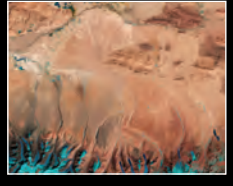
Summer 2016 issue 46

space:uk

Return to Earth

Satellite data challenge



Principia science success

The UK on Mars

UK SPACE AGENCY

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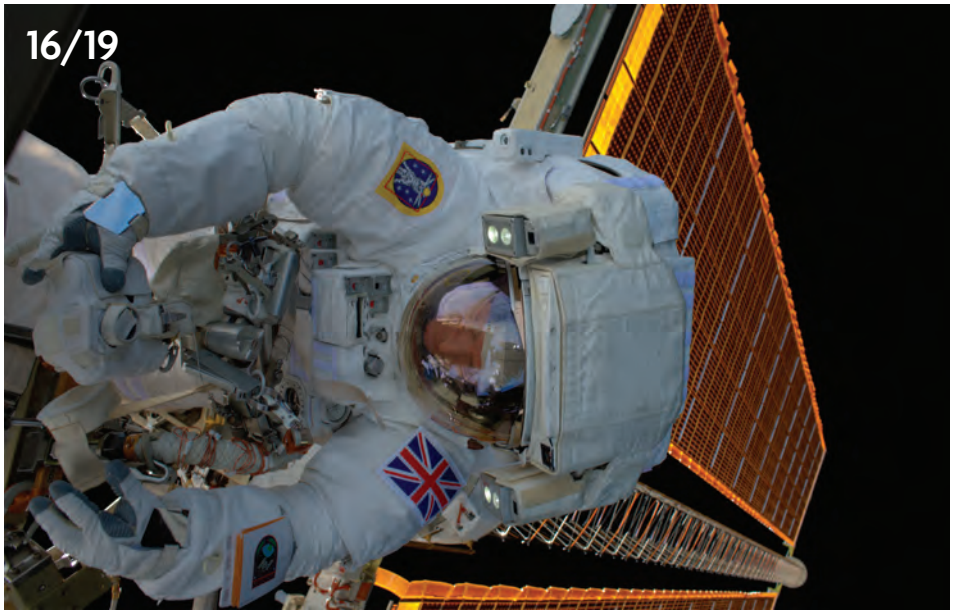

Front cover image Tim Peake's charred Soyuz capsule landed on its side in Kazakhstan after a fiery descent through the atmosphere **Credit:** ESA, Stephane Corvaja

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Welcome home Tim:

The Soyuz has landed **Credit:** NASA, Bill Ingalls

Tim shortly after landing **Credit:** ESA, Stephane Corvaja

British European Space Agency (ESA) astronaut Tim Peake's Principia expedition to the International Space Station (ISS) came to an end on 18 June, with the landing of his spacecraft in Kazakhstan.

"Incredible!" said Tim Peake, describing his descent to Earth in a Soyuz capsule after 186 days on the ISS. Some astronauts have likened the experience to going over Niagara Falls in a flaming barrel. Peake, however, described it as: "The best ride I've been on, ever."

Tim's ride home, seen here attached to the ISS **Credit:** ESA, NASA

Down to Earth

Peake's return flight to Earth was one of the most dangerous parts of his mission. Strapped in next to Russian commander Yuri Malenchenko and NASA astronaut Tim Kopra, the crew had undocked from the ISS some three and a half hours earlier. After moving slowly from the ISS, they fired thrusters to take them out of orbit on a trajectory towards Earth.

The descent capsule separated from the orbital sections of the spacecraft and entered the atmosphere at some 28,000 km/h. The module's heat shield is tilted towards the direction of re-entry so that it can handle temperatures of up to 1600°C generated by friction as it pushes through atmospheric gases. This is a bumpy and uncomfortable ride for the astronauts – who are forced back into their seats by g-forces of four to five times Earth's gravity.

Ten kilometres above the ground, the spacecraft has already slowed considerably and parachutes open for the final descent to Earth. Just before the capsule hits the Earth, retrorockets fire to reduce the impact speed to 5 km/h. This is still quite a jolt for the astronauts on board, who have spent six months in a weightless environment.

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After being helped out of the spacecraft, the British astronaut's joy at being back on Earth was clear. "The smells of Earth are so strong," he said. "It's wonderful to be back in the fresh air."

Dripping with sweat in his spacesuit, he told waiting reporters he was looking forward to seeing his family and was hoping for "a pizza and cold beer". He was, though, going to miss the view of the Earth from space and couldn't wait to go back.

After being checked out by doctors, Peake boarded a flight to the European Astronaut Centre at Cologne in Germany where he was re-united with his family.

Although Peake's time in space is over (for now at least), this is by no means the end of his mission. The astronaut will spend the coming months taking part in debriefs about the flight.

He will also undergo medical tests and rehabilitation training to see how his body has been affected by his time in space.

It can take astronauts up to a year to regain their full fitness after six months in microgravity. Studies into the effects of spaceflight are crucial if humans are ever to venture further from Earth on long duration missions to destinations such as Mars.

Meet the media

Three days after landing, a refreshed-looking Peake appeared in front of a packed press conference in Cologne to be greeted by cheers from friends, colleagues and the media.

"I would do it again in a heartbeat," Peake said of his mission.

Peake even enjoyed the ride from the landing site **Credit:** NASA, Bill Ingalls

Checking that he still fits in his seat in the Soyuz **Credit:** ESA, NASA

"Working and living on board the International Space Station is the best place you could wish to be," he said. "You're very aware you're doing absolutely cutting edge technology."

During the press conference he urged the UK to continue its contribution to human spaceflight, decisions that will be taken at the forthcoming ESA Ministerial meeting later this year.

"We certainly need to be inspiring those young minds," he said, "to show them that you can be an astronaut, you can join the European Space Agency and you can go to the Moon."

Peake was also asked whether he ever had time on the ISS to reflect about his position high above the Earth. "You have to make time to dream – to be aware of your situation," he said. "As human beings we normalise everything in order to be able to function and the first thing you do on the space station is to make it normal."

"You get up in the morning, you make a cup of tea, have a bacon sandwich and go to work," he said. "And it's normal but you need to make time to just sit in the Cupola and look out and reflect on your position and enjoy it."

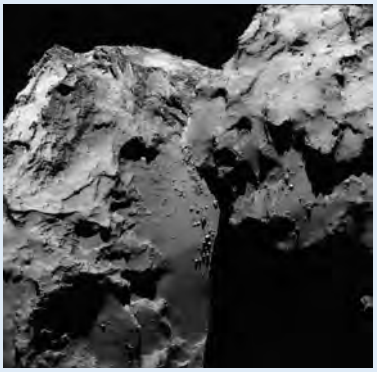
Peake was joined at the event by ESA's Director of Human Spaceflight and Robotic Exploration (and former head of the UK Space Agency), David Parker. "Of all the space activities, exploration is the one that's most exciting," said Parker. "It's driven by a combination of curiosity and opportunity – the curiosity to go out there and discover and the opportunity to bring back to planet Earth discoveries that have a value to us."

Most of Peake's time in space was spent tending to many of the 250 or so experiments being carried out in the orbiting laboratory. He also took part in an extensive education and outreach programme, captured incredible views of Earth, participated in a food experiment with chef Heston Blumenthal and presented a Brit award to Adele.

With so many mission highlights to choose from, Peake said that the spacewalk he carried out, to replace a failed power unit, would be "etched in my memory forever."

Rosetta closes in

This image of comet 67P was taken in June
Credit: NASA

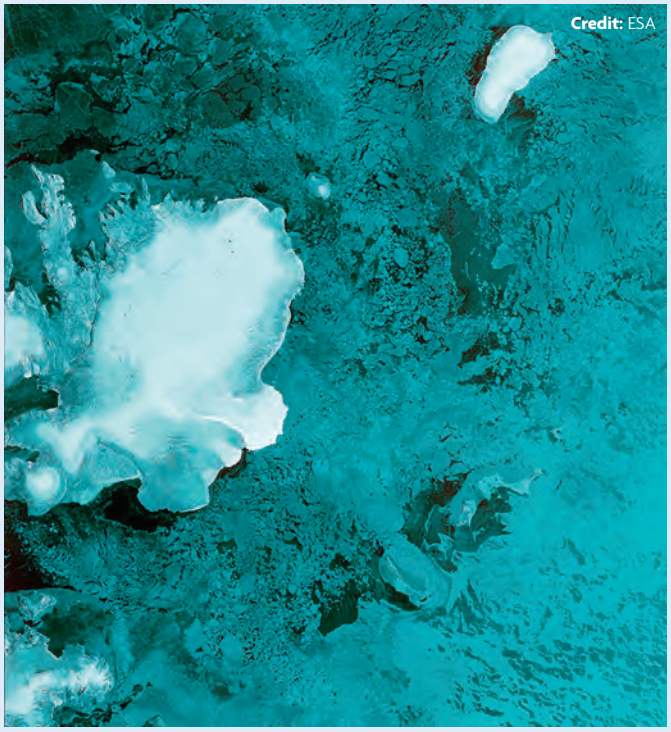


The end of its mission may be in sight, but Rosetta is continuing to release new science and break records – after flying an orbit a mere five kilometres from the surface of comet 67P/ Churyumov-Gerasimenko.

The mission has now detected the noble gases xenon and krypton, as well as most of their isotopes. It has also found phosphorous and has made repeated confirmed detections of the amino acid, glycine. These findings are essential to understanding the history of how the Solar System formed and the origins of life.

Rosetta has been orbiting comet 67P for almost two years, as the comet approached, encountered and moved away from the Sun. Before it spirals down to the comet on 30 September, the spacecraft will enter an elliptical orbit, possibly reaching as close as one kilometre from the surface.

Fourth Sentinel joins the fleet



Europe's latest Earth observation satellite, Sentinel-1B, has taken its place in orbit after a successful 25 April launch on a Soyuz rocket from French Guiana.

The satellite forms part of Copernicus – the comprehensive European Earth observation program – and carries a C-band synthetic aperture radar, which can capture images of the Earth's surface in all weather conditions.

Sentinel-1B returned its first picture (above) just two hours after its radar was switched on – a new record. It shows the archipelago of Svalbard in the Arctic. The satellite will operate in tandem with Sentinel-1A, which orbits in the same plane but on the opposite side of the Earth.

UK wins Biomass contract

A major contract to build an ESA mission to monitor the extent of plant life, or biomass, across the planet and how it changes over time has been awarded to Airbus Defence and Space in the UK. The appropriately-named Biomass mission is scheduled for launch in 2021 and will be the seventh of ESA's Earth Explorer satellites designed to investigate our planet's environment.

"Biomass is a revolutionary mission," said UK Universities and Science Minister Jo Johnson, "helping us better understand our planet's carbon cycle to help tackle climate change."

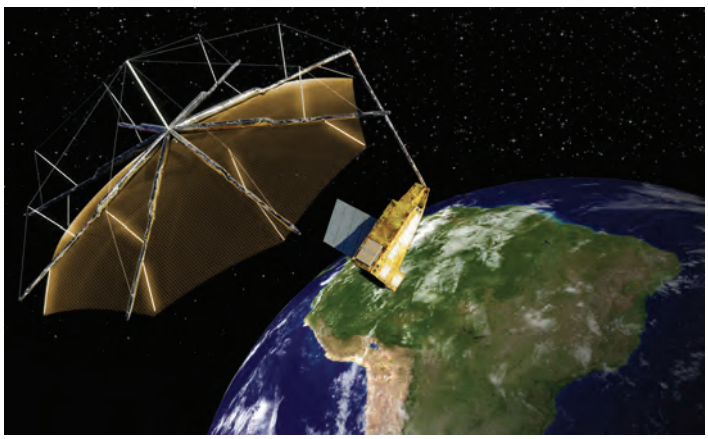
"It is our membership of ESA and our reputation for science and innovation that enables UK industry to win major satellite manufacturing contracts such as this one, creating jobs around the country," added the Minister.

Biomass will be fitted with a radar instrument enabling it to see through foliage to the vegetation below. This will give a measurement of forest density as well as its height. The radar is based on technology developed by Airbus Defence and Space for previous satellites.

The satellite will produce extremely accurate data on the extent of global plant life, information that cannot be obtained from ground-based observations alone. By mapping the entire planet every six months, Biomass will be able to track annual changes in the mass of vegetation growing above ground.

Beyond its contribution to improving our understanding of the carbon cycle and the effects of climate change, Biomass will support United Nations treaties such as the Reduction of Emissions due to Deforestation and Forest Degradation (REDD+). It will also provide information on geology in arid regions, permafrost, glaciers and ice sheets.

"Collecting accurate data on the world's biomass is key to our understanding of the climate," said Airbus' Head of Space Systems, François Auque. "We are very pleased to help ESA with this mission that will provide key data for scientists around the world."



An artist's impression of the Biomass satellite **Credit:** Airbus Defence and Space

Success for gravity mission

The LISA Pathfinder mission launched in December 2015 and has been testing the technology required to detect and measure gravitational waves in space since March. First predicted by Einstein a hundred years ago, these ripples in space-time pass through matter and produce minute changes – around a millionth of the size of an atom – making them extremely difficult to find.

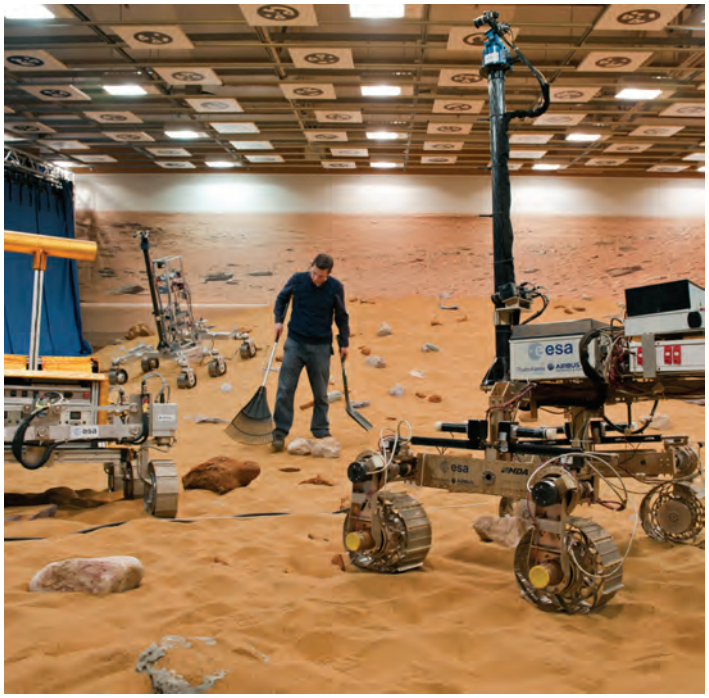
A ground-based detector, LIGO, recently measured gravitational waves directly for the first time. These ripples had relatively high frequencies but, because gravitational waves cover a wider range of frequencies, a space observatory could detect waves whose frequencies are a million times smaller. These low frequency gravitational waves are produced by extremely large moving objects in space, such as two galaxies merging.

LISA Pathfinder contains two 46cm gold-platinum cubes in free-fall, shielded from all external forces except gravity. The mission not only confirmed the technology, it proved that the relative movements of these test masses can be tracked by lasers to an accuracy of less than the width of a hydrogen atom.

Teams from the universities of Glasgow, Birmingham and Imperial College London developed much of the science technology at the heart of LISA Pathfinder. Most of the spacecraft itself was built in the UK by Airbus Defence and Space with SciSys Limited developing the onboard software.

LISA Pathfinder being prepared for launch **Credit:** ESA

Mars delay



Sweeping up after the test rovers in the Stevenage Mars yard
Credit: Airbus Defence and Space

The launch of the second ExoMars mission, which will carry a European rover to Mars, has been moved from 2018 to 2020.

The joint ESA and Russian space agency mission has slipped as a result of equipment delays from Russia and Europe. ESA Director General, Jan Woerner, has expressed his frustration as the delay will mean increased costs. "For me it is very important that we first find out about the money and who we might ask for more money and is there some possibility of reducing the amount," said Woerner. "We are not at a time when money is printed easily."

The first ExoMars mission launched in March and will arrive at Mars in October. It consists of the Trace Gas Orbiter to study the planet's atmosphere and the Schiaparelli lander, which will demonstrate key landing technologies for the follow-up mission. UK scientists and engineers are playing key roles in both ExoMars missions.

Airbus Defence and Space is building the rover for ExoMars 2020 in the UK and a new £2.5m STEM centre in Stevenage will take educational advantage of the company's ExoMars Rover test facility, or Mars Yard. The centre, which will be operated with North Hertfordshire College, aims to attract more than 5,000 students a year and is due to be completed by December.

Site Director of the Airbus site, Andy Stroomer, said: "By investing in this centre and making the most of the Mars yard test area we hope to encourage students to follow science and engineering careers in the growing space industry and the wider industrial community."

Galileo is go

Europe's ambitious Galileo navigation system is on track to begin operation later this year, following the May launch of two more satellites and the delivery by Surrey Satellite Technology Limited (SSTL) of the last of 22 navigation payloads that are at the heart of each Galileo spacecraft.

The early morning launch of the latest Galileo satellites **Credit:** ESA, Arianespace

The 13th and 14th members of the planned 24-satellite Galileo constellation lifted off together on a Soyuz rocket from Kourou, French Guiana. The twin craft was boosted into orbit at about 23,000 km altitude, and is currently in a testing phase before their scheduled promotion to the working fleet later this year.

"Today's launch brings Europe's Galileo constellation halfway to completion, in terms of numbers," said ESA's Director of the Galileo Programme, Paul Verhoef.

Back on Earth, the job of building the large fleet of satellites (24 operational plus 6 in-orbit spares) is coming to an end with the delivery of the last Galileo navigation payload by SSTL to the German company responsible for assembling the satellites, OHB Systems in Bremen. These modules contain each satellite's navigation, positioning and timing services.

SSTL has produced one payload every six weeks since the first was delivered in 2012 – almost mass production by space industry standards. "It takes approximately five months to build and test each payload, so SSTL used three bays in the cleanroom simultaneously to achieve this fast rate," said SSTL's Head of Navigation, Gary Lay. "Each bay has its own test equipment, dedicated engineering team and a 'payload captain' to lead it."

SSTL will remain involved in the Galileo program, providing support for satellite testing and maintenance of the operational constellation. "We currently have 10 payloads in space and we have a sizeable team that supports operations," said Lay.

Although Galileo does essentially the same thing as the American Global Positioning System (GPS), it offers better accuracy and its deployment ensures that Europe will not rely on a US military system to deliver the location-based services that are now part of our daily lives. These will become even more important as technologies such as self-driving cars evolve. Critical to this accuracy are high-precision atomic clocks which lose less than 1 second every million years.

"I must pay tribute to the talented and dedicated team here who have worked tirelessly to keep the production line rolling for the past four years," said John Paffett, SSTL's Director of Telecommunications and Navigation. "We are extremely proud of our contribution to Europe's new navigation system, and we are all looking forward to the day the service comes on stream."

A message from Katherine Courtney, interim CEO of the UK Space Agency


Credit: UK Space Agency

I've had a fascinating start to my time with the UK Space Agency. From witnessing the signature of a major ESA earth observation contract for UK industry to watching Tim Peake carry out a trial of remote manoeuvring of the Mars Rover from the ISS, the past months have been a real eye-opener about the success story of the UK in space.

We have an exciting year ahead, full of opportunities. The outcome of the recent Referendum on the UK's membership in the European Union has created some new challenges, but the UK space sector will continue to thrive. Space is a global business and the UK's strong position in the global space sector is not dependent on EU membership. While Britain renegotiates its relationship with the EU, we can look to our collaboration with ESA as an example of how the UK will continue to work internationally.

My priorities are focused on continuing our government's active engagement in the sector, and working with you to continue to drive growth towards our shared target of 10%, worth £40bn to the UK economy, of the global space market by 2030, including:

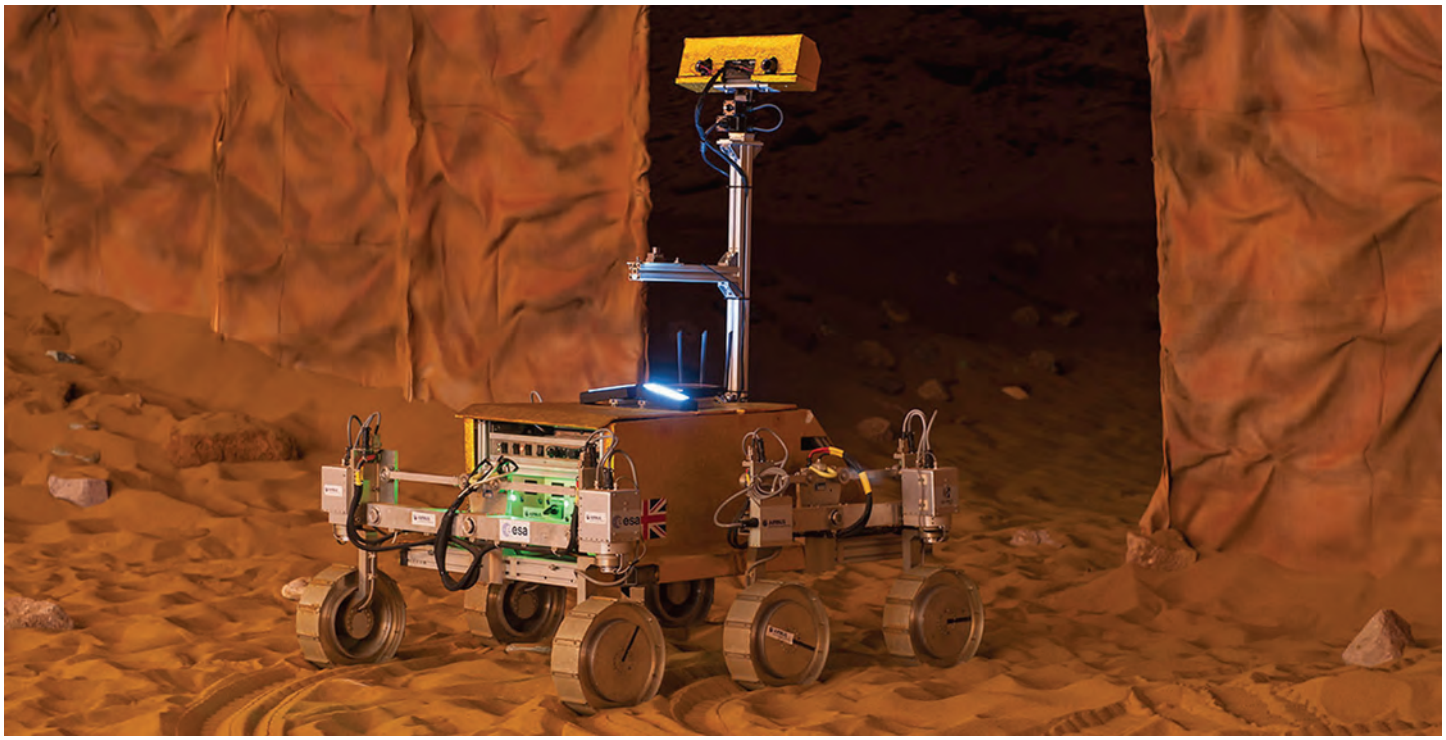
- ESA's Council of Ministers in December - This is a top priority for the Agency this year, as we firm up our investment plans for the next five years. We want to secure the best benefit for UK industry while continuing to support our world-class research institutions.

- Commercial satellite launch and spaceflight - Having made a strong declaration of strategic intent to develop a UK launch capability, we intend to take a big leap forward towards realising that ambition.

- Joining up across government to promote growth in the space sector through the 'Science is GREAT' campaign, encouraging innovation in downstream applications and looking for opportunities for space to better connect across sectors and drive economic growth.

- Continuing the momentum generated by Tim Peake's Principia mission to the ISS. Thanks to excellent work by our teams in the Agency and in ESA, Tim's mission has fired the public's imagination and put UKSA on the map. The £3m STEM outreach programme, which ran alongside Tim's mission, has seen young people in particular engage in space in a new way. I'd like to see that same level of excitement and interest for all of our missions.

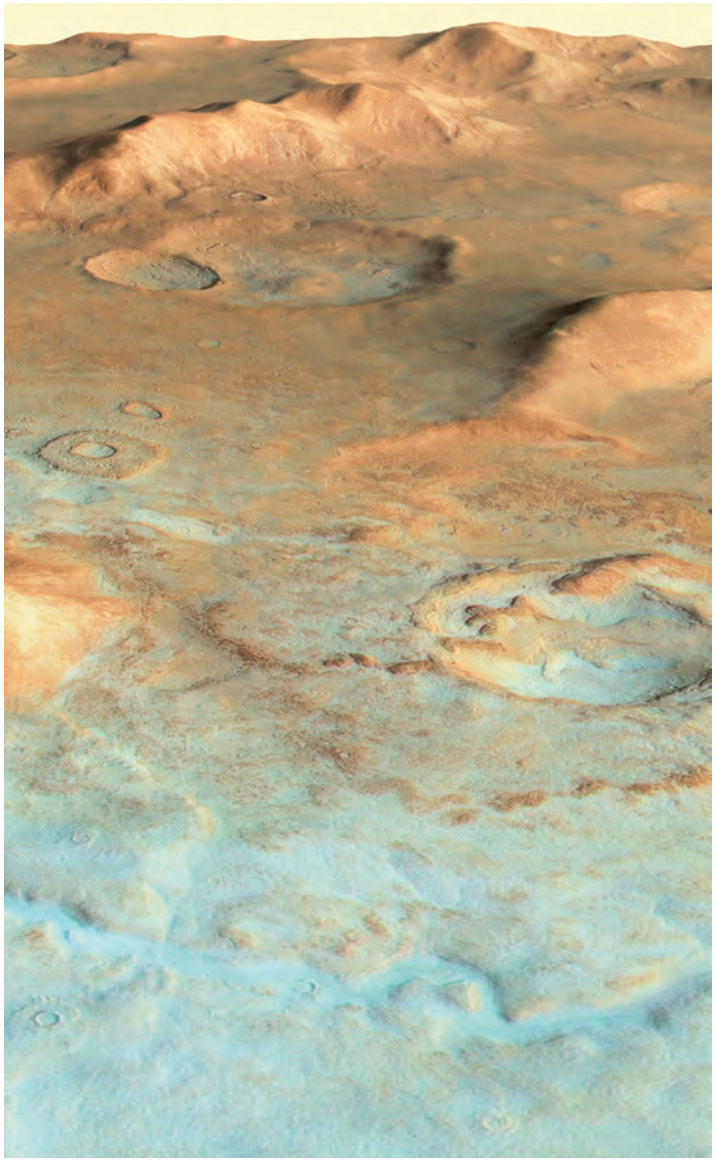
This next year will be a landmark year, shaping the future of the UK in space. The UK Space Agency will continue to work to secure the UK's position in this thriving global market, making connections and promoting successful partnerships across sectors and borders.


METERON experiment **Credit:** UK Space Agency, Max Alexander

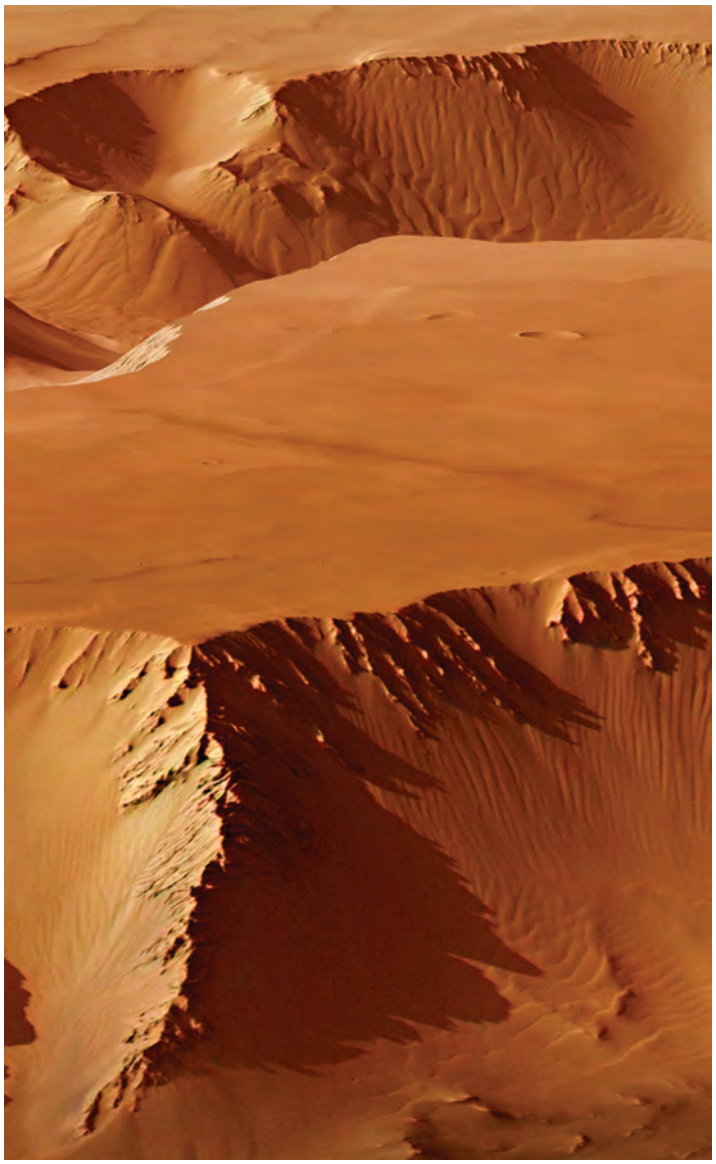
Missions to Mars

From Mars Express and Beagle-2 to Curiosity and ExoMars, UK scientists and engineers continue to play a leading role in missions to the red planet.

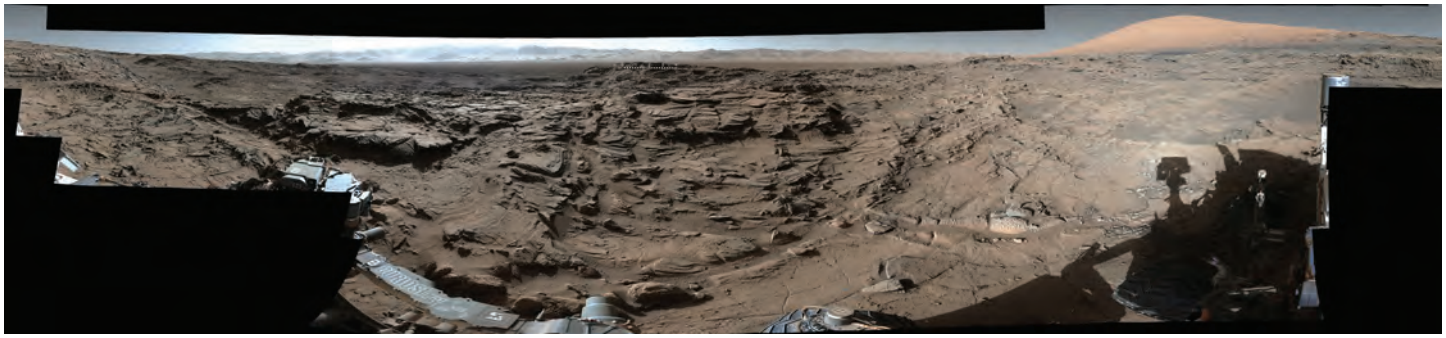
Future missions will investigate signs of life and the next generation of Mars rovers is being developed in the UK. One day astronauts could orbit the planet to control robots on the surface and, in time, we may even take our first steps on this barren, dusty world.



This Mars Express image shows the frost-covered Hellas Basin in the southern hemisphere of Mars. In orbit since 2003, Mars Express was ESA's first mission to Mars and included British-built lander Beagle-2. Although Beagle-2 never contacted Earth from the Martian surface, recent images prove it landed successfully and began to deploy its solar arrays **Credit:** ESA, DLR



Another spectacular view from Mars Express showing a portion of the 5km deep Noctis Labyrinthus or Labyrinth of the Night **Credit:** ESA, DLR



Meanwhile, on the surface, NASA's Curiosity rover continues to send back spectacular images, including this panorama. Several UK scientists are involved in this high-profile mission **Credit:** NASA

Europe's latest mission to Mars, ExoMars 2016, blasts off the pad on a Proton rocket from Baikonur. The spacecraft, arriving at Mars in October, consists of an orbiter and lander. A science team from the UK's Open University is among those working on the mission
Credit: Roscosmos

The next ExoMars spacecraft – now due for launch in 2020 – will include a rover being led from the UK. A prototype Mars rover at Airbus in Stevenage was recently controlled from the International Space Station by Tim Peake
Credit: Airbus Defence and Space

UK science on the ISS

The microgravity environment of low Earth orbit provides a unique platform for science **Credit:** ESA

British European Space Agency (ESA) astronaut Tim Peake has spent six months conducting science experiments on the International Space Station (ISS). Stuart Clark reports on the scientific achievements of the Principia mission and looks forward to future UK science in orbit:

We all have days when we have to squeeze as much out of our working time as we can. For Tim Peake on the ISS, that day has been every day. During his six months on the station, he has conducted over 100 experiments. Out of these, between 30 and 40 of them are for ESA. During his Principia mission, Peake has helped measure brain pressure in his fellow astronauts, taken care of bacteria exposed to the vacuum of space, and driven a prototype Mars rover around a simulated Martian landscape.

The ISS is a unique laboratory where around 300 experiments are performed every year. Being in orbit 400 km above the Earth, the ISS experiences permanent conditions of microgravity. This alone means that the breadth of studies is huge because microgravity is potentially useful to all disciplines.

"We have been used to studying things in a 1 g environment for as long as we have been studying things," says Andrew Kuh, the UK Space Agency's Human Spaceflight and Microgravity Programme Manager. "When you take the gravity away, that sheds a new light on a whole number of physical and biological phenomena. That's before you get to the human, the psychological, and the psychosocial stuff. So it really does cover a large range of things."

There are two aspects to the research conducted on the ISS. The first is to use the station to develop the necessary technologies and accumulate the new knowledge needed for long-duration human spaceflight. Using the ISS as a test bed, the long-term goal is to eventually send a human mission to Mars.

This ultimate ambition is agreed by all the ISS partners. "That is what everything is leading to at the moment," says Kuh. He points to a document called the Global Exploration Roadmap. Published in August 2013 by the International Space Exploration Coordination Group, it reflects a coordinated international effort to prepare for collaborative space exploration missions beginning with the ISS and continuing to the Moon, near-Earth asteroids, and Mars.

The second research aspect is an open call for pure curiosity-driven research to look for the best science across all disciplines that can be done in microgravity. "It's not a dichotomy. Lots of the former feed into the latter," says Kuh.

Mars roving

The European Meteron project was very much in the first category, and coincidently one of the most media-friendly science experiments. It is designed to prepare for human missions to the Moon, Mars and other celestial bodies.

A fuel-efficient – and safer – way to explore a planetary surface is for the astronauts to remain in orbit and deploy rovers to the ground. This saves the complexity and expense of landing astronauts and their necessary life-support habitats.

Building on previous tests, ESA, the UK Space Agency and Airbus Defence and Space collaborated on an experiment that saw Peake control a rover from orbit, driving it around a simulated Mars environment. The venue was the Mars Yard at the Airbus Stevenage site.

Housed inside a windowless, warehouse-sized building, the floor of the yard is covered with red sand and rocks. For Peake's test drive, the lights were low to simulate a Martian twilight and part of the yard had been shielded so that the inside was like a cave.

Given just ten minutes to prepare himself, the astronaut's job was to drive the rover inside the cave and identify target rocks that had been marked with UV-reflective paint. Under the gaze of the national media, Peake completed the mission in the allotted 90 minutes. During this time the rover moved little more than a couple of hundred metres, yet the astronaut controlling it had circumnavigated the world.

Less publicly, Peake has been using the electromagnetic levitator (EML), a furnace in the space station's Columbus laboratory that is used for studying metals. The EML heats metals to 2100°C, holding them in place using a magnetic field. It studies the changes in the metal during heating and cooling using high-speed cameras.

The Thermolab experiment and the (catchily-titled) Non-equilibrium Solidification of Industrial Alloys (NEQUISOL) uses the EML to investigate the thermo-physical properties of new alloys. Data collected on the ISS can then be used in computer models to develop new alloys and for manufacturing on the ground.

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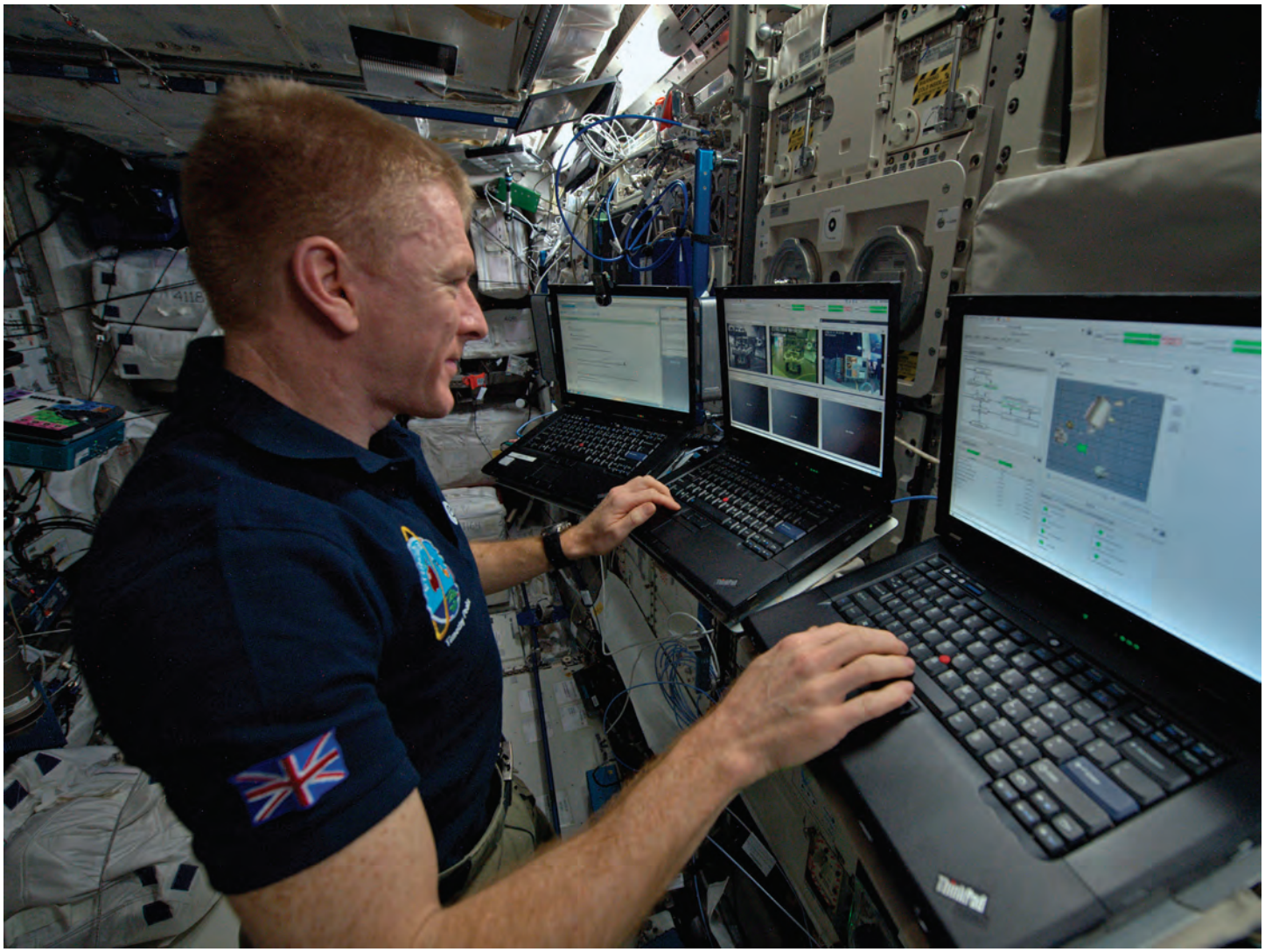
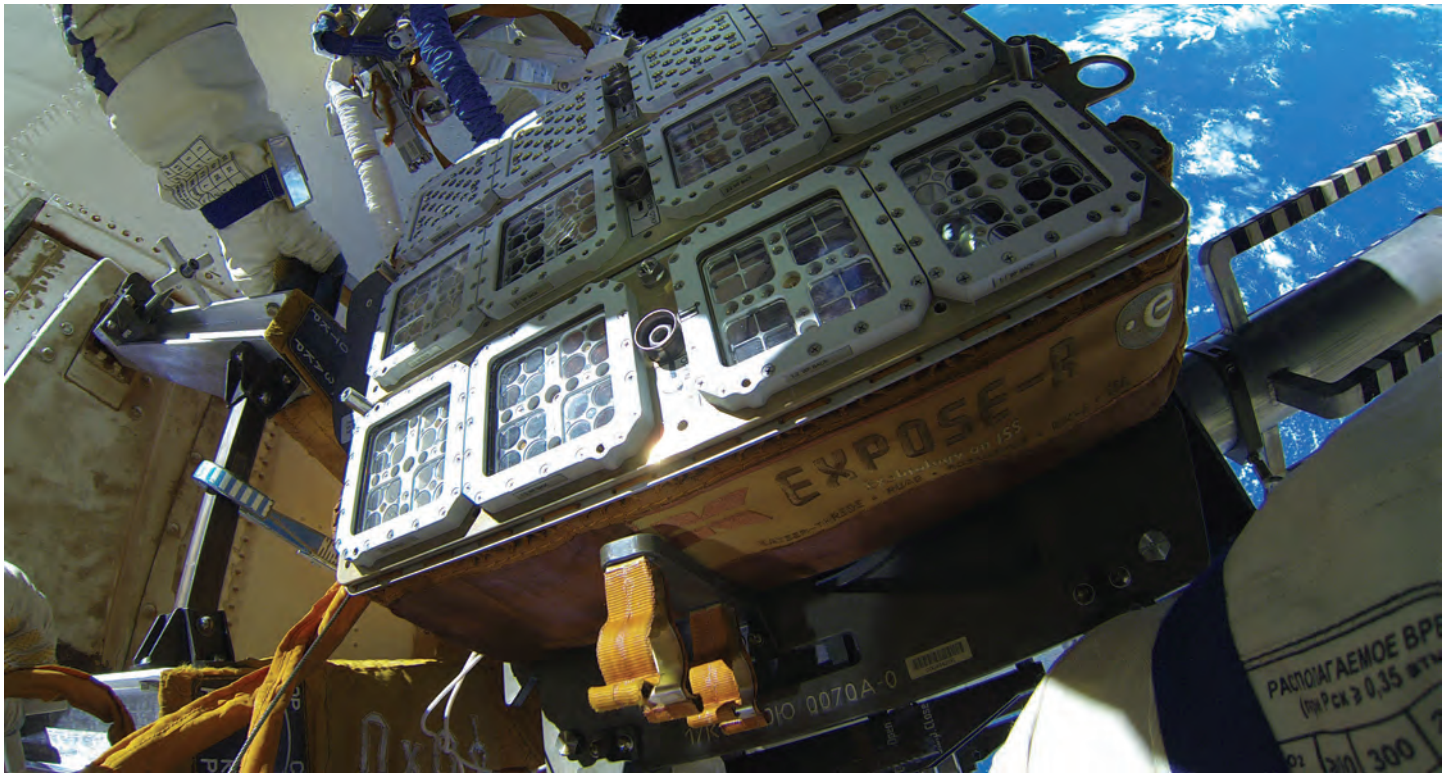


Tim controls a Mars rover in Stevenage from the ISS. For a picture of the rover see page 8 **Credit:** ESA, NASA



The EXPOSE-R2 experiment, seen during a July 2015 spacewalk **Credit:** Roscosmos

Hitch-hiking bacteria

Hitching a ride back with Peake on the Soyuz capsule in June, in fact sitting right underneath his seat like a piece of cabin baggage, was a package full of bacteria. Eagerly awaiting that package is Charles Cockell from the University of Edinburgh.

Cockell is part of the BIOMEX and BOSS experiments that use the EXPOSE-R2 module, located on the outside of the Russian science module. In short, these experiments place micro-organisms outside the ISS to see how they survive in space.

There are many dangers to living cells in space, such as radiation and extreme temperature, not to mention the lack of atmosphere. It is possible that none of these life forms will have survived the ordeal. But if they have, culturing them to grow more and studying them will help us to understand the limits of life. This could guide us in our search for life elsewhere in the solar system, and also in our understanding of how life began on the early Earth.

For example, aeons ago the Earth's surface was bathed in more ultraviolet radiation than today because there was no ozone layer. To study the effect this could have had, one thing to do is to go higher than the ozone – in other words take microbes into orbit above the Earth and expose them to the ultraviolet radiation of space.

As well as looking into the past, the research also points to the future. "Microbes are used in many industrial processes, such as drug production. There is no reason when we go into space that we won't be using microbes there as well," says Cockell. Certain microbes produce oxygen and so these could be used in life support equipment. Or astronauts could use microbes in food production. Even simple pickling to preserve food requires lactic acid bacteria. Working out which microbes are best suited to a space environment could therefore be key to survival.

Cockell got the chance to send microbes to the ISS about a decade ago through an experiment coordinated by the Germany Space Agency, DLR. "We happened to be looking at some microbes on the cliffs down in the village of Beer in Devon," he says. Cliffs are quite an extreme environment for microbes because there is very little food there, they are exposed to solar radiation and they dry out.

"We were trying to understand how microbes survive the desiccation and radiation on the cliffs when we were offered the opportunity to send microbes to the ISS. So, we sent up some rocks from Beer, which then spent a year outside, exposed to space," says Cockell.

When they came back, he and colleagues asked a simple question: did any of the microbes survive? One type did. It was a cyanobacterium, which produces oxygen, and so could be useful for life support equipment. The team grew them in the lab and then sent them back into space, where they have spent a further 18 months outside. Now Peake is bringing them back so that the researchers can again see if any of them have survived.

"We are lucky to be involved in these experiments. We are not principal investigators on any of them. If we want to lead them, and we want to play an active role in designing them then we need missions like Tim Peake's because we need to be actively involved in space exploration," says Cockell.

British ESA astronaut Tim Peake reads from a signed copy of Yuri Gagarin's autobiography, Road to the Stars. The first British astronaut, Helen Sharman, also had this book with her during her mission to the Mir space station Credit: ESA, NASA

UK SPACE AGENCY

Britons in space:

Juno

On 18 May 1991, scientist Helen Sharman became the UK's first astronaut. She had been selected from more than 13,000 applications after responding to a radio advert: "astronaut wanted, no experience necessary".

Although initially a private enterprise – and with no Government backing – most of the funding for Sharman's Juno mission came from the Soviet Union. Under reforming leader Mikael Gorbachev, the country was keen to build closer ties with Britain.

By the time Sharman launched on a Soyuz rocket to space station Mir, she had undergone some 18 months of intensive training. This included learning Russian, simulated flights in a Soyuz training capsule as well as medical and physical testing.

Sharman blasted off alongside cosmonauts Anatoly Artsebarsky and Sergei Krikalev and the crew docked with the space station two days later. During her six days on Mir, Sharman carried out science experiments and spoke by radio to British schoolchildren.

After a bumpy return to Earth in the Soyuz capsule, Sharman became a space consultant and science communicator. She was awarded an OBE in 1993 and now works at Imperial College, London.

Helen Sharman reunited with her spacesuit at the Science Museum in London, during the celebration of the 25th anniversary of her flight Credit: Science Museum

Almost astronauts

In March 1984, the British government announced the names of four British astronauts selected to fly on the Space Shuttle. The candidates – representatives from the armed forces and civil service – would oversee the launch the UK's Skynet military communications satellites.

The first two astronauts, Nigel Wood and Richard Farrimond, began training alongside NASA astronauts in Houston. Wood, an RAF fighter pilot, was due to fly on the Space Shuttle in June 1986.

On the morning of 28 January 1986, shortly after lift-off, Space Shuttle Challenger exploded. The seven astronauts on board were killed, including Christa McAuliffe who was to be the first school teacher in space.

As a result of the disaster, the Shuttle fleet was grounded. The Skynet satellites were launched on conventional rockets and the British trainee astronauts would never fly.

Britain's ESA astronaut

Tim Peake was selected as Britain's first ESA astronaut in May 2009 and launched to the ISS on 15 December 2015. He has spent six months working on science experiments and outreach projects. In January he conducted a spacewalk to replace a faulty power unit. He has also helped dock spacecraft, launch satellites and even remotely operated a Mars rover on the ground in Stevenage.

Since 2012, the UK has contributed to ESA's human spaceflight programme with investment in microgravity research and new communications technology on the ISS. Decisions on Britain's future commitments to human spaceflight will be made at the ESA Ministerial meeting in November 2016.

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the first 25 years

British-born astronauts

Four British-born astronauts have flown Shuttle missions: Michael Foale, Piers Sellars, Nicholas Patrick and Gregory Johnson. Space tourists Richard Garriott and Mark Shuttleworth were also born in the UK.

Foale, a Cambridge graduate, became one of NASA's most experienced astronauts. He has flown in the Space Shuttle and Soyuz, helped repair the Hubble Space Telescope and has served on Mir and the International Space Station (ISS).

Foale was on Mir in 1997 when the station was hit by a robotic Progress supply ship, puncturing the hull. The crew's lives were saved thanks to their rapid action in sealing off the affected area.

During his mission to the ISS in 2008, video game entrepreneur Richard Garriott produced videos and carried out a series of education experiments for UK schools.

Michael Foale is suited up for a 1999 Shuttle mission Credit: NASA

Tim Peake during his January spacewalk Credit: ESA, NASA

The launch of Tim Peake to the ISS in December 2015 Credit: NASA

UK SPACE AGENCY

Tim using ESA's scary-looking muscle measurement machine on the ISS **Credit:** ESA, NASA

Feeling the pressure

Another study that involves the UK in a major way is NASA's Fluid Shifts. From the beginning of the space race, astronauts and cosmonauts have reported problems with their vision. In certain individuals those problems have become permanent.

A popular hypothesis is that this deterioration in eyesight could be because fluid pressure increases in the brain during spaceflight flattening the back of the eyeball, crimping the receptors, or it could be pressing on the optic nerve. The normal way to measure the pressure of fluid in the brain is to use an invasive technique called a lumber puncture. This is a skilled medical procedure and difficult to perform in space. Thanks, however, to work started more than forty years ago, Robert Marchbanks of Marchbanks Measurements Systems (MMS) Limited has a solution.

"It's a long story," he says about how he came to be supplying equipment to NASA. "It started as an undergraduate project – so I still haven't finished my undergraduate work yet."

Marchbanks was originally given the task of measuring movements of the eardrum, which are extremely small. In terms of the volume, the changes are measured in nanoliters – a nanolitre is the volume of a single shard from a pin head that has been chopped into a thousand equal pieces. He succeeded. Then, thanks to research he performed at University Hospital Southampton NHS Foundation Trust, he discovered there is an open fluid link between the brain and ear. Hence, changes in the eardrum can reveal the fluid pressure on the brain.

He developed an in-ear monitor that NASA is now using to measure astronaut brain pressure. Recently, two year-long studies of astronauts on the ISS have been performed, and more data is being collected. Although Tim Peake is not one of the subjects, he has been supporting the campaign during his stay.

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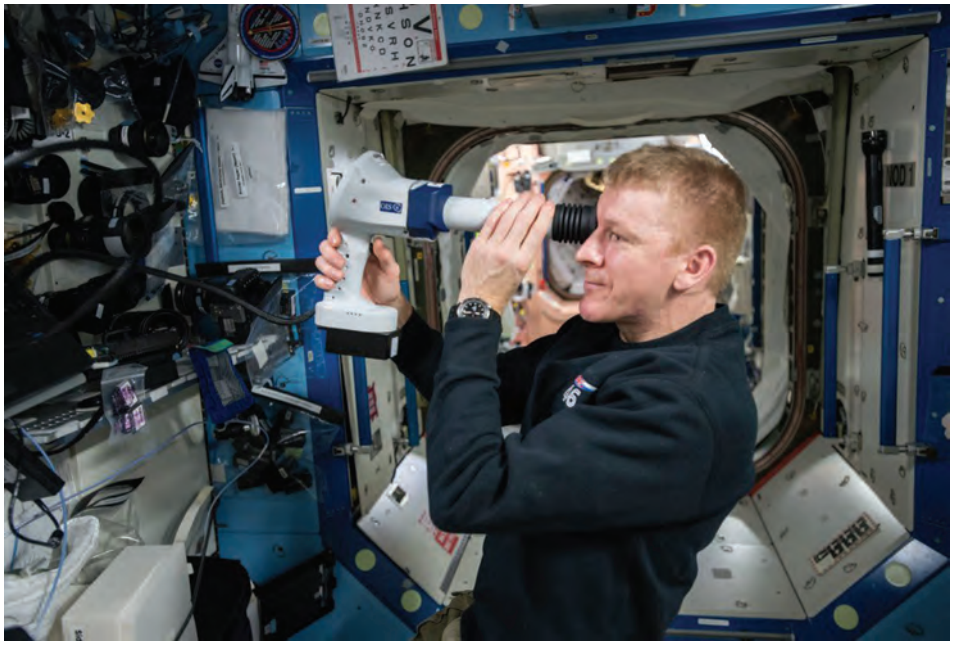
This device is used to capture images of blood vessels in the eye as part of studies of eye health in astronauts **Credit:** ESA, NASA



Apart from astronaut health, Marchbanks believes the equipment has plenty of applications on the ground. It is currently being used in Southampton and a few other places to diagnose patients. "We have referrals for patients with rather obscure cognitive, balance and hearing problems. We look to see if brain pressure is involved," he says.

In essence, brain pressure is a vital sign every bit as important as blood pressure and body temperature. Traumatic brain injuries and concussion, or possibly early onset dementia, and liver failure could all be monitored more effectively if such equipment were widespread. "We've also conducted research in Kenya were it has been used to look at cerebral malaria in children," says Marchbanks.

The problem is that funding bodies do not usually supply money to develop apparatus. This is why the UK's active participation in human space exploration could be crucial to this device.

"The main contributions of the space agencies in this area is that they are putting their weight behind a non-invasive way to measure brain pressure. Everyone knows that this is important but no one has wanted to fund it," he says. "Now, because it is a critical problem for the space business, they are willing to supply money. They also facilitate getting heads around tables to consider and talk about these issues. They contribute in many different ways."

Applying technology developed in space to medical diagnosis for brain, or intracranial pressure, at University Hospital Southampton **Credit:** UK Space Agency, Alexander

The future

UK science does not come to an end on the ISS once Tim Peake returns to Earth. Launching in 2018 will be ESA's Atomic Clocks Ensemble in Space (ACES) experiment. This includes a caesium atomic clock, which will be mounted on the external platform of ESA's Columbus module.

It will be compared with various atomic clocks at ground stations spread across the globe, including one at the National Physical Laboratory in Teddington. Atomic clocks in space could have spin-off technologies for time keeping on future satellites but primarily they are used to look for discrepancies in Einstein's theories of relativity.

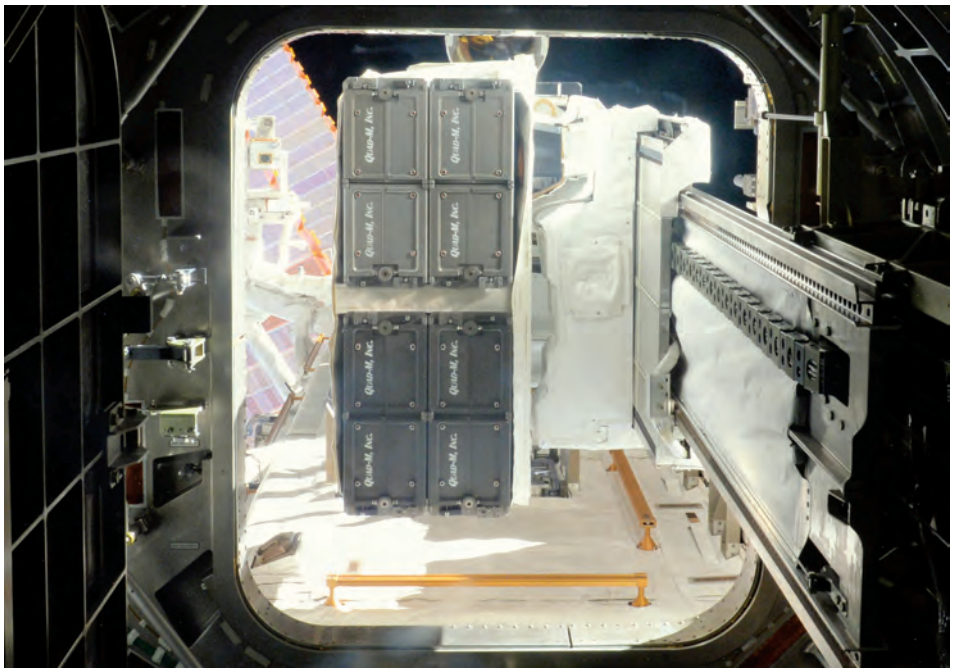
In particular, ACS will look for any evidence that the speed of light in a vacuum is variable, or that the traditional constants of nature can vary in time and space. Any hint of these behaviours will provide a big signpost to so-called 'theories of everything' that lie beyond Einstein's relativity.

There are so many aspects of science that Tim Peake's mission has touched upon and advanced. Andrew Kuh sums it up like this: "We hear from our ESA colleagues that Tim is efficient at delivering results. One metric of his effectiveness is how much science he has delivered. He has exceeded expectations week in and week out. It has been a resounding success."

"We need missions like Tim Peake's because we need to be actively involved in space exploration"

Charles Cockell
University of Edinburgh

Tim has also been releasing small satellites called Cubesats – he took this picture showing them outside the airlock, ready for launch **Credit:** ESA, NASA



University of Edinburgh scientist Jennifer Wadsworth investigating whether bacteria could survive in similar conditions to Mars
Credit: UK Space Agency, Max Alexander

Principia: Inspiring the young

Could UK schoolchildren one day follow in Peake's footsteps? **Credit:** ESA, NASA

Space inspires the young, writes Stuart Clark. It is a phrase repeated so often that it has become commonly accepted wisdom. But is it true? Tim Peake's Principia mission to the International Space Station (ISS) is providing a unique opportunity to scientifically test this statement.

"Many people believe that having an astronaut is good for STEM education, full stop – and there is plenty of anecdotal evidence to this effect," says UK Space Agency Human Spaceflight and Microgravity Programme Manager, Andrew Kuh. "But we think a robust study on this subject needs to be done, so if we make these claims of lasting impact, we have the evidence."

To gather that evidence, the UK Space Agency has commissioned a study from the department of education at University of York. This in-depth research is aimed at assessing any change in attitude to STEM subjects. "As far as I know there has been nothing done on this scale elsewhere in the world," says Kuh.

The person charged with running the study is Judith Bennett. She has designed the research to collect both quantitative data and qualitative data about young peoples' responses to STEM subjects.

"We plan to collect data at three points: before, during and after Tim Peake's mission," she says. "We are collecting the second set of data now. We will follow up about a year down the line, to see what his legacy has been."

The first round saw an online survey that was completed by about 2500 students in the age range 9 to 13. It showed that overall, young people are already positive towards space and the STEM subjects, and very positive about the possibility of travelling in space

themselves as tourists. Perhaps worryingly though not so many are interested in careers involving space science (See First Results box).

Bennett and her collaborators also visited 17 schools to talk to the pupils and the teachers. "We've only got the data before Tim Peake launched. One of the quotes from one of the secondary school students was 'Tim Peake, isn't he the swimmer?'," she says. "We are hoping not to hear that again when we go in next time!"

An enormous effort has gone into the educational aspects of the mission. Astronaut Flight Education Programme Manager for the UK Space Agency, Libby Jackson, has been there since the beginning.

"As soon as Tim's mission was announced, the astronaut said that he really wanted to inspire children," says Jackson. "He's got two young boys himself, he really knows how important space can be to children and how important it can be to provide that inspiration and excitement about space."

In response, the UK Space Agency created a vision statement: 'We want to put together a national celebration for everyone in the UK to engage with if they wish, inspiring greater interest and understanding in STEM in general and UK space methods in particular.'

At the first planning meeting, Jackson imagined a grid with all the different STEM subjects across the top and all the different age groups down the side. She thought to herself that there needed to be at least one project in every single box.

"That's really what we have done," she says. "It is a huge education project the like of which to my knowledge has never really been done for any other mission before, certainly not in Europe. I think this is unique."

To date more than a million school children have been reached by the thirty or so education projects designed around Peake's mission. Two of the biggest are Rocket Science and Cosmic Classroom.

The UK Space Agency is keen to attract more young people into the country's £11.3 billion space sector
Credit: Airbus Defence and Space

First results

Before Tim Peake launched, the first round of the University of York study revealed that:

Overall, both primary and secondary students are positive about the value of STEM subjects, and about space. They believe science makes an important contribution to people's lives, and technology and engineering can also help improve things. Their views of the contribution of maths are less positive.

Space science is viewed very positively and seen as making a worthwhile contribution to people's lives, with the majority of both primary and secondary age students believing that space science makes lives on Earth better. There was also support for sending people into space to find out more about the Universe, and that this activity was worth the money spent on it.

Space is a topic of significant interest to students, both in school and outside school. The positive responses are particularly pronounced in the primary age group.

There is a belief that you need to be clever to do a job in space science or technology, even more so than the need to be clever to do maths and science.

Students are very positive about the possibility of them travelling to space, though not as interested in careers involving space science. Boys are particularly positive about travelling to space, with the divide between boys and girls more pronounced in the secondary age group.

The findings are based on the responses to an on-line survey of 1,600 students aged 11-12 and 797 primary school students aged 8-9.

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The Rocket Science project invited school children to grow rocket salad leaves from seeds that have previously flown in space and compare them with a control set that stayed on Earth. A staggering 8400 schools and other groups – meaning 600,000 young people – are currently engaged in this work. The data is being coordinated by the Royal Horticultural Society, and those involved expect to publish a research paper from the findings.

"The project answers genuine questions about whether seeds could be taken into space and grown after months in storage," says Jackson. "It has been hugely successful in every single regard."

For Cosmic Classroom, children got to ask Tim questions in a live link-up to the International Space Station. The children submitted questions for him, and then a randomly chosen group of schools travelled to the World Museum in Liverpool to take part in the exchange.

To maximise the number of people reached, the UK Space Agency joined with the Times Educational Supplement and webcast the event to schools across the country. In this way hundreds of thousands of school children got to experience the class. Tim performed experiments and demonstrations that highlighted the difference between being in space with microgravity, and being on Earth.

"I meet people on public transport who tell me about children they know who took part in cosmic classroom," says Jackson. Her hope is that the effort has made children think about science in a new way. She envisages it as if the children are on a ladder with each rung representing a level of awareness or interest in space. Some will naturally be near the top, others nearer the bottom.

"If we've been able to move everybody up one rung then we will have done really well," she says. "So for people who have never been excited about science before, perhaps we show them that this does link to real life. Further up, for people who already like science, perhaps we have got them thinking about a career in space."

And that is the real goal. Despite the growing importance of the space sector to the UK economy, space is no longer a requirement on the national curriculum for upper primary and lower secondary age ranges. Peake's mission could not have come at a better time for showing school children that space is now a viable career.

Tim Peake with packets of seeds flown on the International Space Station as part of the Rocket Science education experiment **Credit:** ESA


Pupils taking part in the Cosmic Classroom in Liverpool **Credit:** UK Space Agency, Max Alexander

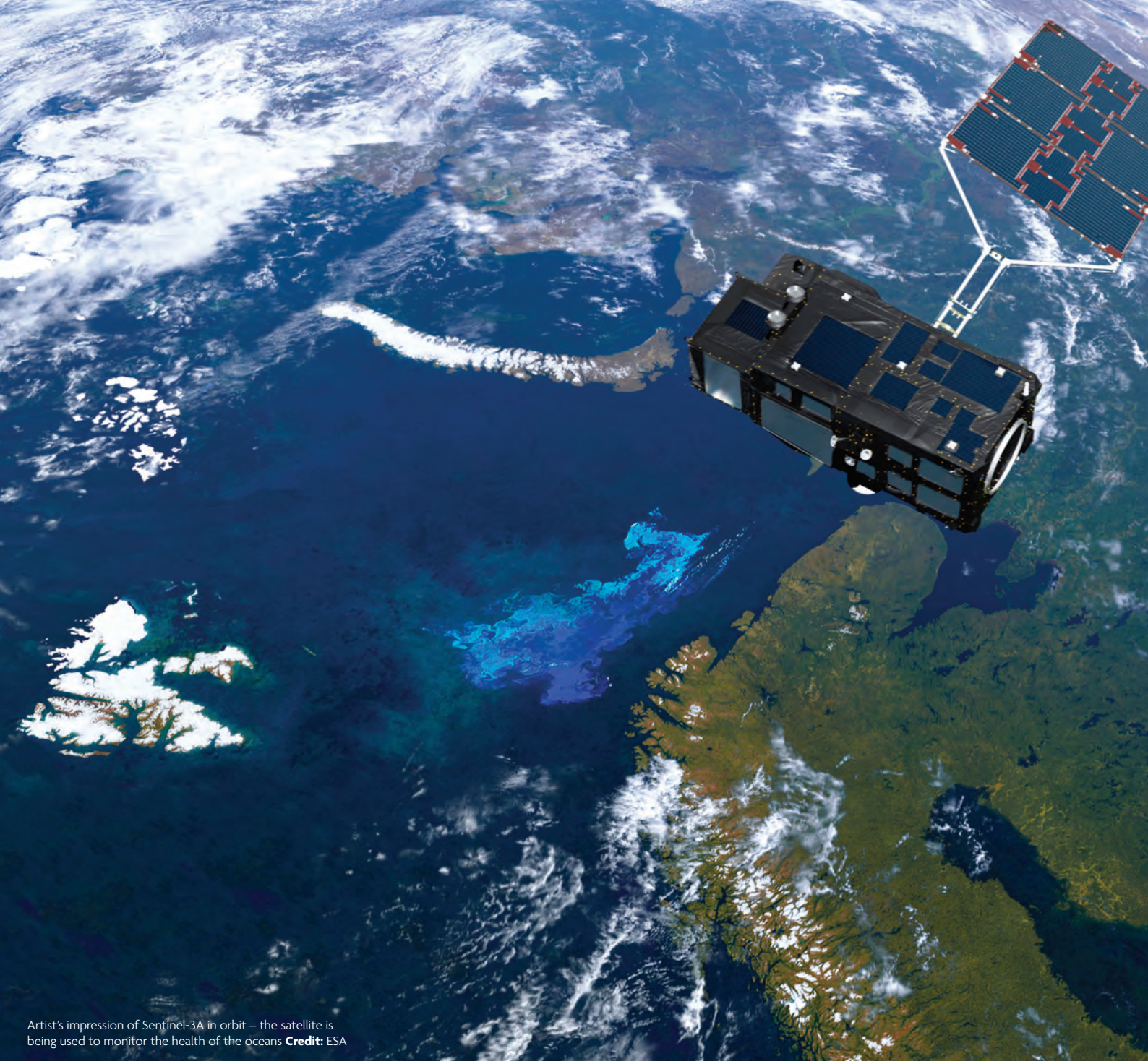
"There hasn't been a British astronaut in so long, we had a kind of blank sheet," says Kuh. "I distinctly remember Helen Sharman's mission from when I was young, and it certainly inspired me, but for children today Tim's mission will be the first time they have been aware of a British astronaut."

And the impact of this will be assessed in Bennett's study. "Clearly, I hope that it will make them feel more positive about STEM subjects but we need to wait to see what the data tells us," Kuh says.

According to Kuh, even if it shows that there is no impact, this is not a disaster. "If it shows that there is no impact then we continue to justifying space for the science and technology return, which is ample justification all on its own. Education is not why we joined the human spaceflight programme in the first place. It was all about science and industrial return. Education would be a glorious benefit. And one of the more visible benefits."

Whatever the result, it is yet another piece of solid science to come out of Tim Peake's mission.


Peake is the first British astronaut to visit the ISS **Credit:** ESA, NASA



Artist's impression of Sentinel-3A in orbit – the satellite is being used to monitor the health of the oceans **Credit:** ESA

Making sense of Sentinel

Satellites monitoring the Earth have transformed our understanding of the planet and how it is changing. Europe's latest Sentinel missions are providing a wealth of new data but, as Richard Hollingham discovers, dealing with so much information can prove a challenge:

Every 90 minutes, Sentinel-3A orbits the planet. The satellite is designed to measure the temperature, colour and height of sea surfaces – vital information for weather forecasters, climate scientists and biologists examining the health of the seas.

During each pass, the satellite sends back the data it has gathered to a network of ground stations. Over a day this amounts to some 2 Terabytes of information – roughly equivalent to the memory capacity of a high-end home or office computer. Over a week the amount of data from Sentinel-3A adds up to 14 Terabytes (TB). In a year this represents 712 TB – equivalent to more than 700 home computers.

And Sentinel-3A is just one satellite in the Copernicus Earth observation programme.

There are currently two Sentinel-1 satellites in orbit – producing radar images of land and ocean – as well as Sentinel-2, which captures high-resolution images of the planet. The combined information these four satellites send back adds up to almost 3000 TBs, or 3 Petabytes, of data a year.

Eventually, the intention is to have twelve Sentinel satellites in the Copernicus constellation – monitoring everything from land to air to ocean. You do not have to do the maths to conclude that this system will generate a seemingly overwhelming mass of data, images and measurements for scientists on the ground to process and interpret into anything meaningful.

This is why the UK needs JASMIN.

Superdata

"It's like a supercomputer," says Head of Earth observation at the Centre for Environmental Data Analysis, Victoria Bennett. "But we call it a super-data-cluster."

"A supercomputer is a big computer designed for high powered processing and a data centre is used for storing information," says Bennett. "JASMIN is a hybrid – optimised to process data in an efficient way."

Operated by the Science and Technology Facilities Council and funded by the Natural Environment Research Council, JASMIN is located on the Harwell campus in Oxfordshire. The super-data-cluster contains 15 Petabytes of high-performance storage. This is connected to over 4000 computing processing cores. For handling a mass of scientific information, this makes JASMIN the most powerful computer in the UK.

"The amount of data coming from satellites is enormous, so by centralising it all on JASMIN, we can avoid duplicating data storage in many locations," says Bennett. "This allows the scientists to process the data, study and validate the information, develop the algorithms and draw conclusions."

To cope with the demands of processing information from the new generation of Earth observing space missions, JASMIN has recently been expanded with the addition of the UK Climate Data from Space Zone (CDS).

"This new zone is a computing infrastructure which enables people to produce data of climate quality on it," says Director of the National Centre for Earth Observation (NCEO), John Remedios. "We can take a set of long-term satellite data and do the extra processing to ensure it's of the highest quality and assurance."

Inside the JASMIN superdata cluster **Credit:** STFC

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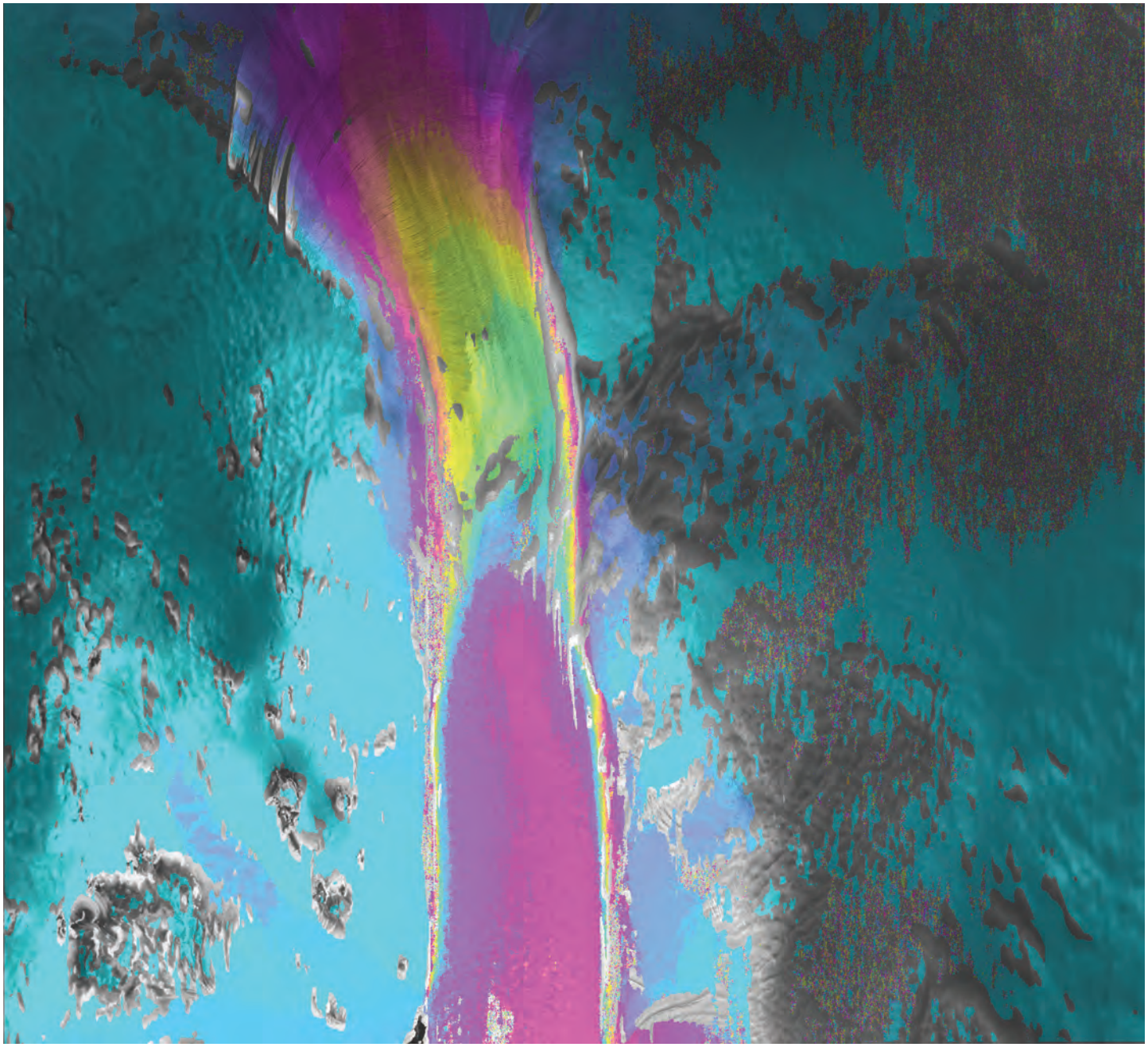
Seamless

To make any meaningful assessments of how the Earth is changing, as a result of climate change for example, scientists need decades worth of measurements. Computer models predicting future climate rely on considering past records of factors such as temperature, global ice coverage, sea surface height and colour to make long-term predictions for the future. Although this goal remains important, thanks to the new CDS, scientists plan to move into more immediate applications of climate data.

"Traditionally in climate data you go back through historical records," says Remedios. "But if you want that data to show people what the current state of the planet is, and what changes are going on now, then current data is important. The idea is to produce high integrity data as soon as possible after it's streamed out from satellites to Earth."

Funded by NCEO and the UK Space Agency, CDS is designed to provide a seamless supply chain of climate data from space. "A good example for how this might be used is the current El Nino global climate cycle," Remedios explains. "This is an extremely important event across the globe in terms of food security, air quality and storminess of the weather." With our food supply coming from across the globe, anything that affects the quality of the growing season, crop yield or food prices could have a major impact on millions of people.

Although the UK is not alone in seeking to better understand the Earth's climate and make better use of climate data, it is certainly an acknowledged world leader. The Government – through the UK Space Agency – has invested heavily in ESA Earth observation programmes



The colours on this radar image of Pine Island glacier in Antarctica illustrate the flow of ice **Credit:** Copernicus data, University of Leeds

The April 2016 launch of Sentinel-1B **Credit:** ESA, Pedoussaut

and Remedios believes we are starting to reap the rewards both in terms of science and the economic benefits.

Data from the Copernicus satellites is available free to anyone who wants it, the key is to add value to that information. This is why the CDS is so important.

"In the recently published Innovation and Growth Strategy, we clearly identified that climate services are an important area for growth for space applications," Remedios says. These commercial applications of climate data from satellites might include services that provide accurate and timely information on crop growth, improved weather prediction, flood defence or forest protection.

"It's an exciting and challenging area," says Remedios. "It's an area with unknown prospects but sometimes the best markets are like that – it depends on the combination of skills and expertise to get it right."

Science at the speed of light

Data and images from Sentinel satellites will soon be available even faster, following the successful testing of a new space laser communications system. The European Data Relay System (EDRS) enables satellites in low-Earth orbit, fitted with EDRS terminals, to relay data via laser to communications satellites in higher geostationary orbits.

EDRS – a public-private partnership between ESA and Airbus Defence and Space –means the Sentinels can send data back to Earth for much longer periods during each 90-minute orbit. When the system is fully operational later this year, it will give users on the ground much faster updates from these satellites, providing rapid access to images in developing situations such as natural disasters.

On 31 May, Sentinel-1A successfully transmitted the first image to the EDRS terminal fitted to communications satellite Eutelsat 9B. A major achievement.

"You're setting up a laser link over a distance of around 45,000 kilometres between two objects that are both moving at relative speeds of several thousand kilometres per hour," ESA's EDRS Project Manager Michael Witting tells space:uk. "You could compare that to pointing from the UK with your torch and hitting a car in New York."

EDRS uses laser links between satellites in low Earth orbit and those in higher geostationary orbits to relay data to the ground **Credit:** ESA

"The amount of data coming from satellites is enormous"

Victoria Bennett, Centre for Environmental Data Analysis

Mission X

Mission X uses the excitement of space exploration to inspire students in primary and middle schools to learn about the science of nutrition and exercise. Space scientists and fitness professionals have designed new and fresh resources to complement their other popular activities. Look out for the next Mission X challenge at the start of the Autumn term for your chance to train alongside an astronaut. Once registered, the Mission X team and the UK Space Agency will support you and provide ideas on how you can deliver Mission X in your school.

www.trainlikeanastronaut.org

Principia Schools Conferences

The UK Space Agency is holding two schools conferences later this year to showcase work linked to British ESA astronaut Tim Peake's Principia mission – at the University of Portsmouth on 2 November and the University of York on 5 November. The conferences will include keynote talks from leading figures, opportunities for presentations from students and an exhibition of students' work. It is hoped that Tim Peake will attend both events as long as his schedule allows.

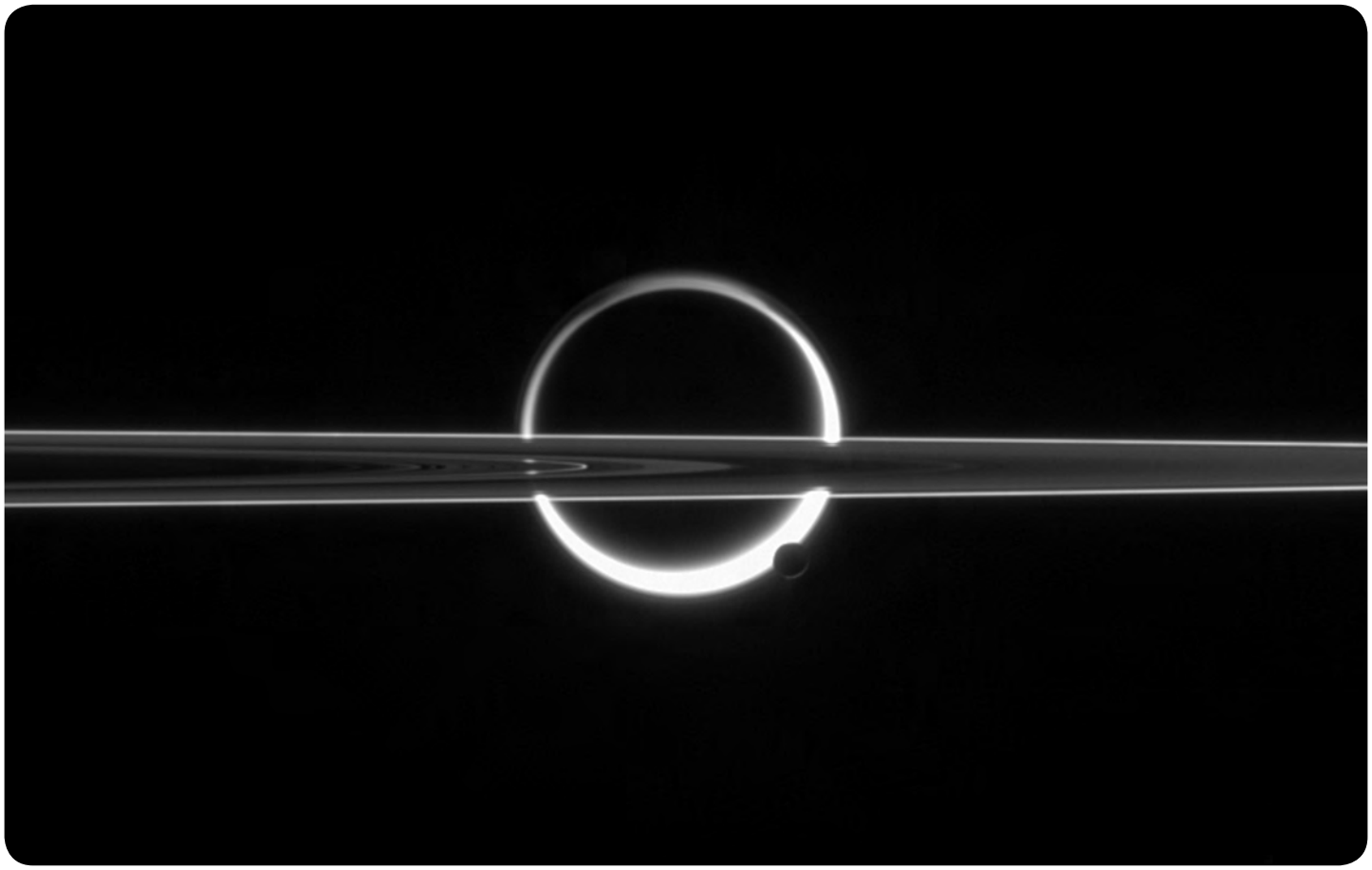
Individuals or groups of young people can apply to present or exhibit though a competitive application process. If you are interested in taking part or attending one of the conferences, visit the Principia website for more information.

Odysseus II

A second round of this European Commission funded competition will open in the Autumn term for almost any age group of students (7-22 years old). From 1 September you will have the opportunity to submit any student's work on the themes of the Solar System and Space Science, Europe in Space, Human Beings on Mars and The search for Life in the Universe. It could be work that has already been completed – perhaps related to Tim Peake inspired work – or something brand new.

Prizes range from iPads and state of the art computer driven telescopes, to trips to South America to see a launch and internships at space agencies.

www.odysseus-contest.eu



Saturn's rings cut across the moons of Titan (the larger moon) and Enceladus in this image captured by the joint NASA-ESA Cassini-Huygens spacecraft **Credit:** ESA, NASA

Glasgow-based Clyde Space is a supplier of CubeSats and small satellites. Founder and Chief Executive, Craig Clark, explains how the company has grown:

Craig Clark
Credit: Clyde Space

Image top right: Clyde Space offices and cleanroom in Glasgow
Credit: Clyde Space

Bottom image: Working on the solar panels of a CubeSat – giving an idea of the size of these small satellites
Credit: Clyde Space

What does Clyde Space produce?

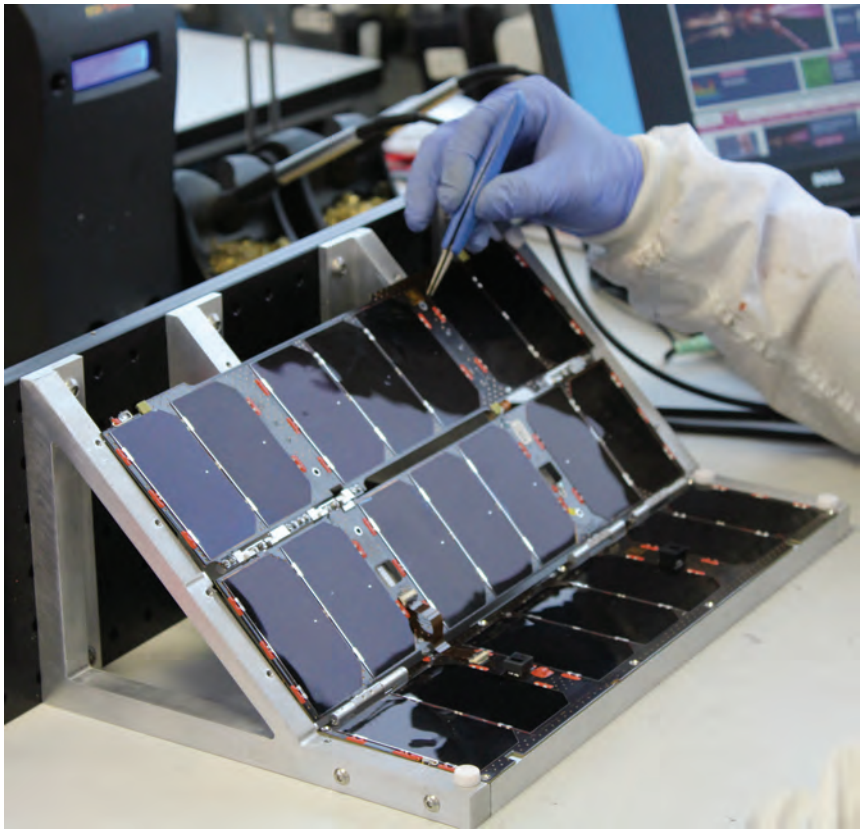
We provide full satellite missions – from design and manufacturing, to testing and operation in orbit. Clyde Space was the first company in the world to develop power systems for CubeSats. We also supply solar panels, batteries, control systems, onboard computers, structures and full platforms.

Our systems can be found in most NASA centres. We also supply the US defence community and our systems contribute to a range of projects at the Massachusetts Institute of Technology.

What are the applications for CubeSats?

The applications for CubeSats constantly increase and our products provide a standard platform that supports this. These systems and payloads are designed to fit into standardised CubeSat units of 10cm x 10cm x 10cm.

One of our current missions monitors the gases in the atmosphere. Another Earth observation mission is looking at the oceans and coastlines to determine their health. Our satellite communications project, OUTERNET, will deliver free data to many remote areas across the globe.



How did you start in the industry?

I graduated with a degree in power engineering and became a power systems engineer at Surrey Satellite Technology Limited. This was an innovative workplace and, as a small company, I was involved in most aspects of the business and mission delivery.

After 11 years I wanted to move back to Glasgow. There wasn't a space industry in Scotland then and I considered changing career. Instead, I started Clyde Space in 2005. We've just celebrated our 11th birthday and, earlier this year, announced the creation of our US company Clyde Space Inc.

What has been your most important mission so far?

Once we started working on CubeSats, we realised it wasn't only the components we needed to build, it was full satellites. The most challenging and rewarding mission was manufacturing UKube-1. Not only was it one of the most advanced Nanosatellites ever made, it was also the first satellite to be designed and built in Scotland.

Transitioning from power systems to a full spacecraft was technologically challenging and took three years, finally launching in 2014. The mission set out to test the capability of useful science that could be performed within a CubeSat sized spacecraft. As a direct result of this successful mission, we're now building six satellites a month.

Westcott

An early test firing at Westcott **Credit:** Westcott Venture Park

Once a World War Two training base, Westcott remains at the forefront of rocket propulsion research.

Westcott Venture Park in Buckinghamshire is the UK home of rocket research for defence and space development.

Originally created as a training base for bomber crews, the 650-acre site became a Government research centre in 1946. Early research at the Guided Projectile Establishment focused on rocket engine propellants and solid rocket research.

By the late 1950s, more than 1000 employees were researching and developing rocket motors for guided missiles including Blue Streak. Other major rocket propulsion programmes included Black Knight – built to test the design of a missile re-entering the Earth's atmosphere – as well as the top-secret Chevaline nuclear warhead project.

The Waxwing rocket motor, designed at Westcott, played an important role in the UK's first and only satellite launched on a UK-built rocket. The motor formed the third stage of the Black Arrow launcher, which successfully placed the Prospero satellite in orbit in October 1971.

In recent years NASA's Mars Global Surveyor, the NEAR asteroid mission and NASA's Messenger spacecraft have used propulsion engines made by Westcott's Moog ISP UK. Its LEROS 1b engine is currently helping to power the Juno spacecraft on its five-year voyage to Jupiter.

Companies based at Westcott Venture Park continue to make significant contributions to the UK space industry. These include the Falcon Project, which designs and manufactures rocket systems, and European Astrotech which is providing test and launch support services for the new Galileo satellite navigation system.

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July 2016. UK Space Agency www.gov.uk/government/organisations/uk-space-agency