's internal magnetic field. However the satellites' precision sensors also pick up the natural and powerful electric currents flowing through the ionosphere and magnetosphere, but these are normally considered as a noise source in Swarm measurements, with Cluster helping to disentangle them. On the other hand, enhanced understanding and eventually predicting of strong currents in the ionosphere is important because they can disrupt power grids and pipelines via induced electrical components, even triggering component burnout in transformers and other electrical devices.

Cluster and Swarm began joining up to better understand FACs and other complex magnetic behaviour around Earth in spring 2014. They will continue working together into the future, with more joint campaigns planned until 2018.

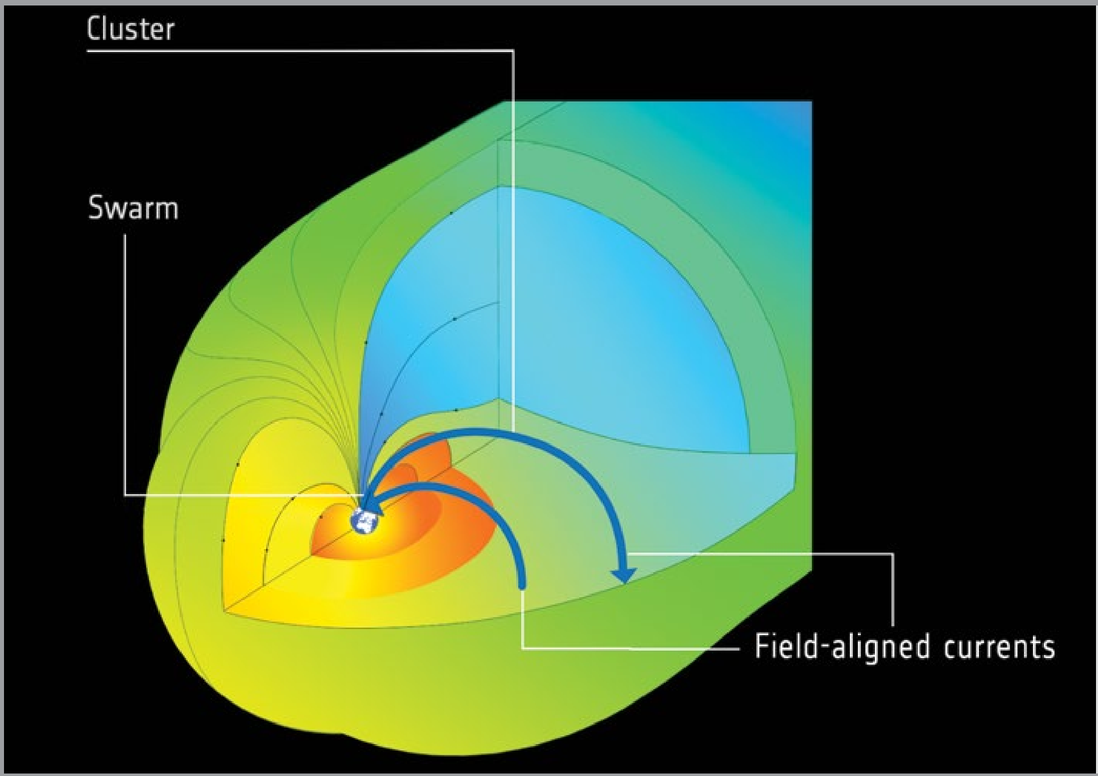


Brightness (intensity) as seen by the hard-X-ray imager on Integral, IBIS/ISGRI, in number of recorded photons per second against time over about 52 hours. The brightness of the Crab Nebula as seen with the same instrument is indicated as well

→ INTEGRAL

On 15 June, black-hole binary X-ray transient V404 Cyg (GS 2023+338) made an extraordinary comeback after 26 quiet years. During its outbursts, the luminosity of the system increases by six orders of magnitude, reaching the Eddington limit – the maximum before violent shedding stellar winds. Repeated bright flashes of X-rays were observed on time scales shorter than an hour, becoming the brightest object in the X-ray sky – up to 50 times brighter than the Crab Nebula.

The first signs were spotted from NASA's Swift satellite on 15 June, detecting a sudden burst of gamma rays. Soon after, the MAXI instrument on the ISS observed an X-ray patch from the same patch of sky. These detection triggered a



Locations of Cluster and Swarm during the study of April 2014. It is highly likely that both missions sampled the same large-scale field-aligned current (ESA/ATG medialab) massive multi-wavelength observation campaign from both Earth and space observatories, with Integral disrupting its existing programme to join the monitoring of V404 Cyg during 17–19 June and 26 June to 13 July, plus a pre-approved Announcement of Opportunity programme performed on 20–25 June, whose principal investigator kindly agreed to make the data publicly available. As a further service to the astronomical community, ready-to-use light curves and spectra of all publicly available source observations are available through the ISDC Data Centre for Astrophysics.

One of the best-established accreting black-hole binary systems, V404 Cyg comprises a co-orbiting star and a black hole of about nine solar masses. Located in the constellation of Cygnus, V404 Cyg is only 2.4 kiloparsecs away, making it one of the closest of its kind. Currently the source is in a lull, but if it follows previous behaviour it may soon become bright again.

→ ROSETTA

A press conference at the European Geosciences Union meeting in Vienna in April was held to discuss magnetism near the comet. This was the first lander-related science result at the comet, as well as Rosetta's first science result at the comet to combine both Philae and Rosetta instruments. The study used ROMAP data from the Philae lander plus RPC magnetometer data from the orbiter to show that the comet has no magnetic field – an important result in terms of constraining theories of small body formation such as comets in the early Solar System.

The Rosetta team announced with great sadness in July the passing of their colleague, US Project Scientist Claudia Alexander. She will be greatly missed

A number of science results are being published as part of an *Astronomy and Astrophysics* special issue, available at the end of this year. Included is an updated morphological map of the comet surface, with different regions named after Egyptian goddesses – the 'head' of the duck-like comet – and gods – the 'body'.

Rosetta was also reoriented to image Pluto during NASA's New Horizons flyby. Pluto was more than five billion km away from Rosetta at the time, and required an exposure time of three hours coupled with sophisticated image processing to retrieve the image – Pluto being the most distant Solar System body that Rosetta has ever looked at.

In July, the lander briefly regained contact with the orbiter, although to date persistent stable communication with the lander has not been achieved. The team is continuing to investigate optimising lander communication while also carrying out important orbiter observations throughout comet perihelion.

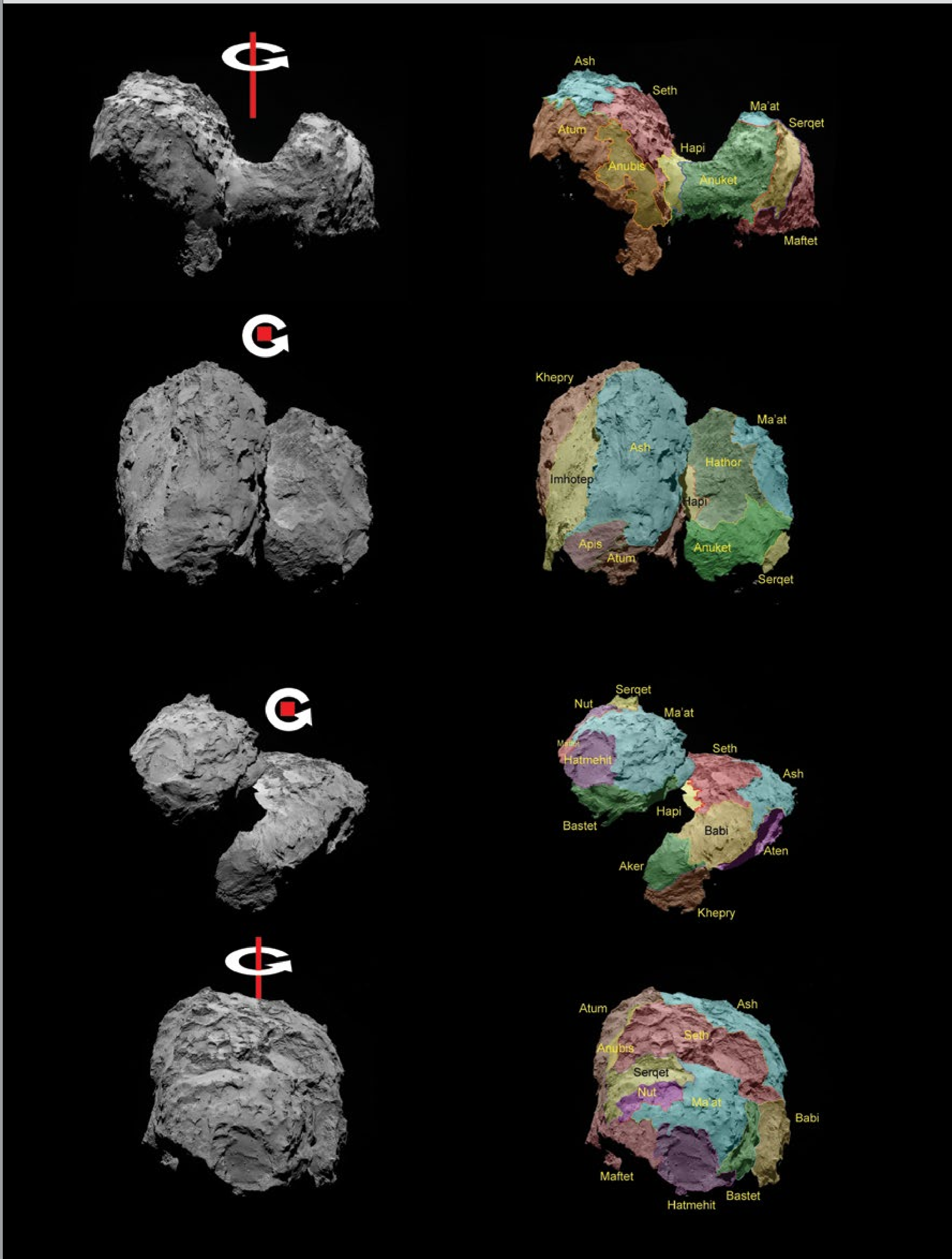
→ HERSCHEL

The mission is in its post-operations phase. Its full science archive has been reprocessed with the latest version of the data processing software (HCSS 13.0), offering further improvements in pointing reconstruction as well as refined and new data products. The Herschel Science Archive itself offers the possibility of performing more tailored queries based on instrument-specific observational parameters.

The Herschel Science Centre supports the astronomical community in using Herschel data to do science, by continuously improving Herschel data products and archive functionality, while also organising workshops and providing Helpdesk support.

One of Herschel's most prominent results is the discovery of 'filaments' in nearly molecular clouds and their role in star formation. However filamentary structure is ubiquitous at various scales throughout the Milky Way – the very largest can reach up to galactic scale as part of the spiral arm structure. Such large-scale filaments have been hard to identify systematically and before Herschel only a few were known.

Rosetta OSIRIS images showing Comet 67P/Churyumov–Gerasimenko in different orientations (ESA/Rosetta/MPS for OSIRIS Team)



The G49 filament seen by ESA's Herschel (ESA/Herschel/PACS/SPIRE/Ke Wang et al)

Herschel has mapped the entire galactic plane in five colours as part of the Hi-GAL project, results that have been used to search for these, the largest, coldest and densest filaments in our parent Galaxy, directly in emission in the far-infrared. Extrapolating from this pilot study reveals that there could be about 90 of these large structures called 'bones' as part of the 'skeleton' of the Milky Way.

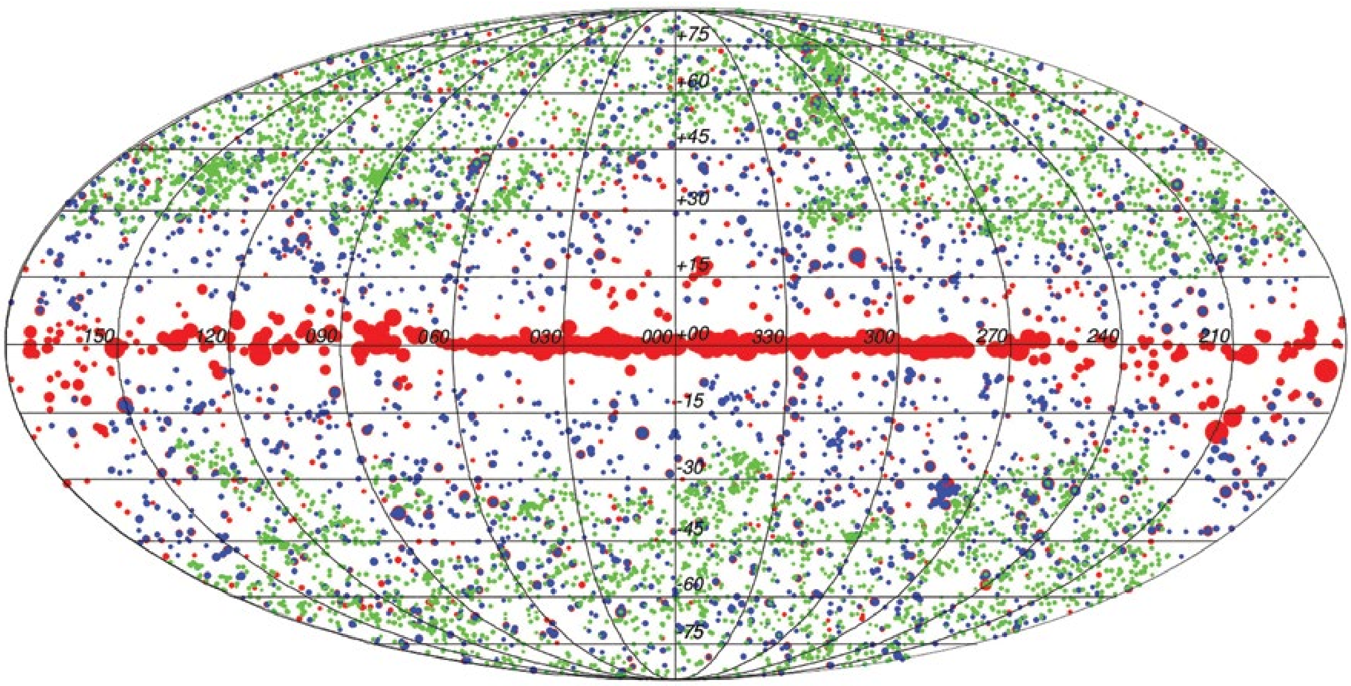
→ PLANCK

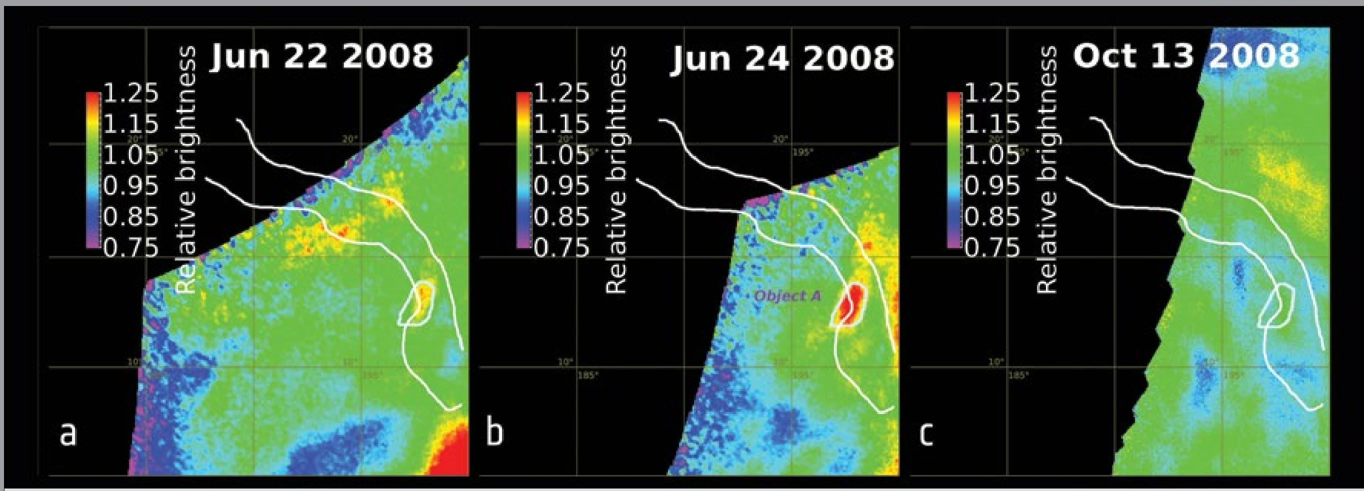
February marked the public release of the latest set of Planck data via the Planck Legacy Archive, with additional products added subsequently. One of them is the Second Planck Catalogue of Compact Sources. In addition the initial delivery of polarised maps at 30, 44, 70 and 353 GHz has been complemented with those at 100, 143 and 217 GHz, In summary, all of the data acquired by Planck during its operational lifetime has now been made public, to be analysed by a wide community of cosmologists and astrophysicists. In the meantime the Planck Data Processing Centres continue to refine their understanding and improve the cleaning and calibration of the data products. These refined products, due for release in mid-2016, will constitute the 'legacy' of Planck.

→ VENUS EXPRESS

Analysis of images from the Venus Monitoring Camera (VMC) has revealed areas of hot lava on the surface of Venus, providing evidence of present active volcanism. Within a few days, limited surface areas have shown dramatic temperature increases, dropping back to normal within a few weeks. The first direct evidence of active volcanism was found at Ganiki Chasms in Atla Regio, located in the equatorial region, where four hotspots were detected. This is

The distribution of compact sources across the sky, as seen by Planck, just a selection of the tens of thousands of compact sources included in the Second Planck Catalogue of Compact Sources. The catalogue includes data from the full Planck mission, surveying the entire sky in nine different wavelengths spanning the far-infrared to radio, covering the spectral range 30 GHz to 857 GHz. Featured here are the sources found using three of Planck's nine channels: 30 GHz (red), 143 GHz (blue) and 857 GHz (green)





Brightness changes detected by Venus Express in data from 2008 on the Ganiki Chasma rift zone in Atla Regio on Venus (E. Shalygin et al)

an area that has previously been identified as a tectonic rift zone, where potential volcanism would be more likely.

The VMC images were taken at a wavelength around one micrometre, allowing surface thermal radiation can escape through the atmosphere without too much attenuation. Much work has been put in to reduce the atmospheric contribution for a sole focus on surface effects. The spatial resolution is limited by scattering in the atmosphere and clouds to about 100 km, but the size of the active hot lava field is likely to be much less – on the order of 1 km^2. The hot fields' temperature has been estimated at 830 °C, much higher than the global average surface temperature of 480 °C.

Frequent volcanism has long been theorised as a mechanism to release Venus's internal heat generated by radioactive decay. On Earth, plate tectonics provides just such a mechanism, but previous investigations have shown Venus lacks plate tectonics. Previous findings have given indirect indications of present volcanism, such as areas of fresh surfaces detected by the VIRTIS instrument and episodic increases in sulphur dioxide detected by SpicaV. The new findings of hot lava fields provide convincing evidence, representing one of the major findings of the mission now that Venus Express has ended its operations. A very large data set was collected over 8.5 years of operations, and additional discoveries may well be made as these data are further analysed.

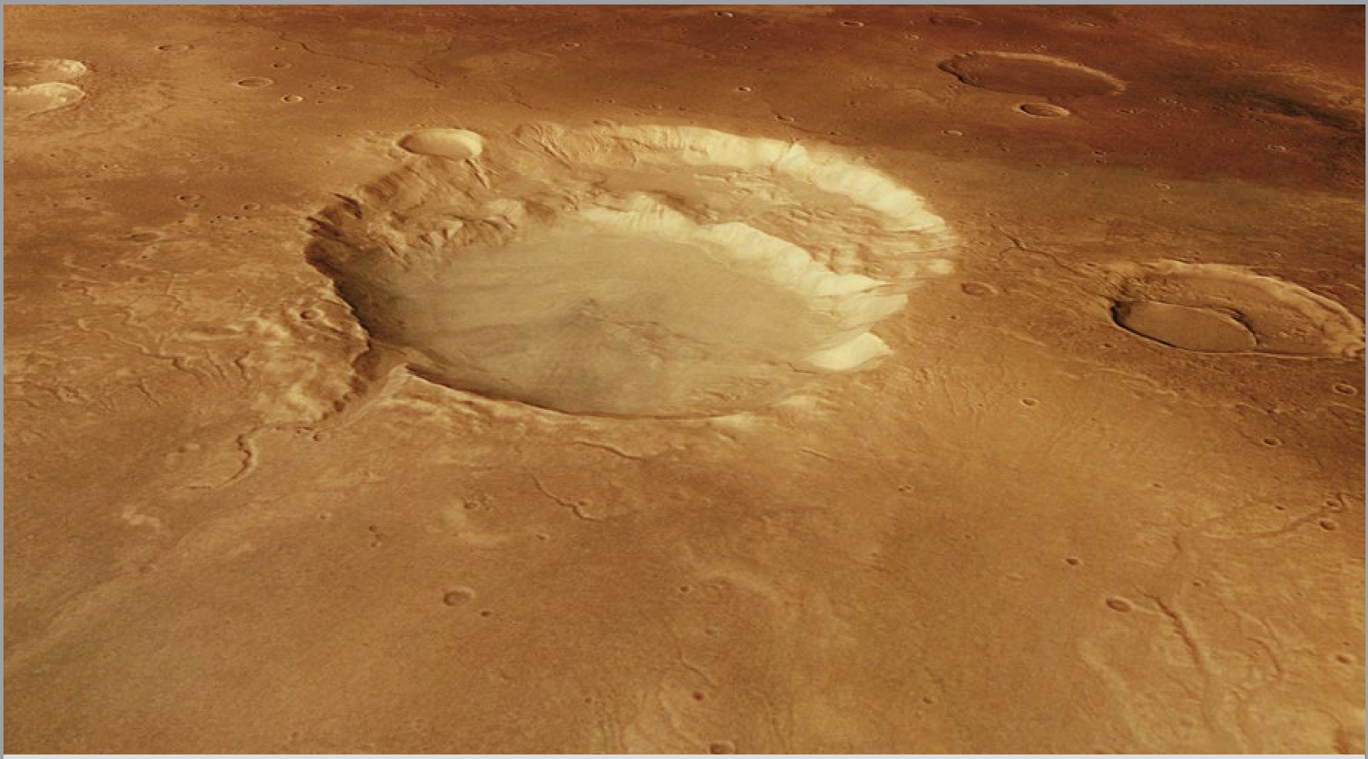
→ MARS EXPRESS

Mars Express has begun its second decade in Mars orbit in excellent health. Several papers summarising the mission results from 10 years of operations have been published. Science highlights include analyses of geological processes and landforms from HRSC imaging on a local-to-regional scale, a comprehensive study of surface albedo and its variations by the OMEGA imaging spectrometer, hunting out minor trace gases using the sensitive PFS spectrometer.

Subsurface sounding of various regions as well as determining the thickness of the polar caps was performed with the MARSIS radar, also used for sounding of the ionosphere to reveal a complex interplay between atmospheric plasma, crustal magnetic fields and the solar wind. The MaRS radio science experiment was used to probe Mars's ionospheric structure and interior of its moon Phobos, while ASPERA's observations of the plasma environment and atmospheric escape now cover a complete solar cycle – alongside continuous monitoring of atmospheric dust and annual evolution of the polar caps with the VMC wide-angle camera.

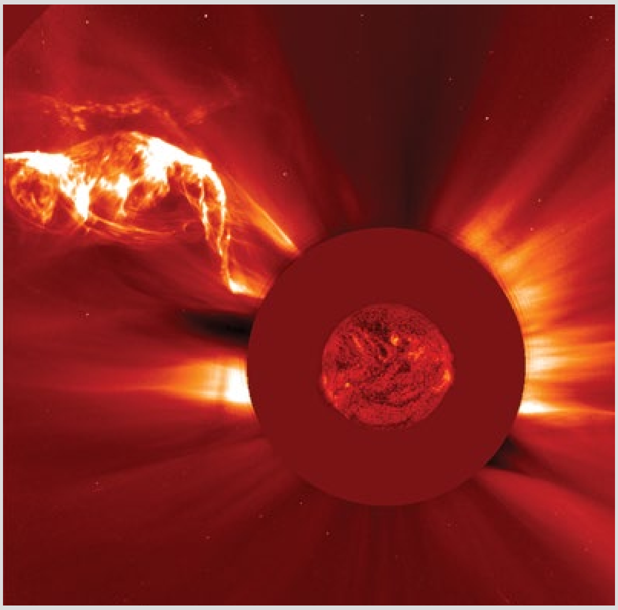
May and June saw a suspension of science operations because of a solar conjunction. But during this period more than 30 radio soundings of the solar corona were performed. One recent HRSC image shows a highly debated feature in the Arabia Terra region, called Siloe Patera – a large circular depression, approximately 40 x 30 km, bearing a nested secondary circular depression. Is it simply a degraded impact crater, or a whole new class of martian volcanic constructs?

Some scientists believe that it represents, along with similar features elsewhere in Arabia Terra, what are called 'plains-style caldera complexes' resembling terrestrial super-volcanoes. The deepest parts of Siloe Patera reach 1750 m below its surrounding plains with the shallower depression about 700 m below the surrounding surface. The question is in no way settled, but the super-volcano theory fits with the observation of numerous deposits of fine-grained, layered sulphate- and clay-bearing materials distributed



The highly debated feature in the Arabia Terra region, called Siloe Patera – a large circular depression – as seen by Mars Express (ESA/DLR/FU Berlin)

in the equatorial regions, many in Arabia Terra, which have yet to be conclusively explained. The presence of pyroclastic volcanic centres could account for these deposits as well as significant periods of global warming.



The coronal mass ejection associated with the elongated solar filament in April as seen by SOHO (ESA/NASA)

→ SOHO

On 28 April, an elongated solar filament that extended across almost half the Sun's visible hemisphere erupted into space in a large burst of bright plasma. Filaments are unstable strands of plasma suspended above the Sun by magnetic forces. Solar astronomers around the world had their eyes on this unusually large filament and were thrilled to see it erupt. SOHO's LASCO coronagraph shows the coronal mass ejection associated with the eruption.

→ GAIA

A decontamination procedure was executed in early June to clear the Gaia mirrors of a thin accumulated ice layer that had an impact on transmission. Recovery of the focus, after this thermal impact, is being followed, for adjustment if necessary. Transmission has been fully recovered and Gaia observes on average some 50 million objects daily.

In advance of the decontamination procedure, a set of tests was performed to study Gaia's thermal properties. For astrometric measurements the angle between the two lines of sight must be well understood and any small changes well measured. The changes observed between the two lines of small – one milliarcsecond – but larger than anticipated before launch. Knowledge of this 'Basic Angle Variation'

(BAV) is crucial to data processing. During the tests, internal heaters were used to provoke large BAV in order to better model the variation.

Data processing proceeds towards the first intermediate data release planned for summer 2016, based on the position and brightness of stars. The long-awaited parallax and proper motion analysis can be deduced later after more data has been collected. Gaia's Data Analysis and Processing Consortium is furthermore looking into possibilities to add some specific data products to the first intermediate data release.

→ LISA PATHFINDER

The environmental test campaign concluded with a vibro-acoustic test at IABG GmbH in June. The mass and inertia of the Science Module and the Propulsion Module have been measured, coming within expectations. Other activities included an electrical and mechanical fit-check with the launcher vehicle adapter – provided by Arianespace – and numerous end-to-end, functional tests and health checks. The FAR is ongoing.

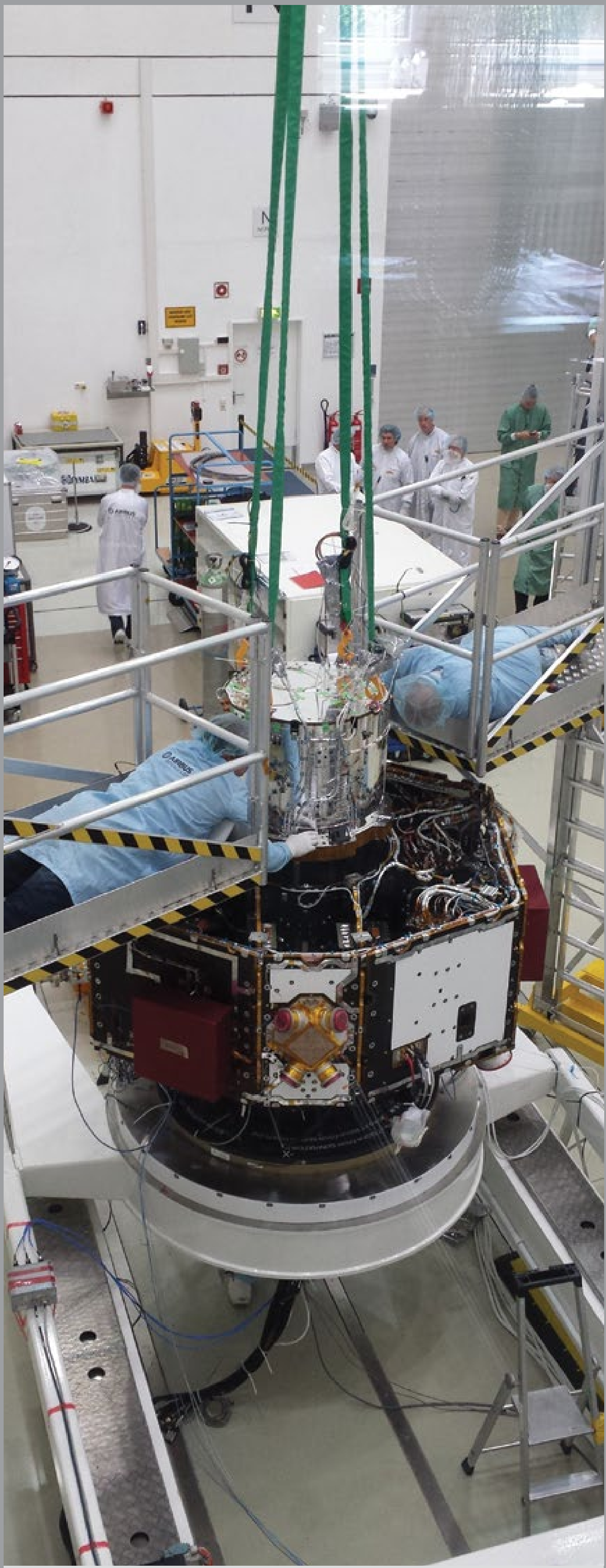
The integration and verification of the LTP Core Assembly (LCA) – the main mission instrument – was completed in May and the LCA installed into the spacecraft. The simulation campaign for in-flight operations began in June, being conducted at ESOC where the mission will be run for real. The ground segment development and testing at ESOC and ESAC is complete, along with the science operations preparatory activities. The launch vehicle is Vega VV06: the launcher's final mission analysis is ongoing.

→ BEPICOLOMBO

Following the mission CDR, detailed data analysis of the Mercury Planetary Orbiter (MPO) thermal test confirmed good overall thermal performance. Small local adaptations of thermal design were implemented.

Integration and test activities on the MPO and Mercury Transfer Module (MTM) system level progressed with the completion of the exchange slot of some instruments from qualification to flight models. In addition the mechanical/electrical integration of the MPO Remote Interface Unit has been completed, along with integration of the Solar Array Drive Assembly, thrusters and flow control units of the MTM's Solar Electric Propulsion System.

Excepting two payloads, all other instruments are integrated on the MPO in flight quality. For the two outstanding instruments representative replacement models are being used for system-level electrical/mechanical tests.



The LISA Pathfinder Core Assembly integration into the Science Module in Ottobrunn(Airbus Defence & Space/IABG)

The BepiColombo High Gain Antenna Mechanism Assembly Qualification Model being prepared for thermal testing at ESTEC

The High Gain Antenna Mechanism Assembly QM has been installed in ESTEC's thermal test chamber, awaiting testing at 10 solar constants. The cell lay down of the first MPO solar array panel was completed and has been released for all remaining panels. Vibration testing was completed at panel level. The MTM solar array STM wing production is projected to be complete at the end of July.

JAXA's Mercury Magnetospheric Orbiter (MMO) was shipped to ESTEC in April, and is awaiting close out of some open work, well in advance of its anticipated need date. The critical path of the overall system schedule is defined by the Power Processing Units of the Solar Electric Propulsion Subsystem in the MTM and the High Gain Antenna Mechanism Assembly of the MPO.

→ MICROSCOPE

Integration of the flight hardware is progressing at CNES. The first two batches of ESA's cold-gas micropropulsion system – eight thrusters, half the total – were delivered to CNES at the end of July. The two electronics units were due to be shipped to CNES in August.

→ EXOMARS

Implementation for both the 2016 and 2018 missions is proceeding. System-level integration and test activities for the 2016 mission are progressing at Thales Alenia Space France, Cannes. After a close-out meeting on 6 May, project teams are concentrating on procurement activities of the 2018 mission.

Mechanical testing in launch configuration was completed on the 2016 mission's Trace Gas Orbiter (TGO) and Schiaparelli lander. A launcher separation test using the Russian-provided launch vehicle adapter was also achieved. After the test, the composite spacecraft was demated so that each spacecraft FM could continue with system-level verification activities.

Thermal vacuum/thermal balance (TV/TB) testing was carried out on Schiaparelli, representing the cruise and coast phases prior to its arrival in the martian atmosphere. Electromagnetic compatibility testing on the TGO was completed, followed by system functional testing ahead of its own TV/TB testing. TGO instrument exchanges were completed, so that the NOMAD, ACS and FREND instrument FMs are all integrated and participating in system testing. The CaSSIS instrument will be integrated later in the verification flow due to its late start in the programme.

The DREAMS instrument exchange was completed prior to the start of TV/TB testing for Schiaparelli. Compatibility testing of the Schiaparelli UHF radio with NASA orbiters at Mars will take place in Littleton, Colorado. Helicopter-based Radar Doppler Altimeter testing for Schiaparelli's radar system was recently completed in Rome – the results are under detailed assessment, but first-look analysis indicates the radar is working well.

The 2018 mission passed its System PDR, opening the path to the full Phase-C/D development of all mission elements. Rover development is proceeding. The Analytical Laboratory Drawer (ALD) QM integration facility is complete and final tests for its prime objective of maintaining an ultraclean environment during ALD assembly are ongoing. The facility will be used for the integration of the Sample Preparation and Distribution System QMs and the Pasteur Payload analytical instrument QMs to prove the concept for the FM build.

→ SOLAR ORBITER

The CDR is ongoing. Issues identified during the process are being addressed systematically.

The spacecraft's STM – including the Heat Shield STM, Instrument Boom and QM and High Gain Antenna STM – has passed mechanical testing at IABG, including acoustic noise, sine vibration, clamp-band release shock testing, appendages release and alignment checks. The STM spacecraft has now been shipped back to the prime contractor to be reconfigured for thermal tests to follow later in the year.

Tests on the On-Board Computer Test Bench are near completion. On the spacecraft Engineering Test Bench (ETB), the Antenna Pointing Mechanism Electronics EMs have been integrated. Testing of the Solid State Mass Memory continues and integration activities continue with the Solar Array Drive Electronics EM.

Manufacturing of a number of spacecraft FM units continues, with most communications subsystem units due for delivery in the summer. Efforts are continuing at two different suppliers to produce the Solar Generator panel substrates, based on technology developed for BepiColombo. Assembly of solar cell assemblies began at Airbus Defence & Space in Ottobrunn.

Electromagnetic compatibility tests have been performed on the On-Board Computer and several instruments, giving good results, continuing as new units become available. Reconfiguration and simplification and the SORA payload radiator continues, yielding performance improvements and enables the SORA to meet long-standing requests for increased cooling flux from several instruments.

CDRs for instruments comprising SoloHI, MAG, SPICE, EUI, PHI and EPD have been completed. The reviews of STIX and SWA are done but closure is pending for resolution of some issues. The STIX close-up is planned for late summer, those for RPW and SWA expected in the autumn.

→ JAMES WEBB SPACE TELESCOPE (JWST)

The JWST programme continues to progress according to the plan established in 2011, with a planned launch date in October 2018. Manufacturing of the first flight sunshade foil has been completed, the other four being in different stages of production.

The upgrade of all the science instruments to final flight configuration has been completed, with all instruments installed on the Integrated Science Instrument Module (ISIM) – meaning it is now in flight configuration. The ISIM sine vibration test has been completed. The cryo-test campaign of the telescope pathfinder has begun at NASA's Johnson Space Center. Delivery of the MIRI Cryo Cooler Assembly to NASA's Jet Propulsion Laboratory is imminent and will be followed by a series of end-to-end cooler system tests including cooler assembly and electronics.

Integrated Science Instrument Module in flight configuration after reinstallation of all the upgraded instruments (NASA/C. Gunn)

→ EUCLID

Now in Phase-C/D. Prime contractor Thales Alenia Space Italy in Turin has completed the PDR. Definition of the subsystem requirements has been completed, advancing the system design. All the first latter subsystem contractors have been selected. Many second-layer contracts under the Payload Module and several of the Service Module have also been selected and contracts begun.

The Visible Imager (VIS) instrument is progressing. The detailed design of the subsystems is ongoing and the subsystem CDRs will start shortly. Several subsystem STM tests have already been performed and EMs are being assembled. The contract with e2v for the development, qualification and FM production of the VIS CCD detectors proceeds on schedule.

The Near Infrared Spectro-Photometer (NISP) instrument PDR has been completed with the lower-level PDRs nearly all done. The manufacturing of the STM instrument, mainly made of silicon carbide, is proceeding. The NISP schedule has been reviewed by the funding agencies under CNES leadership and a substantial delay of several months to one year has been reported. The project is presently working on reshuffling the overall schedule in order to minimise the impact on the launch date, previously planned for the first quarter of 2020 by Soyuz from French Guiana. Procurement of the NISP detector systems is ongoing. Teledyne Imaging Sensors of Camarillo, USA, has manufactured all necessary detector systems for the evaluation and qualification phase, with qualification testing of the detector now completed.

→ JUICE

In response to ESA's ITT for Phases-B2, -C/D and -E1, two industry proposals were received from Airbus Defence & Space France and Thales Alenia Space France in March. Evaluation took place, with the recommendation for contract placing presented to ESA's IPC in July.

Several technology activities are addressing the most critical mission elements such as the solar array, propulsion system and navigation system. All instruments have entered their implementation phase although their rate of progress is not yet homogeneous.

→ CHEOPS

With launch readiness planned for the end of 2017, manufacture of CHEOPS platform structural elements has been completed by Airbus Defence & Space Spain, with integration and alignment of the primary structure ongoing. System testing of the EFM and PFM was planned for September. Equipment procurement is progressing: key avionics units including the onboard computer and power conditioning and distribution units passed their manufacturing readiness reviews.

The Instrument Consortium, led by the University of Bern, took delivery of the planned interface hardware units from the prime contractor. Flight units of the instrument CCD have also been delivered by e2v. Assembly of the instrument STM is complete and its test campaign ongoing, enabling delivery of the STM to the prime contractor for spacecraft-level tests at the end of August.

The Mission Operations Centre PDR concluded in June, followed by the Third CHEOPS Science Workshop at CDTI in Madrid.

→ AEOLUS

The laser transmitter was integrated in the Aladin instrument, with the redundant laser transmitter in undergoing final preparation before its own mounting in the instrument.

DLR and NASA aircraft during the Aeolus airborne demonstration campaign (DLR)

Integration and alignment are performed with extreme care in order to avoid laser-induced damage on apertures and sensitive surfaces close to the nominal beam path.

The In-Situ Cleaning Subsystem was integrated and tested for key safety-related requirements such as ability to withstand proof pressure, compatibility with pure oxygen and overall leak tightness.

An Aeolus airborne demonstration campaign was carried out in cooperation with DLR and in close coordination with NASA. A DLR Falcon aircraft performed several test flights using the development model of the Aladin instrument. A DC-8 aircraft from NASA measured the same scenes with complementary lidar instrumentation. Data processing is ongoing, one objective being to test the operational Aladin ground processor software.

→ EARTHCARE

Assembly of the PFM ATLID laser transmitter at Selex in Italy was completed with the integration of the optical amplifier and the harmonic stage. A major milestone was achieved with the generation of the first UV pulses. Integration of the second FM transmitter also began.

Integration of the PFM Broadband Radiometer Optical Unit is nearing completion at the Rutherford Appleton Laboratory, UK. The MSI Thermal Infrared Camera subsystem assembly is complete while integration of the PFM camera is ongoing at Surrey Space Technology Ltd. In Japan, the Cloud Profiling Radar PFM underwent its vacuum bake-out campaign.

→ BIOMASS

Preparation for full implementation of the Biomass mission continued: A request was issued to European industry to submit proposals to build the Biomass satellite. Evaluation of proposal submissions will lead to the selection of a prime contractor in the second half of 2015.

→ METEOSAT SECOND GENERATION

Meteosat-8/MSG-1

Located at 3.9°E longitude. Now the operational backup for Meteosats-9 and -10.

Meteosat-9/MSG-2

Located at 9.5°E longitude and providing the Rapid Scan Service – with one picture every five minutes of the

MSG-4 fuelling (CNES)

northernmost third of Earth in 12 spectral channels – complementing the full-disc mission of the operational Meteosat-10.

Meteosat-10/MSG-3

Located at 0° longitude, performing the full-disc mission (one image every 15 minutes in 12 spectral channels) as well as the data collection, data distribution and search and rescue missions.

MSG-4

The satellite was shipped to Europe's Spaceport in French Guiana in April, ready for its Ariane launch on 8 July. MSG-4 will be stored in orbit after launch and commissioning. It will ultimately bridge the gap between Meteosat-10/MSG-3 and the first Meteosat Third Generation satellites.

→ METEOSAT THIRD GENERATION

Implementation of the STM and EM models is progressing. On the platform side, the STM Central Tube was delivered to OHB by Ruag (SE) while the panels required to complete the STM Propulsion Module Structure (PMS) integration are undergoing final manufacture by CASA with first batch delivery expected in July. Airbus Defence & Space in Lampholdshausen is ready to receive the PMS and integrate the STM propulsion subsystem equipment.

For the platform EM, the baseline configuration and detailed test objectives are under final definition and review. The Software Validation Facility (SVF) and Avionics Verification Model (AVM) required for software and equipment interface validation prior to the EM activities are also progressing.

The design phase of the FCI and IRS instruments was completed, with hardware manufacturing beginning. The critical path for the FCI – and MTG-I satellite – runs through the instrument structural design, where a phased manufacturing release of the STM and EM hardware is under way. Progress on the critical Scan Assembly has also allowed the release of the SCA development hardware. The PDR of the Lightning Imager was completed and its recommendations are being implemented.

At MTG-I and MTG-S satellite level, despite some evolution, the main engineering budgets (mass and power) remain within specification and predicted compliance to instrument performance requirements remains very high.

The MTG-I and MTG-S PFM Flight Acceptance Reviews are currently scheduled for February 2019 and January 2021 respectively. Significant pressure remains on these dates. Based on the current health of the MSG satellites in orbit, and the scheduled launch of the last MSG in early July, these predicted dates remain consistent with Eumetsat needs.

Sentinel-2 spacecraft encapsulation at Europe's Spaceport in French Guiana

→ METOP

MetOp-A
The satellite will operate in parallel with MetOp-B until the successful commissioning of MetOp-C.

MetOp-B
MetOp-B is Eumetsat's primary operational polar-orbiting satellite.

MetOp-C
The satellite is in storage and will undergo an annual reactivation to confirm the good health of its hardware. Nominal readiness for launch on Soyuz by French Guiana is currently planned for October 2018.

→ METOP SECOND GENERATION

MetOp-SG consists of two series of satellites – A and B – embarking a total of ten different instruments, set to provide operational meteorological observations from polar orbit from 2021 to the mid-2040s. The build-up of the industrial consortia through 'best practices' procurements – covering a total of 165 items – continues, with the ITTs for half of these items released. Design of the satellites and instruments is being consolidated in preparation for the PDR in September.

→ COPERNICUS

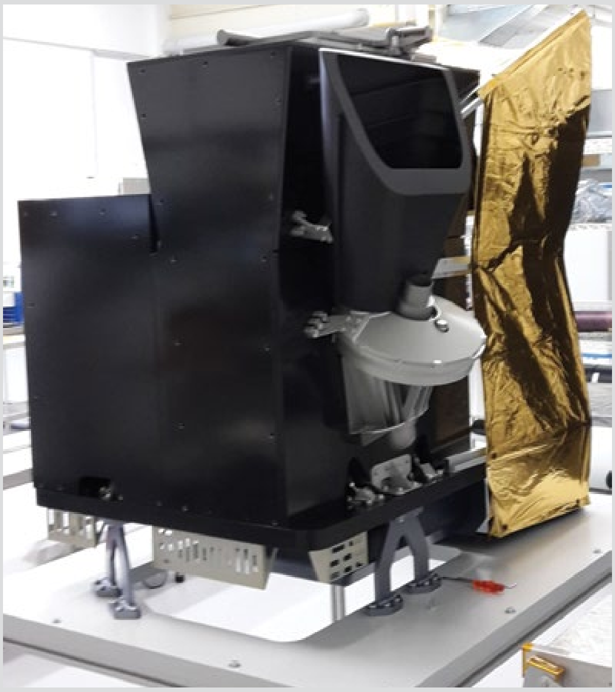
Sentinel-1
Sentinel-1A continues to maintain its excellent performance while systematically providing free, full and open data to users through the scihub.esa.int website. The first Routine Operations Review confirmed that Sentinel-1A remains in a safe, stable state, using all its prime units and running in pre-programmed operational mode, ensuring the continuous production of consistent long-term data series.

Sentinel-1B is being readied to join Sentinel-1A in orbit early in 2016 on a Soyuz from French Guiana. AIT campaign activities continue at Thales Alenia Space Italy in Rome. The Synthetic Aperture Radar payload, developed by Airbus Defence & Space in Friedrichshafen, has been delivered to the satellite after a detailed test campaign that demonstrated excellent instrument performance.

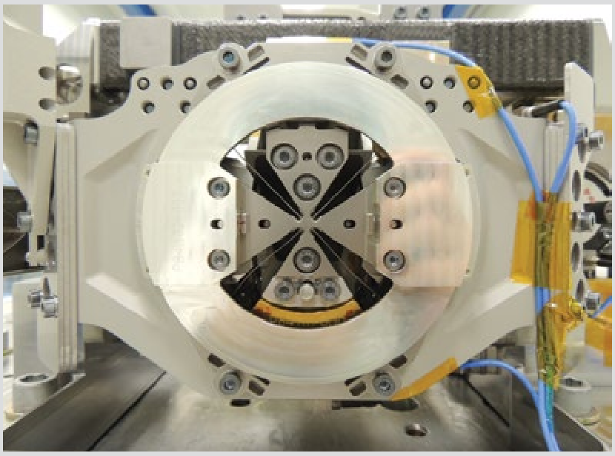
Procurement of the follow-on Sentinel-1C and -1D satellites is in progress, guaranteeing the continuation of the Sentinel-1 mission through the next decade.

Sentinel-2
Sentinel-2A was launched on a Vega from French Guiana on 23 June, concluding a flawless launch campaign. The Launch and Early Operations Phase was completed in three days and the first raw image was acquired on 27 June. All satellite

Sentinel-2 being prepared for launch on Vega vehicle VV05 in June



Sentinel-4 Optical Instrument Module mock-up (Airbus Defence & Space)



Sentinel-4 scanner mechanism structural breadboard (RUAG)

subsystems performed very well and in-orbit verification, calibration and validation was initiated.

Delivery of the second payload instrument FM by Airbus Defence & Space in France is expected in December. Ongoing Sentinel-2B integration and testing remain consistent with a launch in September-November 2016.

Sentinel-3

Sentinel-3A's AIT campaign is close to completion. The TB/TV test campaign concluded in May, with the satellite now undergoing post-environmental functional checks.

At instrument level, the calibration phase for SLSTR FM2 is completed, including instrument thermal qualification in vacuum. The instrument was delivered to the satellite prime contractor, to replace the 'uncalibrated' SLSTR currently installed on it. Some of the other payload instruments will undergo more retrofit and refurbishment to complete their flight readiness. The satellite's shipment to the Plesetsk launch site is set for the second half of September, for launch by a Rockot launch vehicle.

Sentinel-3B AIT has been put on hold, with priority given to the launch preparation of Sentinel-3A. However the Sentinel-3B platform is mostly integrated and, as soon as the AIT team return from the launch site, the integration of the Topography Payload onto the Sentinel-3B will take place. Procurement for the next set of satellites – Sentinel-3C and -3D – is proceeding. The industrial offer was received and evaluation began.

Sentinel-4

Manufacturing of the PFM of the telescope assembly mechanical parts continued and the verification campaign of the EM telescope to demonstrate its opto-mechanical performance will be completed in July.

Environmental testing of a structural breadboard of the scanner mechanism has been completed. Production of the raw panels for the instrument baffle and vanes of the STM of the Optical Instrument Module is complete and the cutting has begun. PDR and CDR processes for the subsystems progressed, with a system CDR planned to start in 2016.

Sentinel-5

ITTs for all the spectrometers, electronics and calibration units have been issued. The last flight instrument optical subsystem to be procured is the Telescope, Scrambler and Beamsplitter assembly.

The first optimisation of the instrument's optical assembly structure was performed and taken into account in preparation of the PDR analyses and documentation. The system PDR has begun with the Board meeting foreseen for 8 July.

Sentinel-5 Precursor

A fully calibrated/characterised and environmentally qualified TROPOMI payload was delivered in May, and integration with the Airbus Defence & Space AS250 platform in Stevenage is complete. Satellite SVT with ESOC took place in July. The satellite was then transported to Intespace Toulouse for a four-month environmental test campaign. Overall Ground Segment validation began in April and will continue until November.

Final Mission Analysis Review for the Rockot launcher took place in April. A launch window from mid-April to mid-July 2016 was confirmed by the launcher authority.

Meetings between NASA/NOAA and ESA on the in-flight tandem operation of Sentinel-5 Precursor and Suomi-NPP continue. An orbit definition Interface Control Document was agreed and an in-orbit control strategy document is in preparation.

Jason CS/Sentinel-6

Following the PDR, the satellite design is being consolidated, refining the specifications and analysis at all levels. Prototyping activities for the new Poseidon-4 digital architecture gave good results for securing the development of high-performance Application Specific Integrated Circuits (ASICs) at the heart of the altimeter.

Phase-C0 is ongoing, with the procurement of all elements of the system using ESA 'best practices' procedure; about 40% of the suppliers have been selected so far. The procedure should be nearing completion by the end of 2015.

The Jason CS/Sentinel-6 mission relies on three European partners: the European Commission through the Copernicus programme, ESA through the GSC-3 programme and Eumetsat. While the programmes of the other two are in force, Eumetsat's programme approval is expected at the end of the summer.

The industrial contract with Airbus Defence & Space Germany will then proceed through Phase-C1/D, including procurement of the Sentinel-6/Jason-CS recurrent model.

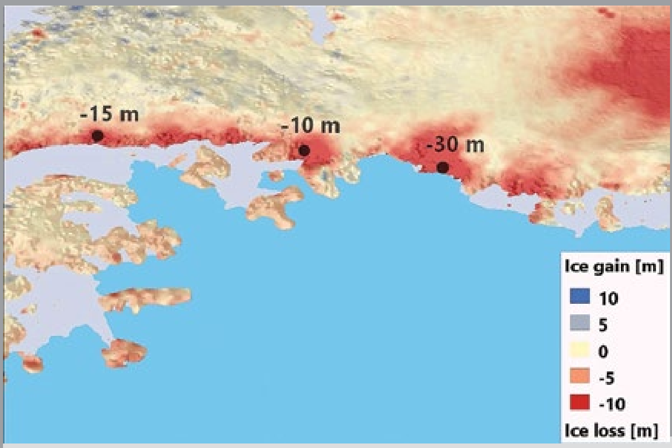
→ SMOS

SMOS has been in orbit for more than five years; thanks to its excellent technical and scientific status, the mission continues to operate beyond its nominal lifetime. Following a joint mission extension review with platform-operator CNES, SMOS mission operations have been extended to the end of the Earth Observation Envelope Programme 4 in 2017. All data have been available to the scientific community since 2010.

The radio frequency interference situation continues to improve, particularly over Europe. A second reprocessing of the entire SMOS dataset is currently ongoing. Reprocessed brightness temperature data became available in May, with reprocessed soil moisture and ocean salinity data becoming available in autumn. The second SMOS science conference took place in May at ESAC, see **http://www.smos2015.info** for details.

→ CRYOSAT

The mission continues to operate flawlessly after five years in orbit. All onboard systems are in good health, giving reasonable confidence that the mission could continue operations until 2020 at least.



Using CryoSat data, some areas of the Southern Antarctic Peninsula have been shown to have lost up to 30 m in ice since 2009 (Univ. Bristol)

The new CryoSat Operational Polar Monitoring system (**http://cpom.ucl.ac.uk/csopr**) run by the NERC Centre for Polar Observation and Modelling in the UK is now providing operational CryoSat polar products to scientific and operational organisations.

The latest findings by a University of Bristol team, published in *Science*, show a recent acceleration in ice loss in a previously stable region of the southern Antarctic Peninsula: With no sign of warning, in 2009 multiple glaciers suddenly began to shed ice into the ocean at a rate of about 60 cubic km per year. This makes the region one of the largest contributors to sea-level rise in Antarctica. Some glaciers along the coastal expanse are currently lowering by as much as 4 m annually.

→ SWARM

With the excellence of the science data from the three-satellite constellation, mission exploitation continues at a rapid pace. Scientific productivity is extremely high in all mission areas, ranging from the deep interior outer core via the mantle, lithosphere and crust, through to the thermosphere and magnetosphere. Swarm has meanwhile produced its initial field models in areas while also demonstrating beyond all doubt that its constellation approach is instrumental in the disentanglement and separation of the complex and dynamic contributors to the total magnetic and electric field measurements.

Constellation maintenance activities are proceeding very well, in particular keeping the lower pair at optimum operation for measurement of magnetic field gradients. This is especially relevant and important for achieving the best-possible estimate of all contributors to the total measured magnetic field.

Spring saw the release of the first official geophysical models following a period of validation activities. Likewise, in terms of external fields and geospace measurements, Swarm instruments continue to demonstrate their feasibility to detect current systems and ionospheric features, additionally underlining the high quality of mission data. This holds for both elements of the electric field instrument – the Langmuir probe and the thermal ion imager.

The mission's calibration/validation effort continues, with particular emphasis on detailed assessment of instrument data quality. As a direct result, significant improvement to all mission products have been achieved through lessons learned from onboard tests and/or processing algorithm evolution.

→ SMALLGEO

The satellite reached IABG Ottobrunn in February to begin its environmental test campaign. OHB, together with ESA and Hispasat, have prepared the campaign to close out the last non-conformances detected during the inspection stages of the satellite AIT. OHB also performed an antenna reflector installation and alignment dry-run completed satisfactorily and on time. Testing looked like to have been slowed down over the summer by the investigation and unavailability of the Solar Array Drive Mechanisms (SADMs), but the environmental test campaign should be back onto a normal path by the autumn, following the reintegration of the flight SADMs, for the satellite vibration test.

→ NEOSAT

A total of 36 predevelopments have been initiated with industry during Phase-B, preparing technologies for Neosat development. System PDRs were completed for both platform lines with Airbus Defence & Space and Thales Alenia Space in early 2015. The supplier selection process for the development of common and specific Neosat building blocks and procurement of their first flight tests is well advanced. Separate contracts are now being prepared with the two companies to develop respectively the Eurostar Neo and Spacebus Neo product lines, with their first flight applications to validate these new product lines in orbit.

→ QUANTUM

The public-private partnership contract for the pioneering 'software-programmable' Quantum payload was signed between ESA, Eutelsat and Airbus Defence & Space UK at ECSAT in Harwell in July. The payload will be supported by a new modular geostationary telecom platform from Surrey Satellite Technology Ltd that can scale up to 7 kW with a 450 kg payload, to be launched at the end of 2018.

→ EDRS

The EDRS-A payload is being embarked on the Eutelsat 9B satellite, planned for launch this year, along with the ASI Opportunity Payload (ASI OP) – providing Ku-band broadcasting services over Italy.

The satellite is in storage awaiting clearance for its shipment to Baikonur for a Proton launch at the end of the year – pending confirmation of the Proton launch manifest by the Failure Review Oversight Board held after the May Proton failure.

The EDRS-C payload including a second LCT will be launched into its 31°E geostationary slot on a dedicated satellite in the first half of 2017. Built by OHB and based on the SmallGEO platform, it will also embark Avanti's Hylas-4 as a 'hosted payload'.

EDRS-C's satellite CDR was completed in June, providing the formal go-ahead for the satellite's FM AIT activities to start. The EDRS-C CRD will follow in the first half of 2016, ensuring the satellite's consistency with the ground segment to verify overall mission performance.

The first flight hardware elements have been delivered with flight hardware AIT underway at several sites in parallel: integration of the Core Platform Module has begun at OHB in Bremen; Propulsion Module assembly started at Avio in Italy; the EDRS-C payload is being integrated on its dedicated repeater panel at payload prime contractor TESAT and Avanti's Hylas-3 hosted payload is being assembled on its own repeater panel at MDA in Canada.

All EDRS ground segment hardware is being manufactured, while the stations in Weilheim, Redu and Harwell are deployed and undergoing their acceptance test campaigns.

→ ARIANE 6

The industrial proposal was received in May. Negotiations are still ongoing. The PDR took place in June. The contract signing with Airbus Safran Launchers is expected in August.

Industrial activities are ongoing with the review of several trade-offs, in particularly in terms of the launcher integration scenario (horizontal versus vertical). No final decision was taken, but a 'full horizontal' rupture scenario will be studied. A comparable decision on the Lower Liquid Propulsion Module integration is being considered. Trade-off studies are also ongoing for the Upper Liquid Propulsion Module in terms of diameter and tanks architecture, as well as for the Upper Part considering a 5.4-m mono-diameter launcher configuration. The second Design Analysis Cycle DAC-2 took place in July.

Stefano Bianchi, Head of ESA Launchers Development Department, during the 'Ariane 6 Industrial Day' conference, at the Paris Air and Space Show, Le Bourget, on 16 June

The Ariane 6 Launch Base Request for Quotation was received in May and the contract should be signed in June. The 'Sécurité et Protection de la Santé' contract negotiation is ongoing. The Launch Base industrial activities will cover the earthworks, which commence in August, and subsystems such as Mechanical, Control Benches, Fluids, Low Current and Safety, Optic and Video and Launch Range Adaption.

On the system architecture, a procurement proposal for the P5.2 Bench was approved during June's IPC with a fourth Authorisation To Proceed to be placed to extend activities until December. For system engineering and the Requirements Key Point, the opening meeting and collocation were performed. Launch System Level-0 documentation was released.

→ VEGA

The Vega-C Authorisation to Proceed is finalised. The P120 Solid Rocket Motor (SRM) and Thrust Vector Control activities are covered by Ariane 6 Launch System and Vega-C Authorisations to Proceed. Proposals for the BEAP test stand adaptations were received in May. Industrial activities are ongoing, with the SRM PDR planned for July.

→ FUTURE LAUNCHERS PREPARATORY PROGRAMME

On the system side, the Propulsion and Launcher System RFQ is being prepared. The proposal for rider 1 of the Expander Technology Integrated Demonstrator-1 is expected in August. The POD-X CDR was held on 27 May.

The Cryotank Demonstrator with Sandwich Common Bulkhead was tested in cryogenic conditions at CSL in Belgium, confirming its excellent mechanical and thermal performance. An innovative metallic cryotank manufacturing technology is being tested with NASA on a sounding rocket in September.

The Composite Booster-casing Demonstrator CDR was completed. The Deorbitation Observation Capsule PDR was held in June, while the first series of Hexapod Sloshing tests were performed in Bremen with DLR support.

→ HUMAN SPACEFLIGHT

ISS

ESA astronaut Samantha Cristoforetti's Futura mission ended on 11 June with the landing of Soyuz TMA-15M in Kazakhstan, together with Terry Virts (NASA) and Anton Shkaplerov (Roscosmos). Having spent 199 consecutive days in space, Samantha set new records for the longest time in space for an ESA astronaut and for a female astronaut.

During her flight, Samantha performed countermeasure exercise training, involving intense daily use of the Advanced Resistive Exercise Device, the treadmill and the cycle ergometer – the first time that countermeasure exercise data for a female European astronaut was collected. Directly after landing Samantha completed a three-week daily reconditioning programme at NASA's Johnson Space Center including physiotherapy and exercise sessions.

The sixth commercial flight of SpaceX's Dragon to the ISS took place from April to June, though the follow-on seventh flight suffered a launch failure, now under investigation. Progress 59P suffered its own launch failure in April, though Progress 60P was scheduled for launch to ISS on 3 July.

Soyuz launches to ISS were rescheduled as a result of the Progress 59P loss. The Soyuz TMA-17M launch, with ESA's Tim Peake on the backup crew, was delayed from May to July, while his own launch, TMA-19M, was delayed from November to December.

Astronauts

Preparations for the direct return of ESA astronaut Andreas Mogensen from Kazakhstan to EAC were progressing; because a business jet instead of a fully equipped ambulance jet was to be used, the Space Medicine Office is organising medical equipment and contingency medical support.

Andreas, along with his backup Thomas Pesquet, started final preparations at Star City for the upcoming Soyuz TMA-18M launch including seat-liner fit checks and emergency training. Tim Peake was fully qualified as TMA-17M backup and has now begun final preparation for the TMA-19M launch. Thomas achieved crew qualification as JEM Core Systems and Robotics specialist.

ESA astronaut Samantha Cristoforetti enjoying the view on her 200th day in space on the International Space Station (NASA/ESA)

Samantha Cristoforetti seen here after her Soyuz capsule landed on 11 June 2015 in the Kazakh steppe after a three-hour journey back from the International Space Station

→ ATV

Decommissioning of the ATV Control Centre continues, along with the archiving of ATV mission data and knowhow transfer. The LIRIS experiment database was delivered to ESA, including all results and images, processed together with ATV mission timeline/telemetry – the last milestone of the LIRIS experiment. The Proximity Communication Equipment stored aboard the Russian segment of ISS was trashed with Progress 57P, with contract close-out activities ongoing.

The SpaceX CRX-6 Dragon seen berthed to ISS on 20 April (ESA/NASA)

Samantha Cristoforetti enjoys her first drink from the new ISSpresso machine on the Space Station. The espresso device allows crews to make tea, coffee, broth or other hot beverages (NASA)

Samantha Cristoforetti installing the TripleLux-A science experiment in April (NASA)

Multi-Purpose Crew Vehicle/European Service Module

The system CDR is planned for December. STM manufacturing and testing is on schedule for shipment to NASA's Plumbrook test site in October. Delivery of FM-1 to NASA's Kennedy Space Center on 29 January 2017 remains challenging.

Exploitation

A bilaterial meeting was held with NASA in April on ISS Exploitation, during which a Technical Understanding for MPCV FM1/FM2 was signed, with agreement on the transportation rollover for 2020–24, the balance of the accumulated up/download use versus ATV credit.

RESEARCH

European research on the ISS

The European ISS utilisation programme reached a conclusion for the Futura mission, and has been continuing with the assistance of Expedition 44 crew members. Highlights up to 30 June include:

Samantha Cristoforetti completed her final sessions as a test subject for the Circardian Rhythms and Skin-B experiments, respectively studying alterations in circadian rhythms in orbit and helping to develop a mathematical model of ageing skin and other body tissues, improving our understanding of skin-ageing mechanisms, which are accelerated in weightlessness.

After the conclusion of the TripleLux-B experiment at the end of March, the follow-up TripleLux-A was launched to the ISS in April, undertaken in the Biolab facility in Columbus from the end of April to mid-May. These two experiments are comparing mechanisms causing impairment in weightless immune systems.

Between these two TripleLux experiments, the Stem Cell Differentiation experiment was performed on one of ESA's Kubik incubators, with samples from the two-week experiment returned on Soyuz TMA-15M in June. The aim is to examine the effects of the space environment on human Mesenchymal Stem Cells, which play an important role in bone maintenance – relevant for counteracting bone loss in both astronauts and old people.

Activities began in the Electromagnetic Levitator (EML) – a key element of ESA's ISS materials research – performing melting and solidification of electrically conductive samples under ultra-high vacuum and/or high gas purity. Samples were processed for three of the five first batch experiments during the Futura mission.

The Plasma Kristall-4 experiment was installed inside the European Physiology Modules rack, undergoing experiment commissioning at the start of June, including reference experiment runs with neon and argon. Data hard disks were returned for analysis on Soyuz TMA-15M, investigating complex or 'dusty' plasmas containing micro-particles as well as charged gases.

Solar and radiation research continued within the SOLAR facility, which completed three data acquisition periods in April, May and June, and the Dose Distribution inside the ISS 3D experiment which continuously acquired data on the internal Columbus radiation environment. The Expose-R2 payload continued astrobiology research on the external survivability of biological samples.

The first two parabolic flight campaigns with the new A310 aircraft took place at the end of April through to June. The first was a joint flight campaign with CNES and DLR with 12 experiments, the second was the 62nd ESA campaign, including 12 experiments in the areas of life and physical sciences (five of them being reflights from the previous campaign).

→ EXPLORATION

International Berthing Docking Mechanism (IBDM)

A task force was set up with participating Member States – Belgium, Italy, Spain and Switzerland – to define programmatic aspect of ESA's cooperation with the Sierra Nevada Corporation (SNC) for supplying the IBDM to the Dream Chaser vehicle. Two negotiation meetings were held with SNC during June to define the funding and industrial activity aspects, in time for SNC to send their final proposal to NASA for the ISS cargo resupply services contract (CRS-2) using IBDM as a docking system. The ESA/SNC draft cooperation agreement was submitted to the IPC as an information document.

The refitted Airbus A310 Zero-G aircraft takes off on a testflight for parabolic flight research in May

As a result of the agreement with NASA for the standardisation of docking systems, the results of testing performed at the Johnson Space Center were discussed and documentation on the respective docking systems exchanged with NASA.

Operational Avionics Subsystem (OAS)

Work on the development of a representative crew transportation cockpit continued in Europe while a team from SAS in Belgium cooperated with SNC on software and hardware aspects of Dream Chaser. Energia and Roscomos confirmed their interest in performing an ISS-based experiment to validate the Individual Crew Aids heads-up display in support of crew operations.

Multi-Purpose End-to-End Robotic Operations Network (Meteron)

The Meteron project continued with Haptics-2, representing the very first space-to-ground bilateral control experiment with force feedback: an ESTEC-based joystick directly copied any motion/force exerted on a linked Columbus joystick and vice versa.

Lunar exploration

The procurement proposal for the Phase-B+ of the PILOT (Precise and safe landing) and PROSPECT (drilling and sample analysis) were prepared, needing to be initiated as soon as possible in order to provide reliable inputs before the next Ministerial Council in 2016. Progress with the Russian partners regarding definition of technical interfaces and finalisation of the complementary agreement is continuing. Two parallel contracts for the mission assessment study for Lunar Polar Sample Return were awarded.

International cooperation

An EAC delegation (training, medical) met with the Astronaut Centre of China in Beijing in April, at the same time as meetings were held with the Chinese Manned Space Agency related to utilisation and infrastructure.

Space exploration strategy

ESA chaired the International Space Exploration Coordination Group (ISECG) workshop in Pasadena in April, where a medium-term international human exploration mission scenario was advanced, as well as the approach for engaging the global science community in implementing the ISECG Global Exploration Roadmap.

More than 55 ideas were received in response to the Call for Ideas (CFI) on 'Space Exploration as a Driver for Economic Growth' and an ESA expert panel began to review ideas. ESA held a well-attended information day on the CFI in April. A workshop on Partners for Space Exploration was held in July with representatives from industry, national space agencies and ISS international partners.

→ SPACE SITUATIONAL AWARENESS

Space Surveillance & Tracking (SST)

Operations of the monostatic breadboard radar were handed over to the Spanish Ministry of Defence in a ceremony on 25 June. ESA retains ownership and the right to access the radar for the execution of its SST test and validation campaigns.

Space Weather (SWE)

Three new services and one new service provider were introduced in the SSA SWE at the start of June. Athens Effective Solar Flare Forecasting (A-EFFort) is a 24-hour forecasting service for major solar flares. Service Supporting Resource Exploitation System Operators (RESOSS) is a tailored geomagnetic and ionospheric service to support resource exploitation. Aviation Dosimetry (AVIDOS) 2.0 is an upgrade of the existing AVIDOS application integrated into the SSA SWE system during its first phase, with major solar particle Ground Level Events being taken into account in estimating the radiation dose at commercial aviation flight altitudes. All SSA SWE services are available for registered users at **http://swe.ssa.esa.int**

Implementation activities for two hosted payload mission for space weather instruments continued. Development of the Next Generation Radiation Monitor FM for EDRS-C is close to finalisation, and expected to be delivered to ESA in September. Development of the Service Oriented Spacecraft Magnetometer Set for the Korean Space Environment Monitor instrument package for the GEO-KOMPSAT2 meteorological satellite continued.

Near Earth Objects (NEOs)

The monthly NEOs newsletter has become a regular activity, available for subscription at neocc@ssa.esa.int. In June, ESOC hosted a workshop with national emergency agencies to discuss reactions to an asteroid impact threat. This was the second workshop helping ESA to define an information strategy in this area, with six countries represented – UK, Denmark, Switzerland, Luxembourg, Romania and Sweden.

Development of support tools for NEO front-desk operators has begun. These tools will include, among others, visualisations of potential impact ground tracks and star maps showing asteroids in the sky.

Harald Posch (1995-2015)

On 21 May 2015, former Chair of the ESA Council Harald Posch passed away in Wiener Neustadt, Austria, at the age of 60.

His death left an immense void and was a tremendous loss to his family, to ESA and the European space community. His contribution to Europe's efforts in space cannot be overstated. He was a great servant of ESA, of European space and, of course, of his homeland Austria.

Mr Posch's career in the space sector spanned more than three decades, first in industry with Austrian Aerospace and Österreichische Raumfahrt- und Systemtechnik GmbH, then in governmental service. Since 2005, he led Austria's Aeronautics and Space Agency, part of the Research Promotion Agency (FFG). In this role, he was key in shaping Austria's engagement in space and represented his country in international forums and organisations. His natural authority, humility, integrity combined with a keen intelligence and a friendly sense of humour, allowed him to always rally support. Under his leadership, solidarity and common interest always won over divergences and uncertainty.

Within ESA, too, Mr Posch held the most prominent of roles, in particular those of Industrial Policy Committee Chair and, from 1 July 2014, Chair of Council. In this latter function, he played a central role in the preparation of the Council meeting at ministerial level held in Luxembourg. He was also instrumental in the setting up of the European Space Policy Institute (ESPI) in Vienna, and served as Chair of its General Assembly since its inception.

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