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Sentinel Success

A British-built satellite to measure air pollution is in excellent health in orbit, following a successful launch.

Sentinel-5P forms part of the joint European Space Agency (ESA)-European Commission environmental monitoring programme, Copernicus. It will study the atmosphere to track the spread of pollutants – such as ozone, nitrogen dioxide and methane – to help assess their effect on our changing planet.

The satellite was constructed by Airbus Defence and Space in Stevenage and incorporates a high resolution atmospheric sensor, Tropomi, built in the Netherlands. Sentinel-5P was blasted into space on 13 October using a Rockot launcher from the Plesetsk Cosmodrome in northern Russia.

"The successful launch is a clear demonstration of the UK's valuable contribution to improving global knowledge through satellite data, and the heights we can reach by collaborating with our European partners," said Science Minister Jo Johnson.

In the days after launch, engineers at ESA's mission control centre in Darmstadt, Germany, worked around the clock to check Sentinel-5P was operating correctly. The full commissioning of the satellite will take around six months but, once operational, it will be able to map pollution across the entire globe every day.

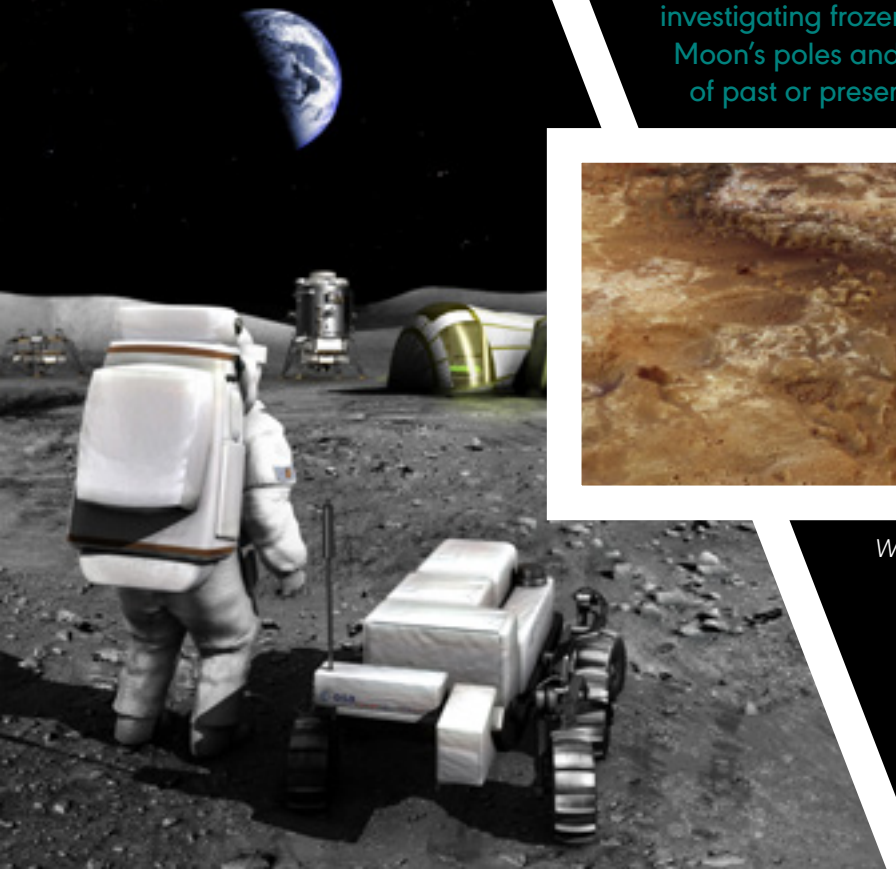
Sentinel-5P joins a fleet of five other Sentinel satellites already in orbit, delivering a wealth of environmental information about our planet. The UK invests in Copernicus through the European Union, with additional UK Space Agency investment for technology and instruments through ESA.

"Sentinel-5P and successor satellites will give us a consistent measure of the quality of our atmosphere over the next decades and monitor the success of the really significant steps society wants to take towards a healthier lifestyle and clean economy," said John Remedios, Director of the National Centre for Earth Observation. "It's encouraging to see the excellent UK participation with its expertise on this mission."

The launch of Sentinel-5P from Plesetsk

◀ *Credit: ESA*

New Moon Money



There is renewed international interest in returning to the Moon

Credit: ESA ▼

The UK Space Agency has awarded more than £3 million to UK researchers working on future exploration of the Moon and Mars. The funding from the Aurora Science programme will go towards investigating frozen water at the Moon's poles and the likelihood of past or present life on Mars.

Was there ever life on Mars?

▲ *Credit: ESA, DLR*

The UK has a major investment in ESA's ExoMars missions, which aim to better understand Mars' environment and atmosphere. A UK-built rover will be the first to drill deep into the martian soil in an attempt to answer questions about possible life.

"Science enables and shapes the UK's future in space exploration," said Science Minister, Jo Johnson. "Research and innovation are at the core of our Industrial Strategy and, by investing in these types of projects, we are reinforcing our position as a world leader in these important and exciting areas."

The new money will be shared between 17 academics and scientists working at UK research organisations. "This funding really helps us get the very best science results from our involvement," said Matthew Balme from the Open University, one of the award recipients.

An additional £230,000 has also been awarded to studies on potential experiments for the International Space Station (ISS). British ESA astronaut Tim Peake performed many science experiments during his six-month ISS mission – several with contributions from UK scientists.

"Microgravity science in the UK has grown rapidly since we joined the ISS programme back in 2012," said UK Space Agency Human Spaceflight and Microgravity Programme Manager, Libby Jackson. "Any future mission to the ISS represents a really exciting opportunity to build on this and to ensure that the UK science community is properly placed to capitalise on the research opportunities that a flight offers."

For more on the rover, see *Made in the UK.*

Planet Hunting Mission

A mission to determine the structure of planets outside our Solar System is being prepared for a 2018 launch.

The European CHEOPS (CHaracterising ExOPlanet Satellite) mission – a partnership between ESA and the Swiss Space Office – is a high precision space telescope that will examine exoplanets as they cross their parent suns.

CHEOPS will use a technique known as photometry to search star systems already known to host planets. The telescope will detect changes in light intensity as planets pass in front.

UK engineers helped build the scientific hardware onboard the mission, which will further our understanding of the formation and evolution of planetary systems.

"It's a fantastic mission," said Andrew Collier Cameron, Professor of Astronomy at the University of St Andrews and the UK member of the CHEOPS science team, who is coordinating a team of exoplanet scientists across Europe.

"The idea is to make sure that everybody has the software available for determining the size of the planet, the properties of the host star and the inclination of the orbit," said Cameron. "These are all the things you need to know in order to determine the size and temperature of the planet."

"We'll also be looking for the drop in light when the planet goes behind the star," he said. "This will give us some idea of how reflective the planet is and an insight into the properties of the atmosphere."

The planets CHEOPS observes will be targeted by future missions. These include ground and space-based observatories, such as the James Webb Space Telescope.

CHEOPS has successfully completed vibration tests at the University of Bern and is due for launch on a Soyuz rocket, into low Earth orbit, from the European spaceport in French Guiana.

A member of the CHEOPS team examines the telescope's primary mirror

▼ *Credit: ESA*

CHEOPS will examine planets transiting alien stars

◀ *Credit: ESA, NASA*

Sunshine Smile

UK science teams will lead a new mission to study the interaction between the Sun and the Earth. The UK Space Agency has awarded £3 million to support academics working on SMILE – the Solar wind Magnetosphere Ionosphere Link Explorer.

The ESA mission, being delivered jointly with the Chinese Academy of Sciences, will be used to build-up an accurate map of the magnetosphere. This magnetic bubble protects the Earth from cosmic radiation and the charged particles streaming out from the Sun, known as the solar wind.

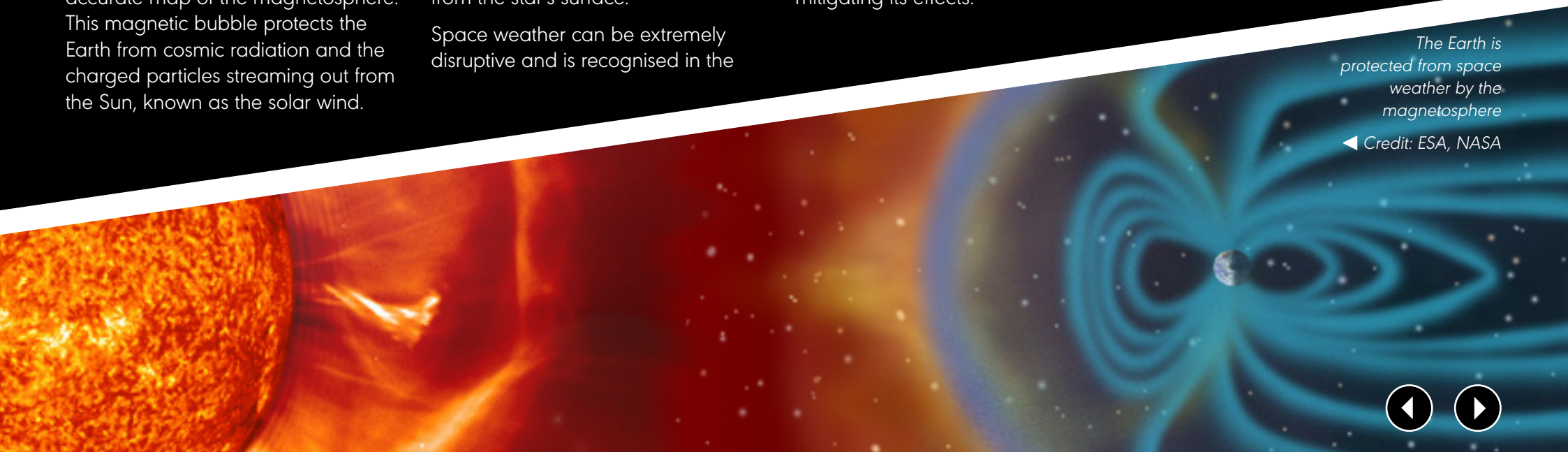
Our planet has the strongest magnetosphere of all the rocky planets in our solar system. Its protective role is believed to be crucial for the evolution of complex life on Earth.

As well as investigating the behaviour of the magnetosphere, SMILE will be used to improve our understanding of space weather. This refers to everything the Sun throws at us – from the solar wind, to eruptions and flares from the star's surface.

Space weather can be extremely disruptive and is recognised in the Government's National Risk Register as a threat to our technological infrastructure. It could potentially damage satellites, communication networks and even power grids.

"SMILE is a most innovative space mission," said Co-Principal Investigator, Graziella Branduardi-Raymont. "It will explore scientifically what drives space weather and return knowledge that will eventually lead to mitigating its effects."

The mission is due for launch in 2021 and the £3 million investment package will be used to support academic groups at UCL's Mullard Space Science Laboratory, the University of Leicester and Open University. Detectors on board the satellite will be developed by Teledyne e2v Limited and Thales Alenia Space UK has been awarded a contract by ESA to develop the spacecraft's design.



The Earth is protected from space weather by the magnetosphere

◀ *Credit: ESA, NASA*

Cassini's Last Stand

Every so often a space mission reaches rock star status. It makes headline news, captures people's imaginations, and inspires a new generation of scientists and engineers. In 2016 it was Rosetta. This year it was the Cassini-Huygens mission to Saturn.

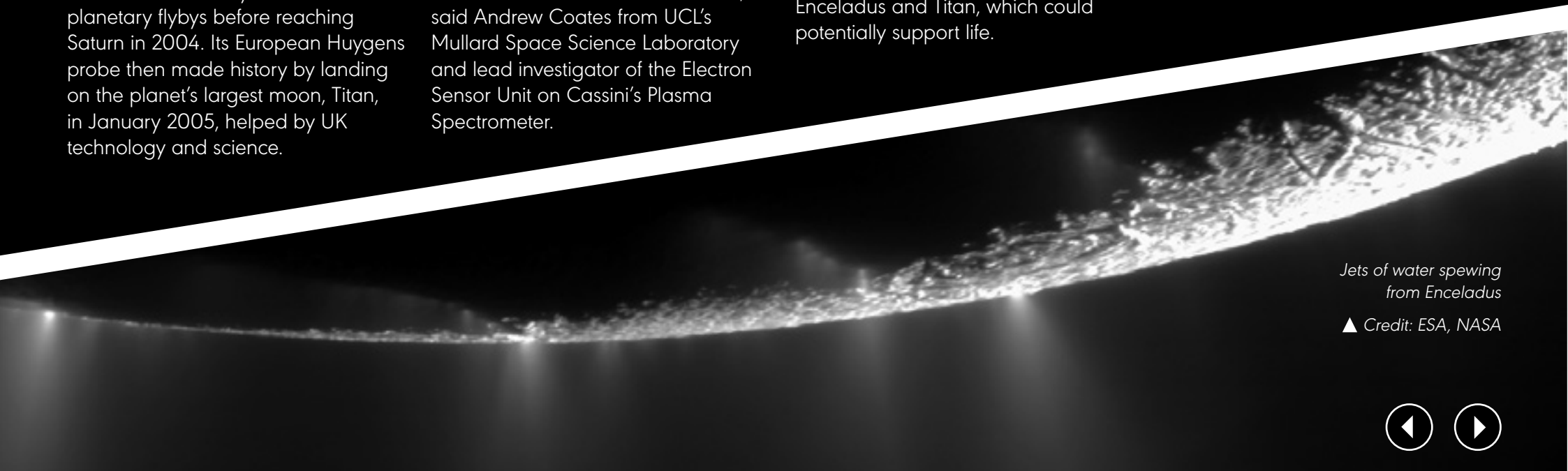
Launched in 1997, the joint ESA/NASA and Italian Space Agency mission took seven years and several planetary flybys before reaching Saturn in 2004. Its European Huygens probe then made history by landing on the planet's largest moon, Titan, in January 2005, helped by UK technology and science.

Since then the orbiter – which also has UK involvement – has continued to examine Saturn, its rings and moons. Cassini has spent more than a decade collecting stunning images and making scientific discoveries, such as finding a hidden ocean and observing icy plumes on Saturn's moon Enceladus.

"Cassini-Huygens has rewritten the textbooks on Saturn and its moons," said Andrew Coates from UCL's Mullard Space Science Laboratory and lead investigator of the Electron Sensor Unit on Cassini's Plasma Spectrometer.

Cassini bowed out in spectacular fashion. It performed a series of 22 dives between the planet and its rings before the final descent. Then, while live-streaming data from eight of its 12 science instruments, it plunged into the gas giant's atmosphere on 15 September and disintegrated. This manoeuvre was specifically chosen to avoid any potential contamination with Saturn's moons, especially Enceladus and Titan, which could potentially support life.

Analysis of data from Cassini's final moments, suggests a tough descent. Saturn's atmosphere has hardly any air at the altitude where it lost contact and is similar to the environment surrounding the International Space Station (ISS). But while the ISS travels around the Earth at 28,000 km per hour, Cassini's descent was an eye watering 112,000 km/h.



Jets of water spewing from Enceladus

▲ *Credit: ESA, NASA*

Cassini also had an 11 metre magnetometer boom sticking out of its side and, even though the gases in the atmosphere are minimal, they pushed against the boom so the spacecraft's thruster jets had to make corrections to keep the antenna pointed towards Earth. These thrusters were firing at full capacity during the 20 seconds before the spacecraft's signal disappeared.

The orbiter continued to perform science until the last moment. The final eight seconds of data show that Cassini began slowly tipping over backward. The antenna's radio signal began to point away from Earth and then there was silence.

"It was a bittersweet moment," said Coates, who had watched the launch in 1997 and had just finished a live broadcast on BBC TV when the mission ended. "As I was walking off the set, confirmation came of loss of signal. It was an emotional moment after 28 years on the mission but later I reminisced with some of the team and then celebrated at home. I must admit a tear came to my eye thinking it's finally gone. It was a huge achievement by thousands of people worldwide."

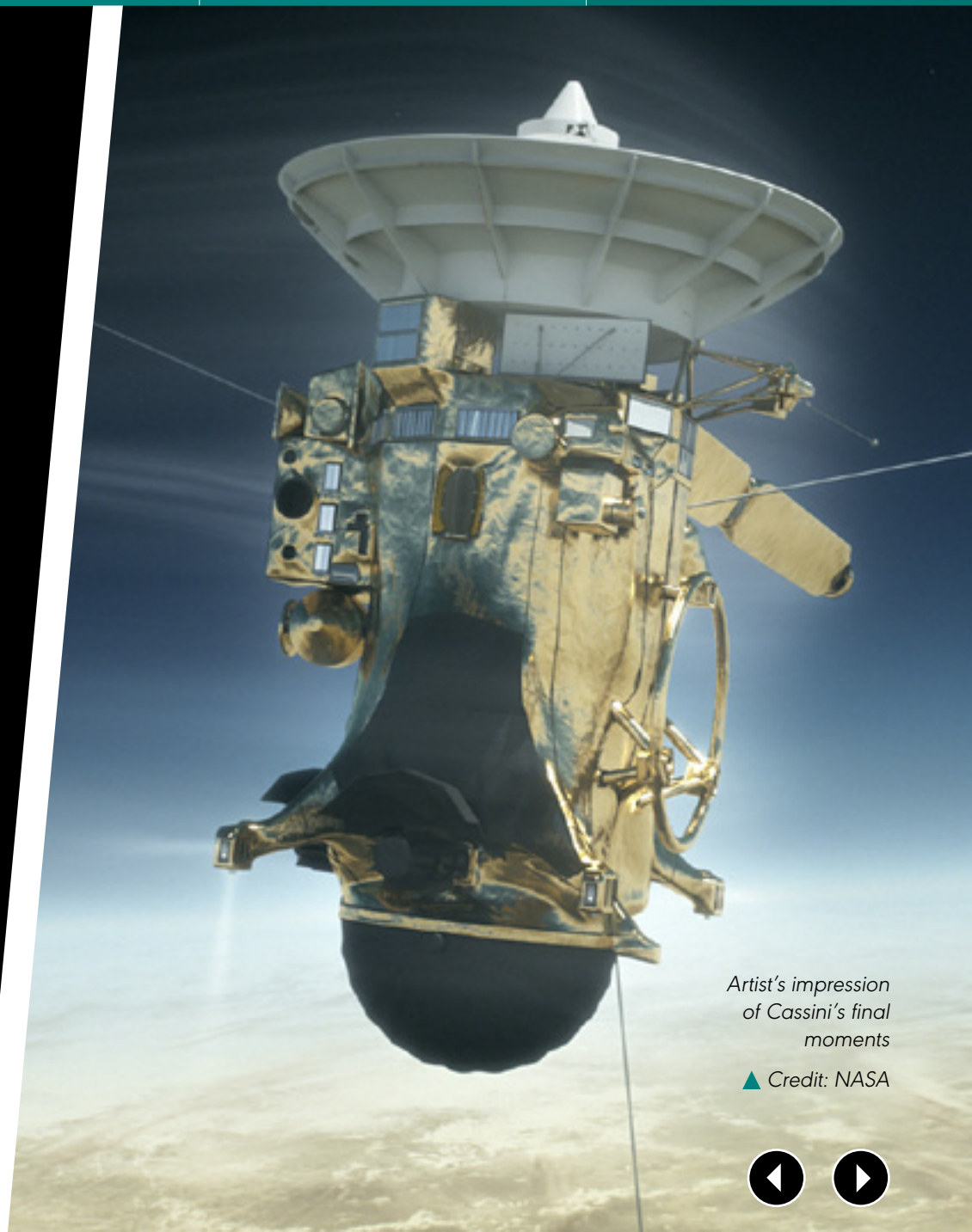
According to Coates, the Cassini-Huygens mission has redefined the habitable zone for life in our solar system by adding Saturn's moons Enceladus and Titan as "real possibilities".

Apart from the Plasma Spectrometer, the UK was also involved in Cassini's Composite Infrared Spectrometer and the Magnetometer. UK academics also contributed to the Radio Plasma Wave instrument, the Imaging Science Subsystem and the Cosmic Dust Analyser.

"Cassini-Huygens has been an incredible journey of exploration and we are very proud to have supported the UK scientists and engineers who have led many of the discoveries from this mission," said Head of Space Science at the UK Space Agency, Katherine Wright. "Its data legacy will keep on producing first class science for many years to come."

Watch Cassini's launch on *YouTube.*

See also our feature on *Huygens.*



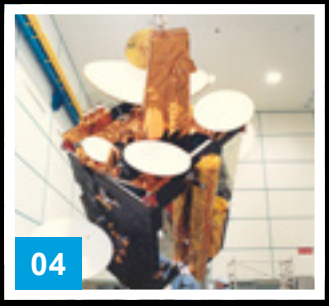
Artist's impression of Cassini's final moments

▲ *Credit: NASA*

Connecting the World

The UK is a world leader in the design, manufacture and operation of communications satellites. These spacecraft provide TV (including Sky TV), broadband, phone and secure communications services to every country on Earth.

Britain was in at the very start of this communications revolution. The Goonhilly ground station in Cornwall received the first transatlantic TV broadcast via the Telstar satellite.



01 *Launched in July 1962, Telstar enabled the first high-quality live TV pictures to be broadcast across the Atlantic*

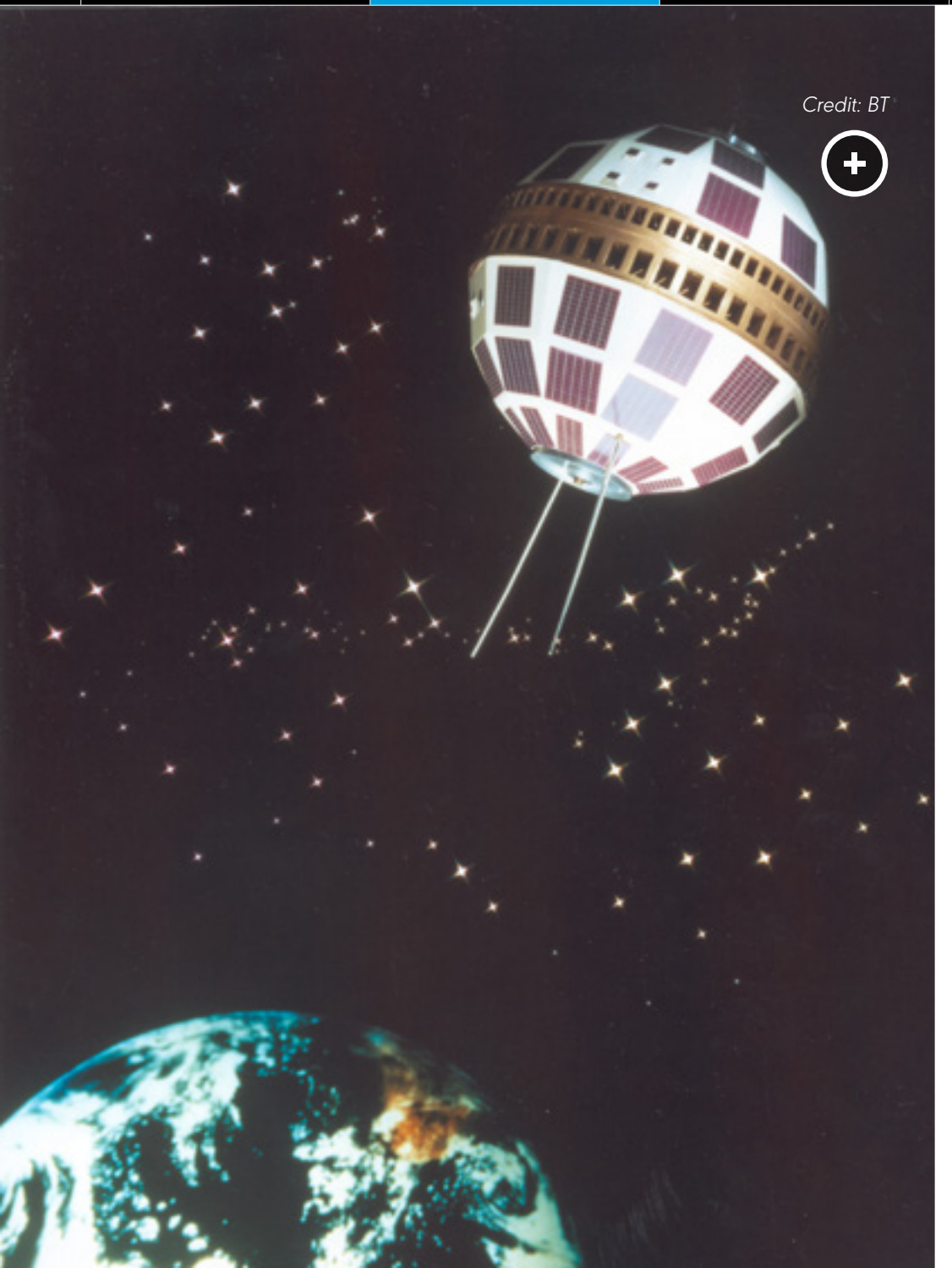
02 *This Intelsat IV satellite was built in the early 1970s, as part of an international consortium, by the British Aircraft Corporation in Bristol. The satellite could relay 6000 phone calls or 12 colour TV channels*

03 *A Skynet 4 satellite under test – the UK armed forces have been using Skynet satellites for secure global communications since the 1970s*

04 *Launched in July 1989, ESA's experimental Olympus satellite was almost lost after a command sent the spacecraft spinning out of control. 50 engineers worked over two months to nurse the spacecraft back to life*

05 *An Inmarsat 3 satellite being tested in Portsmouth. Developed in the 1990s, Inmarsat still uses four of the five satellites in this series as part of its global communications network*

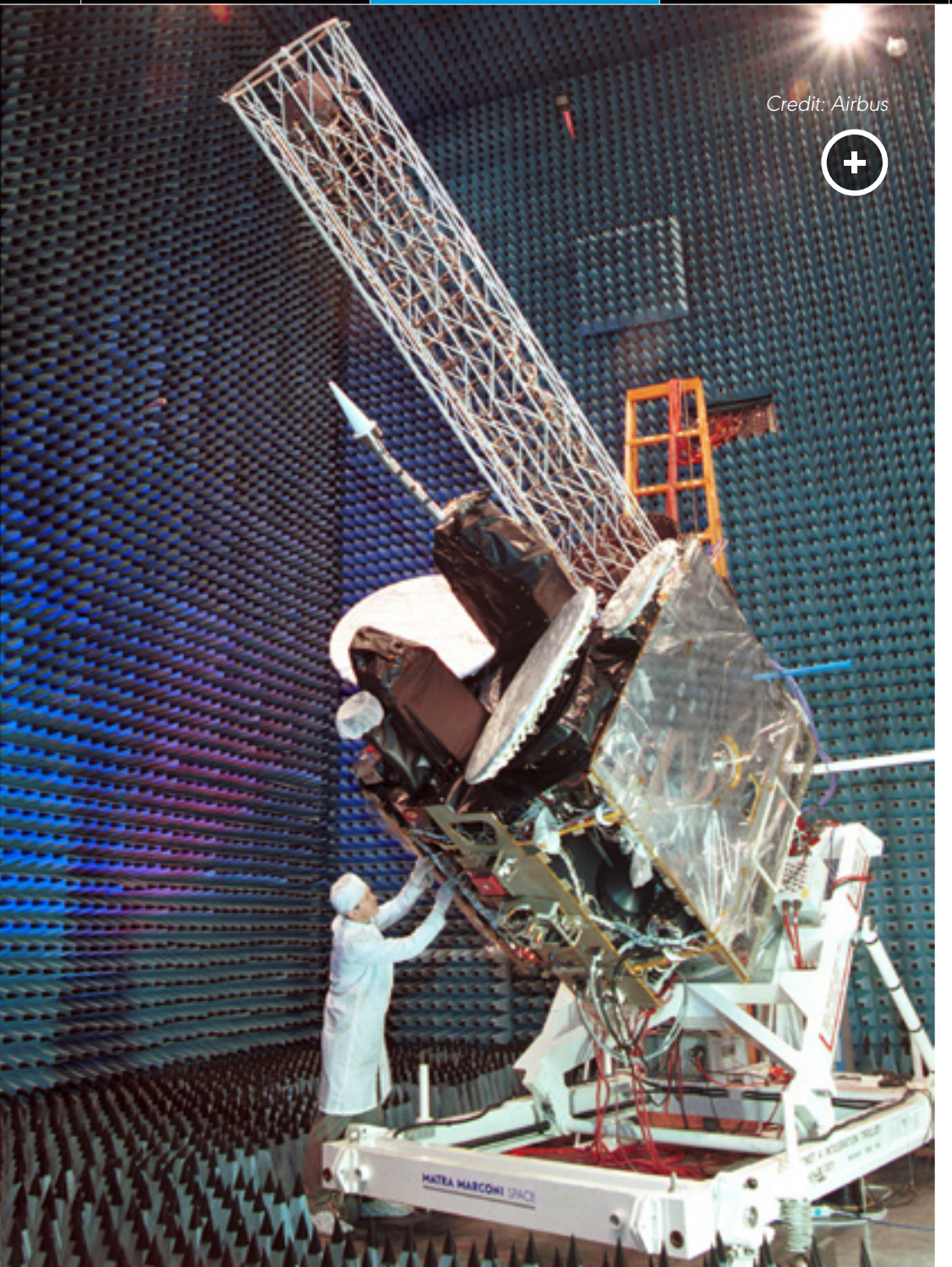
06 *Weighing more than six and a half tonnes, AlphaSat is one of the most powerful commercial telecommunications satellites ever built. The mission, a partnership between ESA and Inmarsat, includes innovative laser communications technology*



Credit: BT

Credit: Airbus

Back to In Pictures


Credit: Airbus
MATRA MARCONI SPACE


Credit: Airbus
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Credit: Airbus

Credit: ESA, Airbus

Back to In Pictures

The aftermath of Hurricane Irma in the Florida Keys

Credit: iStock ▼

The Space Emergency Service

By Richard Hollingham

A UK team is part of a global operation to provide satellite information when disasters strike.

Tuesday 5 September 2017. Remote Sensing Analyst, Amalia Castro, was working at her desk in the Airbus offices in Guildford.

"I was on call 24/7 for the whole week," says Castro. "We received this email at 12.26pm with details of the latest disaster."

The email was an official request under the International Charter Space and Major Disasters, to mobilise satellites to capture images, radar and other data as Hurricane Irma advanced across the Caribbean. Once Castro had verified the source of the request, she set to work checking which satellites could be deployed.

From her computer monitors, Castro can track all the available Earth observation satellites in orbit and see when they pass over a particular area. "I need to think which satellites will be best, what's their resolution and prepare to task those satellites," she says. "We know, from our systems, which satellites are available, their agencies and specifications."

The International Charter provides images and other satellite information

The Caribbean island of Saint Martin captured by the Pleiades Satellite in the aftermath of Hurricane Irma

▲ *Credit: Airbus*

free of charge to emergency response agencies around the world whenever major disasters – natural or otherwise – strike. These could range from earthquakes and volcanoes, to floods, fires or oil spills. The Charter has also been activated to monitor the movement of refugees and to help track the spread of Ebola in West Africa.

Management of the Charter is shared between 16 signatory agencies around the world, with teams in several countries responsible for on-call duties. Between April and October this year, the lead for the agreement has been held by the UK Space Agency, with the Airbus team in Guildford responsible for coordination.

The activation for Hurricane Irma would be the ninth in a month, following floods in Venezuela, Vietnam, Nepal, Sierra Leone and Bangladesh, two earthquakes in China, and Hurricane Harvey which left vast tracts of Texas under water.

"For each activation, we have checklists which summarise what to do with each disaster," Castro explains. "This makes the system more robust, so if you receive a call at 3am, and you're not thinking clearly, the output still needs to be good."

Once Castro has decided which satellites are best equipped and located to provide data, she contacts their operators – public and private – to request their deployment. "In this case I was asking for everything," she says. "We had the potential for storms, floods, flash floods, landslides...I asked for data from 15 different satellites from several different companies and agencies."

Satellites requested to provide images for Hurricane Irma included spacecraft operated by the US, Russia and France. Charter members work together to ensure the process runs smoothly. "Using more satellites not only gives you more opportunities for data," says Castro. "It also means we have more chances to find gaps in cloud cover."

"I think that's the great thing about the Charter," says Chris Lee, who leads the UK's membership of the Charter for the UK Space Agency. "It's the collection of all the available satellites from all around the world."

These include UK-DMC2, the latest in a series of satellites built by Surrey-based SSTL and operated by Airbus, specifically designed for disaster response. In future, there will also be more radar satellites available, such as the UK's NovaSAR, which can see through cloud cover.

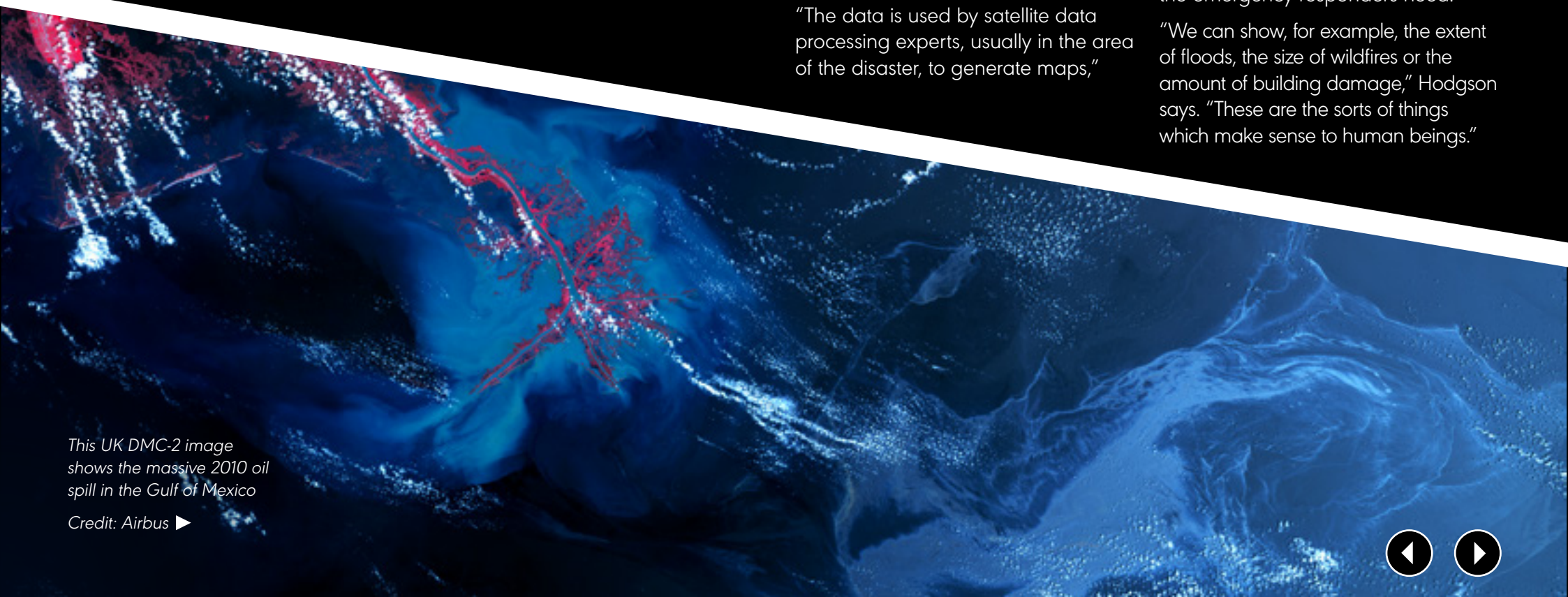
"With all the new satellites, one day we'll get to the situation where they'll be a satellite available anywhere you need it," says Lee.

When Hurricane Irma made landfall on 6 September, the devastation it brought was every bit as bad as expected. With winds in excess of 250 km/h – some of the fastest ever recorded – it tore across Barbuda and Saint Martin, destroying some 95% of buildings. It ripped through Anguilla, damaging almost half the island's structures, and crossed the Leeward, Virgin, Turks and Caicos Islands.

In total, the storm killed at least 44 people and left thousands homeless or without power, food or access to clean water. With rough seas, blocked roads and damaged airstrips, rescuers struggled to reach those affected. But when they did, the satellite data made available by the Charter was employed to maximum effect.

"The data is used by satellite data processing experts, usually in the area of the disaster, to generate maps," says David Hodgson from Airbus, who is responsible for implementing the Charter on behalf of the UK Space Agency. Very often this can mean the involvement of several different agencies on the ground – dealing with public health, environmental protection or resources. "They process the images – which use different optical bands and radar – to provide useful information and the intelligence the emergency responders need."

"We can show, for example, the extent of floods, the size of wildfires or the amount of building damage," Hodgson says. "These are the sorts of things which make sense to human beings."



This UK DMC-2 image shows the massive 2010 oil spill in the Gulf of Mexico

Credit: Airbus ▶

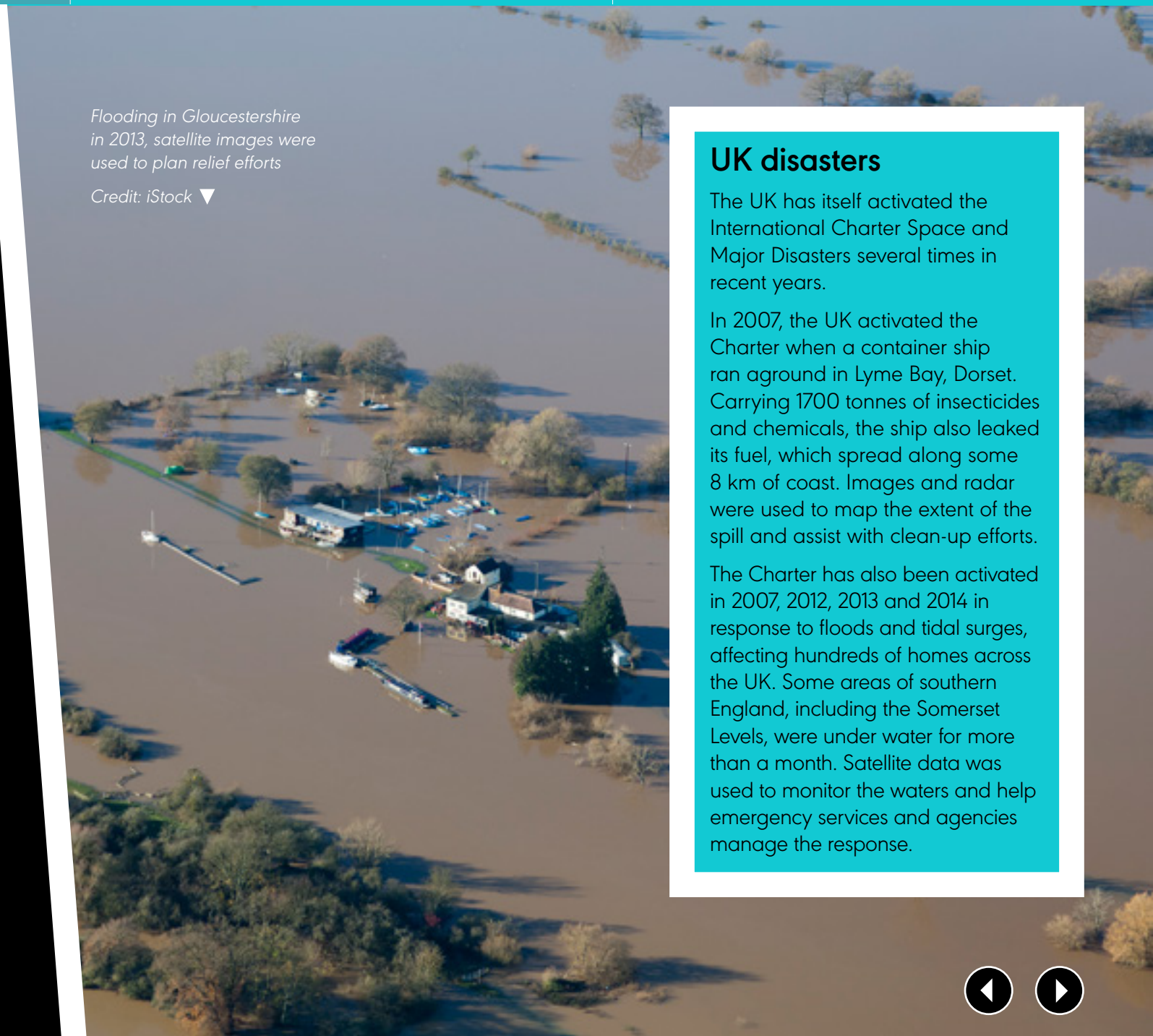
The maps are augmented with additional information that people on the ground might need. This could include data on location, important assets or population – anything relevant to dealing with the disaster.

Products produced in the aftermath of Hurricane Irma included detailed maps of infrastructure and flooding damage across the Caribbean islands. Ultimately, this is about using space technology to directly benefit the victims of tragedy.

"I think it's made a tremendous difference," says Hodgson. "Being able to provide a picture of the disaster as it evolves helps to determine the best way to respond and, in the end, saves lives."

By 10 September, after skirting the edge of Cuba, Hurricane Irma turned north to hit the Florida Keys. For Castro, the storm then took on personal significance. "I have friends in Key West and relatives in Orlando," she says. "It was quite overwhelming - I could see it coming but all you can do is manage the response."

"Fortunately, they're alright," she adds, "but it made it very real."



Flooding in Gloucestershire in 2013, satellite images were used to plan relief efforts

Credit: iStock ▼

UK disasters

The UK has itself activated the International Charter Space and Major Disasters several times in recent years.

In 2007, the UK activated the Charter when a container ship ran aground in Lyme Bay, Dorset. Carrying 1700 tonnes of insecticides and chemicals, the ship also leaked its fuel, which spread along some 8 km of coast. Images and radar were used to map the extent of the spill and assist with clean-up efforts.

The Charter has also been activated in 2007, 2012, 2013 and 2014 in response to floods and tidal surges, affecting hundreds of homes across the UK. Some areas of southern England, including the Somerset Levels, were under water for more than a month. Satellite data was used to monitor the waters and help emergency services and agencies manage the response.

Cleaning-up Space

By Sue Nelson

A chain reaction of colliding space junk could put the Earth's orbiting satellites in danger. An innovative UK-built mission, RemoveDEBRIS, is testing ways to reduce that risk...one piece at a time.

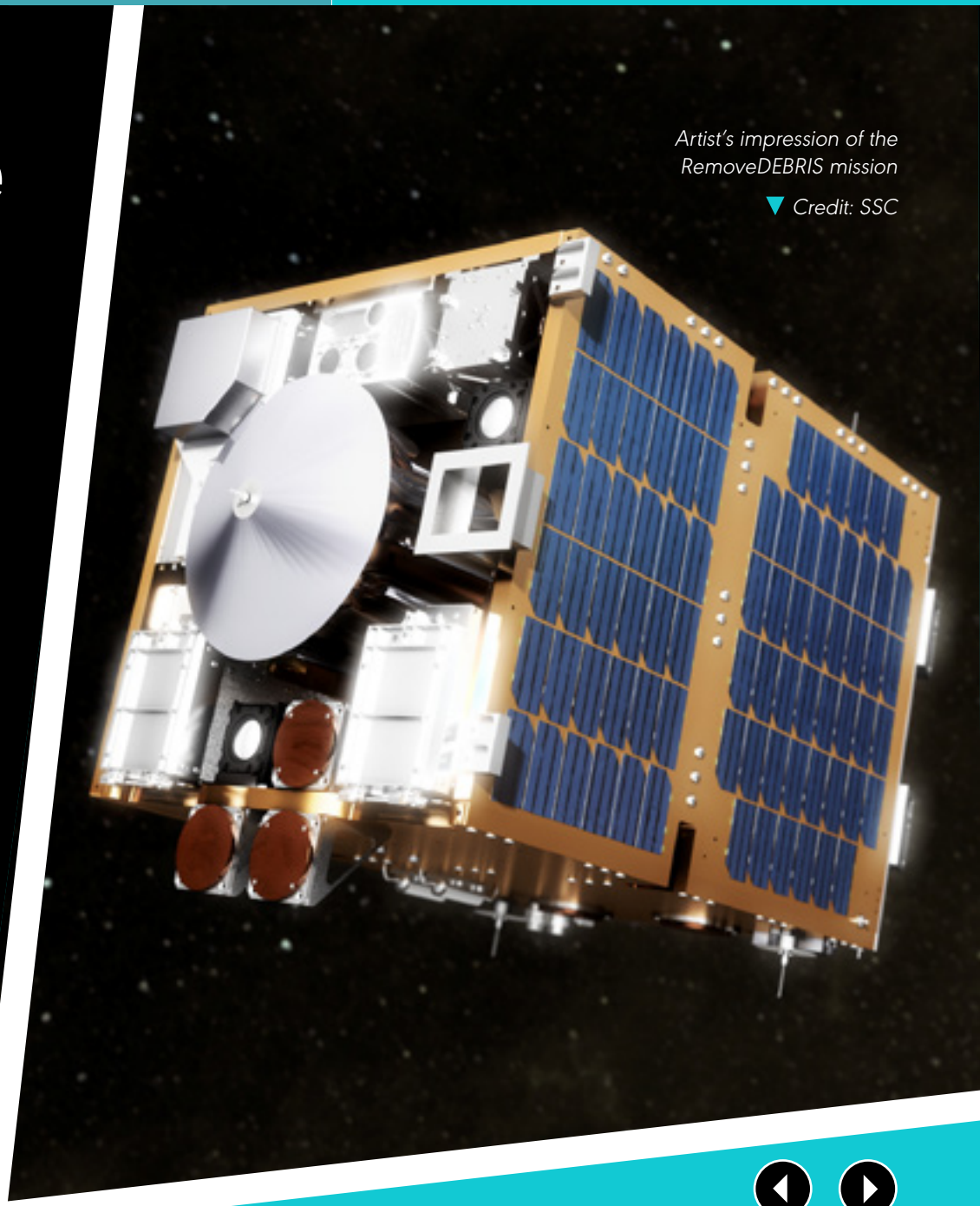
In 2015, when astronaut Scott Kelly tweeted a picture from a film he was watching on the International Space Station (ISS), no-one expected to see a freeze frame from the movie Gravity. Perhaps because it's a disaster film where orbiting debris becomes lethal bullets, travelling up to 28,000 km/h, destroying spacecraft, smashing the ISS and killing astronauts.

In this Hollywood world of space, the debris results from a fictitious Russian missile strike on a defunct satellite. But, in 2007, a similar scenario happened for real when China used a missile for an anti-satellite test. Two years later, the problem was compounded when a spent Russian satellite collided with an American Iridium communications satellite.

Today, there are more than half a million pieces of debris in orbit around the Earth, with around 6,800 tonnes' worth in low Earth orbit. This space junk ranges in size from flecks of paint and an astronaut's glove, to a satellite as big as a double decker bus.

"There is this risk, called the Kessler Syndrome or Kessler Effect, where one piece of debris breaks up and hits another so it becomes a cascade," says Director of the Surrey Space Centre (SSC) at the University of Surrey, Guglielmo Aglietti. "It would make sense to remove some of the largest and most dangerous pieces of debris in orbit."

To address this potentially catastrophic problem for satellites and astronauts, SSC is coordinating the European



Artist's impression of the RemoveDEBRIS mission

▼ *Credit: SSC*

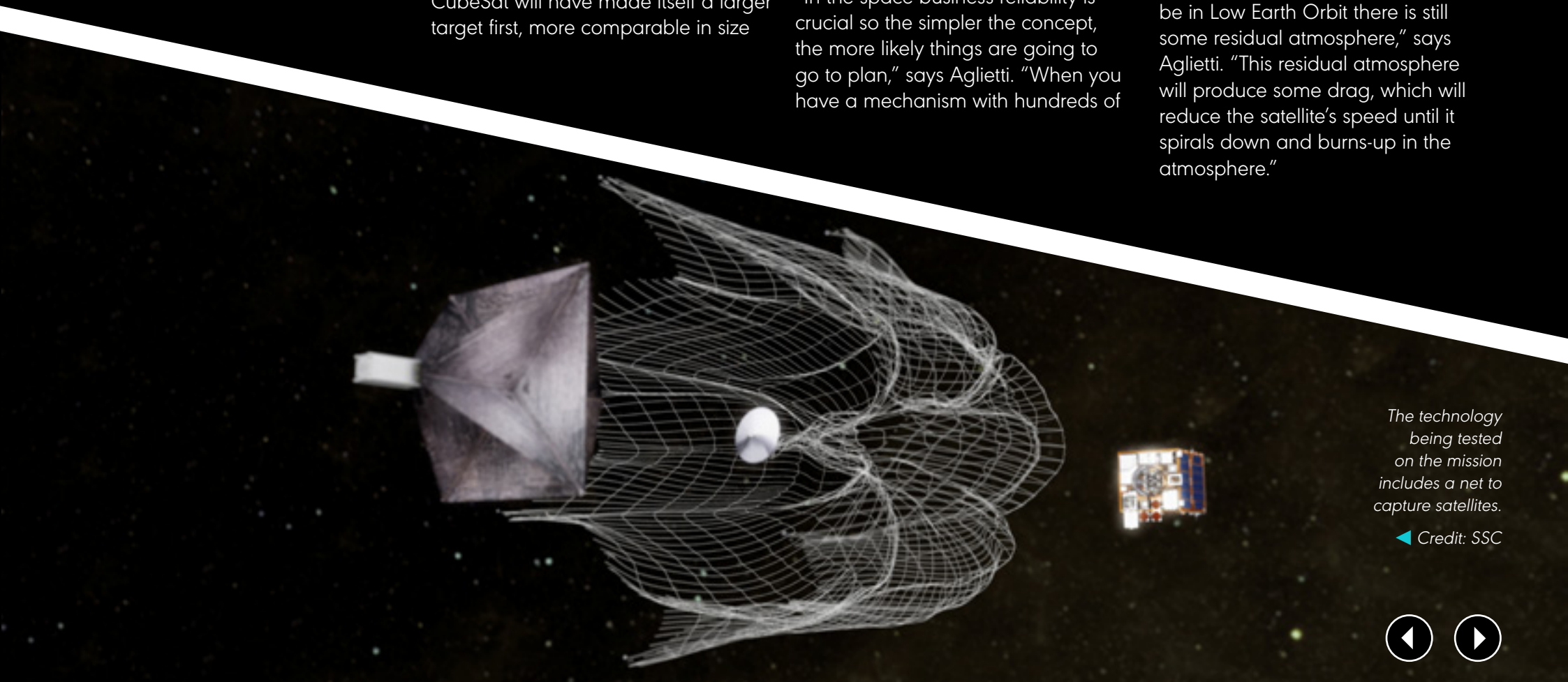
RemoveDEBRIS mission. It consists of a spacecraft, built by Surrey Satellite Technology Limited (SSTL), about as large as a washing machine. This will release two shoebox-sized CubeSat satellites built by SSC.

The mission will test two different capture methods. A pen-sized harpoon, built by Airbus Defence and Space in the UK and assembled at SSC, will be fired at a target on the end of a boom. The other method involves capturing one of the released smaller satellites using a net. This CubeSat will have made itself a larger target first, more comparable in size to a normal satellite, by inflating a diamond shaped sail.

But, considering the technology and engineering required to get this mission into space, doesn't the use of a harpoon and net seem a somewhat primitive way of tackling debris?

"In the space business reliability is crucial so the simpler the concept, the more likely things are going to go to plan," says Aglietti. "When you have a mechanism with hundreds of moving parts, you really increase the probability it won't work as well."

The mission will also use a drag sail as part of the de-orbit procedure, a concept proved on SSC's recent InflateSail mission. "Basically, you deploy a sail which works like a parachute and because we will be in Low Earth Orbit there is still some residual atmosphere," says Aglietti. "This residual atmosphere will produce some drag, which will reduce the satellite's speed until it spirals down and burns-up in the atmosphere."



The technology being tested on the mission includes a net to capture satellites.

◀ *Credit: SSC*

A satellite breaking-up in orbit would have a serious effect

Credit: ESA ▲

Uniquely for a UK-built satellite, RemoveDEBRIS will be launched from the ISS. It will be carried there in a SpaceX Dragon supply ship, due for launch on a Falcon 9 in early 2018. The mission will then be deployed by an astronaut using a robotic arm from the station's Japanese Experimental Module.

"It's great to be the first spacecraft to go up on a Falcon 9 for the UK," says Martin Pointer from SSTL. "Also, we've never deployed two small CubeSats from a spacecraft before."

"We consider the fact that they're planning to go off the ISS, to be very responsible," says Richard Crowther from the UK Space Agency. The Agency has to issue a licence for the mission before it can launch into orbit and detach from the Space Station.

"They're going to be performing all of their testing manoeuvres below the altitude of the ISS," says Crowther. "If at this low level it doesn't work there are limits to the consequences."

"When you're confident and you've got some maturity and confidence in the technologies and techniques," he explains, "you can go up to higher altitudes where the real targets are, and bring those back into the atmosphere."

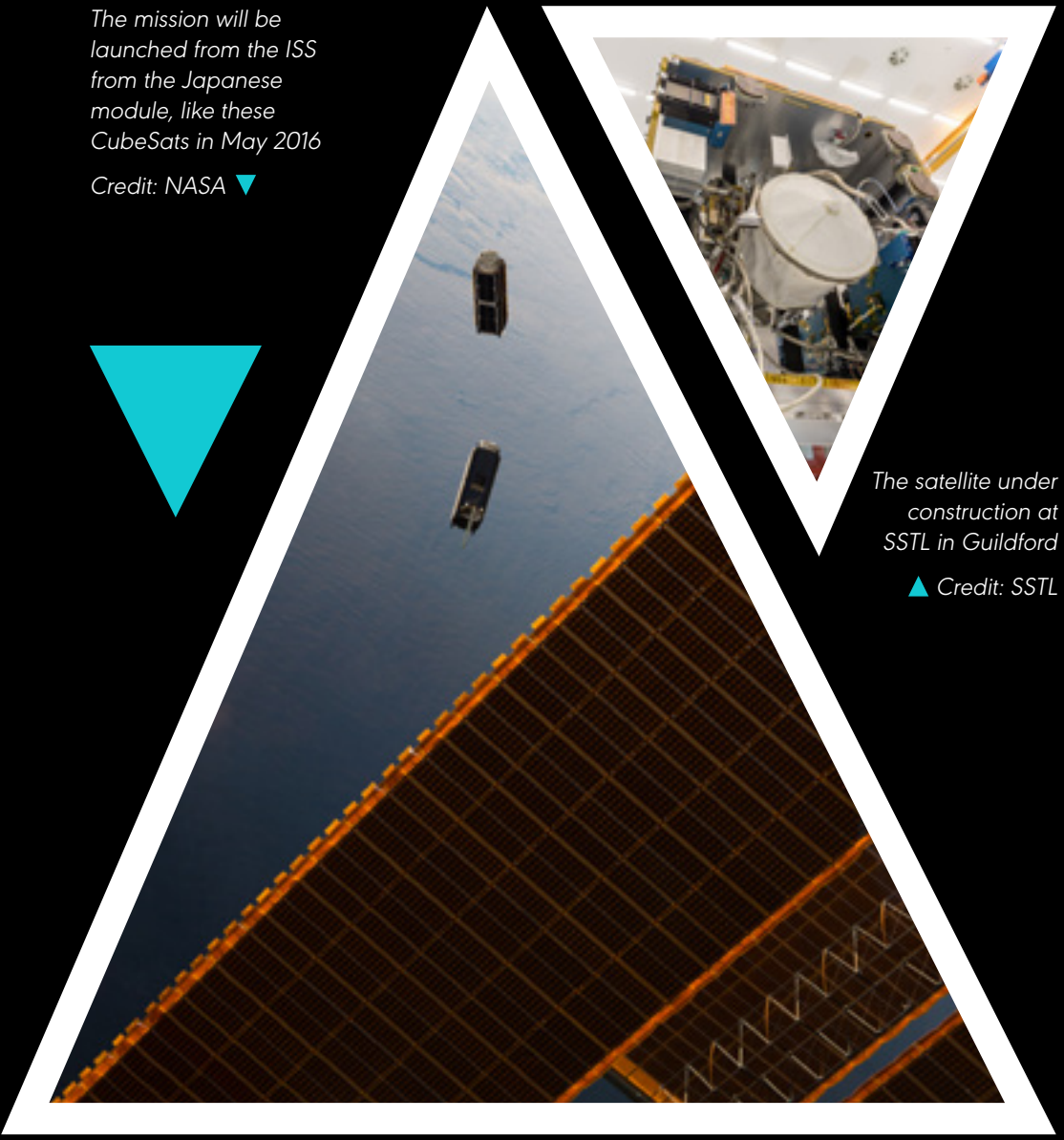
Crowther also believes the simplicity of the techniques is a distinct advantage: "The problem is that most of these debris objects were never designed for retrieval – they don't have anything on board which allows them to be easily grappled and they're no longer under control."

"The benefit of these systems that use tethers, is that you don't physically, mechanically grab and link to the object," he says. "If you grab something and it's tumbling there's a good chance you're going to tumble as well, so it's a good way of de-coupling some of the dynamics between the chaser spacecraft and the target spacecraft."

Originally it was thought that the growth of space debris could be managed by mitigation measures, such as providing enough fuel for a satellite to return and burn up in the atmosphere at the end of its working life, or by placing it in a higher

The mission will be launched from the ISS from the Japanese module, like these CubeSats in May 2016

Credit: NASA



The satellite under construction at SSTL in Guildford

Credit: SSTL

altitude "graveyard" orbit. But China's destruction of a satellite and the US-Russian collision changed that.

"Those two incidents made us realise we couldn't just rely on mitigation, because they increased the number of objects in parts of low Earth orbit by up to 30%," says Crowther.

If new satellites are operated responsibly and the risk of potential collisions monitored, the debris risk does not necessarily need to increase. However, future Low Earth Orbit constellations of communications satellites will add to the burden on space surveillance and tracking systems in an already busy space environment.

"In future, we need to make it easier to retrieve satellites that might fail in orbit," says Crowther. "The UK has a good track record - my team at the Royal Aerospace Establishment led the way with modelling in the early days, developing software risk tools since adopted by ESA."

"Subsequently," he adds, "those people have gone out into senior posts within industry and agencies and are strong advocates for confronting the space debris issue."

"I think it's really exciting," says Pointer. "It pushes people into thinking of innovative ideas and putting them into application to try them out. There aren't many people who are doing that in the world."

"As a mission, it's something that's needed," says Crowther. "Each uncontrolled object in orbit is potentially a reservoir of fragments just waiting to be released – we need to address the root cause."

"There's a belief by both NASA and ESA," says Pointer, "that if you remove 10 large orbital debris objects per year, you can start to stabilise and try to prevent the Kessler Effect."

Imagining the consequences of the Kessler Effect resulted in a blockbuster film. So, since Pointer, Crowther and Aglietti are all involved in a real mission concerning space debris, what did they think of Gravity?

Surprisingly, not one of them has seen it. "But," says Aglietti, "it's on my to-do list."

Meet the CEO

Dr Graham Turnock was appointed as the new Chief Executive of the UK Space Agency earlier this year.

A space enthusiast since childhood, he will be overseeing the UK's involvement in missions to Mercury and Jupiter, the launch of Hubble's replacement – the James Webb Space Telescope (JWST) – and new satellite services for Earth observation, navigation and communications. He will also be facing the challenges of developing the UK's launch capabilities and growing the UK space sector...while navigating Brexit.

Space UK caught up with Turnock to ask how he saw the role of the Agency over the coming years.

Most of your career has been in the Civil Service, what's your background?

If you scrape all the layers of paint and rust off me, you come back to a scientist. I studied physics and have a Phd in particle physics from Cambridge. In the end, I decided I'd like to do something different. I applied to the Civil Service and eventually took-up a senior role in the Department of Business, leading on regulatory policy.

Have you always been interested in space?

As a kid, I was a space nut. I was a member of my local astronomical society and I was massively switched onto things like the Space Shuttle. I even wrote a book about a space detective called Mr Satellite. Space was my passion as a teenager but the lure of the experiments at CERN drew me into particle physics.

How far do you feel the UK has come in space over the last few years?

When I was starting my degree in the 1980s, there was little significant talk about the UK being involved in major space programmes. Since then there've been great strides forwards and it's fantastic to see that.

How do you see the role of the UK Space Agency?

It's a very exciting role. The fact that we have responsibilities as a delivery organisation and also a policy unit advising ministers and working with other agencies at an international level, makes it even more interesting. When the Agency was formed, the aim was to bring all the areas of space into one organisation. This enables us to make better links

This recent Hubble image shows two galaxies colliding

Credit: ESA, NASA ▶

between policy and delivery than you often see. It's a very exciting job from that point of view.

What are your priorities for the UK in space?

The Agency has both a growth objective and science objective. We're aiming to capture 10% of the global space market by 2030. Added to that we've got to navigate our way through Brexit – seizing the opportunities and managing the risk. So, for me, it's about accelerating the development of the UK space sector.

How will you achieve that 10% in just 12 years, particularly as there are major new space powers emerging such as China and India?

You can see those nations as a threat or an opportunity. The presence of those countries should be a positive driver of demand for space services and useful partners for us in supporting trade. We are at 6.5% already, which I think is very good, so we've come a long way. In our strategy, we've identified increasing services from space as the best way to grow the sector.

How does the UK's plans for its own launch capability fit into the growth plan?

Launch has a draw-factor. If you can provide, within the UK, all the infrastructure to take you from design to launch to orbit, then you've created a very exciting sector for investment. And small satellite launch itself is a developing market, which could be worth several billion to the UK space economy. It's also a very visible project that gets attention and interest.

You mentioned Brexit, how concerned should the space sector be?

The Government has been clear in its position papers that we would welcome an agreement to continue to collaborate with the European Union on space programmes. All the options for achieving that need to be discussed as part of the negotiations.

I'm optimistic that our European partners see the benefit of our participation in those programmes, from both a scientific and industrial point of view.

Columbia blasts off for the first Space Shuttle mission in 1981

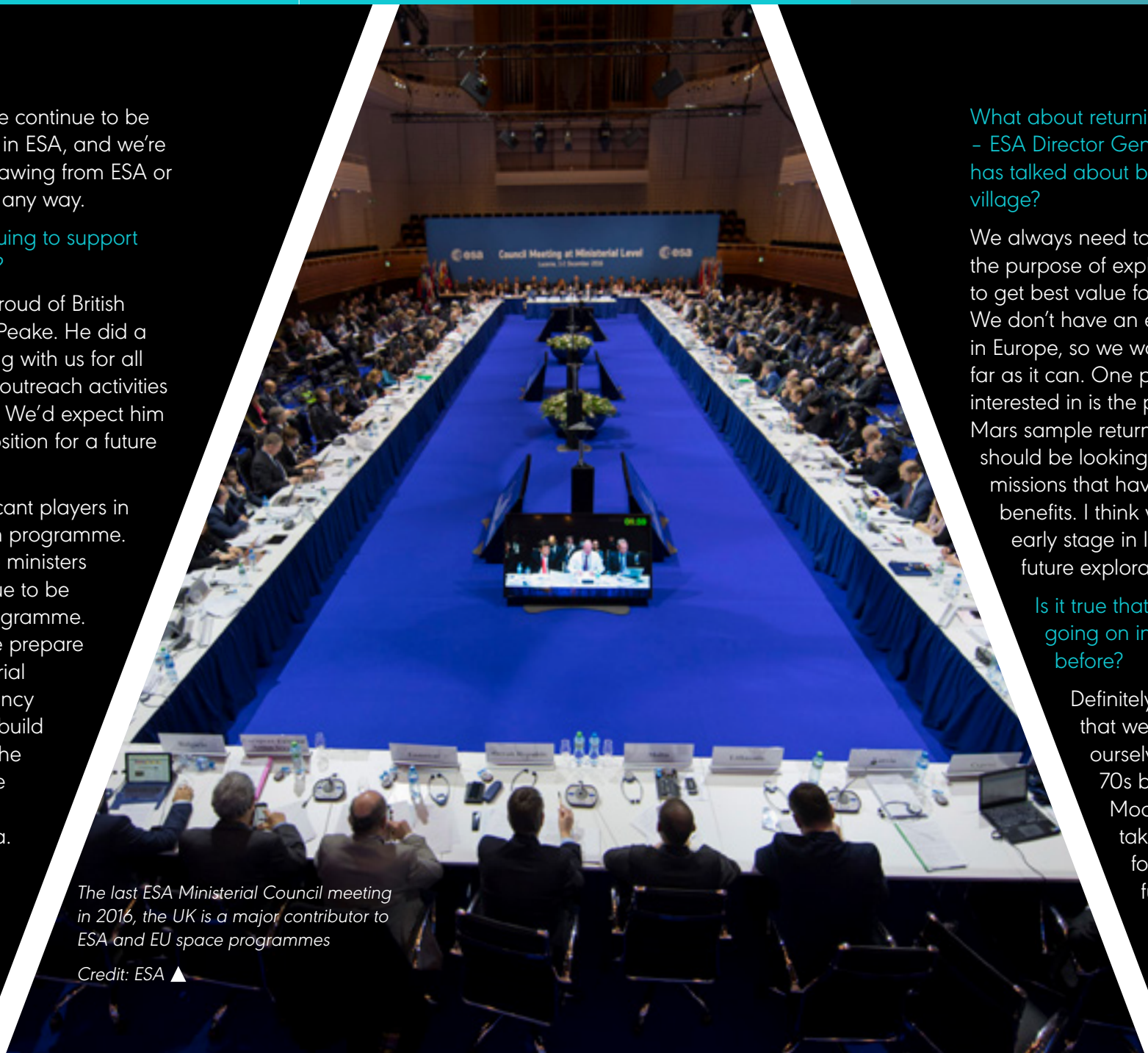
▼ *Credit: NASA*

I'd also add that we continue to be very strong players in ESA, and we're certainly not withdrawing from ESA or European space in any way.

What about continuing to support human spaceflight?

We're immensely proud of British ESA astronaut Tim Peake. He did a fantastic job working with us for all the education and outreach activities around his mission. We'd expect him to be in a prime position for a future mission.

We are now significant players in the ESA exploration programme. Obviously, it's up to ministers whether we continue to be involved in that programme. But I think when we prepare for the next Ministerial Council, at the Agency we'll be looking to build the arguments for the Treasury for why we should continue funding in that area.



The last ESA Ministerial Council meeting in 2016, the UK is a major contributor to ESA and EU space programmes

Credit: ESA

What about returning to the Moon – ESA Director General, Jan Werner, has talked about building a Moon village?

We always need to focus in on what the purpose of exploration is and try to get best value for our investment. We don't have an enormous budget in Europe, so we want it to go as far as it can. One project we're very interested in is the potential for a Mars sample return mission. What we should be looking for are exploration missions that have clear scientific benefits. I think we're still at an early stage in looking at what future exploration priorities are.

Is it true that there's more going on in space than ever before?

Definitely. You could argue that we got ahead of ourselves in the 60s and 70s by getting to the Moon so quickly. It's taken 30-40 years for the technology, funding and ambition to catch-up again but

now we're talking about missions that are, arguably, more exciting than the Moon landings.

In the next few years we've got the Bepi-Colombo mission to Mercury and the JWST - both have a lot of UK involvement. Then we've got the next phase of ESA missions to look forward to, with missions to Jupiter and a future mission to investigate gravitational waves.

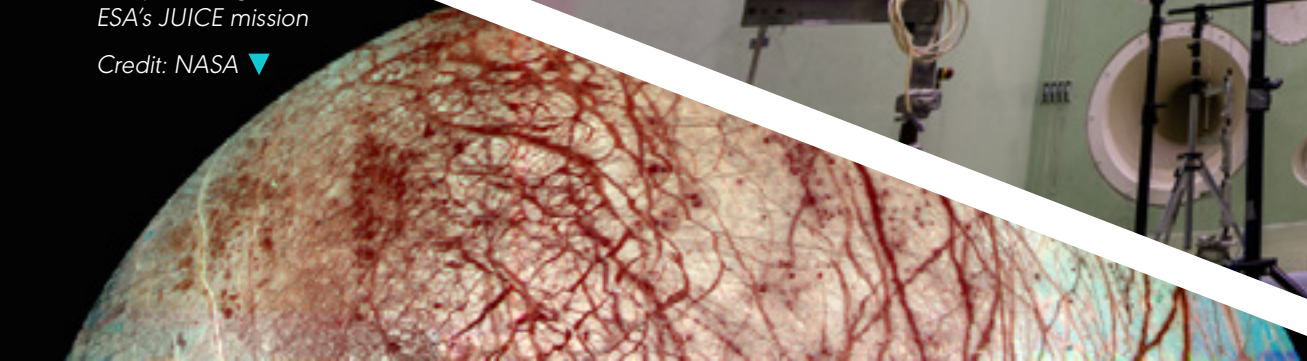
On the commercial side, we've got new Sentinel missions and satellite constellations such as OneWeb. The UK is also developing the SABRE propulsion system. Since the Apollo missions I don't think there's ever been such an exciting time in space – and certainly not in the UK.

Would you ever want to go into space?

I'd pack my bags and go tomorrow! To do anything useful in space though, you have to have a vast amount of training and that ship has probably sailed for me. While I'd love to be a space tourist, I don't earn the sort of money that you need!

The Bepi-Colombo spacecraft during recent testing

Credit: ESA ▶



Jupiter's moon Europa, a target for ESA's JUICE mission

Credit: NASA ▼

Education Resources

Seven new projects are to receive funding from the UK Space Agency for education and outreach activities. Chosen following a recent selection process, they are focussed around the UK's involvement in Earth observation, the James Webb Space Telescope (JWST) and the new satellite launch programme.

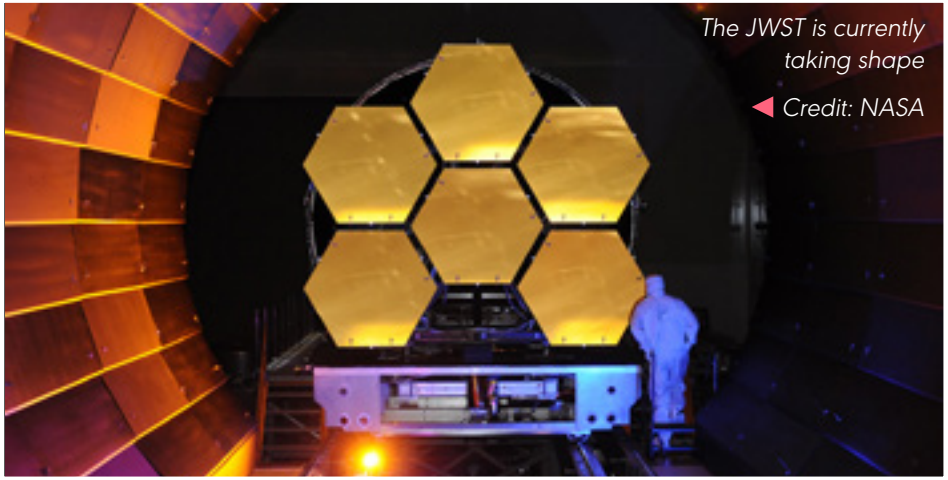
The Institute for Research in Schools' MELT (Monitoring the Environment, Learning for Tomorrow) project is inspired by a collaboration with Robert Swan's latest *Antarctic expedition*. During his South Pole Energy Challenge, Swan and his son, Barney will ski 600 miles to the Pole surviving solely on renewable energy, a first in polar-exploration.

"I'm delighted to be working on the MELT project," says Swan. "Students looking at Earth observation of the poles will be directly observing our South Pole Energy Challenge and seeing what a crucial role the [polar regions] have in understanding and taking care of their environment."

The Triathlon Trust will be building on its recent successful *Space to Earth* challenge for Tim Peake's mission to the International Space Station. The project will help inspire pupils to collectively travel the distance from Earth to a satellite using the sport of duathlon (run-bike-run).

The Design and Technology Association has taken on the challenge of designing three new resources aimed at young people aged 11 to 16. "These innovative resources will inspire young people to imagine new possibilities, drawing on their existing STEM knowledge, and applying it to real-life space contexts," says Emma Watson from the Association.

Space zones' *I'm a Scientist and I'm an Engineer* will be creating three online zones of STEM outreach events. School students will be able to send questions to STEM professionals involved in space science and engineering, and have live text-based chats.



The JWST is currently taking shape

◀ *Credit: NASA*

The European Space Education Resource Office-UK (ESERO-UK) is focussing on a JWST Design Challenge, which aims to engage young people in the engineering challenges associated with building the giant space telescope.

The UK's satellite launch programme has inspired *Children's Radio UK (Fun Kids)* to create a series of short audio and animated programmes introducing children to plans to develop commercial spaceflight, spaceports and launchers.

Glasgow Science Festival's Get Me into Orbit! will enable students to follow the journey of a satellite, from its production to launch, through monthly videos, classroom experiments and Q&A sessions. Along the way, students will pitch questions to real engineers, to gain an insight into research and space careers.

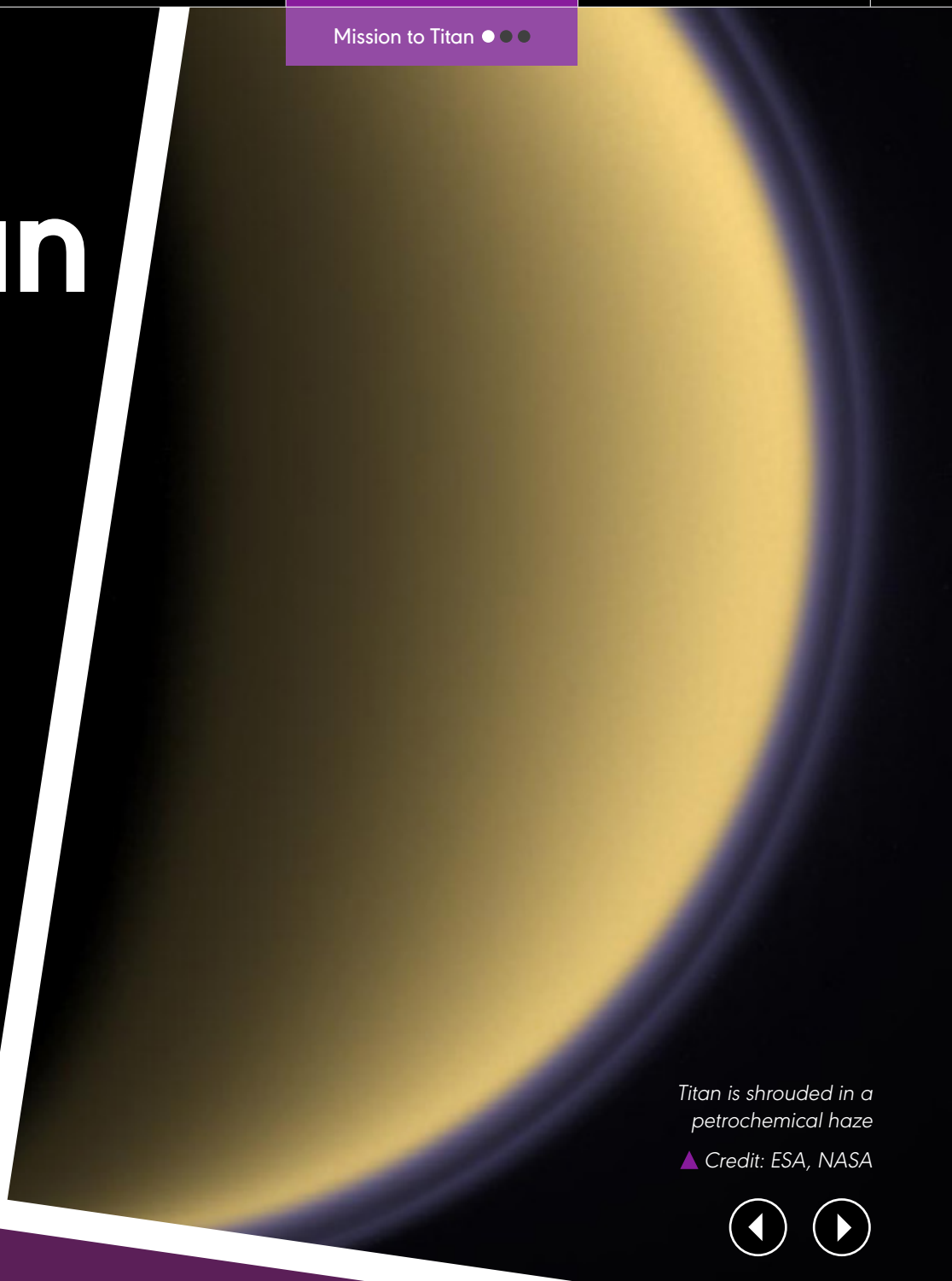
Mission to Titan

The final demise of the Cassini spacecraft in Saturn's atmosphere in September ended a successful 20-year mission and made news around the world. The UK played a key role in many aspects of the mission, including the dramatic 2005 landing of ESA's Huygens probe on Titan.

On Christmas Day, 2004, after a seven-year journey and during its third orbit around Saturn, the Cassini spacecraft released its probe. Huygens had a 20-day voyage towards Titan until it descended through the moon's atmosphere on 14 January 2005, using a series of three parachutes.

The first part of the probe to touch the surface of Saturn's largest moon was made in the UK. "It was the penetrometer," says John Zarnecki, principal investigator of the Surface Science Package (SSP) and co-investigator of Huygens' Atmospheric Structure Instrument, two of the six instruments on board the probe.

"It's like a finger, an instrumented finger, that measures the force of impact and penetration and from that you can say something about the physical nature of what you're putting it into," says Zarnecki. "It's the sort of device used by the food industry – you put an instrument like that into your sponge cake or crème brûlée to test that the texture is right."



Titan is shrouded in a petrochemical haze

▲ *Credit: ESA, NASA*

Like many space missions, Huygens was an international effort by NASA, ESA and the Italian Space Agency. The SSP was built at the University of Kent, with European and US partners, but its data was analysed at the Open University in Milton Keynes, where Zarnecki and his team moved three years after Cassini's launch.

Contracted by ESA as an atmospheric probe, Huygens is usually referred to as a lander by the media. Does Zarnecki mind? "Back then if I had the temerity to call it a lander I got into big trouble," he says. "Now of course it doesn't matter. It's semantics now. So yeah," he laughs, "let's call it a lander, I'm okay with that now."

The two-and-a-half-hour descent through the orange haze of Titan's atmosphere was an extraordinary one. Saturn's moon has weather, clouds and precipitation while the nitrogen-rich atmosphere contains methane and other organic compounds.

On the moon's surface, Huygens encountered solid, but soft, ground, causing it to gradually settle by a few millimetres. The texture of the landing site has been compared to wet clay, sand or lightly packed snow.

Though Huygens was designed to survive for a maximum of three minutes, the probe exceeded all expectations and transmitted much more data than expected. "We never dared to dream that it would survive for 72 minutes on the surface," says Zarnecki, "otherwise we'd have added lots of bells and whistles!"

The probe's fixed camera, staring in one direction, sent back images of sandy dunes and icy rocks. "Titan has lakes, seas and liquid methane on the surface, that's stunning isn't it?" he says. "It's the only other place in the Solar System where there are big seas and lakes."

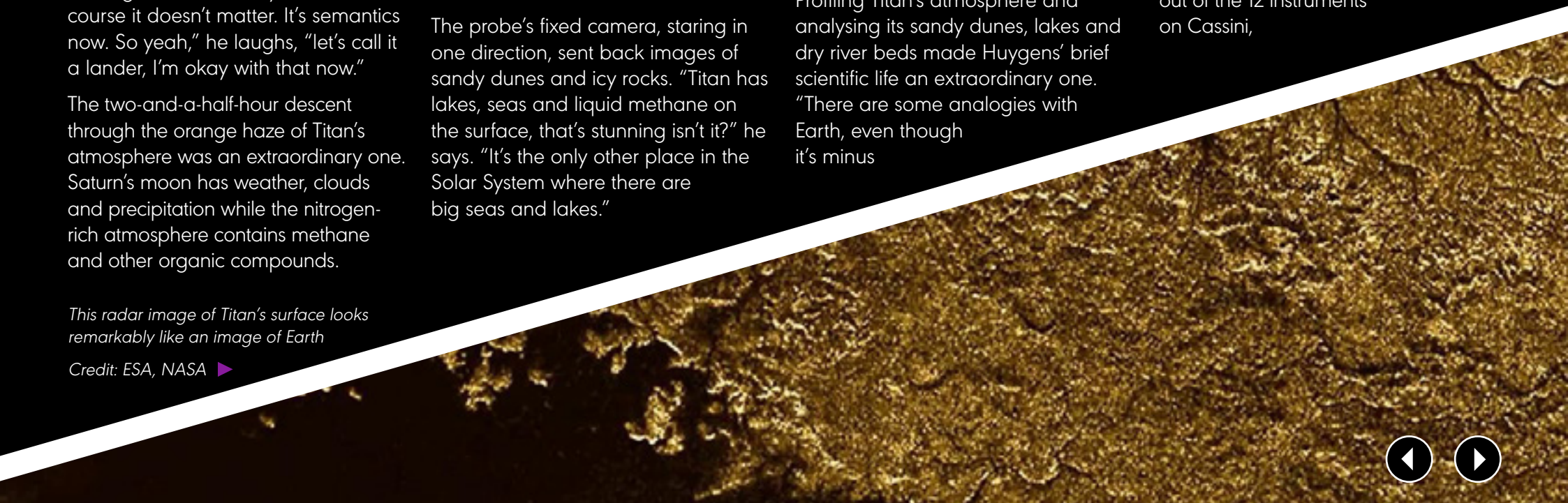
More recently, during Cassini's 'grand finale', new images of Titan have been released during flybys, giving the moon a new audience on social media. When Huygens landed in early 2005, the likes of Twitter, Instagram and YouTube didn't exist and Facebook was yet to be expanded from university campuses.

"It was pre-social media days so it perhaps didn't make the splash it would have today, as with Rosetta for example," says Zarnecki. "But it gradually sinks into the consciousness."

Profiling Titan's atmosphere and analysing its sandy dunes, lakes and dry river beds made Huygens' brief scientific life an extraordinary one. "There are some analogies with Earth, even though it's minus 180 degrees C. Everything's at such a low temperature so everything works much more slowly, but the processes are remarkably similar," says Zarnecki. "It's just lacking grass and cows."

More than ten years after landing, scientific papers are still being published on Huygens' data. And data from Cassini is likely to produce research for, by Zarnecki's reckoning, at least another twenty years.

The recent spotlight on the mission has also highlighted the significant input from UK academia and industry. Six out of the 12 instruments on Cassini,



This radar image of Titan's surface looks remarkably like an image of Earth

Credit: ESA, NASA

and two out of the six instruments on Huygens, involved UK science or engineering teams. Martin Baker Space Systems and Irvin GQ made Huygens' parachutes while LogicaCMG supplied the on-board software.

"There were people here doing all the cool technological stuff," says Zarnecki. "Hopefully, they were aware of scientists like us doing the scientific work."

Zarnecki, who has now retired from the Open University and is currently President of the Royal Astronomical Society, counts the Huygens mission – along with his work as project manager of the comet-mission Giotto's dust instrument – as one of the highlights of his career.

He recalls ESA's former head of science and robotic exploration, David Southwood discussing the mission at a recent astronomy conference. "He called Huygens the most distant standing human artefact and I thought, bloody hell he's right!" says Zarnecki. "We are the most distant and we will remain so for a hell of a long time."

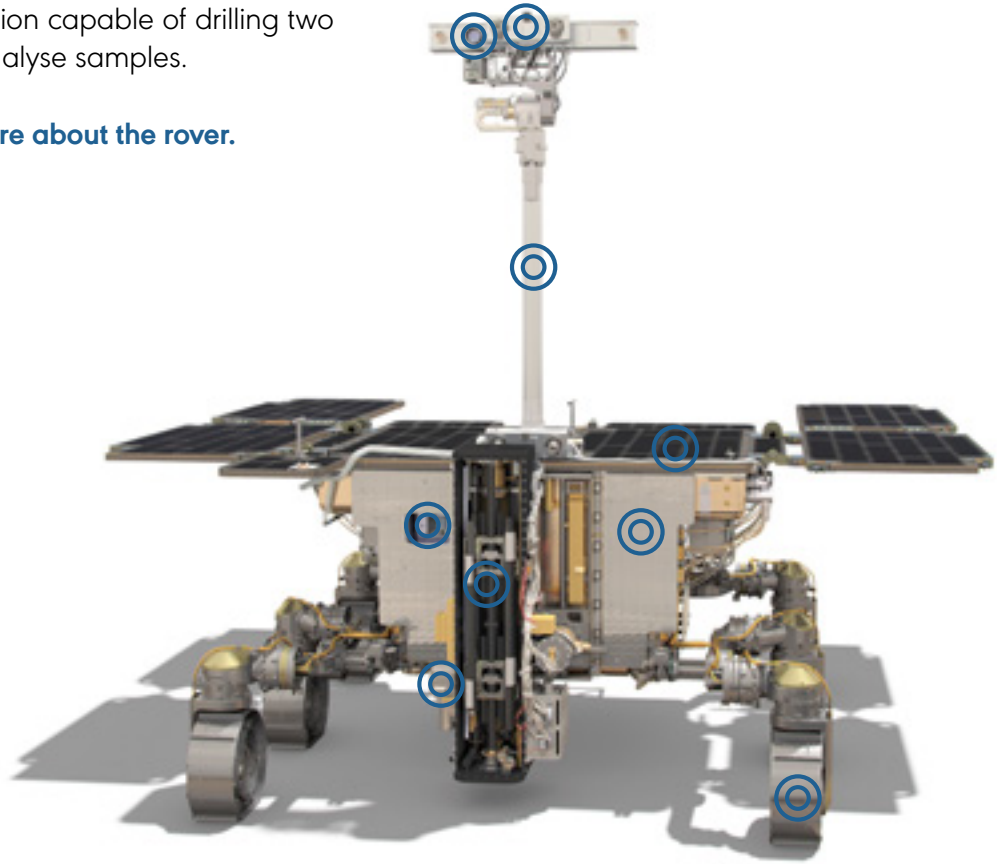
Artist's impression of Huygens on the surface of Titan

▼ *Credit: ESA*

Made in the UK: 2020 ExoMars Rover

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

Click or tap the highlighted areas to find out more about the rover.



Original image credit: ESA ▶

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