UK SPACE AGENCY

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UK Space Conference special edition

SPACE UK

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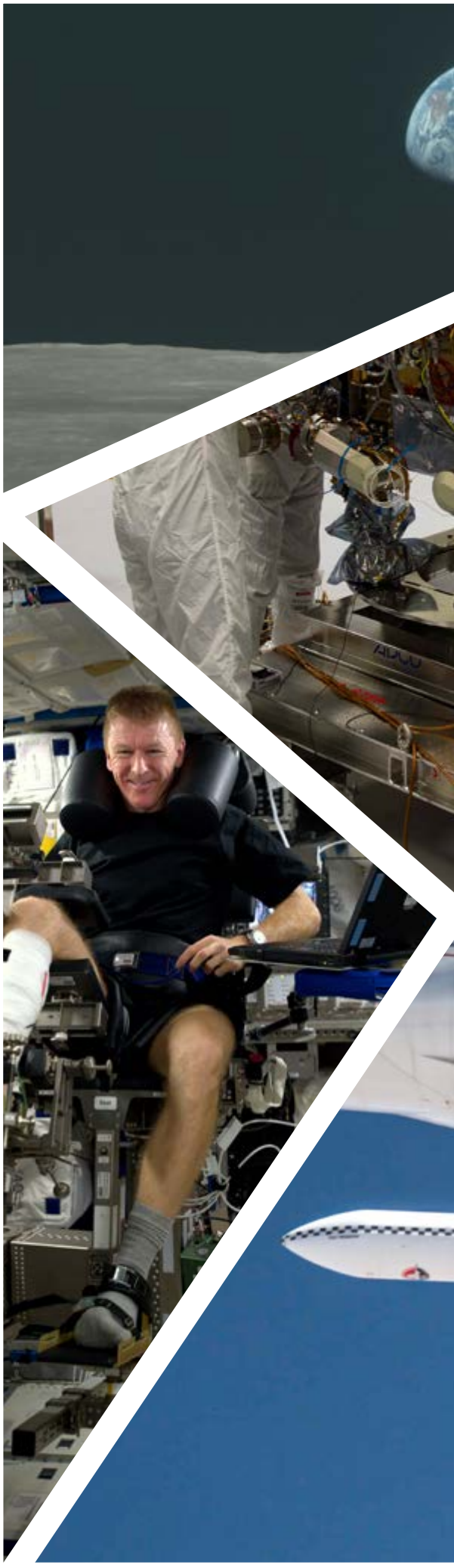


Cover page credit: Airbus Defence and Space


AIRBUS
LAUNCHERONE

Welcome

What an exciting time it is for the UK space sector.

This year has given us a chance for reflection, as we saw with the 50th anniversary of Apollo 11 in July. But 2019 has also been about looking to the future and how we can all work together to turbocharge growth and ensure the UK plays a leading role in the new space age.

We are working hard to maximise the uptake of space technology and services to advance the UK's economy, society, security and international collaborations of world-leading science, in order to capture 10% of the global space market by 2030.

Together we have seen our sector continue to grow. It's now worth a total of £14.8 billion, employs 41,900 people and support over £300 billion of UK GDP with satellite services for navigation, meteorology, Earth observation and communications.

We have announced a National Space Council which will provide strategic leadership on space across government. This will coordinate all aspects of the UK's space strategy, investment and use of space through a new National Space Framework. This is a real upgrade in terms of how the UK government will support the space sector and ensure the benefits it brings stretch across the whole country.

We are enabling spaceflight from the UK to tap into the high value market for small satellite launch and sub-orbital flight and are already seeing an increase in industrial activity as a result. We are also supporting exciting UK companies, such as Reaction Engines, who are developing their innovative hybrid rocket-airbreathing engine which could transform space travel.

This year we also have the ESA Ministerial Council in November, which provides an opportunity to demonstrate our strong ongoing commitment to ESA and build on our global leadership in the sector.

These pages contain only a small selection of activities that have inspired us at the UK Space Agency. This is the most exciting sector of the UK economy and I can't wait to see what the future holds.

Graham Turnock,
CEO UK Space Agency

Go for comet chaser

An ambitious mission to investigate a comet that has not yet been discovered, has been given the go-ahead by the European Space Agency (ESA). Comet Interceptor was proposed by UK scientists and will be the first mission to travel to a comet before it reaches the inner solar system.

Due for launch in 2028, the mission will travel around a million miles from Earth to wait for a suitable comet to intercept. Astronomers will search for either a pristine comet, travelling from the far reaches of the solar system for the first time, or an interstellar object passing through our cosmic neighbourhood.

Comet Interceptor consists of three spacecraft – a mothership to make observations from a distance, and two smaller probes to study the target object in detail. ESA has designated the mission as 'fast', because it will use existing flight-proven technology to accelerate development.

The proposal for the mission was led by teams from University College London and the University of Edinburgh and involves an international consortium of scientists and engineers.

Previous comet missions, including Rosetta's recent rendezvous with comet 67P, have investigated comets that orbit the Sun. This new mission will target objects visiting the inner solar system for the first time. This means they have been untouched by the effects of the Sun and will provide scientists with an opportunity to study materials from the dawn of the Solar System.

ESA's Rosetta mission investigated comet 67P

Credit: ESA

Close to the Sun

Solar Orbiter's heat shield will face the Sun
Credit: ESA

A space probe built to take the closest ever pictures of the Sun is nearing the end of its testing campaign, in preparation for launch in early 2020. The ESA's Solar Orbiter satellite was constructed by Airbus Defence and Space in Stevenage and several of its instruments are led by UK teams.

Solar Orbiter will circle the Sun in an elliptical orbit to capture detailed images of the star and investigate the solar wind – the stream of charged particles the Sun ejects into space. These particles interact with the Earth's magnetic field, producing spectacular auroral displays.

The Sun also releases bursts of matter and high energy particles. These can cause surges in electrical activity around the Earth, damaging satellites in orbit and even bringing down power grids.

"We'll be flying-in close enough to the Sun that we'll be able to see where the solar wind is coming from and measure it before it gets disrupted on its travels through the Solar System," said Louise Harra, Co-Principal Investigator for the probe's Extreme Ultraviolet Imager. "It will help us understand in detail the processes that create the wind that bombards us."

Flying close to the Sun is extremely challenging and the spacecraft has a thick multi-layered heat shield to protect its ten instruments. "The front of the heat shield will be taking the blast of 500 degrees," said Harra, "that's many times hotter than your oven."

The spacecraft left Stevenage in September 2018 and has spent the last year being tested at the IABG facilities near Munich in Germany. The international mission, which also involves NASA scientists, is due to be launched from Cape Canaveral in Florida.

Testing the solar arrays
Credit: ESA

Space innovators choose UK

Two innovative companies are investing in the growing UK space industry.

Israeli satellite communications company hiSky is set to create more than 100 jobs in London and Oxfordshire, and space tech firm SatixFy is investing in centres at Farnborough and Manchester.

h iSky is building a satellite communications system designed to provide global low-cost voice and data services, integrating into future 5G networks. The UK Space Agency has provided £9 million to enable the company to develop new telecommunications technology at the Harwell Space Cluster – now home to more than 90 space businesses.

SatixFy serves some of the world's largest satellite manufacturers and operators with antennae and processor technology. The company's new development centre in Manchester designs advanced space-hardened silicon chips for satellites. SatixFy UK recently received a commitment of more than €30 from ESA's Advanced Research in Telecommunications Satellites programme (ARTES).

Other recent UK space success stories include Glasgow-based Spire, which launched its 100th British-built satellite earlier this year.

▼ ESA's ARTES programme supports the development of new satellite technologies

Credit: ESA

Engine passes supersonic test

A key component of a revolutionary British-built rocket engine has passed the first phase of testing. Reaction Engine's air-breathing SABRE engine is designed to fly at up to Mach 5 (more than 6,000 km per hour) in the atmosphere, before switching to liquid oxygen to reach space. To achieve this speed, it employs a heat exchanger to cool incoming air.

During the first phase of a test campaign at the company's facility near the Colorado Air and Space Port in the United States, engineers found that the precooler successfully coped with incoming air of 420 degrees Celsius. This intake temperature replicates conditions experienced at airspeeds three times the speed of sound.

"This is a hugely significant milestone," said Reaction Engines' Chief Executive, Mark Thomas. "This provides an important validation of our heat exchanger and thermal management technology, which has applications including across high-speed flight and hybrid electric aviation."

The Government has previously committed £60 million via the UK Space Agency and ESA to support the development of the engine. In addition to the precooler tests, Reaction Engines is in the final stages of constructing new test facilities at Westcott Venture Park near Aylesbury in Buckinghamshire, where it will begin testing the SABRE engine core next year.

▼ The precooler test rig

Credit: Reaction Engines

Moon mining on the ISS

A UK-led experiment to investigate Moon mining technology has been launched to the International Space Station (ISS).

BioRock involves 18 matchbox-sized biomining reactors containing basalt rock and cultures of bacteria. The devices will be used to test how low gravity affects the ability of the microbes to extract materials such as iron, calcium and magnesium from rock.

"This experiment will give us new fundamental insights into the behaviour of microbes in space, their application in space exploration and how they might be used more effectively on Earth," said project leader Charles Cockell from the University of Edinburgh.

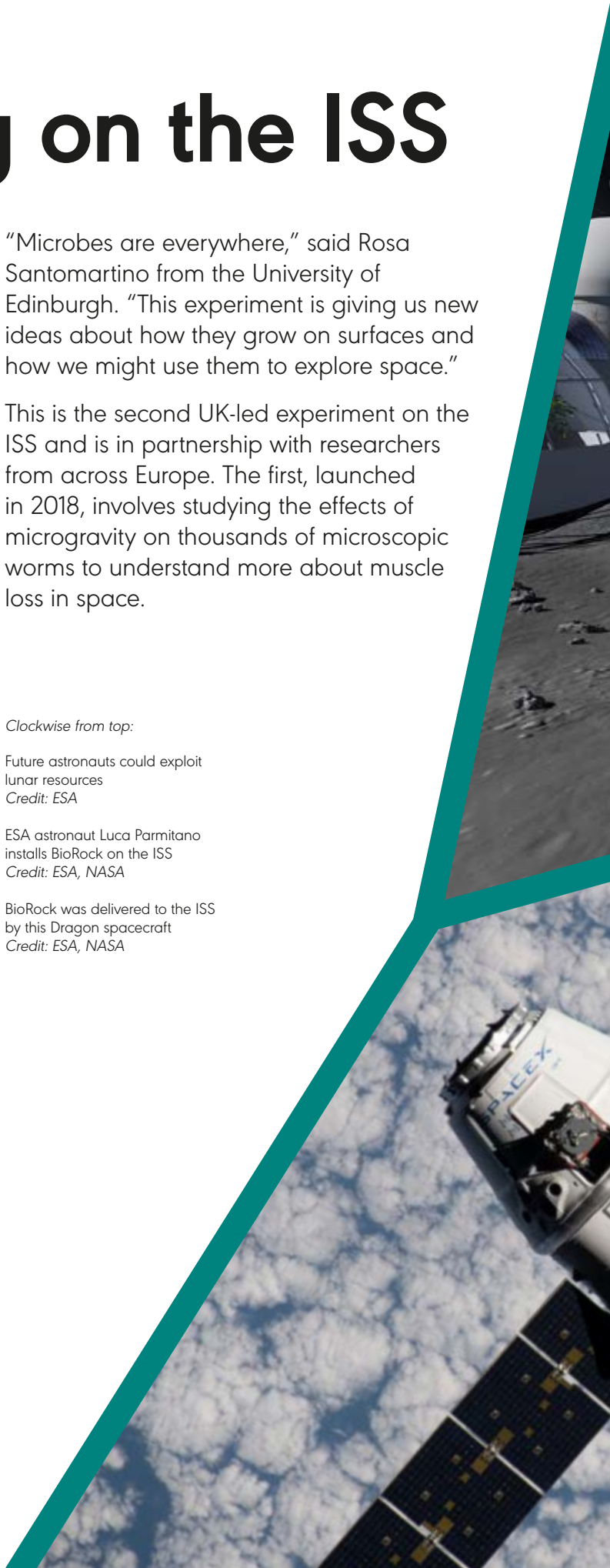
Backed by the UK Space Agency, BioRock is funded by the Science and Technology Facilities Council. The experiment will also be used to investigate how microbes form layers – known as biofilms.

Mining for useful elements in space could provide astronauts with the resources to live for long periods on the surface of the Moon, Mars or asteroids. The technology could eventually enable humanity to establish space colonies on alien worlds.

The findings of the experiment are also likely to have applications on Earth, including developing new ways to recover metals from ores and the use of biofilms in industry and medicine.

"Microbes are everywhere," said Rosa Santomartino from the University of Edinburgh. "This experiment is giving us new ideas about how they grow on surfaces and how we might use them to explore space."

This is the second UK-led experiment on the ISS and is in partnership with researchers from across Europe. The first, launched in 2018, involves studying the effects of microgravity on thousands of microscopic worms to understand more about muscle loss in space.



Clockwise from top:

Future astronauts could exploit lunar resources
Credit: ESA

ESA astronaut Luca Parmitano installs BioRock on the ISS
Credit: ESA, NASA

BioRock was delivered to the ISS by this Dragon spacecraft
Credit: ESA, NASA

Building Rosalind Franklin

By Richard Hollingham

In just a few months, the European Space Agency's (ESA) Rosalind Franklin rover is due to be launched to Mars. Space UK visits the Airbus factory in Stevenage to see the final vehicle taking shape.

I am struggling to put on a pair of rubber gloves.

"The inside of the glove is allowed to be dirty when it touches your skin," explains Liz Seward, Senior Space Systems Strategist at Airbus Defence and Space. "But you can't touch the outside with your bare hands."

After a few minutes of contorted hand-wiggling and stretching, I manage to get half a glove over three fingers. Next comes a mask, hairnet, hood and goggles – giving my face a duck-like appearance. There are also tunics, overalls, shoes, overshoes and gaiters. It's not a look that's likely to catch-on among social media influencers.

The purpose of the glove procedure is to demonstrate how much effort the engineers assembling ESA's Rosalind Franklin rover have to put in to protect the vehicle from any biological contamination.

"People are the dirtiest element of this process," says Seward. "A person can shed a billion flakes of skin in 24 hours and each of those flakes will have bacteria – if these landed on the rover they'd grow into a colony and that's what we have to prevent."

The rover, named after the scientist whose work was key to the discovery of the structure of DNA, is part of the joint European and Russian ExoMars 2020 mission. It's designed to search for past or present life on the red planet.

The vehicle is being constructed behind sealed windows in a specially built clean room. Three storeys high and around the size of a five-a-side football pitch, the facility's walls are lined with shiny stainless-steel panels and it's filled with highly-filtered air.

Only people who have been on a special three-day training course in cleanliness procedures are allowed inside. All the equipment that moves in and out has to be sterilised and, as well as all the protective gear, engineers have to pass through a shower of filtered air to blast away any lingering particles of dust.

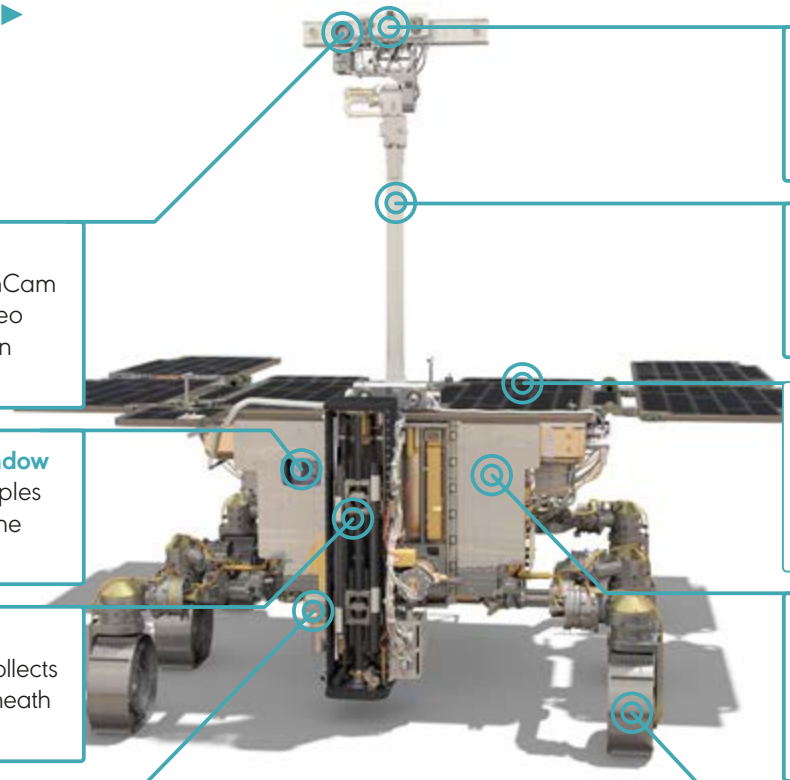
"There are international regulations on how clean something has to be to get to Mars so you can preserve the science of Mars," Seward says. "As the rover is designed to look for signs of life, what we don't want to do is find life from Stevenage when we get to Mars."

We watch through the glass of the viewing gallery as five fully-suited and duck-hooded engineers begin the process of piecing together the final components of the rover. The main boxy body of the vehicle is mounted on a plinth at the centre of the room. Golden in colour it's like some treasured exhibit or ancient relic. Because of its shape, this main structure of the rover is known here as the 'bathtub'. It is packed with instruments, computers and control systems produced by science and engineering teams from across Europe. These include a drill, designed to reach two metres into the soil to collect a sample for analysis by the rover's sophisticated onboard laboratory.

Beneath the body, the locomotion system consists of six wheels pivoted in pairs to cope with tough terrain. This will give the rover the ability to 'walk' itself out of any difficulty. The rover is topped with solar panels to provide power and a mast fitted with a powerful UK-built camera is mounted on top.

As we look, engineers make adjustments to the folded solar panels ready to attach them to the rover and seal the equipment inside. Fitting this lid over the instruments is one of the most delicate parts of the assembly operation.

Original image credit: ESA ▶



Navigation cameras
These enable the rover to plot a best course to target sites

Mast
This gives the rover the best possible view of its surroundings

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

Laboratory
Instruments inside the rover analyse samples for chemical composition and any indicators of life

Flexible wheels
Each wheel is independently steered and driven to cope with the rocky terrain

Panoramic Camera
Led from the UK, PanCam provides 3D and stereo images of the martian landscape

Sample Delivery Window
The drill delivers samples here for analysis by the instruments inside

Drill System
The retractable drill collects samples from 2m beneath the eroded surface

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

"This is one of the critical phases for planetary protection," says Planetary Protection Officer Silvio Sinibaldi, who has the weighty responsibility of protecting Mars from biological contamination. "We have to be really careful because the inside of the rover has a less stringent biological requirement than the outside and we need to avoid cross-contamination between the two."

Every aspect of the assembly is designed to minimise contamination. As they work, the engineers wipe down surfaces with alcohol and change their outer gloves whenever they move between components.

"We have to make sure everything is as clean as we think it is," says Seward. "So, we've got assay plates dotted around the room to collect samples – we measure bacteria to make sure levels stay within the required limits."

The next challenge will be to maintain cleanliness as the rover leaves the Airbus factory for final testing in France and launch from Baikonur in Kazakhstan.

"This is a big headache for me," Sinibaldi says. "At every single step there is a risk of contamination and potentially a problem with the mission."

▲ Final assembly of the rover in the Airbus cleanroom

Credit: Airbus Defence and Space

As well as checking all the systems are operating correctly, the testing at Airbus' facilities in Toulouse will involve subjecting the rover to the conditions it will experience during launch and on the voyage to Mars. Tests will include shaking the rover to simulate the noise and vibration of launch and placing it in a vacuum chamber to ensure it can cope with high and low temperatures. Engineers have already subjected a test model of the rover to the same conditions, so they are confident of success.

Unlike previous Mars rovers, one of the unique aspects of the Rosalind Franklin rover will be its ability to operate autonomously, using cameras and onboard navigation systems. Albeit at a sedate 60 cm a minute. A few metres away from the clean room, in a decidedly dirtier test arena – or Mars yard – a series of test rovers have been put through their paces over the past few years to refine the self-driving navigation software. During his Principia mission in 2016, British ESA astronaut Tim Peake even remotely controlled one of them from the International Space Station.

This latest ExoMars mission has faced a series of delays but, assuming testing of the vehicle and landing system goes well, the Rosalind Franklin rover will leave for the launch complex in early 2020 and finally blast off towards Mars on a Proton rocket in July. It is due to land on the surface, along with a Russian science platform, in spring 2021.

"It's a busy time but it finally looks like a rover," says Seward. "For me it's really exciting because, when I was a younger engineer, one of my first jobs was working on a study of the Mars rover – and I can see a few parts that are my design."

Once the Rosalind Franklin rover leaves Stevenage, the specially constructed clean room will be empty. But not, perhaps, for long.

"We are now the expert centre for European Mars rovers," Seward says, "and we're already working on designs for the next one."

▲ The ExoMars2020 descent module is taking shape at Thales Alenia Space in Turin

Credit: Roscosmos

This new rover will form part of a sample-return mission – designed to bring back small amounts of Martian soil and rock for analysis on Earth. "The Americans are building a rover to collect samples on the surface of the planet and they'll just leave them like a little trail of breadcrumbs in capsules," Seward says.

"We're designing the sample fetch rover which will land a few years later and pick up those samples and get them to a Mars ascent vehicle." This will carry them into orbit to dock with a return spacecraft designed to bring the samples back to Earth.

"And that is going to be amazing!"

▲ NASA's 2020 rover will collect and leave samples on the Martian surface

Credit: NASA

A camera for Mars

The Rosalind Franklin rover is fitted with the most powerful scientific camera system ever sent to Mars. Mounted on a mast, PanCam consists of two wide angle cameras, positioned 50 cm apart, to give the rover a 3D view of the landscape, and a High-Resolution Camera to provide colour images of rock texture.

"It's the science eyes of the rover," says Principal Investigator Andrew Coates from UCL's Mullard Space Science Laboratory in Surrey. "PanCam will help us decide where to drill to look for signs of past, or even present, life."

Each wide-angle camera is fitted with filters enabling the rover to see different wavelengths of light. "We'll be able to see the landscape, composition and texture of the rocks and study the amount of water and dust in the atmosphere," says Coates. "What I'm really looking forward to is watching the sunset on Mars and measuring the amount of water between the Sun and the rover."

Mars was once very different to the barren, dusty world of today. 3.8 billion years ago, water flowed across the surface and there were clouds and a blue sky. "It was very much like when life was developing on the early Earth and that's why we think there might have been life on Mars," Coates says.

The rover will be targeting sites, such as dried-up riverbeds, where there was once water.

"I'm really excited about this mission," says Coates. "It gives us the best chance of any mission so far to find life on Mars."

Spaceport Cornwall

By Sue Nelson

Southwest England promises Sun, Sea...and ready access to Space.

There are many reasons to visit Cornwall, not least the winning combination of sun, sea and surf. But there will soon be another attraction: space. Cornwall Airport Newquay plans to be the UK's first horizontal spaceport.

Unlike conventional vertical launchers, such as the Russian Soyuz or the European Ariane 5 rocket, horizontal launchers take off and land on runways, much like the Space Shuttle did before retirement. However, horizontal launch vehicles will not carry astronauts and may not even go into space themselves.

Instead, modified aircraft act as a piggyback ride for satellites. These are housed inside a smaller rocket launcher beneath the wings. At the appropriate altitude, the carrier plane releases the rocket which completes the satellite's journey into space.

Virgin Orbit intends to launch small satellites, weighing between 300 and 500 kg, from Spaceport Cornwall. The US-based company will deliver satellites into orbit using its LauncherOne rocket from a modified Boeing 747 aircraft called Cosmic Girl.

"Cosmic Girl isn't that different from an ordinary 747," says Will Pomerantz, Vice President of Special Projects at Virgin Orbit. "We've added some computer stations to the upper deck for our flight engineers and lots of instrumentation so we can monitor the health of the aircraft and rocket."

Passenger seats have also been removed and a pylon installed under the plane's left wing to hook LauncherOne into place. But even with the rocket attached, the plane is flying light.

"Fun fact," says Pomerantz. "747s were actually designed to carry weight on the same wing. It's called the fifth engine pod and is normally used to transport spare engines from one place to another – kind of like a spare tyre on the back of a jeep."

Newquay Airport does not normally host 747s but its history as a former military base means this capability is already there. "One of the advantages of the airport is that we have a very long runway of 2,744 metres and this means we'll be able to accommodate the Cosmic Girl 747 aircraft," says Al Titterington, Managing Director of the airport.

"A340s, A330s and military C17 aircraft regularly land here and we've also handled the Antonov aircraft," says Titterington, referring to the largest cargo plane in the world. "We've handled those on the Echo apron on the south side of the airfield where Cosmic Girl will be based."

"For us it's another aircraft and will fit within the terms of our normal operating procedures," he says. "We look forward to welcoming it here for the first time, hopefully, in the early 2020s."

Spaceport Cornwall is more than the airport, however. It's a consortium involving Cornwall Council, Virgin Orbit and the Goonhilly Earth Station on the Lizard Peninsula, which will provide mission management services for launches such as tracking, as well as the aerospace community involved in the supply chain.

The UK Space Agency, Cornwall Council and the Local Enterprise Partnership intend to make up to £20 million available to support horizontal launches, subject to business approval. The funding will support domestic satellite launches which could be used to help local weather and space weather forecasting. Solar flares, for instance, can affect and damage electronics and communications both in space and on the ground. Horizontal spaceports can also be used for suborbital activities involving space planes or balloons, such as scientific experiments or tourist flights.

The Government sees the UK playing a key role in the emerging business of commercial spaceflight. "We want to support the development of innovative technologies like horizontal launch which could be a game changer in terms of how we put satellites into orbit," says the UK Space Agency's Sophia Mitchell.

"People have been launching satellites for decades now," she says. "But horizontal spaceports, such as the one proposed at Cornwall, give the UK a real opportunity to launch satellites and sub-orbital spaceplanes from existing airports."

▼ Cosmic Girl prepares for take-off during a test flight in California

Credit: Virgin Orbit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Newquay Airport has an extremely long runway

Credit: Cornwall Airport Newquay

Efforts to engage the public in the potential benefits of a local spaceport are also underway. Step off a plane at Newquay and arriving passengers are confronted by a billboard showing a surfer on the foaming white crest of a wave with the words: 'Our Space – satellites launched from Cornwall will help predict and track weather conditions.'

It's an astute combination, since it makes clear the connection between space activities and our everyday lives – whether you're a surfer or even couch-surfing watching satellite TV, or using GPS to navigate your way from Truro to Penzance – space technology is here to stay. And the airport itself is a key reason for the spaceport's location.

"We were initially shortlisted as a potential site because of our existing infrastructure and having one of the longest runways in the UK," says Melissa Thorpe from Spaceport Cornwall. "We don't have to build from scratch. We don't have to be a Spaceport America," she says, referencing the world's first purpose built commercial spaceport located near the White Sands Missile Base in New Mexico, USA, whose tenants include Boeing, Pipeline to Space and Virgin Galactic.

"We also have a heritage here," Thorpe says. "We still have the ex-military site (including RAF St. Mawgan's runway) and we were a secondary landing site for the Shuttle programme."

The space connection doesn't end there. Over the summer, the Edinburgh-based firm Skyrora used one of the airport's nine hardened aircraft shelters to test the 3D printed engine of its XL rocket. Unlike horizontal launchers, the XL rocket is a vertical rocket using technology inspired by Britain's Black Arrow, which launched between 1969-71.

During a tour of the airport facilities by car, we stop off at the dark green and curved hangar 7, built by NATO during the 1980s to house Tornados. Its shape and colour brings back flashbacks of Gerry Anderson's Thunderbird 2. Alarms sound and its huge doors open in an equally tantalising fashion. "It's basically a reuse of a Cold War piece of infrastructure," Thorpe says. "It's quite cool and very Bond-esque."

The James Bond connection doesn't end there. The hangar has long been used as a test facility for rocket engines. "Initially we did rocket testing here with the Bloodhound project," says Thorpe. Bloodhound SSC is the British supersonic car powered by a Rolls-Royce jet engine and a Nammo rocket.

Nearby, in the beautiful Cornish countryside, is a recently completed Aerospace business hub where Spaceport Cornwall and Virgin Orbit will eventually have offices.

In July, Virgin Orbit performed a successful 'drop test' of its LauncherOne system above the Mojave desert in California. Cosmic Girl carried a full sized LauncherOne, filled with water rather than propellants, to test the dynamics of release, since the rocket needs to fall for several seconds before the first stage engine ignites.

"Our first commercial mission will be for NASA Venture Class Launch Services," says Pomerantz. "Most rocket companies will wait about a year between their first flight and second, but we're aiming to move much quicker than that, potentially launching within a few months of our orbital test flight."

This means there is a real possibility that we could see a launch from Spaceport Cornwall in the early 2020s.

"From a physical infrastructure perspective, we're pretty much already set," says Titterington. "There is some investment which we will need to do over the next 12 months but, given that we're looking at a relatively low launch frequency in the early years of between one and three per annum over the first four to five years, we don't actually need to invest into significant infrastructure just yet because we're looking to do this low cost with our partners."

Pomerantz describes the Spaceport Cornwall team as "fantastic partners" for bringing LauncherOne to the UK. "Cornwall is an ideal launch location for us as it offers clear, uncontested airspace as well as easy access to launch sites over the ocean, where we can safely deploy our rocket."

▼ Artist impression of a future Spaceport Cornwall

Credit: Spaceport Cornwall

Orbex plans to launch from Scotland in 2022

Credit: Orbex

The county's growing space businesses will also help the region economically. "You've got Goonhilly Earth Station down on the peninsula," says Titterington, "plus a number of the businesses which are starting to relocate or grow within Cornwall on the back of the spaceport activity."

Spaceport Cornwall estimates the site will create 150 jobs, around 80 of them locally, and could add around £200 million to the economy. "This will also attract further business and investment to the area," says Mitchell, "helping to inspire the next generation of space scientists and engineers."

"Our vision as an Agency is for the UK to be leading the new space age," says Mitchell. "Our support for Cornwall and other prospective spaceports will help the UK to realise and harness the commercial opportunities offered by the global space industry."

Thorpe is also looking forward to the realisation of Spaceport Cornwall. "What's really exciting is that we aim to be the first place globally that will fully integrate space launches with a civilian airport," she says. "How inspirational is that going to be?"

Space Hub Sutherland

The Government is funding a range of industry-led projects to help grow the UK's spaceflight capabilities. These include £31.5 million to help establish launch services by Lockheed Martin and Orbex at a new spaceport in Sutherland, Scotland.

In May this year, the UK Space Agency also opened a £2 million fund to support plans for small satellite launch and sub-orbital flight from airports in the UK

Space Hub Sutherland will include a launch site and the infrastructure required for transport and support for the launch vehicles.

In August, the Utah-based In-Space announced that it will partner with Orbex to deliver its Faraday satellite into orbit from the UK's Sutherland launch site in 2022.

Highlands and Islands Enterprise estimate hundreds of jobs will be created as a result of the Scottish spaceport with up to 40 full-time posts locally by 2023.

Inside Virgin Orbit's factory in California

Credit: Virgin Orbit

Space for the NHS

By Izzie Clarke

From exploring distant stars to satellite communications, the technology developed for space is being brought down to Earth for the NHS.

Every two minutes someone in the UK is diagnosed with cancer. Our body is made up of trillions of healthy cells that grow, divide and adapt to our needs. But with cancer, it's a different story. Damaged or abnormal cells grow, surviving when they should die, and new cells develop when they are not needed. Symptoms include rapid weight loss, night sweats and fatigue. But diagnosis can be difficult.

"You can miss things if you're just taking a medical history in the setting of a GP surgery – someone could be tired for a range of reasons," says Christina Mackaill, an emergency care specialist at Queen Elizabeth University Hospital in Glasgow.

"Sometimes cancer doesn't even have symptoms at the beginning," she says. "But the aim of the game is earlier detection, that's what the NHS and the space industry are trying to achieve."

As part of last year's 70th anniversary celebrations of the founding of the NHS, the UK Space Agency and NHS announced a £5 million fund to adapt space technology for patient care. One of the winners of this open competition was space imaging company Adaptix. Based at the Rutherford Appleton Laboratory at Harwell near Oxford, it's using x-ray detection technology originally designed to spot exploding stars and black holes.

Adaptix's device consists of two vertical flat panels, both the size of a pizza box, that move in parallel as the patient stands in between them. One is made up of small X-ray emitters, which fire off X-rays in multiple directions. These travel through the patient to reach the detecting panel and produce a detailed 3D image. The technique not only avoids the traditional (and drawn-out) need to physically move an X-ray source to create an image and the patient receives a fraction of the radiation dose of a CT scan.

▼ Technology developed for Space Shuttle fuel pumps is being used for heart patients

Credit: NASA

"Cancers can go undetected with 2D X-rays," says Mackaill. "The potential benefit of this technology is that it could be used more quickly than a CT machine and therefore spot cancer sooner, without waiting for a hospital appointment."

There is a long history of adapting space technology to benefit human health. In 1983, for example, NASA Space Shuttle engineer David Saucier suffered a heart attack. He was given a transplant by world-renowned heart surgeon Michael DeBakey. Later, the two realised that artificial heart pumps and Shuttle fuel pumps were similar but the heart pumps available to patients awaiting transplant left a lot to be desired. The result? A new mechanical pump that assisted the heart. The technology has become a vital, life-saving procedure for patients awaiting heart surgery.

Today, digital technology is finding new applications in medicine. Another of the winners from the UK Space Agency's initiative is using Artificial Intelligence (AI) and satellite communications systems to target bowel cancer.

"Bowel cancer is the second most common cause of cancer-related deaths in the UK and it's growing," says CEO of Odin Vision, Peter Mountney.

▲ Astronauts exercise to try to counter the effects of microgravity

Credit: ESA, NASA

People with suspected bowel cancer are sent for a colonoscopy. The test uses a narrow, flexible, camera to look at the lining of the large bowel. Cancer specialists are looking for small pieces of abnormal tissue, called polyps, which could develop into cancer.

"The problem is that finding them is extremely difficult and there are lots of studies to show doctors miss over 20% of these polyps," Mountney says. "Our software is using artificial intelligence and space communications technology to help detect and diagnose cancer during the procedure, it's like having a second pair of eyes to spot areas of abnormal tissue."

The technology is similar to the Video Assistant Referee in football. As the doctor carries out the colonoscopy, a live video feed is sent to a cloud database via a fast and reliable data connection originally designed for high-speed satellite communication. The system, Early diAgnosis Real-Time Healthcare System for CANcer (EARTH SCAN), then uses AI to analyse the colonoscopy and identify whether or not a patient has cancer.

The AI technique at the heart of EARTH SCAN has learnt to identify cancerous tissue by comparing images of healthy bowels with signs of cancer. And there are numerous benefits. The speed of the technology means patients can receive a diagnosis straightaway, rather than having to wait for up to a month. Plus, because it's a cloud-based system, EARTH SCAN can be accessed anywhere in the World.

"Better early detection and diagnosis, especially with bowel cancer, leads to much better outcomes for patients," says Mountney. "Survival rates for early detection can be 90% and the cost of treating early polyps is very cost-effective compared to treating late stage cancer." It's still early days but the technology will be progressing through clinical trials in the next year.

As we live longer, the NHS is under increasing pressure to treat a wide-range of age-related diseases. More than a third of all cancer cases in the UK, for example, are diagnosed in people aged 75 and over. By 2034, almost a quarter of the UK population – some 15 million people – will be over 65.

"There are more and more old people, because of demographic changes which are associated with lifespan and development," says Malcolm Jackson from the University of Liverpool's Institute of Ageing and Chronic Disease. Jackson is leading a project called MicroAge, investigating the loss of muscle mass as we age, which is also an issue astronauts encounter when living in space.

On Earth, our muscles are constantly working against Earth's gravity. In the weightlessness of space, however, astronauts have to exercise at least two hours a day to prevent bone and muscle loss. During his mission to the International Space Station (ISS), British ESA astronaut Tim Peake investigated this impact of the space environment on his body. He had muscle samples taken before and after the mission for analysis, with MRI scans comparing the state of his tissue.

Adaptix is adapting technology developed for ESA's XMM-Newton Space Telescope

Credit: ESA

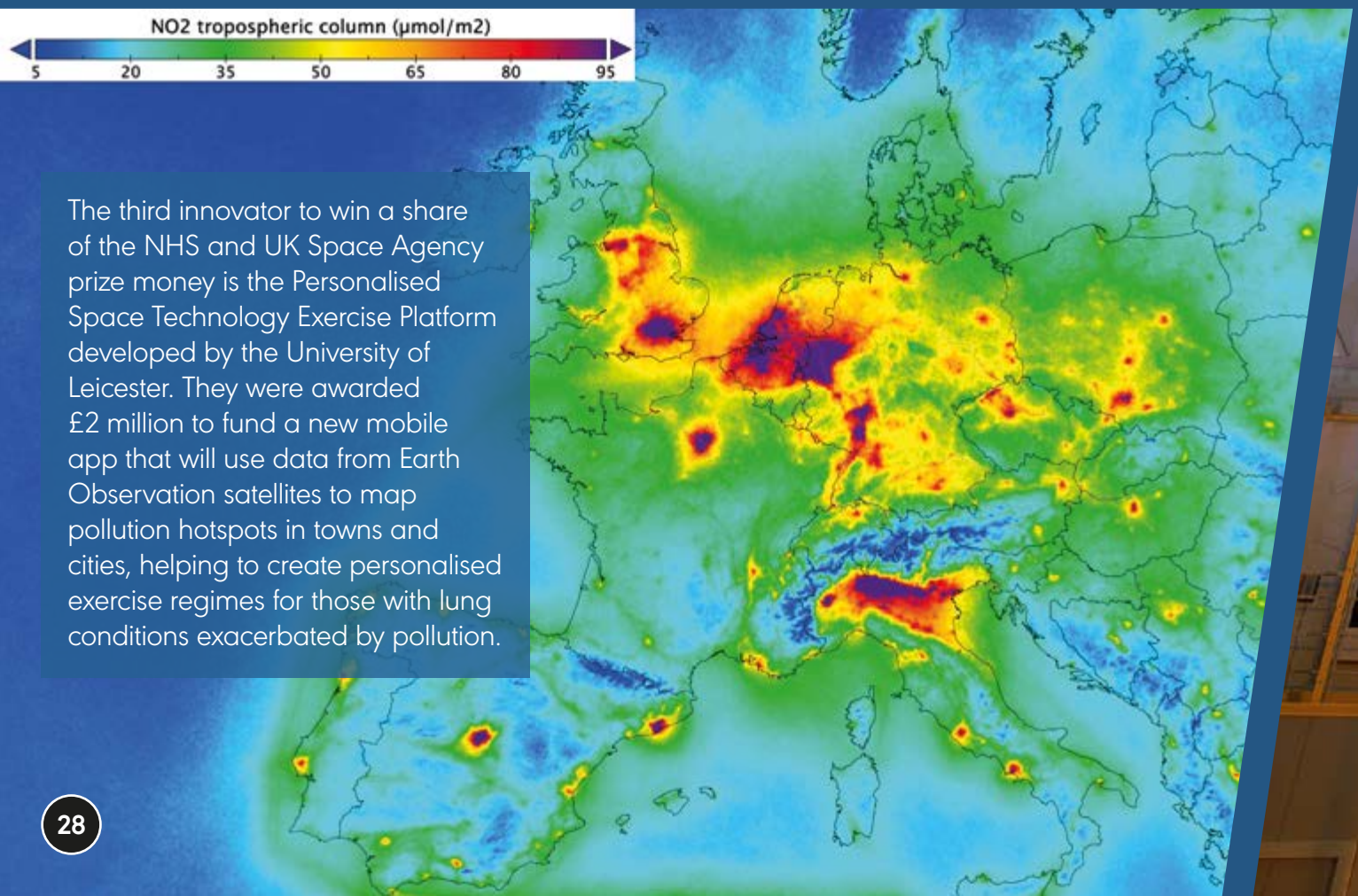
"We were struck by the fact that by trying to ameliorate the changes that go on in space, astronauts now do very large amounts of exercise on a treadmill or resistance training," says Jackson. "Despite that, when they return to Earth they can't walk initially – almost by definition they are not responding to exercise."

The MicroAge team plans to send cultures of muscle tissue up to the ISS in 2021. These will be kept at ambient conditions in a special incubator, developed by Kayser Space Limited. In microgravity, the muscle samples will receive electrical stimulation to contract. Scientists will then analyse the responses that protect and repair muscle proteins, a process that does not occur in older samples.

The same experiment will be taking place on the ground, enabling scientists to build-up a better understanding of the effects of microgravity on muscle synthesis. If all goes well, this could be the beginning for drug-development studies that attempt to identify loss of muscle mass in elderly individuals, helping them to lead a more active life and reduce the strain on the NHS.

"We're trying to address how we can keep people mobile and relatively healthy," says Jackson. "A lot of that is around lifestyle and exercise and there's potential for some selective pharmacology within that."

Over the coming years, the benefits of all this space technology could make a significant difference to NHS care and all our lives here on Earth.



Pollution data from satellites will be used to provide personalised exercise advice

Credit: ESA

The third innovator to win a share of the NHS and UK Space Agency prize money is the Personalised Space Technology Exercise Platform developed by the University of Leicester. They were awarded £2 million to fund a new mobile app that will use data from Earth Observation satellites to map pollution hotspots in towns and cities, helping to create personalised exercise regimes for those with lung conditions exacerbated by pollution.


esa

The Brits of Apollo

By Richard Hollingham

British engineers were at the heart of the Apollo programme. Fifty years after humans first walked on the Moon, the missions continue to inspire the next generation.

In the early hours of 21 July 1969, Pauline Brown woke her one and two-year old sons and took them downstairs to watch TV in their Cheltenham home. As Neil Armstrong stepped down from the lunar lander onto the surface of the Moon, the family huddled together on the sofa.

"You won't remember this," she told her children, "but we want you, in the future, to know you watched this live as it happened."

The story is one of 50 personal recollections captured in the Moon Landing Memories e-book, a joint project between the Arts and Humanities Research Council and UK Space Agency.

"We knew it was going to be a time for everybody to look back and think: Wow wasn't that amazing," says Libby Jackson, Human Exploration Programme Manager for the UK Space Agency. "Many people think it was just an American endeavour, but we knew it was much more global."

Many contributors to the new book were so inspired by the Moon landings, that they went onto illustrious careers in space science and engineering. Others became designers, writers or artists – with space exploration at the heart of their work.

Brown and her family were among an estimated 600 million people who watched live on TV as Neil Armstrong took his small step. But the Apollo missions have influenced many millions since. Space entrepreneurs Elon Musk, Jeff Bezos and Richard Branson have all talked of how the missions inspired their ambitious for space exploration. And many people would not be working in the space sector today if it wasn't for the lunar landings.

"I wasn't born in 1969 but it was the Moon landings that inspired me to follow a career in space," says Jackson. "I've never been in any doubt of that."

"I can think of no other moment where people have known ahead of time it was going to be a historic moment that had an international significance about it," Jackson says. "What surprised me from putting together the book, and through all the celebrations, was how lovely it was to see that level of connection to it."

"It was 2.30am when I crept downstairs and switched on our black and white Phillips TV. Finally, that impossibly grainy, upside down image of Armstrong coming down the ladder. I remember the exhilaration of that moment...an exhilaration shared with bleary-eyed friends later that morning in school assembly."

Nigel Shadbolt, Knighted for services to science and engineering in 2013

"The examples of courage, perseverance, determination and endurance set by the Apollo missions have stayed with me from childhood. I studied for my first degree at the age of 43. When I completed my PhD in 2014, I celebrated with a pilgrimage to Cape Canaveral."

Caroline Ness

Although NASA's Apollo Moon landing programme was funded by the American taxpayer, what many people didn't know fifty years ago was that British engineers were instrumental in making the missions possible.

"We were very fortunate that we got some very experienced British engineers enrolled in the program," says George Abbey, a retired senior NASA manager who worked on Apollo.

Many of these aerospace engineers had been working for aircraft manufacturer Avro in Canada on a new supersonic jet fighter, the Avro Arrow. "It was a fighter that was way ahead of its time and really hadn't been equalled," says Abbey. "But then the Canadian prime minister decided overnight to cancel it, they were laid off."

Learning of the redundancies, NASA bosses flew to Toronto to recruit the best of the engineering team and fast-track them into the US space programme.

"They were put in major roles and responsibilities in the Mercury, Gemini and Apollo human space programmes," Abbey says. "They played a significant role in what we did in those early years and really should get the recognition they deserve."

The British born and educated engineers included Tecwyn Roberts, who would set up NASA's global communications network and help design mission control. John Hodge – originally from Essex – would become one of NASA's first Flight Directors, overseeing many early US spaceflights.

"I had just graduated when Apollo 11 landed in 1969 and I stayed up all night waiting to see the first Moon walk. I soon joined Colin Pillinger (later of Beagle 2 fame) in trying to prove that the tiny amounts of carbon in the Apollo dust samples had come from the Sun."

Peter Cadogan, now working on software to automatically count lunar craters

Other UK-born NASA engineers included Keith Wright, who worked on experiments that Apollo astronauts carried to the lunar surface. He scratched his name and drew a union jack flag on the back of one of the instruments. It remains on the Moon to this day.

John Tribe was an engineer for spacecraft contractor North American Rockwell. "We were running a test on Apollo and I had a Mexican electrical engineer working with me and a German pad leader," Tribe recalls. "And there was one American technician and finally the technician said: Doesn't anybody speak American on this programme?"

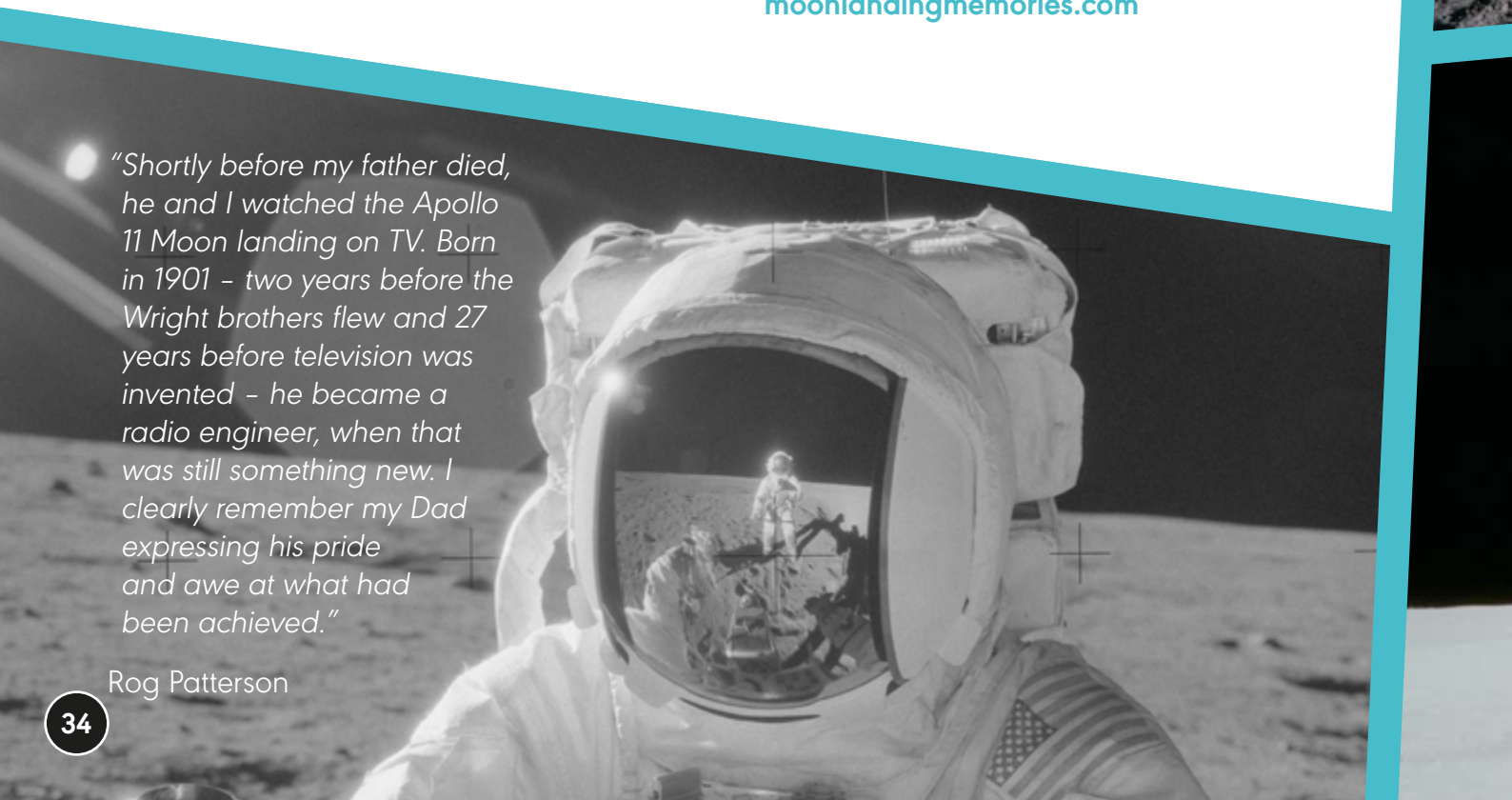
A British engineering team was also responsible for building a communications ground station on Ascension Island in the mid-Atlantic and a British scientist, Tom Bacon, developed the fuel cells which provided power and water for the astronauts. Twelve groups of British scientists also worked on soil and rock samples brought back by the astronauts. In fact, the UK has some 10% of the Apollo Moon rocks.

Fifty years on, the return to the Moon is going to be an international endeavour. NASA plans to land astronauts on the lunar surface by 2024, and with the European Space Agency (ESA) providing the service module for the Orion spacecraft to get them there, the UK will be fully involved. British ESA astronaut Tim Peake might even be among the new lunar pioneers.

"I get really excited when I think of how Apollo inspired people in the UK and what that will mean for the next generation, who are about to see a new chapter of human lunar exploration," says Jackson. "The UK is aiming to provide lunar communications for the return to the Moon, building on our great strengths in these industries."

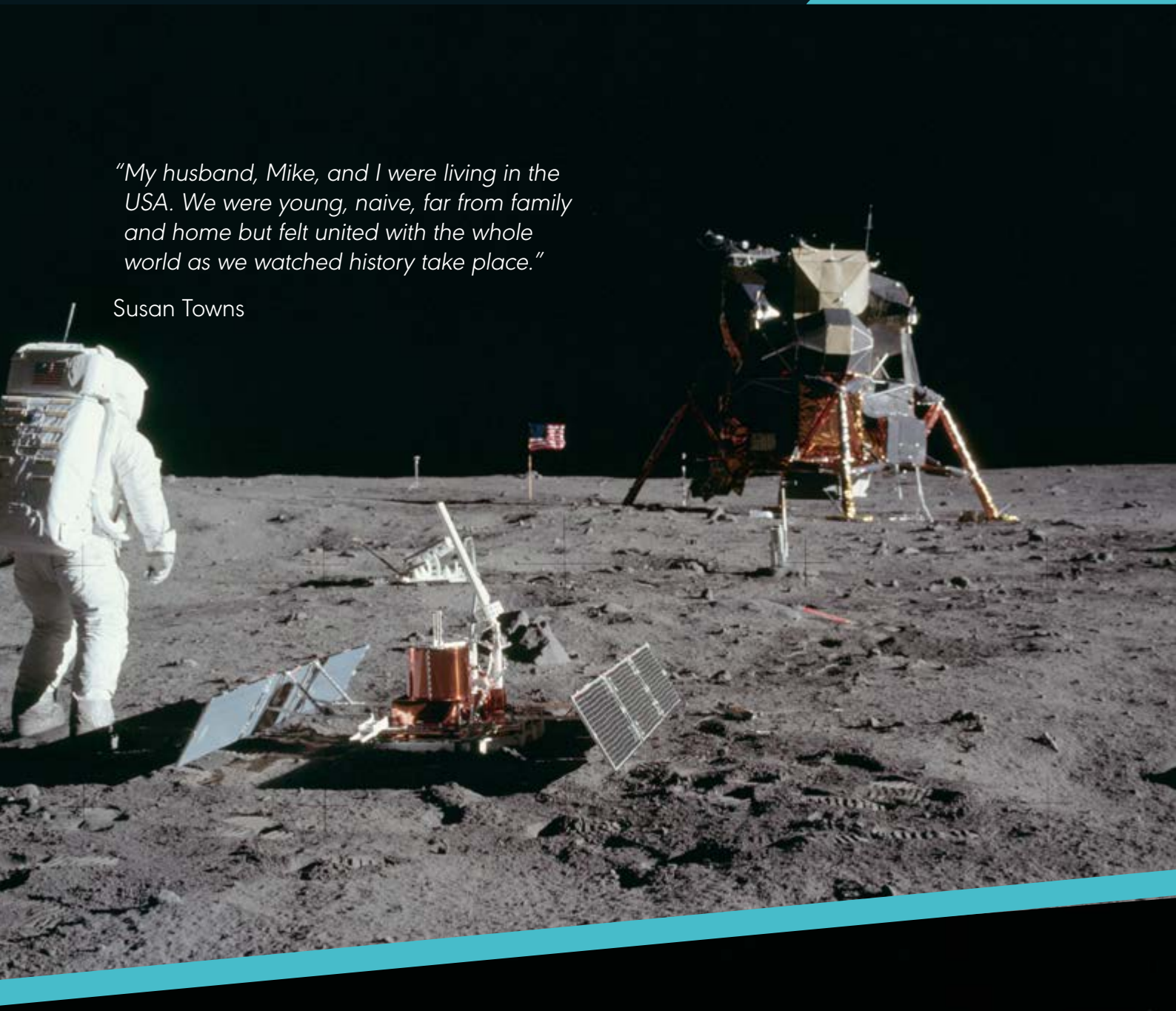
"We know from Tim Peake's mission, which saw over 2 million children directly engage in educational activities, just how much human spaceflight can open people's eyes to the wonders and importance of science and technology."

You can download the Moon Landing Memories e-book (for free) from: **moonlandingmemories.com**



"Shortly before my father died, he and I watched the Apollo 11 Moon landing on TV. Born in 1901 – two years before the Wright brothers flew and 27 years before television was invented – he became a radio engineer, when that was still something new. I clearly remember my Dad expressing his pride and awe at what had been achieved."

Rog Patterson



"My husband, Mike, and I were living in the USA. We were young, naive, far from family and home but felt united with the whole world as we watched history take place."

Susan Towns

"My earliest memory of the Moon landings is sat on the gym floor in St Mary's school, Gosport looking up at a grainy picture on a black and white TV. 50 years later I am privileged to sit at ESA Council with other member states being inspired by future plans to further explore the Moon and go on to Mars."

Maria Cody
now working at the UK Space Agency

Careers in Space

After reading this issue of Space UK, has the idea of working in the space sector intrigued you? Don't stop, explore! There are jobs in many different areas and the only thing holding you back is your imagination.

We could start on the ground, before launch if you like, where scientists and engineers work together to design and build launch systems, satellites and sensors which will provide communications or information essential to our daily lives.

These teams will include people with expertise in specialist types of engineering, like mechanical, systems, electrical and electronic. They will also involve physicists, chemists, mathematicians and computer scientists, as well as scientists who understand the natural world such as oceanographers, meteorologists and geographers.

All these people come together to decide what they need to detect or monitor and then work out how best to do it. Businesses or teams at universities will then decide how they can build the technology. They might be able to develop a business around the data the system will provide. Many space applications require people with a wide range of business and marketing skills.

Once the satellite is in space, the data needs to be 'downlinked' and communications engineers need to be absolutely sure that it's secure, so people can trust the information it provides.

This data goes to a wide range of space-savvy specialists from all sorts of other sectors. These might include agronomists, who need regularly updated information about plant growth patterns, disease and soil moisture. It might be used by vehicle engineers developing autonomous vehicles relying on accurate and real-time position data.

Other users of data from satellites include rescue teams responding to disasters. They need accurate updates on local situations, communications, location and navigation.

Information from space is vital for environmental experts monitoring deforestation, floods or fires, and meteorologists predicting and understanding our planet and the effects of the changing climate.

Many of the sensors on spacecraft look away from our planet, helping us to understand the universe and the origins of the solar system. Even life itself. Scientists working on these missions develop skills that can be utilised far beyond their astronomical data.

▶ *Clockwise from top:*

Testing the UK-built MIRI instrument for the new James Webb Space Telescope
Credit: NASA

Using satellite communications for disaster relief
Credit: Inmarsat

Inside ESA mission control
Credit: ESA

Science is at the heart of many missions
Credit: ESA

Tim Peake with space seeds on board the ISS
Credit: ESA, NASA

Destination Space

You are never too young to start thinking about careers in space. Find out where you could fit into the space sector, by having a go at this questionnaire: **www.destinationspace.uk/meet-space-crew/find-your-role-space-crew**

The UK Space Agency is funding the next phase of the popular Destination Space Programme. The Association for Science and Discovery Centres (ASDC) has created resources, activities and equipment to engage children and adults with the latest space science and Tim Peake's Principia mission to the International Space Station.

This new phase of the programme will celebrate the innovation and skills within the wider UK Space Sector. This includes UK space exploration, including UK spaceports and space launchers, the new James Webb Space Telescope, the ExoMars mission and satellite applications.

Destination Space will run in selected science centres from October 2019 until February 2020. Check out what's on where: **www.destinationspace.uk/visiting-information**

SPACE UK

British ESA astronaut Tim Peake captured this view of the UK during his mission to the International Space Station

Credit: ESA, NASA

Space is one of the fastest growing sectors of the UK economy. The UK Space Agency is at the heart of UK efforts to explore and benefit from space.

An executive agency of the Department for Business, Energy and Industrial Strategy, the UK Space Agency is responsible for ensuring the UK retains and grows a strategic capability in space-based systems, technologies, science and applications.

Our work includes supporting the UK space industry and academic research, licensing spacecraft, cooperating with other space agencies and inspiring the next generation of scientists and engineers.

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