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IN THIS ISSUE:

Go for Launch
Inside the new UK space industry

Mysterious Mercury
Europe's most ambitious mission yet

Zero-G Science
Weightless in the clouds

LAUNCH UK SPECIAL

Contents

News

Features

Launch UK

cover page credit: ESA


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Go for launch

Plans for the first commercial space launches from UK soil have moved a step closer after new laws were given Royal Assent.

The Space Industry Act – the most modern piece of space industry legislation anywhere in the world – will enable companies to launch satellites and scientific experiments from the UK. It also provides a framework for future developments such as hypersonic flight and travel across the globe in spaceplanes, potentially reducing flight time from the UK to Australia to under two hours.

"The Space Industry Act guarantees the sky's not the limit for future generations of engineers, entrepreneurs and scientists," said head of the UK Space Agency, Graham Turnock. "We will set out how we plan to accelerate the development of the first commercial launch services from the UK and realise the full potential of this enabling legislation over the coming months."

This process of drawing up this secondary legislation is now well underway, with plans for the regulations to be in place for the first launch by the early 2020s.

"UK companies are already at the forefront of hypersonic flight advances and satellite technology," said Aviation Minister, Baroness Sugg. "Our recent Space Industry Act has unlocked the potential for hundreds of new jobs and billions of revenue for British business across the country."

The first UK Space Agency grants for the development of UK spaceports are expected to be announced at this year's Farnborough International Airshow.

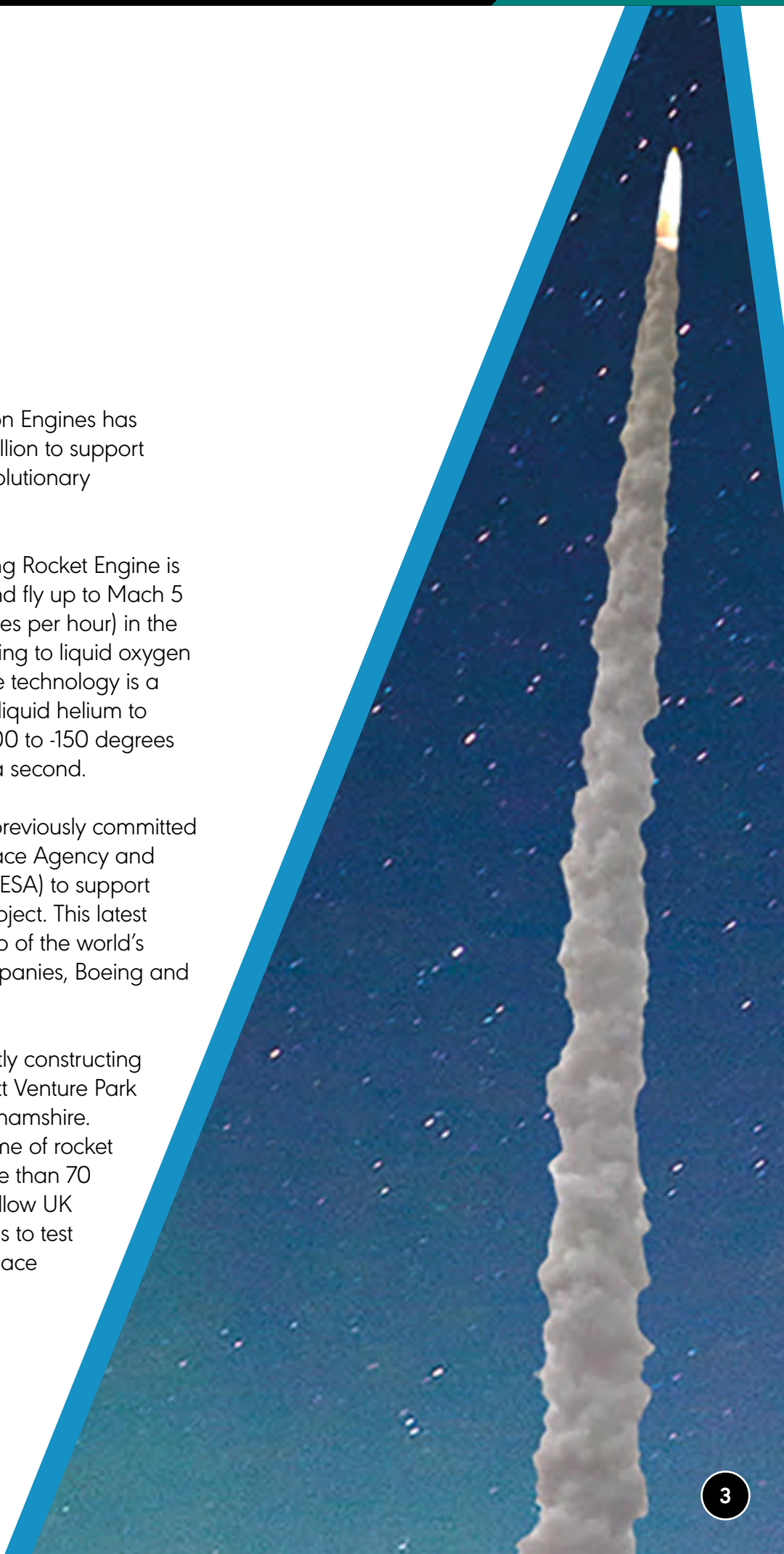
UK rocket tech

Oxfordshire-based Reaction Engines has secured a further £26.5 million to support the development of its revolutionary SABRE engine.

The Synergetic Air-Breathing Rocket Engine is designed to breathe air and fly up to Mach 5 (more than 6,000 kilometres per hour) in the atmosphere, before switching to liquid oxygen in space. The engine's core technology is a heat exchanger. This uses liquid helium to cool incoming air from 1000 to -150 degrees Celsius in a hundredth of a second.

The UK Government has previously committed £60 million via the UK Space Agency and European Space Agency (ESA) to support the development of the project. This latest investment comes from two of the world's foremost engineering companies, Boeing and Rolls-Royce.

Reaction engines is currently constructing a new test area at Westcott Venture Park near Aylesbury in Buckinghamshire. Westcott has been the home of rocket research in the UK for more than 70 years and the centre will allow UK companies and academics to test and develop innovative space propulsion systems.



◀ The SABRE engine could revolutionise propulsion

Credit: Reaction Engines

Rover's return

A rover designed to collect rock and soil samples on Mars for return to Earth, will be designed in the UK.

The sample fetch mission will retrieve samples left by NASA's Mars 2020 rover and transfer them to an ascent vehicle. This will put them in orbit around the planet, where a separate spacecraft will collect them and bring them back to Earth for study.

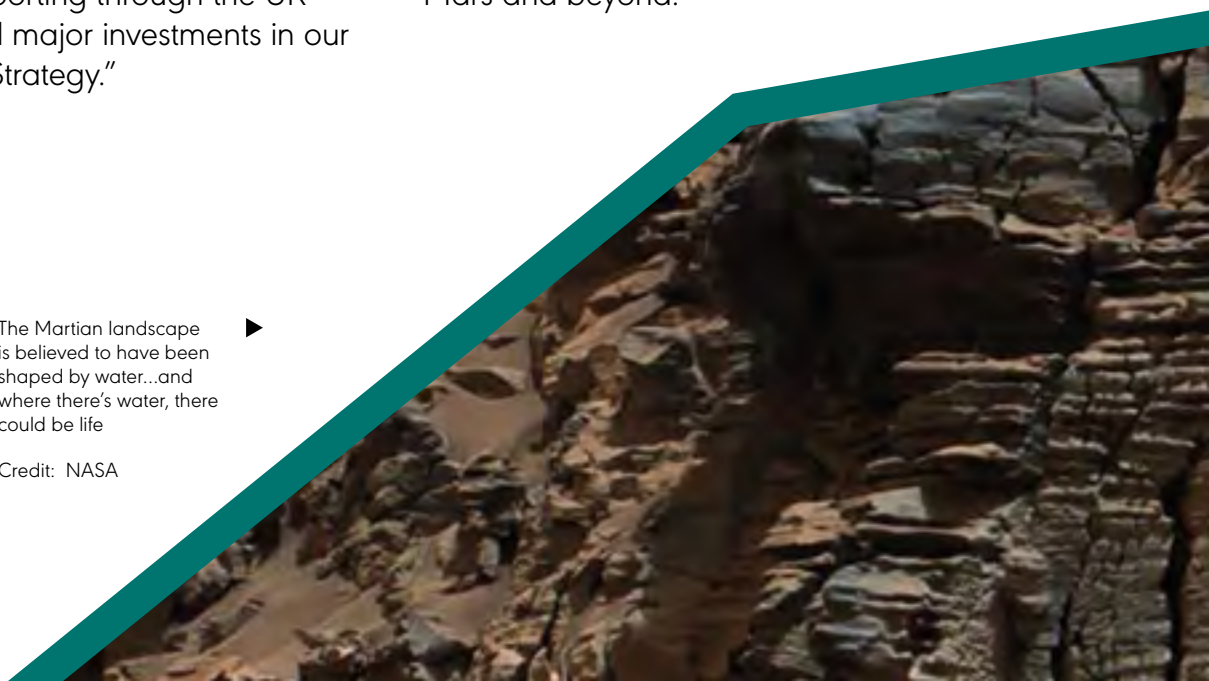
The European Space Agency (ESA) has awarded the £3.9 million contract to design the sample fetch rover to Airbus in Stevenage. The company is currently building ESA's ExoMars rover (see back page) and has the specialist facilities and expertise.

"This is a remarkable new project," said Science Minister, Sam Gyimah. "Winning this contract builds on the UK's world renowned expertise in space and robotics, which the government is supporting through the UK Space Agency and major investments in our modern Industrial Strategy."

NASA's Mars 2020 rover is based on the successful Curiosity rover, which has been exploring the red planet since August 2012. The new NASA mission will be able to collect and encapsulate soil and rock samples in tubes and then leave them in a cache for the ESA mission to collect.

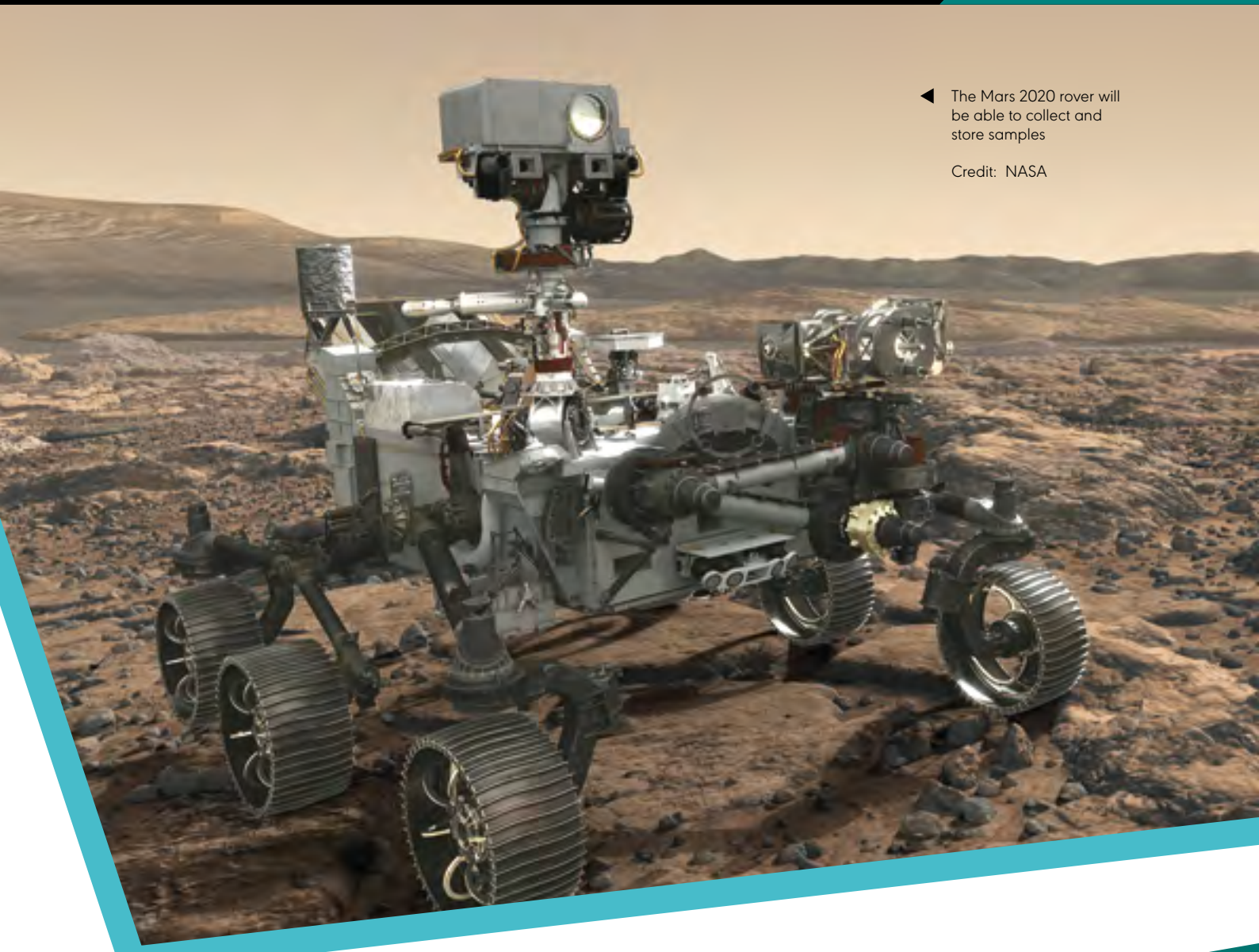
Returning samples from Mars has long been a goal of scientists and this mission will enable them to investigate Martian soil in unprecedented detail in laboratories on Earth. The ESA rover contract was announced at the Harwell space cluster in Oxfordshire during a visit with British ESA astronaut, Tim Peake.

"This is an exciting new era where businesses and space agencies are working closer than ever before on ambitious missions to expand our knowledge of the Solar System," said Peake. "The close collaboration between the UK and ESA will place Britain at the forefront of innovative missions to explore the Moon, Mars and beyond."



The Martian landscape is believed to have been shaped by water...and where there's water, there could be life

Credit: NASA



◀ The Mars 2020 rover will be able to collect and store samples

Credit: NASA

Space for the NHS

The UK Space Agency is offering up to £4 million to transform space technology into medical treatments.

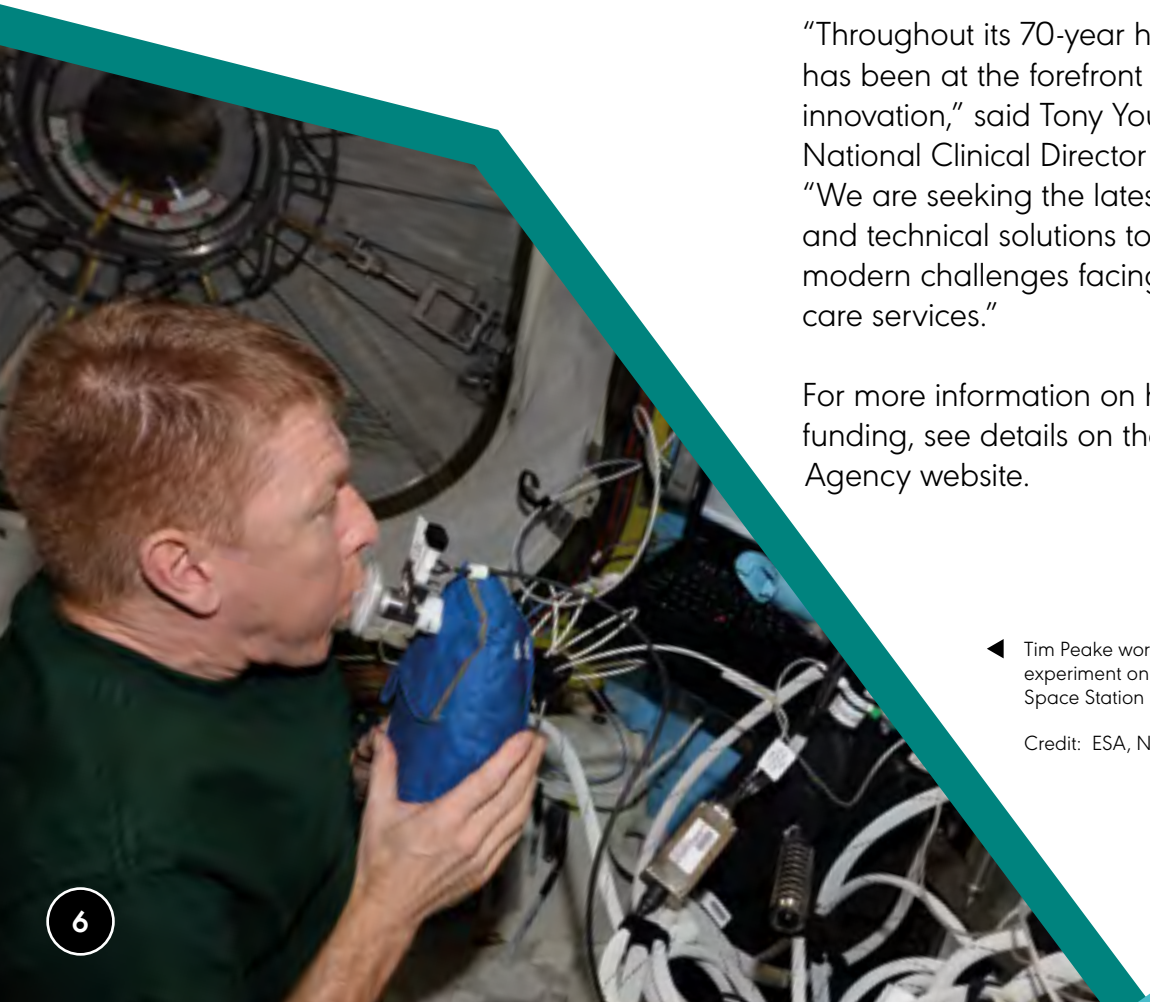
The joint initiative with NHS England, offers innovators the opportunity to bid for money to re-develop technology originally designed for space, into medical applications that improve patient care. Up to four ideas will receive funding, as well as support and advice for their development.

Space tech already adapted for healthcare, and used in the NHS, includes a pill camera that can be swallowed by patients to help investigate problems with the digestive system. Equipped with a miniature video camera and light, it travels painlessly through the gut and sends images back to doctors.

Other applications of space technology include breast screening vans that use satellites to relay images to assessment centres, wearable monitors that help elderly people prevent falls and skin cancer monitoring apps.

"Throughout its 70-year history, the NHS has been at the forefront of healthcare innovation," said Tony Young, NHS England's National Clinical Director for Innovation. "We are seeking the latest, greatest ideas and technical solutions to help address the modern challenges facing our health and care services."

For more information on how to bid for funding, see details on the UK Space Agency website.



◀ Tim Peake working on an asthma experiment on the International Space Station

Credit: ESA, NASA

Catching gravity waves

Scientists in Scotland will work on an ambitious new European Space Agency (ESA) mission to explore gravitational waves – ripples in space and time.

With an initial £1.7 million of funding from the UK Space Agency, teams from the University of Glasgow and the UK Astronomy Technology Centre in Edinburgh will help develop the laser measurement system at the heart of the LISA spacecraft.

LISA – or Laser Interferometer Space Antenna – will consist of three satellites, flying in a triangular formation 2.5 million kilometres apart. The mission, due for launch in the early 2030s, follows on from the success of ESA's LISA Pathfinder.

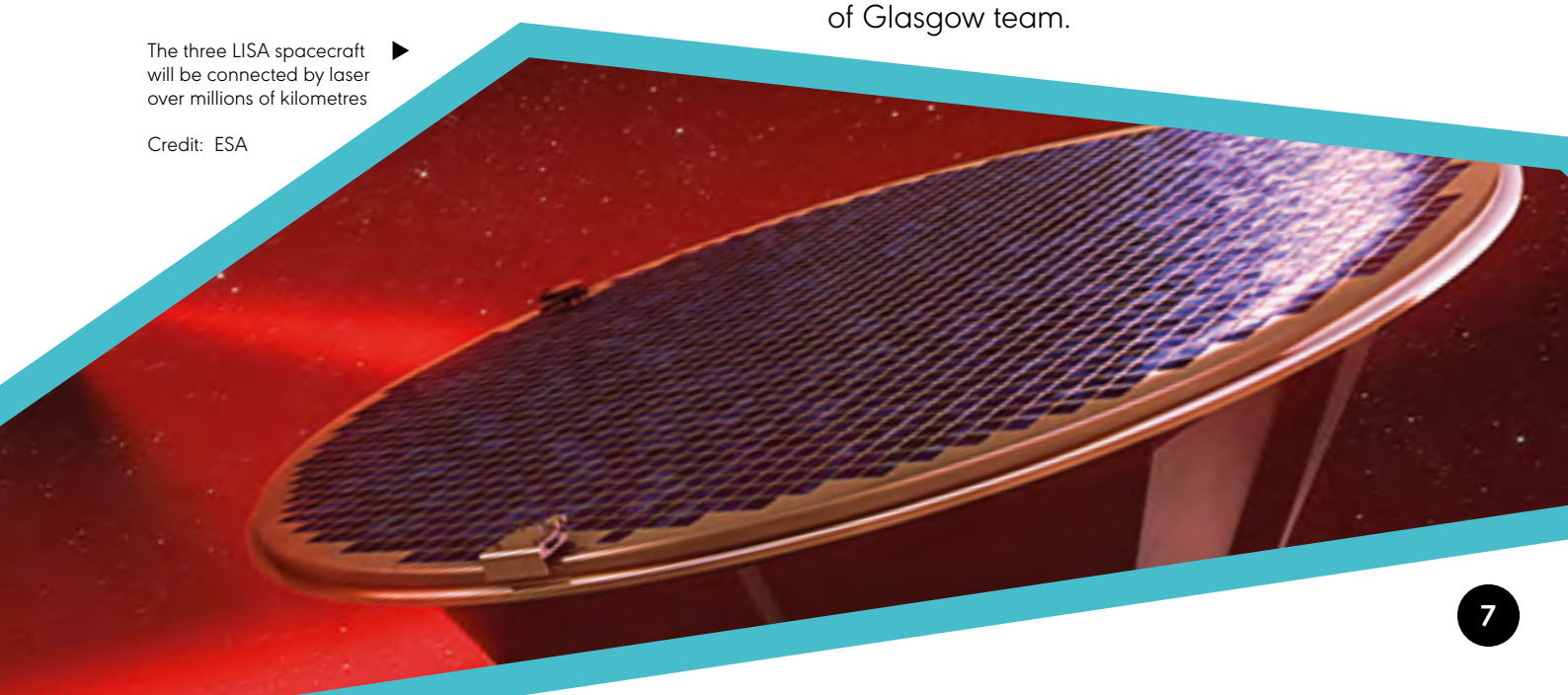
Gravitational waves were predicted by Einstein's 1916 theory of general relativity and were first detected on Earth in 2015. They are thought to be generated by some of the most violent astrophysical events in the Universe, such as exploding stars and collisions of black holes.

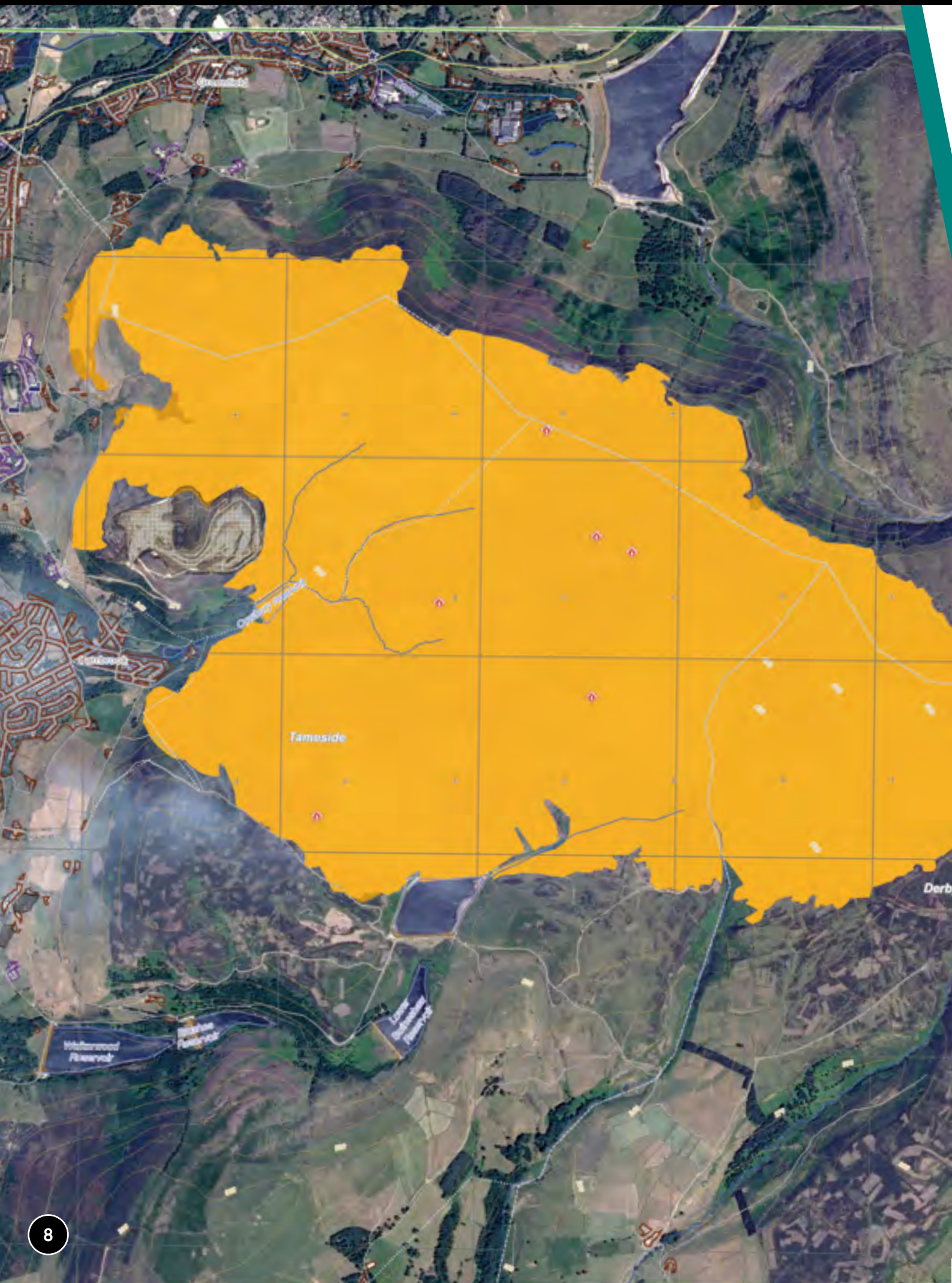
But, despite their origins, gravitational waves are only minute ripples in the fabric of space. To measure them, LISA will use laser beams to track tiny fluctuations in distance between the three spacecraft.

Astronomers believe that studying gravitational waves will reveal the Universe in a whole new way. "The funding sets the Scottish teams firmly on the road to playing a leading role in a mission that promises to provide dramatic new insights into the nature and evolution of the Universe," said Harry Ward, leader of the University of Glasgow team.

The three LISA spacecraft will be connected by laser over millions of kilometres ▶

Credit: ESA




Tameside

Wildfires mapped from space

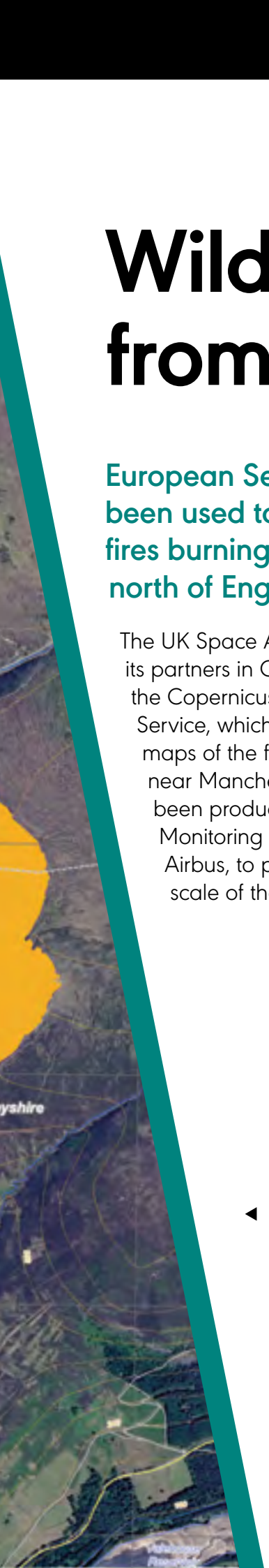
European Sentinel satellites have been used to monitor and map fires burning on moorland in the north of England.

The UK Space Agency has worked with its partners in Government to activate the Copernicus Emergency Management Service, which has provided detailed maps of the fire on Saddleworth Moor near Manchester. Imagery has also been produced by the UK-built Disaster Monitoring Constellation, operated by Airbus, to provide initial estimates of the scale of the blaze.

More than 200 firefighters – supported by the army – have been involved in tackling wildfires on Saddleworth Moor and Winter Hill near Bolton. The maps produced from the satellite data have been used to help coordinate efforts to bring the fires under control.

The UK has been a pioneer in using satellites to manage the response to disasters. The UK Space Agency is a signatory to the International Disaster Charter, which brings together satellites from member nations to collect data and images from areas suffering from natural and man-made disasters.

Since the Charter was founded in 1999, it has been used to aid rescue efforts for 576 disasters around the world.



◀ A map derived from Sentinel satellite data on July 2, showing the extent of the burnt area on Saddleworth Moor near Manchester

Credit: EU/Copernicus

Debris satellite released

A UK-built satellite designed to study ways to clean-up space junk has been released from the International Space Station (ISS).

The Earth is surrounded by some 23 thousand catalogued pieces of space debris – ranging from dead satellites to fragments of paint – any of which could damage operational spacecraft. RemoveDEBRIS is fitted with a net and harpoon, as well as cameras and a laser ranging system, to test technology to capture and remove junk from orbit.

The target debris for the mission includes a smaller satellite released from the main spacecraft. When the experiments are complete, RemoveDEBRIS will unfurl a drag sail to bring itself and the debris out of orbit to burn up in the Earth's atmosphere.

The satellite – at 100kg, the largest ever released from the ISS – was built by Surrey Satellite Technology Limited and the mission is led by the University of Surrey. It was carried to the ISS on board a SpaceX Dragon supply ship, and ejected on June 20 by astronaut Ricky Arnold using the Nanoracks commercial deployment system.

A signal from the satellite was picked-up within minutes of release, as it passed over the Guildford ground station. Engineers will spend the coming weeks commissioning the satellite before the debris capturing technologies are tested.

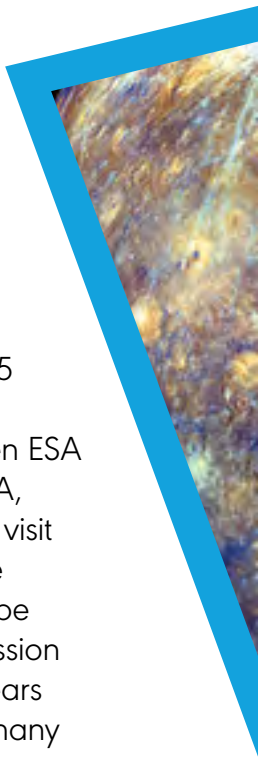
"After almost five years of development, it's exciting to finally be in a position where we can test these extremely exciting technologies in the field," said Principal Investigator for the mission, Guglielmo Aglietti. "If successful, the technologies found in RemoveDEBRIS could be included in other missions in the very near future."

RemoveDEBRIS is released from the ISS ▶

Credit: Nanoracks, NASA

Mysterious Mercury

By Richard Hollingham



The UK is taking a leading role in a major new mission to Mercury, due for launch this autumn.

"One of the most interesting things about Mercury is that it even exists in the first place," says Emma Bunce, Professor of Planetary Plasma Physics at the University of Leicester. Bunce is leader of one of the instrument teams for BepiColombo, the European Space Agency's (ESA) first mission to Mercury. "It's an extreme example of a planet."

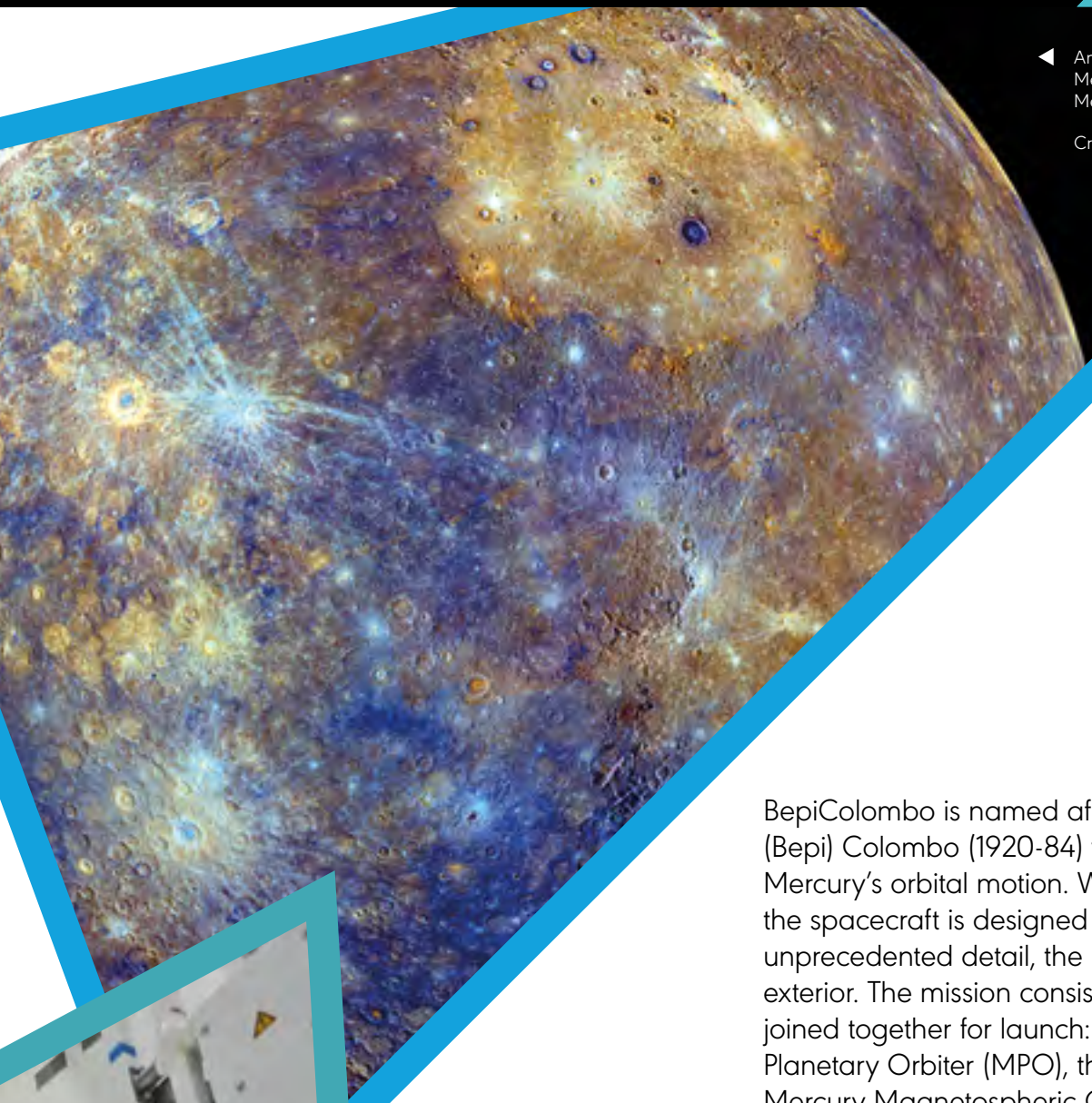
Over the years, the closest planet to the Sun has confounded scientists. For a start, surface temperatures reach up to 425°C and yet ice water has been discovered in craters. There is also the fact that the iron core is apparently solid but Mercury has a magnetic field, which doesn't fit with the theory of how planets should be.

"The planet is a bit like a Malteser," says Manuel Grande, Professor of Physics at Aberystwyth University. "It's got a thin crust of rock on top of an enormous iron core – but how did it get this way?"

"We really want to understand as much as we can about this small body, because it gives us context about our solar system," says Bunce. "The more we understand about how planets form and evolve, the more we can also understand how other solar systems and planets might operate."

Due for launch on a European Ariane 5 rocket from French Guiana in October, BepiColombo is a joint mission between ESA and the Japanese space agency, JAXA, and will be only the third spacecraft to visit Mercury. The first mission to fly past the strange planet was the Mariner 10 probe in 1974. In 2015, NASA's Messenger mission came to an end after spending four years in orbit around Mercury – answering many scientific questions but raising plenty more.

"Messenger has done a fantastic job," says Bunce. "We've been able to adapt our science questions while we've been developing the new mission but there are some fundamental differences between the missions, which means we'll be able to get some very different information about Mercury."



An enhanced colour image of Mercury, captured by NASA's Mercury mission

Credit: NASA

The spacecraft is covered in hand-sewn thermal blankets, installed shortly before launch

Credit: ESA

BepiColombo is named after Giuseppe (Bepi) Colombo (1920-84) who studied Mercury's orbital motion. With its two orbiters, the spacecraft is designed to investigate, in unprecedented detail, the planet's interior and exterior. The mission consists of four modules joined together for launch: ESA's Mercury Planetary Orbiter (MPO), the Japanese Mercury Magnetospheric Orbiter (MMO), a sunshield to protect the MMO, and the Mercury Transfer Module (MTM) which will propel the spacecraft to the planet.

Bunce is the Principal Investigator for the Mercury Imaging X-ray Spectrometer (MIXS), one of 11 instruments on the MPO. MIXS is designed to map the composition of the planet's exterior by measuring X-rays emitted from the surface.

"High energy X-rays coming from the Sun interact with atoms on the surface and cause them to emit X-rays," Bunce explains. "Each element has its own X-ray signature, so MIXS will give us information about the individual elements that make up the surface – then we can start to piece together the jigsaw telling us about the formation of the planet."

MIXS will be able to map elements across the entire surface of Mercury to a few kilometres in resolution. But to produce meaningful results, it needs to work alongside another instrument: SIXS, or Solar Intensity X-ray and particle Spectrometer. This is used to measure material being emitted from the Sun.

"To get the exact composition of the surface of the planet from reflected X-rays, you need to know what the input of X-rays from the Sun is," explains Grande, who's Co-Principal Investigator for SIXS. "Our instrument points at the Sun and measures X-rays and solar particles."

Grande has been working on the mission since its conception, years before the current spacecraft design was adopted. "We put a proposal forward to ESA back in the early '90s, which was quite a radical idea in those days," he says. "ESA liked it so much they made it a large mission and it's taken the next 25 years to get launched!"

The timescale reflects the challenges of developing such an ambitious mission and the learning process that goes into building the spacecraft and instruments. A predecessor of MIXS for example, built by the UK's RAL-Space, was first flown on Europe's Smart-1 mission to the Moon in 2003.

"Smart-1 was a dress rehearsal in many ways for BepiColombo," says Grande, who led the mission's X-ray instrument. "As a result, there's a new generation of instruments on Bepi."

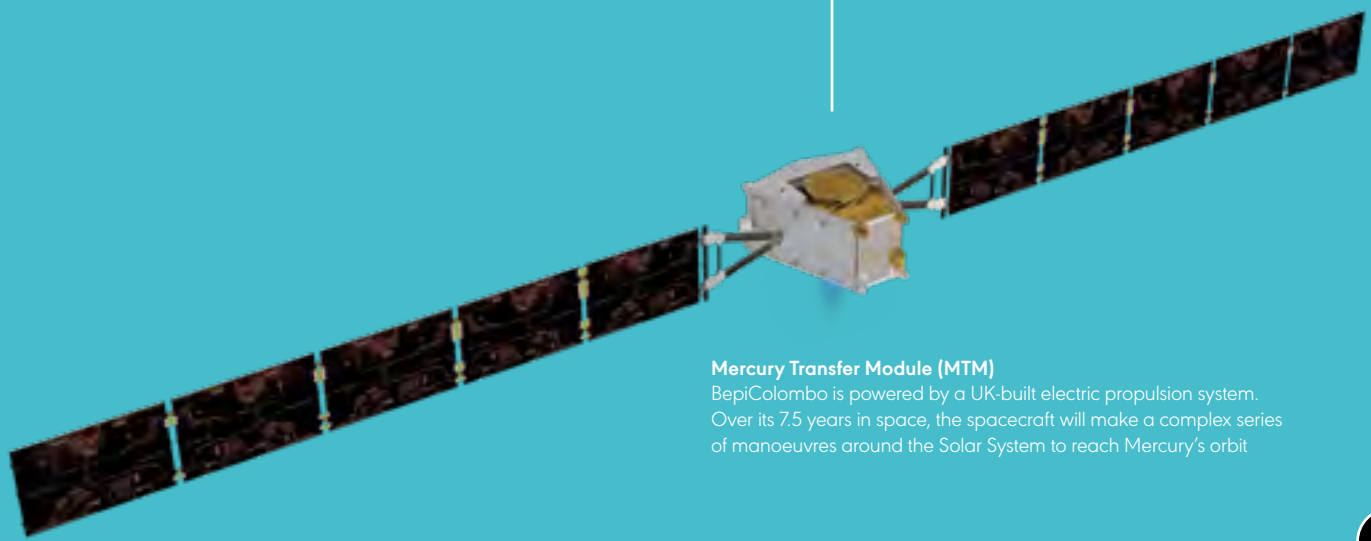
◀ ESA's giant space simulator in the Netherlands was used to test the spacecraft under the conditions it will endure at Mercury

Credit: ESA

Mercury Magnetospheric Orbiter (MMO)
The Japanese orbiter will separate when the spacecraft arrives at Mercury. It will investigate the planet's magnetic field and the magnetic bubble surrounding the planet, known as the magnetosphere

Sunshield
Designed to shield the MMO from the Sun and provide a mechanical and electrical interface between the MMO and the Mercury Planetary Orbiter (MPO) during the journey to Mercury

Mercury Planetary Orbiter (MPO)
The ESA module will also be released once the spacecraft arrives at Mercury. It is fitted with 11 instruments including the UK-led Mercury Imaging X-ray Spectrometer (MIXS), designed to map surface elements



Mercury Transfer Module (MTM)
BepiColombo is powered by a UK-built electric propulsion system. Over its 7.5 years in space, the spacecraft will make a complex series of manoeuvres around the Solar System to reach Mercury's orbit

Test firing one of BepiColombo's four ion thrusters

Credit: QinetiQ

One of the biggest mysteries puzzling scientists is the nature of Mercury's magnetic field – it's the reason both BepiColombo's orbiters are fitted with magnetometers.

"For a magnetic field, theories suggest you need conducting liquid which is convecting and rotating to generate a magnetic field like a dynamo – the same process we have on Earth," says Chris Carr, Co-Investigator for the mission's Magnetic Field Investigation instrument at Imperial College London. "But if Mercury has a solid centre, it shouldn't have a magnetic field and that's not fully understood."

By studying the magnetic field, scientists will also be able to build up a picture of the planet's interior, which should have applications closer to home. "If we understand more about how the dynamo works at Mercury," says Carr, "it may help to further understand what's happening on Earth."

BepiColombo is equipped with an electric propulsion system. Built by QinetiQ in Farnborough and fitted to the MTM, it takes power from solar panels to create a plasma of xenon. Electric thrusters accelerate beams of these positively charged xenon atoms – known as ions – away from the spacecraft to propel it forward.

"It's very efficient," says Jerry Bolter, who oversaw the assembly and testing of BepiColombo modules at Airbus Defence and Space in Stevenage. "Although you get a very small thrust, you can operate for a long period of time."

And that time factor is crucial. Although Mercury is relatively close to Earth, it will take the spacecraft seven and half years to reach the planet. "If you headed straight there, you'd be going too fast to stop because you're accelerating into the gravity well of the Sun," says Bolter. "We calculated that if you put a single engine on there with a conventional chemical propulsion system, you'd need to take 17 tonnes of fuel to get into orbit around Mercury – we only take 600 kilos of xenon."

To reach Mercury at the correct speed, BepiColombo will need to make several detours via Earth, Venus and Mercury itself. "It's mind-blowing, isn't it?" says Bunce. "It turns out that it takes the same amount of energy to slow BepiColombo down as it would to get to the outer solar system – it's not really what you'd expect."

As well as the challenge of reaching Mercury, the other difficulty facing the engineering teams has been how to protect the spacecraft from the extreme temperatures it will need to operate under.

This image of Mercury's pockmarked surface was captured by the Messenger spacecraft

Credit: NASA

"There are times where we'll be flying between the Sun and Mercury, with temperatures of up to 450 degrees on either side," says Bolter. "We have a design to allow components inside to operate at room temperature."

The secret to achieving this thermal protection has been to develop a combination of thick multi-layer insulation on one side of the spacecraft and an ammonia-filled radiator panel facing away from the Sun on the other, which will radiate heat into deep space. Some components, such as the main communications antennae have had to be designed to operate in full Sun.

After final testing, BepiColombo has now been shipped from ESA's test facilities in the Netherlands and is currently being re-assembled and prepared for launch.

Bolter admits the whole long and complex project has been a learning process.

"When we tried out the first thermal test model, for instance, we found we needed a serious upgrade," he says. "It's been tough, but we're absolutely delighted to be so close to launch – I think the scientists will be very pleased with what they get from this spacecraft."

Zero-G science

By Sue Nelson

UK scientists are flying experiments in Europe's 'Zero-G' aircraft to simulate the conditions of space. But these flights are not for the faint-hearted.

After reaching its cruising altitude, the Novespace Airbus 310 Zero-G plane arcs across the sky. Scientists, most of them either standing or sitting on the padded aircraft floor, hold-on tightly to strategically placed straps.

First, the aircraft climbs steeply at a 50-degree angle. Everyone on board experiences 2G and feels twice as heavy as normal. At the top of the arc there are 20 seconds of weightlessness. Then the plane plummets towards the ground for another 20 seconds of 2G, before levelling out again.

After a three-minute break, the aircraft does it all over again. Another thirty times. All science has its ups and downs but, when you're performing experiments in microgravity, these are exactly the sorts of conditions you need.

For me, it's an opportunity to float like an astronaut while witnessing how science is done under extraordinary conditions. The experiments during my flight range from psychology to small satellite tests. There is even an inflatable balloon designed to make measurements in the atmosphere of Mars.

◀ Before his spaceflight, Tim Peake trained in the aircraft

Credit: ESA

For Professor Marco Marengo and his team from the University of Brighton, these 31 parabolas – 93 over three days of flight – enable him to examine how a pulsating heat pipe can help regulate heat in satellites and interplanetary space probes.

The pipe uses an evaporator, which boils a liquid to produce a vapour. A condenser converts this gas back into a liquid phase. This circulation can be used to transport heat, from a hot zone to a cold zone. It's being designed for spacecraft to overcome temperature extremes in space.

"This is an experiment of basic physics," says Marengo. "Without gravity many things change, so the use of the parabolic flight campaign is essential for our work."

These science campaigns usually consist of a week's preparation at the Zero-G plane's base at Bordeaux airport. This is followed by an intensive safety briefing, before three days of flights. On the second flight day, the UK Space Agency's Human Spaceflight and Microgravity Programme Manager, Libby Jackson, joined the Brighton team.

"Each member of the team has one job to do," she says. "This means if someone is ill during the flight or has problems, there is a level of redundancy."

The next stage for Marengo's team is to place their heat pipe on board the International Space Station (ISS) for a longer period of microgravity. Funded by the EPSRC research council and ESA, it will be one of three European physical science experiments on board and will be operated by the astronaut crew.

The University of Brighton team

Credit: Boffin Media

"This is the only microgravity platform where the scientists get to interact with their own experiments in zero gravity," says ESA Parabolic Flight Coordinator Neil Melville, "rather than do it by remote control on a robotic capsule, sounding rocket or on the ISS."

Watching this interaction is an amazing sight. People's hair, together with tethered mascots of cuddly toys, rise upwards into the air during weightlessness and scientists scramble to fine-tune their experiments, correct faults or prepare for different configurations.

The latest campaign, in June, has involved simulating partial gravity, similar to that of the Moon or Mars. On board the aircraft has been a team from Northumbria University's Aerospace Medicine and Rehabilitation Laboratory. They're studying back pain using the motion-capture techniques of Hollywood blockbusters.

Many astronauts experience back problems in space, despite completing two and a half hours of daily exercise. "We know that not only do several months in zero G lead to lower back pain in many astronauts," says Professor of Aerospace Medicine and Rehabilitation, Nick Caplan. "But when astronauts come back down to Earth, in that first year they are at four times the risk of suffering a slipped disc."

It is known that the spine lengthens in space, usually by three to five centimetres. "That can stretch some of the ligaments between the vertebrae, which could be causing some of the pain," Caplan says. "The muscles that keep the spine upright in normal gravity also get smaller and weaker."

Participants in one of the experiments

Credit: Boffin Media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◀ Our intrepid reporter, Sue Nelson

Credit: Boffin Media

◀ The Zero-G aircraft

Credit: Novespace, ESA

The Northumbria team has been using cameras to track the 3D movements of small round markers, placed at various points on the participants' bodies, to accurately track spinal movement. The research has applications for those of us never likely to leave the planet.

"The great thing about using astronauts is that this spinal muscle deconditioning is very similar to what we see in people on Earth," says Caplan. "People with lower back pain or simply what we see as a function of ageing – we will always try to derive terrestrial benefits."

There is a tremendous diversity of research that can be done in microgravity for the scientists that have the stomach for it. But if the experience doesn't agree with you after the first parabolic arc – and I saw several scientists sat at the back with sick bags – then take pity on them as they have 30 more rollercoasters to go.

Fortunately, for most of us, flying in zero-g is a scientific joy ride.

The commercial launch age

By Richard Hollingham

The satellite market is being transformed, making commercial launches and space tourism from the UK an increasingly attractive prospect.

Twenty years ago, space looked very different. Satellites were big and expensive and were owned and operated, for the most part, by governments or large corporations. With a few exceptions, the rockets that blasted them into orbit were similarly controlled by a limited number of big government or commercial players. These launchers were based on designs originally conceived in the 1950s or 60s, often adapted from Cold War missile technology.

Two decades on, the market for satellite technology and applications is changing at an unprecedented rate, with UK companies at the forefront. Commercial manufacturers are building smaller and cheaper satellites, and new operators are developing fleets – or constellations – of spacecraft to provide a range of innovative products, including global communications, broadband and Earth observation services.

In the early 2000s a few dozen small commercial satellites were being launched each year. By 2020 there will be hundreds. By 2030, studies suggest there could be thousands. But although the market for satellite technology and applications is growing at an unprecedented rate, the launcher market remains stuck in the 20th century.

"The problem right now is that the supply and demand doesn't work," says Jan Skolmli, Head of Launch for UK small satellite manufacturer Surrey Satellite Technology Limited. "There aren't enough launch vehicles and isn't enough launch capacity available."

Although there have been new entrants to the launcher market in recent years, including US-based SpaceX and India's PSLV, many other smaller rockets have come off the market.

With this recent test, Virgin Galactic is getting closer to its first space tourism flights

Credit: Virgin Galactic

◀ A SpaceX Falcon-9 can carry several satellites to orbit

Credit: SpaceX

The converted Soviet-era missiles, such as Dnepr and Rockot for example, are now rarely available for commercial launches.

"Launch now costs as much, or more, than the satellite," says Skolmli. "If anything, the price is going up and that's not how it's supposed to be."

Launching a satellite has never been cheap - in recent years, a launch has cost in the region of $40,000 per kilogram. But with companies able to produce highly capable satellites at much lower prices than ever before, coupled with a growth in constellations of multiple satellites, this lack of available launchers presents a potential barrier to the future growth of the space industry.

"If you have a small satellite you can either share a ride on a large launcher – such as a Soyuz, PSLV or SpaceX Falcon – or use a dedicated smaller launcher, but there are very few of these available," Skolmli says. "That's why we're watching with particular interest what's going on in the [spaceport] sector."

◀ Many small launchers like the Russian Dnepr – seen here in 2010 launching ESA's CryoSat-2 – are no longer available to commercial operators

Credit: ESA

Satellites are usually shipped thousands of miles for launch

Credit: ESA

This is the opportunity available to potential UK launch providers. And it's not only SSTL that's in the market for an alternative to existing launch options. Andrew Thorndyke, from market intelligence and advisory services organisation Frost and Sullivan, has been crunching the numbers. "The potential is huge," he says. "In the UK we have significant capability across the value-chain but launch is an area where we've fallen short."

"The ride-share model simply cannot keep pace with the market," says Thorndyke. "What we're looking at in the UK is a dedicated launcher for your satellite where within 60 days you can book a launch and get your satellite into orbit quickly. As a satellite manufacturer or operator, you can work to your own timeframes, not those of the launch company."

Imagine a scenario then – in the not too distant future – where a satellite manufactured in Guildford or Glasgow is loaded into a lorry, driven to a UK launch site and a few days later blasted into orbit. This could be on a dedicated vertical launcher or air launched system. A very different situation to the long journeys, months of delays and complex paperwork involved in existing launches.

But streamlining the process and eliminating paperwork is not enough. For launches from the UK to become a reality, the price has to be right.

"A one stop shop in the UK is very attractive," says Skolmli. "But if the launch is not competitive from a price point of view, it doesn't become that interesting any more. Price is the biggest criteria when our customers consider launch options."

Where the UK's efforts to develop a spaceport – or maybe even several spaceports – stand apart from others is the commercial nature of the enterprise. Although the Government is providing the regulatory framework, launch in the UK won't be a publicly-funded endeavour or national prestige project. The aim is to give the UK space sector an edge and provide a new opportunity for growth. The bottom line is that if a UK spaceport doesn't provide what the market wants, it won't succeed.

"That's a really important distinction," says Claire Barcham, Commercial Space Director for the UK Space Agency. "We'd like to see a vibrant commercial launch market in the UK – led by industry, not government – to drive down costs and improve services to get small satellites into space."

As well as launching satellites, the UK Space Agency and its spaceflight partners the Department for Transport and Civil Aviation Authority also see commercial potential for spaceplanes or other sub-orbital launches. It is likely that these would be from different spaceports to the vertical satellite launchers. Spaceplane flights could carry tourists as well as scientific experiments.

"We have a strong leisure and tourism sector here, it would be a great asset to for the UK to move into space tourism," says Barcham. "And our academic community is well-placed to pursue new opportunities to access space to advance cutting edge science."

The other potentially lucrative incentive for any region looking to develop a spaceport, is the development of businesses to support it. As well as directly creating jobs, UK launches could help stimulate local economies.

"We think there could be huge opportunities for other sectors and industries," says Barcham. "Whether it's in leisure and hospitality for people coming to see launches, transport, logistics or even the financial and legal sectors."

◀ A Soyuz taking-off from Europe's spaceport in French Guiana

Credit: ESA

Because of the strong economic and business case for developing spaceports, the global competition is hotting-up. "We need that first mover advantage," says Thorndyke. "By 2020 we're going to see a huge increase in the number of small satellites and I see us getting involved very quickly."

Skolmli agrees. "The political will is there to help this happen and the market is certainly there," he says. "Maybe the timeframe is a little aggressive but I hope it can be done."

One of SSTL's DMC-3 satellites during final testing ▼

Credit: SSTL

Spaceport UK

By Sue Nelson

Funding to support the development of the UK's first spaceports is due to be announced. But what will they be like?

"When people think of spaceports they tend to think of Cape Canaveral from films like Apollo 13," says Jacob Geer, Head of National Spaceflight Policy at the UK Space Agency. "In other words, a big launch site with multiple launch pads."

The reality for the UK will be no less ambitious but on a much more compact scale. "People are thinking leaner and smaller," says Geer. "Future spaceports we're likely to see in the UK will be based on a launch pad, if it's a vertical launch, with maybe an integration facility, a large industrial building with clean rooms and probably not a lot else."

Some UK spaceports may also need more conventional facilities, more like an airport. "Thinking of the horizontal launch side – spaceplanes or horizontally launched satellites where it takes off under the wing of a plane and is launched over the Atlantic – we are really thinking of an airport with a slightly strengthened runway, an extra building at one end and that's about it," Geer says. "It's not too much more because it has to be lean, low-cost and work for these low-cost satellite operators as well."

Although this is new territory for the UK, it's a path that one other country has already taken. Since 2006 the Mahia peninsula on New Zealand's North Island has been home to Rocket Lab, which operates the world's only private orbital launch facility, Launch Complex 1.

◀ Apollo mission control – a UK spaceport won't look like this

Credit: NASA

◀ Rocket Lab in New Zealand

Credit: Rocket Lab

◀ Heading for orbit

Credit: Rocket Lab


Sutherland
Shetland
Western Isles
Campbeltown
Prestwick
Snowdonia
Newquay

It's licensed to launch 120 flights a year, every 72 hours, to low Earth orbit. While that ambitious launch rate has not yet been reached, business is undoubtedly booming.

"Our launch customers include commercial customers such as Earth-imaging company Planet, weather and ship tracking spacecraft from companies like Spire, through to larger organisations such as NASA," says Peter Beck, Rocket Lab's CEO.

"Rocket Lab is working towards a weekly launch cadence, with monthly launches scheduled in 2018 and fortnightly launches in 2019," says Beck. "We're the only launch provider in the world with the capability to launch with this frequency."

The UK government is aiming for a spaceport by the early 2020s, with spaceflight supply chains, regulators and industrial capability maturing thereafter. Geer calls the deadline "achievable but challenging."

"We're starting to see plans maturing," he says. "People are starting to put down detail of what they'd like to see from a spaceport."

Rocket Lab's experience appears to back up this ambition. "Launch Complex One was built over the course of a year," says Beck. "However, significant research and development went into the design before the perfect site was selected and construction work started."

According to Beck, any potential UK spaceport needs to fulfil some basic requirements in order to be successful and safe. "Low volumes of marine and air traffic are essential conditions for frequent launch opportunities, as well as access to a wide range of orbital inclinations," he says. "The location also needs to be remote enough to ensure launch vehicles aren't flying over land masses or other countries."

Rocket Lab also developed the Electron, the world's only fully carbon-composite launch vehicle, to serve the growing small satellite industry. It has a Commercial Space Launch Act Agreement with NASA and a partnership with Alaska Aerospace Corporation to use the Pacific Spaceport Complex Alaska.

Located on Alaska's Kodiak Island, Alaska Aerospace's path to becoming a spaceport was a much longer one than Rocket Lab. Established by state law in 1991, it took several more years to create the company and secure funding and customers before its first launch in 1998. Since then it has launched 19 rockets with government agencies, including NASA and the US Air Force.

"We currently have five launch pads," says Alaska Aerospace CEO Craig Campbell.

◀ Seven potential UK spaceports have put themselves forward as bases for vertical launches, spaceplanes or air-launched rockets

Credit: DMC-2, Airbus

"One is a larger sized structure that allows for indoor processing of the rocket in all-weather conditions. We also have a small open-air launch pad located near our rocket Integration Processing Facility capable of supporting smaller liquid-fuelled rockets."

The publicly owned spaceport also has two concrete gravel pads used by customers for small launches and "an area blocked for a commercial lease that will eventually be developed by the commercial lease holder into a small launch pad," says Campbell. "In Alaska, we are also supporting the emerging small rocket industry, such as the Rocket Lab's Electron, Vector R, and other small liquid fuelled rockets for the commercial market."

The company's first commercial launch is scheduled for later this year and, according to Campbell, future commercial spaceports need "low cost and maximum flexibility to allow commercial customers to launch on schedule. Reliability and launch schedule assurance at low-cost are critical elements to success."

Alaska Aerospace's transition from government-funded to commercial launches is an interesting one. "Since 2014 we've received no state sustainment or operations funding," says Campbell. "We have diversified our customer base and are doing business outside of Alaska, as well as our launches in Alaska. In 2017 we made a small profit and project another small profit for 2018."

However, he does add a word of caution: "Spaceports by themselves are not large money makers. They are the infrastructure necessary to support the rocket and satellite companies to make profits."

It's this infrastructure that the UK government is keen to support. "We're looking to develop all aspects of supply chain and services," says Geer. "Part of what Innovate UK are doing on our behalf, is to look where the strengths are in the current UK supply chain and where we could grow world-leading products and services, and they will look at things like propulsion, rocketry, avionics, tanks, materials, additive manufacturing. All these things that go into a physical launcher and to understand where the UK could be great and where we could be globally competitive."

◀ Rocket Lab lift-off

Credit: Rocket Lab

Despite its considerable size, Alaska Aerospace has no plans for horizontal launches and they are not planning to accommodate human spaceflights or space tourism either. "We are currently under contract for commercial launches where satellites require Sun-synchronous, highly elliptical, polar orbits," says Campbell. "These are primarily for imaging, communications, navigation, and broadband internet satellite customers. We are not capable of reaching equatorial orbit from Alaska."

Perhaps due to its remote location, few people other than those involved with the satellite and its payload travel to Alaska to witness launches. While the UK Space Agency is primarily supporting business within the commercial space industry, tourism is likely to play a much larger role for any UK spaceport.

"Lots of spaceports see people coming to see the launch as a major benefit to their region," says Geer. "Seeing something of the size of a small satellite launcher going up to space, there's a real interest and excitement around that."

Virgin Galactic's spaceport in New Mexico

Credit: Virgin Galactic

Rocket Science

From planes and rockets, to air-launches and even balloons, there are several ways to reach space. With a potentially lucrative satellite launch market, UK companies are developing new and innovative systems.

Bristol company **B2Space** plans to overcome the cost of climbing through the densest region of the atmosphere by using a stratospheric balloon to lift a launcher up to 35km above the Earth. There, it will be released from an automated platform and fired into orbit.

Based at Prestwick, **Orbital Access** is developing a reusable spaceplane. Designed to be released from beneath a carrier aircraft, the spaceplane will be able to carry up to 500kg to orbit.

Edinburgh-based **Skyrora** is developing new launcher technology inspired by the UK's Black Arrow rocket (see page 42). The company aims to reduce the cost of launches through the combination of proven technology and advanced engineering methods.

◀ The vast SpaceX Launchpad at Cape Canaveral

Credit: NASA

▼ Artist's impression of the Orbital Access spaceplane

Orbital Access

Rocket business

Future UK launches will need to be commercially funded and governed by regulations and insurance – all areas where Britain already has a competitive edge.

Launching rockets is an inherently risky business. Even today, more than sixty years after the first satellite successfully reached orbit, launches still go wrong and the most reliable rockets fail. In 2015 alone, for instance, Russia's Soyuz and Proton as well as SpaceX's Falcon 9 launchers all suffered failures. The Falcon – carrying supplies to the International Space Station – exploded only two minutes after leaving its Launchpad, a second after the NASA commentator reported the rocket to be "on course, on track."

Although satellites were lost in all these incidents, no-one was hurt. Safety processes in place at launch facilities include rigorous procedures for handling fuel and exclusion zones in case anything does go wrong. Commercial satellites destroyed during launch are also insured, which means that insurance companies pick up the bill.

Safety regimes, regulation and an insurance industry are essential components for any launch operation – and they all need to be in place before any rocket or spaceplane launches from the UK, to protect workers, visitors, property, other aircraft and the environment.

"It's a great opportunity to draw on best practice from other launching nations," says Technical Architect, Jeremy Creasey, who's working for the UK Space Agency on developing regulations for space activity and launch sites. "The vision is to provide a single joined-up and transparent regulatory system."

The framework for that system lies within the Space Industry Act, which passed into law in March. The new law includes the concept of reducing risks to as low as reasonably practicable. "This is a well-known process in the UK," says Creasey. "In the oil, gas or nuclear industry this is well understood and we're adopting a similar approach."

The law enables launches from the UK but regulations to facilitate those launches now need to be finalised. This secondary legislation will cover the legal and safety practicalities of launching rockets and spaceplanes and will be designed to complement existing aviation and health and safety legislation.

"It's the first time I've seen a government anywhere really working with industry and the academic community to grow a progressive industry," says Joanne Wheeler, Director at specialist regulatory and commercial consultancy Alden Advisers. "It puts the UK in a very strong position but it's vital that government and regulators now consult closely with industry and industry engages in the process of developing secondary legislation."

◀ Engineers wear protective suits to fuel ESA's Sentinel-3A satellite

Credit: ESA

As Co-Chair of the Satellite Finance Network, Wheeler has an overview of the usually hidden side of the burgeoning UK space sector. "Finance, insurance and law – we have something very special in the UK with these three things in addition to the vibrant space industry," says Wheeler. "It's something people take for granted but it's a huge factor in the development of the space industry in the UK."

London is a well-known global centre for finance and it's the global hub of the space insurance industry. According to the latest independent Size and Health of the UK Space Industry report published in December 2016, these 'ancillary' space services are worth some £392 million to the UK economy.

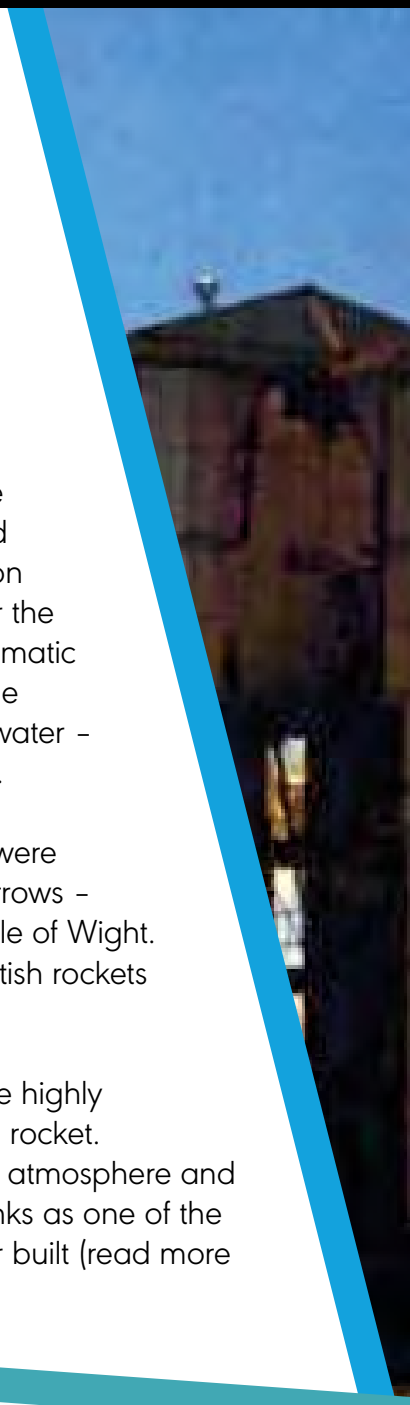
The study also shows that, even without a UK launch facility, the launch-related services sector – which includes spacecraft operations and the brokerage companies that negotiate launches on behalf of satellite operators – is currently worth more than £2 billion.

With the most modern space industry legislation anywhere in the world and an already well established space finance and insurance industry, the UK should be well placed to develop and fund a successful – and safe – commercial launch market.

◀ A successful launch produces clouds of flame and smoke

Credit: ESA

UK space history



The UK was ahead of its time in launcher development

In 1971, the UK became only the sixth nation to launch a satellite into orbit. Its first and only launch vehicle, a three-stage rocket called Black Arrow, placed the Prospero spacecraft into orbit around the Earth from a launch pad in Woomera, Australia.

The success was the culmination of more than a decade of development, and a bittersweet achievement for the engineers and scientists involved. Although the satellite would continue to operate until 1973, the Black Arrow rocket programme had been cancelled a few weeks earlier.

Instead of funding rockets, the Government invested in Concorde. Black Arrow was an excellent launcher for small satellites – a lucrative market today, but not in 1971. Supersonic passenger travel, on the other hand, seemed like the transport of the future and much more likely to deliver an economic return.

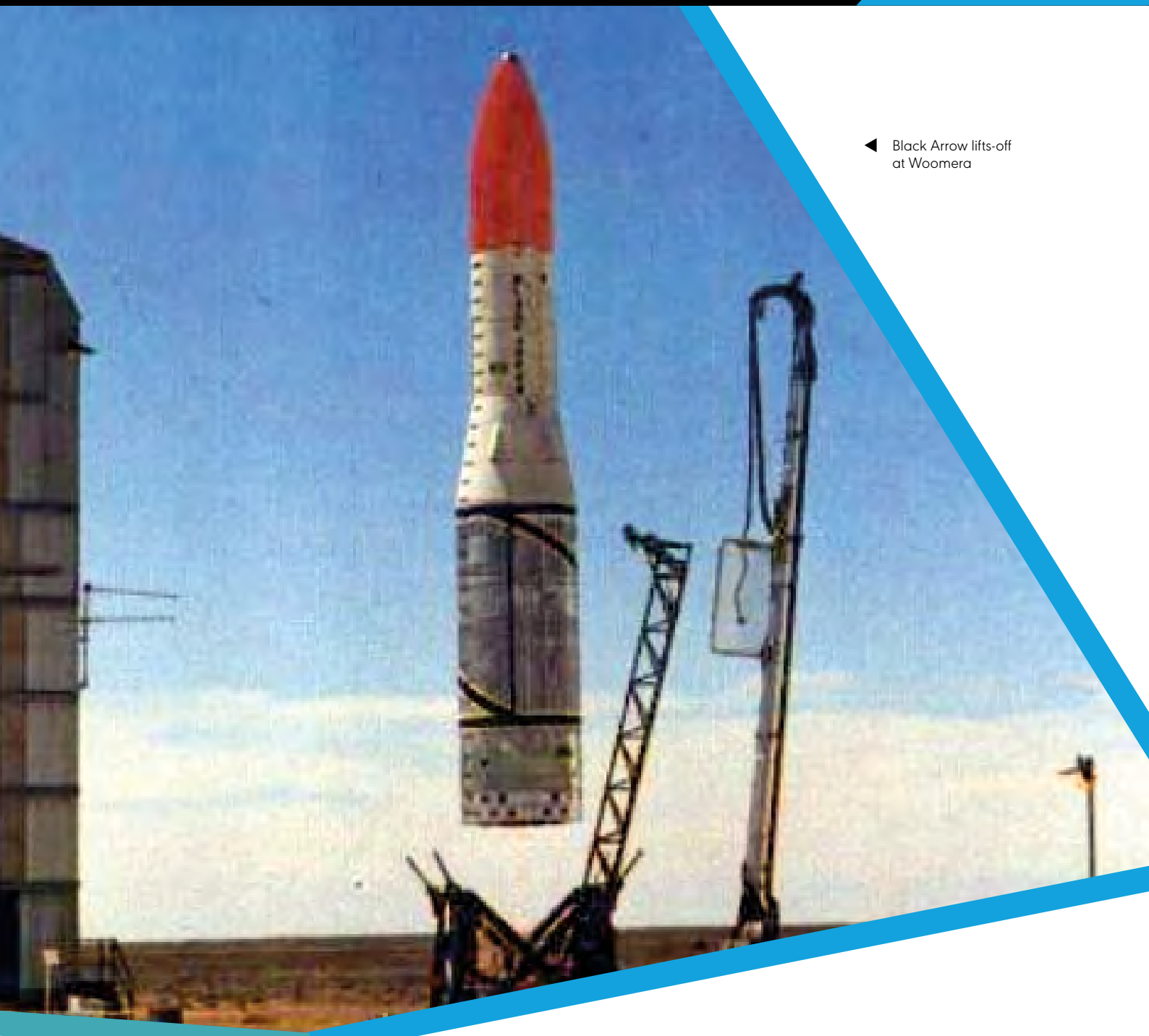
Black Arrow rockets were built by Saunders Roe (later Westland) at Cowes on the Isle of Wight. They were an evolution of Black Knight missiles – designed in the 1950s to study re-entry characteristics for nuclear warheads.

Once built, the rockets were driven across the island and tested high above the sea on the cliffs at High Down near the Needles. The tests were dramatic events, with exhaust from the rockets – cooled by jets of water – blasting out across the cliffs.

A total of 25 Black Knights were launched and four Black Arrows – all built and tested on the Isle of Wight. But they weren't the only British rockets under development.

In the 1950s, the UK built the highly successful Skylark sounding rocket. Designed to study the outer atmosphere and effects of microgravity, it ranks as one of the most successful rockets ever built (read more in issue 49 of Space UK).

Black Arrow being tested at High Down ▶



◀ Black Arrow lifts-off at Woomera

Britain also developed Blue Streak – a missile that never fulfilled its full potential.

Built by De Havilland, this stainless-steel rocket was designed to carry a nuclear warhead but the Government cancelled the project in favour of Polaris submarines. Rather than write-off the investment, agreement was reached for Blue Streak to be used for the first stage of a new European launch vehicle, Europa. The second and third stages of Europa were to be provided by France and Germany, while Italy would build the satellite.

In early tests at Woomera in the 1960s, Blue Streak missiles performed flawlessly. However, when they were mated to the other stages of the Europa rocket, every launch attempt failed.

Eventually, the UK pulled out of the project and the Europa rocket was abandoned. Lessons learned from the programme led to the development of Europe's highly successful Ariane launcher and the formation of ESA.

Today, you can see a Black Arrow rocket in London's Science Museum. You can also visit the test site on the Isle of Wight. Owned by the National Trust, it includes an exhibition in the underground test rooms.

A Blue Streak is on display at the National Space Centre in Leicester, and the Prospero satellite is still in orbit. It will remain there for at least another two centuries. Within a few years, it could be joined by the first British-built satellite to be launched from the UK.

◀ The Prospero satellite being tested

Blue Streak was a sophisticated missile ▶

MADE IN THE UK

ExoMars Rover

In 2020, ESA's ExoMars rover is due to land on Mars. The rover is being built and tested at Airbus in Stevenage and is designed to search for signs of past or present life. It will be the first mission capable of drilling two metres into the Martian surface to collect and analyse samples.

Navigation cameras

These enable the rover to plot the best course to target sites

Panoramic Camera

Led from the UK, PanCam provides 3D and stereo images of the Martian landscape

Solar panels

Powered by the Sun, the rover has batteries to store electricity and heaters to keep instruments warm

Laboratory

Instruments inside the rover examine chemical composition and indicators of life

Close-Up Imager

This camera provides high-resolution images of rocks and drill samples

Drill

The retractable drill can collect samples from 2m beneath the surface

Flexible wheels

Each wheel is independently driven to cope with the rocky terrain

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