Summer 2013 Issue 38

space:uk

Tim Peake: training for the Space Station
Aiming for Jupiter's moons
Glasgow in space

Plus:

European space centre opens in UK • Europe's largest communications satellite • ten years at Mars • the UK from space

UK SPACE AGENCY

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Front cover image Credit: NASA

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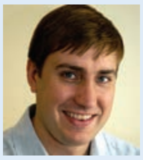

I was shocked to realise, the other day, that I have been editing this magazine for almost ten years. Looking back, the changes that have taken place in the UK space sector in that time have been astounding.

When I started, Britain 'didn't do' astronauts and we rarely put pictures of them in the magazine. Now British astronaut Tim Peake is training for a mission to the International Space Station in 2015. The UK has also become the third largest contributor to the European Space Agency (ESA), leading the way in many aspects of space exploration and technology. There are few international missions without UK involvement somewhere along the line and we even have an ESA centre here.

Ten years ago, the UK had a thriving satellite manufacturing industry but it has since gone from strength to strength, with expanded facilities, expertise and ambition. The Government sees space as a priority for stimulating economic growth. No wonder, given that the sector is expanding at the rate of almost 7.5% a year.

With all this going on, there has never been a better time to be involved in space. We try to capture a flavour of that excitement in *space:uk*. Over the past ten years, it has been a pleasure to see the rise and rise of the UK in space.

Richard Hollingham
Editor

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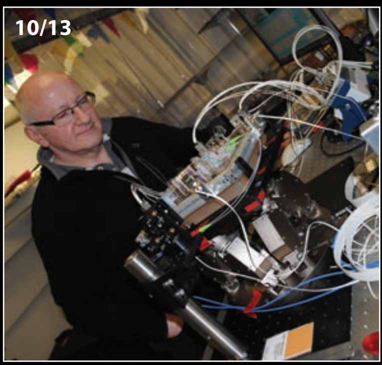
Credit: DMCii



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Credit: UK Space Agency, Boffin Media

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Credit: ESA

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Welcome to the latest edition of *space:uk* writes Director of Policy and Operations for the UK Space Agency, Emma Lord:

As always, *space:uk* covers some of the exciting missions which are being developed with UK involvement, including the European Space Agency's (ESA) JUICE mission. The mission is due to arrive at Jupiter in 2030 and will spend at least three years making detailed observations of the planet and three of its largest moons.

When I first began learning about space, a long time ago now, I remembered Jupiter for being the largest planet in the Solar System with a stormy red spot. Imagine the wonder of the next generations, learning about the possibility that life might exist in vast oceans beneath the surfaces of the planet's moons.

Space missions are, by nature, long-term projects. When I visit schools to talk to the children, they are always quite amazed when I ask them to work out how old they will be when a mission such as JUICE launches. It makes a career in the space industry seem so much more accessible when they realise that these programmes have such a long life span.

When I joined the Agency, the Herschel Space Observatory and Planck Surveyor were gearing up for launch in May 2009. There was a sense of excitement when I attended meetings about these spacecraft and heard the expectations that scientists had for the missions. They have both exceeded expectations.

Herschel, the most powerful observatory ever launched into space, has spent the last four years gathering pictures and data at far-infrared wavelengths that have transformed our understanding of star formation and galaxy evolution. Its sibling, Planck, has analysed some of the oldest light in the Universe and provided images such as the unforgettable all sky survey.

Emma Lord,
UK Space Agency Director of Policy and Operations

The launch of Herschel and Planck in 2009 **Credit:** ESA

Scientists have gathered vital information from these two observatories and will continue analysing it for years. Meanwhile, after a job well done, the signal between Herschel and the control centre was switched off in mid-June, effectively bringing the mission to a close. The spacecraft will now continue to drift around the Sun at just over two million kilometres from Earth. Planck will operate until later this year when it is planned to end the mission and deactivate the signal in the same way.

On the subject of space pioneers, the UK's Tim Peake hit the headlines in May when it was announced that he is scheduled for a long duration mission to the International Space Station in 2015. Like many people, I have always fancied being an astronaut but it is not all about the glamour and adventure of travelling into space. The selection process is tough and the training is rigorous, covering elements from fitness to languages, to first aid to survival.

So hats off to Tim for the reaching the position where he is ready for a mission. I am sure we will all be following his progress over the coming months in the lead up to the launch in 2015. You can read more about Tim later in this issue.

It is always a pleasure to hear from readers so, as always, do keep in touch with us through our website and social media.

European space centre unveiled in the UK

Artist's impression of the new ESA centre to be built at Harwell **Credit:** ESA

The European Space Agency, ESA, has announced its first facility in the UK. The European Centre for Space Applications and Telecommunications (ECSAT) is located at the Harwell Science and Innovation campus near Oxford. ECSAT will support a range of activities related to applications of space including telecommunications, climate observation and future satellite technologies.

ECSAT was officially unveiled by Minister for Universities and Science, David Willetts, and ESA Director General, Jean-Jacques Dordain. Speaking at the opening ceremony, the Minister said: "The UK space industry is increasingly important to growth, contributing over nine billion [pounds] to the economy every year and supporting thousands of highly skilled jobs. ESA's decision to locate its high-tech facility in this country shows that we are creating the right environment for innovation and cutting-edge research."

The UK is now the third largest contributor to ESA and has committed £161 million to the Agency's telecommunications programme – an important sector for the UK space industry. The ESA Director General welcomed the UK's increased involvement in space. "Investing in space is investing in competitiveness and growth, through knowledge, innovation and services," said Jean-Jacques Dordain. "The Harwell Oxford campus is already a unique place of competences and the building up of ESA's presence in this campus will reinforce both ESA and the campus."

Harwell is already home to a strong community of space scientists and space businesses, including RAL Space and the new Satellite Applications Catapult. This Catapult, opened for business on the same day as ECSAT, is designed to help translate new ideas and technologies into commercial applications and businesses.

For the moment, ECSAT has taken over part of an existing building at Harwell for its 60 or so staff. A new purpose-built centre is due for completion in 2015, when the workforce is expected to have risen to around 100. ESA hopes that by having its new centre alongside other space activities, it will help to nurture partnerships that are likely to play a part in many future European space projects.

For the UK Space Agency, Chief Executive David Parker said that ECSAT represented an opportunity to grow the UK space sector. "It helps to anchor the UK presence in ESA, and ESA in the UK. It strengthens our mutual bonds and our relationship for the long term." Parker added: "This is not a short term goal. This is about growing the whole of the European space sector together."

For more on Harwell, see issue 37 of *space:uk* – available on the UK Space Agency website.

Technology developed for space can have many benefits for people on Earth **Credit:** ESA

Training for space

ESA astronaut Major Tim Peake is busy preparing for his first long-duration mission to the International Space Station in 2015.

“There’s a lot to do,” said a delighted Peake, speaking after the announcement of his mission. “I have to become trained to a higher level on the American segment of the Space Station - so that’s the American, European laboratory and Japanese laboratories. I also have to be trained on the Russian segment, and in addition to that, on the Canadian robotic arm.”

“This is a landmark moment for Britain and our reputation as a leading science nation,” said Minister for Universities and Science, David Willetts. “Not only will we have the first UK astronaut for over two decades, but Tim will be the first ever Briton to carry out ground-breaking research on the International Space Station.”

The British astronaut is working with the UK Space Agency to build a strong science programme and develop UK research carried out in weightlessness, or microgravity. “With our new investment in the International Space Station and Europe’s microgravity programme,” said UK Space Agency Chief Executive David Parker, “his flight in 2015 could help expand our international competitiveness in areas such as health and ageing research, innovative materials and plasma physics.”

The UK Space Agency has increased its funding for the European Space Agency (ESA) to £240 million per year, including a £16 million contribution to the Space Station. This investment is expected to secure some £1 billion back in orders each year for British businesses.

"It is a great sign of our thriving British space sector,” said Prime Minister David Cameron, “which has seen real growth thanks to our world-class research, and now supports nearly 30,000 jobs.”

Pressure

Communications during any spacewalk will be done in Russian and so Peake, who has a degree in flight dynamics and was selected for the European Space Agency astronaut corps in 2009, will continue to maintain his Russian language skills as well as his physical fitness.

“Our fitness training will be monitored during the next two and a half years and also during spaceflight and post flight,” said Peake. “The data can all be analysed to see if there are any changes in how we performed before, during and after the mission.”

Peake will also take part in a European educational outreach programme and admits that expectations are high after the media success of the recently retired NASA astronaut Commander Chris Hadfield.

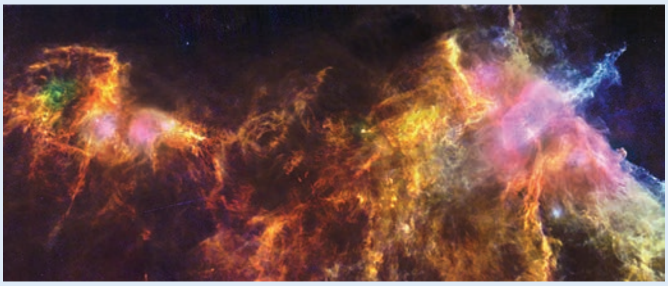
“It does put a certain amount of pressure on you, yes, without a shadow of a doubt,” laughs Peake. “But having said that he [Hadfield] has just done a fantastic job, not just in his educational outreach to the public and getting them enthused again about human spaceflight – from viewing their planet from the pictures and watching him doing experiments – but also as a commander of the space station. He set the bar very high but I thrive on the challenge so I will look forward to it.”

Tim Peake with the Prime Minister at Downing Street, following the announcement of his flight **Credit:** UK Space Agency

Space telescope switched off

At 12.25 GMT on 17 June 2013, the final command was sent to Europe's Herschel space observatory, sending the spacecraft into a long, slow orbit around the Sun. Herschel was the largest and most powerful infrared telescope ever built. During its highly successful four-year mission, the spacecraft produced a wealth of scientific information on the origin and evolution of stars and galaxies. One of the main instruments on the spacecraft – SPIRE – was led from the UK.

The last command issued to Herschel marked the final step in a complex series of manoeuvres designed to shut down the spacecraft's systems and take it into a safe disposal orbit. Although the mission has now come to an end, the data and images produced by Herschel will continue to generate new scientific results for many years to come.



Herschel's view of the Horsehead Nebula **Credit:** ESA

New UK and US partnership

The UK Space Agency is to team up with NASA on three forthcoming space science missions. The first of these, Sunjammer, will be propelled by the largest solar sail ever constructed and will carry two UK instruments. British scientists will also be working on NASA's Mars mission, Insight, which will investigate Martian geology. NASA will partner with the UK and Europe on the Solar Orbiter mission to investigate the Sun's polar regions.

Space harpoon

An international meeting has concluded there is an "urgent need" to remove some of the 30,000 or so bits of space junk orbiting the Earth to avoid potentially dangerous collisions. This material ranges from metallic fragments and an astronaut's glove to old satellites and spent rocket bodies.

Katherine Bennell with her demonstration harpoon **Credit:** Boffin Media

Astrium UK presented a number of ideas at the ESA Space Debris conference, including a concept for capturing objects with a specially designed harpoon and pulling them out of orbit. Astrium engineer Katherine Bennell has been testing this system at the company's Stevenage site by firing a harpoon at a revolving mock-up of a spinning satellite. "The best way to get rid of the debris and reduce the risk," said Bennell, "is to take the big targets away."

Giant satellite ready

Alphasat, the world's most sophisticated commercial communications satellite, is due for launch on an Ariane 5 rocket at the end of July. The mission is a partnership between ESA and UK satellite operator Inmarsat and will be the first flight of Europe's powerful new Alphabus satellite platform.

Alphabus is the heart of the satellite, providing all the core systems such as power and propulsion. It has the potential to support a wide range of commercial payloads for broadcast, broadband or mobile communications services.

Designed and built by Astrium, the Alphasat satellite is larger than a double-decker bus and weighs in at over 6.5 tonnes. It carries advanced communications hardware that will provide improved services for Inmarsat's mobile broadband customers across Europe, Africa and the Middle East. Advanced processors and a massive 11-metre reflector are key elements of the system that adjusts transmission frequency and power across multiple beams, enabling it to respond efficiently to demand.

"If there is a new technology in telecommunications space satellites, we probably have it in this satellite," said Ruy Pinto, Inmarsat's Chief Technology Officer.

Alphasat will be used by Inmarsat to enhance its global communications network and, as well as proving the capabilities of Alphabus, it is also being employed by ESA to test new space hardware. This includes a laser communications terminal to investigate the feasibility of high-speed laser communication between satellites.

"It's a true European endeavour for ESA, Inmarsat and many countries that have participated in this programme", said Pinto.

Alphasat being loaded for its flight to Europe's spaceport in French Guiana **Credit:** ESA

Galileo gets closer

The first fully operational satellites for Europe's new satellite navigation system, Galileo, have come a step closer to flight. UK-company Surrey Satellite Technology Limited (SSTL) has delivered the first four payloads for the satellites to the prime contractors, OHB, in Bremen, Germany. These payloads form the heart of the satellites, containing the highly accurate atomic clocks that are used to generate the navigation signal.

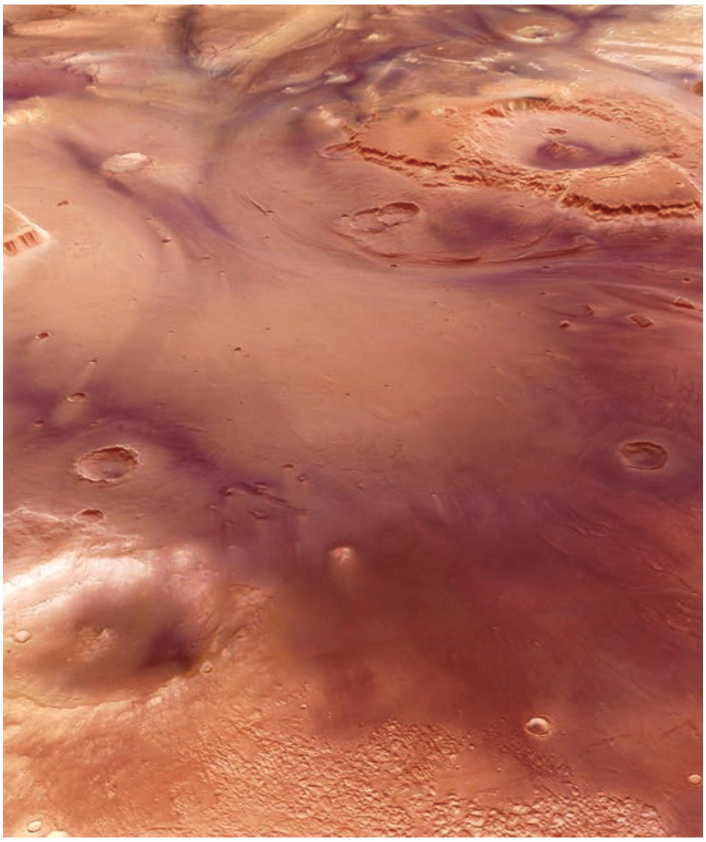
When the Galileo system is complete, it will be able to position objects down to a metre or less – much better than the accuracy that GPS offers today. It will operate alongside GPS and the Russian Glonass systems and work with most new, and some existing, receivers. The satellites will also carry a search and rescue system to provide a fast emergency response for ships or planes in distress.

Galileo will also be the world's first civilian-controlled satellite navigation system – developed by ESA, it will be managed by the European Union. The full Galileo satellite constellation will contain a total of 30 satellites, with 27 in operation at any one time. This also includes four In-Orbit-validation satellites, which are currently in operation and being used to test the Galileo system. SSTL is contracted to build the payloads for 22 satellites.

"This is an exciting step towards completion of the Galileo constellation," said Matt Perkins, CEO of SSTL. "The team has worked tirelessly to achieve this delivery success."

Working on the Galileo payloads at SSTL **Credit:** SSTL

Mars milestone



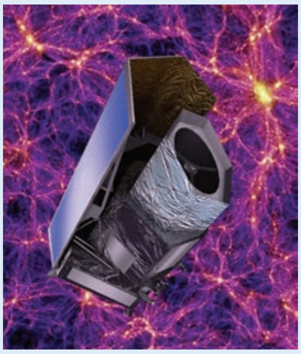
This Mars Express image, showing an area where water once flowed, is on a vast scale – the large crater towards the top right is 100 km across **Credit:** ESA

ESA's mission to the red planet, Mars Express, has just celebrated its tenth anniversary. The spacecraft was launched in June 2003 and has been in orbit around Mars since Christmas of that year. Over the last ten years, Mars Express has sent back stunning images and provided a new insight into the planet's surface, atmosphere and past climate.

Highlights of the mission include evidence for volcanic and glacial activity on Mars, from early in the planet's history until relatively recently. An examination of the surface has also provided evidence for a history of water on Mars and radar sounding has revealed underground ice. Water is considered essential if there is to be any chance of finding signs of life. The spacecraft may also have detected methane in the atmosphere. This could be an indicator of volcanic activity or even suggest there is still life on Mars.

UK science and industry teams continue to play an important role in the Mars Express mission. Britain also built the Beagle 2 probe, which was designed to drill into the surface to look for signatures of life. Unfortunately, no signals from Beagle 2 have been detected since it left the Mars Express spacecraft in December 2003 to begin its descent to the Martian surface and its fate remains unknown.

Dark matters



Euclid is being designed to reveal the hidden Universe **Credit:** ESA

ESA has awarded Astrium, Europe's largest space company, the payload module contract for the Euclid mission. Euclid, due for launch in 2020, will map the shape, brightness and distribution of two billion galaxies, shed light on the roles played by dark matter and dark energy and aim to explain why the Universe is accelerating at an expanding rate.

UK space scientists are playing a number of key roles in this six-year mission. Eight UK universities are collaborating on a computer simulation of the Universe to help with planning. University College London's Mullard Space Science Laboratory is leading the design and building of the spacecraft's huge optical digital camera, e2v is supplying a new image sensor and the UK has the science lead on one of the main instruments.

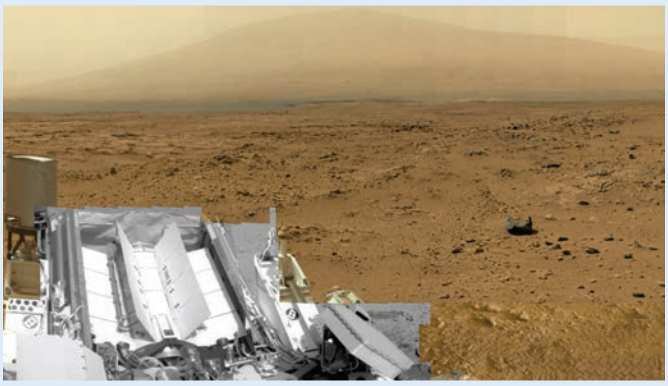
The payload module will carry the telescope and the scientific instruments and Astrium is now waiting to confirm if some of the spacecraft will also be built in the UK.

Fighting locusts

A UK-built satellite is being used to help fight locust plagues in North Africa. The Algerian Space Agency is using images from the UK-DMC2 satellite, provided by DMC International Imaging, to help predict and monitor the threat of these destructive insects. Every year, North Africa is subjected to locust plagues that threaten to decimate crops and endanger food security. Satellite data will help authorities combat locust swarms before they can migrate across the continent.

Mars money

The UK Space Agency has awarded more than £900,000 to UK researchers for science associated with Mars exploration. This new funding is aimed at scientists working on current and future missions to Mars, including NASA's Curiosity rover and ESA's ExoMars. Awards have gone to several projects, including studies into detecting organic molecules on the red planet and efforts to reconstruct Martian weather and climate.



The Curiosity rover is currently exploring Gale Crater **Credit:** NASA

Green light for BIOMASS

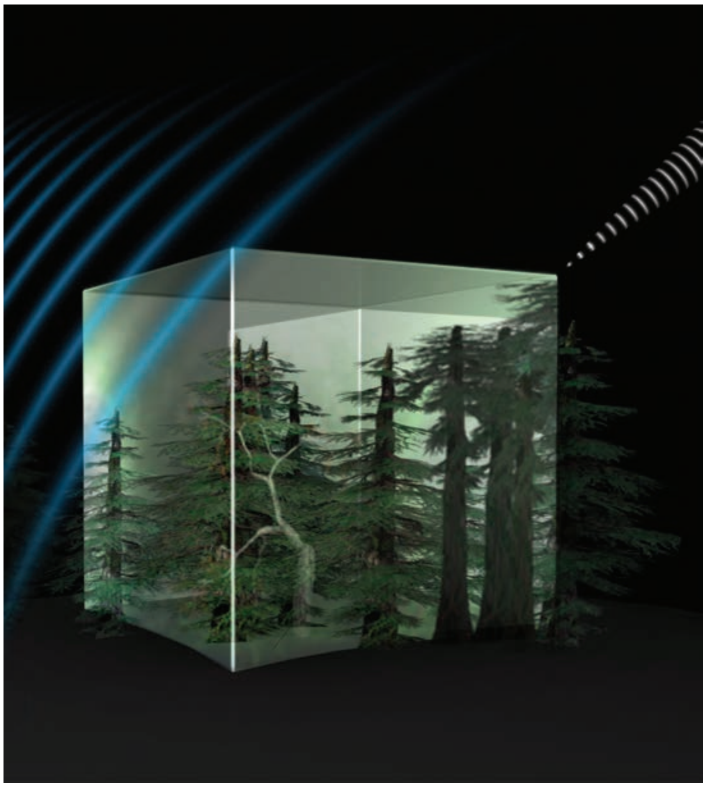
A mission to discover the amount of carbon and living material, or biomass, stored in the Earth's forests has been approved for launch in 2020. UK space scientists helped conceive ESA's BIOMASS satellite, which will measure vegetation with unprecedented accuracy.

"Understanding how the biomass in our global forests changes over time is necessary for improving present and future assessments of our climate," said one of the mission's principal investigators, Shaun Quegan, from the University of Sheffield.

"As trees grow, they take in carbon and store it," explained Quegan. "But during deforestation this carbon is released into the atmosphere. This is just one way carbon cycles between different storage sites and as this global carbon cycle becomes unbalanced more carbon is being released from storage into the atmosphere, ultimately affecting our climate."

It is hoped that the mission will contribute to the United Nations' REDD programme, an international effort to reduce carbon emissions from deforestation in developing countries. BIOMASS measurements will also provide information on geology in arid regions, permafrost, salinity of the sea surface, glaciers and ice sheets.

The £340 million mission is expected to run for up to five years and will be the seventh of ESA's Earth Explorer satellites, designed to investigate the planet's environment.



The BIOMASS mission will be able to measure the mass of the Earth's forests **Credit:** ESA

Go for Gaia

Gaia's skirt or Deployable Sunshield Assembly being tested **Credit:** ESA

UK scientists are preparing for the launch of the Gaia mission. The spacecraft, which will produce a three-dimensional map of our galaxy, recently completed a series of tests ahead of its planned launch in October.

The UK is heavily involved in Gaia, which contains two optical telescopes and three scientific instruments. Astrium UK in Stevenage made the guidance and control system and supplied the computers that will process all the data. The mission also involves SciSys and e2v. The UK Space Agency funds a number of UK institutes working on Gaia including the Open University, universities at Cambridge, Leicester and Edinburgh, the Rutherford Appleton Laboratory and the Mullard Space Science Laboratory.

Once launched, this unique spacecraft will unfold a 10 metre diameter 'skirt' that will shade the telescopes. This Deployable Sunshield Assembly also includes solar panels to generate power. Using sensors with around one billion pixels, Gaia will then chart the position, distance, movement and changes in brightness of every star in the Milky Way. The mission, which will generate a wealth of new scientific data, is expected to discover new planets, asteroids and supernovae.

Train like an astronaut

This year's Mission X came to a dramatic end, when schools taking part in the hugely popular science, education and fitness programme got to see their teachers experience the g-forces on the human body of a ride into space. Students from three Mission X schools – Kingswinford in Dudley, Northbury in Barking and Dagenham and Mountfitchet Mathematics and Computing College in Essex – completed the scheme by visiting the long arm centrifuge at QinetiQ's facilities in Farnborough to witness demonstrations of how astronauts train for launch and landing.

Teachers were among the participants being spun in a pod at the end of a centrifuge arm. Students monitored the teacher's health and performance. The pupils also had the opportunity to meet a range of space experts to discuss the rigours of astronaut training.

Mission X: Train Like An Astronaut is a free international six-week challenge, supported by the UK Space Agency. Aimed at 8-12 year olds, it is designed to bring the excitement of space exploration to schoolchildren through physical and educational activities. Teams of students learn the principles of healthy eating and exercise, compete for points by finishing training modules and get excited for their own educational possibilities.

"Once again, Mission X has been a fantastic success in the UK and across Europe," said British ESA astronaut Tim Peake. "Let's continue to inspire the next generation with fun science, healthy eating and good exercise."

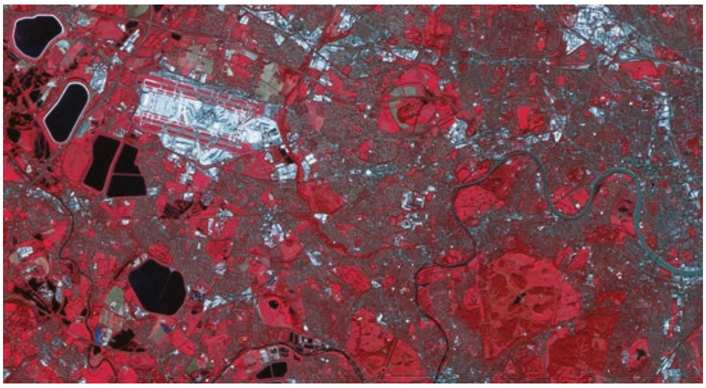
Around 7000 children from 110 schools took part in the programme this year and, although the 2013 challenge has come to an end, schools can register for the class of 2014 via the UK Space Agency website.

Students monitoring the performance of their teacher, seen here on CCTV strapped into the QinetiQ centrifuge **Credit:** Michael Cockerham

The UK from space

Satellites have transformed our view of the Earth. They enable us to track weather fronts or the spread of fires and pollution; the extent of development, forestry and agriculture. Space technology has allowed us to see our planet as a blue, white and green oasis against the blackness of the cosmos. From our smartphones, we can see continents and countries, even pinpoint where we live.

To celebrate the 2013 UK Space Conference, we have collected together some recent images of the UK and Ireland taken from space. We have even found a picture that shows (most of it) without cloud cover:

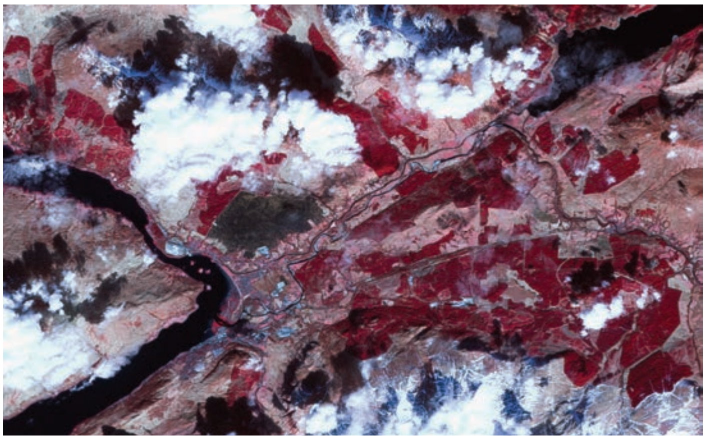


Heathrow Airport seen by British-built satellite, UK-DMC2 **Credit:** DMCii

This Envisat image shows the green swirls of a phytoplankton bloom in the North Sea off the coast of Scotland **Credit:** ESA

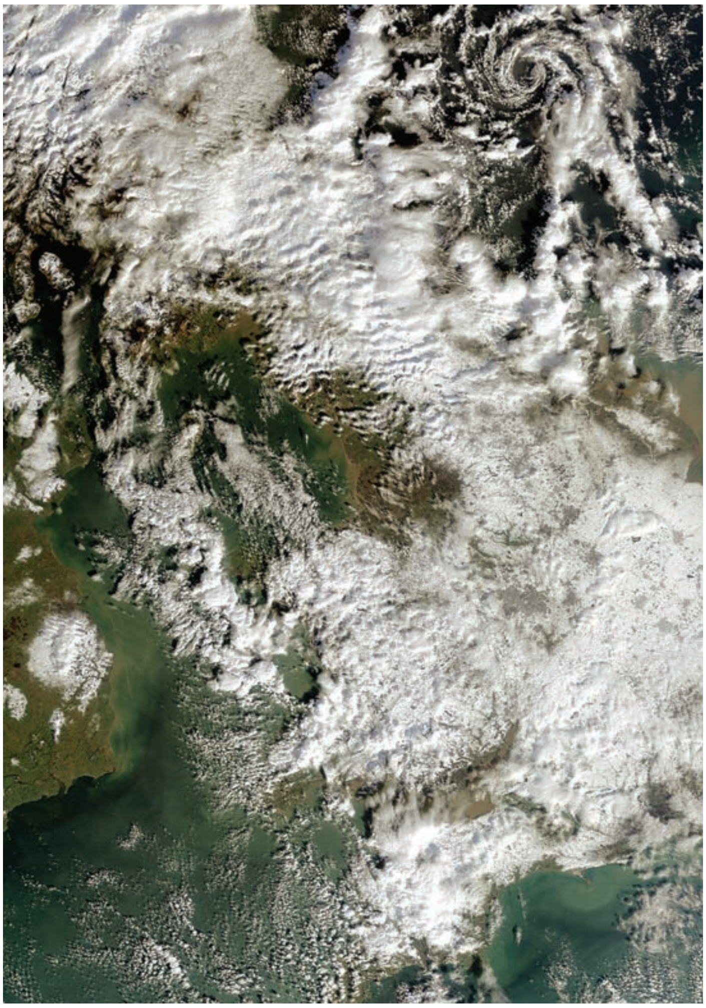
The Olympic Park in London just before the games opened, taken by NigeriaSat-2 **Credit:** DMCii

Cloud free images of the UK from space are extremely rare and, unfortunately, this one does not show all of Scotland. It was captured by Envisat and is one of the last images the ESA satellite sent back to Earth before the mission ended **Credit:** ESA

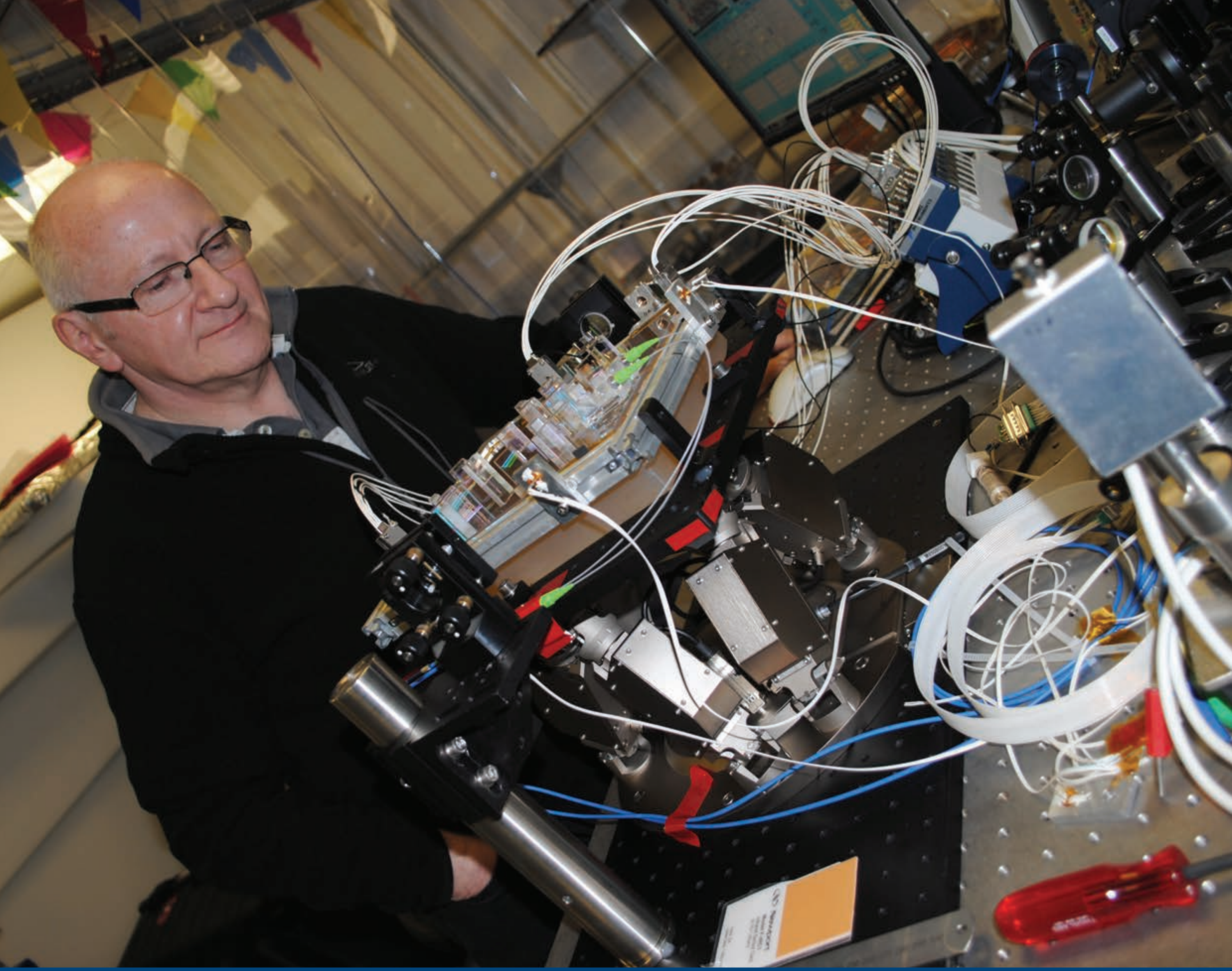


UK-DMC2 image of wildfires near Fort William in western Scotland **Credit:** DMCii

A picture of the UK at night taken by ESA astronaut Andre Kuipers from the International Space Station **Credit:** ESA



A more typical view of the UK from space – seen here covered in cloud and snow **Credit:** ESA



Glasgow in space

Image above: Harry Ward with the test version of the instrument that is being fitted to LISA Pathfinder **Credit:** UK Space Agency, Boffin Media

From building small satellites to developing solar sails and solving the big mysteries of the Universe, as Richard Hollingham discovers, it is all happening in Glasgow:

Cordoned off in the corner of the laboratory at Clyde Space's offices on the outskirts of Glasgow, a small, black, rectangular box sits upright on a table. Around 30cm high and 10cm across, it has four wires, covered in plastic drinking straws, protruding horizontally in a cross shape from the top. Signs posted nearby warn people to keep back. There is a good reason for this. The box is UKube-1, a small satellite with tremendous potential. And right now it is transmitting.

"We're still testing it," says Craig Clark, the CEO of Clyde Space, "just to make sure that everything's okay." In case you were wondering, the straws are there to hold the antennae in place in Earth's gravity.

Small satellites

UKube-1 has been built by Clyde Space for the UK Space Agency and is a CubeSat – a satellite based on standard 10cm cubed units. CubeSats are a lot cheaper to build and launch than traditional satellites and UKube-1 is a pilot project for a possible larger CubeSat programme. Cyde Space already supplies CubeSat components to companies around the world but UKube-1 is the company's first complete satellite.

The spacecraft may be a fraction of the size of traditional satellites but it includes instruments from industries and universities across the UK. Each of these is packed with innovative features and has been specially designed for this mission. Together they add up to a powerful satellite.

"People look at CubeSats and say 'they're so small, clearly not as advanced as larger satellites'," says Clark. "But if you think about it, the satellite still gets launched into space so it has to survive the launch, it has to survive the extremes of space and it also has to do all the things a larger satellite does – the communications, power management, onboard computing."

Experimental payloads on board UKube-1 include a GPS device aimed at measuring space weather conditions, developed by the University

Image bottom left: Craig Clark outside the Clyde Space clean room, with UKube-1 under test in the background
Credit: UK Space Agency, Boffin Media

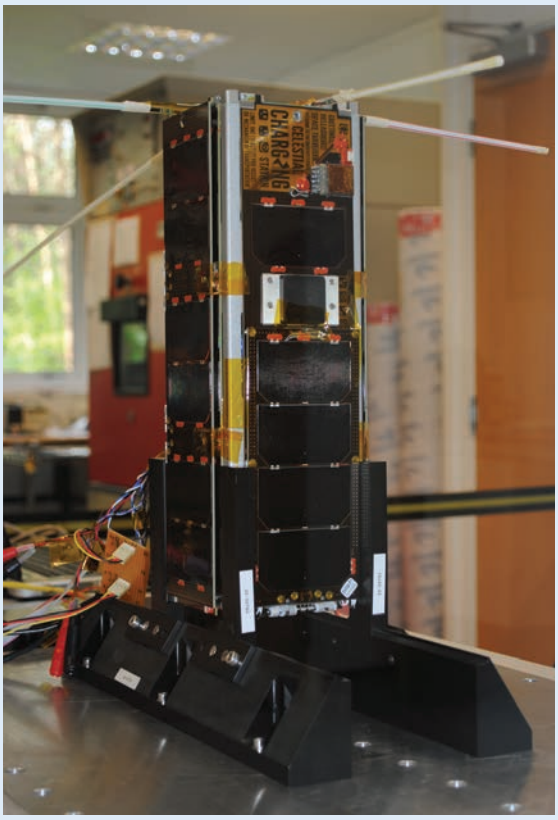


Image top right: UKube-1 seen through the clean room glass at Clyde Space, note the drinking straws sticking out from the top
Credit: UK Space Agency, Boffin Media

of Bath, and a new space sensor built by the Open University. Astrium UK has contributed an experiment designed to demonstrate the feasibility of using cosmic radiation in orbit to generate random numbers in satellites. Random numbers form a crucial part of secure communications systems. The satellite also carries a transmitter and materials science experiment developed by volunteer members and friends of AMSAT-UK, which will allow schools to be involved in the mission.

"I think there's a big future for space in Scotland"
Craig Clark
Clyde Space

UKube-1 is due for launch later this year and will become the first satellite to be made in Scotland. "I see us providing a complementary offering in the UK," explains Clark. "Where you've got your Astriums who can build massive satellites, SSTL who does the washing-machine sized satellites and we can do the tiny satellites. Hopefully it's a UK PLC effort to dominate the world in satellites!"

Big science

There is clearly no shortage of ambition at Clyde Space. The same can be said of the scientists a few miles down the road at the University of Glasgow, who are working on missions designed to tackle fundamental questions about the nature of the Universe. Here, in a cramped and windowless lab, Harry Ward, David Robertson and their team have been building a key component of LISA (Laser Interferometer Space Antenna) Pathfinder. This ESA mission is designed to test technology for a future mission to investigate gravitational waves.

continues >

Glasgow in space
continued

Top image: LISA Pathfinder under construction at Astrium in Stevenage
Credit: Astrium

Bottom Image: Harry Ward (left) and his colleague David Robertson in their lab at the University of Glasgow
Credit: UK Space Agency, Boffin Media

Gravitational waves are ripples in the fabric of space-time. They are predicted by Einstein and permeate out from some of the most violent events in the Universe, from exploding stars to colliding black holes. Unfortunately, no one has yet experimentally proved they definitely exist.

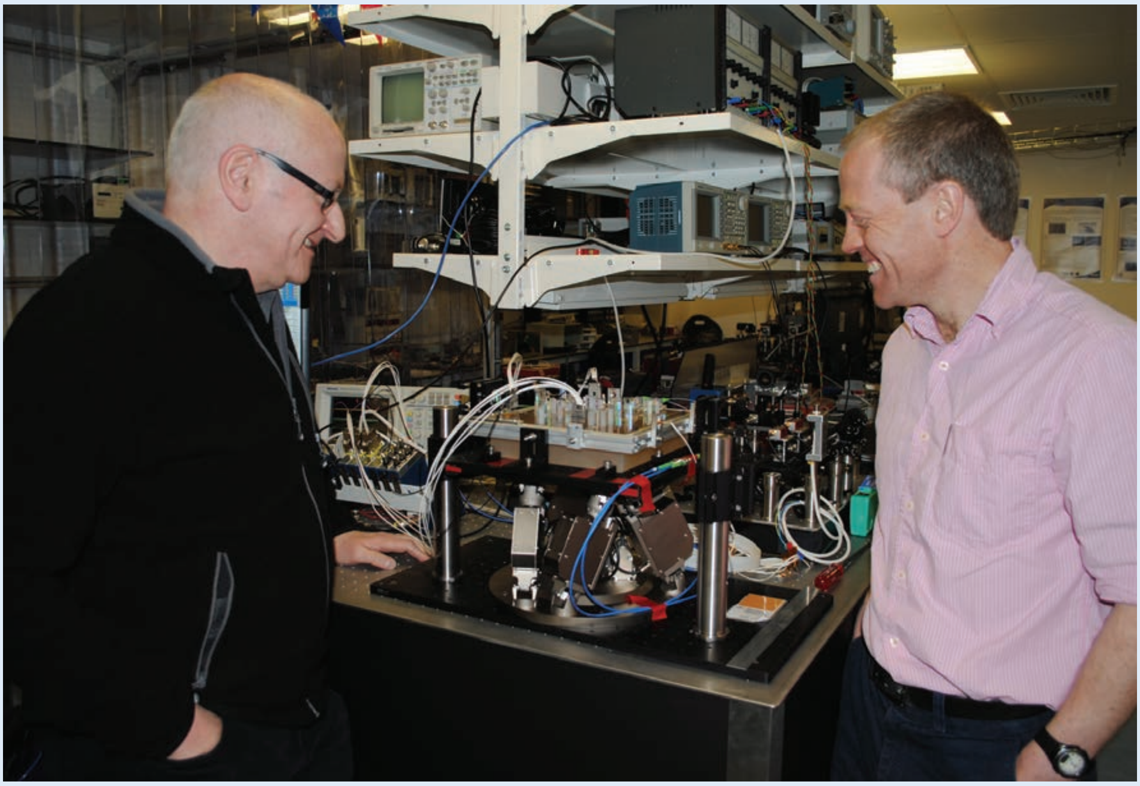
"Gravity is really the master of the Universe," says Ward. "It's what controls the Universe on the grandest scales." And, as we chat, surrounded by shelves of computers and test equipment, he explains that gravity waves are passing through the Earth all the time. "You are being stretched and squeezed as we speak, fortunately the effect is extremely weak so it's not something that's going to worry you!"

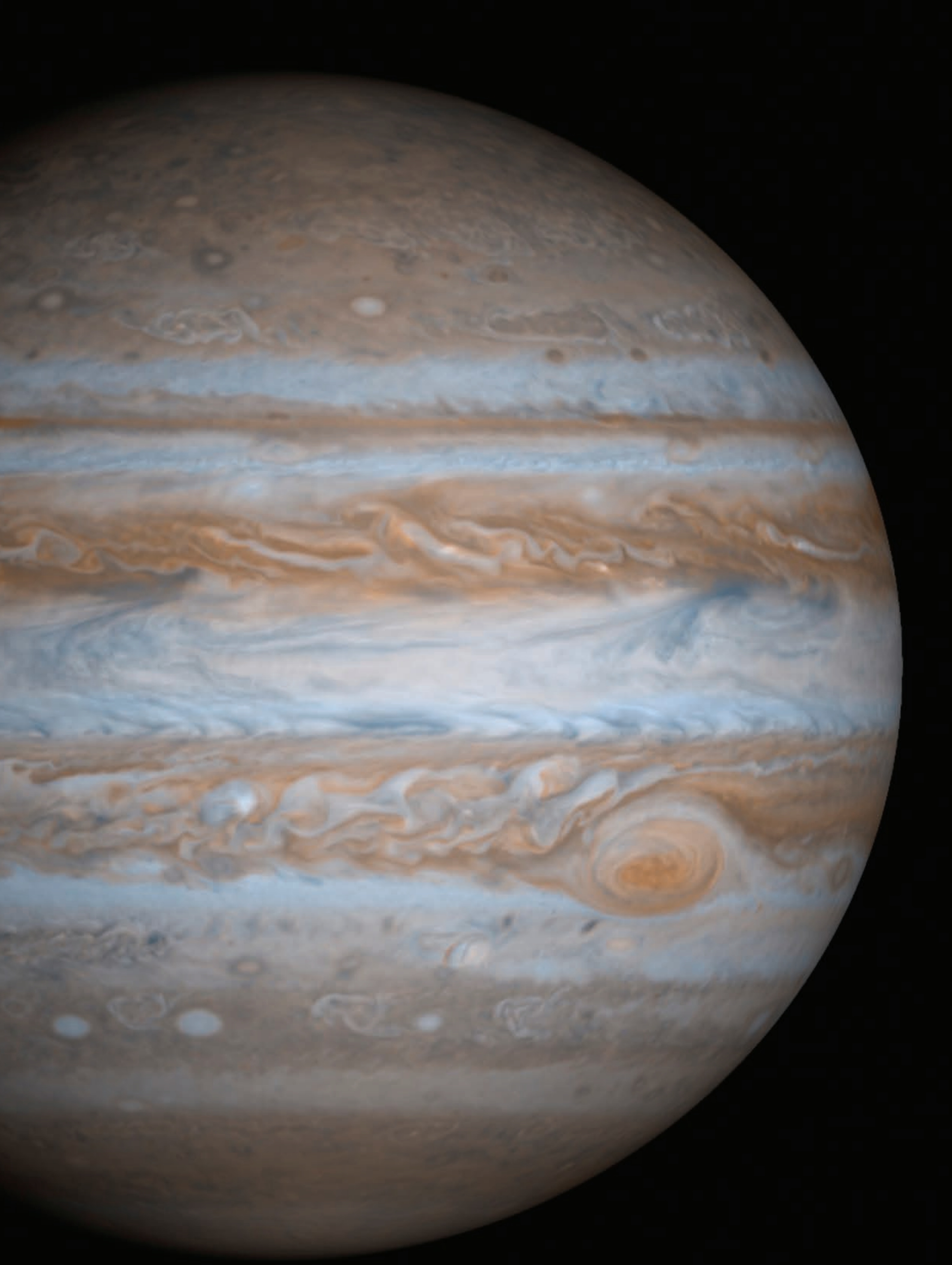
Scientists are interested in studying gravitational waves not only to prove they exist but to investigate the Universe in even greater detail. "The gravitational processes which orchestrate the Universe are invisible to us other than through detecting gravitational waves," says Ward. "Gravitational wave astronomy offers a completely new way of probing the Universe."

Stepping stone

However, because they are so weak, measuring gravitational waves is extremely challenging. The eventual, and ambitious, aim of European physicists working on this problem is to launch three spacecraft, a million kilometres apart. Each would contain a free floating test mass and the idea is to detect any movement between these masses, movement that could only be caused by these ripples in space-time. The masses therefore need to be shielded from all other sources of interference – from movement of the spacecraft to stray electrical charges – and measurement, over vast distances, needs to be accurate to within a millionth of a metre.

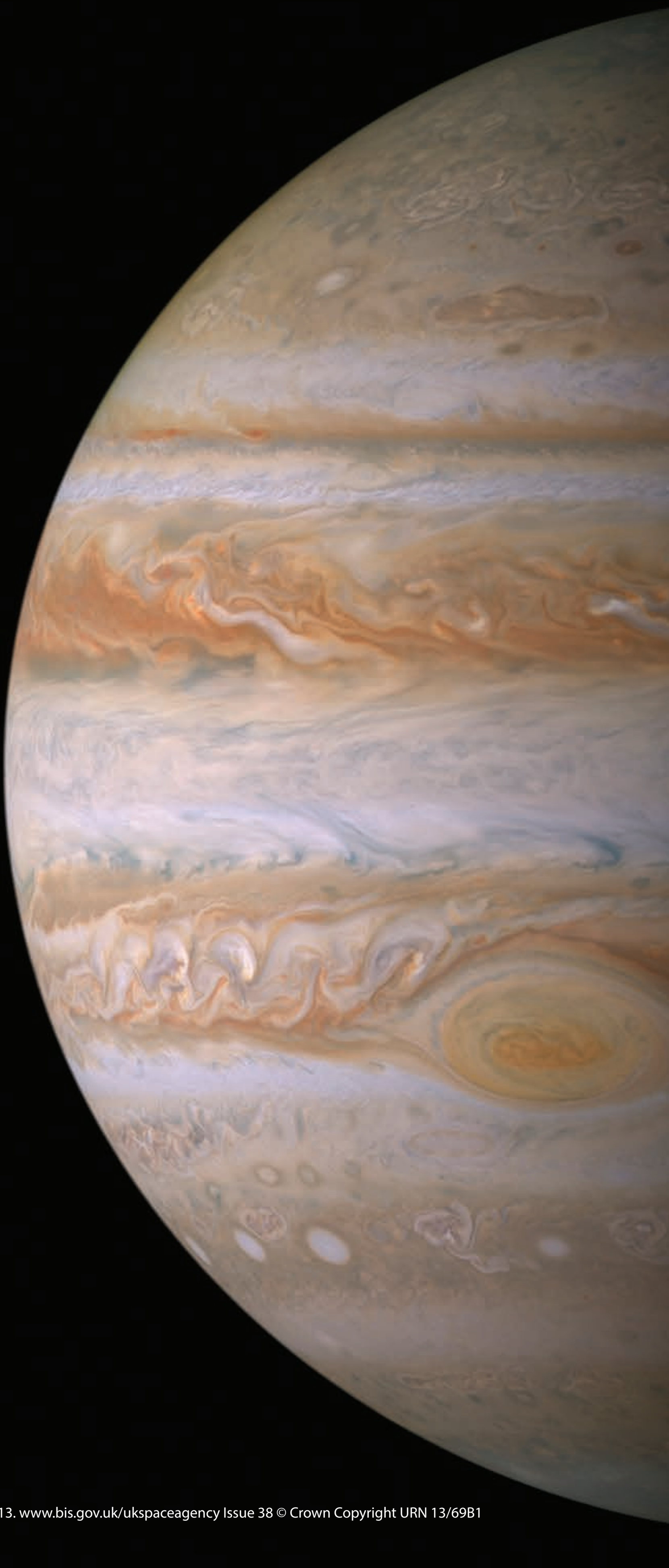
"We started as tabletop physicists and now we're spacecraft engineers – that's been a steep learning curve"
Harry Ward
University of Glasgow





The Cassini spacecraft captured this image of Europa passing in front of Jupiter **Credit:** ESA, NASA

Giant J



Jupiter is the largest planet in our Solar System. In fact, you could fit 11 Earths side by side across its diameter and a staggering 1,321 Earths inside its volume. Jupiter shines brighter than most stars and sports distinctive orange and white stripes. These stripes are clouds, which can also be yellow, brown or red depending on the chemicals in the atmosphere. The large cloudy storm in the southern hemisphere is known as the Great Red Spot. It is over 32,000 kilometres across.

Commonly referred to as a gas giant, Jupiter is mostly made up of hydrogen and helium. But while these elements are gases on Earth, they are squeezed into a liquid on Jupiter because of the enormous pressures inside the planet. The surface is gaseous so there is no solid surface for a spacecraft to land on.

Jupiter currently has over 60 known moons with the four largest being discovered in 1610 by Galileo. They were named Io, Callisto, Ganymede and Europa.

Missions to Jupiter include Ulysses, en route to observe the Sun's poles, and Cassini during its highly successful (and ongoing) mission to Saturn. Galileo was the last dedicated mission to Jupiter, arriving in orbit in 1995. ESA's forthcoming Juice mission is due for launch in 2022.

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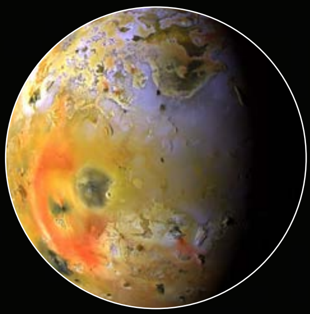
Jupiter

Io

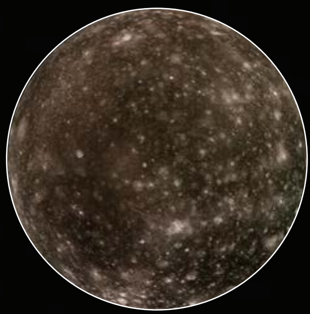


Credit: NASA

Io is a violent and fiery world of volcanoes and molten lava. Not much larger than our own Moon, it is the most volcanically active body in our Solar System. Its yellow hued surface reflects different forms of sulphur spewing out from huge plumes of toxic gases. Tidal forces on Io cause its surface to bulge inwards and outwards, generating heat that keeps most of its subsurface crust liquid.

Callisto

Callisto is an ancient moon heavily pockmarked by craters and covered in a crust of icy rock. Similar in size to Mercury, this world orbits beyond Jupiter's main radiation belts and its surface age, of around 4 billion years, makes it one of the oldest landscapes in our Solar System.



Credit: NASA

Ganymede

Credit: NASA

The largest moon in our Solar System, Ganymede is bigger than the planet Mercury. It has a metallic iron core, a rocky mantle and an outer shell of mostly ice. Ganymede is also the only moon known to have its own magnetic field and, beneath its icy surface, there is evidence for water. This makes it a possibility for life although its thin oxygen atmosphere could not support life as we know it.

Europa

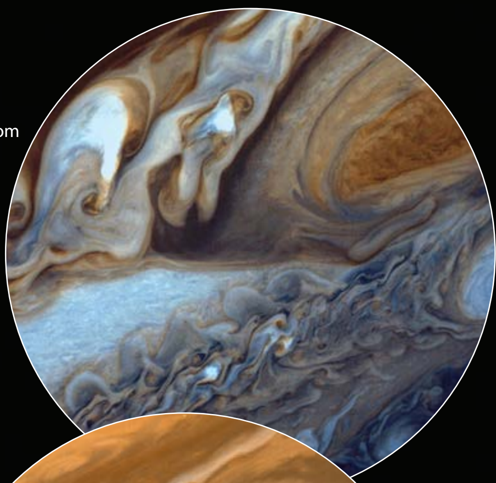
Europa is slightly smaller than Earth's Moon and has an icy surface. There is evidence that, beneath this crust, there are liquid water oceans – increasing the chances for life. Tidal heating below the moon's crust is thought to have caused cracks in the surface making Europa warmer than expected and a potential candidate for life, in the form of simple organisms, in its oceans.

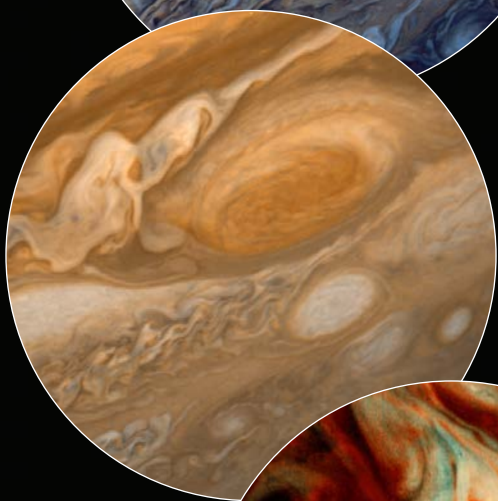
Credit: NASA

Jupiter

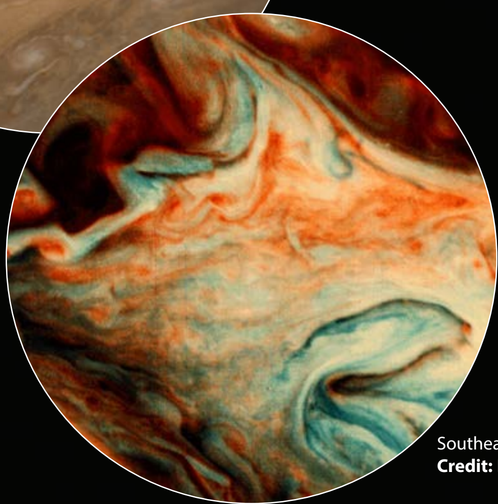
The largest planet in the Solar System, Jupiter has no solid surface and is known as a gas giant. The planet has four large moons, including icy moons where there may be liquid water and even the possibility of life.

Swirling clouds around Jupiter's Great Red Spot. This image was assembled from Voyager 1 images **Credit:** NASA





Jupiter's Great Red Spot **Credit:** NASA



Southeast of the Great Red Spot on Jupiter **Credit:** NASA

UK SPACE AGENCY

The complexities of that mission are so vast, and the technology untested, that a stepping stone mission was proposed and that is what LISA Pathfinder is all about. This mission will fly a short version of a single LISA arm - two free-floating masses separated by around 40cm. It is designed to prove that the LISA concept is feasible.

Funded by the UK Space Agency, LISA Pathfinder involves several British teams and the satellite itself is taking shape at Astrium in Stevenage. At the University of Glasgow, they have been working on the laser instrument to measure the relative movement of the masses. The result is a briefcase-sized box, which is ready to be integrated into the spacecraft.

"It's taken a large effort," admits Ward. "We started as tabletop physicists and now we're spacecraft engineers – that's been a steep learning curve." And although this mission is designed to investigate big cosmic questions, the immediate benefits may be closer to home.

"You have to look at the technologies that are developed and whether they have applications elsewhere," says Ward. "Other interested parties see what we've done and are now suggesting that perhaps our techniques could be applied to their industrial applications."

So understanding a fundamental of the Universe could make some money? "Absolutely," Ward agrees. "The space business in the UK is one of the things that's growing apace. When you're pushing the frontiers, that's when new technologies pop-up and you can be sure they will have applications as time goes by."

Solar sails

New applications of space technology are also being investigated across the city at the University of Strathclyde. As well as working with Clyde Space on UKube-1, Engineers at the University's Strathclyde Space Institute have projects with the UK's new Satellite Applications Catapult at Harwell (see page 2). "We are trying to make the connection between the space sector and energy sector – an important sector for Scotland," says Colin McInnes. "We are looking at using satellite data to measure wind speed and use that data to predict the output of offshore wind farms."

But as Director of the University's Advanced Space Concepts Laboratory, McInnes is also interested in looking ahead. "We're thinking into the future of new ways of using space, new applications of space."

One of these projects is the development of spacecraft propelled by solar sails. The idea is that spacecraft fitted with these sails would employ the stream of charged particles from the Sun – known as the solar wind – to push them along. "As sunlight reflects off the sail, it imparts a small kick to it," McInnes explains. "The pressure on the sail is tiny but in the vacuum of space, that's enough to propel the solar sail."

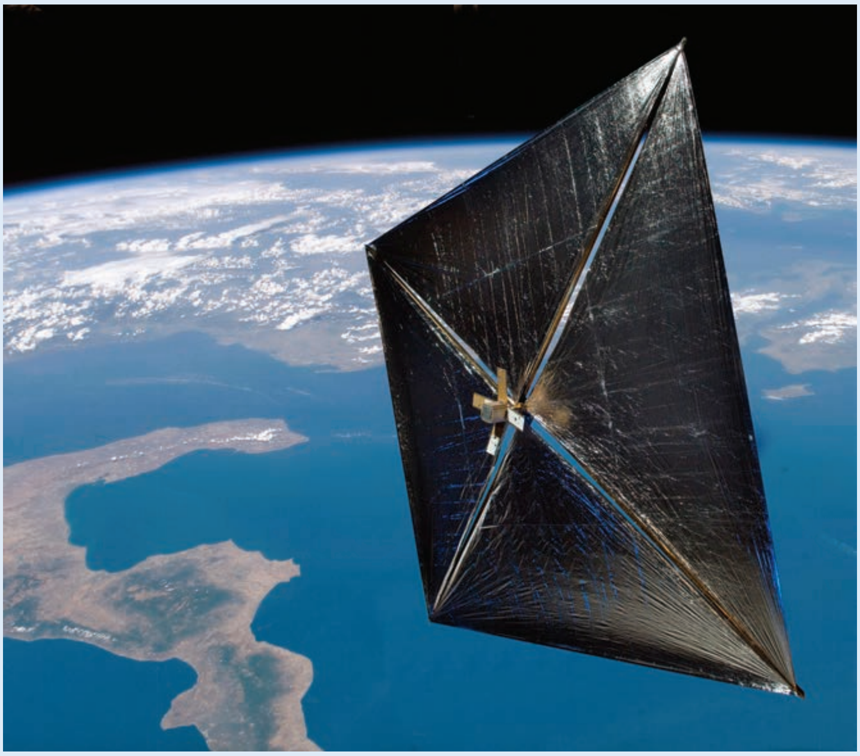
McInnes' team is currently working with US company L'Garde, helping develop the orbital mechanics of the NASA Sunjammer solar sail mission scheduled for launch next year. "Solar sails are a very effective means of propulsion, you don't have to carry any propellant, so you're not limited in the same way that conventional spacecraft are," he says. "In the future, solar sails could be used for long duration or high energy missions."

From the work on UKube-1 at Clyde Space, to the innovative technologies and concepts being pursued at the Universities of Glasgow and Strathclyde, it is clear that Glasgow is going to have a growing presence in the UK space sector. This burgeoning space industry in Glasgow complements the work being done at the United Kingdom Astronomy Technology Centre in Edinburgh and at other Scottish universities. Craig Clark agrees: "The combination of what we're doing at Clyde Space and what's going on at the universities, has catalysed the emergence of a new market."

"I think," says Clark, "there's a big future for space in Scotland!"

Bottom Image: Artist image of a solar sail mission
Credit: NASA

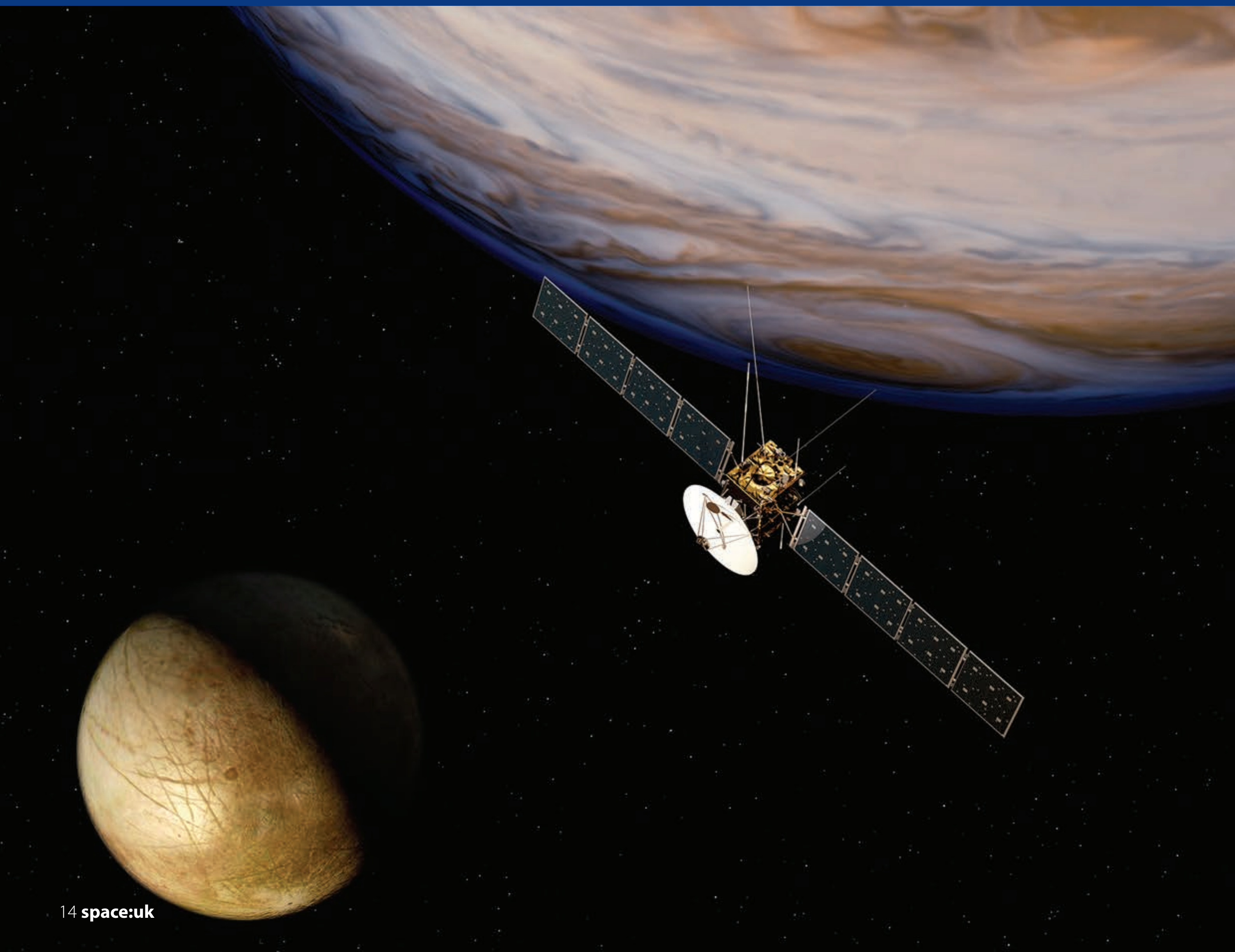
"People look at CubeSats and say they're so small, clearly not as advanced as larger satellites"
Craig Clark
Clyde Space



JUICE with ice

Artist's concept of the JUICE mission in orbit around Jupiter
Credit: ESA

Violet Berlin discovers why scientists are excited about ESA's new mission to the outer planets, seeking habitats that can support life:



"Every time we send a new probe out to Jupiter or Saturn we learn things that are not only interesting but completely unexpected," exclaims Lewis Dartnell, pausing to take a sip of his frothy coffee. Dartnell is a UK Space Agency Research Fellow working at the University of Leicester in the field of astrobiology. My local café feels too ordinary, too casual a setting to talk about a mission to the outer planets and life on distant worlds, but that's exactly what we are doing.

"We've got a lot of confidence in astrobiology at the moment," he tells me. "By studying the most extreme forms of life on Earth and how they survive, it helps us understand the survival limits of life in general, and what kinds of environments are sensible to talk about for expecting living things."

Home from home

One potential environment for life can be found far from Earth, on some of the satellites orbiting the outer planets of our Solar System. Jupiter, for instance, has at least 67 moons, and the three large, icy ones may well be habitable – Europa (the smooth one), Ganymede (the big one) and Callisto (the cratered one).

That is because, beneath their hard, cracked surface, these far-flung snowballs may well harbour the four 'conditions for life' sought by Dartnell and other astrobiologists: liquid water, an energy source, organic molecules and enough time for life to develop.

UK scientists have a track record in making discoveries in this area. Cassini mission scientist Michele Dougherty's group at Imperial College London has already discovered three of these ingredients on Saturn's icy moon Enceladus. I give her a call to find out more.

"What we found was there was heat leaking out from cracks at the South Pole, there was water vapour coming out, along with dust and organic material," she recalls. "Most surprising was that Enceladus was not a dead body. We expected that its interior would long have cooled down, but there is very clearly a heat source inside, which is heating the ice beneath the surface and keeping it liquid."

JUpiter ICy moon Explorer

The magnetometer instrument on Cassini that led to this discovery was built by Dougherty's team. She is now principal investigator on a new magnetometer for the European Space Agency's planned mission to the Jupiter system, the JUpiter ICy moon Explorer or JUICE. The name might be a bit odd, but the objective is staggering. JUICE will be the first mission ever to go into orbit around a moon at the outer planets. By the end of it, we will better understand if the conditions are right for life to form there.

"The critical science I'm interested in is related to the moons," says Dougherty. "There are almost certainly liquid oceans under their surfaces. We will measure the size of the electrical currents flowing in the ocean, which will enable us to resolve the depth and conductivity of the water. We want to know how the ocean might have formed, has it always been under the surface, and are there organic materials and salts leaking out from the rocky interior of the planet and into the water itself?"

The moons under scrutiny – Ganymede, Callisto and Europa – are three of the four satellites first spotted by Galileo back in 1610, the fourth was Io. When this cluster of worlds orbiting Jupiter came into view through his homemade telescope, it kicked off a revolution that forced the scientific and religious leaders of the age to admit that not everything revolves around the Earth.

"A two year old now could be a person doing a PhD when the spacecraft gets to Ganymede"

Andrew Coates
Mullard Space Science Laboratory

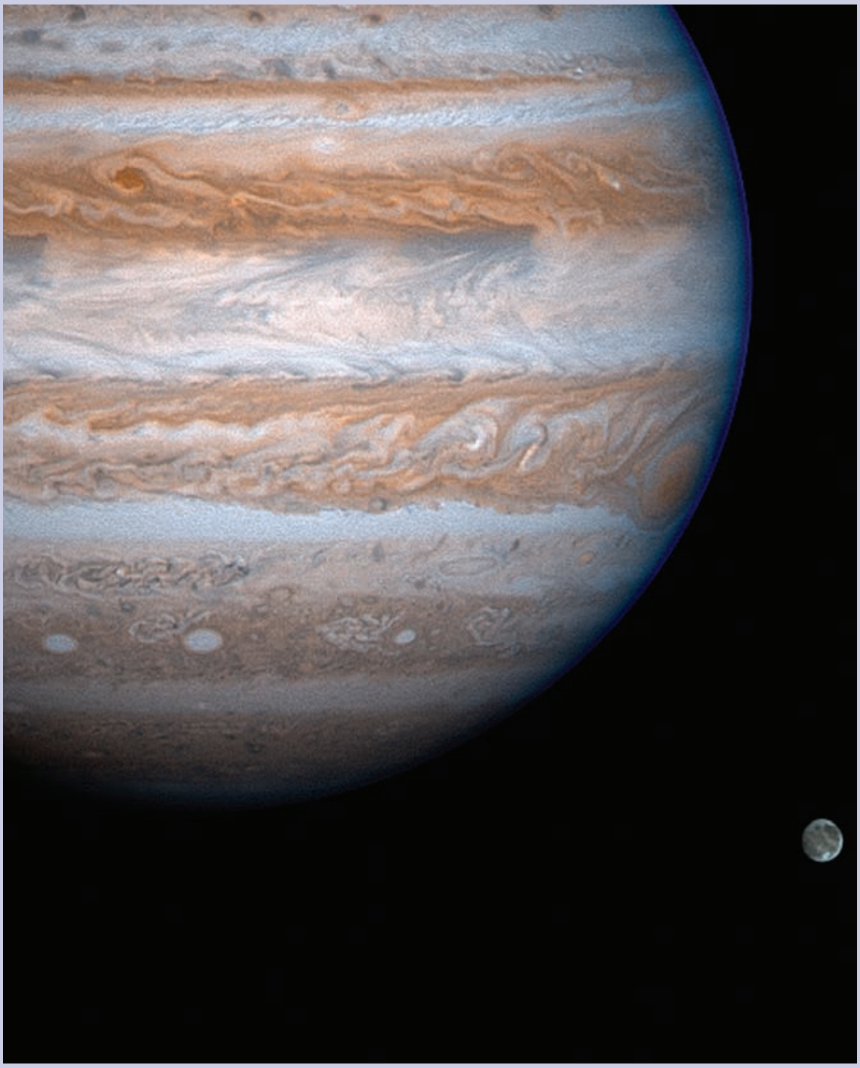
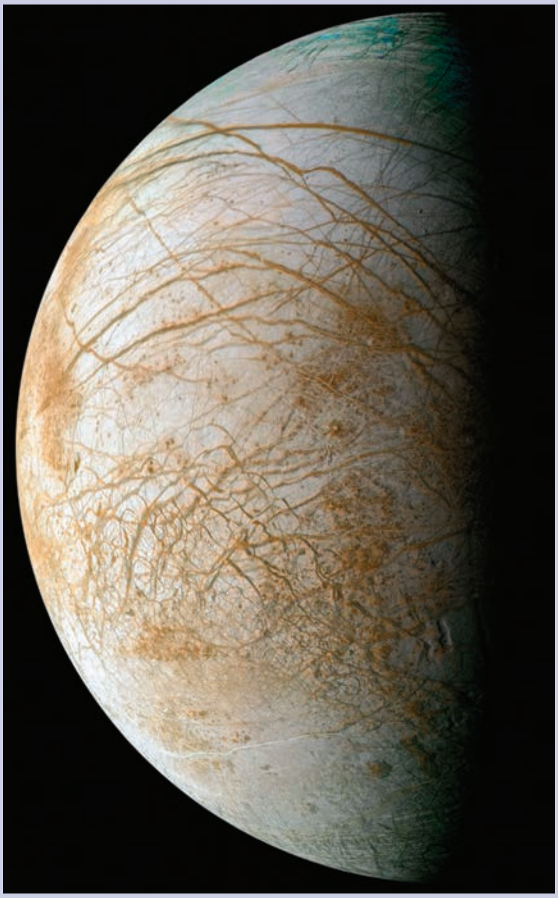


Image below: Jupiter and Ganymede seen by the Cassini spacecraft
Credit: NASA, ESA

JUICE with ice
continued

Top image: The cracked icy surface of Europa
Credit: NASA

Bottom Image: Ganymede is also covered in ice
Credit: NASA



Life, the Universe, and Europa

400 years later and Galileo's moons could, again, change how we see our place in the Universe. Pondering these big questions with me, Lewis Dartnell explains that while it is true we may not be alone in the Solar System, he is not expecting to find habitats that can sustain anything more complex than 'hardy bacteria'. He picks the closest icy moon to Jupiter, Europa, as the prime candidate to be the most 'habitable' of them all.

"It is smack bang in the middle of Jupiter's radiation belt, which could be crucial to keeping Europan life alive" Dartnell explains. "The radiation beating down onto the surface ice of Europa may be creating nutrients, mainly oxidants. So, it's like a solid atmosphere laced with nutrients which hopefully get washed down into the ocean below and help support life."

JUICE will perform two fly-bys of Europa, collecting data and scouting potential landing sites for a possible future mission. Lingering longer is not an option, due to the harmful effects of the radiation belt on the spacecraft's own systems. Instead, the craft will then perform fly-bys of Callisto, and Jupiter itself, before settling into orbit around Ganymede.

Potential for life?

One of these moons, or all three, could harbour the conditions for life in oceans of liquid water that lie beneath an icy shell:

Europa (the smooth one)

Like Earth, it has a salty ocean which lies on a rocky seabed.

Could be a geologically active world, driven by heat energy within.

Possible future destination for a probe to land and drill.

Ganymede (the big one)

Largest moon in the solar system (bigger than the planet Mercury).

Like Earth, it generates a magnetic field — protection from high energy rays.

Many water-rich planets outside our Solar System are like Ganymede

Callisto (the cratered one)

The many craters reveal how Jupiter and its moons were formed.

It is far from the pulling and squeezing tidal forces created by Jupiter's gravity.

Other rocky worlds have layers of different materials, but Callisto may be the same throughout.

JUICE is clearly a momentous mission, but perhaps let down by one small but highly visible aspect: its name. I return to Dougherty, who led the Science Definition team, for an explanation. "It's an awful name, an absolutely awful name," she laments. However, it may yet change. "At the moment we're in a 'definition phase' where the instrument and industrial contractors are studying whether we can fly JUICE on the timeframe and under the cost cap set by ESA. At the end of 2014 ESA will say 'okay, it's ready to go' and then we will be allowed to change the name."

Image top left: Much of what we know about Jupiter's moons comes from the Galileo mission. Here, the spacecraft is seen being deployed from the cargo bay of Space Shuttle Atlantis in 1989
Credit:

Image bottom right: A plume of material is ejected from Saturn's icy moon Enceladus, in this enhanced image
Credit: NASA, ESA

Going to Ganymede

Dartnell is rather less wide-eyed about the prospect of finding living conditions on Ganymede, although he urges me to talk to his former PhD supervisor Andrew Coates of University College London.

"Ganymede is bigger than Mercury, you know, it's a planet-sized object," says Coates. "And not only is it the largest moon in the Solar System, but it is the only one with a magnetic field. On Earth we have a magnetic field and it's one of the things that's protected life on this planet from cosmic radiation."

Coates is Head of Planetary Science at the Mullard Space Science Laboratory. Like Dougherty he is also part of the Cassini mission to Saturn and has since been involved in creating the JUICE mission profile. He is now helping to develop two instruments in its payload. The 'Janus Imager' camera will take photos that are 50 times more detailed than previous images, and the PEP (Particle Environment Package) will measure charged particles swirling around the spacecraft. Altogether, 11 instruments will bring us valuable data right up to its final moment when JUICE falls to the surface of Ganymede in 2033.

Brave new worlds

Coates expects a data bonanza. "One of the best things from our point of view is to be able to measure the atmospheric composition of Ganymede on the way down. Actually measuring in situ – effectively smelling and tasting with the instrument – is going to be very exciting."

This will provide revelations about the Jupiter system and so much more. Ganymede is like many of the new worlds being discovered orbiting stars other than our own Sun. This means that the data could tell us just how habitable many of these extra solar planets might be for life.

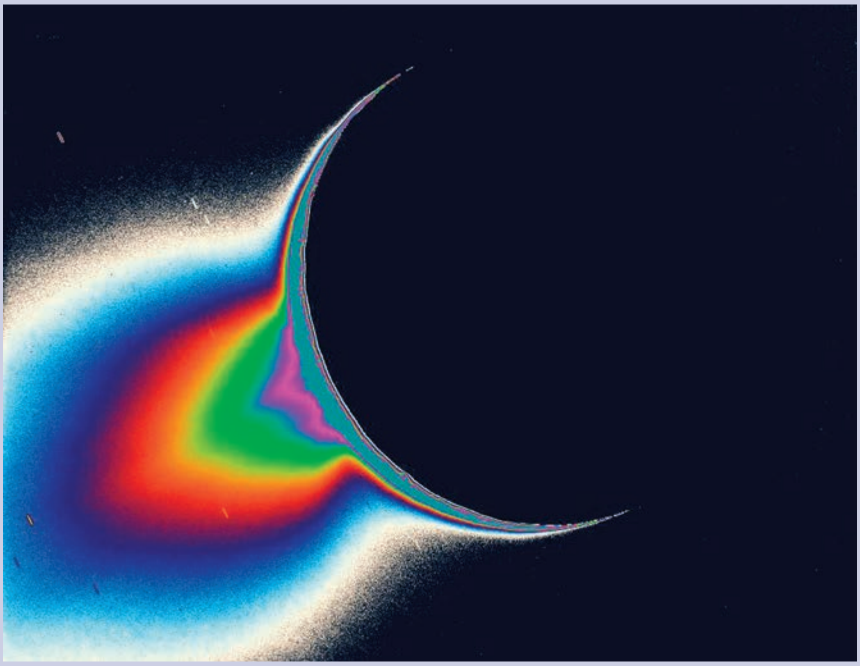
Excruciating wait

I find myself wondering what else might change in the world during the long gap between now and 2022 when JUICE is due for launch, and then further on, to the 2030s, when the spacecraft will reach the Jupiter System and start sending back data. Coates puts it in perspective for me: "A two year old now could be a person doing a PhD when the spacecraft gets to Ganymede, so, the young generation is a key thing for this mission."

It is clear from the people I've spoken to that when the spacecraft sets off in 2022, the 11 scientific instruments will not be the only things of value on board, it will also be packed with the hopes, demands, and clamoring questions of curious scientists, old, young and not yet born. It's going to be an excruciating wait.

I point this out to Dartnell in the café, then realise I may have said the wrong thing. "Rub it in my face, why don't you?" he says with the conviction of man who knows that whatever JUICE finds out there, it's not only going to be interesting, but completely unexpected.

"Every time we send a new probe out to Jupiter or Saturn we learn things that are not only interesting but completely unexpected"
Lewis Dartnell
University of Leicester



Meeting Major Tim

Image above: Tim Peake meets the media at the Science Museum
Credit: UK Space Agency

Major Tim Peake, Britain's first official ESA astronaut, speaks to Sue Nelson about the preparation for his 2015 mission to the International Space Station (ISS):

How did you find out you'd been assigned to a space mission?
It sounds really cheesy but I was in between Apache sorties flying with the British Army. My boss Frank De Winne said 'give me a call' and he told me over the phone I'd been assigned to the 2015 long duration mission…so I was absolutely thrilled.

What will you do between now and 2015?
There's a lot to do. I have to become trained to a higher level than I already am on the American segment [of the International Space Station] so that's the American laboratory, the European laboratory and the Japanese laboratory. I also have to be trained on the Russian segment and, in addition to that, I have to go to Canada and become more highly qualified on the Canadian robotic arm.

What about the training you've done so far, particularly the training in caves that simulated being on an asteroid, is that all redundant now?
Not at all, that training all stays with you. I learnt some valuable lessons during that caving exhibition. Seven days living underground with a mixture of astronauts of various different nationalities and we actually simulated a space mission during that trip. We were doing real scientific research. In fact we found new microbiological life forms in this cave in Sardinia, which was excellent. We were doing true exploration and also photography, which is clearly an important part of an astronaut's role as well. In addition to that, of course, the main point of living in a cave was to explore those psycho-social skills of interaction, of decision making, leadership etc. So when you become this international crew on board the station you're able to work together as a team much better.

How is your Russian?
Officially, I was classified intermediate-mid-level in my last exam. I'll need to do that exam again in the near future and the Russian language lessons will continue right up until launch. Clearly a very important part of our job is to converse in Russian, especially during the Soyuz launch and recovery, and if the opportunity arose to do a Russian spacewalk that would all be purely dealt with in Russian.

It's a long duration mission, do you know at this stage what those five months are likely to include?
Not in terms of specific science activity, it's too early to tell. It gets firmed-up within about 12 months prior to the mission. But clearly the space station has fixed payloads on board in terms of the science laboratories – there's a biological lab, fluid physics, material science, human physiology, medical research – so there'll be a mix of experiments in those kinds of areas.

Having our first official ESA astronaut is going to be a huge boost for STEM (Science, Technology, Engineering and Maths) subjects in the UK, do you have a science background?
My science background is A levels in maths, physics and chemistry. Then I had a big decision to make. I was going to go to Manchester University to study aeronautical engineering but the Army Air Corps had offered me a place at Sandhurst to do pilot training and that's a long drawn out process. So I decided that it was better to get on with that, leave school after A levels to go to Sandhurst and I ended up with my degree in flight dynamics. I did that later in life while I was a test pilot.

Credit: UK Space Agency

Image opposite: During cave training
Credit: ESA

continues >

Meeting Major Tim
continued

Top image: Inspecting the type of Russian spacesuit he will wear to the ISS
Credit: ESA

Do you think your background as a pilot has helped you to where you are today?
Absolutely. Really it's my background as a pilot that gave me the skills and qualifications when ESA had their selection process. I was a pilot then with just over 3000 hours as a qualified test pilot and a degree. But I think it was really the fact of my experience as a pilot that helped the application process.

It's quite a traditional old-fashioned route as during the 'Right Stuff' days in the 1960s, astronauts were always test pilots. Was becoming an astronaut always at the back of your mind?
It wasn't really at the back of my mind, purely because the opportunities weren't there. A lot of people in the UK didn't think they could be an astronaut unless, like Michael Foale, Nick Patrick and Piers Sellers, you were to move to NASA. So as soon as I saw ESA open up their selection process in 2008 to include UK nationals, and I had the right qualifications at the right time, that's when I jumped on board.

With the Space Shuttle no longer in existence, for many ESA astronauts the days of multiple trips have gone and this may be your only mission into space. What happens to an astronaut once their mission's over?
First of all, when I was selected four years ago, Britain didn't pay into human spaceflight. We had six astronauts but we only had five flight opportunities and the last one was in 2019 and there was no guarantee I'd even have a slot. I'm now sitting here and I'm flying in 2015 on a long duration [mission] and all six of us will have flown by 2017 and we still have an ESA flight in 2019.

To answer the second part of your question: ESA also trains our management skills. My direct boss and head of the astronaut centre is Frank De Winne, who commanded the space station in 2009. The director of human spaceflight is Thomas Reiter, the most experienced European astronaut in terms of time in space, so you can see that astronauts fulfill management roles throughout ESA. Others have gone back into the science division of ESA as well. So there are a plethora of different avenues within the space agency that you can take after you've flown.

Between now and 2015 there's a lot of work to do, are you expected to keep physically fit as well?
Yes, we are expected to do a certain amount of exercise and we also target specific areas in terms of endurance training, cardiovascular, good strength training for EVAs [Extra Vehicular Activity] or spacewalking. EVA uses really strange muscle groups, because the suit isn't particularly well ergonomically designed to suit the human body, so many of the major muscle groups in the EVA you can't use them to the full extent. So you end up using small muscles in your shoulders, for example, that you wouldn't normally use.

We end up doing strange exercises in the gym to try and build up and target those specific muscle groups so that we don't have injuries during EVA.

"I learnt some valuable lessons during that caving exhibition"
Major Tim Peake

Top image: With the Prime Minister at Number 10
Credit: UK Space Agency

Bottom image: Canadian astronaut, and accomplished musician, Chris Hadfield with his guitar on the ISS
Credit: NASA

Our fitness training will be monitored during the next two and a half years and also during spaceflight and post flight so that data can all be analysed to see if there are any changes, how we performed before, during and after the mission.

A lot has been made of the money - £16 million - effectively behind you. What's in it for the UK?
There's so much in it for the UK. It's a relatively modest investment and we're going to get a huge return. We currently get about a 4:1 return on all the money that the UK pays into ESA. Now in terms of science, this £16m was coupled with £12m for the Space Station's science programme, ELIPS, so British scientists are now able to propose British-led experiments in microgravity and hopefully we're going to see some of those on board the ISS. So it's opened up the door to the whole British science community to start studying microgravity research.

In addition to that, it's opened up the door for UK industry to compete for bids and be awarded contracts by ESA. And possibly more importantly than that, it's an inspiration to our younger generation of scientists and engineers that science is exciting, space is exciting and you have these opportunities open to you.

Commander Chris Hadfield has upped the game on the inspirational aspect of being an astronaut, does this put an enormous amount of pressure on you to become an all singing, all dancing social media expert?
[LAUGHS] It does put a certain amount of pressure on you yes, without a shadow of a doubt. But having said that, he has just done a fantastic job not just in his educational outreach to the public, and getting them enthused again about human spaceflight from viewing their planet from the pictures and watching him doing experiments, but also as a commander of the space station, he did a fantastic job in terms of the activities and science performed. He set the bar very high but I thrive on the challenge, so I will look forward to it.

You can hear an extract from Tim's chat with Sue on the UK Space Agency website and a longer version in the Space Boffins Podcast, available on the Naked Scientists' website.

"Clearly a very important part of our job is to converse in Russian, especially during the Soyuz launch and recovery"
Major Tim Peake

Ask the experts

In this issue our questions – on space junk, black holes and exploding astronauts – come from Oliver, Nathan and Harris, students at Neston High School in Cheshire:

Katherine Bennell
Engineer
Astrium UK

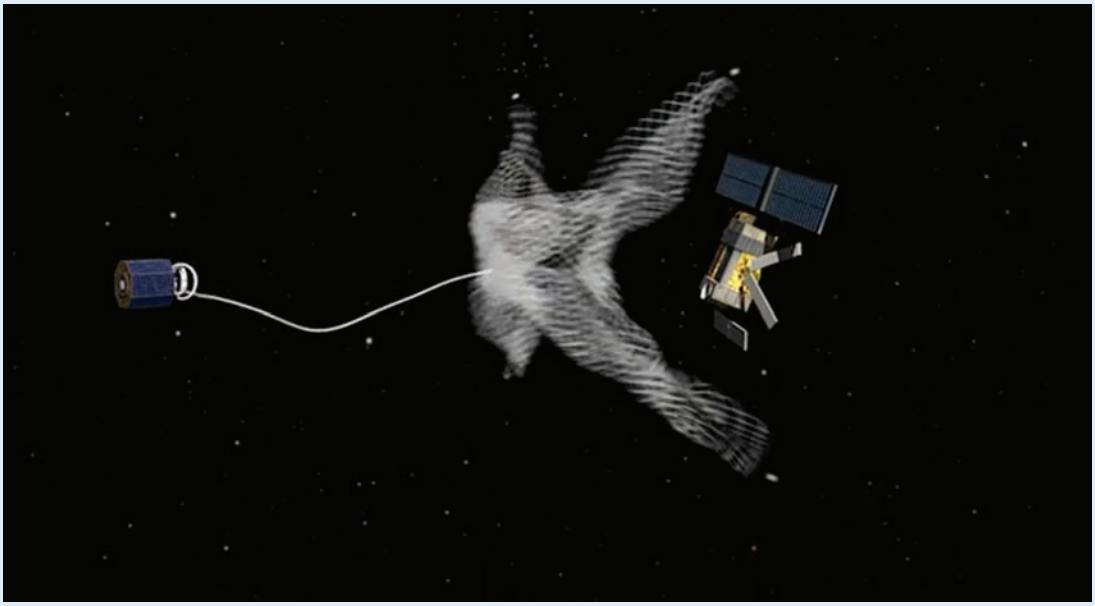
Will space junk orbiting our planet have any implications for future space launches?

Many in the industry consider space junk to be the greatest threat to the future of spaceflight. Even if we were to launch no more satellites, all the debris flying around like bullets in Low Earth Orbit (LEO) would continue to collide with large dead satellites and rocket upper stages. As these break up, the number of these 'bullets' grows exponentially causing even more collisions. This runaway behaviour is known as the Kessler Effect.

It is a bigger problem in LEO since we have a lot of satellites there and satellites have to move much faster in lower orbits to maintain their altitude. In fact, head-on collision speeds can be up to 10 kilometres per second – 25 times that of a speeding bullet. This means that even a small fleck of paint can have a big impact. If this runaway effect of debris generation is not addressed, LEO will become increasingly hazardous to spacecraft and astronauts.

Fortunately, organisations and agencies are taking the issue seriously and are investigating ways to tackle the problem. We now know that if we can remove between five and ten big dead satellites and upper rocket bodies from LEO each year, for the next few decades, we can prevent the amount of debris from growing.

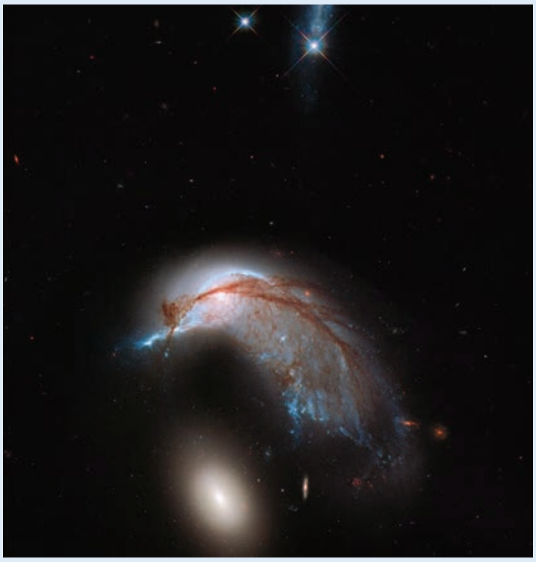
At Astrium we are developing many types of debris removal mechanisms to capture and drag large debris out of orbit. We have a space-harpoon (see page 4), a net to envelop satellites and robotic arms. We are even looking into more radical solutions like tentacles or fly-traps! What is exciting is that these technologies are also useful for exploration missions (like capturing asteroids) or for spacecraft servicing.



: Concepts for removing space debris include capturing objects with a net **Credit:** ESA

What would happen if you travelled faster than the speed of light?

Albert Einstein's theory of relativity says that the speed of light is constant, no matter how fast the person observing it is moving. If you managed to travel at half the speed of light (no small feat in itself) you would still measure the speed of a light beam in front of you at 300,000 kilometres per second.



The laws of relativity also say that nothing can travel faster than the speed of light. Thanks to Einstein's famous equation, E=mc2, as an object gets faster its mass also increases. So, if you started approaching the speed of light, your mass would become almost infinite. And an infinite mass would need an infinite amount of energy to move it.

But if you could travel almost as fast as the speed of light, you would notice 'time dilation,' where time appears to slow down. At 90% the speed of light, time would appear to be running half as fast as usual. You would also get some serious tunnel vision, because all the light particles, photons, that you would see would look like they are only coming from in front of you.

If we want to visit galaxies far, far away, then – within the laws of physics as we understand them – we will not be able to get there faster than the speed of light **Credit:** ESA, NASA

Kelly Oakes
Media Officer
The Institute of Physics

If you went into space without a space suit would you explode?

No – but you would still die – just not as dramatically.

A space suit is built for survival. It provides oxygen, so that astronauts can breathe. It is insulated to regulate body temperature because temperatures in space can vary by hundreds of degrees. It is pressurized, so that fluids in our body – such as blood – remain liquid. And, last but not least, it offers protection from micrometeoroids through layers of bulletproof material such as Kevlar.

Warning…do not go outside without a space suit **Credit:** ESA

If an astronaut went for a space walk without a suit, the pressure difference is not enough to cause their body to explode. Space temperatures can be extreme but because there is no air or water to transfer body heat it is unlikely that astronauts would freeze to death either. However, if not in the shade of the Moon or Earth or wearing factor 5000, direct ultraviolet radiation exposure will inflict severe sunburn.

The space environment will also produce some swelling of soft tissue in the unprotected body, loss of vision, impaired judgement and skin will eventually turn blue. But death results from asphyxiation. There is enough oxygen in the blood for at least 15 seconds of brain activity but, after blacking out, complete brain death would take about three minutes.

Theoretically, there is always the possibility of a more dramatic death. If an astronaut was on a collision course with a spacecraft or space debris orbiting at 28,000 kilometres per hour, there is no chance of survival – suit or not.

Sue Nelson
Science journalist and
Space Boffins presenter

education &
careers

Teaching resources

Meet the team:

Allan Clements
ESERO-UK Manager

Tom Lyons
ESERO-UK Teacher Fellow

Alice Coates
STEM Project Officer

image opposite: A section of the massive mirror for the James Webb Space Telescope. A key instrument on this mission has been developed and built in the UK
Credit: NASA

ESERO-UK is an education project of the European Space Agency (ESA). It is funded by ESA and the Department for Education and is based at the National STEM Centre at the University of York.

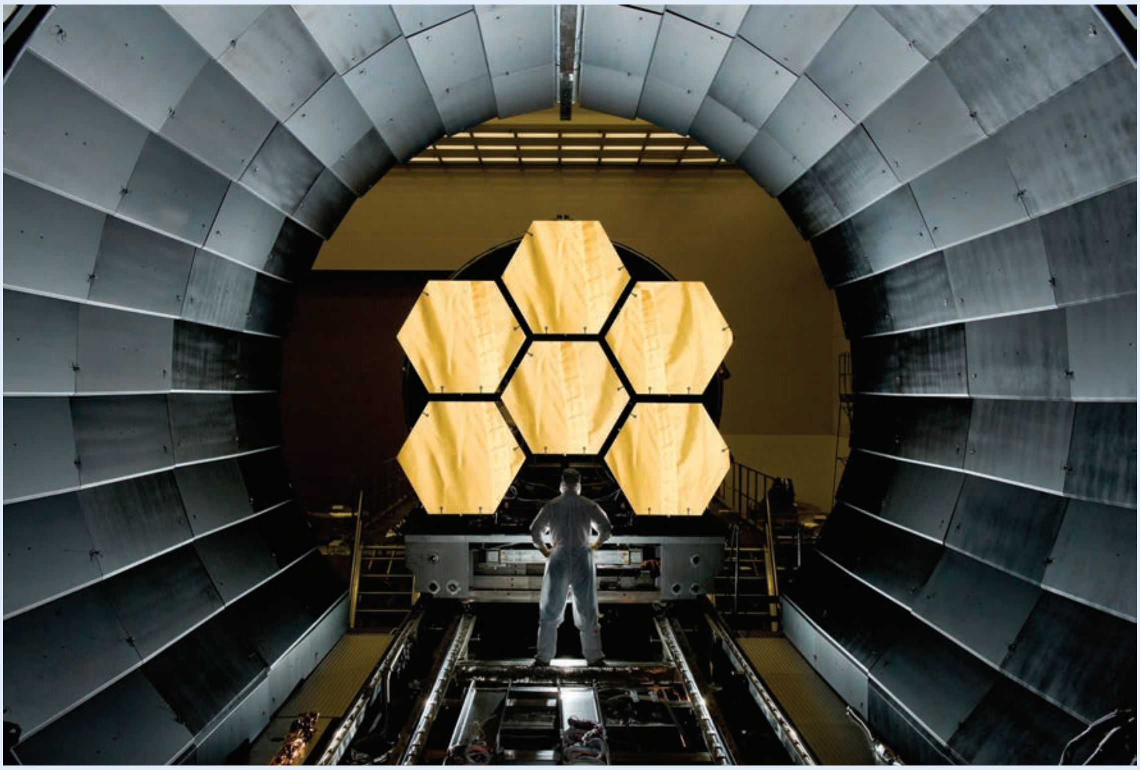
The principle aim of ESERO-UK is to encourage teachers in schools and colleges to use the inspirational context of space to enrich the teaching of STEM subjects, particularly science and mathematics. Since 2010 ESERO-UK has worked with more than 5700 teachers from both primary and secondary schools. It has collated 280 'Space Context' resources, which teachers can easily access and download from the National STEM Centre eLibrary.

ESERO-UK has also developed the resource Is there anyone out there? and facilitated the delivery of Continuous Professional Development (CPD) for teachers. This includes the CPD course based on the context of the James Webb Space Telescope mission. The course runs at York and the Royal Observatory Edinburgh and introduces teachers to the scientists and engineers who are part of the mission.

ESERO-UK projects for the next two years include:

- Ensuring that a coherent space and astronomy 'offer' is available for teachers and college lecturers.
- Continuing to work with teachers and college lecturers by facilitating the delivery of 1800 teacher training days.
- Using an enlarged Space Ambassador Network to support 1500 schools and colleges using space context in their teaching.
- Promoting to schools the education and outreach components of space missions, particularly Gaia in 2013 and Rosetta in 2014.
- Working with primary schools to increase pupils' confidence, engagement and enjoyment of science.
- Continuing to promote space via the ESERO-UK website and maintaining and adding to the eLibrary resources.

Further information is available at **www.esero.org.uk** where teachers can access news items, events and general information about the use of space as a context for learning.



Made in the UK

Selex ES is a major electronics company that also makes key components for satellites and space instruments. Space capability manager Mark Hartree tells *space:uk* about the company's expertise.

Mark Hartree
Space capability manager

What does Selex ES do in space?

At Edinburgh we make gyroscopes for satellites and in Southampton we make infrared detectors for scientific instruments.

What do gyros do on a spacecraft?

A satellite needs to know whether it's moving and in particular whether it's rotating or tumbling. If it's a telecoms satellite, for example, clearly it wants to be pointing at the Earth so that you get your phone, television signal or GPS position. Without the satellite knowing which way it's moving or tumbling you can't correct it. So the gyro is one of those critical bits of kit without which a satellite would be useless.

What missions have your gyros flown on?

They've been on scientific, telecoms and Earth observation missions since the 1970s. Our latest gyro, developed with partner companies, flew as a flight experiment on CryoSat-2. That was an early technology demonstration of our new gyro. It's one of the world's smallest, lowest power gyros, and is less than a kilogramme in weight. We're currently delivering to ESA's Earth Observation satellite, Sentinel-3, and we are in the final phase of negotiations for another large ESA mission.

Who do you make your infrared detectors for?

We make them for contractors who are developing and manufacturing an instrument for a space mission by, for example, ESA or NASA. At the moment we're working for Arizona State University on an instrument that will be used on the NASA sample and return mission, Osiris-Rex, to a near-Earth asteroid. The instrument will map the composition of the asteroid to find the best region to take a sample.

A similar type of infrared detector has been on the Mars Opportunity rover and our other detectors have been used on satellites for weather forecasting and pollution monitoring. Other technology has been adapted – for example into a sensor for the European Southern Observatory to be installed on the Very Large Telescope in Chile. It will enable astronomers to look much further into our galaxy than ever before.

Who do you employ?

We have around 100 people across both UK sites working in space. In Edinburgh we do systems integration so we need good degree level engineers. In Southampton we're more focused on materials and vacuum technology so a lot of physics and maths is involved. We've recently been working with a year-in-industry student who's between her A levels and university. It has been brilliant for the team, as she knows how to do things in a different way, using various approaches that we haven't really looked at. We give her a problem and she'll go away and solve it!

Image bottom right: Detectors made in the UK are being used by the Opportunity rover on Mars
Credit: NASA

SPACE PIONEERS

The Royal Observatory Edinburgh

The Royal Observatory Edinburgh, with its distinctive copper-green turret tops, has an international reputation for astronomy and an impressive history. Strategically sited on Blackford Hill, and the former home of the Astronomer Royal for Scotland, it now hosts the STFC UK Astronomy Technology Centre and the University of Edinburgh's Institute for Astronomy.

Designed in 1896, the green turrets are domes above two octagonal towers. A 36-inch reflecting telescope was installed in the green East Dome in 1930 and two further telescopes were housed in the West Dome in 1951 and 1963. These telescopes cemented the Observatory's international reputation for astronomy and space science.

In the 1970s and 80s, when telescopes began to be sited on top of remote mountains around the world, scientists at the Observatory had the expertise to create and operate telescopes in Australia and Hawaii.

The Observatory is also famous for its archives and houses one of the most prestigious astronomical libraries in the world. The collection contains 15,000 manuscripts and first editions including work by Galileo, Isaac Newton, Johannes Kepler, Tycho Brahe and a 1543 copy of Copernicus' *'De Revolutionibus'*. This book challenged what was known at the time about the order of the planets and helped transform astronomy.

Today, the Astronomy and Technology Centre designs and builds state-of-the-art instruments for many of the world's major telescopes both on the ground and in space. After being involved in both the Infrared Space Observatory and Herschel telescopes, the Centre recently delivered the MIRI instrument for the new James Webb Space Telescope.

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