Winter 2011 Issue 33

space:uk

Mysterious Mercury: UK teams in mission to the weird planet

UK satellite celebrates 40 years

Space: it's dangerous out there!

The cosmos in the classroom

Plus:

Europe's SatNav success, new mission to the Sun, underground astronauts and Mercury pull-out poster

UK SPACE AGENCY

Contents

Front cover image: Mercury seen by the Messenger spacecraft
Credit: NASA

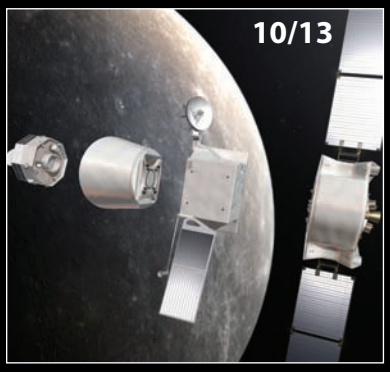
From the editor

Putting together this latest issue of *space:uk* has made me realise something: the UK is really good at building things that fly in space. From Ariel 3, the first all-British satellite, and Prospero, the first British satellite to be launched on a British rocket, to BepiColombo – the remarkable spacecraft currently being built in Stevenage that will be in orbit around Mercury in a few years.

The UK also builds some of the most sophisticated scientific instruments – from the first component to touch down on the surface of Saturn's moon Titan to a key instrument on Hubble's replacement, the massive new James Webb Space Telescope. At the less glamorous end of the scale, the UK also builds advanced telecommunications and navigation satellites. These technologies have transformed our lives, even though we may not always realise it.

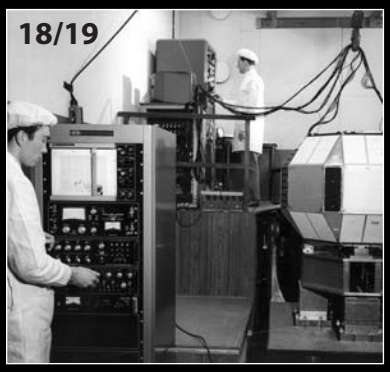
In *space:uk* we try to cover the whole range of Britain's space endeavours. There's so much going on that we've expanded the magazine by an extra four pages, so I hope you enjoy reading all about it. As ever, do get in touch with any comments or suggestions.

Richard Hollingham
Editor



Credit: ESA

Credit: ESA



Credit: UK Space Agency, Astrium

Credit: NASA

The UK Space Agency is an executive agency of the Department for Business, Innovation and Skills

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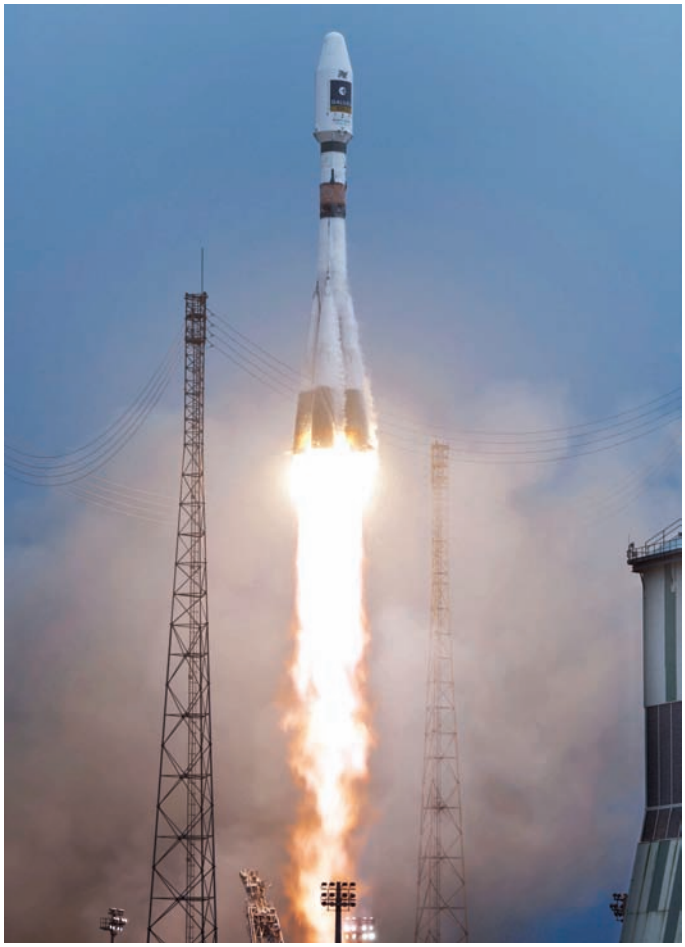
Go for Galileo

The first fully operational satellites for Europe's new satellite navigation system are being tested in orbit after their successful launch on 21 October. The two Galileo 'In-Orbit Validation' (IOV) spacecraft were the first satellites to be launched on the Russian Soyuz rocket from the European spaceport in French Guiana. The sections of the satellites that will provide the Galileo navigation services – known as the payload – were built in the UK.

"The launch marks an important milestone for the Galileo programme," said Minister for Universities and Science, David Willetts. "It's testament to the continued success of the UK space industry which has played such a decisive role in constructing the Galileo system and these first satellites."

When it's operational from 2015, Galileo will provide the world's only global positioning system under civilian control. It will eventually consist of a constellation of satellites, ground control centres and a complex global communications system. The first two test satellites, GIOVE-A and GIOVE-B were both built in the UK. GIOVE-A was launched in 2005 and has far exceeded its expected lifespan.



Credit: ESA, Arianespace

Launch of the first Soyuz from Europe's spaceport in French Guiana

Credit: ESA, Arianespace

The Galileo satellites being attached to part of the upper stage of the launcher

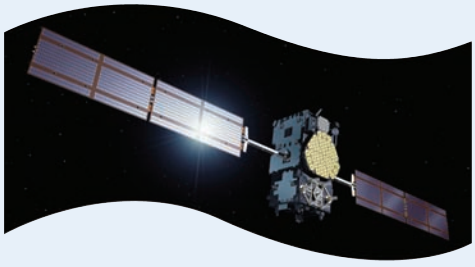
Astrium in Portsmouth is responsible for building the IOV satellite payloads, which include the most accurate atomic clocks ever flown in space. UK companies Surrey Satellite Technology Limited, Logica and Astrium have also secured key contracts for the development of the Galileo system. The European Commission has calculated that the economic benefits to the European economy from the system over the first 20 years of operations amounts to some €90 billion.

"This launch is a huge step forward for the Galileo programme," said Ann Sta, Director of Growth, Applications and EU Programmes for the UK Space Agency. "The Government is supporting the UK space industry's ambitious goals for growth - growing revenues from £7.5 billion to £40 billion by 2030 and creating 100,000 high-value jobs. Much of this growth is going to come from applications using new space services such as Galileo."

How it works

A navigation satellite carries an extremely accurate atomic clock. The satellite transmits this time signal and its exact position to receivers on the ground – like the sort you might have in a smart phone. The receiver has its own internal clock and by comparing the two times can calculate how long it takes for the satellite signal to arrive. This is used to work out the distance between the two clocks.

A signal from one satellite can tell you how far away that satellite is. By taking signals from at least 4 satellites, the receiver can work out its location on Earth. The more satellite signals that the receiver picks-up, the more accurate your position can be calculated.



Artist image of a Galileo satellite in orbit
Credit: ESA

Welcome

Emma Lord, Director of Policy and Operations for the UK Space Agency, looks back at the past 12 months and an exciting year ahead…

Welcome to the latest issue of *space:uk*, and the last edition of 2011 – the year that the UK Space Agency became an executive agency responsible for the UK civil space programme. The transformation, in just 12 months, from a partnership of ten Government departments, agencies and Research Councils to an executive agency has been a significant achievement by a small committed team. Behind the many successful space missions the UK is a part of, this small group of dedicated and enthusiastic colleagues carries out an enormous amount of hidden work behind the scenes.

Other highlights this year include the opening of the International Space Innovation Centre (ISIC) at Harwell. ISIC provides facilities for the private sector and academia to work together, encouraging them to develop new space applications and supporting the £10 million National Space Technology Programme announced in the Budget earlier this year.

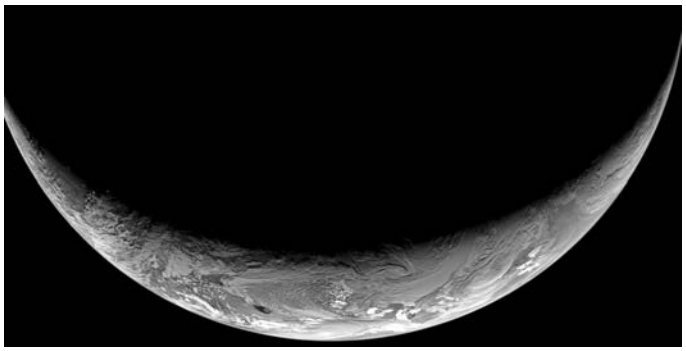
In May, the UK took on responsibility as Chair of the International Charter: Space and Major Disasters. At the first meeting under UK Chairmanship, members of the Charter agreed that there should be universal access to satellite images during natural emergencies. This means that any country, whether or not they are a member of the Charter, can access vital information in times of crisis. This can make the difference between life and death for those affected.

The many spacecraft with UK involvement continued to progress. Rosetta has gone into a deep hibernation on its way to intercept a comet, Mars Express sent back new images of the southern polar region of Mars, the first sea-ice map based on information from the Cryosat mission was published, and

Credit: Swindon Advertiser

"any country, whether or not they are a member of the Charter, can access vital information in times of crisis"

Emma Lord,
UK Space Agency Director of Policy and Operations



Credit: ESA,

Rosetta sent back spectacular views of Earth on its last flyby

Herschel provided new images of the Milky Way which may lead us to a better understanding of how our galaxy was formed.

There were satellite launches throughout the year. A particular highlight was the successful launch of the first two fully operational Galileo satellites. This European satellite navigation system is one of the biggest space projects ever initiated in Europe. This launch marked another milestone as it was the first time a Soyuz launched from the European spaceport in French Guiana.

So what can we look forward to in 2012? A lot of time and effort will go in to preparing for the European Space Agency (ESA) ministerial meeting at the end of the year at which Member States will agree the forward programme. We will also continue working on the growth review actions for space which look to remove some of the regulatory barriers which the space industry currently faces. The EU has an increasingly important role in space and we will be working with colleagues across Europe to define how the roles of the EU and ESA can complement each other, while continuing to develop innovative new space technologies. The next Galileo satellites should also be launched and we can hope for more information from the space missions out there exploring the Universe. Keep reading *space:uk* and visiting our website for up to date information. To close, I'd like to wish you all a happy and prosperous 2012.

Credit: Boffin Media, SAMS

CryoSat is Europe's first satellite dedicated to the study of the polar ice caps

New missions see the light (and dark)

Two new European missions that will investigate the Sun and search for dark matter and energy have been given the go-ahead by ESA. Backed with funding from the UK Space Agency, both Solar Orbiter and Euclid involve teams of British scientists and engineers with Astrium UK leading the industrial development of the mission to the Sun. Due for launch between 2017 and 2019, the missions are part of ESA's Cosmic Vision programme and were selected from more than 50 proposals.

Solar Orbiter is designed to travel closer to the Sun than any previous solar mission. The spacecraft will fly in an elliptical orbit, allowing it to take pictures of our star's polar regions. And, by tracking the Sun's rotation, it will be able to observe the same regions of the Sun's surface for several weeks at a time.

Two of the experiments on Solar Orbiter are being led by UK scientists, including Tim Horbury from Imperial College London. "It will give us a unique close-up view of the Sun's atmosphere and how it blows away into space, past the Earth and into the far Solar System," he said.

Euclid will tackle fundamental questions about our understanding of the Universe, investigating the nature of dark energy and dark matter. It will carry one of the largest cameras ever flown in space and capture the light from distant galaxies. UK astronomy and industrial teams are leading efforts to design and build this unique scientific instrument.

Credit: ESA, NASA

Euclid will try to answer fundamental questions about the nature of the Universe

Scream in space

Credit: ESA, NASA

Can you hear a scream in orbit?

They say that in space no one can hear you scream…now a UK-built satellite is setting out to prove it. The 'Scream in Space!' application is one of the winners of a competition to design an app to run on a smartphone-powered satellite, STRaND-1. Built by Surrey Satellite Technology Limited (SSTL) and the Surrey Space Centre, STRaND-1 will explore the concept of using the computing power of an android phone in space.

Developed by students at the University of Cambridge, The Scream in Space! app will involve people uploading videos of them screaming to a website. Selected videos will be played on the phone when the satellite is in orbit and the scream recorded using the smartphone's microphone.

Other winning applications for the satellite, which is due for launch next year, are:

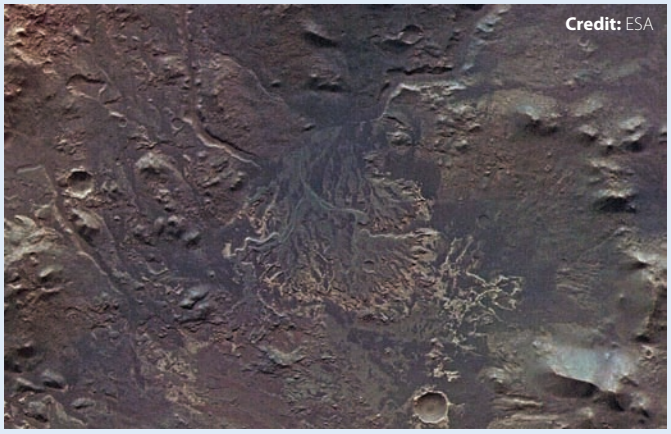
'Postcards from Space' and '360' – these joint winners use an app to take pictures using the smartphone's camera and the phone's onboard technology to establish the satellite's position. People will be able to request their own unique satellite image of the Earth.

'iTesa' – this app will be used to record the magnitude of the magnetic field around the satellite. If successful, this will provide proof that smartphones on satellites can be used for science.

The 'STRaND Data' app will show satellite telemetry on the phone's display, which can be viewed by an additional camera on board. Graphs and other data generated by the phone can then be seen and transmitted to the ground.

Mars's watery past

ESA's Mars Express spacecraft has sent back new images of what appears to be a dried-up river delta. This fan-shaped structure, in the southern highlands of Mars, was first discovered by the Mars Global Surveyor spacecraft and provides firm evidence that water once flowed on the Martian surface. Mars Express has been in orbit around Mars since 2003 and several UK science and engineering teams are involved in the mission.



Credit: ESA

Agency board appointed

Science Minister David Willetts has announced the external membership of the UK Space Agency Steering Board. The Board will advise Ministers on the strategies to be adopted by the Agency and provide advice and guidance on its performance, operation and development. Rob Douglas CBE, a business consultant with extensive experience of the space sector, has been appointed as Chair. He also chairs the South East of England Development Agency and is a member of the Space Leadership Council.

Satellite anniversary

Credit: ESA

A demonstration satellite that was only designed to last a few years has just celebrated its tenth anniversary in orbit. Only a cubic metre in size, ESA's Proba-1 satellite carries the Compact High Resolution Imaging Spectrometer (CHRIS). Built by Sira, which is now part of Surrey Satellite Technology Limited, CHRIS has sent back more than 20,000 pictures of Earth. It has been used for everything from monitoring pollution and responding to disasters, to mapping ancient Roman remains.

CHRIS image of Portsmouth and the Isle of Wight

Satellites to the rescue

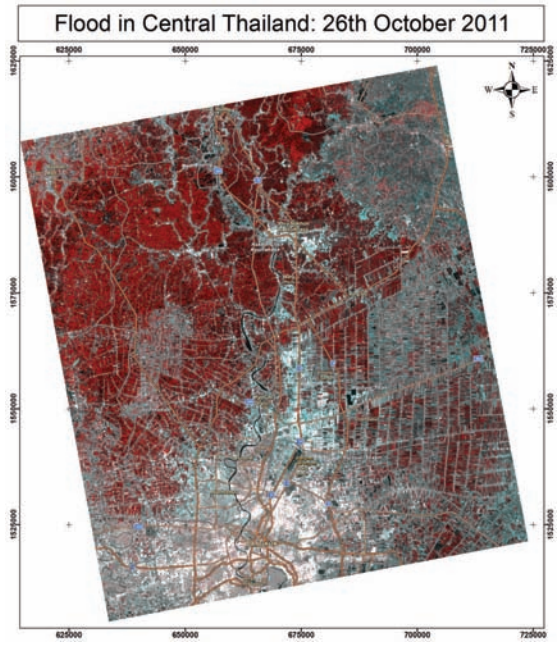
A charter that provides satellite images to countries or agencies following disasters has been strengthened by a new agreement. The deal was brokered by the UK during its chairmanship of the International Charter: Space and Major Disasters. Member nations take turns to chair the organisation and, during its time in charge this year, the UK has secured unanimous agreement that all countries – regardless of whether they are members or not – will be able to benefit from the Charter.

"This means it effectively becomes a humanitarian response from space agencies to help with disasters," said Alice Bunn, Assistant Director of Earth Observation for the UK Space Agency, who has chaired the Charter on the UK's behalf.

When the Charter is activated, satellites – including the UK's Disaster Monitoring Constellation – are used to provide images of the affected area. This data from space can prove vital in helping rescue workers and aid agencies see the full extent of any damage and reach victims quickly. The information can also be transcribed into maps for use in disaster recovery.

Recent activations include the aftermath of Hurricane Irene in the USA, floods in Nigeria and October's earthquake in Turkey's Van province. In a statement, the Turkish government said the Charter had made an "immense contribution to our efforts for rehabilitation and recovery studies after the Van earthquake".

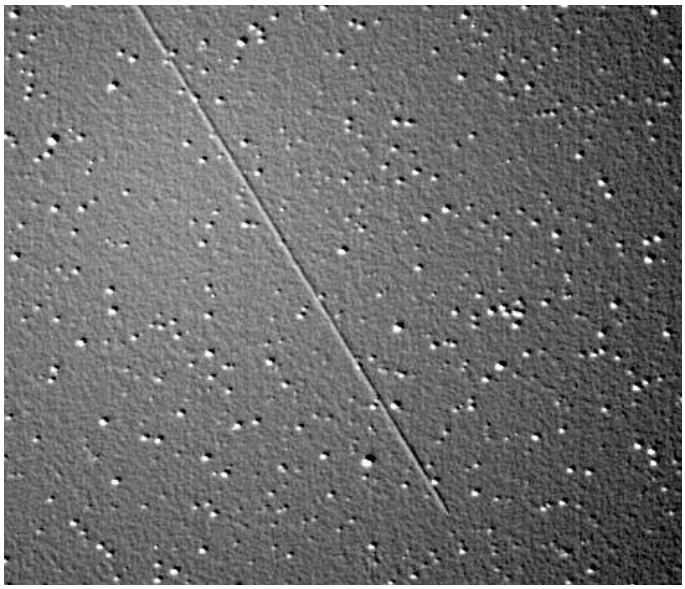
Chairmanship of the Charter board has now been handed over to Canada. Bunn said: "The challenge ahead is to make sure all the right links are in place to ensure that Charter data gets to the people who need it, wherever they are, quickly."



Credit: DLR, Map produced by Asian Institute of Technology (AIT)

A map produced under the Charter showing flooding around Bangkok on 26 October – the red patches indicate the water

40 years for UK satellite



Credit: Space Insight

This image proves that the forty-year-old British Prospero satellite is still in orbit. The picture was captured by UK space surveillance company Space Insight using its Starbrook sensor. It shows Prospero streaking at 27,000 kilometres per hour across the constellation of Pegasus in a near-polar orbit, which varies in height from 500 to 1300 km.

The Prospero satellite holds the honour of being the only British satellite to be launched on a British rocket. It was launched on 28 October 1971 from Woomera in Australia atop a Black Arrow. It was the first and only time the UK's Black Arrow launched a satellite into space – the launcher programme had been cancelled by the Government a few months earlier.

Prospero carried a set of experiments to investigate the space environment. The satellite continued to operate until 1973 and was reactivated annually until 1996. It is expected to survive in orbit for another 200 years.

To commemorate the anniversary of the launch, a team from University College London's Mullard Space Science Laboratory has been attempting to communicate with the satellite. They report detecting some signals and are now working to determine if these signals are from Prospero itself. Over the coming months, the satellite's orbit will change so that it will be on closest approach to the Earth over the UK. This should make conditions more favourable for contact.

See our special feature on Britain's rockets on page 18.

Water, water everywhere…

ESA's space observatory Herschel has made the first discovery of massive quantities of cold water vapour in the 'disk' of dust and gas surrounding a young star. The implication of the finding is that water-covered planets like Earth may be common.

Disks of material around stars coalesce to form planets. Water in warmer areas, closer to central stars, had been seen before. However, this is the first evidence for vast quantities of water extending out into the cooler far-reaches of the disks where comets form.

A widely held theory is that the Earth's water came from comets when they collided with the newly formed planet. The more water available in disks for icy comets to form, the greater the chances that large amounts will eventually reach planets through comet impacts.

The star with this waterlogged disk, called TW Hydrae, is 10 million years old and located about 175 light years away from Earth in the constellation Hydra. The cold watery haze detected by Herschel is thought to originate from ice-coated grains of dust.

The UK is leading the science team for one of the three instruments, SPIRE, on board Herschel. The largest space telescope ever launched, Herschel is examining some of the coldest and most distant objects in space.

Credit: ESA

Artist image of a planetary disk forming

African satellites in orbit

Credit: NASRDA

Following its successful launch, NigeriaSat-2 – built by UK company SSTL – has sent back its first pictures from orbit. It was launched with NigeriaSat-X, built by 26 Nigerian engineers working alongside SSTL staff in Guildford. The highly advanced Earth observation satellites are designed to help Nigeria with food security by monitoring crops, assisting with urban planning and, through the development of engineering skills, advancing the growth of new technologies in Nigeria.

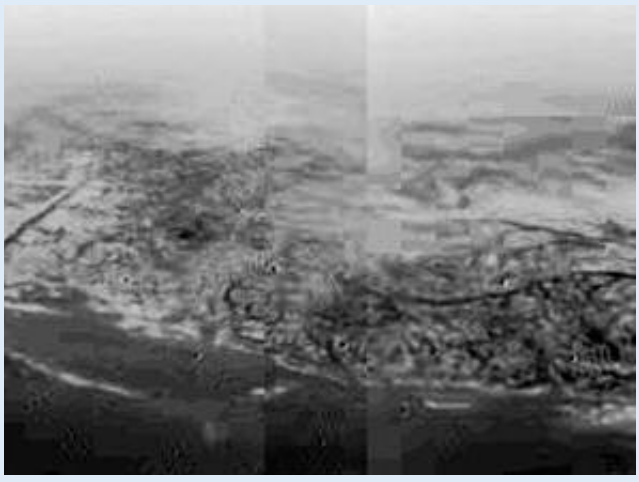
One of the first images from NigeriaSat-2: Salt Lake City Airport in the US

Spaceplane tests

The UK company developing a spaceplane told *space:uk* that tests of its crucial heat exchanger are progressing well. Reaction Engines' unpiloted 84m long Skylon combines both jet and rocket technology and is designed to take-off and land like an aeroplane. The design uses oxygen from the air for the first part of its ascent. But as air will enter Skylon's engines at around 1.5 kms per second with temperatures of over 1000°C, a new type of heat exchanger is needed to provide cooling.

Seas of Titan

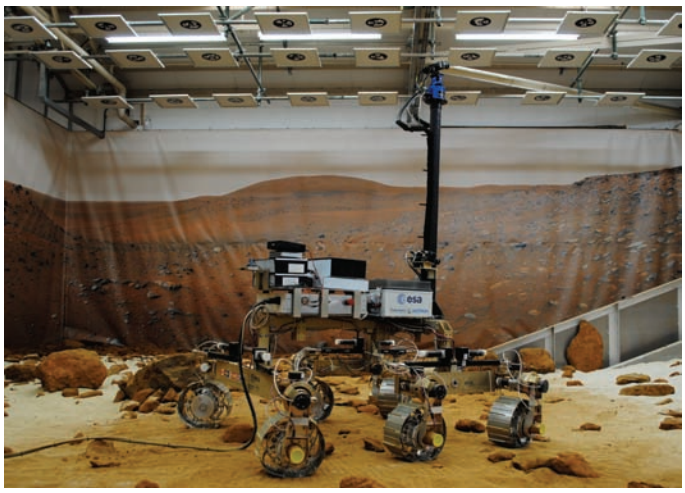
Open University space scientist John Zarnecki hopes to 'sail' a boat on the seas of Saturn's moon, Titan. The (unmanned) Titan Mare Explorer has been shortlisted for a future mission by NASA. Zarnecki was one of the lead scientists for ESA's Huygens probe, which landed on Titan in 2005. Huygens sent back remarkable images of the moon's surface – with its methane lakes and petrochemical atmosphere – which left scientists wanting more. The new mission is designed to spend several months afloat, taking measurements of this peculiar alien world. A decision on whether it will go ahead is expected in the New Year.



Credit: ESA

Huygen's view of Titan composed from several images

Funding for Martian adventures



Credit: Boffin Media

A prototype Mars rover under test at Astrium in Stevenage

The search for life on Mars has been given a boost with £1.6m for missions to the red planet from the UK Space Agency. Mars is one of the first stops in the Aurora programme – a long-term European plan to explore the solar system. The next European mission to Mars is planned for 2016.

The first stage of ExoMars, a joint ESA programme with NASA, will launch a rover to look for methane and other gases that could point to life on the planet. The second instalment in 2018 will see two more rovers hunting for signs of life. They'll also test new equipment – so samples of Martian soil and air can be brought back to Earth in future missions.

UK industry and research is central to the missions, with involvement in many of the key instruments onboard the rovers. "Understanding the conditions that could have supported life on Mars is an important step towards addressing one of mankind's most fundamental questions: are we alone in the Universe?" said UK Space Agency Chief Executive David Williams as the funding was announced.

ExoMars and the Aurora programme build on past missions to Mars that have already uncovered some of the red planet's amazing secrets. ESA's Mars Express mission recorded stunning images of frozen water on the Martian surface in 2005. And NASA's Spirit and Opportunity rovers discovered signs of water and volcanic activity, pointing to the right conditions for life. Many scientists expect future missions to find frozen water just below the surface – a key ingredient for life as we know it.

The funds from the UK Space Agency will be used to develop new researchers, to employ research assistants and to help get the most out of Mars mission data.

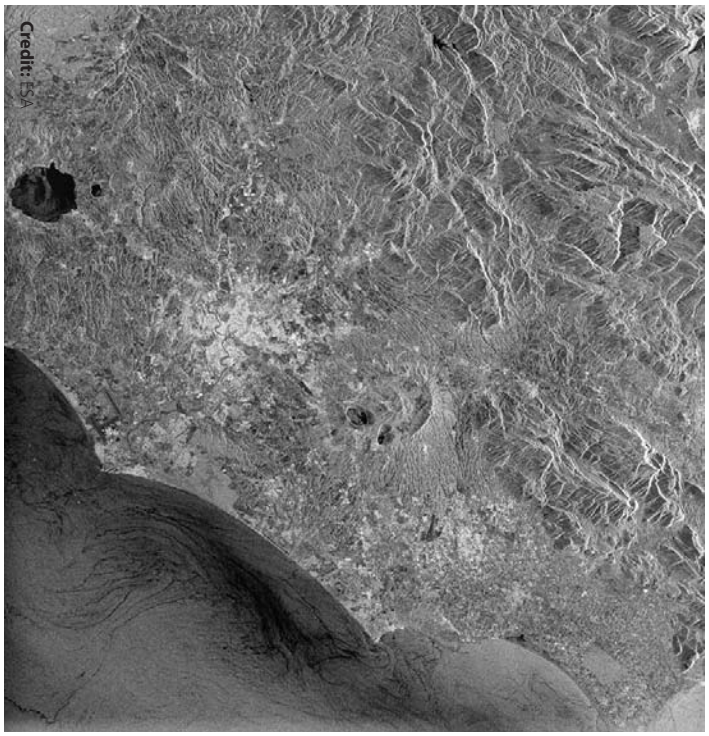
Farewell to climate satellite

After more than 20 years, Europe's ERS missions have sent back their final images of the Earth. In September, the ERS-2 satellite was shut down and its orbit lowered – it will eventually burn up in the atmosphere.

The highly successful ERS-2 was launched in 1995 to join its partner ERS-1, which had already been in orbit for four years. ERS-1 stopped working in 2000. Carrying suites of sophisticated instruments to study the complexities of the atmosphere, land, oceans and polar ice, these two missions were the most advanced of their time, putting Europe firmly at the forefront of Earth observation.

"Data from the two satellites has revolutionised our understanding of the planet," said Ruth Boumphrey, Head of Earth Observation for the UK Space Agency. "Although the ERS-2 mission has now ended, it leaves a legacy of data that will continue to underpin future research and provide a long term record from which to work."

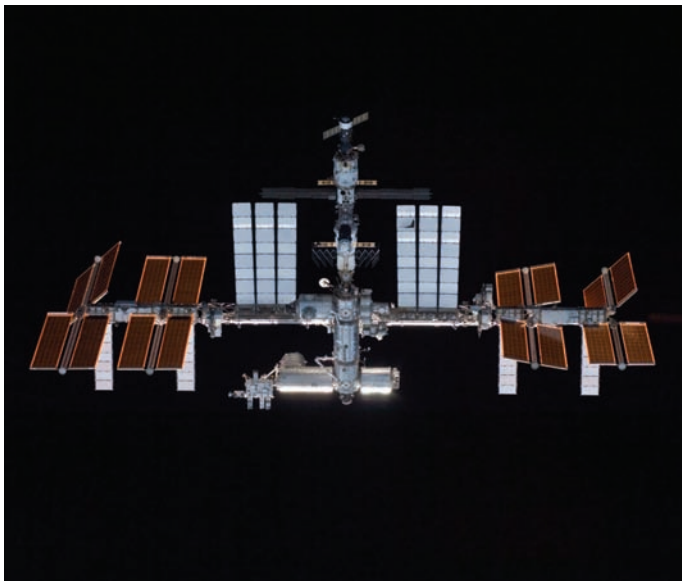
The ATSR (Along Track Scanning Radiometer) instruments on ERS – which provide precise measurements of global sea surface temperature were designed and developed by a consortium of research institutes, led and supported by the UK's STFC Rutherford Appleton Laboratory and the Natural Environment Research Council. Science teams across the UK continue to rely on information obtained by the ERS missions, with much of this work carried out by the National Centre for Earth Observation.



Credit: ESA

The final image from ERS-2: Rome, Italy

Agencies agree Mars plan



Credit: NASA, ESA

First stop on the road to the stars?

A new strategy to explore the Solar System could be the start of an ambitious plan for humans to live and work in space. With both robotic and human missions, the Global Exploration Roadmap's major focus is human exploration of the Moon, asteroids and Mars. Its ultimate goal is to find out more about the places we could live in the Solar System.

The Roadmap is the first of its kind - an international long-term space plan that plots feasible routes for space exploration over the next 25 years. It has been developed by the International Space Exploration Coordination Group – made up of 14 space agencies including NASA, ESA and the UK Space Agency.

The roadmap begins at the International Space Station. It then has two 'pathways' to choose from. The first begins with a robotic mission to an asteroid, followed by manned lunar missions. The second option visits the Moon first, and then explores asteroids. Both pathways lead up to a human mission to Mars. And both will also look for signs of life and the right conditions for life in the Solar System.

The plan highlights the technologies and resources that might be needed for these missions and is a starting point for the next generation of space exploration. It will evolve over the years but, for now, the space agencies of the world are agreed – Mars is definitely where we are heading.

Underground astronauts

Credit: ESA

It's cold, dark and inhospitable to life…not space, but a complex of caves in Sardinia. ESA's CAVES venture is aimed at preparing astronauts to work in an international team under real exploration conditions. The latest crew – including British astronaut Tim Peake – has returned to the surface after spending six days underground.


Credit: ESA

Day one and Tim Peake (right) is still smiling.

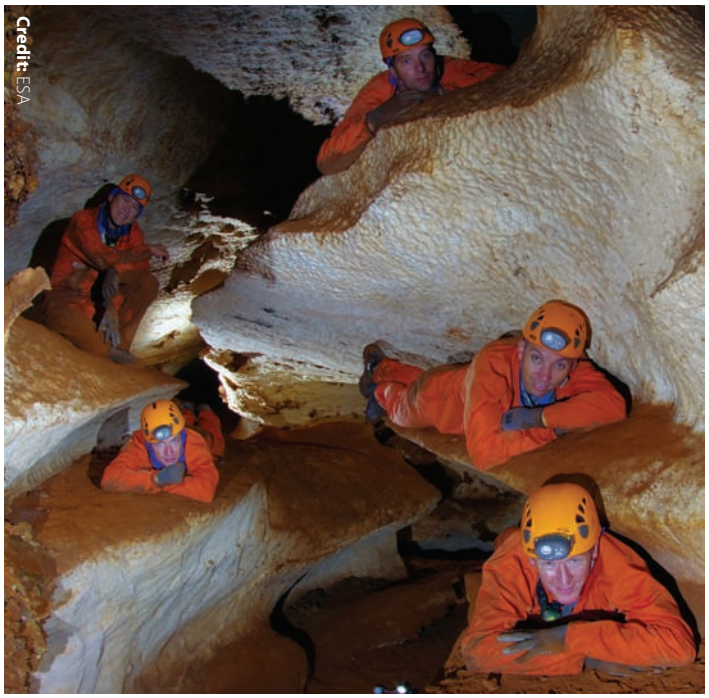

Credit: ESA

The campsite on day three. "Life in the dark, cool, humid underground environment can be a completely new situation with interesting psychological and logistical problems," said astronaut trainer Loredana Bessone.


Credit: ESA

The astronauts still seem to be enjoying themselves or perhaps hysteria is setting in? The daily routine was organised, like a space mission, around timelines. Planning sessions were held twice a day through a dedicated telephone line to a support team at the cave's mouth.

"The cave environment is isolated from the outside world," said astronaut trainer Loredana Bessone. "There is confinement, minimal privacy, technical challenges and limited equipment and supplies for hygiene and comfort – just like in space." Peake was joined by fellow ESA astronaut Thomas Pesquet, along with Randolph Bresnik from NASA, Norishige Kanai from Japan and Sergey Ryzhikov from Russia.



The astronaut edition of 'Where's Wally'

"It was a rare opportunity to experience problems encountered during a space mission in a training environment," said Peake. "Our mission required teamwork and working through problems as a small international team where different cultures and primary languages require consideration."

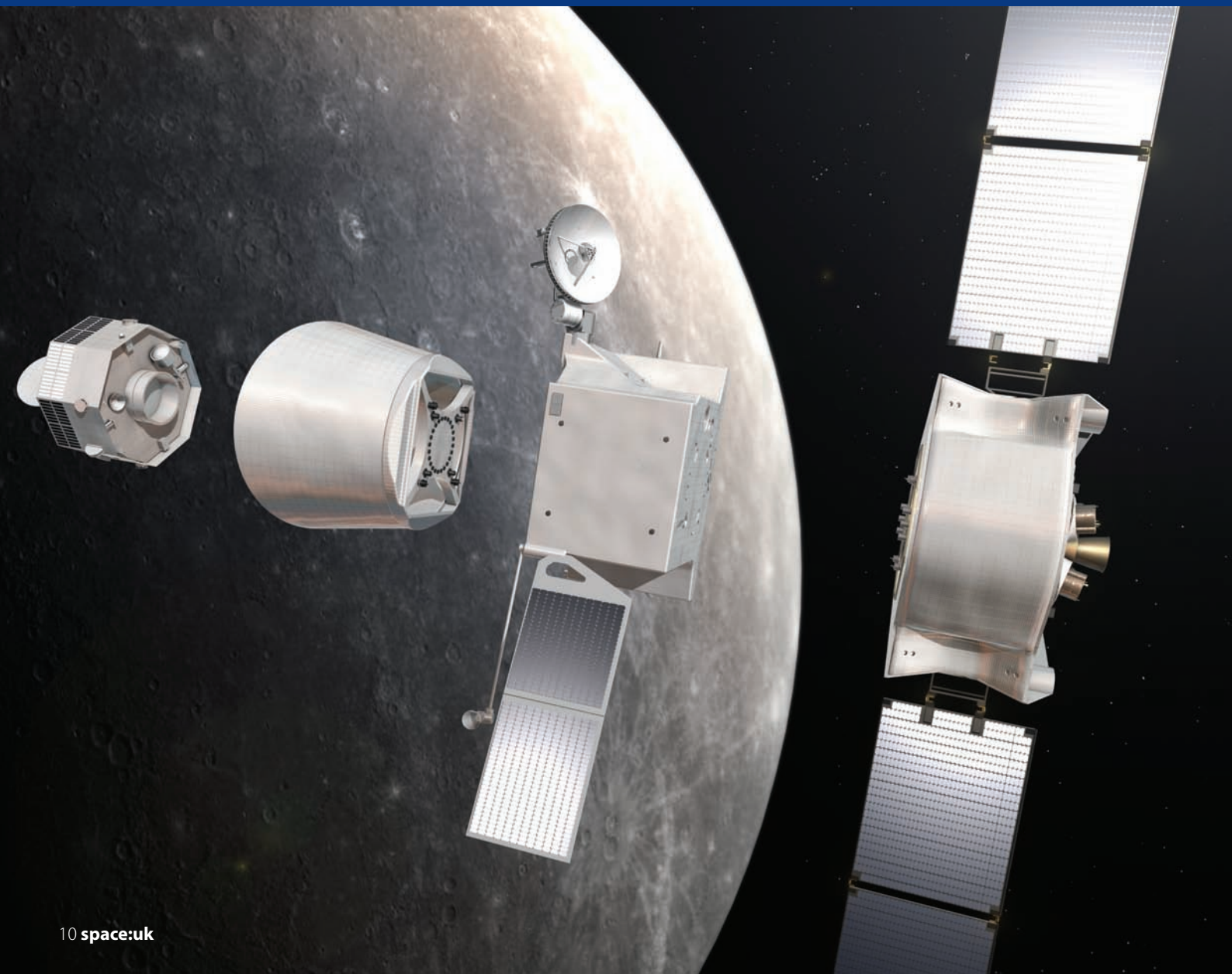
The cave equivalent of a spacewalk. "Being in a cave was something like mountaineering, but much more challenging – with isolation, darkness and the need for full situational awareness to avoid snagging ourselves on sharp rocks or crevices," explained ESA astronaut Thomas Pesquet.

The team after returning to the surface. "It took about five hours to come back from the cave to our campsite, requiring technical caving and a support team to help us," said Peake. "We really had a feeling of being far away."

Mission to Mercury

An ambitious international mission to Mercury, BepiColombo, is starting to take shape at Astrium in Stevenage. Richard Hollingham went see a major part of the spacecraft just after it was unpacked…

Main image: Artist image of the components of BepiColombo. From r-l: Mercury Transfer Module (MTM), Mercury Planetary Orbiter (MPO), sunshield, Mercury Magnetospheric Orbiter (MMO)
Credit: ESA



"It's a bit like unwrapping a Christmas present," says Ralph Cordey and you half expect to see a tear in his eye as the spacecraft is revealed. This is the first time Astrium's Head of Science has seen the real BepiColombo. "Up until now I've seen lots of drawings and concepts, now I'm seeing the real article."

We're standing in Astrium's Andromeda clean room at its factory in Stevenage. The high white room – about the size of a large sports hall – is brightly lit and surrounded by the windows of a viewing gallery. To be allowed inside you have to change into a blue gown and put on overshoes and hat before passing through a security door. This is all to keep the satellites from outside contamination – a fleck of dust in the wrong place could damage a vital component. And with satellites costing hundreds of millions of dollars, that's not a risk anyone's prepared to take.

We walk past the bulky structures of two communications satellites – their shiny propellant tanks glinting under the glare of the lights. They're surrounded by testing equipment and consoles with dials and wires. But we're not interested in those. The thing we've come to see has only just been rolled out of its box, which has 'do not drop' written helpfully in large red letters on the side, and is now covered in plastic sheeting. Around the size of a Transit van, and currently little more than a skeleton, this is the Mercury Planetary Orbiter (MPO). Or at least it will be.

This angular, boxy frame is not, at the moment, much to look at. "This is the structure of the spacecraft," explains Cordey. "It's going to take all the loads and thermal stresses – the basic chassis on which the instruments and equipment are going to be mounted."

Due for launch in 2014, the BepiColombo mission to Mercury is a joint project between the European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA). It's by far the most ambitious and complex planetary mission Europe has ever led and will be launched as a stack of three spacecraft. The section we're looking at will ride with a second, smaller, orbiter being produced in Japan. Both of them carried to their destination by a transfer module containing the propulsion system. Much of this is being designed and built in the UK, including key instruments and the main engine.

"It's a very specialised spacecraft," says Cordey. "It's going to an environment we've never been to before in Europe, the design is new, some of the materials are new, the way we're building the solar array is new, the propulsion system is new." There are good reasons for all this: getting to Mercury is tough and operating in orbit is even tougher. It'll be worth it though because there's a lot about the planet that's turning out to be just, well…weird.

Image below: The MPO being worked on at Astrium, Stevenage
Credit: Astrium UK

continues >

Mission to Mercury
continued

Image below: At first glance, Mercury's surface looks like the Moon
Credit: NASA

Weird world

The closest planet to the Sun and the smallest planet in the Solar System (if you exclude Pluto – which is no longer officially a planet), at first glance Mercury looks much like the Moon. Like the Moon, its surface is pock-marked with craters – the result of being hit repeatedly by asteroids and meteors. And, also like the Moon, Mercury has no atmosphere to speak of. But there the similarities end.

"Mercury is a mystery," says Chris Castelli, Head of Space Science at the UK Space Agency. "It appears to have a very large iron core – as Mercury is surprisingly heavy for its size – and an internally generated magnetic field." And that magnetic field is offset from the planet's centre. Which is very weird indeed.

Although Mercury was observed in ancient times, and named after the Roman messenger of the gods, most of what we know about it has been discovered by the only two spacecraft to visit. Mariner 10 passed by the planet three times during a series of flybys in the early 1970s and NASA's Messenger probe is currently in orbit. Since its arrival in March 2011, Messenger has sent back spectacular images and tantalising scientific data.

As well as evidence of lava flows, the Messenger scientists have found unusual depressions on the planet's surface. These irregularly shaped hollows are seen in patches right across the planet, suggesting they're fairly common. It's just that nobody quite knows what they are.

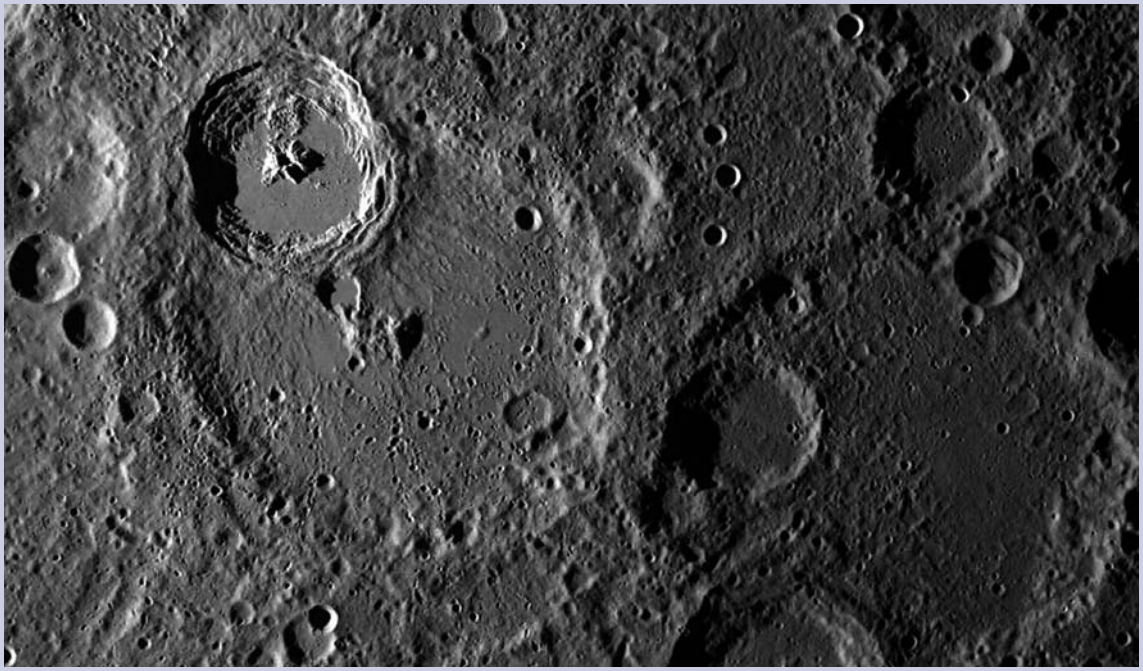
"I'm very excited about what Messenger's discovered," exclaims geologist Dave Rothery from the Open University. Rothery is the lead scientist on BepiColombo's British-led Mercury Imaging X-ray Spectrometer (MIXS) and is working closely with the Messenger team. But, with all that Messenger's discovered from the hollows to the offset magnetic field, why is BepiColombo still needed?

"Messenger is helping us revise the sort of questions we want to ask with BepiColombo but it won't answer all the questions before we get there, that's for sure," says Rothery. "Messenger is providing the hors d'oeuvre and Bepi the feast."

And understanding Mercury has far wider implications: "We really don't even know how it's formed," says Rothery. "That casts into doubt the formation of the terrestrial planets in general. In fact it's casting into doubt our theories of the early evolution of the Solar System."

We all want to know how we got here which, says Castelli, makes BepiColombo even more important. "The key science goals are to explore Mercury's unknown hemisphere, the geological evolution of the planet, internal structure, origin of the magnetic field as well as it's surface," he says. By taking the most accurate measurements ever of the movement of Mercury, BepiColombo will even be used to test Einstein's theory of gravity.

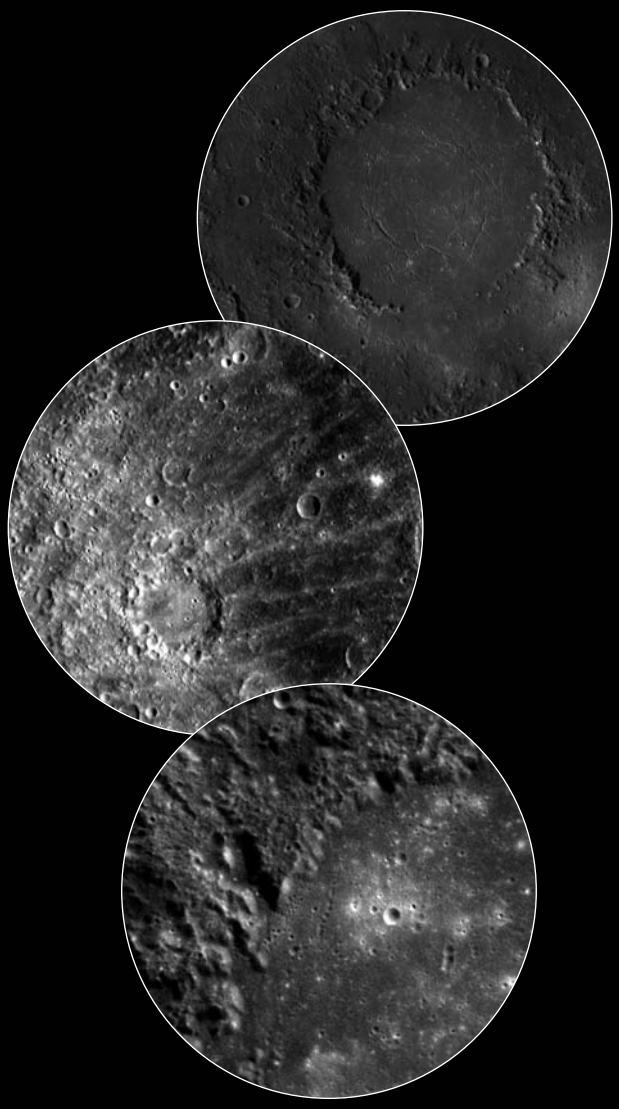
"You can't even get too close to Mercury as the planet itself is very hot"
Ralph Cordey, Astrium



Mercury as seen by NASA's Messenger spacecraft
Credit: NASA

Mercury

The closest planet to the Sun, Mercury is heavily cratered with no water or atmosphere. The planet was first seen in close detail in the early 1970s when Mariner 10 carried out a series of flybys. Now, the Messenger spacecraft is in orbit around Mercury and a future joint European and Japanese mission – BepiColombo – is under construction. Many sections, instruments and components for BepiColombo are being designed and built in the UK.



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Mysteries o

**The closest planet to the Sun, Mercury is a world of extremes. Its cratered and desolate surfa
been visited twice by space probes, with Messenger currently in orbit. A new mission, BepiC**

Extreme world

At first glance, Mercury looks very much like the Moon. The rocky planet is pockmarked with craters and scoured by ancient lava flows. Mercury has no atmosphere as such – although it does have a very slight 'exosphere' formed from gas given off by surface rocks.

The planet travels in an elliptical orbit around the Sun, with its distance from the star varying from some 46 million kilometres to 70 million kilometres. A year on Mercury is equivalent to just 88 Earth days.

Mercury also spins on its axis, which gives the planet days and nights. A day on Mercury lasts the equivalent of 58 Earth days. At night, temperatures can dip as low as minus 170°C, with daytime temperatures reaching anything up to plus 420°C. During the day, the Sun is eleven times as bright as it is on Earth.

Missions to Mercury

The first mission to Mercury, Mariner 10, flew past the planet three times between 1973 and 1975. The spacecraft sent back close up images of the planet's surface. It discovered that the planet had no atmosphere, a weak magnetic field and a dense iron-rich core.

There were no further missions to Mercury until NASA's Messenger mission was launched in 2004. After a series of flybys of Earth, Venus and Mercury, it eventually arrived in orbit around Mercury in March 2011. Instruments on board include an imaging system, a spectrometer to measure the relative abundance of chemical elements on the planet's surface and a magnetometer to investigate the magnetic field.

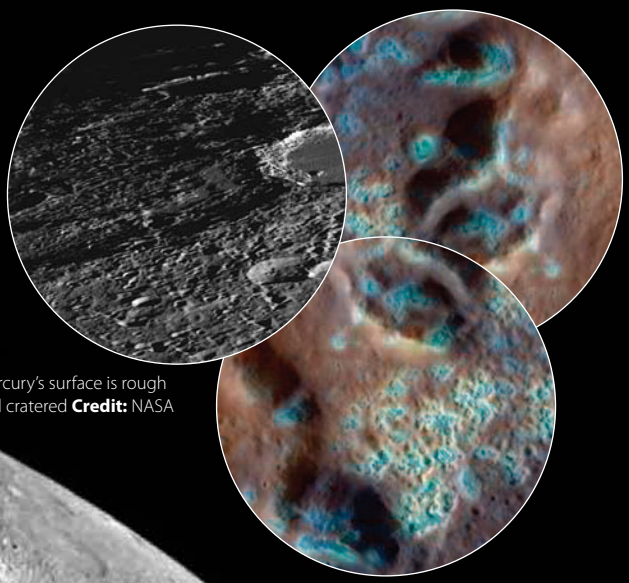
The next mission to Mercury will be a joint mission between the European Space Agency and Japanese space agency called BepiColombo. Due to arrive at Mercury in 2020, Bepicolombo will have two orbiters: the Mercury Planetary Orbiter (MPO) will study the planet itself and the Mercury Magnetospheric Orbiter (MMO) will study the magnetic field and magnetosphere – the magnetic 'bubble' surrounding a planet.

Much of the MPO is being built by Astrium Limited in the UK and a team led by the University of Leicester is developing a spectrometer to study the composition of the planet's surface. Scientists involved in BepiColombo have been working closely with the Messenger team to build on the mission's achievements.

Messenger image of Mercury **Credit:** NASA

# of Mercury

ace conceals mysteries that space scientists are only now starting to unravel. The planet has olombo, is being built with key involvement from UK industry and space science teams.



Mercury's surface is rough and cratered **Credit:** NASA

The mysterious hollows discovered by Messenger **Credit:** NASA

New discoveries

Investigations of Mercury are helping scientists develop general theories about how planets form and evolve.

Mariner 10 discovered that Mercury has a magnetic field, which has been investigated further by Messenger. It turns out that the magnetic field is offset far to the north of the planet's centre. Relative to Mercury's size, this offset is much more than for any other planet and scientists have not yet decided how to account for it.

Messenger is capturing images of Mercury down to a resolution of 250 metres per pixel. By studying these images, planetary scientists have concluded that volcanic rocks cover much of the planet's crust. This suggests that lava once flooded across Mercury - although most of the surface is now covered in meteorite and asteroid craters.

Scientists have also discovered unusual depressions on the planet's surface. These irregularly shaped hollows have been found in many places, suggesting that they are fairly common across Mercury. No-one is yet certain what has caused them.

Mercury fact file

Discovered by: Known by the Greeks and Romans

First mission: Mariner 10 in 1973

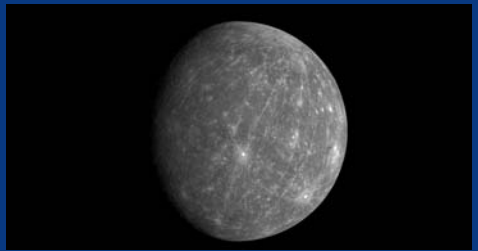
Distance from the Sun: 46 million to 70 million km

Diameter: 4,879 km (approx a third the size of Earth)

Surface gravity: 3.7 m/s^2 (Earth's is 9.8 m/s^2)

Length of day (time of a full rotation around its axis): 58 Earth days

Length of year (time to travel around the Sun): 88 Earth days



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Extreme planet

Back in the clean room at Astrium, engineers and technicians are carefully examining the MPO spacecraft's structure before moving it through to the next stage of the assembly process. Unlike the communications satellites being built nearby, BepiColombo has a unique design. It not only has to support all the instruments it's designed to carry but also survive the mission.

"You can't even get too close to Mercury as the planet itself is very hot," says Cordey. "You're sandwiched between the blazing Sun on one side and the hot planet Mercury on the other." With surface temperatures on Mercury hitting some 420 degrees Celsius and with the Sun ten times as bright as on Earth, the MPO employs a special 3.7 metre wide radiator panel on one side to radiate heat out into space.

Building Bepi

BepiColombo is named after Giuseppe (Bepi) Colombo (1920-84) who studied Mercury's orbital motion. The spacecraft consists of three sections, the Mercury Planetary Orbiter (MPO), Mercury Magnetospheric Orbiter (MMO) and the Mercury Transfer Module.

In the UK, Astrium is the co-prime contractor for the electrical and chemical propulsion systems and the structure of all modules. QinetiQ is building the engine for the Transfer Module and SEA has a major role in developing key spacecraft components.

Mercury Transfer Module: This is powered by an electric propulsion system. It uses electricity produced by solar panels to generate an electric field. This accelerates a beam of positively charged atoms – known as ions – away from the spacecraft to propel it forward.

Mercury Planetary Orbiter: the larger of the two orbiters, this carries a suite of eleven scientific instruments. These include the Mercury Imaging X-ray Spectrometer (MIXS), which is led by Principal Investigator George Fraser from the University of Leicester.

MIXS works like this: when sunlight shines on the planet's surface, chemical elements in the rock absorb X-rays and then emit them. Each element emits a distinctive pattern of X-rays. By detecting these rays, MIXS will build up, a detailed map of the elements on Mercury's surface.

Mercury Magnetospheric Orbiter: the Japanese contribution to BepiColombo will carry five advanced scientific experiments to investigate the planet's magnetic field and exosphere – the gases surrounding the planet.

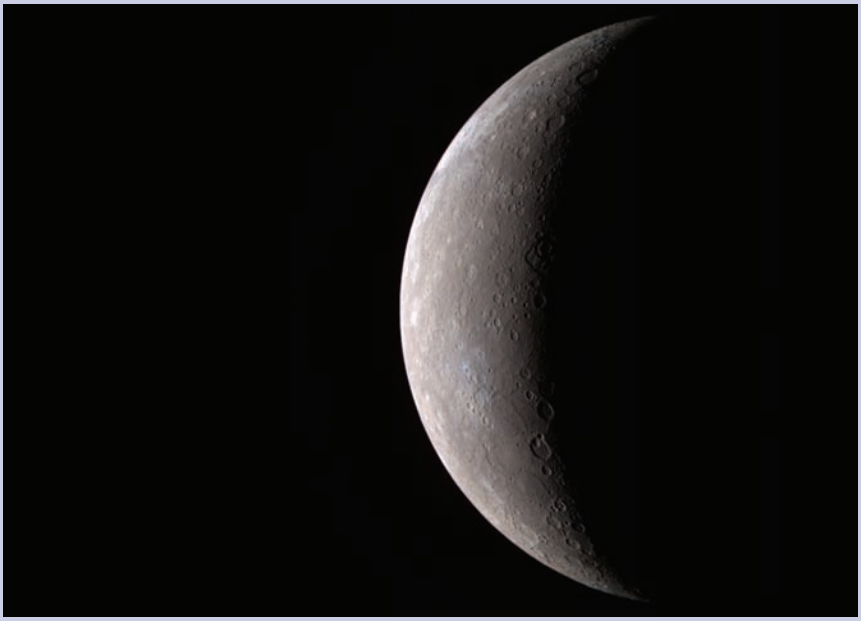


Image above: One of Messenger's first images of Mercury
Credit: NASA

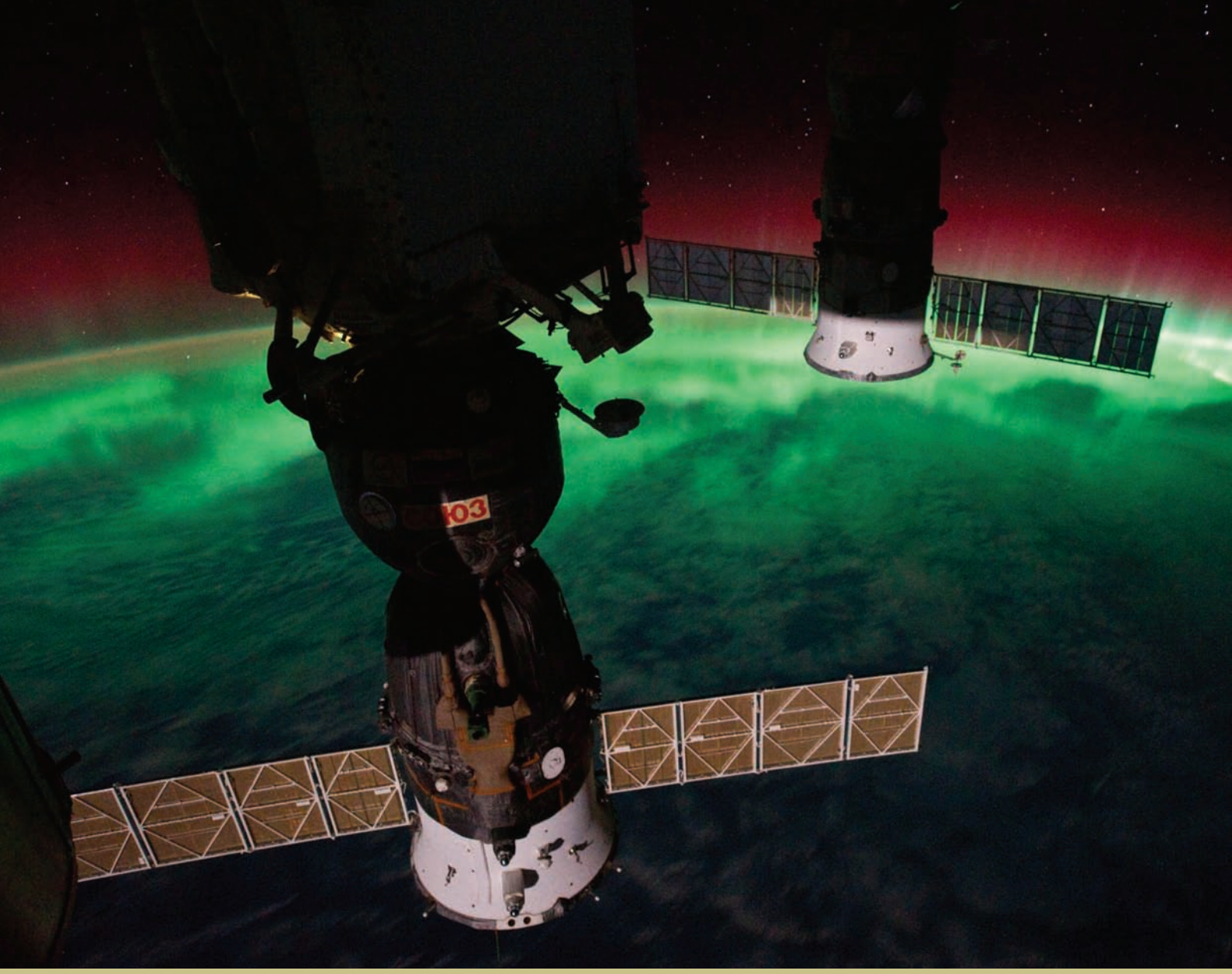
Even getting to Mercury is proving a challenge – it will take six years from launch and rely on a new electric propulsion system built by UK company QinetiQ (see box). "It's more difficult in energy terms to get to Mercury than Pluto," says Cordey, "so having this ion engine is a vital element of the journey."

With launch less than three years away, there's a lot of work to be done. And then there's the long wait before BepiColombo reaches its destination in 2020. Rothery admits it's going to be a challenge to maintain interest and keep the science teams together. "We want people in the UK working on Messenger data now, and for the next decade, so we've got skilled people when we get to Mercury."

But with Mercury holding so many mysteries, everyone agrees that it'll be worth the wait.

"Messenger is providing the hors d'oeuvre and Bepi the feast"
Dave Rothery, the Open University

BepiColombo will employ an ion engine, a development of the one used by ESA's GOCE satellite, seen above in this artist's impression
Credit: ESA



Warning: space can damage your health

Main image: The aurora seen from the International Space Station
Credit: ESA, NASA

Sue Nelson examines the hazards facing satellites: is it a containable risk or an accident waiting to happen?

"The risk of collision of two satellites, or a satellite and a piece of debris, is not only possible but increasingly likely"

David Wade, Atrium Space Insurance Consortium

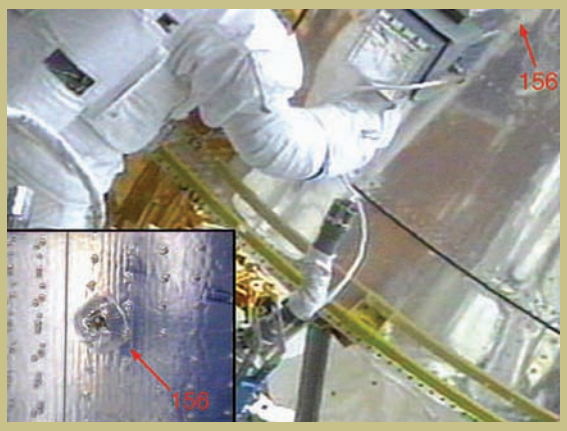
If two cars crash on a motorway at 70 mph the drivers will be lucky if they escape with their lives, but their vehicles are probably write-offs. Now imagine the orbital equivalent of motorways at different altitudes around our planet. In these space highways are hundreds of satellites, travelling up to 17,500 mph, without a speed camera in sight.

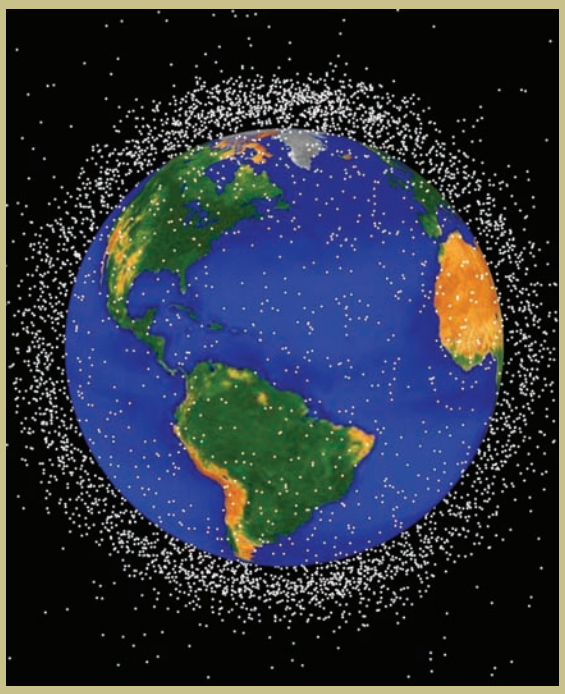
These satellites could be beaming down TV or mobile phone signals, measuring vital information about ice cover in Antarctica, or helping a search and rescue operation at sea. And while cars in the wrong lane, bad weather or obstructions on the road increase the chance of accidents on Earth, there are similar hazards in space.

Space weather, space debris and full-on collisions can all disrupt or destroy a satellite. When a US communications satellite collided with a defunct Russian military satellite two years ago, for example, it produced more than a temporary loss of service to customers. The accidental satellite crash in space produced around 2,500 pieces of debris, increasing the likelihood of further collisions in the future.

Iridium, who owned the US satellite, called it a "very low probability event" but nowadays not everyone would agree. In September, in a US National Research Council report, scientists warned that the amount of space junk around our planet has reached a 'tipping point'.

"Tipping point is a very emotive term," says Richard Crowther from the UK Space Agency, which is a member of the global Inter-Agency Space Debris Coordination Committee. "Certainly we have reached the point where we need to actively manage the environment. Business as usual is not an option."





Debris also compromises the safety of astronauts on the International Space Station. In June a potential collision with debris forced the crew to prepare for an emergency evacuation in their escape capsules. The situation wasn't helped in 2007 when the Chinese used a dead satellite as target practice for an anti-satellite weapons system.

Some 22,000 orbiting objects are currently tracked on the ground. Any potential problems are predicted to allow satellites to make manoeuvres or use protective shields. The greatest risk, however, is considered from untracked objects.

"We can only track objects down to about 10 cm in size," says Crowther. "Anything below and we can't track them. There are hundreds of thousands of untracked objects with the capability to destroy satellites." And in space, size isn't everything.

"Think of a pound coin hurtling in space," he adds. "Because of its orbital velocity it has the same energy as a minibus travelling at 100 km per hour, all focussed in a small surface area that could destroy a satellite very easily."

It's a serious problem. A recent report by reinsurers Swiss Re noted that, out of the 16,000 identified objects currently in space, less than 1,000 are working satellites.

Image bottom left: Orbital debris damage seen during Hubble Space Telescope repairs
Credit: NASA

Image top right: Computer generated image of all the tracked objects in Low Earth Orbit – the most concentrated area for orbital debris
Credit: NASA

continues >

Warning: space can damage your health
continued

Image bottom left: The surface of the Sun seen by the International Hinode mission
Credit: ESA, NASA, STFC

Image top right: Inspecting a Space Shuttle window for damage from orbital debris
Credit: NASA

"We're developing a warning system called SPACECAST for satellites in orbit"
Professor Richard Horne, British Antarctic Survey

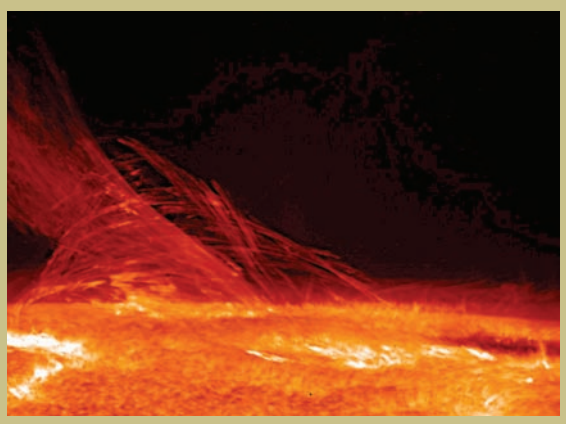
Apart from man-made debris – from rocket parts to dropped astronaut gloves – there are also naturally occurring micrometeoroids. These are dust-sized meteoroids that can also cause damage to satellite components and solar arrays or even puncture propellant tanks due to their orbital velocity and energy.

Fuel tanks have another problem: old age. "The most common form of fragmentation has been explosions of fuel tanks," says Crowther. "After 10-20 years in space the tanks can rupture and you get uncontrolled mixing of fuels. It's almost impossible to predict when an explosion is likely to occur. These old launch vehicle stages are like time bombs."

David Wade, a space underwriter with the Atrium Space Insurance Consortium, must assess these risks. A former aerospace engineer, Wade uses this experience in the insurance market. "It's true that some satellites are ticking time bombs," Wade says. "Propellants tend to boil in their tanks and unless the pressure is released propellant tanks of old satellites, and particularly spent rocket stages, can explode. In addition some batteries use pressure vessels which can explode if not discharged at the end of their lives."

Newer satellites can address these problems. "We've encouraged launch vehicle providers to change the operation or design in order to remove any propellant at the end of the operational lifetime," says Crowther, "so you vent the fuel into space." Satellite manufacturers can also take precautions by ensuring that critical electronics are sited in safer, more protected areas.

But all satellites, both new and old, face a common adversary in the form of space weather. "The Sun gives out a whole range of light and heat in the form of electromagnetic waves," says Richard Horne, from the British Antarctic Survey.



"As well as bursts of energetically charged particles in shock waves just above the surface of the Sun. They can travel through space, through the Earth's magnetic field and cause damage to satellites, affect aircraft on polar routes and communications on the ground."

The Earth's magnetic field acts as a shield for some aspects of space weather but the Sun also has an 11-year sunspot cycle and its activity fluctuates. "If we have large bursts of solar flares and an increase in UV radiation the Earth's upper atmosphere heats up and expands. This increases the drag on spacecraft and can cause uncontrolled re-entry of spacecraft in Low Earth Orbit."

This is what happened recently with the Upper Atmosphere Research Satellite, as NASA couldn't predict accurately where its remaining fragments were going to land after re-entry.

Coronal mass ejections (CMEs) are also hazardous for satellites. These huge bursts of charged particles can trigger a geomagnetic storm and increase the number of energetic particles in the Van Allen radiation belt.

"This increased radiation can damage spacecraft, cause charging and electrical discharges which damage components and also cause phantom commands," says Horne. "These phantom commands may tell the spacecraft to do something which was not controlled from the ground." At the end of October in 2003, for example, the so-called Halloween storm caused 47 satellites to report malfunctions and destroyed the Japanese scientific research satellite, Midori-2.

Space weather is even included in a House of Commons Defence Select Committee enquiry as a developing threat. It is also one of four areas of science collaboration outlined by President

Barack Obama for the UK and the US while ESA has a space situational awareness programme that includes space weather.

Predicting geomagnetic storms isn't easy, as CMEs that trigger them can take hours or days to reach the Earth. "We're developing a warning system called SPACECAST for satellites in orbit," Horne says, who is leading the programme. "It will issue warnings and alerts for free and an initial prototype will start running from March 2012. SPACECAST will help protect the new Galileo radio-navigation satellites, the European equivalent of GPS."

Horne has advised the space insurance industry in the past on risks to satellites. "In the event of an anomaly space weather is usually ruled out very quickly," says Wade. "We know space weather is worse during times of solar maximum but, over the past 15 years only about 2.5% of insurance claims have been attributed to space weather. I question sometimes whether it is ruled out too quickly. This is something that the industry still needs to address in my opinion."

Currently, the total value of all insured satellites in orbit is around $20 billion. "About $19 billion of this is for satellites in geostationary orbit where debris is less of a concern," Wade adds. "The risk posed by debris in low Earth orbit is much greater."

Low Earth orbit, between 700 and 1100 km, is relatively crowded, primarily with Earth observation satellites monitoring the environment as well as the Hubble Space Telescope and the International Space Station. With space tourism emerging, and space planes such as the UK's Skylon in development, insurance and risk is an important part of the equation – although many space tourism ventures will remain sub-orbital.

The Government plans to rewrite the Outer Space Act to cap UK operator liability. "The rewrite is intended to balance the share of risk between Government and industry," explains the UK Space Agency's Crowther. "As part of this, the Government will want to quantify hazards, to inform risk management and lead to a more sustainable exploitation of space."

It's a delicate balancing act. "Looking to the future," warns Wade," the risk of collision of two satellites, or a satellite and a piece of debris, is not only possible but increasingly likely."

"Even if we stop launching now," says Crowther, "we'll still see collisions among the current population of satellites."

Image below: Explosions on satellites are caused by pressure build-up in propellant tanks, battery explosions or the ignition of fuels. Each explosion creates thousands of pieces of debris
Credit: ESA

"There are hundreds of thousands of untracked objects with the capability to destroy satellites"
Richard Crowther, UK Space Agency

UK rocket pioneers

Image above: The Prospero satellite under test prior to launch
Credit: UK Space Agency, Astrium

Image below: A Black Arrow in its test gantry at High Down in the late 1960s
Credit: UK Space Agency

On 28 October 1971, the only British satellite to be launched on a British rocket was blasted into orbit. To mark the fortieth anniversary, a special public event was held at the launcher test site at High Down on the Isle of Wight. *space:uk* Editor Richard Hollingham went along…

"Here they are!" exclaims Jim Scragg as he kicks at a severed bundle of cables hidden in the grass beside the cracked concrete road. Scragg recalls spending a bitterly cold winter's day hauling these cables through a duct. "We worked so hard," he says, "we were stripped down to our shirts." Now concealed by undergrowth, these wires once conveyed control signals to Black Knight and Black Arrow rockets.

It's a beautiful location – although perhaps not in the depths of winter – today it's warm and sunlight glints off the gently rippling sea below us. To our right the sheer cliffs of the Needles rise from the waves with the red and white striped lighthouse at their furthest point. We're standing on a crescent-shaped road cut into the cliff. "It would have looked very different," says Scragg. "At each end of the arc there would have been a fifty foot high aluminium clad gantry, each one had a winch to lift the rocket into."

Construction of Scragg's former workplace began in 1956 and the site operated until the cancellation of the programme in 1971. The rockets tested here were built 18 miles away by Saunders Roe (later Westland) in Cowes. The first to be developed was the ten metre long Black Knight missile. The next programme – Black Arrow – was far more ambitious and designed to

place satellites in orbit. The team began work on Black Arrow in the mid-sixties and the programme culminated in the launch of Prospero.

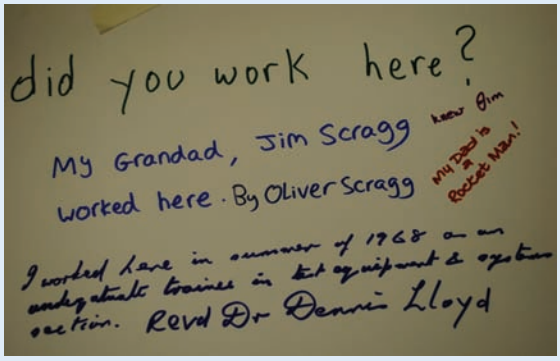
Once the rockets arrived at the site, they were winched into place, fired and the results analysed. When the engineers and technicians were satisfied, the rockets were shipped off to Woomera in the Australian desert for launch. A total of twenty-five Black Knights were launched and four Black Arrows. All were built and tested on the Isle of Wight.

The test gantries are long gone but beneath the road are the remains of the 'buckets' where the exhaust from the rockets was cooled by a torrent of water and sprayed out from the cliffs. But if you'd been on the site during firing you would have been safely out of the way, either in the underground control room on the other side of the hill or outside the exclusion zone around the site. They even cleared any fishing boats from the bay. "We wanted to prove the rockets performed properly," Scragg explains. "We did everything here that they'd do in Australia, except let it go!"

The event that brings Scragg, and several of his former colleagues, back to the site was organised by artist Katayoun Dowlatshahi. She has an exhibition at Quay Arts in nearby Newport. "I just think it's such a fantastic place," she says. "I was inspired, not just by the archaeology of the place but also by the vision, by what they achieved here and the aspiration behind the whole space programme."

Fortunately, Britain's space programme didn't end with Prospero. Among the participants at the celebrations, two teams of apprentices from UK space company Astrium demonstrate pulse jet engines. Resembling oversized car exhausts, these tubular engines are set up beneath where the gantries used to be. When they fire, flames shoot out and a throbbing booming noise reverberates across the bay – the first time rockets have been fired here for forty years.

"It's been very exciting," says Curtis Mews, who's leading one of the apprentice teams. "It's interesting to meet the older generation to see how they've influenced our technology. Hopefully we go into the future to have the same effect on the next generation."



During the 1950s and '60s, the engineers on the Isle of Wight achieved remarkable things and Black Arrow was the impressive culmination of their work. But in the economic climate of 1971, there were good reasons why the Government chose to cancel the programme. After all, rockets don't come cheap.

The legacy of these space pioneers lives on in today's UK space industry – its successes apparent throughout *space:uk*. And, forty years on, with Skylon (see page 6) Britain is once again developing launchers. Many of Jim Scragg's colleagues have passed away but events like this prove that their efforts are still being remembered. Prospero will continue to orbit the Earth until at least 2200 and those wires in the cliff are going to be around for a good while yet.

Katayoun Dowlatshahi's exhibition runs until 3 December at Quay Arts, Newport, Isle of Wight. The High Down site is owned by the National Trust and is open all year round. There is a small (free) exhibition in the underground test rooms – check the National Trust website for details of opening times.

For more on the history of Britain's space programme search for 'space 50 podcasts' on the UK Space Agency website.

A longer interview with Jim Scragg can be heard in the November edition of the Space Boffins podcast: audioboo.fm/spaceboffins

Image bottom left: The 'memory wall' at High Down
Credit: Boffin Media

Image top right (inset): Lighting a pulse jet
Credit: Boffin Media

Image top right: Demonstrating a pulse jet
Credit: Boffin Media

Image: below: Entrance to the National Trust exhibition
Credit: Boffin Media

education & careers

Ask the experts

If you have a question about space, we'll track down the right people to answer it.

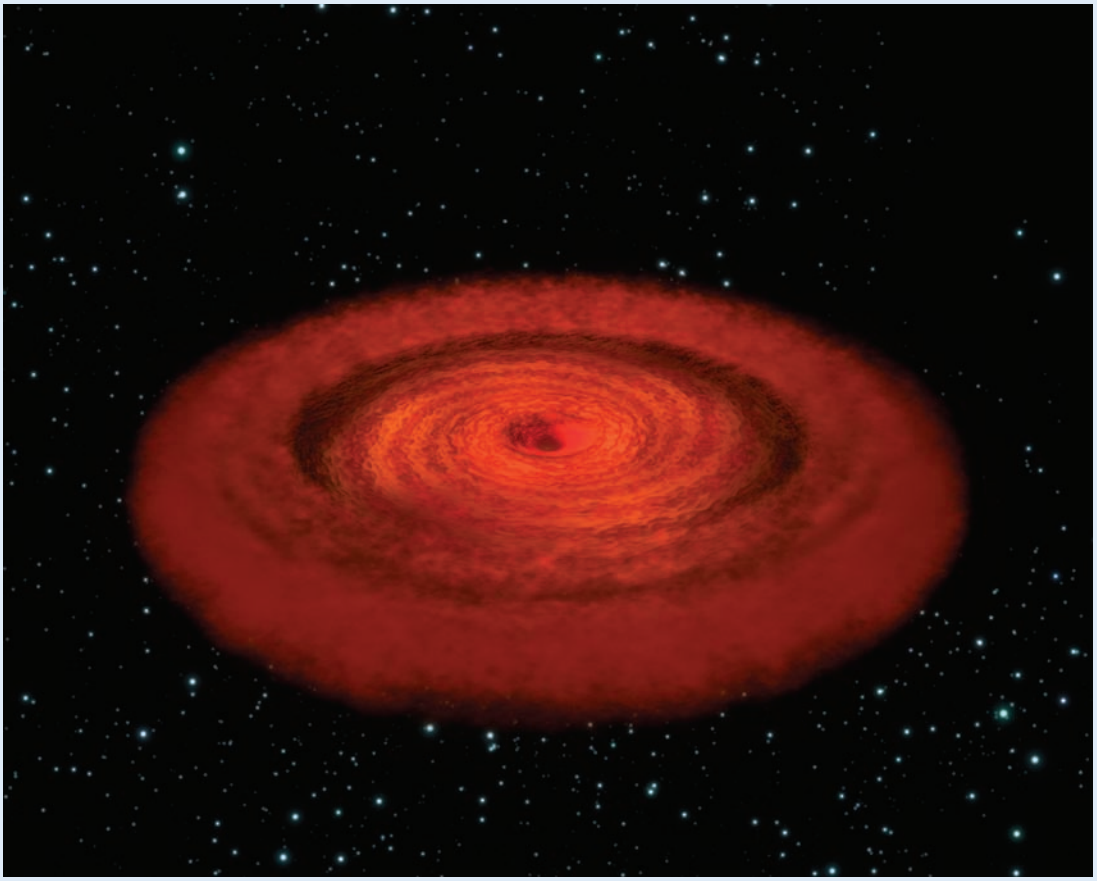
This time our questions come from year 9 students at Callington Community College in Cornwall.

Laura Thomas
Outreach Manager for Mathematics and Physics, Queen Mary, University of London

How are black holes formed?

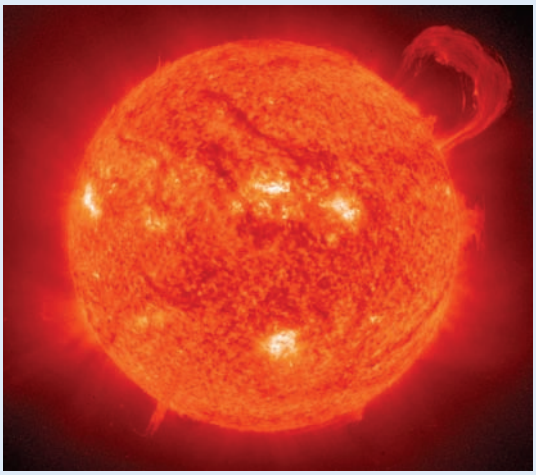
Black holes are elusive objects but we know that they are spread throughout the Universe. A black hole is what is left when a massive star dies and they can be produced in more than one way. One example is when the star runs out of fuel – it is unable to act against gravity pushing down on it, so it collapses on top of itself. It's black because it takes in the surrounding light and the light then can't escape due to the strength of gravity.

The star needs to be around 20 times larger than the Sun for a black hole to be produced. However, we have discovered black holes that are millions of times the size of the Sun. These super-massive black holes are found in the centre of galaxies and it's believed that most, if not all, galaxies have one. There is still a lot we don't know about these fascinating objects and there is more we can do to understand the strange goings on in the centre of black holes.



Artist image of a supermassive black hole at the centre of a galaxy
Credit: ESA

How far can the Sun's heat travel?



The Sun seen by the SOHO spacecraft
Credit: ESA

Well the short answer is a long way! It warms us up here on Earth and we're 150 million kilometres from the Sun. It's also powering the Rosetta spacecraft (through solar panels) until it gets as far as Jupiter, that's about 770 million kilometres from the Sun - a very long way.

Apart from the planets, the Solar System is mostly empty space and so there is nothing to absorb the heat and light from the Sun, it just keeps going. Even on Neptune (4.5 billion kilometres away) part of the planet is about 10 degrees hotter than the rest because it gets more exposure to the Sun.

However, the heat does get more and more spread out. If you imagine the heat and light from the Sun spreading out in all directions, it would fill a sphere that got bigger and bigger the further away from the Sun you got. So the same amount of heat energy gets spread out over a bigger and bigger area and you feel its warmth less and less. This is called the inverse square law. If you move twice as far away from the Sun, you get one quarter as much heat. If you are three times as far away, you get one ninth of the heat and so on. This is why spacecraft can't really use the Sun's energy to get much further than Jupiter.

Judith Green
Robert Smyth School
Space Education Centre,
Leicestershire

What is the longest anyone has spent in space?

When it comes to long-duration spaceflight, the Russians are the clear winners. After the end of the space race, while the US was developing and flying the Space Shuttle, Russia operated seven Salyut space stations and then the Mir space station. This gave them plenty of opportunities to put cosmonauts into space for extended periods of time. As a result, they hold the records for the ten longest continuous human spaceflights (though the seventh spot is held jointly with an American – see below) and also the longest cumulative time in space.

The record for the longest continuous flight is held by Valeri Poliakov. He travelled to Mir in January 1994 and returned to Earth in March the following year after 437.7 days and 7,075 orbits of the Earth. By comparison, the longest an American has spent in space is 215.4 days. This was Michael Lopez-Alegria who, together with Russian Mikhail Tyurin, stayed on the International Space Station between September 2006 and April 2007.

Turning to the longest cumulative time in space, the record for this is held by uber-cosmonaut and current Director of the Gagarin Cosmonaut Training Centre, Sergei Krikalev. Over six space flights – in Soyuz and the Space Shuttle and on Mir and the International Space Station – Krikalev has built up a total of 803 days in space, more than two years in orbit.

Sergei Krikalev at work on the International Space Station
Credit: NASA

Chris Welch
Director of Masters Programs at the International Space University, Strasbourg, France

Teaching space

Main image: Another day at the office for ISS astronaut Ron Garan. Studying how people live in space can be used to teach the whole range of STEM subjects
Credit: NASA

Teachers are being encouraged to use space to teach a whole range of science and maths subjects. *space:uk* learns how space can help inspire the next generation of scientists and engineers…

"It would be a brilliant challenge to teach the whole of a science course based on a spaceship or on Mars"

Becky Parker, Head of the physics department at the Simon Langton Grammar School for Boys

The thing to remember about using space to teach science is that it doesn't have to only be about space. "It's relatively easy to go from space to any STEM subject you like," says Allan Clements – the Manger of ESERO-UK, the UK space education office. "Space is a very, very good hook to get teachers and students on board."

Clements is based at the National STEM (Science, Technology, Engineering and Mathematics) Centre in York where some 400 space-related resources are available to teachers as part of a larger library of more than 3000 STEM teaching resources. "We're absolutely sure that we can inspire people with space and make them want to learn," says Clements, "we can get them learning without realising they're learning!"

And it's the cross-curricular nature of space that is encouraging more and more teachers to use it in the classroom. "I think the space sector is sitting on an educational gold mine," says Jeremy Curtis, Head of Education for the UK Space Agency. The Agency works closely with organisations including ESERO-UK and the Leicester-based Space Academy.

"Space has a unique ability to excite people, especially the young, and it covers such a huge range of topics," says Curtis who cites the example of Mission-X, featured in issue 31 of *space:uk* (and available via the Agency and ESERO-UK websites). Developed in partnership with space agencies around the world, Mission-X invites primary and early secondary students to train like an astronaut. UK schools involved in last year's pilot project had their pupils improving their diet and fitness while learning about the science of nutrition and exercise. The pilot scheme was so successful that the UK Space Agency is now expanding the programme to reach more schools.

There's also a bigger picture: the UK Space Agency is keen to use the inspirational nature of space to help encourage more young people to study science and technology, which should benefit the UK economy as a whole. "The UK space sector needs more skilled people if it's to grow," says Curtis. "And if there are more skilled workers available in the UK, that has to help the space sector too."

Fascinating physics

For Becky Parker, space is important when it comes to teaching physics. Parker is the Head of the physics department at the Simon Langton Grammar School for Boys in Kent, which also takes girls at sixth form. She has plenty of examples where space can bring scientific concepts alive. "You can use the International Space Station (ISS) as a brilliant context to test Newton's laws and, by understanding behaviour in apparent weightlessness, you actually get a better understanding of fundamental principles on Earth," she explains. "Conservation of momentum with tennis balls is brilliantly clear on the ISS but more difficult to show on Earth where frictional forces act."

Parker is also Director of the Langton Star Centre – a research base set up within the school. "There is the potential for real involvement of students

Image bottom left: The Langton Ultimate Cosmic ray Intensity Detector is designed to monitor the radiation environment in space
Credit: Simon Langton Grammar School

Image top right: Mission X helps pupils train like an astronaut. Here, ESA astronaut Frank De Winne is working out on one of the ISS treadmills
Credit: ESA

continues >

Teaching space
continued

Image bottom left: The International Space Station relies on its solar panels for electricity
Credit: ESA

Image top right: Space offers a unique perspective on the Earth – this image from ESA's Envisat shows smoke pouring from Mount Shinmoedake in Japan
Credit: ESA

at the forefront of research in space," she says. And to prove the point, the Centre has recently worked with Surrey Satellite Technology Limited (SSTL) and other Kent schools to develop LUCID – the Langton Ultimate Cosmic ray Intensity Detector. Based on technology developed for the Large Hadron Collider at CERN, the instrument will be flown on the UK TechDemoSat-1 satellite and contribute new scientific data on the space environment.

But if the idea of developing a new satellite instrument is a bit daunting, Parker believes space has a role across the science curriculum. "Space covers such a huge range," she says. "From metabolism – what happens to your body in space, heating and cooling in extremes of temperature – to energy production with solar panels or the possibility of finding life elsewhere, which involves deciphering how you define life."

"I think the space sector is sitting on an educational gold mine"
Jeremy Curtis, UK Space Agency

Resources for teachers

Allan Clements says there's no lack of enthusiasm from the more than 3000 teachers they've already worked with, but admits the challenge is to harness the available resources. "In the coming year we're going to help teachers use those resources more effectively in the classroom – to make them classroom-ready almost," he says. "We're also going to focus on more professional development for teachers with ESERO running a lot more events in the coming months." And there's clearly demand. "The recent one-day conference held in parallel with the UK Space Conference in Warwick attracted more than 100 teachers."

So, if reading about space in the classroom has got you thinking, how about this idea from Becky Parker? "It would be a brilliant challenge to teach the whole of a science course based on a spaceship or on Mars," she suggests. "I find space wonderful because it's an area where we can allow the imagination to run free. But when we come down to Earth, to this fragile and beautiful planet, we can use the understanding we have from space to phenomenal effect!"

Featured resource

The Science and Technology Facilities Council (STFC) has produced some great space-related teaching resources. Available to download from the ESERO-UK eLibrary, the resources illustrate STFC's work in areas such as particle physics, astronomy and cosmology that can be used in the classroom. The collection includes information on: the ExoMars mission, robotic telescopes, astrobiology and the Large Hadron Collider. View the full collection at: **http://stem.org.uk**

Made in the UK

Welsh company Qioptiq Space Technology produces specialised glass and optical reflectors for satellites and space missions. Development engineer Glenn Jones explains what the company does…

Glenn Jones
Development engineer at Qioptiq Space Technology

Where do your glass products end up?

We supply components for pretty much the majority of satellites – from commercial telecoms such as Sky and GPS to Earth observation satellites and science missions for ESA and NASA. Our components are also on the Hubble Space Telescope, the Mars rovers and there's some of our cover glass on the International Space Station too.

Let's start with the cover glass then, what is it?

A cover glass is a specially formulated glass that is put on the front of solar cells on a solar array to protect it from the space radiation environment – such as solar flares, UV radiation, electrons and protons. They are typically 100 microns (0.1 mm) thick, thinner than a human hair.

Normal glass would darken through damage from radiation but this glass, because of its composition, doesn't darken and stays transparent for the lifetime of the satellite. If it darkened the amount of light going into the solar cell would decrease and the power from the satellite's solar array would be reduced.

Is the same cover glass used on each satellite or mission?

No. Cover glasses are customized to suit the satellite or mission, based on the solar array design, mission duration and radiation environment. We supply three types, in 11 thicknesses, and they are also coated with thin films to enhance the properties of the glass. These can be single or multi-layer anti-reflection coatings, conductive coatings and UV or infrared coatings. For NASA's Kepler mission, which is searching for planets similar to Earth around other stars, we supplied cover glasses with a UV and infrared reflection coatings designed to decrease the operating temperature of the arrays.

How do you make the glass covers?

Raw materials such as sand, limestone and others are heated in a furnace or melter. It is a drawdown process: molten glass produces glass ribbons, which are drawn downwards by rollers. The speed of the rollers determines the thickness of the glass and these ribbons are then snapped

off – somewhere between the size of an A4 and A3 sheet of paper. They are then stored or processed – cut, machined, flattened and toughened into the final sized product – and finally, coated.

Is the cover glass officially 'made in Wales'?

Yes, Qioptiq was once a Pilkington's glass company and we use a Pilkington's melter here in Bodelwyddan near Rhyl. The glass is made and stored here, then we do all the processing and the coating in the same factory before it's shipped out to solar array manufacturers around the globe.

What are you working on at the moment?

The development team is currently undertaking an ESA programme to space qualify an infrared reflector cover glass for future European scientific missions. We are also collaborating with NASA on the development of solar arrays for Solar Probe Plus, a mission to examine the Sun and we are part of a team that is testing glass for ESA's BepiColombo mission to Mercury.

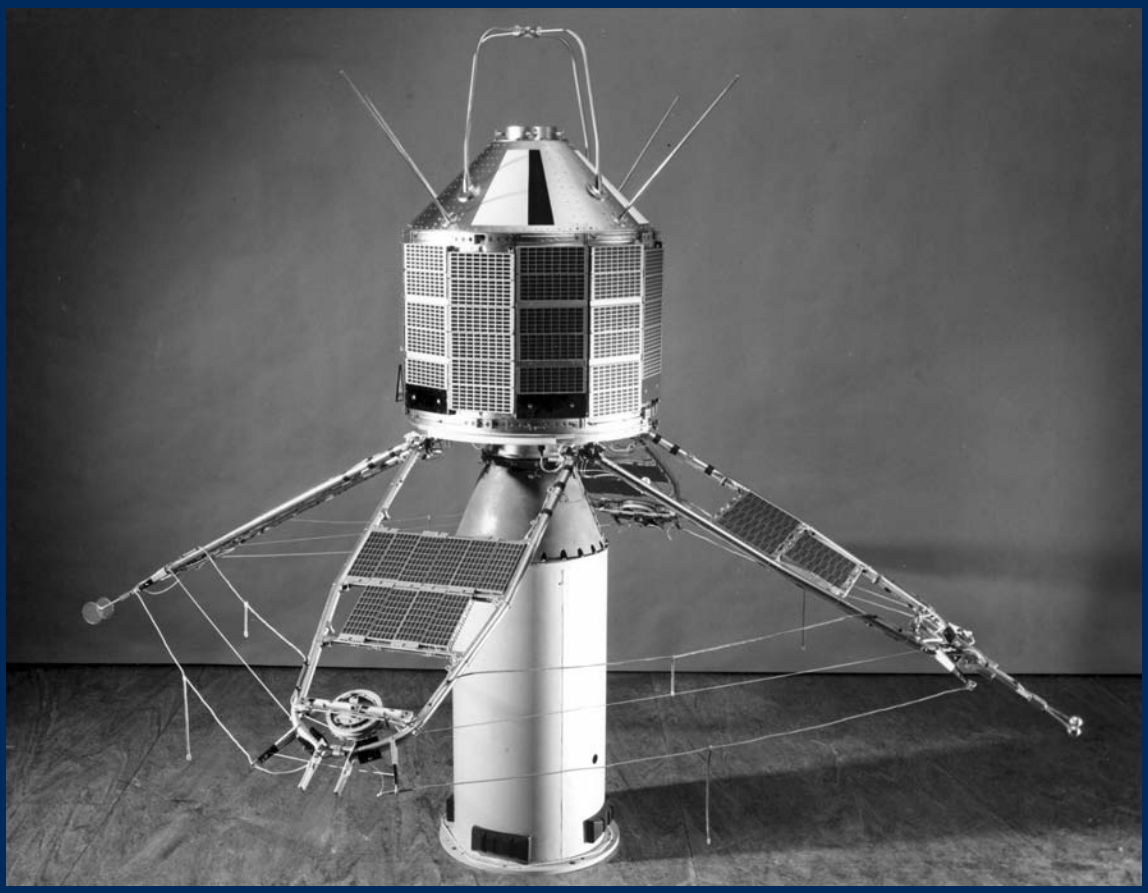
Image top left: Glenn Jones
Credit: Qioptiq

Image bottom left: Samples of the cover glass produced by Qioptiq
Credit: Qioptiq

Image top right: Hubble image of 'Mystic Mountain' – the Hubble Space Telescope uses glass from Qioptiq Space Technology
Credit: ESA, NASA

UK SPACE PIONEERS

Ariel 3



Ariel 3 with its four paddles extended **Credit:** NASA

Launched in 1967, Ariel 3 was the first satellite to be designed and built entirely in the UK.

The curious-looking Ariel 3 was built by the British Aircraft Corporation under contract from the Ministry of Technology and followed the success of the two previous Ariel satellites. Although Ariel 1 and 2 had incorporated UK scientific instruments, they had been constructed in the United States.

Much like its predecessors, Ariel 3 was designed to investigate the space environment. It carried five experiments, including instruments to study the ionosphere – the electrically charged area of the Earth's upper atmosphere – and measure the oxygen found at high altitude. The project involved scientists from the universities of Sheffield and Birmingham as well as Jodrell Bank and the Met Office.

The spacecraft consisted of a 57 cm high prism, its twelve sides covered in solar panels. Beneath it, there were four 'paddles' joined together by antennas. As well as more solar cells, these also held some of the sensors for the instruments. Inside, the satellite boasted a tape recorder – this enabled data to be stored when the spacecraft was out of site of receivers on the ground.

An American Scout rocket launched Ariel 3 on 5 May 1967 and two days later it sent back its first useful data. The satellite performed well for the first five months of operation until the tape recorder began to malfunction. The instruments continued to gather data for a further two years until Ariel 3 was switched off in September 1969. It broke up in the atmosphere in December 1970.

Today, Britain is a world leader in satellite manufacture – a legacy it owes, in part, to the pioneering scientists and engineers who worked on Ariel 3.

Printed by RCUK's internal service provider on sustainable forestry paper
December 2011. UK Space Agency www.bis.gov.uk/ukspaceagency