UK SPACE AGENCY

Issue #47

SPACE UK

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WINDOW ON THE UNIVERSE

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LaunchUK

Seven sites across the British Isles are in the running as potential spaceports. The UK Space Agency is considering grant proposals to help them develop capabilities for spaceflight.

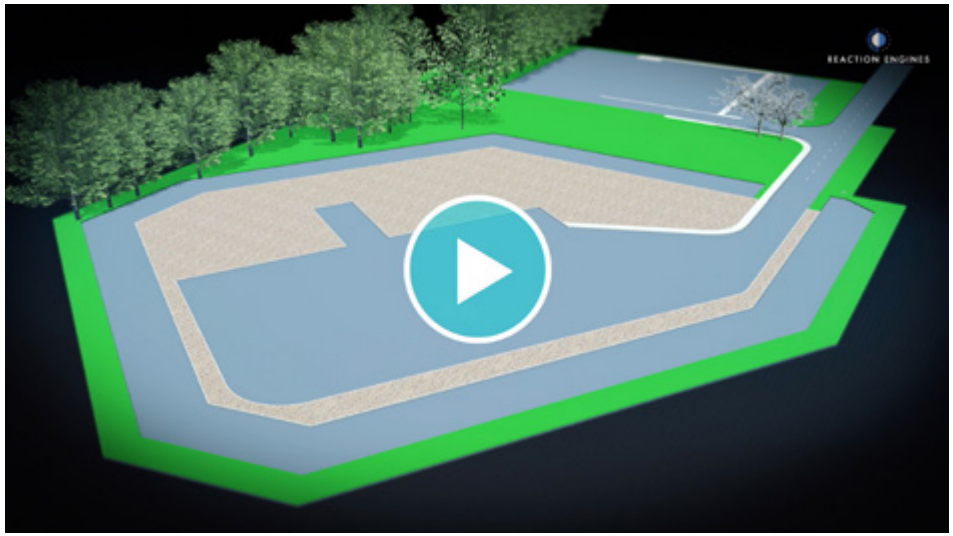
Speaking to a packed session at the UK Space Conference in Manchester, founder of British satellite company SSTL, Sir Martin Sweeting, described the development of a spaceport as "important and exciting."

"We've seen growth in the UK space sector and the questions are where does it go and what do we need to make the most of it," Sweeting said. "I think one of the ingredients that completes the jigsaw is the decision to have one or more spaceports in the UK."

The draft spaceflight bill the Government published earlier this year is aimed at facilitating and regulating launches from the UK – these could be with spaceplanes, vertical launchers or launches from aircraft. It is part of the strategy to increase the UK's share of the global space sector to 10% by 2030.

One of several UK companies developing new launcher technology is Reaction Engines. Supported by a £60 million government commitment, it has invented a new type of air-breathing rocket engine called SABRE.

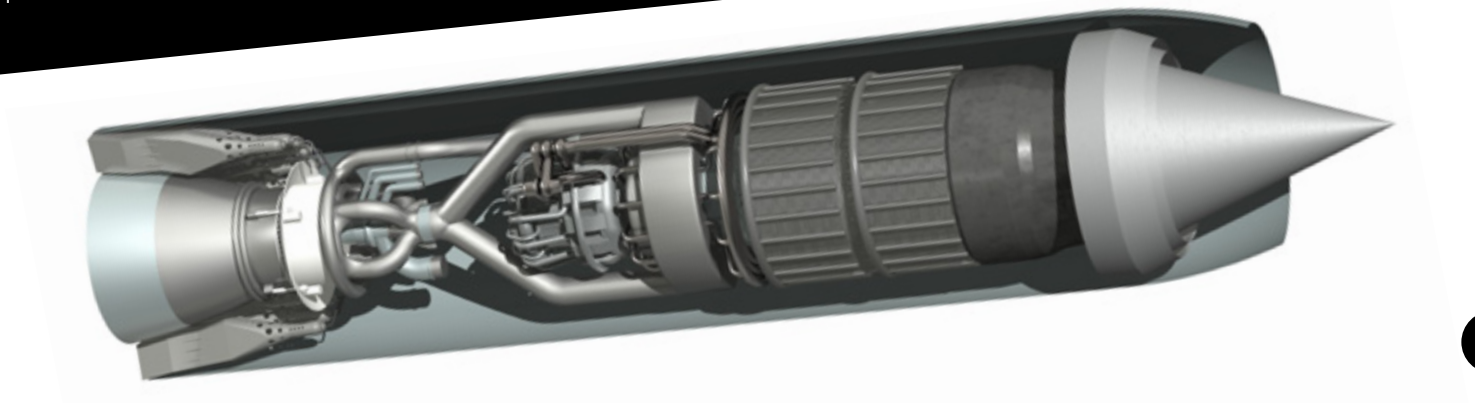
Reaction Engines has begun constructing a new engine test facility at Westcott in Buckinghamshire to carry out the first ground-based demonstration of the SABRE system and hopes to carry out the first test firings in 2020.



Reaction Engines' new test facilities

▲Credit: Reaction Engines

*Watch in HD on **YouTube***



The Sabre engine

Credit: Reaction Engines ▶

Conference Success

1,200 people from across the global space sector gathered in Manchester at the end of May for the largest ever UK Space Conference.

The three-day event was titled 'inspire, enable, connect' and featured 28 sessions on subjects ranging from international growth and security, to launchers and Mars exploration. Speakers included Director General of the European Space Agency (ESA), Jan Woerner, British ESA astronaut, Tim Peake, and Major General Clinton Crosier of the United States Strategic Command.

The UK space industry is currently worth some £13.7 billion and continues to grow. A record 109 organisations took stands in the conference exhibition hall and a parallel event of hands-on interactive exhibits and educational activities was open for free to the public.

UK Space Conference 2017 ▲◀

Space Awards

This years' Sir Arthur Clarke Awards for outstanding achievements in space activities were presented at a gala dinner on the second day of the UK Space Conference.

They included a posthumous Special Lifetime Space Achievement award for British-born NASA astronaut, Piers Sellers, who died in December from pancreatic cancer. Accepted on his behalf by his niece and nephew, it recognised the astronaut's "amazing spaceflights and his extraordinary contribution to astronautics, Earth and space science, climate change and education and outreach."

Gala Dinner and Sir Arthur Clarke Awards 2017 ▼

Piers Sellers during a spacewalk outside the International Space Station in 2006

Credit: NASA ▶

Video from Space

A UK company has announced plans for a new constellation of Earth observation satellites, providing high-resolution images and – for the first time – full-colour video.

Surrey-based Earth-i will launch a test satellite later this year and plans five further spacecraft by 2020. The new satellite, manufactured by the UK's SSTL, will be able to see features as small as one metre across. Its video capability could be used to track moving objects such as cars, ships and aircraft; or might be used to build-up 3D models of a particular location.

"Our ambition as a company is to be a world leader in Earth Observation and the interpretation of data from space," said company CEO, Richard Blain, speaking at the UK Space Conference in Manchester. "As the number of satellites in the constellation grows, our ability to feed more applications will expand to find new ways of improving our lives on Earth."

Earth-i is already a well established company, providing satellite images and services using the existing DMC3/TripleSat satellite constellation. "The challenge is getting data from space on demand," said Blain. "If we have clients who need data in a very short space of time, with our new satellites we'll be able to do that."

The market for images and other data from Earth observation satellites is expected to grow significantly. Pictures from space are already being used for mapping, agriculture and environmental monitoring but are increasingly being adopted for a wide range of new applications. These include measuring energy resources, responding to disasters and improving border security.

"There is an almost insatiable demand for data from space," said Josef Aschbacher, ESA Director of Earth Observation. "People are realising its true value to both their planning and daily operations."

Bristol (right) and Hong Kong captured by DMC3

Credit: 21AT, Earth-i

Sniffing Mars

Six months after arriving at Mars, ESA's Trace Gas Orbiter has begun the next challenging phase of its mission: adjusting from an elliptical orbit to a circular one. Mission controllers are using a technique known as aerobraking, which uses the resistance of the Martian atmosphere to slow the probe down.

"It's a bit like putting your hand out of a car window," said Manish Patel, a member of the ExoMars team from the UK's Open University. "You can feel the resistance of the air against your hand and that's essentially what we're doing with the orbiter."

However, the changing nature of the atmosphere on Mars, combined with the fact that the probe is travelling extremely fast, means the manoeuvre is somewhat complicated. "If something unexpected happens, we could lose control of the spacecraft very rapidly," said Patel. "The real risk is that it starts to tumble out of control."

To avoid this, ESA has opted for lots of small 'dips' into the atmosphere over the course of a year so that controllers can assess the probe after every manoeuvre. Patel is hoping there may even be some opportunities to perform science during this section of the mission.

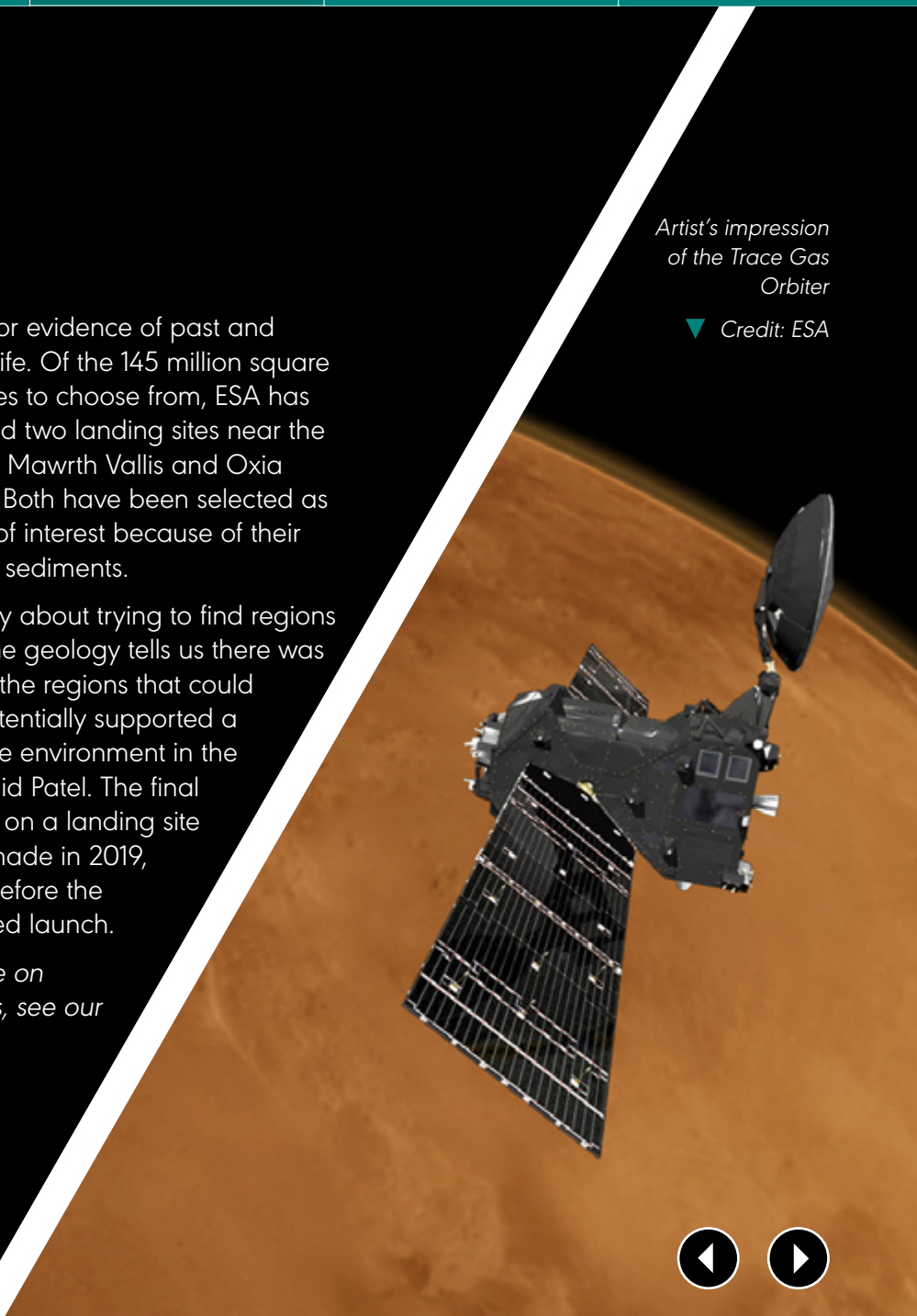
"What we're hoping for is to get a few sunrises and sunsets, where the Sun is behind Mars," he said. "You can then look at the sunlight as it passes through the atmosphere. Certain molecules absorb certain wavelengths of light and from that, you can figure out what molecules are there."

A molecule of particular interest is methane. More than 90% of Earth's methane is created by living creatures. The discovery of the gas on Mars, by ESA's Mars Express, warrants further investigation to determine whether it has biological or geological origins.

In 2020, the next ExoMars mission will land a rover on the Martian surface to look for evidence of past and present life. Of the 145 million square kilometres to choose from, ESA has shortlisted two landing sites near the equator: Mawrth Vallis and Oxia Planum. Both have been selected as regions of interest because of their clay-rich sediments.

"It's really about trying to find regions where the geology tells us there was water – the regions that could have potentially supported a habitable environment in the past," said Patel. The final decision on a landing site will be made in 2019, a year before the scheduled launch.

For more on ExoMars, see our feature.



Artist's impression of the Trace Gas Orbiter

▼ *Credit: ESA*

Space for Forests

The UK Space Agency has awarded a £14 million contract for a new satellite monitoring programme, which aims to protect 300 million hectares of tropical rainforests across the globe.

This is the largest project, so far, to come from the Agency's International Partnership Programme – a £152 million scheme to support the UK space industry in addressing societal and environmental issues in developing nations.

Forests 2020 uses software developed by Edinburgh-based Ecometrica. By drawing on several datasets from satellites like ESA's Sentinels 1 and 2, the project seeks to make information about changes in forest cover much more accessible than it currently is.

"A lot of these datasets are fragmented – they're in different institutions, with different people having access to some files but not others," said Richard Tipper of Ecometrica. "What our software allows is for the data to be managed and brought together in a much more systematic way and updated more regularly, so it can have an impact on monitoring national forests."

Globally some 130,000 square kilometres of forest are lost each year to logging, agriculture and forest fires. This new project will help developing countries take swift action against illegal activities, identify areas at risk of fire and also pinpoint areas suitable for restoration.

For more on Ecometrica see Made in the UK

Sentinel 2 is fitted with a powerful camera

◀ *Credit: ESA*

Gone with the Wind

A new wind-measuring satellite has been shipped from the UK for final testing prior to launch. ESA's Aeolus satellite, built by Airbus Defence and Space in Stevenage, is undergoing tests in France and Belgium to ensure it will survive the traumas of take-off and the harsh environment of space. It's due for launch from French Guiana at the end of the year.

Aeolus will be the first satellite to measure wind speeds across the entire Earth, from the surface to the high stratosphere. It will do this by firing an ultraviolet laser into the atmosphere to survey the light scattered by air molecules. This will reveal factors such as the direction and speed of the wind, as well as the altitude of the wind streams. Meteorologists will be able to incorporate this new information into their forecasting models to help better predict storms.

Currently, forecasters measure air currents with windmill-like anemometers and weather balloons. More than a thousand of these balloons are launched daily. Aeolus will be able to generate 100 wind profiles an hour, giving much more coverage than has ever been available before.

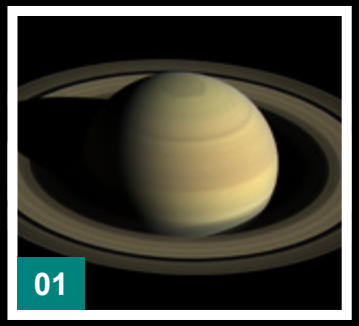
Aeolus at Airbus in Stevenage

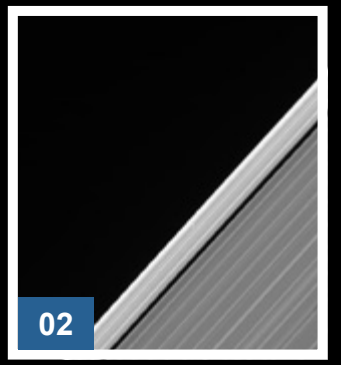
◀ *Credit: Airbus Defence and Space*

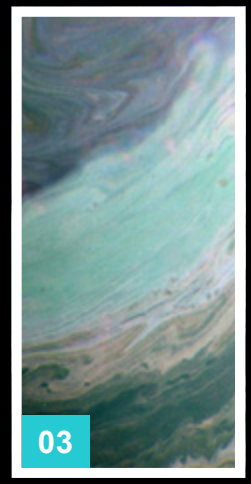
Cassini's Grand Finale

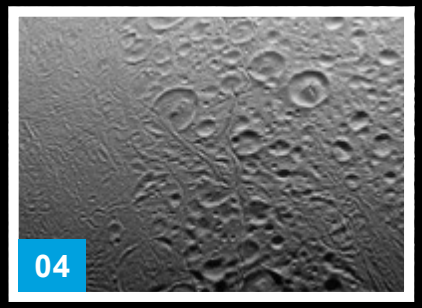
After 20 years in space, the international Cassini spacecraft has begun the final leg of its voyage. Since April, the mission – which involves several UK science and engineering teams – has been skirting the inner edge of the planet's rings. It has also been 'tasting' Saturn's atmosphere to find out what it's made of.

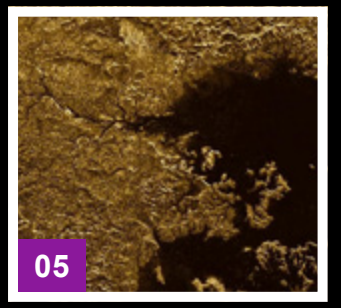
In September 2017, the orbiter will plunge into Saturn and burn up on impact. This dramatic ending will ensure it won't contaminate two potentially habitable moons – Titan and Enceladus – which scientists hope to explore in future.











All images credit: NASA, ESA

01 *Cassini captured this spectacular view from high above the planet in 2016*

02 *Saturn's rings consist mostly of water ice and range from dust-sized specks to boulders*

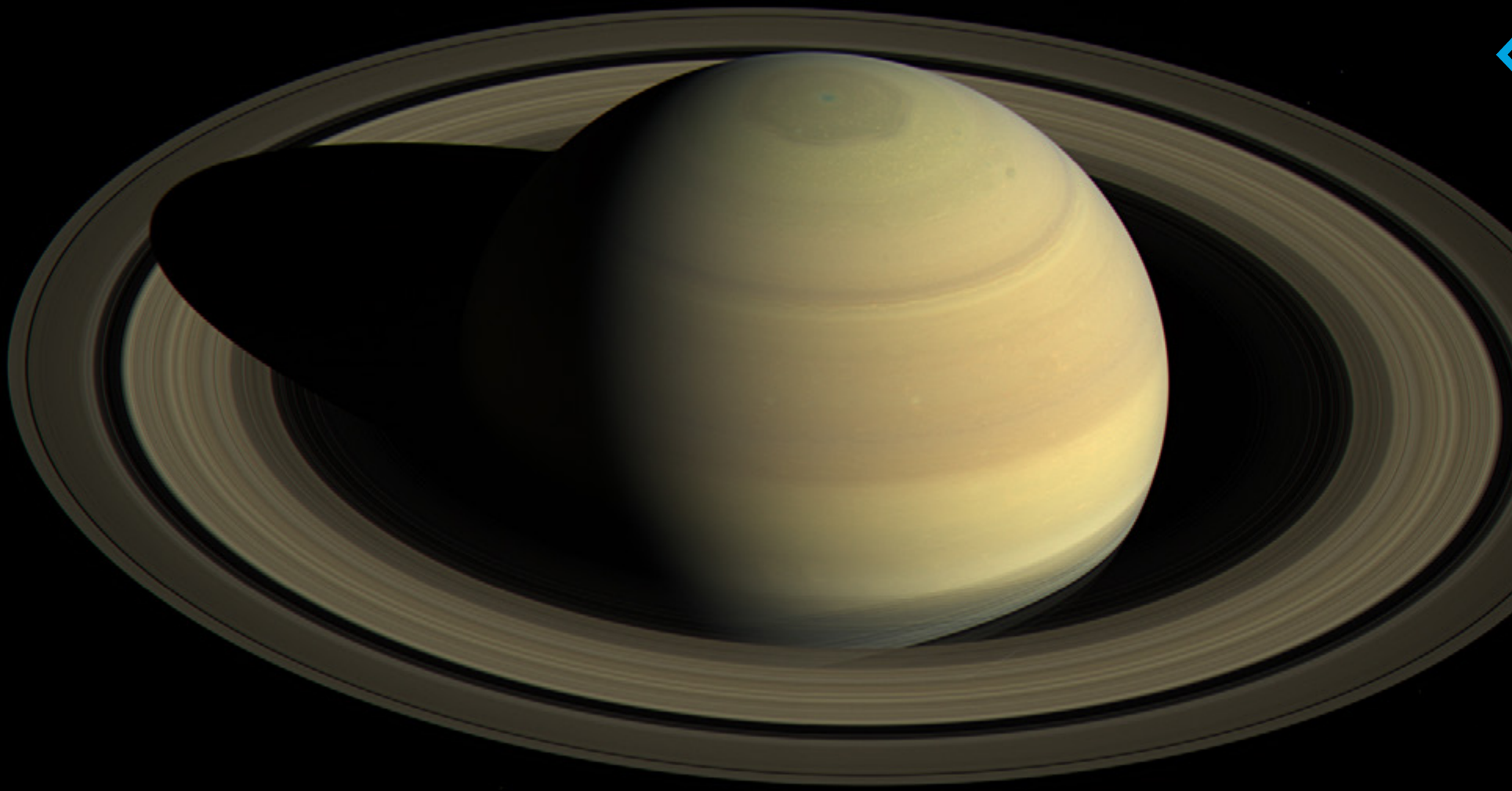
03 *The colours have been enhanced in this close-up image showing clouds in Saturn's northern hemisphere*

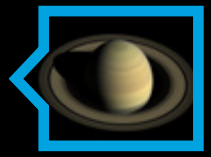
04 *Buried beneath Enceladus' icy crust is an ocean of water. This moon may provide the best chance of finding life elsewhere in the Solar System*

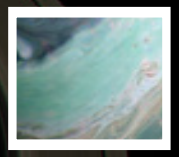
05 *This looks like a satellite image of Earth but actually shows the methane seas of Saturn's moon Titan. In 2005, ESA's Huygens probe landed on Titan – the first part to touch the surface was made in Milton Keynes*

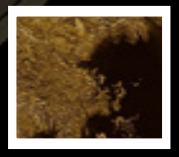
06 *No, it's not a sponge but a false-colour image of Saturn's moon Hyperion*

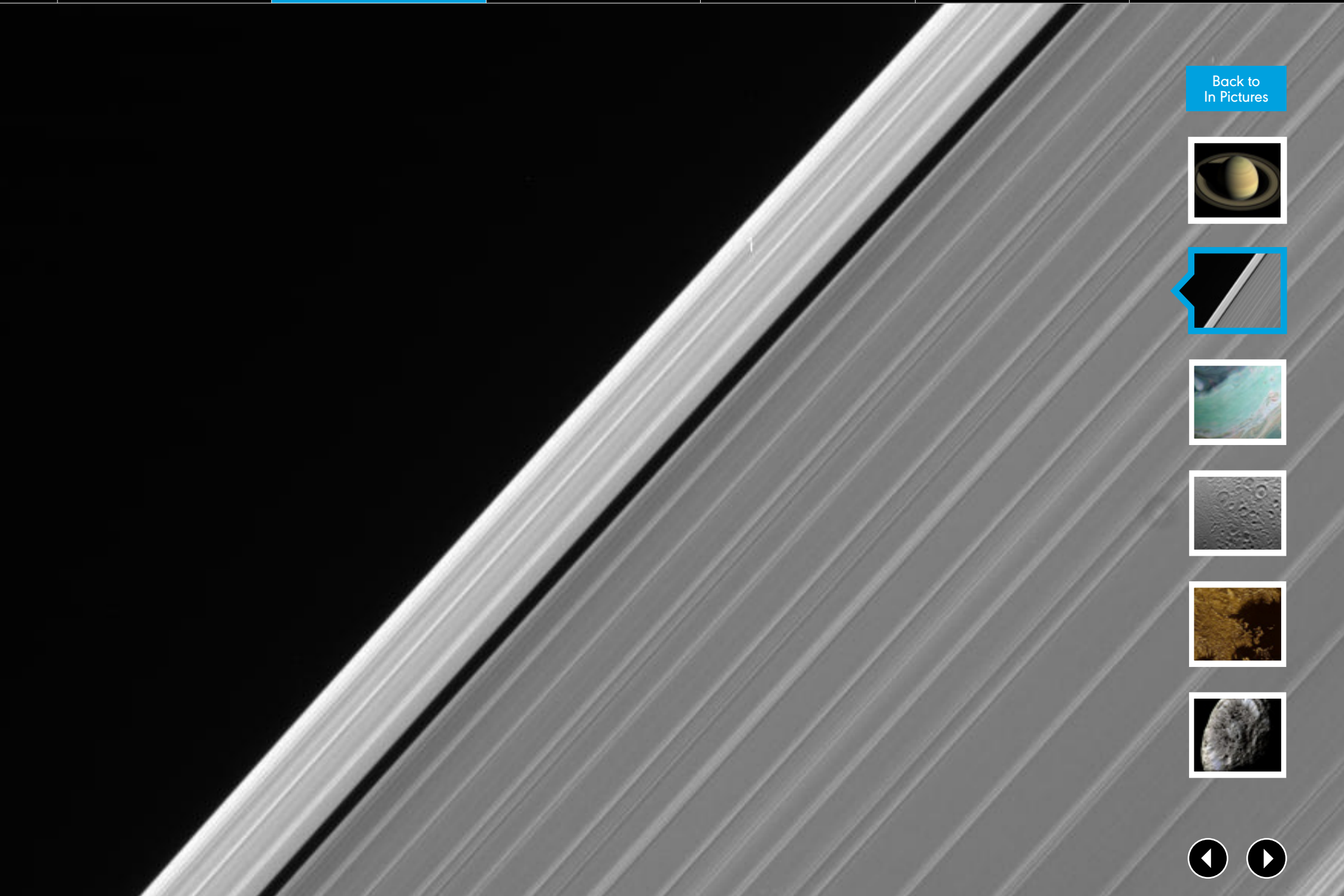
Back to In Pictures











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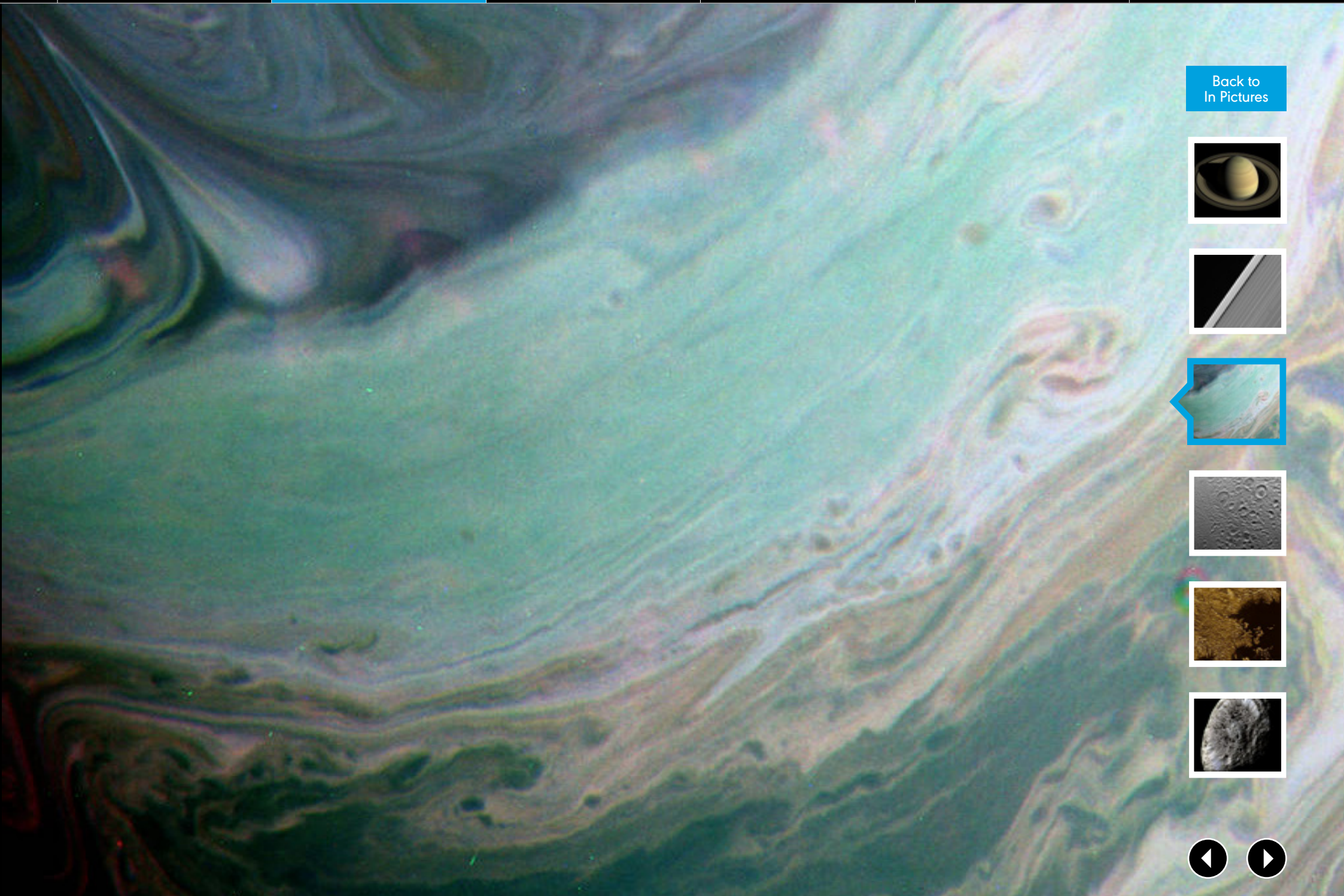

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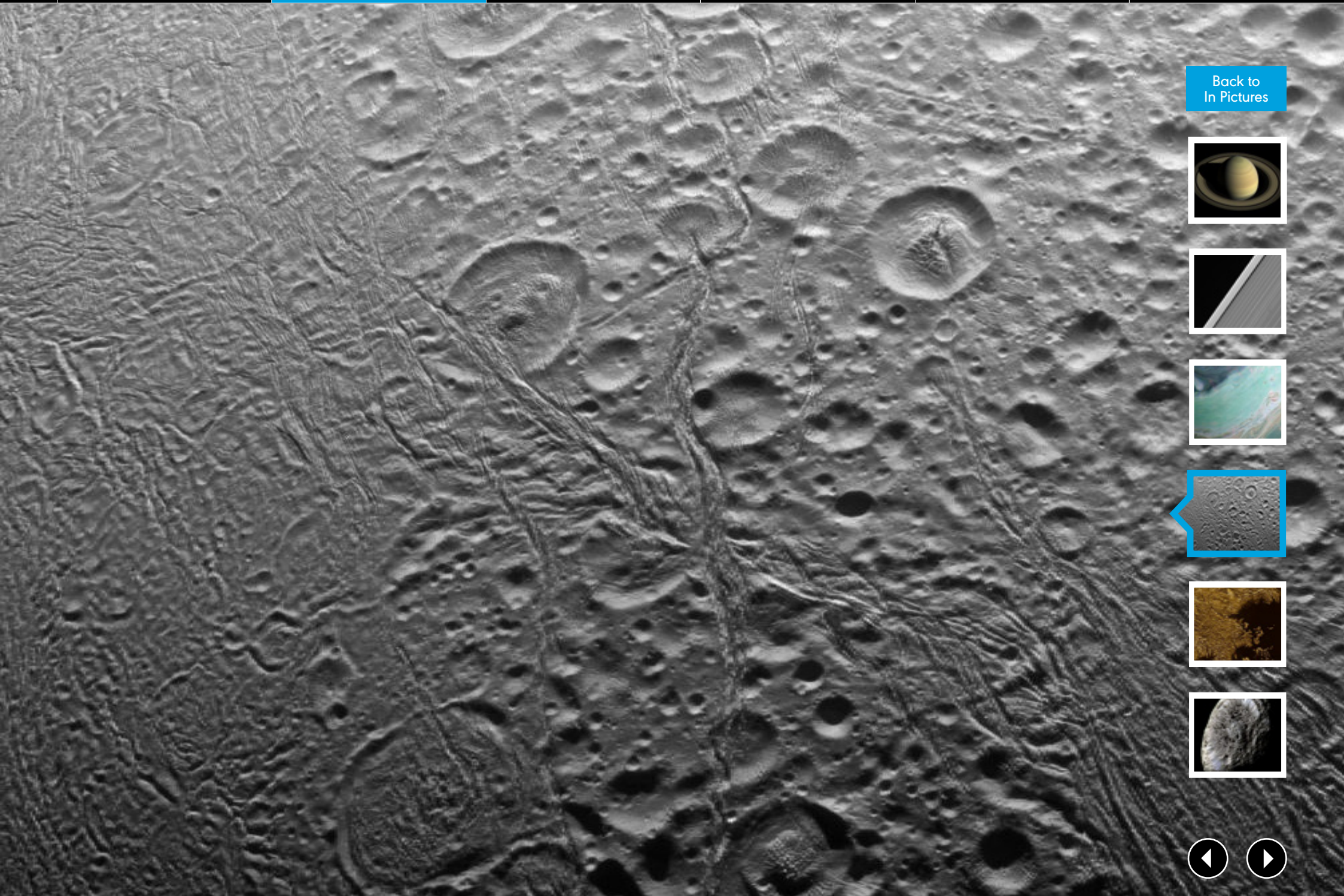

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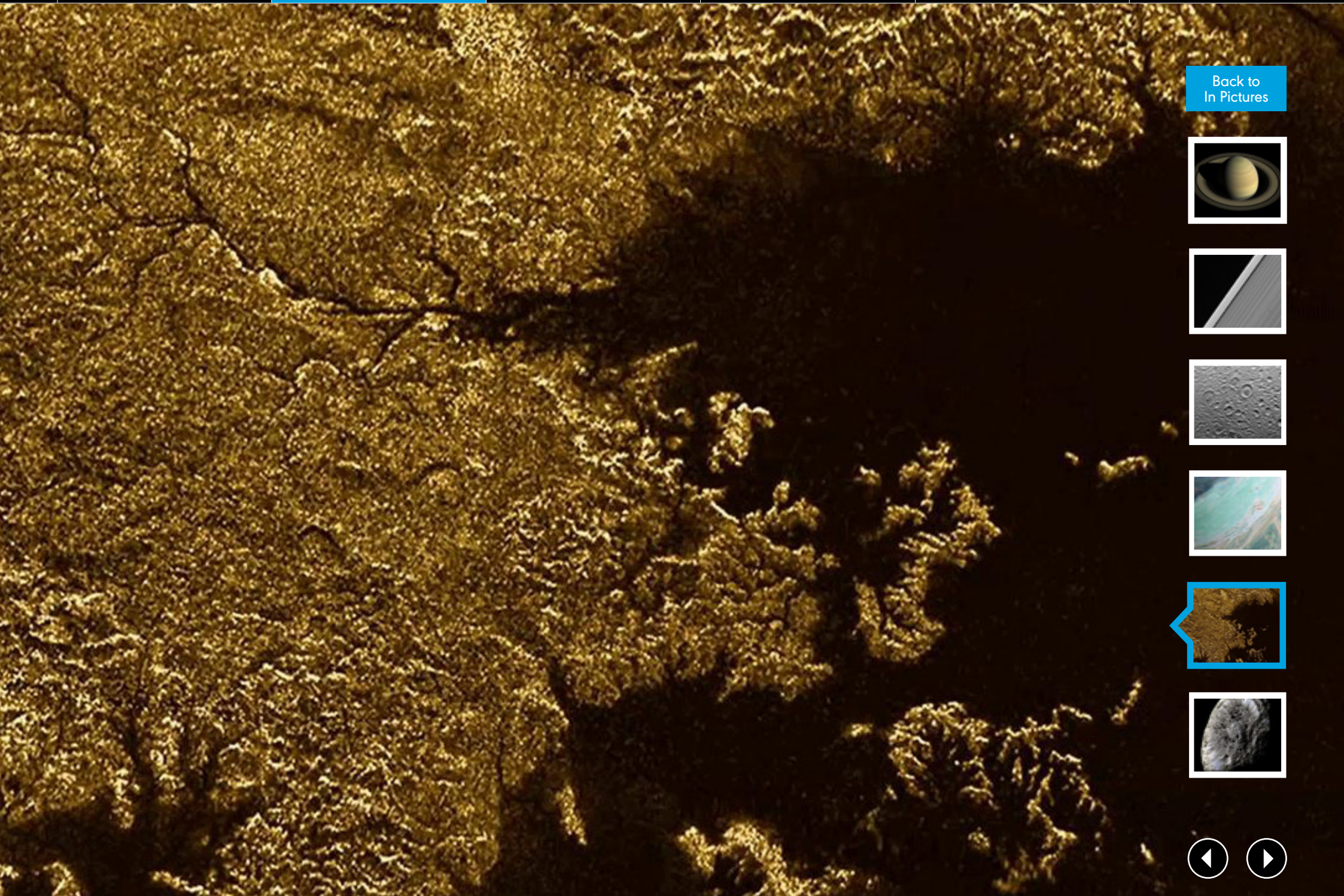

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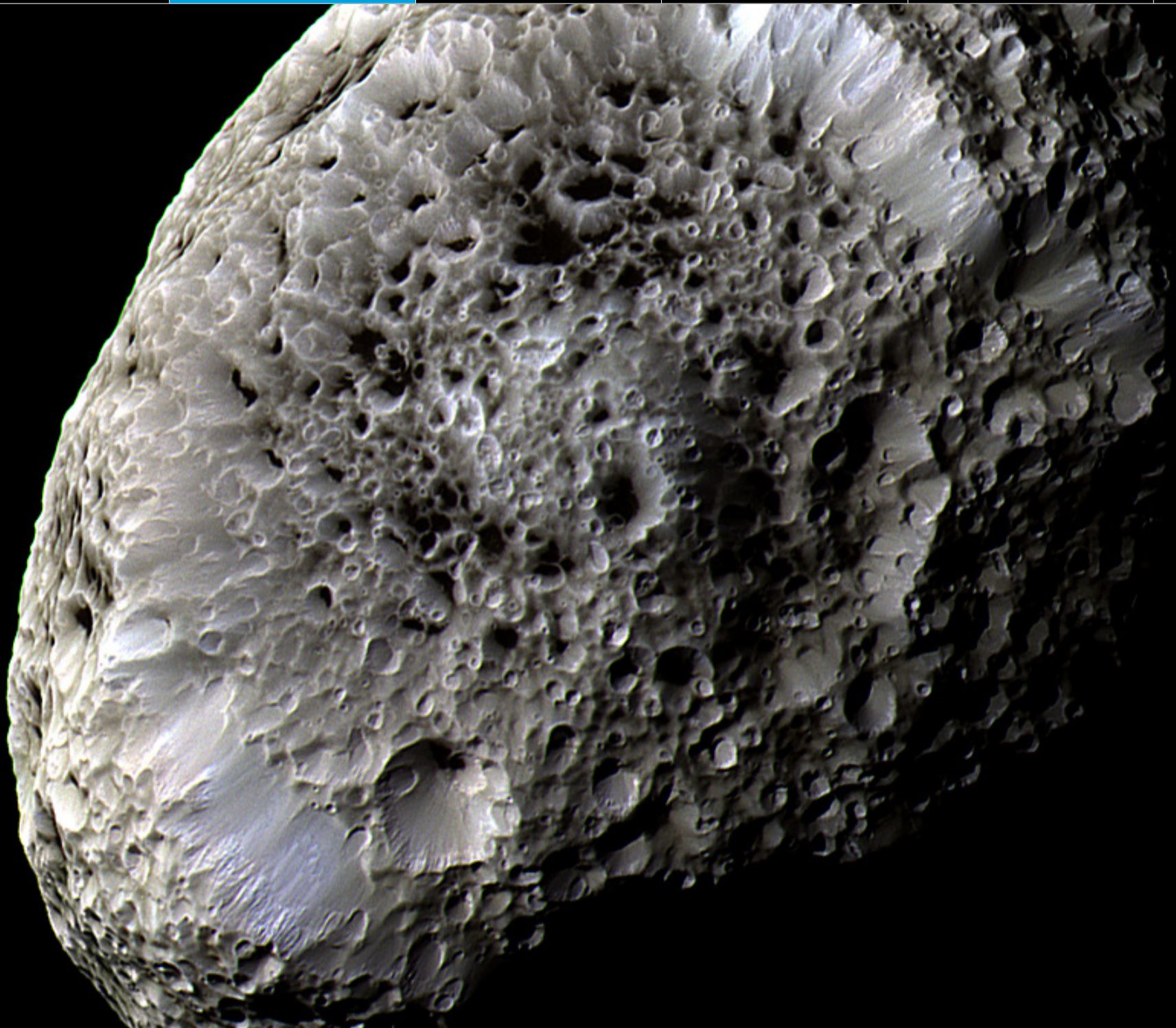

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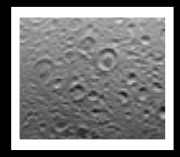
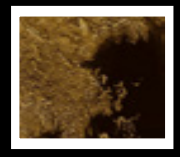
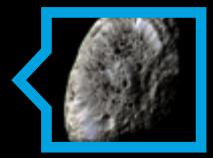






ESA's latest Sentinel mission, Sentinel-2B, ready for launch in March. The constellation provides a vast amount of information about the Earth

Credit: ESA, Corvaja

Growing Space UK

By Richard Hollingham

The government has ambitious plans to grow the UK space sector but how will these goals be achieved?

May 2030, and a space rocket has blasted into orbit from a UK spaceport. On board are 100 satellites, all manufactured in Britain. These next-generation CubeSat spacecraft – based on cubes just 10cm across – are equipped with high-definition UK-built cameras to help provide daily images of Britain's changing landscape.

This data will be used by local authorities to ensure the preservation of green space, farmers to plan their planting and government to monitor the effects of climate change. You can even download the images yourself to see your house from space. Although for most people this novelty has long worn-off.

The launch receives little attention in the news – UK launches are commonplace and most people take the use of space technology for granted. Without it there wouldn't be any self-driving cars, accurate weather forecasts or internet.

Although this is a future vision for the UK space industry, most of it's already taking place. Britain is already a leading manufacturer of small satellites – as well as some of the largest in the world – UK companies also produce sophisticated imaging systems and data from space technology is used daily by government and business.

We use space to navigate our cars, check the weather and for communications. Even a spaceport is on the cards, with the government announcement of legislation to regulate launches of spaceplanes and rockets from the UK.

Growth Catalyst

A recently published independent report into the Size and Health of the UK space sector shows it's currently worth some 13.7 billion. The government's stated goal, however, is to grow the space business to £40 billion by 2030. This would represent 10% of the global space market.

"One of the reasons the government backs the UK space sector so strongly is the wider benefits to the UK economy," says Catherine Mealing-Jones, Director for Growth at the UK Space Agency. "We've got 13.7 billion but maybe the more significant figure is that £250 billion of output in the UK is supported by satellites in some way – that's a huge growth catalyst."

This potential for growth has led successive governments to identify space as a strategic priority. This is reflected in the increased levels of investment made by the UK into European Space Agency (ESA) programmes. At the December 2016 meeting of ESA's Council of Ministers meeting in Lucerne, Switzerland, the UK pledged €1.4 billion over five years for European space projects.

The headlines focussed on commitments to Mars exploration and the International Space Station. However, decisions made at the summit mean the UK is now the largest funder of ESA's Earth observation, satellite navigation and telecommunications programmes.

"The best days of the space age are still to come"
Catherine Mealing-Jones

"We really believe there's a wealth of opportunity in using the wealth of data from space to grow new businesses," says Mealing-Jones. "And that was the philosophy that drove our decisions at the ESA Ministerial."

The investments at the Council of Ministers meeting included €670.5 million for satellite technology. Of that, €30 million is destined for a new navigation technology programme, €60 million will be used to develop

A rare (almost) cloud-free image of the UK captured by Sentinel-3A. Data from the Sentinel satellites is available for free

▼ *Credit: ESA*

The UK committed €1.4 billion to space projects at the ESA Council at Ministerial Level meeting in Lucerne

Credit: ESA ▲

the commercial uses of space data and €10 million will go towards Incubed – a programme to help industry develop new markets in Earth observation technologies.

"People think of the space sector as astronauts and satellites but they're also starting to think about it as applications and services," says Mealing-Jones. "To reach our targets, we're trying to make an investment that encourages this downstream growth."

Breaking the Space Barrier

One of the challenges facing anyone attempting to start or grow a space business, is that space technology sounds difficult and expensive. "The word space can be a barrier," admits Stuart Martin, Chief Executive of the Satellite Applications Catapult. "There's a lot of misunderstanding about space technology – there's a perception that it's high cost, high risk and long-term. Our job is to make people see it differently."

This is one reason why the Satellite Applications Catapult, based on the Harwell campus in Oxfordshire, does not have 'space' in its title. Opened in 2013, the Catapult helps to support new (space) businesses to get products and services into the market as quickly and effectively as possible.

"There aren't many countries doing anything similar," says Martin. "We're still pretty much ahead of the rest of the world here in the UK."

"We have 70 companies at Harwell that weren't there five years ago with 700 people working on applications," he says. "Pretty much everywhere you look in the economy, people are seeing this as an area where they can make money."

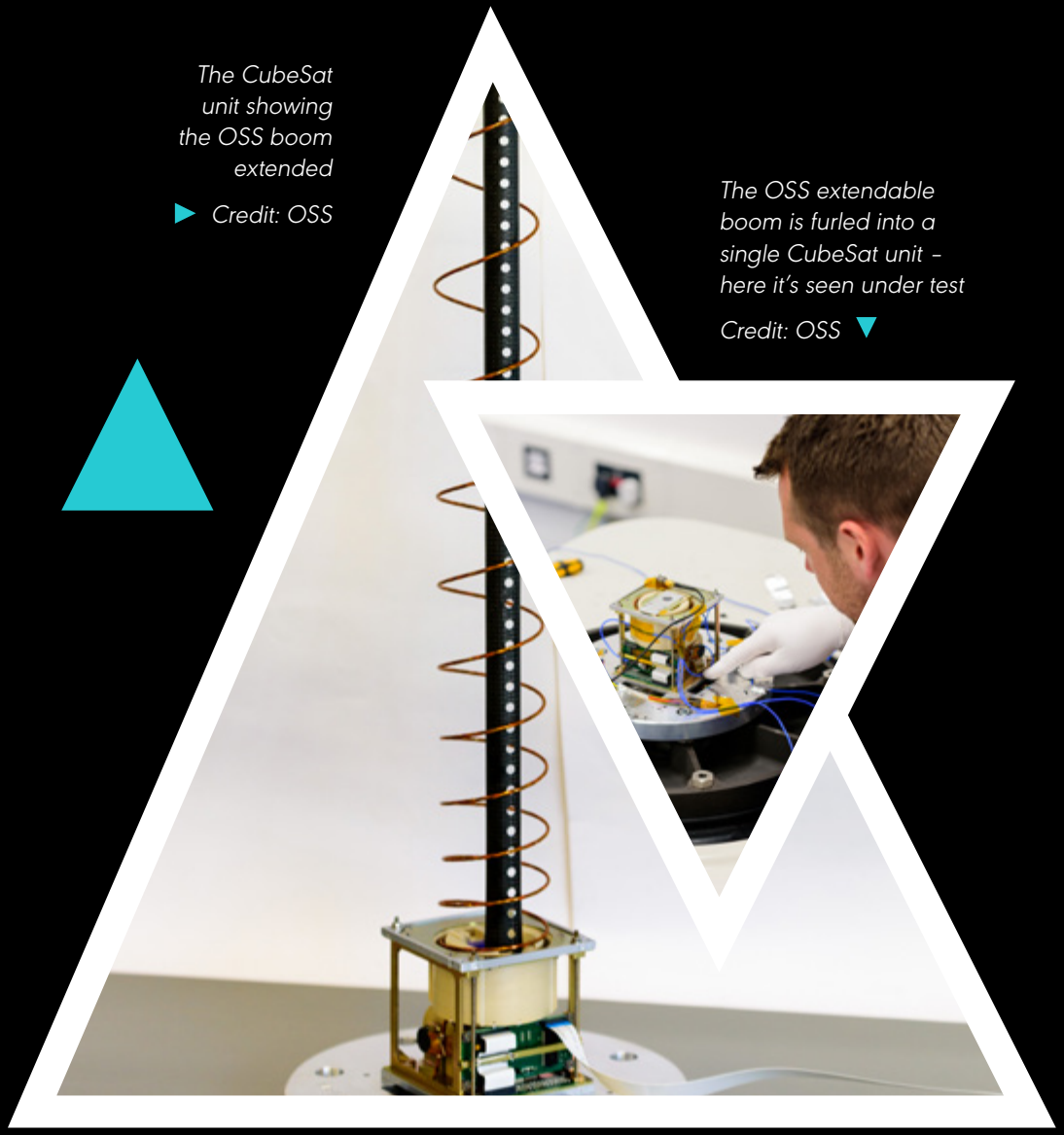
One of the largest potential growth areas is in developing commercial products based on data from Earth observation satellites. With many publically-owned satellites, such as Europe's new Sentinel satellites, much of the raw data is provided for free. Other satellite providers are launching constellations of small satellites. Because there are so many of these satellites, it enables any area on the planet to be viewed several times a week.

But the market is not necessarily about providing raw images or data from the satellites but in making sense of that data and turning it into useful products and services.

New British company Sterling Geo, for instance, supplies and supports software that allows clients to visualise, analyse and process images or other data from satellites. The software might be used to monitor development, predict flooding or by the gas industry for geological mapping. "We enable clients to turn data into useful information," says Sterling Geo CEO, Andy Wells. "There's massive potential in this market."

The company is currently developing a new service using data from various satellite constellations to see changes in an area over time. This technology might be used, for instance, by local authorities to monitor new development or see how a town is evolving.

"When the system finds new data for that area, it grabs it, analyses it and looks for changes, before translating it into something the client can understand, such as a map," explains



The CubeSat unit showing the OSS boom extended

Credit: OSS

The OSS extendable boom is furled into a single CubeSat unit – here it's seen under test

Credit: OSS

Wells. "The client can have the answer to the questions they want without capital investment, just a subscription."

Space Revolution

It's not only the government that is investing in space. Within three years, start-up Oxford Space Systems (OSS) has secured around £2 million in private investment. The company is developing a new range of products based on innovative materials, including a flexible carbon composite.

"Most people see composites with tennis rackets, golf clubs or fishing rods and they tend to be stiff structures," says company founder and CEO, Mike Lawton. "We play around with the way the carbon fibres go together so we can roll the material up like a tape measure – we get all the advantages of being able to store in a tight manner and then unfurl into some large structures."

One of the company's first products is currently in orbit on AlSat Nano, a joint CubeSat mission between the UK Space Agency and Algerian Space Agency. Launched from India in September 2016, the satellite is based on three CubeSat units and is only 30cm long by 10cm across. OSS has used its composite technology to build an extendable boom – the world's longest retractable boom from a CubeSat – which is able to deploy up to 1.5 metres in length from a volume not much bigger than a matchbox.

Although the technology OSS has developed could find applications on Earth, Lawton's company made a deliberate choice to develop products for space. "The reason we're initially focused on space is the excellent support the government is putting into the sector," says Lawton.

OSS has focused on CubeSats as a way of proving the applications. "CubeSats give us the ability to fly things really quickly to prove our technology to a notoriously risk averse market," says Lawton, "it's an extension of the lab bench."

The successful demonstration has led to international interest in OSS, including offers of overseas investment.

Although the global market for CubeSats is growing – and Glasgow company Clyde Space is now a major player – Lawton sees this as only the start. "As well as seeing CubeSats as a potentially lucrative revenue stream they provide a fast-track route to validate materials in space," he says.

"We see them as the stepping stone to develop the technology – the ultimate prize is to get our products into the large geostationary platforms that provide services such as satellite TV and global communications."

21st Century Business

So, does all this add up to a £40 billion space industry?

"If you want to treble the size of the industry by 2030, you can't expect the large incumbents to treble in size," says Lawton. "The growth has to come from small and medium-sized innovative companies."

Mealing-Jones agrees that the space industry is ideal for small business growth. "You don't need to be a space expert or have the vast riches of Elon Musk to get into the space sector," she says. "It's the ultimate 21st century business, you can access the data and get started on providing services. We can help you understand the potential, and off you go."

Certainly, government enthusiasm for the space industry has come a long way over the past decade. More money than ever before is being invested in space and, with the government backing the development of a UK spaceport, that commitment shows no signs of diminishing. Much of the investment, however, is through ESA and Lawton cautions that companies need to look beyond Europe

"We should be thinking globally," he says. "I'd advise any start-up to look for as many opportunities away from Europe as possible, because they're out there."

The effects of Brexit on the UK space industry are also uncertain. Although ESA is separate to the EU, two of the major space programmes – the Galileo satellite navigation system and Copernicus Earth observation programme – are funded by the EU.

"The value of European collaboration in research and innovation – particularly in space – is specifically mentioned in the Brexit white paper," says Mealing-Jones. "We're determined to make a success of it."

In fact, when it comes to space, the general feeling is one of optimism for the future. "We're continuing to project ourselves as a powerful space nation," Mealing-Jones says.

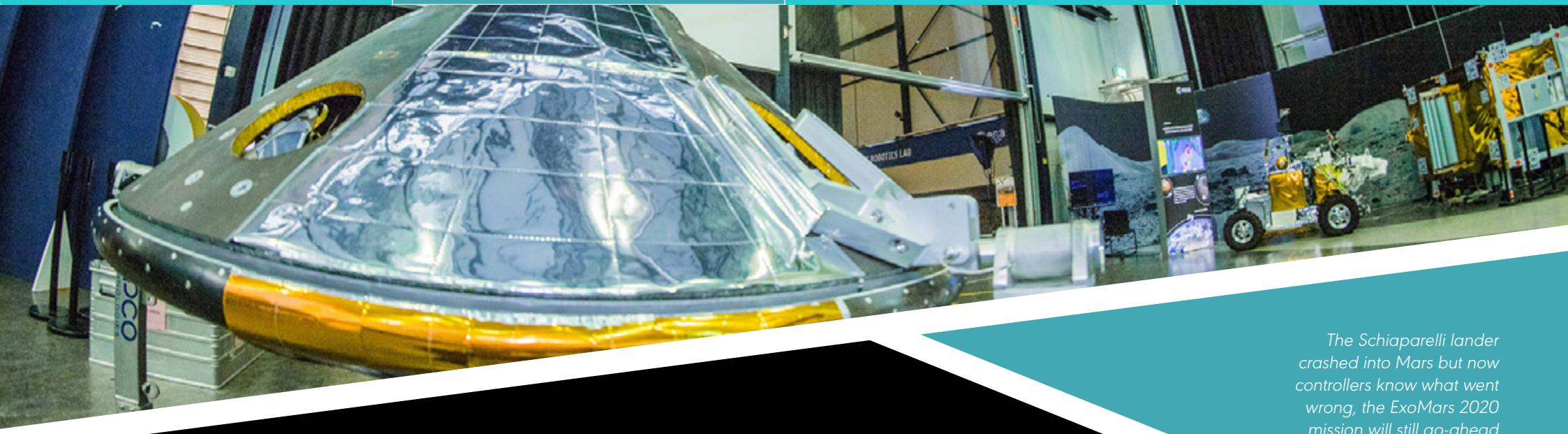
And Martin is convinced that the market for new products and services for space can only continue to grow. "We have come a long way but we're still only at the beginning," he says. "The best days of the space age are still to come."

The UK is a major contributor to EU programmes such as Galileo

Credit: ESA

The Satellite Applications Catapult in Harwell

Credit: Satellite Applications Catapult



The Schiaparelli lander crashed into Mars but now controllers know what went wrong, the ExoMars 2020 mission will still go-ahead

▲ *Credit: ESA*

Destination Mars

By Sue Nelson

Europe is returning to Mars in 2020 and the UK is building the mission rover. Space UK reports on the rover's progress and how its construction, together with a new education centre, will inspire the next generation of engineers.

Just off the A1 motorway behind a shopping centre in Stevenage, is a small piece of Mars. It's called the Mars Yard and was built to simulate the red sandy and rocky terrain for a future European rover. The facility – around a third the size of a football pitch – belongs to Airbus. For years in Hertfordshire the company has been building and testing rovers designed for another planet, patiently waiting for the approval of ExoMars 2020 – the joint ESA and Russian Mars mission.

ExoMars was planned as two missions, with ExoMars 2016 reaching Mars last October. After its Trace Gas Orbiter made a successful entry into the planet's orbit, all eyes were on the entry, descent and landing demonstrator module, Schiaparelli. The lander was testing technology that would bring a European rover onto the Martian surface.

The parachute deployed successfully and the heat shield released but from an altitude of 7.8 kilometres onwards the descent sequence triggered earlier than expected.

As a result, thinking it had already landed, Schiaparelli went into freefall and crashed into Mars at 540 kilometres per hour.

When ESA Member States met in Paris in December 2016 to discuss

Artist's impression of the Trace Gas Orbiter – successfully in orbit around Mars

▼ *Credit: ESA*

budgets and green-light (or not) future missions, it's fair to say there were some anxious space scientists and engineers across the UK. Landing on Mars isn't easy and even though time proved that Europe's first lander, Beagle 2, had in fact arrived intact despite over a decade of silence, there must have been moments of doubt. Fortunately, the mass of data returned by Schiaparelli helped inform the decision to keep calm and carry on.

The approval of the ExoMars 2020 mission, which consists of an orbiter and a rover, was a huge boost for UK science and engineering. "We've been going to Mars for ten years," says Justin Byrne, UK Head of Science Projects at Airbus, smiling. "But it's fantastic when you know you really are going. It's just brilliant."

Head of space exploration at the UK Space Agency, Sue Horne, has no doubt the decision is important for UK science and technology. "UK scientists are leading the rover's Panoramic Camera," says Horne. "We are also providing the detectors for the Raman spectrometer – a key instrument to understanding the mineralogy of Mars with the potential for detecting evidence of past life."

The rover will carry a drill which can burrow up to two metres below the surface. "It will give us data that none of the other rovers have provided to date," says Byrne. "If we can get below the top one metre you're getting to pristine Martian conditions that were around millions of years ago when oceans were still on Mars. If you're going to find signs of life that's the best chance you're going to get, below the irradiated surface."

With UK Space Agency funding, via its subscription to ESA, UK industry is also benefiting from the decision to go-ahead with the Mars rover mission. "UK companies are involved in the mission management software, the navigation software and inertial measurement unit," says Horne. "Importantly, the UK has a vibrant planetary science community to exploit the data."

Airbus has a long history of building satellites and spacecraft but the ExoMars rover demanded something new – a bioclean room. "It's next to

"It will give us data that none of the other rovers have provided"

Justin Byrne

the Hercules clean room where we've built Solar Orbiter and Aeolus," says Andy Stroomer, Airbus Stevenage Site Director.

"The big difference is that the rover needs to be bioclean, organically clean, because you can't take organic life to another planet. The worst thing we can do is get to Mars and find we've brought life from Stevenage."

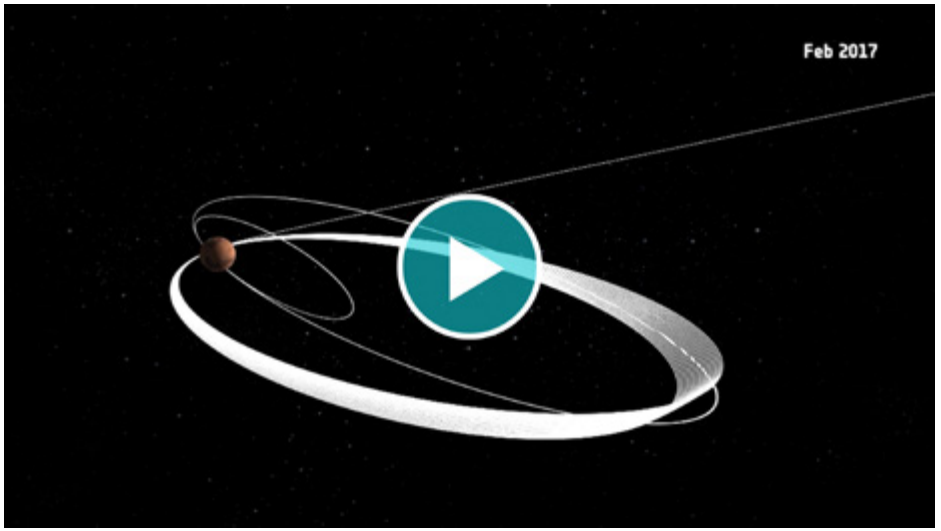
The new bioclean facility took a year to build and around the same time to fit it out and train its workers. They need to be masked, fully covered in what look like white spacesuits and go through air showers. Stroomer points out a fully kitted-out colleague in one of the three partitioned rooms. No food or drink is allowed inside and there are no toilets, so shifts are two hours long before a break.

The first room is a 'grey' area, which is clean but not bioclean. Then there's a second chamber and a third, which resembles a huge stainless steel professional kitchen, where the final flight assembly of the rover takes place.

So how is this room bioclean? "It's a question of recycling air and filtering," Stroomer replies, "and ensuring the purging of air in the chamber is done to a very high level of assurance."

The rover has just completed an ESA critical design review, where its design and science requirements were checked. This included the rover's range, drill, radar system and batteries, as well as ascertaining how much dust the solar arrays can take before losing too much power.

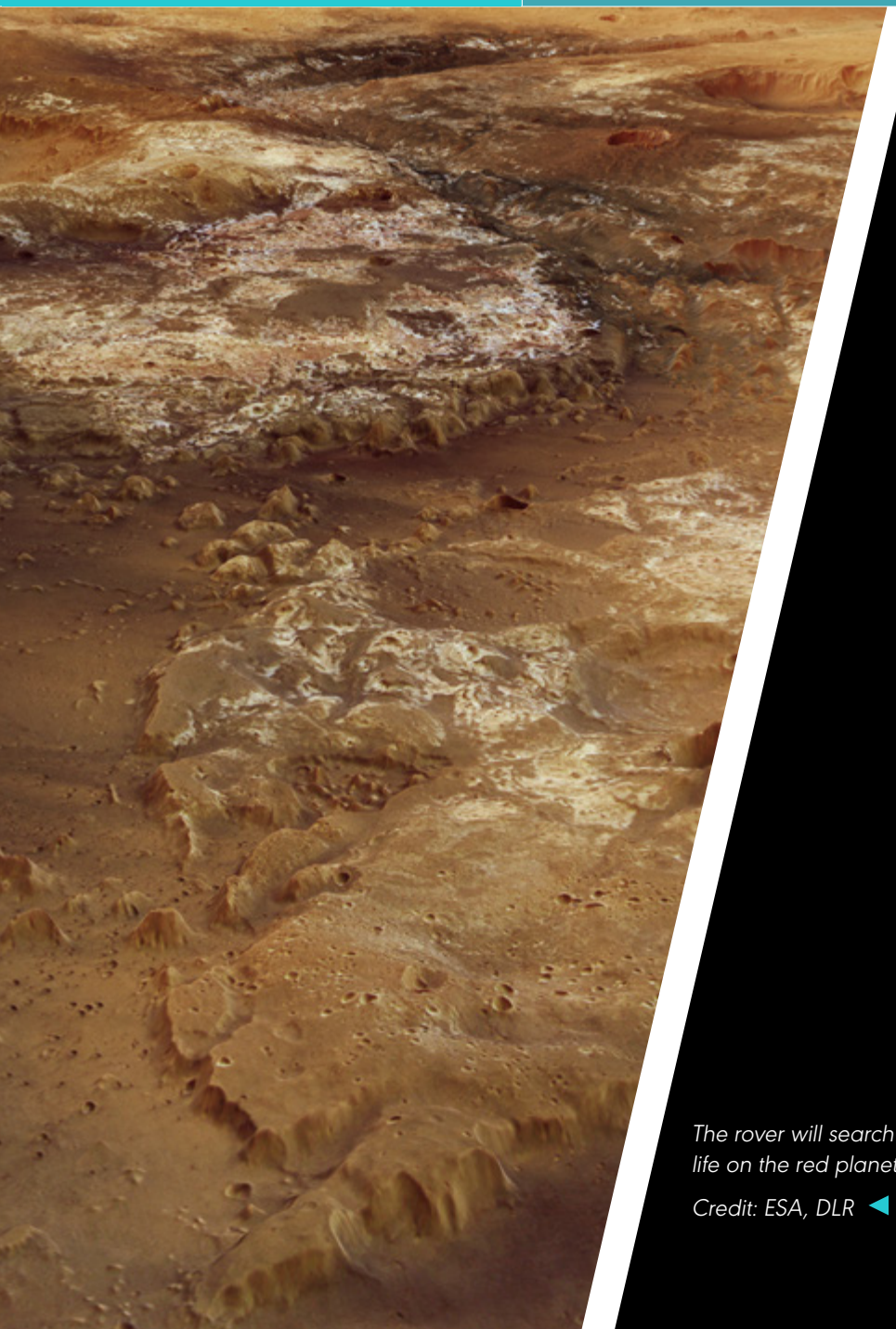
In April 2016, British ESA astronaut Tim Peake remotely controlled a rover at Airbus around a number of obstacles



The long process of slowly changing the TGO orbit

▲ *Credit: ESA*

Watch in HD on ***YouTube***



The rover will search for signs of life on the red planet

Credit: ESA, DLR

while on board the International Space Station. On 26 January 2017 Peake was at the Mars Yard in person, to open Airbus Foundation Discovery Space, a new education centre built around the robotic testing area.

Exhibits include a payload module, built to flight standard, for the LISA Pathfinder mission as well as interactive displays with names like 'magnetic pendulum' and 'momentum machine. The stars of the show, however, are definitely the rovers. Yes, there is not just one.

"There will be one flight rover at the end but we effectively build four," says Byrne. "The structural thermal model proves thermally and mechanically that it works. The ground test model says operationally it works and the electrical testbed model says that the electronics and software works. They're all parts of the jigsaw."

The flight model will be delivered in 2019 but the other three rovers will be seen trundling across the red sands of the Mars Yard from the newly built viewing area as part of the centre. It's a magnificent sight and one that will definitely provide any visiting students with a wow factor.

The centre will initially target schools in Hertfordshire but will be open to students across the UK. "We're really excited at the prospect of building education experiences and resources which leverage the unique inspirational power of the ExoMars rover project," says Matt Hamnett, principal of North Hertfordshire College, which will help run the centre.

"The thrill of going to Mars and the science that the rover is going to do is world changing. It's stuff that could change our view of the solar system," adds Byrne.

"If we find signs of life on Mars what does that say for the rest of the Milky Way? It's something we could look back on and say we changed the thinking of how the universe developed."

Down to Earth with Tim Peake

His Soyuz capsule may be battered from its mission but Tim Peake remains as unruffled as ever. After a hugely successful six months in orbit, the British ESA astronaut is set to return to the International Space Station (ISS) in the next few years. Space UK caught up with Peake after he opened the new education centre at Airbus' Mars test yard in Stevenage:

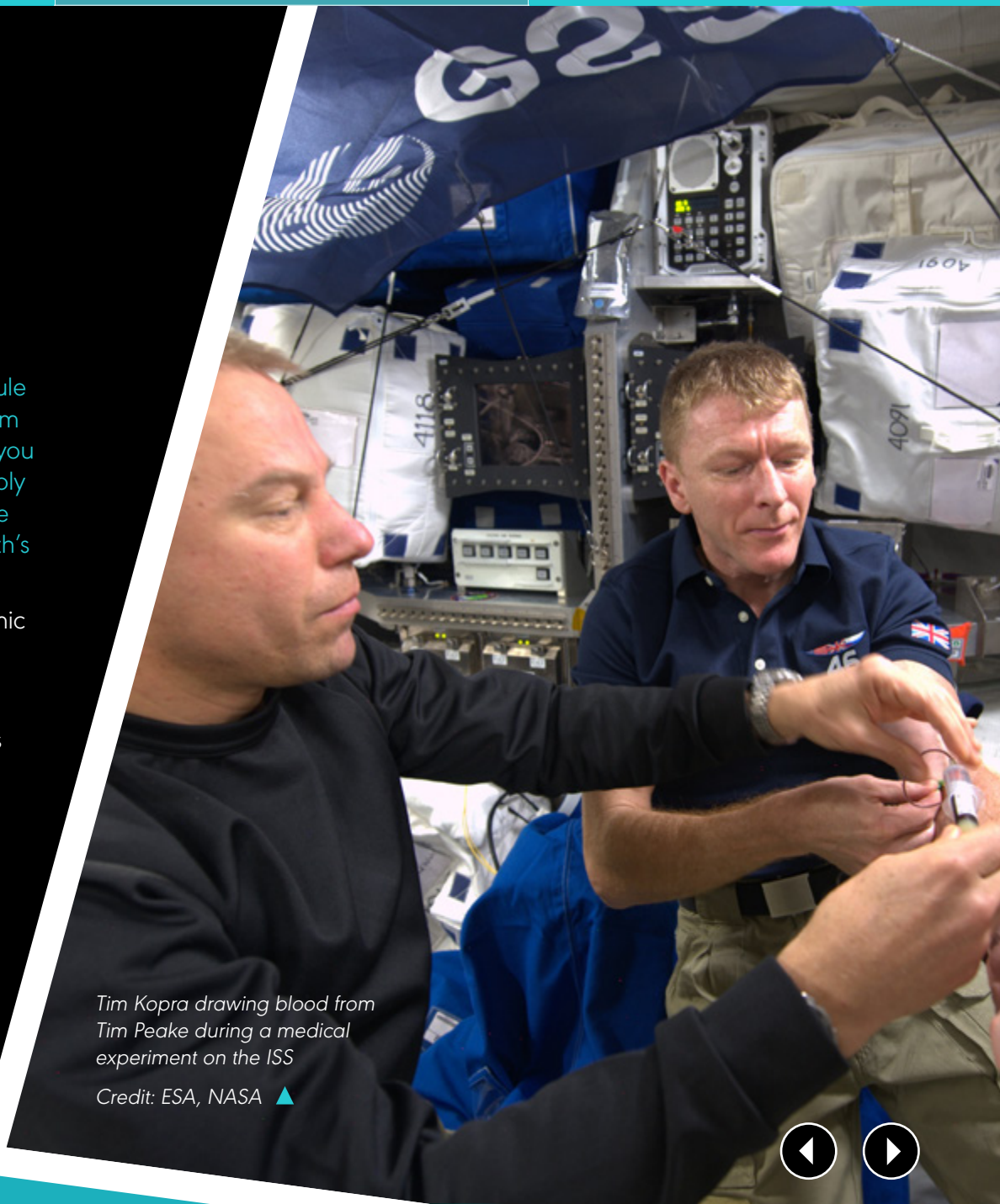
"The launch is almost graceful. It's exciting and you get this huge sensation of acceleration"
Tim Peake

This morning you saw your capsule on display at the Science Museum in London for the first time since you landed in Kazakhstan – it is terribly charred. Can you give us a sense of what that re-entry into the Earth's atmosphere was like?

The re-entry was the most dynamic phase of the mission...

Dynamic?!

The launch is almost graceful. It's exciting and you get this huge sensation of acceleration. And finally, the main engine cuts out and you're in orbit. You then have six months of dealing with a very graceful situation in microgravity where your body adapts to zero gravity.



Tim Kopra drawing blood from Tim Peake during a medical experiment on the ISS

Credit: ESA, NASA

Floating around is very peaceful, even though you're very aware that the Space Station is moving fast, with 16 orbits a day.

And then there's coming back to Earth and experiencing all the explosions that go with a re-entry. The spacecraft separates and suddenly you begin to feel the acceleration as the motors fire. Eventually, the Earth's atmosphere begins to pick you up and gradually, you get a building of g-forces as you decelerate. That stage is not violent, but you get about 5-6 g of deceleration, which is quite a lot after six months of microgravity.

It's also very, very hot.

Then the braking shoot opens and that's when it's quite violent. A good tip that my commander Yuri Malenchenko told both Tim [Kopra] and me was to use the deceleration to tighten the straps as tight as you possibly can because that's what's going to keep you in your seat. The capsule is bounced around, it spins, it swings – that's when you're really thankful that you've got the moulded seat liners. You can really hunker down into your seat. That goes on for about 20 seconds. Once you're under the main canopy, you get about a 15-second respite before the impact of landing.

Do you miss being in space?

It's impossible not to miss being up there. It's a very challenging place to work but it's a very exciting place to work as well.

You seemed to cram in a lot of work up there, did you have a personal competition to get your work done quickly?

If you can do the work quickly, then that's a bonus but I think everybody in the programme would rather you worked accurately rather than quickly. Tim and I had the benefit of getting on board and being briefed by Scott Kelly. He was already eight months into his year-long stay, so he knew that space station inside out and there was nobody better to learn from. Learning from the master, Tim and I were able to get into a very good working regime. Of course, what happens is that the longer you're up there, the more efficient you become about planning your day. For instance, you get to know how the space station operates, where all the tools are and how to stow it away again.

All this helps the programme. The astronauts are the most vital resource in terms of cost and expenditure on the space station. The more work you can get done, the better.

Tim Peake During his January 2016 spacewalk

Credit: ESA, NASA ▶

You must be very pleased with the amount of outreach you got done. Particularly because it had to be fitted in alongside the core work – the science, the maintenance and just living...

After we'd done the maintenance and cleaned the space station on Saturdays, we have some time to do voluntary outreach work. So every weekend, I'd plan with the ground teams what it was that I wanted to get done – anything from videos to education programmes. I was delighted that we managed to achieve so much.

And there's still so much excitement around the mission – everyone wants a selfie with you!

There is, which is wonderful and it's something we're trying to encourage because if we can keep people enthused about space then we can use that as a tool for encouraging kids to start studying science, technology and engineering. It's just wonderful to see there's still so much enthusiasm surrounding the mission.

What's it like to be back in the Mars Yard, having seen it from the International Space Station?

I always love visiting Stevenage. The Mars Yard is something that's looking to the future, our dreams of exploration of the solar system so it's great to be here and it's great to see the rovers in action again.

How difficult was it controlling a rover from the Space Station? It looked quite complicated with multiple screens, there were a few communication glitches and, after all, you were up there and it's in Stevenage.

It was very hard to see what was close to the wheels. You might have a camera that's looking straight ahead but that's no help if there are rocks in the immediate vicinity. There was also some disruption of communication, which meant that commands were being delayed or interrupted. All these things reduce your ability to control the vehicle. We're working through these challenges so that we can accurately control a vehicle on another planet from a spacecraft.

Controlling a rover in Stevenage from the ISS

▲ *Credit: ESA, NASA*

The charred Soyuz capsule arrives back on Earth

Credit: ESA, Corvaja

Do you think robotics is likely to be the future of a lot of exploration?

If you think about the Mars scenario, it makes sense. Rather than incurring a possible eight-minute delay in controlling a Martian rover from Earth, you could have astronauts who are in orbit or on transit to Mars. They'll be dealing with much shorter delays and have much better control over those rovers.

And what are you doing now?

Over the next couple of years, my job is primarily in a support role for Paulo Nespoli, who launches this summer to the ISS, followed by Alex Gerst and Luca Parmitano. All of these astronauts need a huge amount of support for their missions and it's part of my job to provide that.

We don't have a date yet but we know you'll fly again. However, there's a chance it might not be in a Soyuz. Does that mean you'll be training in another vehicle?

Currently, commercial crew vehicles are expected to come online at some time between 2018-2019. ESA procures its seats through NASA, which means that it's likely that most European astronauts beyond 2019 will be flying in one of the new commercial crew vehicles – that's either the Space X or the Boeing vehicle. It could involve training on one of those vehicles.

Are you looking forward to the next few years?

There's going to a lot happening over the next few years. The ISS will go on to 2024, but right now we're focusing on what's going to happen beyond that. At the same time as my mission, we had the first commercial module attached to the space station, the Bigelow module, and that's going from strength-to-strength. By the end of the decade, we might even see the first commercial space station in orbit.

The robotic missions are also very exciting as well. At the Mars yard, we're looking at the ExoMars mission. It's already had its first phase and now we're looking forward to the next phase, which is to put the rover on Mars and start doing the scientific exploration. This is a stepping stone to our human mission to Mars, which will hopefully take place in the 2030s, maybe 2040s. So it's a very exciting future.

Window on the Universe

By Izzie Clarke

Due for launch next year, the giant James Webb Space Telescope will give us a new insight into the Cosmos. For the UK team leading one of the key instruments, the tension is building.

"I'll be terrified when it launches", says Gillian Wright. "I've spent years of my career working to make this thing happen." Wright is leading the development of a crucial instrument for the James Webb Space Telescope (JWST). And the pressure is on.

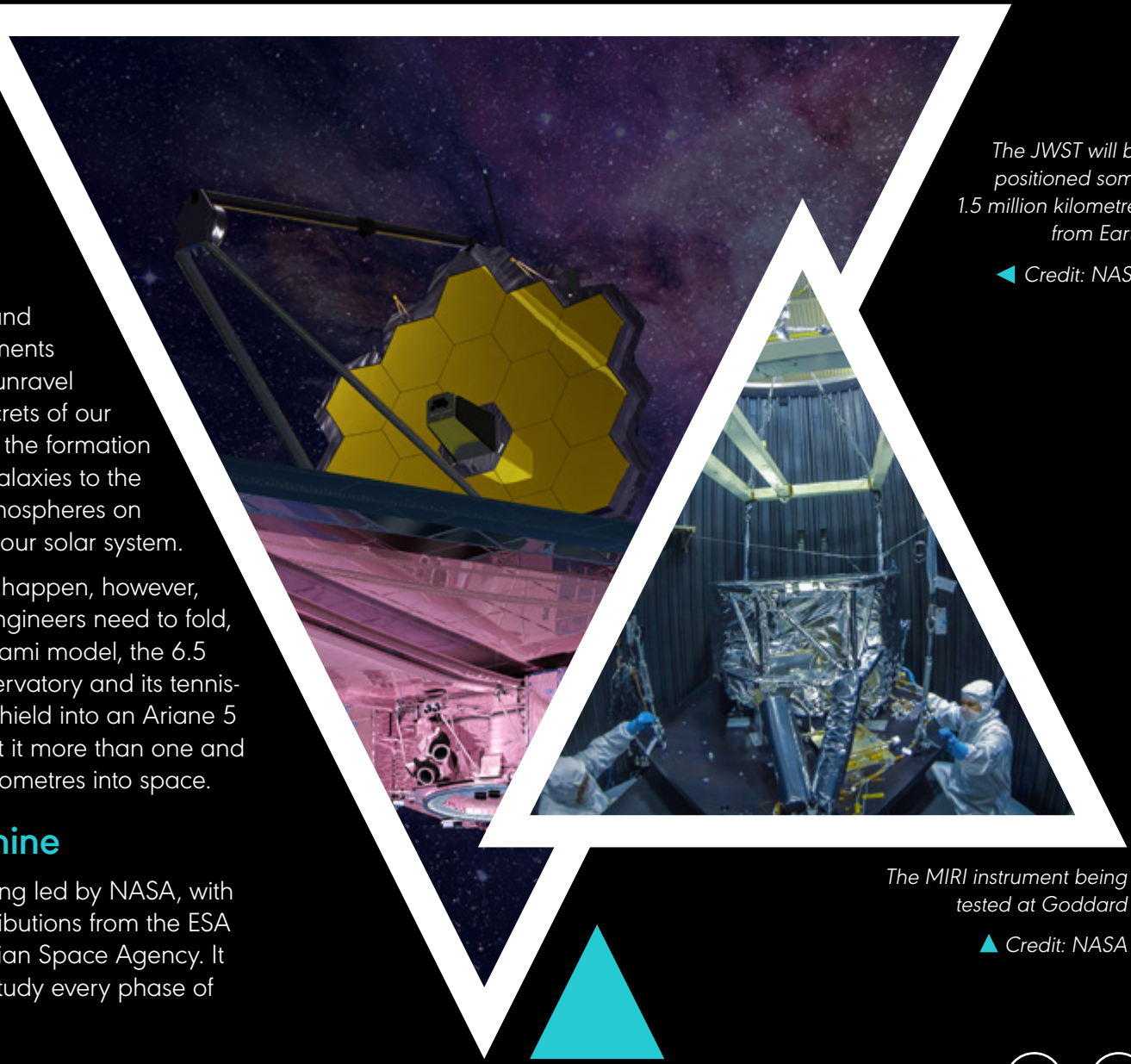
"It all comes together at the moment of launch," she says. "It has to be right first time."

The JWST is the successor to Hubble and, after almost 20 years of construction, is now undergoing a final round of testing before beginning its long-awaited mission in October 2018. The new telescope's exceptional size, sensitivity and precision instruments will be used to unravel many of the secrets of our universe – from the formation of the earliest galaxies to the detection of atmospheres on planets outside our solar system.

Before that can happen, however, scientists and engineers need to fold, like a giant origami model, the 6.5 metre high observatory and its tennis-court sized sunshield into an Ariane 5 rocket and blast it more than one and a half million kilometres into space.

Time machine

The JWST is being led by NASA, with significant contributions from the ESA and the Canadian Space Agency. It is designed to study every phase of



The JWST will be positioned some 1.5 million kilometres from Earth

◀ *Credit: NASA*

The MIRI instrument being tested at Goddard

▲ *Credit: NASA*

The mirror is made up of 18 hexagonal adjustable sections

Credit: NASA

our cosmic history and will be seven times more powerful than Hubble which, during its 26 years in orbit, has discovered billions of galaxies, stars and planets.

NASA describes the new space telescope as a "powerful time machine with infrared vision". A "time machine" because, even travelling at the speed of light, some of the electromagnetic radiation that reaches the telescope will have originated billions of years ago, at the very dawn of time.

One of the new capabilities of the JWST is its infrared vision. This will enable the space telescope to detect material through previously impenetrable clouds of cosmic dust. Peering into these clouds should give us the answer to one of astronomy's biggest mysteries: what were the first luminous objects to form after the Big Bang?

The instrument that will identify these earliest galaxies is the Mid-Infrared Instrument (MIRI). It is fitted with a camera so sensitive it would be able to detect a candle flame on one of Jupiter's moons.

MIRI is a UK-led project, in partnership with a European Consortium and NASA's Jet Propulsion Laboratory, and is the result of decades of work headed by Wright, who is also the director of the UK's Astronomy Technology Centre.

The instrument's other primary objective will be to reveal, for the first time, planets orbiting stars in other solar systems. "We've found lots of these kinds of planets but we don't know very much about them," explains Wright. "MIRI offers us the unique opportunity to study them."

"For the first time ever we'll have direct images of the planets and we'll also be able to take spectra," she adds. "We can look at what the planet is made up of by looking at their chemical signatures from their light."

Much like shading your eyes from the sun, MIRI will be able to block out star light to examine these planets. "We make a spot that is exactly the size of the image of the star and that stops the light from getting to our detectors," explains Wright. "You don't see so much of the light from the star so it's easier to see the light coming from the planets."

MIRI is one of four all-important instruments at the heart of the telescope. The others are the Near Infrared Camera (NIRCAM), the Near-Infrared Spectrograph (NIRSpec) and the Fine Guidance Sensor (FGS). Together, they will be able to reveal the universe in a whole new level of detail.

Size Matters

As well as sophisticated instruments, the other thing you need if you want to peer into galaxies 13.5 billions of light years away, is a mirror. A larger mirror will gather more light than a smaller one, much like a bucket will collect more rainwater compared to a teacup.

The primary mirror for the JWST is 6.5 metres in diameter and consists of 18 hexagonal segments made of gold-coated beryllium. Once launched, these segments will unfold and piece together as one immense mirror.

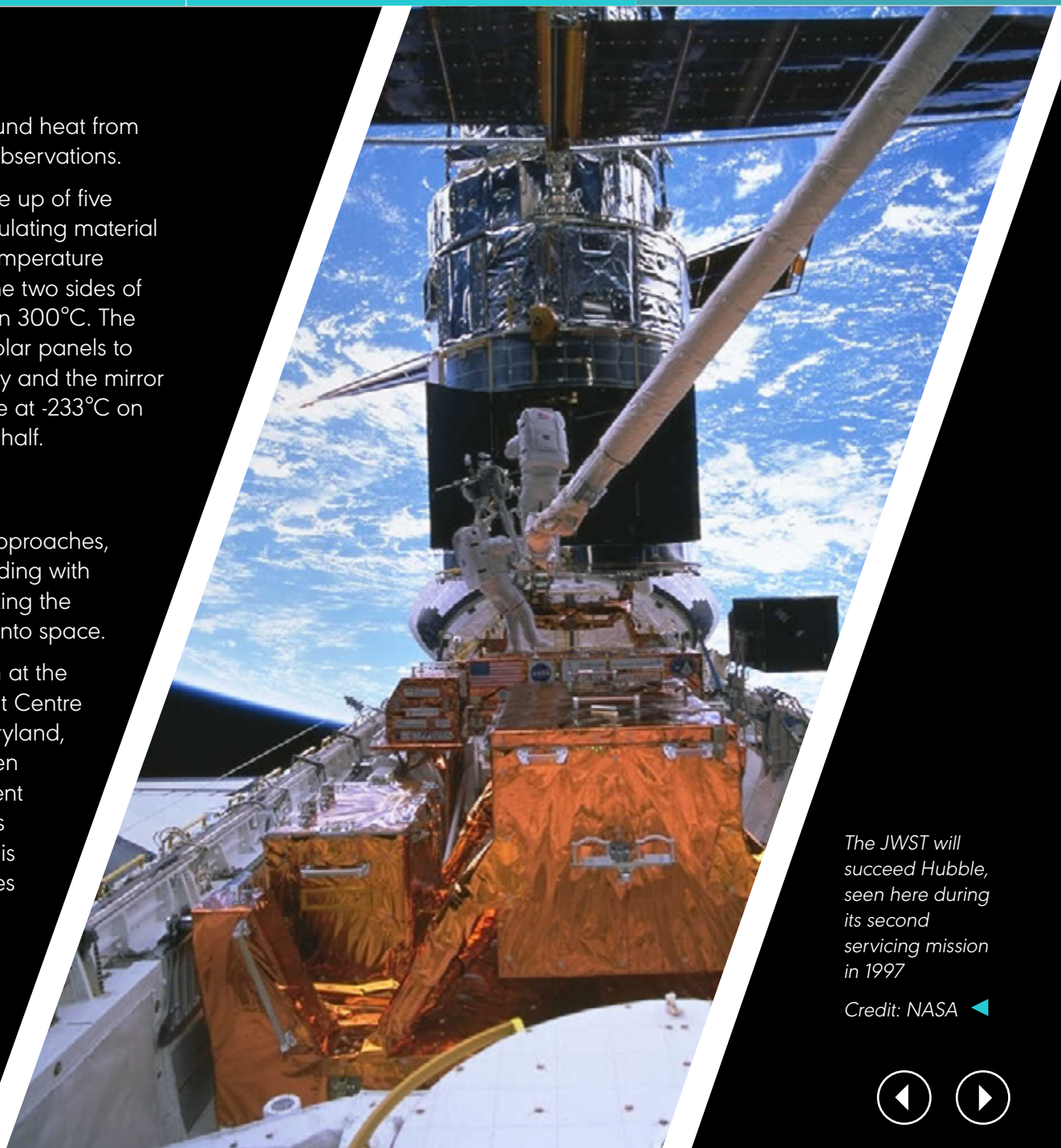
Another engineering feat for the mission is the JWST's sunshield. Northrop Grumman in Redondo Beach, California, has designed a sunshield the size of a tennis court to shadow the telescope's instruments to prevent any background heat from interfering with their observations.

The sunshade is made up of five layers of a flexible insulating material called Kapton. The temperature difference between the two sides of the shield is more than 300°C. The sun-facing side has solar panels to power the observatory and the mirror and detectors operate at -233°C on the cold and shaded half.

A Shaky Start

As the launch date approaches, engineers are contending with the challenge of blasting the advanced telescope into space.

In a giant clean room at the Goddard Space Flight Centre in the US state of Maryland, the telescope has been experiencing the violent sounds and vibrations of a rocket launch. This involves forces 10 times stronger than gravity and blasts that rival a rocket explosion. The team has to be certain that nothing disrupts



The JWST will succeed Hubble, seen here during its second servicing mission in 1997

Credit: NASA

NASA describes the new space telescope as a "powerful time machine with infrared vision"

The telescope will be launched on an Ariane 5 from the European space port in French Guiana

Credit: ESA, Corvaja ▶

the telescope once it's inside the Ariane rocket and on its way.

During this whole process, the primary mirror's precision is continuously assessed to verify that its surface and alignment will not degrade. This 'Centre of Curvature' test is fundamental to the telescope's development.

In early December, during one of the simulated launch tests, one of the restraints on the primary mirror was found to be moving slightly due to the extreme shaking.

"Now that we understand how it happened, we have implemented changes to the test profile to prevent it from happening again," says Lee Feinberg, an engineer and Optical Telescope Element Manager at Goddard. "We have learned valuable lessons that will be applied to the final pre-launch tests of Webb once it is fully assembled in 2018.

With the schedule back on track, Goddard will up the intensity of the vibrations. Knowing that the JWST can survive conditions more severe than the launch gives Feinburgh and his team "confidence that the launch itself will be fully successful."

But it's not just mechanical assessments that are taking place this year. "A lot of the work that is also going on right now is software development," says Sarah Kendrew, an ESA Instrument Scientist in Baltimore. "We're making sure we can control the instrument properly."

"We've had successive test campaigns, where more and more hardware gets put together," says Kendrew. "Now MIRI is just one piece of this enormous telescope and spacecraft."

In the coming months, the JWST will move to the Johnson Space Flight Centre in Texas, where it will undergo a thermal vacuum test. Using the same chamber that was originally used to test Apollo, the telescope and its integrated instruments will be subjected to chilling temperatures – 40 degrees above absolute zero – to monitor how they will perform in space.

From there, it's off to California for one final and momentous challenge. The telescope and scientific payload will be attached to the giant sunshield and sailed down the coast to the launch site in French Guiana by mid-2018.

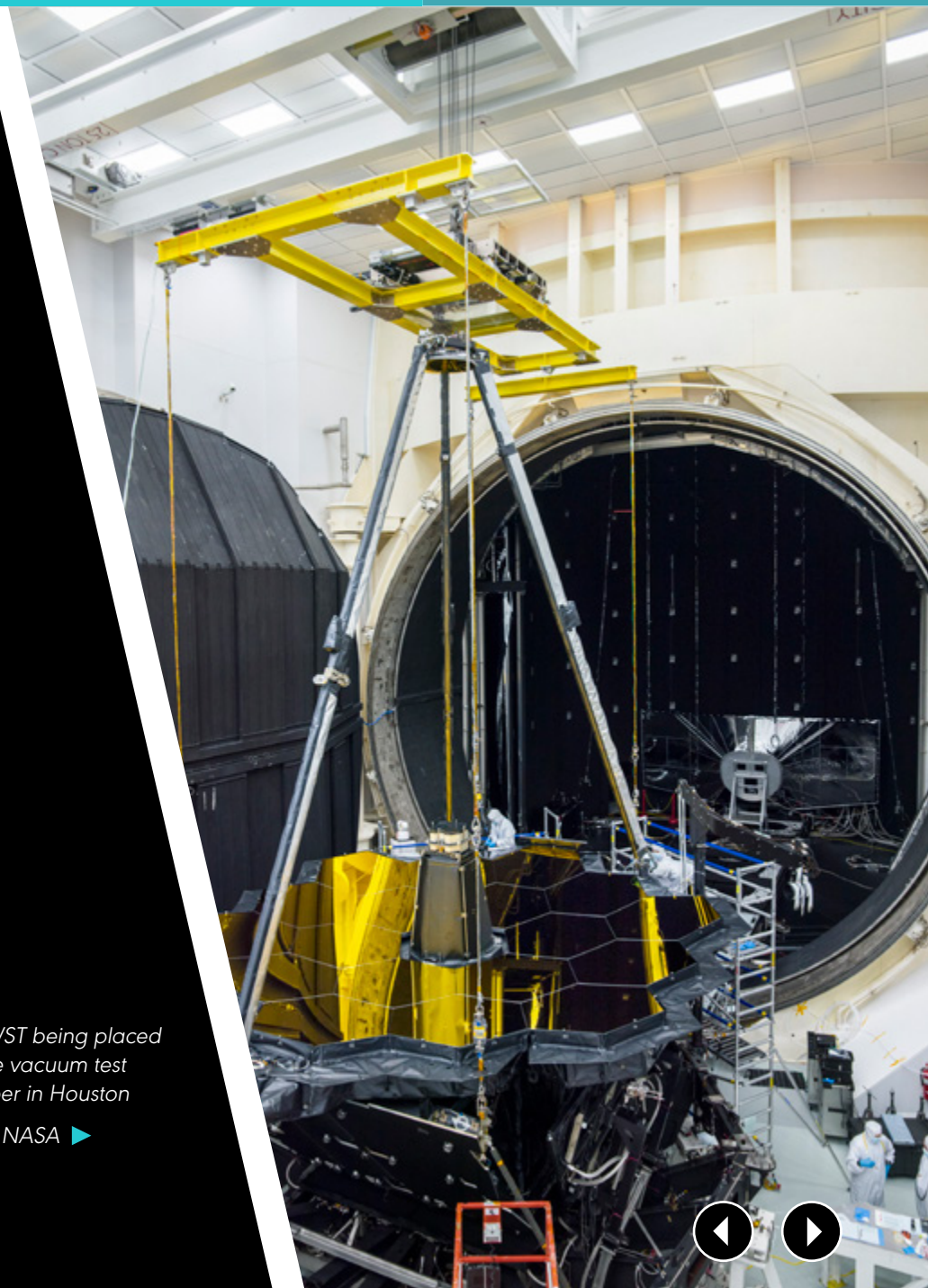
After launch, the scientists will have to wait a few weeks before they know if everything has gone according to plan; the sunshade is cooling and the telescope deploying. With the telescope positioned 1.5 million kilometres from Earth, there is nothing anyone can do to repair any damage. It really does have to be right first time.

With scientific meetings scheduled for later that year, Wright is already looking ahead. "It will probably be about six months after launch that we get the first images back."

"We're talking about the plans for early images and how are we going to commission the instruments," she adds. "It's a very exciting time."

Fact File

- The James Webb Space Telescope is named after NASA's second administrator, James E. Webb
- The development for the JWST started in 1990 – over 1000 people in 17 different countries are involved with the mission
- Whilst Webb is six times larger in area than Hubble, it weighs just over half of its mass
- The amount of gold used to coat the primary mirror weighs the same as a golf ball
- MIRI will be turned on three months after launch, a month later than the remaining instruments
- The instrument will be cooled to seven degrees above absolute zero to minimise the effect its own heat has on its observations



The JWST being placed into the vacuum test chamber in Houston

Credit: NASA ▶

More than 1.6 million children have taken part in at least one of the education projects surrounding Tim Peake's Principia mission to the International Space Station (ISS).

The extensive education programme reached people not normally attracted to space by incorporating a wide range of topics. Although Tim returned to Earth a year ago, the education programme continues and the resources are still available to be enjoyed.

For primary students, the **Space Diaries** are as popular as ever, enabling primary school students to learn about space, strengthen their literacy skills and much more. The authors have also published a special booklet to help encourage girls into STEM subjects.

Earth Observation Detective has produced resources encouraging students to become an Earth observation 'detective'. Classroom activities introduce primary and secondary students to Earth observation by providing teachers with satellite data, astronaut photographs and ideas about how to use these in their lessons. Topics include weather and climate, forest, habitats and natural disasters.

For older students, the Institute of Research in Schools continues to flourish, with **TimPix** and **Amazing Atmospheres**, giving students the opportunity to use real data from the ISS or to become part of the ESA ExoMars mission from Earth. One student has even made **headlines**, telling NASA of an anomaly he had found in the Timepix data.

The National Space Academy's Astro Academy: Principia includes videos made by Tim to demonstrate otherwise hard to grasp physics concepts. These secondary school resources bring physics to life and will help teachers inspire their students.

All resources can be downloaded from ESA's **Space Education Office in the UK** (ESERO-UK). However, the UK Space Agency education team will soon be launching its new website. This will include education resources as well as information on skills and careers in the space industry.

Tim Peake took this picture of the UK and France from the ISS

▼ *Credit: ESA*

Made in the UK: Ecometrica

Ecometrica develops software to advance the use of Earth observation data from satellites, aerial surveys, ground sensors and other sources. Executive Chairman Richard Tipper argues that data from satellites is vital when it comes to protecting the environment.

You're clearly motivated when it comes to sustainability, what drives you?

When I was doing my first degree in agricultural science, I worked on a lot of different projects in forests and agriculture. I saw inefficiencies and lack of effectiveness and it was really frustrating. I thought things could be done better. If we had better access to information, we could make better decisions. So really, the motivation came from a grumpy person who wasn't satisfied with the way things were.

You were recognised as part of the 2007 Nobel Peace Prize?

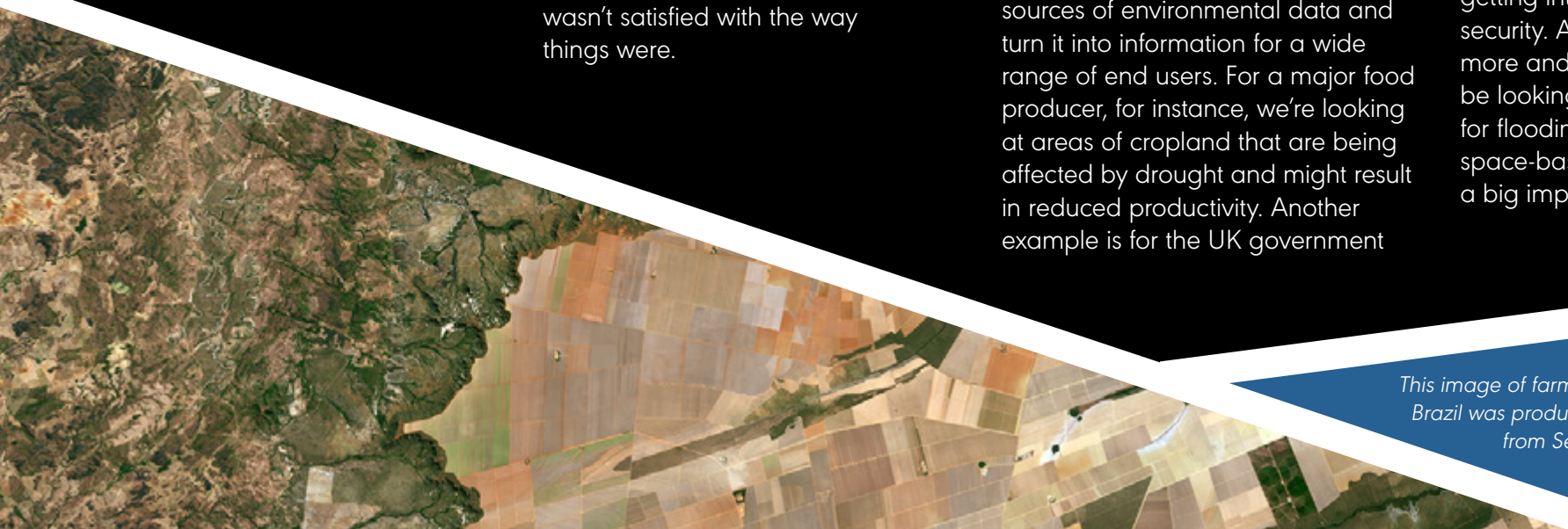
Yes, it was lovely to be recognised. I was a member of a large international team working on the Intergovernmental Panel on Climate Change. I worked mainly on the question of land-use change and how that affects climate change.

After that, you co-founded Ecometrica. What do you do?

We take satellite data and other sources of environmental data and turn it into information for a wide range of end users. For a major food producer, for instance, we're looking at areas of cropland that are being affected by drought and might result in reduced productivity. Another example is for the UK government where we're monitoring which forest conservation projects around the world are successful.

How important do you think space-based monitoring is for protecting our environment?

It's really important and there're a huge range of applications. So far, Ecometrica has focused on environmental monitoring – agriculture, coastal areas and forests. But we're beginning to broaden out, getting into disaster response and security. As climate change affects more and more communities, we'll be looking at early warning systems for flooding for instance. I think space-based monitoring could have a big impact.



This image of farmland in central Brazil was produced using data from Sentinel satellites

◀ *Credit: ESA*

Ariel 3

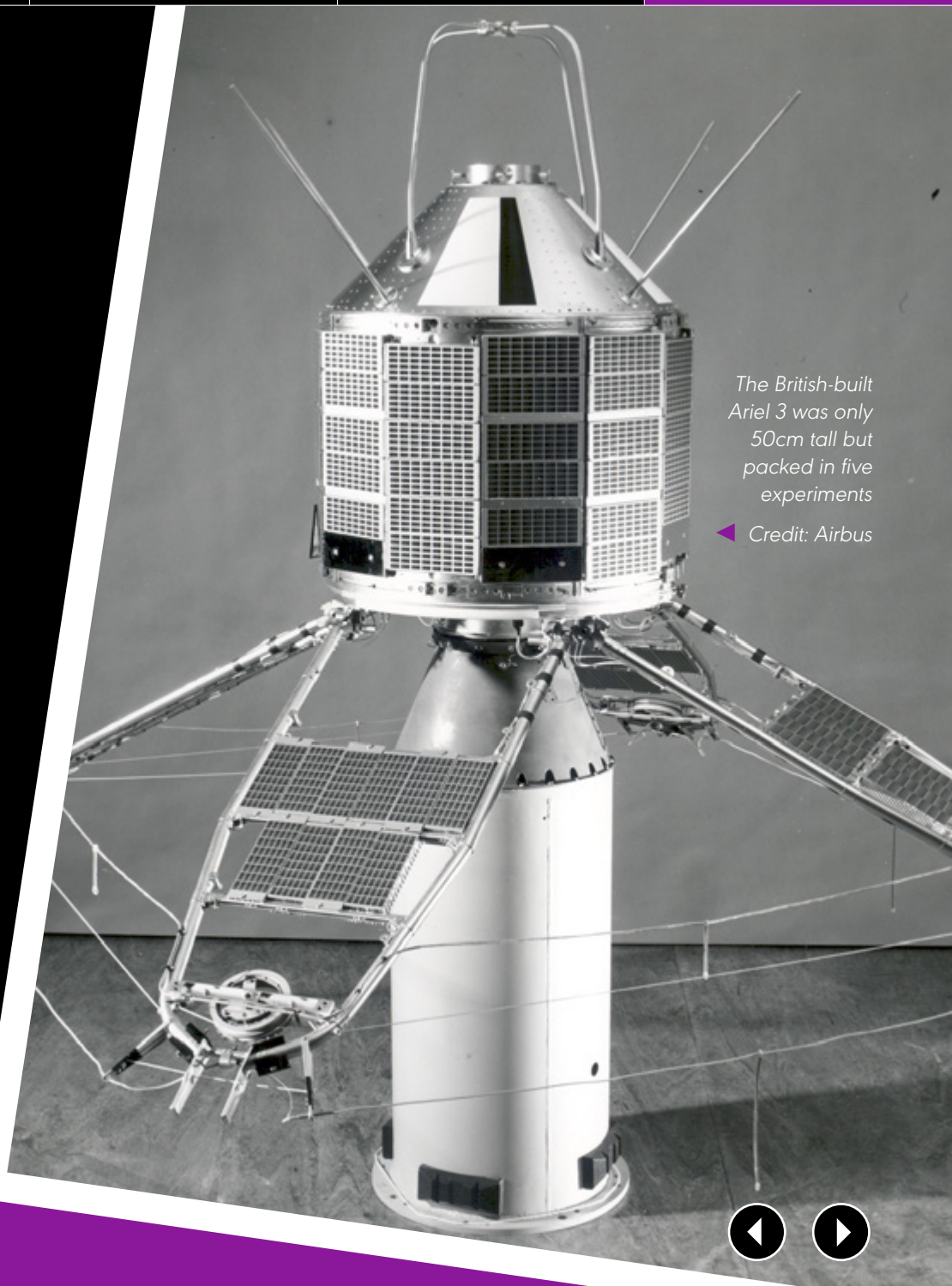
This year marks the 50th anniversary of the first all-British satellite.

Ariel 3, was launched into orbit from Vandenberg Air Force Base in California on 5 May 1967. With five experiments on board, it was designed to investigate the environment of space.

The small satellite – about half a metre high and weighing in at around 90kg – was manufactured by the British Aircraft Corporation (now part of Airbus) with experiments supplied by Sheffield and Birmingham Universities, Jodrell Bank and the Met Office.

Ariel 3 carried a miniature tape recorder to store scientific data when the satellite was out of touch with the ground. Unfortunately, this innovative device only lasted a few months before breaking down. The satellite itself, however, continued to operate until September 1969 and broke up in the Earth's atmosphere a year later.

Ariel 3 was a significant achievement for the UK, providing valuable scientific information on the upper atmosphere and radiation from space. It also helped build the skills and expertise of the UK space industry, leading to the development of today's sophisticated scientific and commercial satellites.



The British-built Ariel 3 was only 50cm tall but packed in five experiments

◀ *Credit: Airbus*

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