AERO SPACE

www.aerosociety.com

May 2021

UK SPACEPORTS

Q&A WITH SPACE COMMAND CHIEF

THE SPACE SKILLS GAP

The UK Space special issue

THE GREAT BRITISH LIFT-OFF

PUTTING THE UK ON THE GLOBAL SPACEFLIGHT MAP

ROYAL AERONAUTICAL SOCIETY

ROYAL AERONAUTICAL SOCIETY

RAeS President's Conference: UK in the 2020s - An Emerging Space Power

19 - 20 May 2021 I Virtual

Join us for this exciting conference which will focus on current and evolving market trends in the global space sector, how these will shape the international business ecosystem in the 2020's, and in what areas the UK can take commercial leadership.

Keynote Speakers

Amanda Solloway MP, Minister for Science, Research and Innovation
Will Whitehorn, President, UKspace
Her Excellency Sarah Al Amiri, Chair of the UAE Space Agency
Air Vice-Marshal Harv Smyth, Director Space, UK MOD
Graham Turnock, Chief Executive Officer, UK Space Agency

Tickets

RAeS Member: £70+VAT
Non Member: £110+VAT
RAeS Corporate Partner: £90+VAT
RAeS Student/Apprentice Affiliate Member: £20+VAT
Student/Apprentice: £25+VAT

LEAD SPONSOR

TELESPAZIO
a LEONARDO and THALES company

SPONSORS

AIRBUS

Aviation Logistics Network

ROLLS ROYCE

Find out more and book your place www.aerosociety.com/presconfspace

AERO SPACE

Volume 48 Number 5
May 2021

EDITORIAL

UK reaches for the stars

It would not be surprising to learn that the late Duke of Edinburgh, the Society's Hon President in 1966, with his keen interest in engineering and as a holder of a helicopter pilot licence, would have found the first flight of a small helicopter on Mars last month fascinating – and it is sad to note in his passing he just missed this historic 'Wright Brothers' achievement by NASA. Nearer to Earth, only 20 years ago the idea of a UK rocket launching a UK payload from UK soil was something that usually ended up in the 'and finally' oddity slot in TV news, inviting people to laugh at crackpot garage inventors aiming to compete with NASA. Today, it is no laughing matter and, as this special 'UK space' issue, ahead of the RAeS President's Conference on 'UK in the 2020s, an emerging space power' later this month, there are multiple spaceports and launch companies attempting to do just that – returning Britain into the club of space-launching nations that it left almost 50 years ago in October 1971. Today, the barriers to entry of developing, building and operating space assets have fallen considerably, opening up new opportunities and at the same time new challenges. However, as exciting as rocket launches and spaceports may be, this edition of *AEROSPACE* shows that they are only a part of the UK's fast growing and dynamic space ecosystem that encompasses everything from space debris removal to a key role in another landmark Mars mission – that of sample return. Meanwhile in military space, the formation of UK's Space Command (p 30) presages a more muscular approach to orbital matters. Yet, while the hardware is important, it may be that the UK's biggest contribution to maintaining peace in space may be in its diplomatic 'soft power' and influence as a key coalition partner and ally in setting and highlighting international norms for this common resource, on which so much of modern society depends.

Tim Robinson FRAeS, Editor-in-Chief
tim.robinson@aerosociety.com @RAeSTimR

Correspondence on all aerospace matters is welcome at: publications@aerosociety.com

Editor-in-Chief
Tim Robinson, FRAeS
+44 (0)20 7670 4353
tim.robinson@aerosociety.com

Deputy Editor
Bill Read, FRAeS
+44 (0)20 7670 4351
bill.read@aerosociety.com

Production Manager
Wayne J Davis, FRAeS
+44 (0)20 7670 4354
wayne.davis@aerosociety.com

Publications Executive
Chris Male, MRAeS
+44 (0)20 7670 4352
chris.male@aerosociety.com

Production Executive
Annabel Hallam
+44 (0)20 7670 4361
annabel.hallam@aerosociety.com

Book Review Editors
Tony Pilmer and Katrina Sudell
book.reviews@aerosociety.com

Original artwork
©Wayne J Davis/RAeS

Editorial Office
Royal Aeronautical Society
No.4 Hamilton Place
London W1J 7BQ, UK
+44 (0)20 7670 4300
publications@aerosociety.com

www.aerosociety.com

AEROSPACE is published by the Royal Aeronautical Society (RAeS).

Chief Executive
Sir Brian Burridge CBE FRAeS

Advertising
+44 (0)20 7670 4346
partners@aerosociety.com

Printed by Buxton Press Limited, Palace Road, Buxton, Derbyshire SK17 6AE, UK

Distributed by Royal Mail

2021 *AEROSPACE* subscription rates: Non-members, £190

To place your order, contact:
Wayne J Davis
+44 (0)20 7670 4354
aerosubs@aerosociety.com

Any member not requiring a print version of this magazine should contact: membership@aerosociety.com

USA: Periodical postage paid at Champlain New York and additional offices.

Postmaster: Send address changes to IMS of New York, PO Box 1518, Champlain NY 12919-1518, USA.

ISSN 2052-451X

AERO SPACE Online

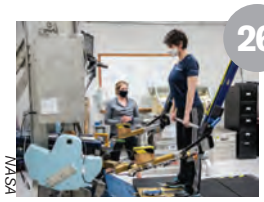
Additional content is available to view online at: aerosociety.com/aerospaceinsight
Including: UK spaceports, Business passengers return to the air, Risk management of mental health in civil aviation, Airline pilot training, New Member Spotlight, Implications of the UK defence and security review, AI and the future of air combat, An analysis of the Celera 500L aircraft design.

Contents

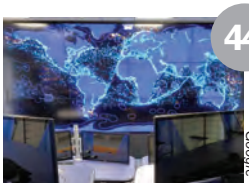
Regulars

Features

Lockheed Martin



NASA



Google

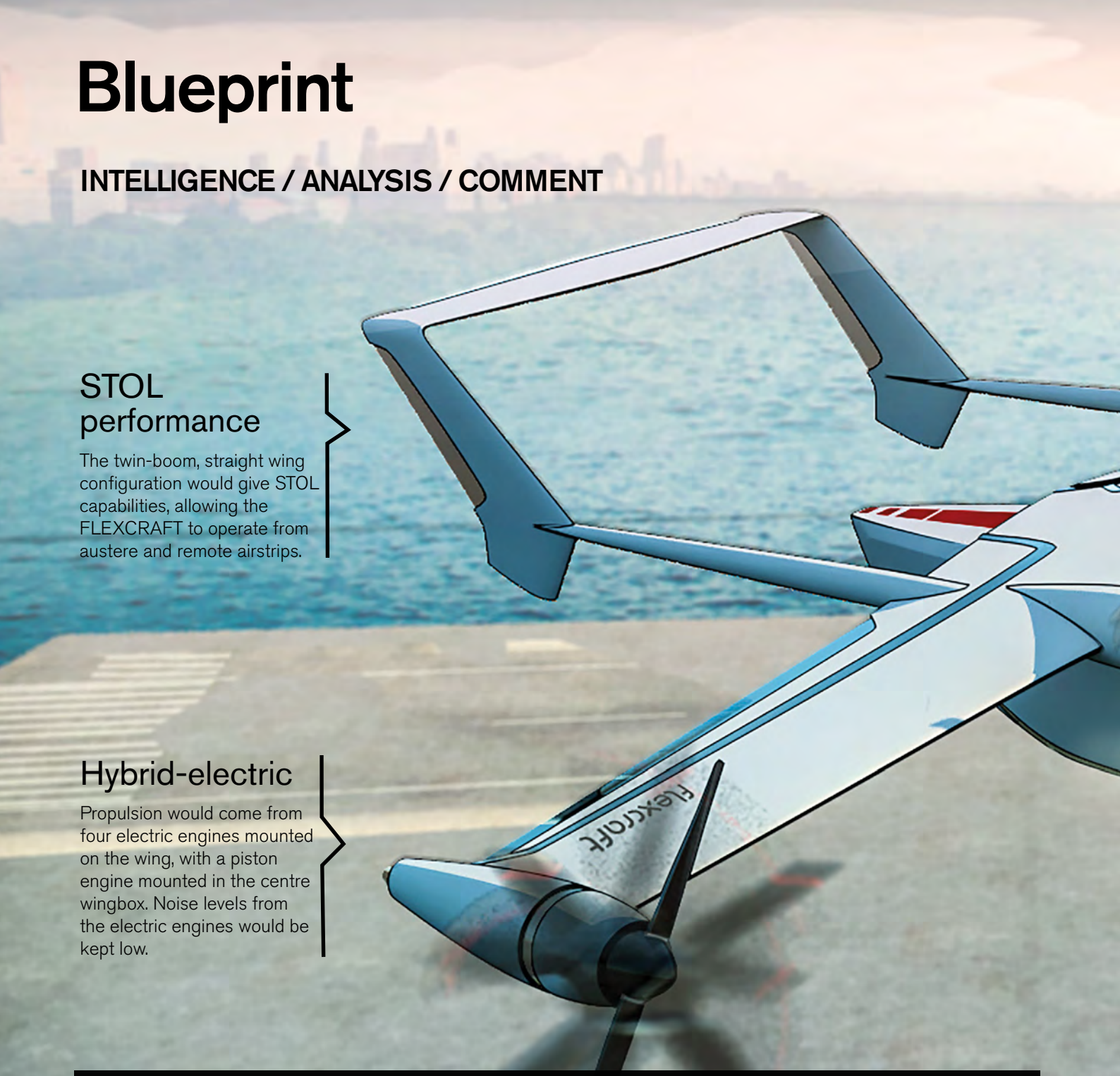
Afterburner

AERO SPACE APP

Read *AEROSPACE* and the insight blog on your smartphone or tablet with the *AEROSPACE* app. available from iTunes and Google Play

Blueprint

INTELLIGENCE / ANALYSIS / COMMENT



STOL performance

The twin-boom, straight wing configuration would give STOL capabilities, allowing the FLEXCRAFT to operate from austere and remote airstrips.

Hybrid-electric

Propulsion would come from four electric engines mounted on the wing, with a piston engine mounted in the centre wingbox. Noise levels from the electric engines would be kept low.

Embraer

GENERAL AVIATION

FLEXCRAFT wins award

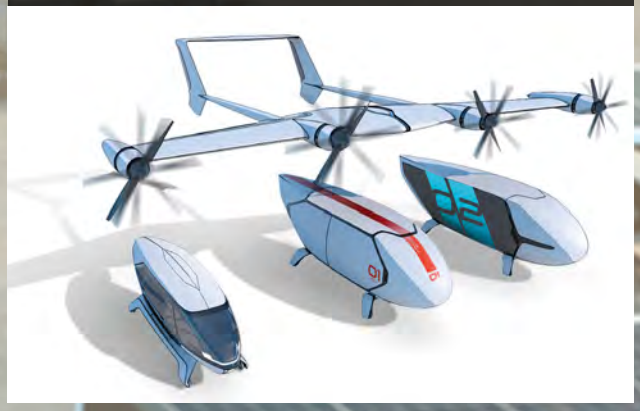
STOL modular aircraft concept FLEXCRAFT, the product of an Embraer ccollaboration, has received an International Design Award in the Transport Design Category. The concept is the brainchild of a Portuguese consortium led by Sociedade de Engenharia e Transformação, that brought together Embraer Portugal, Instituto Superior Técnico (IST), Almadesign, Instituto de Ciência e Inovação em Engenharia Mecânica e Engenharia Industrial (INEGI), plus support from Embraer Brazil.

Specifications

Cruise speed	400kph
Range	400km
Wingspan	13-15m
MTOW	3.5tonne
Payload	1tonne

Modular pods

FLEXCRAFT would see multi-mission pods for VIP, passenger, cargo or air ambulance missions which could be quickly swapped around for maximum versatility. The integrated wing would be able to fly separately.



Remotely piloted

The FLEXCRAFT would be remotely piloted and able to take on a variety of missions, including passenger and cargo, civil protection, surveillance, medevac and agriculture.

COVID-19

AIR TRANSPORT

Airlines plan return of superjumbos

Qantas

In growing signs of optimism, UK flag carrier British Airways has said that its grounded Airbus A380 fleet will return to service. Meanwhile, Australian flag carrier Qantas has announced that it plans to return all 12 of its currently grounded A380s to service by 2024, joining four other carriers, as well as BA, in putting the aircraft back into revenue service.

AEROSPACE

UK reveals global travel taskforce roadmap

The UK government has released details of its Global Travel Taskforce roadmap, which lays out recommendations for a return to international air travel from 17 May. The recommendations include a 'traffic light' system based on risk of infection, alongside the restrictions and additional measures. Travellers from 'green' countries will not need to quarantine but will need to take two Covid tests on departure and arrival. However, the plan drew criticism from the UK aviation and travel sector, which slammed it for its cautious approach to reopening. Budget carrier Jet2 went further and extended the grounding of its fleet until 23 June due to a 'lack of clarity and detail' in the goverment's plan.

AIR TRANSPORT

Latest airline bail-outs

Franco-Dutch flag carrier Air France-KLM has received a €4bn bail-out from the government of France to help it weather the Covid-19 pandemic crisis. The state investment, which may require further funds before the end of the crisis, brings the French state's stake in the joint airline to just under 30%. In order to obtain EU approval for this state rescue package, the airline has agreed to give up 18 daily slots at Paris Orly airport.

● Meanwhile, Canadian flag carrier Air Canada has secured a rescue deal with the Canadian government worth nearly $4.69bn in loans and equity. The rescue package makes the state the largest stakeholder since the 1980s with 9.7% of shares.

AEROSPACE

32% of global airline fleet still in storage

A recent report from Cirium has revealed that, in February, a total of 21,635 commercial passenger aircraft were in operation while 10,183 were in storage (equivalent to 32% of the world's fleet). According to Cirium's *Airline Insights Report* 2,937 of aircraft in North America, 3,536 of European aircraft, 619 Latin American-based aircraft, 1,065 aircraft from the Middle East and Africa and 1,956 aircraft from the Asia-Pacific region were all in storage.

NEWS IN BRIEF

Russia's Rostec has announced that United Engine Corporation has successfully conducted the first stage of ground testing of a pulse detonation engine that promises up to 50% increase in specific thrust when compared to conventional jet engines. The PDE from A. Lyukli Design Bureau has applications for hypersonic aircraft and space launchers, with the company saying it would also increase the range and payload of aircraft by 1.3-1.5 times.

US airlines, including Southwest, American and United Airlines, have grounded around 60 Boeing 737 MAXs due to an electrical power system issue. The recommendation to temporarily pull aircraft from service was given by Boeing on 8 April, to address a manufacturing flaw that could affect the operation of a power system. The MAX had only returned to service in November after a 20 month grounding due to two fatal crashes.

According to Janes, Leonardo UK is set to unveil a new medium helicopter demonstrator in May at its Yeovil factory. The helicopter, a civil AW189, will be repainted black to represent the similar-sized AW149 which is being pitched towards the UK's medium helicopter requirement to replace the RAF Puma fleet. If the bid is successful, production of the A149 could be moved from Italy to Yeovil, together with training and support infrastructure.

The UAE Space Agency has signed a contract with Japan's ispace which will see a Japanese lander deliver a UAE lunar rover to the Moon's surface in 2022. If successful, the mission, part of the HAKURO-R programme, will see Japan and the UAE become the next two nations to land a spacecraft on the Moon after the US, Russia and China.

Research conducted by private jet broker Colibri Aircraft has found that the market for pre-owned business aircraft in 2020 held up surprisingly well, given the pandemic, with 2,227 second-hand jets worth $14.5bn sold last

DEFENCE

South Korea rolls out new stealth fighter

Korean President's Office

South Korea has officially rolled out the first prototype of the indigenously developed stealth fighter, the Korean Aerospace Industries (KAI) KF-X, now known as the KF-21 'Boramae' (Young Hawk). The prototype was unveiled in a ceremony on 9 April by South Korean President Mann Jae-in. The twin-engine, twin-tail fighter will replace ageing RoKAF F-4E Phantoms and F-5Es in front-line service. First flight is planned for May 2022, with a fleet of six aircraft in the testing fleet. IOC is aimed for 2028.

AIR TRANSPORT

France bans short-haul air travel under 2.5hrs

On 10 April, French lawmakers voted to ban short-haul domestic air travel under 2.5hrs if the journey can be taken by train instead. The move is intended to encourage more sustainable travel and is a scaled-back version of the original plan, which called for all flights under four hours to be taken by train if possible. The ban will see flights from Paris to Nantes, Bordeaux and Lyon affected by the ruling, with connecting flights excluded.

- Meanwhile, a Twitter poll by *MoneySavingExpert's* Martin Lewis found that of 74,979 votes, 33.7% of under-40s and 45.4% of over-40s supported a similar ban on UK flights, with around 10% in both age groups against.

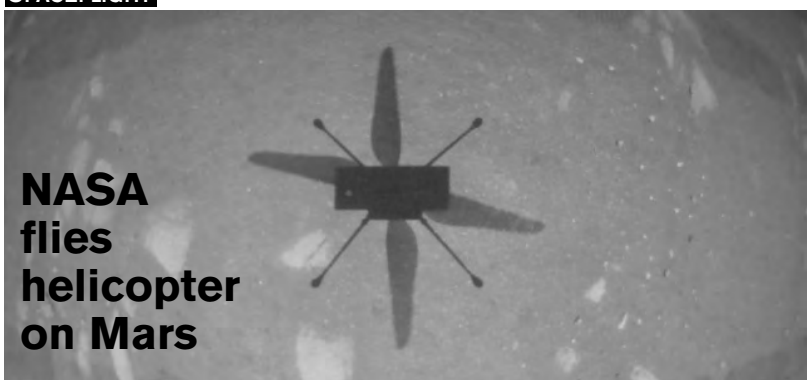
AEROSPACE

Project Fresson switches to hydrogen

The UK Project Fresson initiative to develop a green propulsion system for the Britten-Noman BN-2 Islander has switched its proposed power source from hybrid electric to hydrogen fuel cells which will be fitted to the wings. A consortium led by Cranfield Aerospace Solutions (CAeS), Project Fresson plans to shortly acquire an Islander platform to modify as a zero-carbon technology demonstrator with a first flight in 2022. The change in architecture has meant that Rolls-Royce, which was to provide the power management system, is now to leave the consortium, together with Delta Motorsport and WMG. Engineering services company Ricardo will supply the fuel cells and Innovatus Technologies the hydrogen storage system.

SPACEFLIGHT

NASA flies helicopter on Mars



NASA

As *AEROSPACE* goes to press in mid-April, NASA's JPL mission control received the first telemetry and then images (above) on 19 April that its *Ingenuity* Mars helicopter had made an historic first ever controlled atmospheric flight on another planet. The 40 second flight, saw the tiny contra-rotating rotor helicopter make a short hover to 10ft and return to the surface. *Ingenuity* carries a small piece of the Wright brothers' 1903 Flyer.

---

year. This compares to 2019, where 2,067 pre-owned business aircraft were sold.

Rolls-Royce has announced it has begun the build of the world's biggest turbofan, the UltraFan, at its DemoWorks facility in Derby, UK. The first demonstrator example of the 140in diameter jet engine is set to be completed by the end of the year before undergoing ground testing. The UltraFan is expected to deliver a 25% increase in fuel efficiency compared to first-generation Trent jet engines.

New UK low-cost long-haul start-up airline, flypop, which aims to connect the UK directly with the Indian subcontinent, is to lease Airbus A330-300s as its first type. The airline has signed a 'multiple aircraft' leasing deal with Avolon, with the intention of starting operations with one aircraft later this year and then adding another aircraft every six months.

On its centenary, the Royal Australian Air Force has announced that it is to replace the gender-specific term 'airmen' with 'aviators' 'to instil a stronger sense of identity'. However, the move saw some critics object, saying that the new neutral term refers to pilots and does not represent technical support crew.

Virgin Galactic has rolled out the newest sub-orbital spaceplane SpaceShip III – *VSS Imagine*. As well as reflective new livery, SpaceShip III incorporates design and manufacturing lessons from the previous SS2, with improved maintenance access and flight rate. A second SSIII, *VSS Inspire,* is now under construction, with test glide flights of *Imagine* planned for this summer.

Chinese logistics and freight company SF Express, with its Germany subsidiary Amazilia Aerospace, is to partner with Slovenia's Pipistrel to develop a large eVTOL hybrid cargo UAV. The drone, aimed at supplying remote and isolated areas, would be able to lift more than 300kg in cargo over 500km.

SPACEFLIGHT

NASA selects SpaceX to provide Artemis lunar lander

NASA

On 16 April, NASA announced it had picked SpaceX as its commercial space partner to land future American astronauts on the Moon as part of its Artemis Lunar mission, with the company beating rival bids from Dynetics and National Team (Blue Origin, Lockheed Martin and Northrop Grumman) for the $2.89bn contract. US astronauts launching on NASA's SLS rocket and Orion capsule will transfer to SpaceX's Starship-derived HLS (Human Landing System) before landing on the surface.

DEFENCE

RAF to field drone swarms this decade

The RAF Chief of the Air Staff, Mike Wigston, has said that he wants uncrewed 'Loyal Wingman' and swarming drones to be fielded operationally by the service within this decade. Talking to the Air and Space Power Association on 30 March, Wigston refuted claims that there is a trade-off between technology and numbers, saying: "I would offer that technology now allows us to take a different view, that you can have both. If the combat utility of today's eight-ship of Typhoons can be replicated with a pair of Typhoons, eight Mosquitos and a hundred Alvina, an entirely different calculus is at play." Mosquito is the LANCA 'Loyal Wingman' while Alvina is the swarming drone project under test by 216 Sqn.

GENERAL AVIATION

Lilium goes public with SPAC deal

German 'flying taxi' developer Lilium has announced it is going public with a $830m merger with a US special-purpose acquisition company (SPAC), Qell Acquisition Corp. Having already flown a five-seat electric-powered eVTOL demonstrator, the investment will help accelerate development of a larger seven-seat ducted-fan Lilium Jet, which the company aims to have in commercial service in 2024 and which it has already applied for concurrent type certification with EASA and the FAA. The seven-seat model will have a range of 250km and fly at 175mph. The company also revealed that an even larger 16-seater eVTOL is in its future roadmap.

AIR TRANSPORT

Southwest orders 100 new 737 MAXs

Boeing

After rumours that it was mulling a historic break from its single-type strategy and eyeing up the Airbus A220, US carrier Southwest Airlines has confirmed its commitment to Boeing by ordering 100 737 MAXs plus 155 options. The order also includes Boeing's Airplane Health Management, Maintenance Performance Toolbox and digital navigation charting tools.

NEWS IN BRIEF

Spanish regional carrier Air Nostrum has announced it is to join Volotea and start-up Dante Aeronautical to accelerate the development and introduction of electric regional aircraft. The three companies have put in a €42m funding bid from the European Commission's Recovery fund, to help develop an electric regional aircraft seating between 9-19 passengers. Certification of the first aircraft would be in 2024, with follow-on versions in service in 2026.

United Airlines has announced that it has set a new target of 50% of the 5,000 new pilots it intends to train in the next decade to be women or people of colour. The airline is now restarting training *ab initio* pilots via the United Aviate Academy, with scholarships available to attract a more diverse set of applicants. United and its credit card partner JP Morgan Chase are each committing $1.2m to scholarships.

The first flight test of the USAF's first hypersonic missile, the AGM-183A ARRW, was aborted on 6 April, when a technical hitch with the rocket booster meant it could not be launched from the B-52H test aircraft.

Boeing has signed a teaming agreement with Australian start-up Hypersonix to study a Mach 12 reusable scramjet spaceplane able to put satellites into LEO. The spaceplane would use Hypersonix's SPARTAN scramjet engines fuelled by green hydrogen for a low-cost, reusable, quick access, space access system.

Middle East corporate jet operator VistaJet has taken delivery of its first Bombardier Global 7500. VistaJet is reported to have an additional 12 Global 7500s on order, as well as ten Challenger 350 bizjets.

French company Aura Aero has announced plans to develop a 19-seat, electric-powered regional airliner. To be produced at Aura Aero's production facility at Toulouse-Francazal airport, the new aircraft is scheduled to fly in 2024 and enter service in 2026. The company is also developing an

AIR TRANSPORT

ICAO pushes to simplify NOTAMs

ICAO has launched a global campaign to streamline NOTAMs (NOtices To AirMen) after a seven-fold increase in the publication of these information sources over the past two decades. Many of these can reach 100 pages of NOTAMs for pilots doing pre-flight briefings, says ICAO, with 20% of these being outdated infomation older than 90 days. ICAO says that on any given day 35,000 active NOTAMs may be circulating, leading to fears of information overload in pilots where safety-critical information can be missed. ICAO's Global Campaign on NOTAM Improvement (NOTAM2021) intends to reduce the number of excessive NOTAMs published.

AEROSPACE

Skydweller claims record in first autonomous systems test flight

Skydweller

US-Spanish company Skydweller Aero, which is developing the solar-powered Solar Impulse into a long endurance UAV for civil and military roles, has announced that its prototype made a piloted flight on 18 April in Spain. The first flight to test autonomous systems and hardware, the flight also saw the team claim a world record of 16,000ft for the highest piloted sustained flight by a solar-powered aircraft.

GENERAL AVIATION

2Excel to support new air racing series

2Excel Aviation

The UK's 2Excel Aviation, parent of The Blades display team, has signed an agreement with World Championship Air Race (WCAR) to provide operational and maintenance support for its upcoming AeroGT air racing series. The AeroGT air racing series, sanctioned by the FAI, is set to launch in the first quarter of 2022.

DEFENCE

France and Germany reach FCAS agreement

A major obstacle to the launch of a pan-European (Future Combat Air System) FCAS programme has been removed with the two lead companies, Germany's Airbus Defence and France's Dassault Aviation, both agreeing to the industrial terms for the sixth-generation fighter system, according to the French Senate. The agreement, described as a 'major turning point' by the Senate panel, is still to be approved by German politicians this summer and opens the door to the next phase 1B of the project and additional investment. FCAS, which is designed to replace Eurofighters and Rafales, is planned to enter service in the 2040s.

electric version of its two-seat light Integral R.

Pilots working for South African Airways (SAA) are threatening to go on strike in a dispute over new employment contracts with the airline's Business Rescue Practitioners (BRP) which is restructuring the airline. Members of the SAA Pilots Association (SAAPA), which represents 89% of SAA's current 350 pilots, claim that many members have not been paid for a year while other members have been locked out and cannot return to work.

On 4 April, the Israeli Air Force received its latest multi-mission ISR platform, a Gulfstream G550-based 'Oron' which is set to enter service in 2023 after being outfitted with its mission equipment. The 'Oron' is an all-in-one ISR platform, combining the roles of AEW, SIGINT and maritime patrol, with conformal radar arrays.

ON THE MOVE

Former Under Secretary of Defense for Acquisition and Sustainment for the US DoD, Ellen Lord has been elected to the board of AAR.

Dirk Hoke, head of Airbus Defence and Space, and Airbus CTPO Grazia Vittadini are both to leave the company on 1 July to pursue other opportunities. Hoke is replaced by COO Michael Schoellhorn, while Vittadini's role will be merged with Head of Engineering and taken over by Sabine Klauke as EVP Engineering.

Willie Walsh is to be the new Director General of the International Air Transport Association.

Piper Aircraft has appointed John Calcagno as its new acting President and CEO following the retirement of Simon Caldecott.

The UAE has selected Nora Al Matrooshi to be part of the country's astronaut corps and the Arab world's first female astronaut.

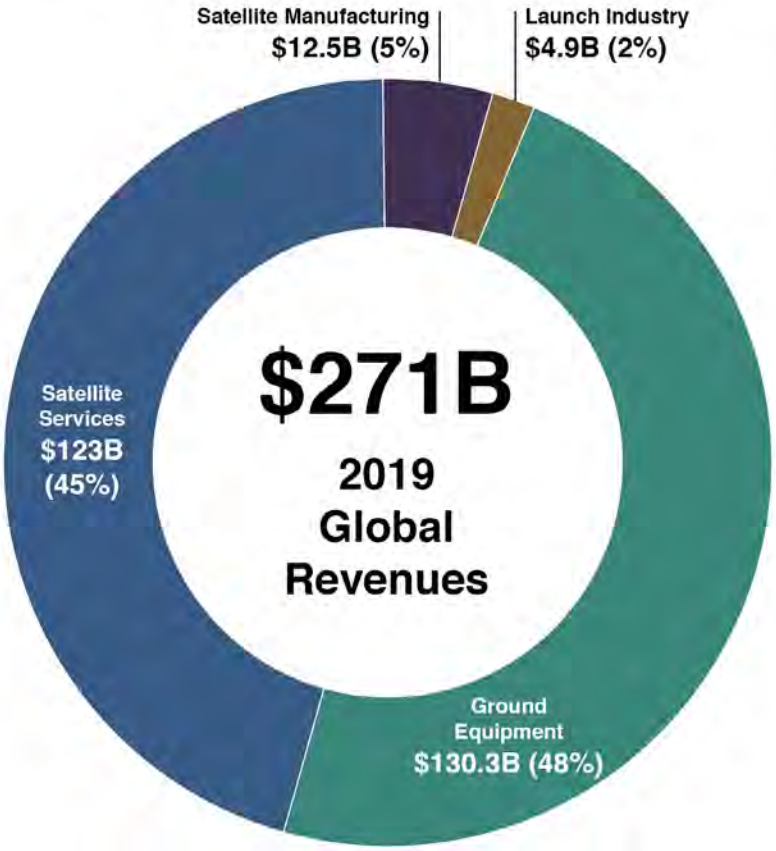
Josh Hardie has been named the new Airbus UK Head of Public Affairs in June, taking over from outgoing SVP Katherine Bennett.

By the Numbers

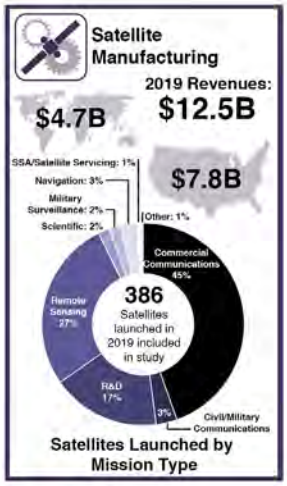
Understanding the world of Aerospace through data

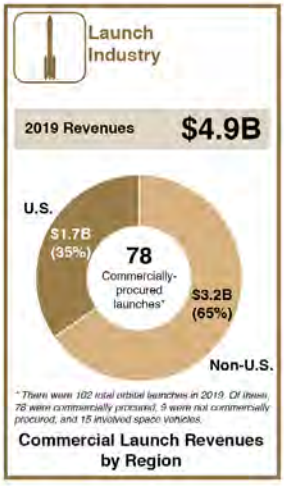
How the world's satellite industry breaks down

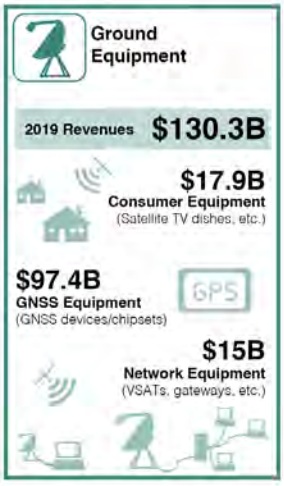
2019 Top-Level Global Satellite Industry Findings



Bryce Tech/SIA







Pushing the Envelope

Exploring advances on the leading edge of aerospace

Robert Coppinger

In-orbit manufacturing – the next big leap

Origami is an ancient art but its principles are still key for the most advanced spacecraft because of the packaging required to squeeze the likes of NASA's James Webb Space Telescope inside the fairing of a rocket. Finishing the fabrication of an immense spacecraft after it is in its orbit would liberate the design of space telescopes and telecommunications satellites and end the origami conundrums.

Ending the fairing challenge would also mean spacecraft structures made in orbit would not need to be designed for the shock and vibration environment of a rocket launch. The in-orbit manufacturing technologies that would realise this new freedom are at an advanced stage of development and the fruits of some of those labours will be seen in the next few years.

Building while flying

From 2022, NASA intends to launch a technology demonstrator spacecraft which would print two nine-metre long beams. These beams are potential solar array structures. In Europe, Airbus has spent internal funds developing a weaving technology for building antenna reflectors on orbit. In the UK, Surrey Space Centre (SSC) is studying robotics and autonomous systems which would be needed for in-orbit manufacture and assembly. The vision the space industry has for the in-orbit assembly of spacecraft ranges from modular spacecraft docking to the literal printing of parts and structures, like NASA's mission. Professor Sir Martin Sweeting is Executive Chairman of Airbus' Surrey Satellite Technology (SSTL), which commercialises SSC's work. He likens the modular spacecraft approach to the modular design used in today's satellite factories. Where different modules are attached in the factory to create a space vehicle with specific capabilities, in-orbit assembly would see specialised spacecraft dock to create a very capable satellite and much larger than anything a fairing could accommodate.

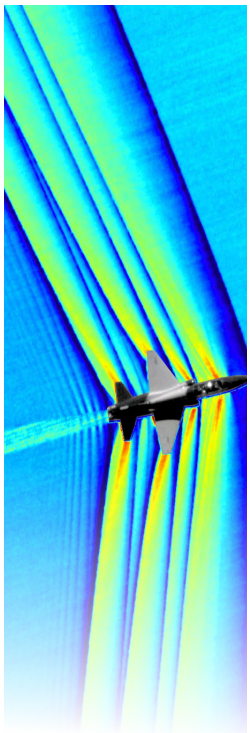
Airbus foresees a telecommunications market which has spacecraft that finish their own assembly on orbit, building their antenna and solar arrays that would be too huge to fit on a rocket. Being able to assemble, or weave with Airbus' technology, huge solar arrays would mean a lot more power was available and that would be advantageous for any spacecraft, telecoms or Earth observation.

Assembling using robotic arms is another in-orbit manufacturing method where a core spacecraft is launched with component parts that it then fits together. Sweeting sees brick-like subsystem modules that can be connected to add functionality. A challenge with robotic moving arms is Sir Isaac Newton's third law of reaction in the opposite direction for every action. These reactions to robot arm movement can destabilise the spacecraft and so it is a challenge the industry is tackling now.

Robot builders

The SSC is leading a UK national hub studying robotic movement and Airbus is managing a European Union (EU) orbital factory project that is also aiming to solve the problem. The orbital factory concept has the unfinished spacecraft dock with the factory to complete its construction using robotic arms. Beyond robotic arms, the ultimate in-orbit manufacture would be to start with the base materials and print everything, zapping particles with a laser. The orbital factory could be launched with everything needed for this. An intermediate step is to send laser printer feedstock for making structures and microelectronic components whose manufacture is more complex than printing allows.

Three-dimensional printing has already occurred on the International Space Station (ISS) but the printers have only been technology demonstrators and will remain so. NASA launched a polymer printer in 2014 to the ISS and, in 2015, ESA and the Italian space agency sent their own to the station. In 2018, NASA sent to the ISS a fridge-sized machine it calls a Refabricator which can recycle its own plastic printed products. Next year, NASA intends to send a metal printer, although nothing it makes is expected to be used for ISS repair. All these printers use a continuous thread of material which is passed through a heated extruder onto a tray, layer by layer, to build an object. Unlike Earth-based 3D printers, powder cannot be used in a microgravity environment and its inhalation by astronauts could be lethal. Ten years ago, any in-orbit manufacturing would have been said to be science fiction, Sir Martin said. Now he says,



> FINISHING THE FABRICATION OF AN IMMENSE SPACECRAFT AFTER IT IS IN ITS ORBIT WOULD LIBERATE THE DESIGN OF SPACE TELESCOPES AND TELECOMMUNI–CATIONS SATELLITES AND END THE ORIGAMI CONUNDRUMS

Transmission

LETTERS AND ONLINE

@aerosociety | Find us on LinkedIn | Find us on Facebook | www.aerosociety.com

Cuts today but jam shortage tomorrow?

Two predictable outcomes of every UK Defence Review since the early 1980s have been: endorsement of a national commitment to modernising the armed services to make them fit and appropriate to meet future threats, combined with more immediate cutbacks in numbers of personnel and front-line capabilities, supposedly to pay for promised new future programmes. This latest announcement is no different. While it identifies the obvious need to make new investments in counter cyber efforts and space access, it also confirms a proportionately massive hit on RAF operational capabilities. Intelligence, surveillance and reconnaissance (ISR) air assets provided by the RAF have played a major role in coalition air power projection for the past three decades, despite the relatively small fleets of specialist aircraft involved. The Sentinel R1s have already gone, to be followed soon by the short-range Islanders and the remaining E-3 Sentry AWACs, while the planned, already minimal, five-strong E-7 Wedgetail fleet is now to be cut to just three, two-three years before the first is ready! Yet, just as the report underlines an increased global ambition for our armed forces, we are about to sell off one third of our tactical air transport fleet, dispose of no fewer than 24 perfectly adequate air defence Tranche 1 Typhoons – a quarter of the RAF's fast jet combat fleet – and an early phase out of all the Puma helicopters after a very expensive update a few years ago and with no replacement likely to be available for a considerable time after the last has gone.


Eurofighter

24 RAF Typhoons are to be retired in 2025.

The critical mass of the RAF has all but disappeared, especially as examples of the remaining Mk3 and Mk4 Typhoons will have to be withdrawn on a rolling basis to incorporate new E-scan radars and other new weapons over the coming years.

Furthermore, what does 'more F-35s beyond the existing order for 48' mean? Two more? The infamous *Sandys White Paper* of 1957 slashed RAF front-line squadrons in favour of missiles – until that decision was reversed just two years later. The *2010 Defence Review*, which featured deep cuts to RAF air power, slashing Tornado numbers and the whole Harrier Force, led to the *2015 Defence Review*, which attempted to restore some of the previous shortcomings. Now we seem to be repeating those acknowledged mistakes by once again creating even bigger gaps in front-line capabilities, in the hope that nothing unexpected happens over the next few years.

Some hope.

Richard Gardner MRAeS

Pilot training in crisis?

@martin04573981 [On airline pilot training - time to revisit the basis[4]] Basic flying and navigation skills are required in all levels I think. Specially the 'magenta' generation of pilots.

@nonrewebsite Too late – things are spooling up and the airlines are already behind.

@MarkbateUK Unless the training schools are reformed from top to bottom, then nothing will change. It's a cartel that for over 20 years has fleeced those undergoing training. The sooner they are gone the better.

@timdavies_uk It's a self-serving racket that constantly talks up pilot shortages in order to get young aspirational people to part with their parents' money. A bit harsh maybe but probably fair.

Future helicopters

@Zaphod2042 [On Blade Runners in 2040[5]] Excellent analysis of the current landscape. Found the Europe/US contrast between capability and sustainability particularly interesting. It's curious how, on both sides of the Atlantic, the two main directions seem to be tiltrotor or compound. Do we risk going for the presumed future tech or else play it safe with the best of the old generation?

New Member Spotlight

Mark Oswald [On New Member Spotlight Siva Marimuthu[1]] Congratulations and welcome Siva.

Mark Timms
Congratulations Siva. Great to see Nilai represented. I have many fond memories of Nilai and Selak Tinggi back in the mid 90s during KLIA construction.

Celera 500L

Geoffrey Wardle [On Celera 500L laminar flow aircraft design[2]] Interesting article on this new and innovative design; it will be interesting to see if the performance gains cited are realised. I am also surprised at the use of mechanical flight control rather than FBW or FBL systems.

Career Flightpath

Gareth Davies [On RAeS Career Flightpath online resource[3]] Great resource!

Vidyasagar Kotha Thanks for introducing it.

From the RAeS photo archives


RAeS/NAL

Above left: A Blue Streak test at Spadeadam.
The de Havilland Propellers Blue Streak was a British Intermediate-range ballistic missile (IRBM), and later the first stage of the Europa satellite launch vehicle. It was cancelled in April 1960 without entering full production.
Above right: A Black Arrow three-stage satellite launcher lifts off from Woomera on 4 March 1970. Its fourth and final launch on 28 October 1971 successfully placed a Prospero experimental satellite into orbit.

UK spaceports

@LeadershipNext1 [On UK spaceports blog[6]] I think the mathematical favourite will be the option furthest south, ie the closer to the equator, the larger the linear velocity on Earth's surface is already baked in before igniting rockets and slingshotting. So you can launch greater payload for less fuel.

@BenSharpUK A fantastic and comprehensive article. Yet, notwithstanding the claims by the operators, is the market there? Can these spaceports be a success without significant government backing?

@mike_carrvick I think the bigger question will be lower airspace capacity if all these air taxis and delivery drones come to fruition. Added to that will be disciplined approach to flight operations that new pilots and drone operators will need.

@DontFailToTri Quite easily; Temporary Restricted areas, the same as Managed Danger areas, such as the D323 complex. When active, aircraft need to take a huge detour; when inactive, more direct routes will be available.

@sheen_alexander I'd suggest using autonomous systems for range clearance etc but we've not exactly cracked that problem yet.

HRH Prince Philip

@MarshallADG [On Memories of HRH Prince Philip (see page 60) We are deeply saddened by the loss of His Royal Highness Prince Philip, Duke of Edinburgh. HRH visited Marshall on many occasions, including in 2009 for our centenary celebrations and for the inauguration of the Marshall of Cambridge room at @AeroSociety in London.

@Brabazon2 Sad news. I never met HRH in person but I know he was a strong supporter of @CranfieldUni and visited a number of times, including a visit in 1963 to deliver the inaugural @AeroSociety Handley Page memorial lecture at Cranfield.

eSchneider Trophy?

Rolls-Royce

ACCEL electric racing aircraft

@Peter_Mugridge [On Rolls-Royce gets set to fly ACCEL in electric race] That aircraft looks like something fit for the Schneider Trophy... which gives me an idea. Perhaps we should have an Electric Schneider Trophy for these?

@fg_domperry First flight now set for May at Boscombe Down in Wiltshire. I knew my home county would be famous for something one day.

Replacing the Sentinel

@JamesFe20066451 [On RAF retires Sentinel spyplane] Interestingly the US has also cancelled their planned business-jet based replacement for the E-8C JSTARS. This type of ISTAR (including AWACS) is likely to go to multiple sensors feeding the combat-cloud rather than big 'single point of failure' platforms in the future. For example, if you network all of the data feeds from F-35, Typhoon, Reaper/Protector, MilSats and whatever else you have over the battlespace, you get much more data than you do from a Sentinel – over a wider area. Fancy software can do the job better.

@DefenceSenseUK Such a waste.

MoD

RAF Sentinel

@greenspike5 Both the USAF and the US Army are working hard on having a capability based on multiple platforms and sensors. I worry about such combat cloud's resilience (or lack thereof) in the face of determined cyber and EW attacks which it would certainly face in a conventional conflict.

@GrumpyWo The comparable NATO capabilities are NATO AGS (of which Sentinel was our contribution to) and JSTARS, which has suffered the same kind of neglect that Sentinel did. I would also argue that the way those two platforms are operated/crewed also gave Sentinel an edge.

Aircrew mental health

@giuliogamba [On aircrew mental health blog[7]] Nothing has been really done to properly address the problem.

@nrogers_aero Human factors understanding the person/machine interface and employer understanding of issues has never been so important in the aviation sector.

@SteffenA380 I think the example with 4U9525 is badly chosen but there is definitely a lot of work to be done in that direction.

eVTOL aerial deliveries

@airlineFlyer [On UPS to field eVTOL delivery aircraft] Folks, we are living in the golden age of eVTOL aircraft renderings. @UPS says it'll take delivery of its first ten BETA Technologies aircraft beginning in 2024 with options for up to 150. Claims of 1,400lb cargo capacity with 250 mile range have been stated.

BETA Technologiues

@Aerosurrance Still to conduct VTO, transition or VL. Cruise speed said to be 145 knots.

@GuardedDon Rapid parcel deliveries and Starlink fast broadband. Everyone will be moving out from the 'burbs' to the boonies.

@AlastairWB It took Bell ten years to develop the 525, so yeh, all these start-ups are going to do it in a third of the time with completely new configurations and propulsion technologies.

1. *AEROSPACE*, April 2021, p 50, New Member Spotlight
2. *AEROSPACE*, April 2021, p 20, Going with the flow
3. https://www.aerosociety.com/careers-education/resources/career-flightpath/
4. https://www.aerosociety.com/news/airline-pilot-training-time-to-revisit-the-basics/
5. *AEROSPACE*, March 2021, p 36, Blade runners for 2040+
6. https://www.aerosociety.com/news/the-magnificent-seven/
7. *AEROSPACE*, March 2021, p 28, Covid 19 – a hidden mental health crisis?

Magnificent Seven

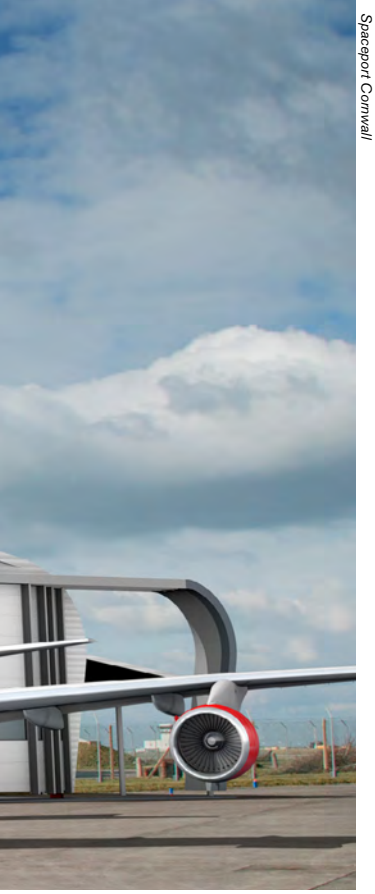
The UK government is working on plans to facilitate the creation of space launch sites located within the UK, with seven sites currently preparing to apply for spaceport operating licences. BILL READ FRAeS reviews the contenders.

One of the highlights of the 2014 Farnborough Air Show was the announcement of a plan from the UK government to select a site for the first commercial spaceport to be located in Britain. After the selection of a site, the schedule was to build a commercial spaceport which would begin operations by 2018. Seven years later, in 2021, we are still waiting but new plans are now under way for the creation of not one but seven spaceports around the UK.

In the original 2014 plan a total of eight sites were considered for possible selection, six of which were in Scotland. These comprised: Campbeltown Airport, Glasgow Prestwick Airport, Kinloss Barracks, RAF Lossiemouth, Stornoway Airport, RAF Leuchars, Llanbedr Airport and Newquay Cornwall Airport. In 2015, this list had been reduced to six possible sites, as RAF Lossiemouth and Kinloss Barracks were dropped due to operational defence reasons. In 2016, RAF Leuchers was also removed from the contenders. In May 2016, the competition was ended with no final selection being made.

However, recent years have seen a revival of the project. While the original plan was to select just one of the alternative spaceports, the government announced in May 2016 that it was cancelling the original bid process in favour of a licensing framework. The aim of the new system is to enable the establishment of a wide range of commercial sub-orbital and orbital operations, using both horizontal and vertical launches. Under the new rules, this means that, with the addition of sites at Shetland and Sutherland, there are now seven potential spaceport sites seeking an operator licence.

In 2018 the government established the Space Growth Partnership with the aim of expanding the UK space industry. The UK's spaceflight programme – LaunchUK – is working with a range of additional partners to establish commercial vertical and horizontal small satellite launch from UK spaceports. The government is encouraging the development of spaceports in two ways, financial and regulatory. The financial incentive has included grants totalling nearly £40m to establish commercial UK spaceports.



Spaceport Cornwall

Meanwhile, the 2018 Space Industry Act has established the legal framework for commercial launch activity in the country. The act establishes the Secretary of State as the regulator for UK spaceports with a primary duty to secure public safety. Regulatory functions are expected to be delegated to the UK Space Agency and the Civil Aviation Authority.

A comprehensive set of rules have been prepared which set out the requirements needed from prospective spaceport operators and launch operators. These include: licensing requirements, environmental considerations, liability and insurance, security and an accident investigation process. Work is now under way to create a final version of the rules which will, according to a statement from the Department for Transport (DfT), enable UK spaceflights to flourish while remaining safe. Once the regulatory and safety rules have been completed, legislation will be introduced which will allow both spaceport and launch operators to apply for a licence from the CAA to begin operations. To be approved for a licence, an operator will have to show that they comply with planning, safety and environmental requirements.

Technology and licences

Another issue that has had to be addressed is that of technology safeguards. Many of the planned launches from UK soil involve the use of American-made rockets and systems, the use of which requires special permission from the US to abide by ITAR and TSA controls. In June 2020, the US and UK governments signed a technology safeguards agreement detailing the procedures to ensure that export-controlled technologies on American vehicles are adequately protected when flown from British spaceports.

Horizontal and vertical

The UK sites will be used for two different types of space launches – vertical and horizontal. As their name implies, vertical launches involve the 'traditional' method of a rocket taking off from a launch pad – although the rockets from the UK launch sites will only be small ones. Horizontal launches involve an aircraft taking off from a conventional runway carrying a rocket which is launched while the aircraft is at a high altitude and then deploys the satellite in orbit. Horizontal launches have the advantages that they cost less than vertical launches, can be carried out more frequently with less fuel and noise, and can be integrated into existing airport facilities. The disadvantage of horizontal launches is that there are limits on the size of rockets that the aircraft can carry which can only carry smaller payloads.

> HORIZONTAL LAUNCHES HAVE THE ADVANTAGES THAT THEY COST LESS THAN VERTICAL LAUNCHES, CAN BE CARRIED OUT MORE FREQUENTLY WITH LESS FUEL AND NOISE, AND CAN BE INTEGRATED INTO EXISTING AIRPORT

Sites

Of the seven proposed spaceport sites, three will be vertical launch sites and four for horizontal launches. Five of the sites are in Scotland (Hebrides, Shetland, Sutherland, Ayrshire and Kintyre), one in North Wales and one in Cornwall. Several spaceports have already got their first customers lined up and are anticipating their first launches as soon as they have obtained operating licences.

No 1. Spaceport 1 – North Uist, Hebrides (vertical launch)

The proposed Western Isles' Spaceport 1 would be located at Scolpaig on the north-west coast of North Uist. In June 2019 the Western Isles local authority, Comhairle nan Eilean Siar (CnES), invested about £1m to purchase the land needed to build a site which would be used for vertical launches of small satellites. Proposals for phase 1 of the plan involve the launch of multiple 'sounding rockets' over a period of three years as test and evaluation for the subsequent phases. The North Uist proposal is being supported by QinetiQ, which operates the nearby Ministry of Defence Hebrides Rocket Range and is a partner in the project, together with Highlands and Islands Enterprise (HIE) and the Commercial Space Technologies consultancy.

Spaceport 1


Shetland Space Centre


Shetland Space Centre

No 2. Shetland Space Centre (SSC) – Unst, Shetland Islands (vertical launch)

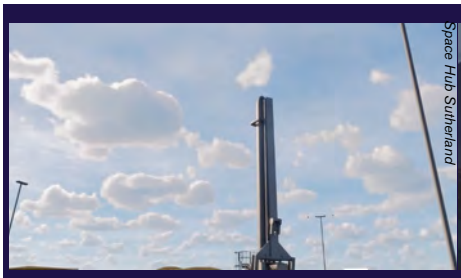
Another vertical launch site is being proposed for the Shetland Space Centre (SSC) located at Saxa Vord on the Lamba Ness peninsula on the UK's most northerly island of Unst – which was also the former site of the RAF Skaw military radar site. The SSC facilities will comprise three launch pads designed to accommodate different rocket payload capacities from 30kg up to 600kg. The larger rockets will be launched from the pads located furthest east and smaller ones to the west. SSC says that it is planning for each launch company to have its own pad but will also be promoting the concept of universal launch pads for the future.

SSC is aiming to have first a ground station and then a functioning launch facility in place by the end of this year. Once the site is fully operational, SSC anticipates that there may be up to 30 rocket launches a year which could take place during the day or night. SSC states that the high latitude of Lamba Ness makes it the ideal site for launching small rockets with small satellite payloads. Such rockets are launched into either polar orbits, where the trajectory of the satellite is over both the North and South poles, or sun-synchronous orbits which are also polar but ahead of the sunrise, allowing a satellite's solar panels to function continuously.

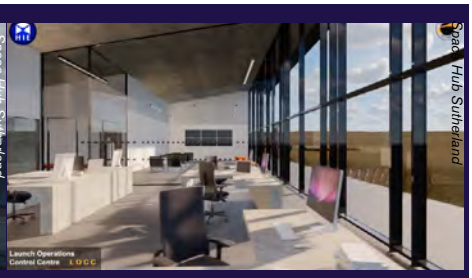
In February 2021, it was announced that Lockheed is planning the first rocket launch from the Shetland Space Centre (SSC) in 2022. Part of a $31m mission named UK Pathfinder, the rocket will place into orbit an orbital manoeuvering vehicle developed by Moog in the UK which will deploy six 6U CubeSats. Lockheed does not currently have a small launch vehicle compatible with the spaceport but has contracted the launch to US company ABL Space Systems which has an integrated GS0 launch system and RS1 rocket. The GS0 launch system is said to be self-contained and will not require any fixed infrastructure at the spaceport. The Shetland Space Centre will provide a flat concrete launch pad, bulk propellant and a mission control centre. The RS1 rocket is currently still in development, with the first launch scheduled for the second quarter of this year from Vandenberg Air Force Base in California. In April it was announced that ABL Space Systems will provide Lockheed Martin with routine launches of RS1 rockets to accelerate payload technologies into orbit. Lockheed Martin will purchase up to 26 vehicles through 2025 and then up to 32 additional launches through 2029.

In June 2020, Shetland Space Centre announced that Canadian small launch vehicle developer C6 Launch Systems plans to launch from the site. C6 is still developing a launch vehicle which will be conducting engine tests at Spaceport America in New Mexico. In February, SSC announced that it had secured a 'further boost' as German rocket maker HyImpulse Technologies planned to begin engine-testing and launching sub-orbital sounding rockets from Shetland this year with a view to a maiden orbital flight in 2023. Paul Riddel, Head of Comms at the Shetland Space Centre, confirmed that there were also other customers but: "until we reach formal terms with them, we are unable to say who."


Shetland Space Centre


Space Hub Sutherland


Space Hub Sutherland


Space Hub Sutherland

No 3. Space Hub Sutherland – Melness, Sutherland (vertical launch)

The only vertical spaceport site on the UK mainland is Space Hub Sutherland located on the A' Mhòine peninsula, Melness, near Tongue in Sutherland on the north coast of Scotland. The site will consist of a single launchpad with an upper limit of 12 flights per year.

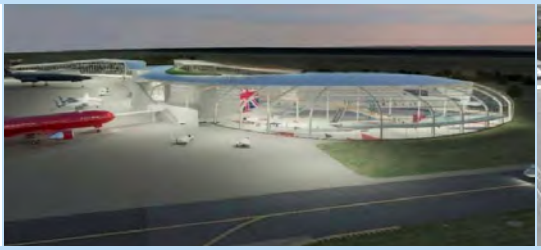
In July 2018 the UK Space Agency announced that the first customers of the Sutherland spaceport would be Lockheed Martin and small launch vehicle startup Orbex. However, Lockheed announced in October 2020 that it has received permission from the UK Space Agency to move the launch site to the Shetlands. Lockheed said that the reason behind the move was because the Sutherland site only had a single launch pad and it wanted to avoid competing with Orbex for a limited number of launches.

Orbex plans to use a small reusable rocket called Prime which it is developing to place a 150kg payload into a 500km sun-synchronous orbit. The rockets and engines are to be made at Orbex's manufacturing plant Forres, near Inverness, using 3D printing technology. The rockets will be powered by liquid oxygen and 'bio-propane' fuel made from biomass.


Space Hub Sutherland

No 4. Prestwick Spaceport – Prestwick Airport, Ayrshire (horizontal launch)

A horizontal launch spaceport is also planned at Glasgow Prestwick Airport in Ayrshire where Prestwick Spaceport claims that much of the infrastructure required for horizontal space launches is already in place, including a long runway, easy accessibility, cargo-handling ability and a broad-based aerospace infrastructure surrounding the site. In addition to the air launch of satellites, proposed future uses include: micro gravity flights, hypersonic flight services and even space tourism human spaceflight.




Prestwick Spaceport

No 5. Discover Space UK – Campbeltown Airport, Kintyre (horizontal launch)

The fifth Scottish spaceport site is Campbeltown airport located in the south of the Kintyre peninsula on the west coast of Scotland. Formerly the RAF Machrihanish air base, Campbeltown airport also has a long runway (3,049m) suitable for horizontal space launches which was used for Vulcan bombers and was also a back-up emergency landing for the Space Shuttle. There is also a 2,970m parallel taxiway which could potentially also be used as a second runway. The site was purchased for £1 from the Ministry of Defence in 2012 and is now owned by the Machrihanish Airbase Community Company (MACC).

Campbeltown is promoting its spaceport ambitions under the name Discover Space UK which signed a memorandum of understanding with QinetiQ and Telespazio VEGA UK in January 2017 to investigate the potential of the site for a horizontal launch spaceport.

Discover Space


Spaceport Snowdonia

Spaceport Snowdonia


Spaceport Snowdonia

No 6. Snowdonia Aerospace – Llanbedr, Wales (horizontal launch)

Another spaceport site is located at the former RAF airfield in Llanbedr, Gwynedd. The former military site is owned by the Welsh government but has been leased to spaceport operator Snowdonia Aerospace. Snowdonia Aerospace is hoping to launch the first sub-orbital flights over Cardigan Bay in 2022-25. The Snowdonia spaceport will also be used for testing new UAVs. The UK Space Agency has granted an additional £86,000 to Snowdonia Aerospace to test how satellite-enabled drones could be used to support healthcare in rural communities.

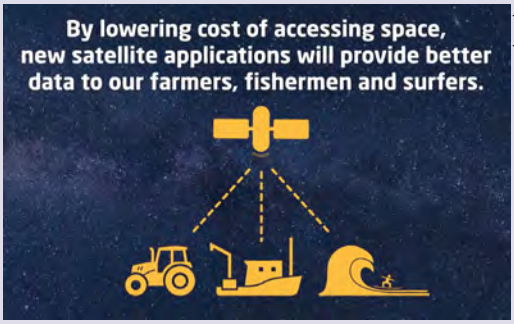
The spaceport has already got its first customer. Newport-based B2Space was also awarded £100,000 by the Welsh Government to use Llanbedr to examine the use of stratospheric balloons as a low-cost option for the launch of small and micro satellites into low-Earth orbit. According to B2Space, the balloons ascend to 40km carrying a 'rockoon' satellite launcher which then separates and carries the satellites into orbit. Balloon launches to test the feasibility of the system began in 2018 from Llanbedr and were completed in March 2020.

No 7. Spaceport Cornwall – Newquay Airport, Cornwall (horizontal launch)

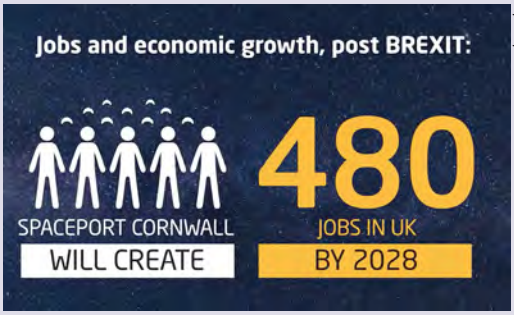
Meanwhile, Cornwall Newquay Airport is planning to become the only one of the seven spaceport sites to be located in England. The proposed Spaceport Cornwall plans to operate horizontal space launches in conjunction with existing commercial airline flights. Work has commenced on the Spaceport Zone 1 plan which includes the Centre for Space Technologies (CST), a large-scale airside development comprising of a 1,700m^2 Space Systems Integration Facility (300m^2 prep area, 400m^2 cleanroom, 1000m^2 integration workspace), and Operations Facility (Mission Ops Centre, Collaboration Space, Offices and Laboratories. The CST will be ready for occupation by the end of this year.

Spaceport Cornwall also has a customer interested in using the site, in the shape of Virgin Orbit which signed a partnering agreement with Cornwall Council at the 2018 Farnborough Airshow. Virgin Orbit is developing a horizontally-launched satellite system using a modified Boeing 747-400 carrying a LauncherOne rocket which is released in flight at 35,000ft. A test flight of the system was carried out in California in November 2018 with the first launch from Cornwall anticipated for early 2022.

Spaceport Cornwall



Spaceport Cornwall



Spaceport Cornwall

ATC and segregated airspace

A practical issue faced by all UK launch sites is how to keep the airspace above the sites clear for rockets to go into orbit. This is less of a problem for the more remote sites but the space site operators will need to ensure that no aircraft are flying over the sea during a launch. "The overall impact on the UK ATM network of a space launch will require deconfliction to ensure that existing airspace users are still able to operate," John Holmes FRAeS CEng Principal Specialist, SMS Development & Commercial Space at NATS told *AEROSPACE*. "Operations of this nature aren't generally compatible with civil air traffic operations and it is CAA policy for these kinds of activities to occur within separate areas which will be classified as 'danger areas' or other forms of segregated airspace requiring all air traffic to fly around them when declared as active. This segregated airspace will be in operation for the duration of the launch window, potentially starting when the rockets are fuelled and then continuing for take-off, descent and any potential recovery of vertical launch vehicles."

"Segregated airspace to support launches will need to be designed and implemented by the operators, applying for permission to the CAA via the airspace change process (CAP1616) for airspace in the UK. The size of each segregated area is expected to be significant to protect third parties from harm in the event of abnormal operations, even for sub-orbital launches."

Customised segregation

Different sized volumes of airspace could be reserved for each launch, at multiple locations for different dates and durations. In addition to the size of the segregated airspace, the impact of a launch on other airspace users will also vary depending of the duration of airspace closure, location of the launch point, time of day, aviation traffic, weather and other factors.

"The exact details of any airspace closures for aircraft and potentially drones over the spaceport prior to the launch window are expected to be determined by the CAA in conjunction with the spaceport and launch operator," explained Holmes. "NATS would then implement those restrictions to assure the safety and integrity of the ATM network. The required volume of segregated airspace will depend on the type of launch – a vertical rocket launch requiring a different volume of airspace from a horizontal take-off air launch. While launch points are fixed for vertical spaceports, mobile launchers from horizontal spaceports or sea launches can choose optimised locations for their desired trajectory and weather," continued John Holmes. "The weather also onloads and offloads the UK ATM network and may cause flights onto non-optimum routings for activities that may be subject to interruption due to weather or other external factors."

> THE OVERALL IMPACT ON THE UK ATM NETWORK OF A SPACE LAUNCH WILL REQUIRE DECON-FLICTION TO ENSURE THAT EXISTING AIRSPACE USERS ARE STILL ABLE TO OPERATE.
>
> **John Holmes FRAeS CEng**
>
> SMS Development & Commercial Space, NATS

Vertical launches

"In the case of a vertical rocket launch, the size of the segregated airspace is driven by the need to protect other airspace users from abnormal operations and failures and to clear the return zones for rocket stages and fairings. A typical vertical rocket launch passes through 60,000ft feet between 80-120 seconds from lift-off with little horizontal travel down range. This restricted airspace might remain active for longer if the launch involves a stage that returns as a ballistic object. The recovery process could also increase the amount of airspace closure for an individual launch. The use of returnable vertical launched rockets could also potentially increase the number of scrubbed launches and increase the number of airspace closures as some of the current recovery technology is more vulnerable to the weather."

Horizontal launches

For air-launched rockets, there would be two stages to consider – the horizontal take-off of the carrier aircraft and the high-altitude rocket launch. The carrier aircraft would be controlled by NATS in the same way as a normal flight – except that this aircraft would be carrying a potentially explosive payload in the form of the rocket. "NATS has a great deal of experience in managing, co-ordinating and controlling aircraft carrying hazardous cargo through our airspace," said Holmes. "The arrangements would depend on the status of the flight conducting the horizontal launch as allocated by the CAA as part of its approval process."

Holmes anticipates that the segregated airspace required for an air-launch rocket will not be dissimilar to that for a rocket launched vertically, saying that: "It is expected that a manoeuvring area to position the aircraft for launch would be needed in addition to the launch protection airspace. The key difference for horizontal space launches is that potentially the launches can be from different starting points on each occasion. This has implications on the types of airspace construct that can be used and mechanisms to implement that with the air traffic management system. The CAA will determine the exact airspace requirements with the launch operators."

An extended version of this article can be viewed in the *AEROSPACE* Insight blog.

Space to 2030

RICHARD LOWE FRAeS, **MALCOLM MACDONALD** FRAeS and **PAT NORRIS** FRAeS look at some of the most exciting missions and trends in the next decade and how the UK might get involved.

The 2020s promise some major developments in space – internationally and, increasingly, here in the UK. The major drag on space progress, launch cost, is reducing as innovation and competition work their magic. As launch costs fall, so do the costs of every other aspect of space technology. Customers are migrating from a conservative 'must work first time' culture towards a more 'adventurous' attitude, emphasising pace and agility (both are drivers for the UK's own launch ambitions). The UK's satellite manufacturers are at the forefront of this change, while national launch capability is rapidly catching up. Orbex will attempt its first launch from a Scottish pad in the next few years. As launches gets cheaper, optimisation can give way to standardisation – driving costs down, and reliability up. The boundary-pushing missions – for national security and for big science – will remain risk-averse but even these will benefit.

Launchers on Mars, quadcopters bound for other worlds, super-observatories, a return to the Moon and holidays in orbit… Coming soon to a planet near you. Watch this space!

Trends

Mega-constellations and/or mega-junk

Although still commercially experimental, mega-constellations are fast becoming normalised. The UK's OneWeb is putting up several hundred. SpaceX's Starlink has launched more than a thousand already (with some 40,000 planned). While efforts are being made to include de-orbit capability for end-of-life, it is a safe bet that many of these satellites will ultimately end up as space junk… but 'where there's muck, is there brass?' Innovators here in the UK, including Astroscale, are aiming to cash in on the need for clean-up. The 2020s will almost certainly see further successful demonstrations of de-orbit technology – and perhaps even some paying clients. Whether such ventures are commercially successful will depend upon the pressure brought on 'polluters' by governments and

OneWeb/Roscosmos and Space Center Vostochny, TsENK

OneWeb's fifth launch in March 2021, carried about by Arianespace from the Vostochny Cosmodrome.

public opinion. Who's paying for a mission to de-orbit another mission? If consumers care enough, they will drive the change. If not, then it will come down to business ethics, legislation or the colder economics of self-preservation. This is the space sector's own 'inconvenient truth'. We may be no less tardy in responding.

So, is low Earth orbit the new home of global communications in 2030? Although spectrum is a scarce resource, technology will continue to unlock more capacity – and it seems certain that, by 2030, low-latency (read 'low Earth orbit') internet will be carrying many terabits per seconds, eclipsing (but not toppling) the traditional stronghold of geostationary communications and challenging the position of companies like the UK's Inmarsat. For anyone with a fibre to their home though, there is little incentive to dig up the cable. It seems safe to presume that satellite communication will remain dominantly about mobile, out-of-town and rapid start-up communication.

Big data world

Long-running Earth observation datasets will become increasingly valuable to science. Multi-decadal continuous data and global baseline observations are important for climate monitoring and decision-making. Services, such as the Copernicus Climate Change Service (C3S), led from Reading in the UK by the European Centre for Medium-Range Weather Forecasts' (ECMWF), will be vital in providing authoritative information about the past, present and future of our climate; this service alone has already delivered over 42TB of data to users – with ESA Harwell, just up the road, driving research on many of the data products that contribute.

Earth observation data is growing exponentially. The coming decade will continue this trend. The second-generation Copernicus rollout will expand the current programme capabilities alongside continued growth in commercial data from companies, such as Spire, whose 100+ 'Lemur' satellites are manufactured in Glasgow.

Commercial synthetic aperture radar, SAR, is already expanding (witness ICEYE's recent success) alongside video from space (eg UK's Anite) and very high temporal resolution imaging (Planet), both driven by the growth in small satellites pioneered in the UK. All are seeing key interest from defence users seeking more bang for their space-buck (MoD included).

The latter part of this decade will likely see commercial multi- and even hyper-spectral imaging. Once again, defence users will provide impetus for broader commercial success. These are bigger products, delivered at higher tempo, feeding 'big data' and, increasingly, AI applications.

Maritime and aviation traffic monitoring; supply chain and animal tracking; deforestation detection – all will give us unprecedented insights to global trade and supply, in a world where transport is never out of sight.

New space races

Today, the internet is the foremost battleground for national and commercial influence but, wherever humanity goes, we take our earthly ambitions and rivalries. The end of the original 'space race' in the early 1990s was, in hindsight, merely a pause; a unique geopolitical moment of Western (US?) monopoly of global power. A broader race is back on. For nations like the UK, space represents economic potential, strategic autonomy and vital defence capability. We have some catching up to do.

Competition will serve to define norms of behaviour – not just in orbit but also on the Moon and everything we land on after that. The US-driven Artemis lunar return programme accord is strongly opposed by Russia, which seems bound to turn towards China for partnering as the decade progresses. The accord seeks to interpret the 1957 Outer Space Treaty in a way which Russia perceives as biased to US state and private-sector interests. The UK, keen to participate in Artemis, has signed up. Whoever gets (back) to the Moon first, and stays there, will start to define the norms of how we 'rule' the resources of the Solar System.

Missions to look out for

Mars

The first steps in a Mars Sample Return mission have already been taken. The *Perseverance* rover, already at work on Mars, is collecting samples and leaving them as caches for a future mission to collect. If all comes together, ESA and NASA will work to launch a mission in 2026 which would set down close to *Perseverance* in 2028 and bring its samples back up to Mars orbit. A further mission would ferry them back to Earth by 2031.

NASA's 'Sky Crane' approach is a gamechanger in Mars exploration. Gone are the days of country-sized drop zones on the flattest areas available, miles from terrain features. The Sky Crane technology enables safe, repeatable, precision landings. Not only does that allow for collaborative missions and infrastructure deployment – but also opens the possibility for descent into hazardous terrain – such as canyons and mountainous regions.

Meanwhile, look out for Martian flight developments. With *Ingenuity* poised to demonstrate Mars-copter technology as this issue goes to press, we may see a more dedicated aerial exploration mission within the 2020s. Consider what a Martian helicopter, with a radio-isotope battery recharging system might be capable of (see also Dragonfly, destined for Titan).

The UK-built *Rosalind Franklin* rover (part of the ESA/Roscosmos ExoMars programme) will be heading off in 2022. China – and Elon Musk's SpaceX – will also be reaching out for Mars. We are entering a decade of both national and corporate branding on the Red Planet.

Institutional human spaceflight

The big news of the decade is expected to be America's return to the Moon's surface – the first humans there since Apollo 17 in 1972. The second half of the decade looks more realistic for this than the Trump deadline of 2024 but will the Biden administration and partners (including the UK) come up with the $20bn+ needed? If not, will Elon Musk's SpaceX step in?

Meanwhile, the current destination for most astronauts, the International Space Station, will run short of funding in about 2025. NASA's attention will turn to the Lunar Gateway, a human outpost near the Moon with the rationale of facilitating robotic and crewed missions to the surface. Assembly will begin in about 2024 with launch of the first two modules – on a SpaceX rocket, not on NASA's own super-costly Space Launch System. The Gateway's high price tag and somewhat fuzzy objectives have led to criticism in the US. Nevertheless, signed-up partners, including ESA, UKSA, Japan and Canada, see it as their route to sending astronauts beyond Earth orbit and driving their own national capabilities.

In 2023, India will likely become the fourth nation to achieve manned spaceflight (a modestly delayed celebration of the nation's 50th year of independence). Will India's next step involve a tie-in with the US, heading for the Moon?

India's great rival, China, will strengthen its lead in Asian-crewed spaceflight with the establishment of its Tianhe (celestial harmony) space station this year followed by its servicing and operation throughout the decade. Will Russia engage with Tianhe as it is doing in lunar exploration (see below), putting the nail in the ISS' coffin? Given the need to first develop a super-heavy rocket, the first Chinese or Russian citizen is unlikely to walk on the Moon until the 2030s.

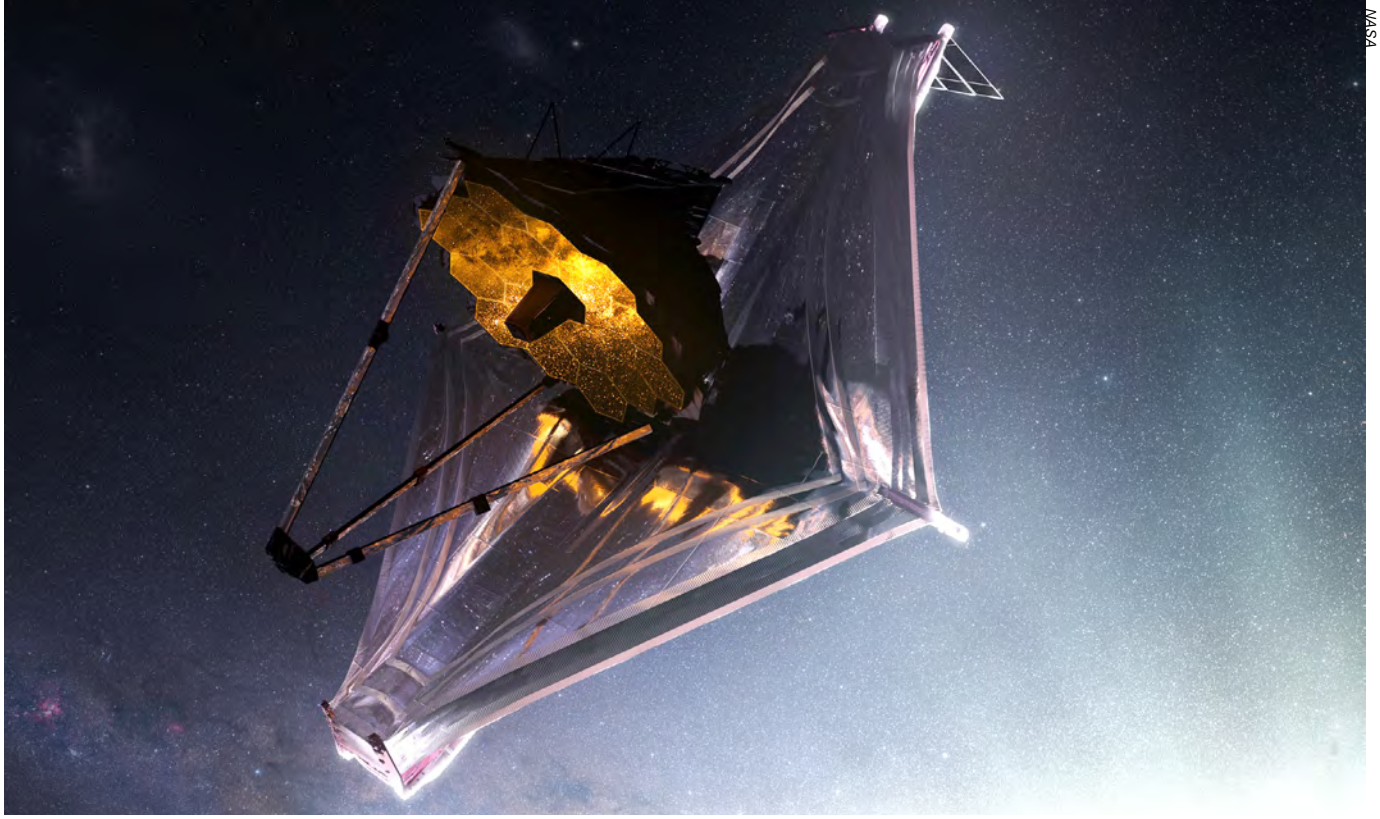
Private human spaceflight

Short trips into space to experience ten minutes of weightlessness and spectacular Earth views should become commonplace for those who can afford the c. $200,000 tickets that will be offered by Sir Richard Branson's Virgin Galactic and Jeff Bezos' Blue Origin from, perhaps, 2022. Within the decade such flights could be happening from the British Isles, where its sister company, Virgin Orbital, is already active. Adding two noughts to the price already gets you a week-long stay in Earth orbit onboard a SpaceX or Russian spacecraft and the price should fall when SpaceX's new Starship rocket is available, mid- to late-decade – perhaps to below $10m.

That same Starship will be able to take you around the Moon and back – one customer has already committed $100m+ for a six-person group to take that ride. Starship's visionary owner, Elon Musk, reckons he will be landing customers on Mars

Could Tim Peake return to space as part of the international Lunar Gateway and Europe's contribution to US Moon missions?

ESA



NASA

The UK provided the lead for the European consortium building the Mid InfraRed Instrument (MIRI) for NASA's James Webb Space Telescope.

before 2030 but many commentators see this date as 'aspirational' rather than likely. In any event, the private sector now seems well positioned to give any nation the chance to routinely fly its own astronauts, for a modest fee. The meaning of 'crewed space programme' may have just changed.

Solar System and beyond

An impressive catalogue of space science missions are lined up for the 2020s. Some are already in flight. BepiColombo reaches Mercury in 2025. ESA's Solar Orbiter (built in Stevenage) and NASA's Parker Solar Probe are both working closer and closer to the Sun. Parker will approach to within just 7m km of the Sun's 'surface' (compare with Earth at ~150m km).

Still to depart is ESA's JUpiter ICy moons Explorer (JUICE), arriving at Jupiter in 2029 before setting its sights on a close-up study of the complex moon, Ganymede. The Principle Investigator (PI) for the mission is Imperial College London's Michele Dougherty. NASA's Dragonfly mission will launch a few years later, in 2027, carrying a quadcopter destined for Saturn's moon, Titan (first visited by ESA's Huygens probe).

Other missions to look out for on the launch pad are targeting asteroids (NASA's Psyche to be launched in 2022, Janus 2022 and DART 2021; ESA's HERA 2024), the Jupiter system (NASA's Europa Clipper 2024), sample return from the Martian moon, Phobos (JAXA's MMX 2024) and ExoPlanet observations (ESA's Ariel 2029).

Throughout the 2020s, we can look forward to seeing the Universe around us in ways never possible before. Consider that, back in 2010, neither a comet nor Pluto had ever been seen as more than a distant ghost-like presence. Today, we have astonishing imagery of both, thanks to ESA's Rosetta mission and NASA's New Horizons probe. Launching this year, the James Webb Space Telescope (JWST) promises to be the Hubble of the 2020s. With its huge mirror and infrared camera, it will reveal a Universe around us that, today, we can only imagine. The UK has led development of one of its four instruments (MIRI), contributed to another (NIRSPEC) and provided components for the spacecraft.

UK Space in 2030

The timescales of the space sector are, necessarily, long. Nevertheless, rapid change is coming – and particularly in the UK, where an 'awakening' is already in progress. By 2030, we can reasonably expect the UK to be launching its own satellites on its own launchers, from its own territory. A national comms mega-constellation will be in orbit and a national navigation system may be under construction. A British-built rover will be on Mars. We might even have an astronaut on the Moon.

With recognition of space as a 'Critical National Infrastructure' sector, the government is duty-bound to build and sustain capability – for communications, for navigation and time, for observation and reconnaissance and for the protection of all those satellites that provide it. The laissez-faire approach of the past is no longer adequate. A sovereign UK Space Programme worthy of the title is reaching the launch pad. What a difference a decade makes.

ABOUT THE AUTHORS

Richard Lowe FRAeS is a space systems consultant and Head of GNSS (UK) for Rhea Group. Prof Malcolm Macdonald FRAeS is Chair of Applied Space Technology at the University of Strathclyde. Pat Norris FRAeS is a former Chairman of the trade association of the UK space industry, UKspace, and author of *Returning People to the Moon After Apollo* (Springer Praxis, 2019).

Commence ignition

The UK may not be a centre for large rocket engine design and development but it is developing unique niches for space propulsion that could pay off in big ways. TIM ROBINSON FRAeS reports.

Half a century ago, the lift-off of the final Black Arrow rocket from Woomera in Australia in October 1971 seemed to close a chapter in Britain's ambitions for outer space and with it the need for large rocket engines from companies, such as Rolls-Royce and Bristol Siddely. Launches were to be left to the US, Europe and Russia – with the UK focusing its efforts instead on satellites and payloads. Ten years after Black Arrow, another attempt to get the UK back into the launcher business via British Aerospace's HOTOL, which would have been powered by a Rolls-Royce RB545 'Swallow' air-breathing rocket, came to naught.

Fast forward to 2021 and, while the UK still lacks the kind of giant rocket engines developed for NASA, ESA and Roscosmos heavy launchers, it is now carving out new innovative niches in space propulsion.

Reaction Engines

Key among these is Reaction Engines, which sees Alan Bond's HOTOL concept tweaked and improved with its SABRE air-breathing rocket that allows 0mph to Mach 5+ operations. Unlike traditional jet engines that cannot cope as the speeds and heat builds up, Reaction Engines' precooler cools the incoming air in a blink of the eye, tricking the engine into essentially thinking it is travelling slower than it actually is. The benefits and applications of this technology are many, with some describing it as the biggest advance since the jet engine in the 1940s – from hypersonic flight, to increasing the efficiency of standard jet engines or for use in industrial power applications.

This concept is not a paper study either, with ground tests of the HX3 precooler and technical validation by other aerospace bodies in the US and Europe that the engineering is viable. Mark Thomas, CEO at Reaction Engines, says that the company has now completed major tests of critical sub-systems "which allows us to now put our thought towards bringing those technologies together in some form of demonstrator, and proving the core of a SABRE engine." Thomas is coy on concrete timelines for a demonstrator engine but says that it "would be within the next couple of years and not more remote than that".

> "WE'VE GOT A GREAT TECHNOLOGY BASIS NOW. SO THE REAL ART NOW IS HOW WE PUT THIS TOGETHER IN AN AFFORDABLE WAY WITH THE RIGHT PARTNERS WHO CAN MOVE WITH PACE
>
> **MARK THOMAS**
> CEO
> Reaction Engines

For spaceflight, though, a SABRE-powered spaceplane would allow single or two-stage-to-orbit operations by removing a large chunk of the oxidiser that traditional rockets have to take with them to burn as they ascend through the thickest part of the atmosphere. Instead, SABRE takes off as a traditional jet engine, before using its precooler to accelerate to hypersonic speeds. Once at the altitude where oxygen can no longer be drawn from the atmosphere, it then switches to internal oxygen tanks for the final part of the ascent. Using a SABRE-powered mothership in a two-stage-to-orbit, flying higher and faster than say the Virgin Orbit 747, means the second stage launcher can be smaller and cheaper. A SABRE-powered spaceplane would also "offer a higher payload capability than some of the systems that are going to be deployed in this first wave here in the UK," says Thomas,

He describes any SABRE-powered spaceplane as a "next or next-next generation of future launchers. We are not trying to compete head-on or directly with anything that's in the marketplace today". The flexibility of a SABRE-powered space vehicle means a two-stage system could potentially fly everyday, just like an aircraft, from existing runways, as well as relocate to. In addition to putting satellites and payloads into orbit, a spaceplane also has a unique advantage in that it can also bring payloads

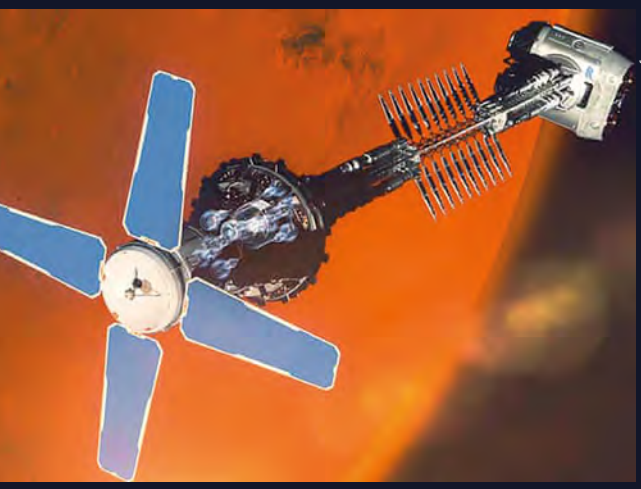
back to Earth. Thomas, however, notes that flexibility is not enough: "There'll be that continual pressure to drive down the launch costs. People will pay for capability and flexibility but fundamentally you would have to beat the best out there in the marketplace in terms of launch costs." – a reference to the market disruption posed by SpaceX. Asked if a SABRE-power launch system could beat Elon Musk's price to orbit, Thomas said "Yes. That would be the intent".

Interestingly, as well as big and bold ventures like spaceflight, the SABRE technology (particularly the precooler) may also be spun off into ancillary markets, such as electric vehicles, fuel-cell hybrid-electric aircraft and anywhere where heat management is needed. Says Thomas: "It's land, sea and air – so everything from cooling technology for electric vehicles, through to fuel cell-powered aircraft and waste heat recovery systems for clean energies."

Reaction Engines may also play a key role in helping the UK to rebuild post-Brexit relations with the rest of Europe as worries about the launcher dominance of SpaceX stalk European capitals. There is now widespread concern that Europe's next rocket, Ariane 6, will not be able to compete with the resuable behemoth that is SpaceX. Thomas explains: "We're doing a large amount of studies with both space agencies and industry partners to understand the utility of a SABRE engine and how that opens up the new space economy through reusable launches."

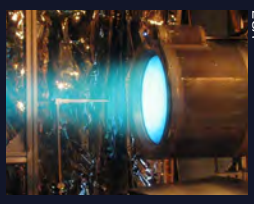
Rolls-Royce – next stop Mars?

Meanwhile, Rolls-Royce is thinking further beyond Earth orbit and is now partnering with the UK Space Agency to investigate the feasibility of nuclear power for long duration space missions. On Earth, R-R already provides nuclear reactors for Royal Navy submarines and is working on the feasibility of small modular nuclear reactors (SMR) which would provide safe, affordable mini-power stations to plug into the electrical grid of tomorrow – providing local power for the zero-carbon economy.



Rolls-Royce

Long duration spaceflight may need to rely on nuclear propulsion.



ESA

Above - QinetiQ's T6 electric thruster for BepiColombo under test.

While nuclear propulsion concepts were popular in the early years of spaceflight, worries about safety on launch meant that nuclear power in space has been confined to radioisotope thermoelectric generators (RTG), a type of nuclear battery that NASA has used on Martian rovers and on the Voyager space probes.

However, the shift to looking at longer duration missions, such as Mars, Jupiter and the outer planets, along with increased power requirements for say human-crewed spaceflight, means that nuclear propulsion concepts are now undergoing a renaissance. Particulaly attractive would be the capability of nuclear engines, with the potential to shorten flight times to Mars from around eight months (when orbits permit) to just three or four months. A reduced flight time would thus mean reduced radiation exposure and zero-gravity for the crew and also would mean fewer supplies of food and water would be needed for transit, potentially opening up longer missions on the surface.

Electric propulsion

The UK has also developed a niche in low-thrust but highly efficent electric propulsion that is expecially suitable for satellite station keeping or long duration exploration missions. Thales in Belfast, for example, is the UK's newest space engine facility for the Xenon Propulsion System (XPS) developed for the all-electric Thales Alenia Spacebus Neo satellite. QinetiQ, too, has been a UK centre for excellence for electric space propulsion since the late sixties, with four of its 5kW T6 Ion thrusters providing the power for ESA's BepiColombo Mercury probe. The most powerful electric propulsion system ever flown, the T6 thrusters will propel the probe to arrive in Mercury's orbit in 2025. QinetQ is also working on larger (T7) and smaller (T5) ion thrusters, building on experience with the T6.

Summary

The UK's long absence from the space launcher sector, and therefore its missing capabilities in larger chemical rockets over the past decades, could perhaps be seen as a missing piece of the puzzle. However, while chemical rockets will still be important, Britain has forged some unique capabilities in space propulsion that can help unlock the 'Space 2.0' economy, particularly in affordable, resusable, high-frequency space access but also in engines and power solutions for more long duration and sustained exploration of the Solar System itself. The match on the UK's blue-touch paper has now been lit, with Reaction Engines' Thomas saying: "We've got a great technology basis now. So the real art now is how we put this together in an affordable way with the right partners who can move with pace."

The UK space skills gap

CATARINA BALDAIA, and **ALEX GODFREY** (RAeS Space Group ECS) along with **JOSEPH DUDLEY** and **HEIDI THIEMANN** (Space Skills Alliance) look at the results of a recent survey on the skills needed to allow the UK space sector to really take-off.

ESA / S. Corvaja

When Apollo 11 set off for the Moon, the average age of the people in mission control was just 26. The average age of everyone working at NASA at that point was 28. Most were hired on CVs alone: no psychometric or analytical test, no group exercises and, in many cases, no interviews. By contrast, today's 26 year olds are finishing graduate schemes and thinking about their next steps. Working on a mission of the same scale as Apollo is a five or ten year career goal. Were the 26 year olds of the 1960s more skilled than their modern counterparts? How can the UK space industry help produce another stellar crop of scientists and engineers? Have we missed the boat?

What is the current status of the sector?

There have been a few changes in the sector since Apollo. One of the most notable is that space is no longer only the preserve of governments and mega corporations. The commercial space sector has finally come of age – witness NASA's commercial crew programme – and is growing at breakneck speed.

While NASA has always been popular, it is only in recent years that space in the UK has gone from an ugly duckling to a beautiful swan in the eyes of the media, public and government, thanks to the impact of Tim Peake's launch and the possibility of domestic launch capabilities. Brexit is likely to intensify this focus as the government looks for post-breakup national success stories and exclusion from the EU Galileo satellite navigation system may force the creation of a homegrown replacement.

UK growth has been strongest in the downstream sector, which uses data from space for everything from farming to monitoring of criminals on probation. New technologies, such as better cameras, have enhanced the quality of data and machine learning has made it easier to process huge data sets. All this data has attracted tech companies, both big and small, and it is easier than ever to start a new technology company.

The sector set itself a goal of having a global market share of 10% by 2030, double its current share of around 6%. To achieve this, it will need to attract and retain many new recruits while fighting off intense competition from tech and other sectors (who pay a lot more). It will also need to navigate more stringent post-Brexit immigration rules.

What are the barriers to achieving growth?

The space skills shortage is well documented, most recently in the UK Space Agency's *Space Sector Skills Survey* (S4), which found that more than half of

companies found it difficult to recruit but it is not an easy subject to get to grips with.

One major challenge is the complex structure of the sector and the long list of highly specialised skills that it needs. A key quote from the S4 report is that there is 'no obvious single focus for training … that would address a substantial proportion of the recruitment difficulties'.

Despite this, there are some broadly applicable skills which are in high demand, notably software, systems, and electronics engineering. Research by the Space Skills Alliance, last year found that half of all early career space jobs asked for software development skills. Catena Space, a space training provider working with the Space Skills Alliance, also found that graduates would benefit from better understanding of the challenges of the space environment (for spacecraft design) and how to apply quality assurance standards, such as ECSS and ISO. The skills gaps are becoming clearer but how to resolve them in an efficient and timely manner is a much more challenging question.

In many ways, the space sector resembles the early tech sector and risks repeating the same mistakes if it takes too long to address its recruitment and retainment issues.

Initiatives introduced in recent years offer a model to learn from. 'Zero to hero' coding boot camps have helped stem the shortage of programmers, and MOOCs (Massive Open Online Courses) have promised similar rapid upskilling. Similar programmes could be implemented in the space sector. However, they rely on close collaboration between the industry and training providers. This is something the sector does not have enough of at the moment.

> IN MANY WAYS, THE SPACE SECTOR RESEMBLES THE EARLY TECH SECTOR, AND RISKS REPEATING THE SAME MISTAKES IF IT TAKES TOO LONG TO ADDRESS ITS RECRUITMENT AND RETAINMENT ISSUES

University challenge

Employers report that, though graduates are in rich supply, they often lack specific, relevant skills and experience because these are not being taught at universities. Portia Bowman, UK Innovation Manager at D-Orbit, says that: "It's easy to recruit young people who are very capable but they don't have the experience". Despite the high demand for programming skills, not enough aerospace engineering courses include this as a core component.

This is not helped by a shortage of opportunities to gain experience. Data collected from delegates to the National Student Space Conference in 2017 and 2018 shows that there is a high demand for internships and research placements which significantly outstrips the number of available positions. However this has improved in recent years with the growth of Satellite Applications Catapult's Space Placements in Industry (SPIN) and student competitions, such as UKSEDS' Olympus Rover Trials, a challenge to design, build and test miniature Mars rovers.

An unwillingness to take a chance on those without experience and to hire and train those from outside the sector compounds the problem. Those applying to work on Apollo could not have experience, as the space sector was too new an invention. NASA's recruiters had to work with what they had and supported bright graduates to develop their skills and, in doing so, created the foundation of the modern industry. Today's recruiters need to do the same.

Broadening talent diversity

Much of the tech sector's problems were caused by its workaholic culture and rampant discrimination which put off almost anyone who did not fit the Mark Zuckerberg mould. A growing number of start-ups now consciously eschew Silicon Valley culture, expanding their talent pool by offering perks that appeal to working parents and funding programmes to train up those from under-represented backgrounds.

While the space sector's culture is not as bad, there is still a lot of work to be done. Among those working on Apollo were many brilliant women and BAME representatives, including Margaret Hamilton, Katherine Johnson, Dorothy Vaughan, and Mary Jackson, the latter three of *Hidden Figures* fame. Results from the 2020 Space Census show that a half century later, the UK space sector is overwhelmingly made up of straight white men.

Why? For starters, recruitment and retention are one end of a very leaky talent pipeline. Extensive research into STEM uptake and attitudes in schools have found that girls turn away from a career in science and engineering at a very early age and at every stage are less likely than their male counterparts to continue on a path to the sector.

This is a result of a range of factors, including lack of encouragement, gender stereotypes perpetuated widely in the media and by the industry, and toxic cultures within companies. The Space Census found that approximately 38% of women, 29% of BAME people and 15% of disabled people have experienced discrimination.

It did not help that two years ago, when astronauts Jessica Meir and Christina Koch were

Left: A young visitor to the RAeS HQ embarks upon her first space-focused training session, while, below her, an ESA astronaut is involved in more advanced training.

NASA

A NASA astronaut in training.

scheduled to conduct the first all-female spacewalk, the male-first thinking of much of the sector was revealed when NASA realised that it had not provided enough smaller space suits to fit both female astronauts. Meir was replaced by her male colleague, Nick Hague, a metaphor for recruitment everywhere.

The sector must do a better job of addressing these issues and proactively supporting efforts to get more people from under-represented groups into STEM. Outreach is not enough. Many studies have shown that the effects of one-off outreach activities are minimal compared to long-term in-school ones. If the sector is truly committed to closing this gap, then it needs to be funding STEM programmes with proven impact, not just those that make for the best publicity.

These programs need to be supported at the earliest point in a young person's education. Some studies have found that even by the age of 7, children held stereotypical views on jobs. At this age, four times as many boys wanted to become engineers compared to girls. Early interventions can have a lasting impact and be a pivotal influence on a child's perception of different occupations.

Improved reach

A huge amount of work has gone into raising awareness of space among school students and the public, most notably during the Principia campaign for Tim Peake's launch. UKSEDS, the national student space society, has made space a much more visible career path, particularly through SpaceCareers.uk, a careers advice website and early career jobs board. Many of those students go on to participate in the SPIN programme, a vital pathway for gaining work experience.

When it comes to recruiting these graduates, the sector does itself no favours in the way it advertises. A Space Skills Alliance report on space job adverts found that, when rated against 10 best practice criteria shown to make jobs more attractive to under-represented groups, the average advert scored just 54 out of 100, and only 8% of adverts scored 75 or more.

Better job adverts are an easy fix with impressive results. Thames Water rewrote an advert for sewage technicians and saw the proportion of female applicants increase from 8% to 46%.

Keeping talent in space

The talent pipeline extends well beyond recruitment however. The S4 report found that graduates tend to leave after a few years when they realise their skills have increased at a faster rate than their salary. This has led to a growing shortage of mid-level professionals and those who remain in the sector tend to get poached and hop between space companies on an almost annual basis.

The Census found that about 4% of people are in the process of changing jobs, 10% are actively looking and 32% are open to changing for the right opportunity. Together, that is almost half of the workforce.

There is a similar story in the United States. A 2016 report of the American space sector by the Society of Space Professionals International (SSPI) found that, of employees with one to five years of service, a whopping two thirds choose to change employers.

Why all this chopping and changing? This is a topic that needs more research but what evidence we do have points to poor working conditions. The Census found that approximately 14% of people have a bad work-life balance and minorities in the sector experience a high level of discrimination.

The cost to the sector of these recruitment and retention issues is substantial. Skills gaps hold back

Space Careers UK

Astronauts may still get the glory, but there is an ever expanding number of space careers and opportunities available for young people.

growth, delay work and increase workloads for the remaining staff (further compounding the problem). Time spent on the recruitment process and bringing new hires up to speed is also expensive and, without proactive steps, this problem will only intensify.

To properly tackle it, we need joined up thinking between industry, government, and academia, and we need to learn from mistakes made elsewhere. Industry needs to be clearer about what their skills needs and expectations are, and academia and other training providers need to better match their courses to those needs. There is a role here for organisations like the Royal Aeronautical Society to act as a bridge and to ensure that the courses such organisations accredits are up to scratch. In addition, training courses and events in some of the unique challenges of space are needed from a variety of providers to support the upskilling of non-space sector entrants. This could be co-ordinated through a central portal which the UK Space Agency could support with modest resources.

There needs to be better support for long-term STEM initiatives in schools that address the early stages of the pipeline and more opportunities to gain experience. Programmes like SPIN aimed at graduates need to be expanded and equivalents for apprentices need to be developed, alongside pathways for engineers to advance in their careers without taking on management responsibility. Programmes like the Civil Service Fast Stream, designed specifically to get people quickly into leadership roles, offer possible approaches to addressing the shortage of mid-level professionals.

More inclusive job adverts will help broaden the pool of applicants and a greater focus on retention through better work environments and culture change will help these actions have long-term impact. This is perhaps the hardest and least flashy task but one of the most important. Culture will not change of its own accord; it has to be deliberately and continuously developed through actions, not just a list of values at the top of the staff handbook. If it is not changed, it is easily replaced by the status quo, which is too often subtle (and less subtle) sexism and racism. We must not allow this to happen.

Looking ahead, beyond the stars

The coming decades promise to be an exciting time for our sector. Low-cost domestic launch will open up new markets and new opportunities. The challenges of space debris and climate change will be ever more pressing and together we will push the boundaries of science and technology even further, to the Moon and perhaps also to Mars.

To achieve all this, we need skilled people of all types from all backgrounds. That means we must open our sector to people we have not considered before. The 26-year-olds of the 1960s were not smarter, or more skilled, or better educated than today's graduates; they were just all that was on offer. NASA had no choice but to take a risk, to trust that bright, hard working people properly supported can achieve extraordinary things.

We must take that same risk today. We again find ourselves with too few experienced hands and a wealth of smart and motivated youngsters willing and able to transform our industry and we must again trust them to achieve extraordinary things. Why? We have no choice.

It is not too late but our skills shortage is not going to resolve itself. We can sit and we can do nothing, rotating the same few highly qualified people from company to company, or we can learn from the mistakes others have made and choose to take action by engaging more closely with educators, by removing unnecessary barriers and by taking a chance on those who dare to dream.

When we do make it to Mars, perhaps mission control will once again be filled with 26-year-olds in whom we have chosen to put our faith in.

A contender from the UKSEDS' Olympus Rover Trials.

UKSED

Plane Speaking with:

Air Vice-Marshal Paul Godfrey

Crown Copyright

On 1 April, the UK's first Space Command was formed, a historic milestone the development of Britain's military space ambitions. *AEROSPACE* caught up with its newly appointed RAF commander, Air Vice-Marshal PAUL GODFREY OBE FRAeS, to ask him about the challenges ahead.

AEROSPACE: What is Space Command? How did it come about?

AVM Paul Godfrey: The history of the command is relatively brief having been born from an announcement in the 2019 Conservative party manifesto. This laid the intent to form the command. As work on the Integrated Review progressed it was identified that a command would feature in the review, this ultimately led to the Prime Minister officially announcing it in November last year. From being appointed as Commander UK Space Command to taking over the role was incredibly quick, a matter of weeks rather than months. I think the timing is perfect. Today we see that the UK needs the ability to contest actions that may threaten the UK, across all domains including space. The national interest in space has also been enhanced with the efforts of SpaceX, NASA and the UK with the likes of Starlink and OneWeb. The MoD's Space Directorate formed first, under AVM Harv Smyth a year ago. They became the focal point for all defence space-related policy, cross-government liaison and MOD international discussions. With the birth of Space Command, we are now the focal point for operations, training and capability. The UK Space Agency will also be an incredibly important relationship in all that we do. The Space Directorate and UK Space Command will work closely to ensure that UK Space Command's foundations are built on collaboration across the space enterprise in the UK and abroad.

We formed on the 1 April and will stand up in June and take over our new headquarters building at RAF High Wycombe. Our aim is to then quickly transition to Initial Operating Capability in the first half of 2022. This first year is about setting the command structures for future success, working with our allies and increasingly closely with industry, academia and the commercial sector. On formation, we took command and control of RAF Fylingdales (with its secondary role of space surveillance) and the Space Operations Centre (SpOC) at RAF High Wycombe.

AEROSPACE: What is Space Command? How did it come about?

PG: We currently have around about 300 personnel, most of whom are based at Fylingdales or in the SpOC with the headquarters itself still building in terms of workforce. We are recruiting people from all three services and the civil service and will expand this to work with academia and industry. In terms of capability development, the potential is huge and we took on an amazing space capability team that had been working for AVM Linc Taylor in Air Command. They've now transferred to the UK Space Command and we're looking to expand the team whilst ensuring we have the right people with the right skills. The first stage be to undertake a training needs analysis where we will work out what skills and education are required across defence and wider government. This will be done in close cooperation with the civilian space sector, to ensure we can support each other rather than duplicate efforts. As I have mentioned, collaboration is key, and we will focus on this area with our allies too. What we will also need is flexibility, that is well understood in air and I know will be one of the keys to effective space power and will allow us to shape the command as we grow.

AEROSPACE: Where does Space Command sit in the chain of command? Does it come under the RAF?

PG: We are a joint command working as the defence focal point for space operations, training and capability as I mentioned. The command will, therefore, need to be representative of defence in its workforce and outlook. Historically the Royal Air Force had been defence's lead on space operations and so that is where most of the current experience is. There'll be a high proportion of RAF to Army and Navy to begin with but I would like to see this even out over the coming years as we build the space expertise across defence. We sit under the RAF and the Chief of the Air Staff has supported the commands establishment, no small feat in the current climate of constrained movements due to COVID. I currently work very closely with Air Vice-Marshal Ian Duguid, Air Officer Commanding 11 Group as they are the RAF's multi-domain operations group. We are working with them to ensure we develop and enhance their work around Space and how it supports the other domains. It is very much led by the RAF at the moment, but that will change over the years as we evolve our direction, understand what our structures are going to look like, and understand more how space affects our day-to-day operations.

> "ULTIMATELY WE NEED TO WORK WITH ALLIES AND PARTNERS, UNDERSTAND WHERE THERE ARE ANY CAPABILITY GAPS, AND FOCUS OUR CAPABILITY DEVELOPMENT IN THOSE GAPS

Left: In 2021, the RAF announced the creation of new 'space operators' wings.

AEROSPACE: What do the day-to-day operations of Space Command involve? Presumably satcom and space surveillance?

PG: You've hit the nail on the head, but in order to do that we need to understand the environment we will be operating in. It is the same as any environment defence wishes us to operate in, to be effective we must understand what is going on. You can imagine the first time you put troops on the ground in country X. You are going to look at the terrain through maps, images and try to understand the lay of the land, the threats and so on. You'll want to see the adversary before they see you, this gives you the tactical and, in some cases, the operational or strategic edge. Understanding the space domain is the number one priority for the command and that is very much what Fylingdales and the SpOC do. Once we understand it, then we can look to ultimately protect and defend the UK and allies' interest in space. It is important to remember space continually evolves, both naturally and with human intervention and so requires constant interaction. You saw AVM Harv Smyth, last year, highlighting possible nefarious activity in space, but you can't do that unless you have the sensors and trained people to understand it. That's space as an operational domain.

A task ahead of us is taking on Satellite Communications from UK Strategic Command. This means we will be taking over the day to day operations of the Skynet satellites, and the way we do that is going to change over the coming years. It is currently done by Airbus as a Private Finance Initiative, but we'll take on more and more responsibility for that in the future. But I return to my original point, the biggest thing is understanding what's going on up there, so called space domain

awareness. This isn't new to defence and is exactly the same in the other domains. I have recently come from the Combined Air and Operating Centre (CAOC) in Qatar where Air domain awareness was the primary mission before we did anything else. It's the same for space, to enable us freedom of action to do what we need to do in terms of military operations around the globe.

AEROSPACE: Are you at the stage where you can run space 'Red Flag' style exercises?

PG: At the moment, we are not looking to organise large-scale space 'Red Flag' exercises. We do participate in those exercises with various partners and allies, as I mentioned before we are seeking to minimise duplication unless there is a clear national need. The US runs some hugely impressive exercises and wargames and we will continue to participate in them. Importantly we will constantly assess the training to ensure it is delivering the very best to personnel in the commands that require it. We will continue to build space as a more active component of defence's exercises. You'll see this in exercises like Cobra Warrior or other large-scale exercises hosted by formations like the Allied Rapid Reaction Corps (ARRC). We will look to play down at the tactical level via denial of GPS, and all the way to strategic with the denial of SATCOM and will test defences backups for providing command and control. As an example, we've got a war ame this month we're sitting down and talking through several scenarios to do with UK operations. Unsurprisingly, given my last job, the first people I spoke to were the Carrier Strike Group's commander and various deputies for the upcoming Carrier Strike Group 21 (CSG21) deployment. What, in training terms, do we need to do for them to be ready when they actually deploy? It is understanding the space environment, and understanding if there are any issues, especially when you're on a ship. The Royal Navy understand how important assured communications are and we will, with UK Strategic Command, support them in providing this service.

AEROSPACE: So the CSG21 will have a 'space liasion officer' onboard?

PG: Yes it will. It is no different to everything we do in any of the other domains where we supply Liaison Officers to partner commands or flanking units. In the CAOC, we had a significant number of liaison officers from across the domains and had reciprocal CAOC air representatives out in the other domains. This is to ensure that you've got an expert and translator talking about air to those who may not have as deeper understanding of that domain. We see that as key in the future. HMS *Queen Elizabeth* will have access to UK Space Command when she deploys, and we will ensure the commander has what they need to make the right decisions. I think that cross-liaison is key as we look to get into full multi-domain operations.

AEROSPACE: What UK space industry capabilities have impressed you so far in developing UK space power?

PG: One of the best things I've done so far was the visit to the Space Cluster at Harwell, which has

USAF

Crown Copyright

Above: the RAF's Carbonite-2 satellite, launched through the Rapid Capabilities Office.

around 105 different companies and 1,000 people doing really impressive work. In the six hours that I was there, I saw so many different and amazing small companies doing different, ground-breaking work. Whether it's building antennas for spacecraft or people working in the electromagnetic spectrum, the teams there are truly impressive. I think in the UK, the breadth and innovative expertise that we have is second to none. How do you harness all of that? The National Space Strategy and the Defence Space Strategy will give a framework of where we are going and how people can support our efforts. As I have already mentioned the command will work increasingly closely with the civilian sector to push forward. We see the use of forums being the main conduit that will enable us to get the smallest space start-up and the largest primes in a room and shape where we are going together and in a collaborative manner. I think the thing that's most impressed me, is the breadth of the space industry in the UK which I had no idea about before I came into this job. It is what makes it so exciting.

AEROSPACE: You have also mentioned the potential of tapping into amateur astronomers as a space 'Home Guard' or perhaps more appropriately an 'Orbital Observers Corps'?

PG: As I have already mentioned, our primary mission is understanding the space domain. I had a friend who lived close to me in Lincolnshire about 10 years ago. He was one of those guys with a surprisingly large telescope pointing up at the universe in his back garden that I mentioned in the FASI webinar the other week. This made me think, how do we draw on the lessons and skills of these people? They may have a level of expertise that would take us years to build. It is a tongue-in-cheek line, but there is a seriousness to my point; how do we harness that ability, because I guarantee, if you manage to do that in the UK right now, you would have a significant base of expertise.

AEROSPACE: What are the UK's strengths as an emerging space power? What can the UK offer to allies like the US that already have huge capabilities in spy satellites?

PG: I don't think, in any way, shape or form, we could replicate the network that the Americans, the Russians or the Chinese have in terms of military-use networks of ISR satellites. But I don't think we need to, because there will be a sweet spot in terms of what commercial partners could provide and what we can develop in defence and dual use of various satellite capabilities by both the civil and military sectors. Earth observation in terms of climate change, is enormously important today in terms of taking measurements, whether it is sea levels, emissions, weather, or other areas. It's exactly the same technology as getting eyes in the sky, if you like, over the top of a point of interest on earth for a military application. Ultimately we need to work with allies and partners, understand where there are any capability gaps, and focus our capability development in those gaps. But at the same time, working with a whole range of other partners in the UK to determine if there's a gap nationally and if we can make it dual use. I think we can be really clever about this, rather than just try and replicate what others have done for the last 50, 60, or 70 years.

We have learnt from the stand-up of Space Force in the US, Within the CAOC I spent a lot of time talking with the space and the cyber teams, because that was where my knowledge gaps were. My rate of learning was steep, I learnt a huge amount about how the US do things and saw the transfer of several personnel to US Space Force. The really interesting elements there are the cultural aspects of standing up an entirely new force for a new domain, something we haven't done since 1918.

For the UK, I think the advantage we've got is that because we are small, we can draw on lessons from our allies and essentially start the command from new, without precedent. Our size makes us agile. We don't have large and complex command and control structures, which are required when you have large amounts of capabilities, large amounts of people. Trying to simplify things as we move into this multi-domain area, I think, will be key. That's where I think the UK has a USP in terms of its agility and flexibility.

SARAH CRUDDAS looks at the growing number of rocket companies aiming to launch

Launching Britain

The way we explore space is changing, whereas once one might have associated launches with NASA and Cape Canaveral, on the aptly named Space Coast of Florida, or perhaps even with the less accessible and once secretive Baikonur in Kazakhstan – home to the launch complex for Roscosmos, the Russian Space Agency. Today, however, space exploration is no longer a tale of two superpowers and, as a result, neither is where we can access space from.

From New Zealand, to China, South America and Alaska, the locations from where we launch to space are global and the list is growing all the time. To quote Mike Curtis-Rouse from the UK's Satellite Catapult: "If you can think of a country, there's a good chance that someone there is thinking about building some forms of launch vehicle."

Of course we are not talking about human spaceflight. For a while our Space Age dreams of regularly crewed flights and deep space missions might have not yet come to fruition, a much more subtle Space Age has been slowing creeping upon us in the decades since Sputnik became the first human object to leave Earth. Today, living in what I like to describe as our unexpected Space Age, the vantage point of Earth orbit has enabled us to use satellites to look back and have slowly transformed life on Earth – in an industry term known to many as 'downstream applications'.

The opportunities from 'downstream applications' are plentiful, from security to connectivity, communications and scientific studies. Our modern world has been transformed and the demand for access to assets in space and their potential to continue to disrupt and transform life on Earth is continually growing. Currently, there is a bottleneck of payloads and satellites needed to get to space and the demand for more is continually growing.

So it makes sense that, with this ever increasing demand, there are more countries looking to have launch facilities for satellites. Among them is the UK – a nation which many others might not initially associate with the space industry but which has steadily and, in a very typically British way of shunning fanfare, developed as a leader in the manufacture of small satellites and currently builds a high proportion of the world's small satellites. The potential to soon be able to launch those satellites from the UK presents an attractive option for future customers – with the UK able to offer manufacturing, launch and operations – essentially the complete package. The hope is that this will encourage new customers and help the UK claim a slice in the launch market, set to be worth £25bn globally over the next two decades.


Orbex

There are also numerous other benefits, from jobs creation to increased defence capabilities without reliance on other governments, as well as the chance to become a leader in this new emerging market. However, it is the ability to be able to provide the full product life cycle of a small satellite which really helps the UK stand out.

Of course there are challenges to this, among them the development of legislation and the investment needed to create launch vehicles and facilities. However, if these challenges can be overcome, the space industry in the UK presents a field with strong potential for growth in a post-Brexit Britain, given the incubation and innovation activities that have been occurring over the last decade. Britain could take a key share of the market and a pivotal role in a new era for the space industry.

Today, several organisations have turned their eyes to 'launch' in the UK, with locations ranging from Scotland to Wales and Cornwall. According to Curtis-Rouse: "There are 16 or so companies in the UK today building launch vehicles, which is a great opportunity. Tie that in with the activity around spaceports and tie that activity around supply chain manufacturing and development and this is a really good win for the UK."

The current hopeful offerings in the UK include both vertical launches, using a rocket launched from the ground, and horizontal – where a rocket is launched vertically from an aircraft. Each method of launches has different advantages, vertical for example has a much greater launch capacity than horizontal which can only take small satellites, whereas horizontal launches have advantage over more traditional vertical launches on cost because you are able to launch from higher in the atmosphere, therefore needing less fuel.

Even though we might not see a British astronaut head to space from home soil any time soon, the launch industry in the UK is – excuse the pun – about to take off!

So who are these key players who are set to launch from the UK? And where are they planning to launch from? Here's a brief overview of some.

Skyrora

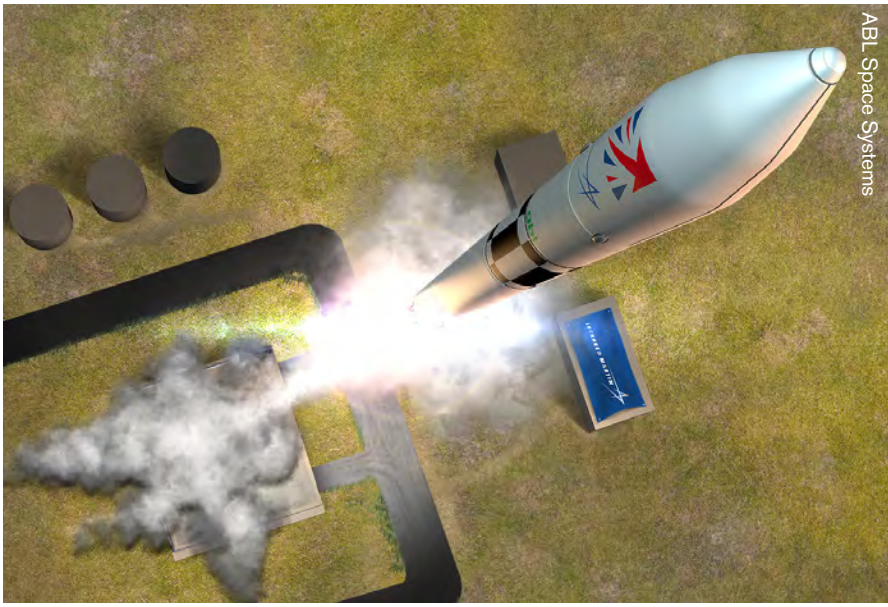
With its headquarters based in Edinburgh, as well as centres in Ukraine and Europe. Skyrora's goal is to clear the way for small satellite manufacturers looking to access space. Founded in 2017, it recently were awarded funding from ESA Boost – the European Space Agency's commercial space transportation Services and support to Member States Program – worth €3m. The goal is to work towards the 'launch gap' and provide access to space for micro to small satellite manufacturers and the company specialises in the manufacture of

Artists' impressions of rockets produced by (from left to right); Orbex, Black Arrow and ABL Space Systems.

from the UK from vertical spaceports by aircraft, balloon and even ships.

into space

Black Arrow



ABL Space Systems

launch vehicles. In 2018 it successful conducted Scotland's first commercial rocket launch by a private company at the Kildermorie Estate in Ross-shire.

Orbex

Like Skyroa, Orbex was also recently awarded funding from ESA Boost – a sum of €7.45m. The company has a focus on the small launch market – with plans to launch small, micro and nano satellites and is currently developing a light launch vehicle called Prime.

Orbex is known for its more environmentally friendly way of intending to launch, using a wide range of advanced materials to create each launch vehicle, including carbon fibre and graphene composites for the main structure and tanks, in addition to low carbon fuel that cuts carbon emissions by 90% and lightweight 3D printed rocket engines.

With an HQ in Forres, as well as offices in Denmark, Orbex hopes to have launches in 2022 from both the Sutherland Spaceport in Scotland, as well as from the Azores.

Virgin Orbit

Launching from Spaceport Cornwall in Newquay, Virgin Orbit intends to provide a horizontal launch service in the UK, helping to lower the cost of access to space, as well as also helping to bring jobs and development to Cornwall.

Using one of the UK's longest runways – 2,744m long – Spaceport Cornwall benefits from a low population density and access to the sea, as well as tracking solutions provided by the nearby Goonhilly Earth Station, one of the world's largest satellite Earth receiving stations.

From this site, Virgin Orbit will provide horizontal launches for small satellites – typically of masses between 300-500kg – using its carrier craft and two-stage vertical launch vehicle. The types of satellites that can be launched include everything from Earth observations to asset tracking and climate monitoring.

Dragon Aerospace

Based in South Wales, Dragon Aerospace is working towards vertical launch. Its launcher is currently in development and its team has conducted a launch in the Vale of Glamorgan using its Red Dragon One small-scale test vehicle. The rocket is the first of many test vehicles that Dragon Aerospace intends to use to develop the technology needed for high altitude launches.

Raptor Aerospace

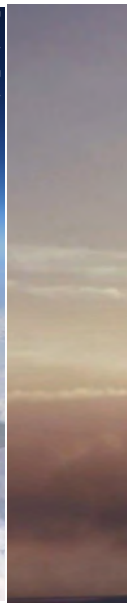
Raptor Aerospace is a commercial sub-orbital rocket launch company which operates from a former RAF base in East Anglia. Raptor Aerospace has a fleet of vehicles capable of carrying small payloads to altitude of 15km and has begun flight testing vehicles, capable of testing altitudes in access of 100km.

Its goal is to provide service for small launch payloads to high altitudes using its existing Kestrel launch series, as well as larger launch vehicles which are currently in development. This includes Merlin which will be capable of getting payloads of up to 5kg up to 70km and Peregrine which, Raptor Aerospace says, has the potential to launch

More computer-generated images of proposed UK rockets including (from left to right): Raptor Aerospace's rocket, Reaction Engines' Skylon, the Red Dragon One test vehicle from Dragon Aerospace, the Skyrora XL rocket and Virgin Orbit's LauncherOne.


Raptor Aerospace


Reaction Engines



payloads of up to 16kg to an altitude of 100km and provide up to three minutes of stable microgravity before re-entry and recovery.

Sub-orbital launches are of importance, particularly as they provide a low cost way for the testing of sensors, to ensure they can survive the rigors of launches, as well as atmospheric testing.

Black Arrow Space Technologies

Reinvigorating the name of Britain's first rocket – the Black Arrow – Black Arrow Space Technologies is a new British company developing spaceflight tech to launch satellites into orbit. The company aims to launch payloads of up to 500kg into polar orbit or 300kg into sun synchronous orbit.

Using its vertical launch vehicle, what is unique about Black Arrow Aerospace Technologies is its intention to launch from the sea using a launch vessel and support ships. This offers the flexibility of being able to move the launch vessel to wherever is needed.

Design and development work is currently taking place in Oxfordshire, with engine test stands and ship fleet based in South Wales. The company plans for initial launches to take place from the Atlantic Ocean, south west of Ireland.

Reaction Engines

Reaction Engines is perhaps one of the more well-known British space companies, building the SABRE engine, as well as the Skylon spaceplane – a series of concept designs for a reusable single-stage-to-orbit spaceplane.

Based in Abingdon, the highly efficient SABRE engine is making more capable space systems possible, by eliminating the need to carry on-board oxidizers during air-breathing flight segments. This has huge potential for the future of horizontal launch – reducing cost, infrastructure and mission timelines.

B2Space

Founded in 2016, B2Space intends to provide reliable flexible and low-cost access to low Earth orbit, based on the concept – 'rockoon' – rocket and balloon. The company intends to use a stratospheric balloon, which will lift a self-operating platform to an altitude of 35km, from which the launcher is then deployed. It intends to use a three stage solid propellent rocket to deliver small satellites, cube satellites or nano satellites into LEO (low Earth orbit) from this altitude.

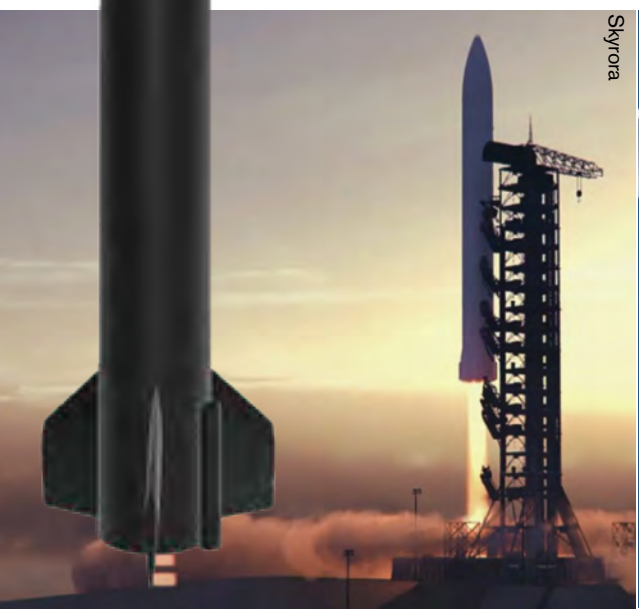
It intends to be able to launch payloads up to 150kg and provide a low-cost solution for the current launch bottleneck. Testing for this concept has taken place from Spaceport Snowdonia in Wales.

ABL Space Systems

Meanwhile, ABL Space Systems will conduct a launch for Lockheed Martin from the Shetland Islands – at the Shetland Space Centre which is currently being developed. At present the mission, known as UK Pathfinder, will place into orbit a tug – a type of spacecraft used to guide small satellites to their final orbit – developed by Moog UK, that will be used to deploy six CubeSats.

The mission scheduled for launch in 2022 is planned to be the first ever vertical small satellite launch from the UK.

Dragon Aerospace



Skyrora

Virgin Orbit

Airbus

Local heroes

From CubeSats to Mars Rovers and from mega-constellations to deep-space probes, Airbus Defence and Space is the home team that makes up 70% of the UK's fast-growing space sector with €1bn in revenue. TIM ROBINSON FRAeS profiles the powerhouse that is aiming for the stars.

Think 'Airbus UK' and you might think airliner wings from Wazzzles, or perhaps, the A400M Atlas. However, the company, via its Defence & Space arm, is also the heart of Britain's fast-growing space sector.

Its capabilities range from commercial telecoms satellites, (every TV satellite broadcast in the UK comes from an Airbus-built satellite) to Mars Rovers, from Skynet secure military satcoms to CubeSats, mega-constellations, solar probes, weather monitoring and even space debris removal. Indeed, pick any European space mission and there is a good chance that AirbusDS has been involved in some way or other through either the UK or one of its European arms. The only space sector (at least in the UK) that it is not involved in, is launchers. Its business divides between 40% commercial, 40% defence and 20% institutional customers – giving it a 'virtuous circle' of sustainable business, according to Sarah Macken – Director of Business Development, Airbus Defence and Space, who says: "our commercial success gives choice to defence and hence underpins and helps make institutional campaigns more affordable."

In the UK, the company is located in Stevenage (satellite design and manufacture), Portsmouth (payload, instruments and electronics), Corsham (comms services), Leicester and Guildford (mapping and imagery analysis, subsidiary SSTL – SmallSat design and manufacture). It has 6,500 highly skilled employees and is the second largest aerospace and defence investor in the UK. This year, it has also taken on the UK's first ever 'space apprentices' – with 19 young people joining the company.

As part of the larger pan-European Airbus, there is no doubt that Brexit has had an effect on business, thanks to the high-profile exit of the UK from the EU's Galileo satellite navigation programme. Macken admits: "Being out of that is eroding our capability in UK PNT (precision navigation and timing) – it was an area where we were leaders in the past. So, we are losing ground in that area at the moment. But, if we can get a national programme under way, then that could be reformed quite quickly."

Yet as one door closes, more doors are potentially opening up, with the UK developing its own post-Galileo GNSS solution, the acquisition of OneWeb, a New Space Command, a shift to develop sovereign space ISR capabilities, upcoming National Space Strategy and UK spaceports – making this the most exciting time for Britain's space sector.

Let's take a look across Airbus' space portfolio

Telecommunications satellites

Much of the 'bread and butter' of Airbus' commercial business has been from telecoms satellites, ranging from OneSat to the new reprogrammable Eurostar Neo and a multimission Arrow – a new low-cost platform derived from the OneWeb satellite. Its Eurostar Neo features electric propulsion, allowing a larger payload and a digital processor – enabling the satellite to be reprogrammed throughout its life. Despite a tough market for GEO telecoms satellites, Airbus has sold eight in the past two years, the most recent one being a OneSat platform to Japan's SKY Perfect JSAT. The company now has four full electric satellites operational in orbit and 17 more electric telecommunication satellites under construction.

OneWeb – a fantastic opportunity?

Airbus also is responsible for building the OneWeb broadband satellite mega-constellation, which eventually aims to field a giant network of 6,000+ small satellites in LEO. From its factory in Florida, Airbus is pioneering the mass production of low-cost broadband satellites, leveraging decades of experience in optimising production lines for airliners.

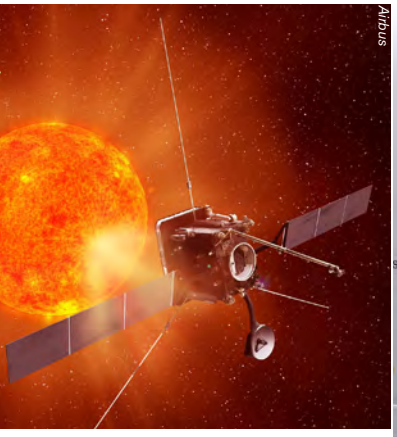
Rescued from bankruptcy by the UK government and an Indian billionaire, Airbus is keen to highlight the future potential of this strategic asset for Britain – with multiple applications that go beyond its already immense value as an LEO broadband constellation able to bring low-cost high-speed connectivity to remote regions. "I think the UK have got a fantastic opportunity, taking ownership of one of the first mega-constellation providers," says Airbus' Macken, adding: "OneWeb has really spearheaded a new era".

Airbus believes that OneWeb satellites, fitted with hosted precision navigation payloads (PNT), could provide low-latency, GNSS services with 20cm accuracy – providing the UK with a highly resilient and unique satnav alternative to Galileo.

As UK Space Director Harvey Smyth notes of any UK Galileo replacement: "We don't want to copy GNSS or Galileo, with 24 satellites in MEO – we want to do things in a different way, so that we can offer meaningful resilience to others," adding: "that would give us a seat at the table".

PNT payloads and the low-latency connectivity of a OneWeb comms/GNSS would not just benefit military customers, says Airbus, but could also help unlock the revolution of a 5G/Internet of Things (IoT)

Left: An artist's impression of an Airbus Skynet 6A satellite.



Airbus

Airbus Defence and Space

Above: Solar Orbiter – built by Airbus.

Right: Manufacturing of a BIOMASS satellite at Airbus' Stevenage factory.

society, where pinpoint accuracy and broadband connectivity could enable self-driving cars, package delivery drones and urban air mobility (UAM).

The company also foresees that the OneWeb LEO constellation, linked in a 'mesh' network with GEO Skynet military communications satellites, could provide highly resilient and superfast connectivity for UK forces and boost critical national infrastructure.

Instead of ground stations providing a two-way uplink/downlink of getting data or a message to commanders, a combination of OneWeb and Skynet satellites could see the message routed among different nodes to optimise speed and security – turning space into multi-node 'Internet' or 'Combat Cloud'. Airbus has already trialed conformal antennas on the A400M and in the future it is likely that similar technology will make it onto Tempest. That then, could potentially enable a Tempest pilot on the other side of the world to transmit HD targeting imagery to HQ in London, or receive moving satellite video directly into the cockpit.

Airbus also proposes that, while Gen 1 satellites would be built in Florida, a Gen 2 production line could be brought to the UK. Says Macken: "For Generation Two, we're committed to delivering that in the UK and having a production line based here." Opening such an 'Industry 4.0' mass-production satellite factory in the UK (with potentially the ability to pull satellites off this line to upgrade and modify them with other sovereign payloads, such as navigation or climate) would thus give the UK a highly valuable industrial asset in the 'New Space' race.

Allen Antrobus, Director Military Space, Airbus Defence and Space, agrees on the wider potential of OneWeb: "Can you now bring mass manufacturing to the UK and really put our stamp on the global stage? Can we do something different with PNT you know, or are we just going to leave it to the Americans again?" Indeed, the idea of leveraging commercial LEO constellations, with short design cycles, mass production and economies of scale, for military applications is something that the US is already working on via DARPA's Blackjack programme.

While the rescue of OneWeb by the UK government has drawn criticism in some quarters, the UK now has a potentially highly valuable strategic space asset of soft power and technology in a stake in a mega-constellation. (It is notable that both China and now the EU are now mulling developing their own mega-constellations – as well as the behemoth that is SpaceX's Starlink network.)

Below upper: The first satellites aligned in the cleanroom at Airbus Toulouse site, ready for shipment.

Below lower: A OneWeb satellite.

Airbus Defence and Space

OneWeb

Skynet and beyond

In military space, Airbus has built up a formidable reputation with its military Skynet communication satellites, which provide robust and secure communications for UK (and other allied forces). From early beginnings as Marconi, BAe and EADS Astrium, the latest Airbus Skynet 5 series satellites were launched in 2007 as a PFI (private finance initiative) with Airbus providing secure communications to the MoD as a service.

However, the current Skynet service contract is now set to end in August 2022 and, with it, the UK MoD is seeking to shake up the way it procures military satcoms – with the aim of doing more 'in-house', growing its own space cadre and knowledge base and splitting the contract into satellites themselves (Enduring Capability) and ground stations (Service Delivery Wrap) – which sees four consortiums bidding to deliver the service.

To that end, MoD has already placed a $630m contract for a Skynet 6A 'gapfiller' satellite, designed to bridge the gap between Skynet 5 and a larger £6bn follow-on Skynet EC at the end of the decade. Even though it is officially a 'gapfiller', Skynet 6A, set to launch in 2025, is a significant leap in capability with a full digital signal processor (DSP) and "over three times the capacity and capability of Skynet 5", says, Rick Greenwood, VP Engineering and Operations, Airbus Secure Defence and Space.

While the full requirements of a next-gen Skynet EC capability are yet to be set in stone, there are

Airbus Defence and Space

The Skynet 5 satellite Teleport ground station at North Colerne, Wiltshire, UK.

already hints that the MoD is looking for a more connected, more interoperable, more diverse, more protected, more resilient and higher bandwidth solution than previous satellites. Greenwood foresees a move to higher frequency military Ka bands – allowing for smaller ground terminals and conformal antennas.

On resilience, Airbus is now actively considering how to make high-value assets like Skynet EC more protected – not just from EW, cyber or jamming but potentially kinetic attacks. Greenwood says that could perhaps take the form of equipping them with sensors, such as cameras, to watch for rogue satellites that may attempt to close with them. Another layer of protection might be in equipping these satellites with aircraft-like RWR (radar warning receivers) which again could incidate whether tracking or a hostile satellite had 'locked-on'.

Finally, Airbus is mulling a concept to provide high-value military satellites with orbital guardians – or 'bodyguard' satellites. These unarmed smaller satellites would act as roving 'football defenders', moving in between unfriendly satellites attempting to close with their charge by blocking their approach. In extremis, a 'bodyguard satellite' could also put itself in the path of a kinetic or ramming attack from a hostile satellite. Although 'bodyguard satellites' sounds like science fiction, Greenwood says: "The technology is there now – it's just the will and the money".

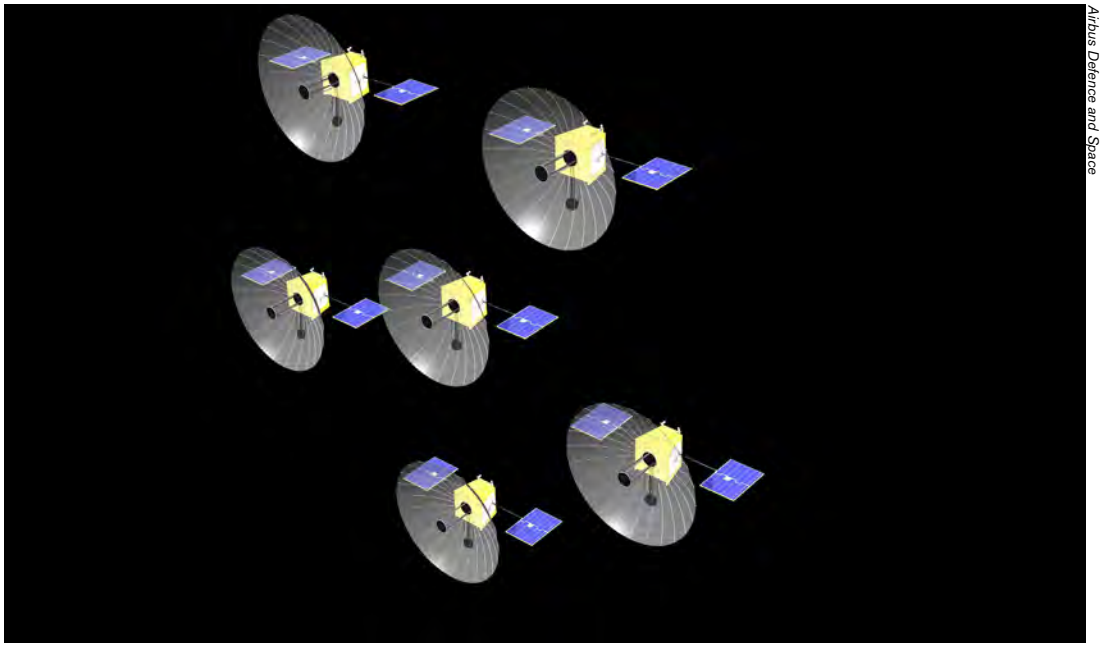
Put together, these measures could vastly improve the survivability and protection of these next-generation military space assets in a more contested future, yet remain essentially defensive in purpose.

While Skynet already has an international dimension, (the US DoD is the biggest user after UK MoD), Airbus also believes that there is an opportunity to export Skynet technology to Australia, which is now launching a search for a new 'defence satellite communications system' under a $7bn JP 9102 programme.

SSTL – the pioneers of 'New Space'

Over the past years, there has been much excitement around 'New Space' companies which range from launch companies (most notably SpaceX) to space tourism, to CubeSat developers and even companies whose whole business model relies on satellite derived data – such as Uber. Yet it is often forgotten, that the 'New Space' revolution of small, cheaper satellites began in the UK, when in 1985 Surrey Satellites Ltd (SSTL) was formed as a tech spin-off from the University of Surrey. Since acquired by Airbus in 2008, SSTL has continued to pioneer the design and manufacture of small affordable satellites and has seen its business grow from strength to strength, developing satellites that range from international disaster monitoring to space debris removal, from the NovaSAR-1 radar satellites, to the RAF's first satellite – Carbonite-2, which was launched in 2018 after only eight months.

With its expertise in imaging and Earth observation satellites, SSTL is also set to be critical



Airbus Defence and Space

An artist's impression of the Project Oberon spy sat constellation. Oberon would provide SAR radar imagery and ELINT intelligence.

in a seismic change in the UK developing its own national sovereign ISR capability – and is part of RAF's Team Artemis, launched in 2019, which aims to fast-track a small satellite constellation. This could see further Carbonite demonstrator satellites include SAR radar and infrared sensors.

Meanwhile, parent company AirbusDS itself has won a design study for DSTL's Project Oberon which sees a constellation of small ultra-high-resolution radar satellites. These would be equipped with RF receivers allowing SAR imagery to be fused with the location of electronic emissions.

SSTL is also looking further into deep space with the first ever commercial Lunar communications satellite – Lunar Pathfinder, which will help unlock low-cost communications to the Moon for a multitude of national and private missions that are expected to develop as part of Lunar Gateway, NASA's Artemis and other initiatives.

Finally, SSTL is also positioning itself for what founder Sir Martin Sweeting describes as the biggest gamechanger in the next decade – in-orbit manufacturing. (See 'Pushing the Envelope, p11)

Mars rover and science

Airbus DS is also a powerhouse for space science missions and Europe's centre of excellence for the ExoMars Rover. Its Stevenage facility is home to the 'Mars Yard' – a testing ground for missions to the Red Planet. Opened in 2014, this facility of Martian terrain has already seen the ESA Mars Rover, '*Rosalind Franklin*' put through its paces, ahead of a launch in September 2022. On arriving at Mars in 2023 the UK-built *Rosalind Franklin* will arguably be the most advanced rover on Mars, using artificial intelligence to drive itself around, rather than be directly steered by time-delay from Earth. This will vastly increase the distance travelled and amount of science that it is able to collect.

Beyond that, the UK is playing a key role in perhaps the most exciting Mars mission yet – sample return – an ESA mission to recover the first soil from Mars set to touch down in 2028. This will see a UK-built Sample Fetch Rover perform a critical part in the return of Martian soil to Earth. Material from NASA's *Perseverance* Rover will be picked up by the Fetch rover, before being launched off the surface of Mars by an ascent vehicle. Once in orbit, the sample will dock with another orbiter, before firing its engines to return to Earth. This complex and ambitious mission is set to be an historic landmark mission in ESA/NASA co-operation and one in which the UK is set to play a critical role. "It's STEM on steroids," enthuses Macken.

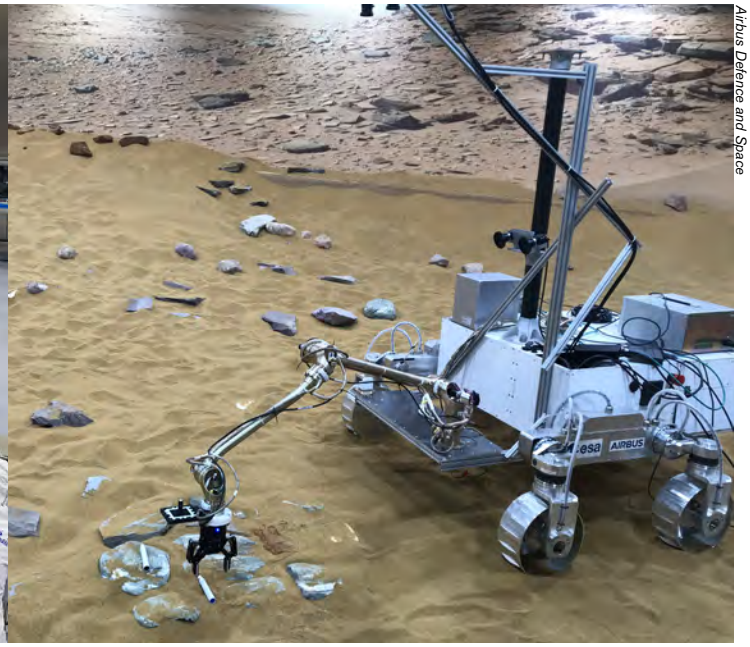
Other landmark science missions built in the UK by Airbus include ESA's Solar Orbiter, the Aeolus weather satellite and the BIOMASS satellite – set to launch in 2022 which will provide vital data on the world's forests.

Time for a 'space Team Tempest'?

However, despite its breadth, experience and expertise across the whole of the UK space industrial landscape, Airbus still sees room for improvement – especially in building up and stimulating the UK space supply chain with small and medium-size businesses. Says Macken: "The UK should really be thinking, how do we develop our supply chain? Why are we sourcing a lot of supply chain material from other countries? How do

> [THE ESA MARS SAMPLE FETCH ROVER]
> – IT'S STEM ON STEROIDS
>
> **Sarah Macken**
> Director of Business Development Airbus Defence and Space

Airbus Defence and Space



Airbus Defence and Space

we bring some of that work to the UK? I think that should be quite a clear strategic target for the UK."

To that end, in 2020 AirbusDS, in partnership with KBR, Leidos, Northrop Grumman and QinetiQ, launched 'Open Innovation – Space' initiative to increase SME involvement in UK future satellite and space activities. Macken notes that the UK space sector needs to reach out to those innovative companies that may be in adjacent sectors but have perhaps not considered the space sector before. "We need to be attracting new companies into space. It can be a low volume of work, so it can be quite a big investment for companies to get into the sector. So we have to attract them."

Furthermore, says Macken, compared to other space nations that have both 'national' and 'international' science missions, the UK currently lacks its own 'national' missions. For companies wishing to relocate or open new facilities, having two sources of space missions to tap into, is thus attractive and something that the UK currently lacks.

What is needed, suggests Macken, is some sort of national UK space mission that could pull and stimulate the sector, attract new companies and provide a focus for UK industry and science – a sort of space 'Team Tempest' project if you will. Macken, warming to her theme, notes that, if the FCAS/ Tempest is used as a model, there is already a doubly appropriate name for any mission – Prospero – a nod to Shakespeare's *The Tempest* and the UK's Prospero satellite, launched by the Black Arrow rocket from Woomera, Australia.

What form then, could a 'Prospero 2' mission take? Macken suggests that, with the UK's expertise in Mars Rovers (along with SSTL's and Goonhilly's Lunar Pathfinder commercial communications mission) there could be scope for a British Lunar Rover mission. This niche could also support US Artemis and wider international Lunar Gateway – as humans return to the Moon for sustained periods.

Above left: *Rosalind Franklin* ExoMars rover in the Cleanroom, Stevenage, UK.

Above right: Testing of the Fetch Rover at Stevenage's Mars Yard – the first mission aiming to bring back samples from Mars.

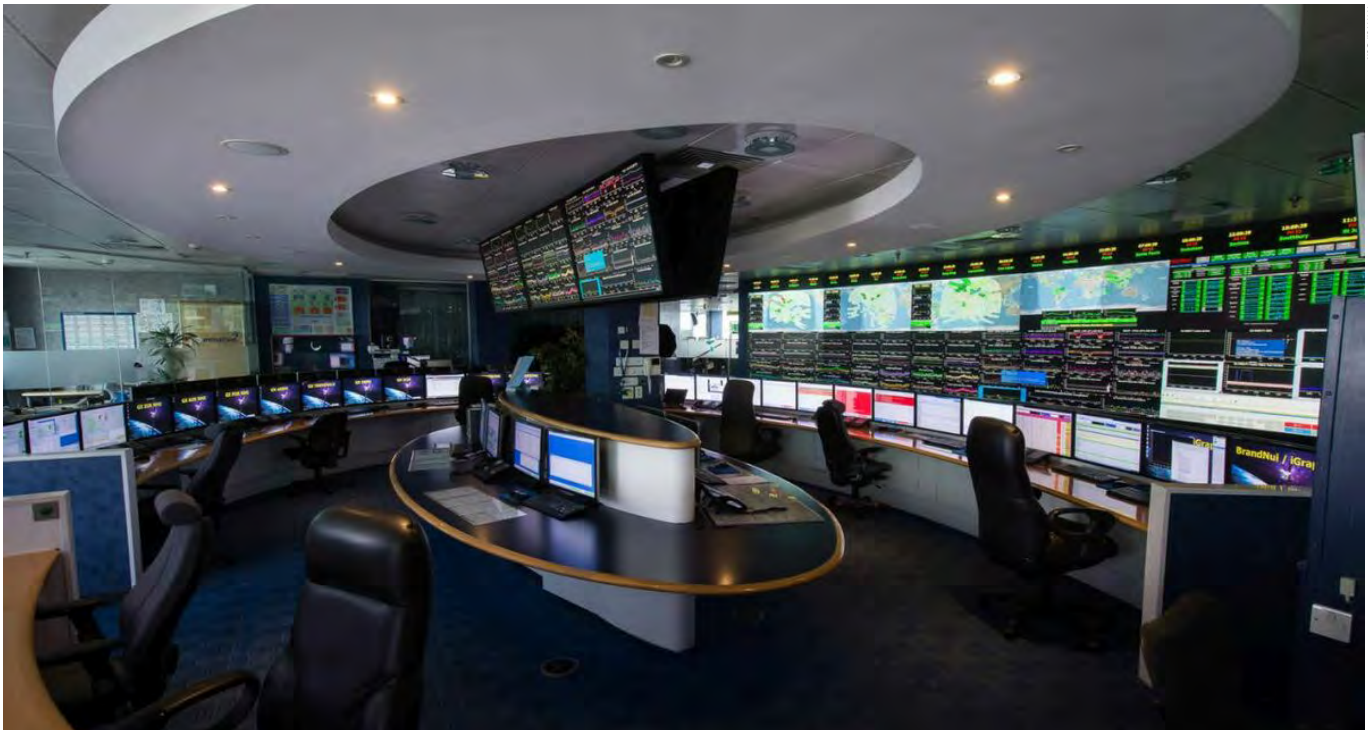
Summary

Despite the uncertainty caused by Brexit and the high-profile UK exits from Galileo, AirbusDS continues to be the bedrock of a thriving and fast-growing UK space sector – that politicians are now looking to help deliver a wider prosperity agenda.

Its deep roots in both military, commercial and science space missions and its breadth of capabilities gives Airbus DS a significant advantage in reusing and spinning off technology from the military sector to the civil sector and vice versa. This 'virtuous circle' can also apply to personnel, scientists and engineers, who can bring their expertise, skills and knowledge from seemingly impossible challenges like a Mars Rover to challenges closer to Earth, such as developing 'bodyguard satellites' to protect future Skynet military satellites. Says Macken: "Our science missions and why that's so important to us is that it really stretches the minds of our engineers."

Its mix of defence, commercial and science business also helps AirbusDS in crucially retaining its expertise and knowledge. Like the UK combat air sector, that has seen the gaps between large programmes widen, with the resultant risk of lost skills, a steady and regular stream of business is essential for space businesses to thrive and prosper.

The company is thus highly optimistic about the UK's potential as an emerging space power, both in military aspects (sovereign ISR, Skynet EC) and commercial (OneWeb) and science missions.


Inmarsat

Taking control

In addition to hosting a large number of space manufacturers, the UK also has a number of ground facilities which can be used to control and operate satellites in orbit. BILL READ FRAeS reports.

As has been described elsewhere in this issue, there are a large number of UK companies specialising in the manufacture of satellites. When completed and launched into orbit, these satellites are controlled from ground stations around the world – many of which are located abroad but a sizeable number of which are operated from the UK. Large international satellite companies often operate a network of interconnected ground stations around the world which can communicate and transfer control to each other. Some of these operators also control satellites from the UK.

A major function of the ground stations is the transmission, collection and storage of large quantities of information including audio, video data and images related to the Internet connectivity, mobile phone transmissions, military and civil Earth observation data. Some of this data is also collected and processed in the UK.

Inmarsat: From sea to space

Probably the most well-known UK-based satellite operator is Inmarsat which is based in London. Set up in 1979 by the International Maritime Organization (IMO) to develop a satellite communications network for protecting lives at sea, Inmarsat has evolved into an international provider of satellite services and solutions. Its customers include: airlines, shipping fleet operators, military, aid agencies, mining, logistics, agritech and many other commercial enterprises.

Currently, Inmarsat flies 14 satellites in geostationary orbit delivering safety and broadband voice and data services around the world. A further seven satellites are planned to be launched over the next three years. Control of Inmarsat's satellites is conducted from the company's Network Operations Centre in London which monitors the network elements of its services. These include the continued and reliable operation of the Inmarsat networks

by supervising network operations, co-ordinating network activities and taking corrective actions as necessary to meet the network availability and service quality objectives. Should there be any problems with the system, Inmarsat can use its ground infrastructure network to take over any functions.

SSTL

In-orbit satellite operations are also performed by UK satellite manufacturer SSTL from its Satellite Operations Centre in Guildford. The centre is linked to other SSTL-equipped ground stations, enabling the control of satellites across the world. While many SSTL customers control their own missions from SSTL-supplied ground stations, the Guildford facility is available for backup operational support.

Satellite Catapult

The UK now has its own a custom-built satellite operations centre which is available for use by space sector organisations. Located in Harwell in Oxfordshire, the newly built In-Orbit Servicing and Control Centre is operated by the Satellite Applications Catapult (SAC). The Operations Centre at the Catapult offers support for satellite flight operations, payload data processing and preparing satellite technology for commercial operations.

SAC's Flight Operations Segment (FOS) offers a 16-seat plus 16 standing ready-to-use ground control facility, consisting of a video wall connected to eight individual workstations with two HD monitors per workstation and a switchable privacy glass wall with security-controlled door. According to SAC, the Operations Centre is capable of operating a variety of missions, including TechDemoSat (TDS) satellites, Disaster Monitoring Constellation (DMC) and European and UK bilateral missions. The Flight Operations Segment (FOS) can operate standard Consultative Committee for Space Data Systems (CCSDS)-compliant spacecraft, as well as low-cost platforms produced by key industry players.

In addition to monitoring and controlling SSTL and CCSDS-compliant missions, the Operations Centre can interface with other SLE compliant ground stations and has the capability to download, process, archive, and disseminate payload data and products. It also offers the Sentinel Data Access Service (SEDAS), on online portal designed to help organisations to search and download data available from public and private satellite operators. Other facilities include the Data Discovery Hub (DDH) which lists both open and licensed Earth observation and geospatial datasets, as well as Climate, Environment and Monitoring from Space (CEMS) offering space-based climate change and Earth observation (EO) data and services. in conjunction with Infrastructure as a Service (IaaS) cloud-based computing.

Astroscale

One company already making use of the In-Orbit Servicing and Control Centre in Harwell is space debris recovery company Astroscale. Headquartered in Japan, Astroscale Holdings has a number of offices around the world, including satellite servicing research and payload development at Astroscale Israel, Administration and Finance in Singapore, business development and technology growth in the US and an Operations Centre at Harwell in Oxfordshire. The Harwell In-Orbit Servicing and Control facility is currently controlling the in-orbit mission of Astroscale's End-of-Life Services by Astroscale demonstration (ELSA-d) satellite. Launched from the Baikonur Cosmodrome in Kazakhstan on 20 March aboard a Soyuz rocket operated by GK Launch Services, the aim of the ELSA-d mission is to demonstrate the core technologies and capabilities necessary for space debris docking and removal. The mission will involve repeat docking and release manoeuvres between the servicer satellite and the simulated client satellite, which is equipped with a ferromagnetic plate to assist the servicer with its magnetic docking procedure.

Skynet

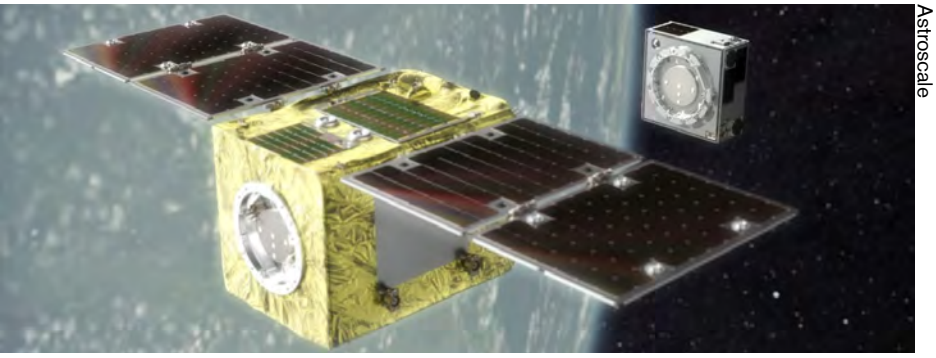
Also at Harwell is RAL Space, the UK's national laboratory to advance the understanding of space and environment. Working with UK and overseas agencies, universities and companies, RAL assists with scientific research and technology development for space and ground-based projects. This includes the provision of operating ground stations and processing and analysing data.

One of RAL's customers is Airbus Defence and Space which, since 2003, has managed the Skynet 5 programme to provide the UK MoD with military communications services.

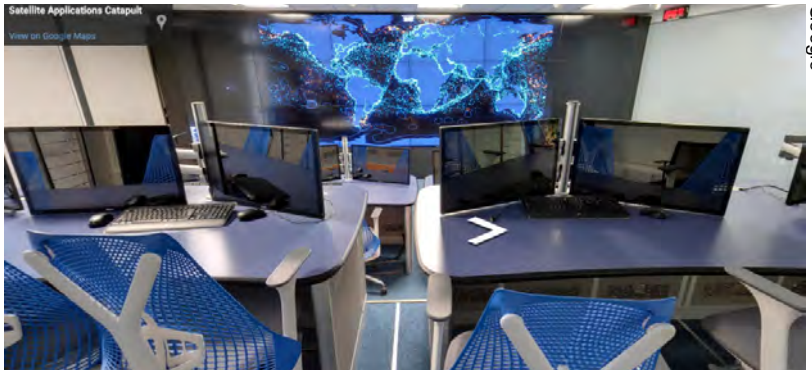
In July 2020 Airbus Defence and Space signed a £500m contract with the UK Ministry of Defence to extend and enhance the Skynet satellite fleet. The contract covers technology development

Upper left: The Inmarsat satellite control room in London.

Below: An ELSA-d satellite.



Astroscale



Google

Satellite Applications Catapult control room.

programmes, new secure telemetry, tracking and command systems, launch, in-orbit testing and ground segment updates to the current Skynet 5 system. It also includes the development, manufacture, cyber protection, assembly, integration, test and launch of a new military communications satellite, Skynet 6A, based on Airbus' Eurostar Neo telecommunications satellite platform. According to Airbus, Skynet 6A will utilise more of the radio frequency spectrum available for satellite communications and the latest digital processing to provide both more capacity and greater versatility than Skynet 5 satellites. The satellite will feature electric orbit raising propulsion, as well as electric station keeping systems for maximum cost effectiveness. Due for launch in 2025, the new satellites are to be integrated at Airbus facilities in the UK and tested using RAL Space's space testing facilities at Harwell.

However, the Airbus D&S contract is due to end in 2022 and is being put out to tender to other bidders. The identity of the bidders is currently confidential but one is believed to be the Athena consortium comprising Serco, Inmarsat, CGI UK and Lockheed Martin UK. If the contract goes to another company, then there will be a one year transition period starting in July 2021.

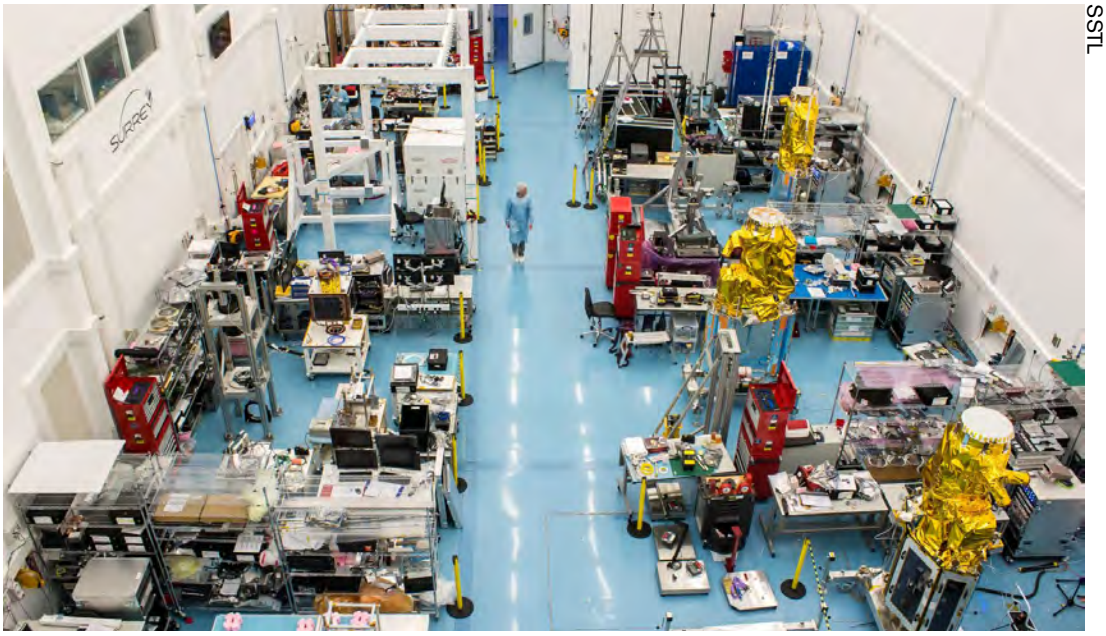
Another military ground network is the US Air Force Satellite Control Network (AFSCN) located at seven sites around the world, including one at MoD Oakhanger in Hampshire. The AFSCN monitors the position of orbiting satellites, as well as space objects.

Testing satellites

The RAL at Harwell also operates the National Satellite Test Facility designed for the environmental testing of space payloads and satellites up to 70,00kg. The NSTF will provide facilities for the assembly, integration and testing of space payloads and satellites, enabling UK companies to develop the new large, complex spacecraft and test them in the UK. From 2022 the NSTF will offer cleanrooms for large satellite preparation and solar array deployment; facilities to measure a satellite's mass properties to ensure that it is consistent with its design parameters; a satellite vibration test facility; pyro-shock tests to simulate separation of the satellite from the launch vehicle adapter; a test facility to simulate the acoustic environment under the fairing of the launch vehicle during launch; a thermal vacuum chamber to simulate the vacuum and thermal conditions in space; and an electro-magnetic compatibility (EMC) and antenna testing facility.

International networks

A number of international space companies have a site in the UK, including satellite solutions and services group Telespazio which designs and develops space systems, manages launch services



SSTL

SSTL satellites under construction.

RAL

Aerial view of RAL Space at Harwell.

and controls satellites in-orbit. Telespazio UK based in Luton focuses on the provision of Earth observation and climate services.

International space-based data and analytic nanosatellite operator Spire collects space-based data through a constellation of over 100 satellites. This data is then available to commercial and government organisations around the world to improve business operations, decrease their environmental footprint, deploy resources for growth and competitive advantage and mitigate to risk. Spire Global, which recently merged with NavSight Holdings, has offices in San Francisco, Boulder, Washington DC, Luxembourg, Singapore and Glasgow.

Other UK satellite companies

Another satellite operator to be operated from the UK is OneWeb which plans to offer broadband connectivity services via a constellation of 650 LEO satellites. In November last year, OneWeb emerged from US Chapter 11 bankruptcy the Low Earth Orbit (LEO) broadband satellite communications company, after being rescued by the UK government and Bharti Global.

The UK also has an interest in several international satellite companies, including NSSLGlobal which provides satellite communications, IT support, voice and data services. Merged with the ESL Group in 2014, NSSLGlobal is headquartered in Redhill and has officies in Newcastle and Cornwall in the UK, as well as Denmark, Germany, Poland, US, Singapore, Norway and Southern Africa.

Another Surrey-based satellite company is Earth-i which operates out of the Surrey Research Park in Guildford. Earth-i specialises in providing geospatial information based on multi-operator, multi-resolution, multi-sensor Earth observation data, including satellite images. The images can be from anywhere on Earth and include particular locations or infrastructure, such as forests, ports, mines, refineries, construction sites, farms, roads or car parks (see *Private eyes on Earth*, April 2021, p 26).

In Cornwall, Goonhilly Earth Station is a carrier-grade satellite communications centre offering mission operations. Goonhilly one of the partners (with SSTL and ESA) in the Lunar Pathfinder 1 project to deploy a lunar lander linked to orbiting lunar CubeSats to relay data between Earth and the Moon. Goonhilly is to provide the communications link and mission operations facility.

Many of the UK's new space companies are based in Scotland. Clyde Space in Glasgow specialises in providing advanced small satellite solutions, mission services and subsystems. The company provides services for government, commercial and educational organisations and builds 80 small satellites a year. In addition to the UK, Clyde Space has offices in Sweden and the USA, with partner networks in Japan and South Korea.

Other Scottish companies involved in satellites include Skyrora which produces the Skyrora XL launch vehicle to carry small satellites into orbit and Orbex based in Forres near Inverness which is building the Prime launch vehicle which will launch small satellites into orbit from Space Hub Sutherland (see The Magnificent Seven, pp 14-19).

Goonhilly

The new UK space industrial base

Professor **KEITH HAYWARD** FRAeS profiles the industrial capabilities of the UK's wide-ranging space sector, from data services to building satellites.

For years, UK space was the poor cousin of the much larger 'aerospace' sector. It had some superb products, especially in satellite development and construction, and Britain was the host of some important 'downstream' players in satellite operation but UK space employment and turnover was a fraction of the overall UK aerospace business. Times have changed. In less than a decade, the space sector has been targeted by successive governments for pump priming with public money, some well-chosen technological investments and a relaunched National Space Agency tasked with implementing a space strategy looking to increase the UK's share of the global space market to 10% by 2030. To back up these ambitions, the UK government has sunk over half a billion pounds in space over the last decade. It has also passed the Space Industry Act of 2018 to facilitate the growth of launch services – regulating 'all spaceflight activities carried out from the UK'.

According to ADS data, UK space sector turnover has grown to almost £15bn a year and 40% of all small satellites currently in orbit are built in the UK. The sector has grown overall by 72% since 2012. In 2018, the UK space industry employed just over 42,000 people and contributed £5.7bn (gross value-added) directly to the national economic output, and another £13bn indirectly. Over a third of industrial output was exported. UK space was also highly focused on the commercial sector, with 82% of sales to consumers and businesses. Although UK-based suppliers have lost access to some EU space markets following Brexit – notably Galileo – ESA and some EU Copernicus contracts are still open.

Cornwall's Goonhilly ground station is aiming to tap into a growing market for private companies wanting deep-space communication services.

New space

The new UK space sector has moved on from its conventional satellite business to embrace the advent of 'New Space', a buccaneering, innovative approach to space hardware and space-based applications. There is even a strong hint that the UK might be back in the launcher business, last seen in the early 1970s; there are certainly plans for UK-located launch sites. All of these novel trends underline the disruptive nature of New Space, turning many of the assumptions of the space economy on its head.

ISECG

The UK Space Agency is one of many from around the world.

In some respects, there are parallels with the impact of UAV technologies on the aerospace sector encouraging the entry of a new set of firms to the aerospace supply chain. The key difference is that, in both cases, the real money is not made by the makers but by the users. As a rule of thumb, building rockets and supplying launch services is the smallest chunk of the space value chain. Satellite manufacturers are better placed and satellite operators (of the big telecommunication birds) have an even bigger share. However, the purveyors of space-based services make the big bucks – think Sky Broadcasting rather than the Astra satellites that beam the signals.

The advent of New Space has changed some of the relative economics of the space value chain. SpaceX launchers and services have lower costs and thus higher potential margins than conventional combinations, such as Ariane/Arianespace. The value of the large geostationary comsats is under challenge from lower Earth orbiting (LEO) constellations and SmallSats generally have brought an entirely new business segment. However, the common theme is that there are even more opportunities to set up space-based services. As ever with tech start-ups – and the space-based service sector increasingly resembles the tech industry in terms of risk/reward calculations – the trick is to sort the valuable wheat from the chaff.

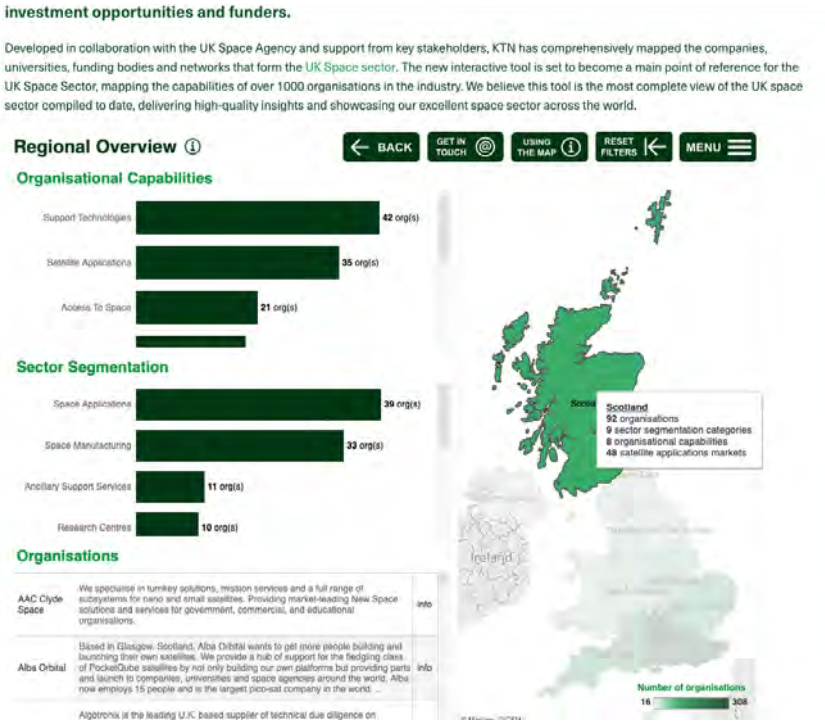
This article focuses primarily on the manufacturing side of the space business, with some glimpses of space-based services. Much of the macro data tends to wrap manufacturing with services – especially if the intent is to boost a political case for investment. However, the KTN-UK Space Agency Landscape Map provides a good way of sorting some of the space sheep from the goats, providing a snapshot of the UK New Space industry.

The geography of UK space

The geography of the UK New Space manufacturing industry is beginning to change away from the traditional clusters around the old core companies, such as Airbus Space and Defence, BAE Systems, Lockheed Martin and Leonardo. While there is still a strong concentration in the South and South East, the map shows a much wider distribution of firms, with a noticeable new grouping in the Central Belt of Scotland – part of the 'Silicon Glen' technology cluster. 'Old Space' had a more truncated supply chain than 'aero', as considerably more of the average satellite comprised 'one-off' equipment and subsystems designed and built by the systems integrator. New Space satellite constructors tend to use more bought-in components but these tend to be 'off-the-shelf' with less specialised input. Those building the new satellite constellations are also closer to volume production than the traditional players with custom-built products, albeit perhaps based on a standard framework design.

Geographically, the South East dominates the map of UK space, with 277 players; the next up is the South West with 96 and, third in England, the East with 81. Over half of the total is below the Wash-Bristol Channel line, which is where the great majority of the biggest players in manufacturing or applications are located. This macro region has 56% of the total space-manufacturing sector in the UK and just under half of those involved in applications. Its Eastern component has the bulk of the space industry systems integrators and big applications players. Scotland registers 87 companies in a balanced spread of manufacturing and applications, including a number of spaceport contenders. The traditional aerospace powerhouse of the North West is in eighth place UK-wide, with 38 entities, mainly SMEs.

The KTN-UK Space Agency Landscape Map.



KTN

Manufacturing

The KTN map shows a total of 347 companies and other entities (research groups) engaged in space manufacturing out of 900 mapped as part of the UK space sector generally: 173 are materials and component suppliers; 96 developing satellites, payloads and sub systems; 70 are engineering and scientific support; and 23 are in scientific instruments.

In terms of size, 89 companies have fewer than 10 employees, 93 between 10-50, 47 up to 250 and 74 companies employ more than 250. Most of the latter are mainly well-established aerospace and manufacturing companies. Over half would be defined as SMEs (up to 50 employees) and a fifth of the total have been in business for less than five years.

The big aerospace players, such as BAE Systems, Textron, Ultra, Thales Alenia, Raytheon, Cobham, Airbus Defence and Space (SSTL is listed separately) and Leonardo, are there – along with four university-based enterprises. The bulk of the companies are in satellite or related activities, reflecting the UK's well-established focus on space vehicles and payloads. Some are in the more exotic contenders, such as the Asteroids Mining Corp and Blue Asteroid, exploring the outer reaches of New Space. The list also includes Garmin, the navigation receiver manufacturer. The 'space' sector also includes general high quality/high value component and materials companies, such as Chemring, Constellium (specialist aluminium) and Graphic Plc (printed circuit boards).

Interestingly, given that the UK has had little interest (officially) since the early 1970s in rockets, 29 are involved in launch vehicles and subsystems (See 'Launching Britain into space', p34). while some might be supplying into Ariane. Others are part of a wider revival of UK interest in this segment. Many are again parts of the New Space world, looking to develop micro launchers but this group includes Reaction Engines, which continues to work on a potentially revolutionary hybrid engine, along with the historically redolent Black Arrow, a SmallSat launcher specialist. Virgin Galactic (and Virgin Orbit) is perhaps the most well known member of this group. As all but six have fewer than 20 employees, this is again perhaps evidence of the flourishing 'start-up' characteristics of the UK New Space sector.

Space applications

The space applications sector lists 308 companies. The main areas of activity are Earth observation and telecommunications. There are 108 companies with fewer than 10 employees, 97 with between 10 and 49, 25 in the 50-249 category and 87 with more than 250. Over 65% of space applications firms are in the SME category. The big players are again well established: Airbus Space and Defence communications, BT, Eutelsat, Inmarsat and Telespazio, as well as the large direct broadcasters, such as Sky and Freeview. In the case of many of the larger companies, the space aspects of their activities may be relatively small but vital: the Sky annual report has little direct reference to its satellite network but has pages of small print mitigation for loss of access.

Inmarsat is perhaps the doyen of UK-located space applications business. Established in 1979 as a non-profit intergovernmental organisation to operate mobile satellite communications for international shipping and later aviation, in 1999 it was privatised and since then has established several partnerships to extend its services. Inmarsat operates 14 GSO satellites from its London base. A key feature is the global maritime distress and safety service. As well as the maritime sector, Inmarsat works across government, enterprise and aviation sectors worldwide, including in-flight internet connections for the European Aviation Network.

The Shetland launch site at Lamba Ness on the island of Unst, as imagined.

Lockheed Martin

Thales UK

Thales Belfast is now a centre for satellite electric propulsion modules.

Nearly a third of companies in this sector are less than five years old, a rather higher proportion than in manufacturing, which would seem to reflect the relative ease and attractiveness of setting up in the downstream arena. A number have been around a lot longer then that. Paddle Logger, a water enthusiast tracking service, has been in business for over five years and Remote Sensing Applications has been using space-based data since 1986. PlanetWatchers, a classic SME which has been operating since 2019, is typical of the new entrants, using space-based data to track and assess storm damage. Similarly, Orbital Witness has been deploying data from satellites in real estate legal cases since 2017.

Some of these UK-based companies are a part of a multinational business. A good example is Spire, the US Earth observation company, operating a constellation of 90 CubeSats offering a range of data analytic services. Its weather forecasting service is in Glasgow. Spire cites good access to capital and technical resources as the reason for choosing Scotland.

Ancillary support services

This sector lists 192 companies, mainly consultancies of one form or another. There are 79 companies with fewer than 10 employees, 34 in the 10-49 category, and 13 between 50 and 249, with 50 big players. The sector has some important commercial actors, including Lloyds, Allianz, Aon, Bird and Bird and Marsh, offering insurance, legal services and general support for the space sector. In general, this is the arena for SME operations: over half have fewer than 50 employees.

Space operations

There are 33 companies in this sector, again companies like Airbus, Avanti, Telespatizio, Serco and QinetiQ (mentioned in all the major categories), but 119 (57%) are SMEs. Fourteen are newly established, or 42% of the total.

> NEARLY A THIRD OF COMPANIES IN THIS SECTOR ARE LESS THAN FIVE YEARS OLD. A RATHER HIGHER PROPORTION THAN IN MANUFACT-URING, WHICH WOULD SEEM TO REFLECT THE RELATIVE EASE AND ATTRACTIVE-NESS OF SETTING UP IN THE DOWNSTREAM ARENA

The OneWeb LEO broadband communications megaconstellation is perhaps the most interesting member of this group. This is a highly controversial public-private investment tipped (at least in the original publicity) as potentially a British alternative to Galileo. The Satellite Applications Catapult, a government-funded innovation hub, is already working with OneWeb to develop add-on positioning, navigation and timing technology that could be used to enhance the resilience of existing navigation services, such as GPS. However, the OneWeb satellites are built by Airbus in the US and any returns will be entirely dependent on selling its services.

The OneWeb LEO constellation was bought out of bankruptcy by a consortium of investors led by the Indian Bharti Global. The UK has invested $500m in a 45% share of the relaunched company but officials refused to sign off on the deal. Its value as a geo-location system is still uncertain but the UK government also believes that OneWeb will fill an important gap in internet access for remote centres. OneWeb will be in competition with megaconstellations funded by Elon Musk and Jeff Bezos.

Spaceports

Encouraged by the UK Space Agency LaunchUK initiative aimed at providing an appropriate regulatory framework, seven sites in the UK – including Newquay in Cornwall, Campbeltown, the Hebrides, Sutherland and Glasgow Prestwick in Scotland, the Shetlands and Snowdonia in Wales – have announced spaceport plans. Four of the seven are located in Scotland. Three are offering vertical and three or four of the sites horizontal launches. The commercial exploitation of these centres has been boosted by agreement with the US authorising export-controlled technologies on American satellites which can be launched from British sites.

The UK government has also agreed to fund facilities to support Virgin Orbit operations. The UK sites will be used to launch SmallSats and perhaps

as centres for space tourism, the former aimed at polar orbits, taking advantage of northern latitude launch of Earth resources satellites. Lamba Ness in the Shetlands was first off the mark; the Shetland centre believes that it will generate over 600 jobs directly and indirectly across Scotland. Some £50m of public money has already been invested in the Shetland site, with Lockheed Martin getting £23.5m to support launch activities. Lockheed transferred its business from the Sutherland Space Hub because Shetland offered a more direct launch trajectory. This was followed by Newquay's horizontal launch site, 'Spaceport Cornwall', with a £7.5m state boost afforded to Virgin Orbit.

Lockheed Martin has contracted the start-up ABL Space Systems to supply a rocket and launch service for operations based in the UK. Its Pathfinder Launch programme is due to launch the first vertical small satellite from the United Kingdom in 2022. The American ABL Space Systems is developing the RS1 small satellite launch vehicle. Lockheed Martin has been a strategic investor in the venture since 2019. Other companies, such as Orbex and Skyrora, both headquartered in Scotland, are also in the small launcher market. Orbex is still the only company with posted commercial contracts for a British launch, in this case from Sutherland. Virgin One's recent successful test is encouraging news for the Cornish horizontal launch site.

Analysts have been quick to point out that, worldwide, there is already considerable competition for the SmallSat launch business – and as a relatively modest element of the space industry value chain, UK launch sites may struggle to make money. The British government contends that the commercial demand for commercial launch services is potentially worth £3.8bn to the UK over the next ten years. This seems somewhat optimistic.

The likelihood that all of these space centres will be profitable is low: and even if modestly so, the wider exploitation of these remote locations (with the exception perhaps of Prestwick), in the form of manufacturing or space services clusters, is doubtful. There may be some utility in having some degree of indigenous launch capability but the major constellation operators are likely to use sites closer to home or an established and proven launch service; even the partly UK-owned OneWeb is looking elsewhere (so far mainly Russian rockets and sites) to launch its satellite network. In this respect, the Lockheed-supported operation seems to be the most likely to make a commercial breakthrough.

Spire Global nanosatellites cleanroom at its Glasgow facility. The company is set to expand further, having signed a 10 year lease in February 2021 to move to a larger 29,511ft² facility in the city's Skypark.

Quentin Gollier

And the next steps?

The UK space industry has grown rapidly over the last few years. This has followed an impressive increase in public funding and active promotion by a revitalised National Space Agency. It has fully embraced the principles and the challenges of New Space. The space applications sector has been especially active in terms of both depth and scope of interests.

In addition to the largely commercial activity described above, the UK is embarking on a more active role in military space. This effort will be boosted by £1.5bn in the latest UK Integrated Review. However, the MoD may want to stretch its funds through co-operation with the private sector, exploiting the 'dual technology' features of many space applications. This could include buying launches, bypassing the emerging SpaceX dominance of the commercial business – if the price and capability is right!

Another interesting trend to watch at the top end of the industry is the emergence of teams bidding for 'end-to-end' contracts. The recently formed Athena, a team comprising Inmarsat, Serco, CGI UK and Lockheed Martin, offers an interesting mix of space goods and services. By exploiting its components' individual strengths, it could deliver a comprehensive range of civil and military applications, offering a 'sovereign UK-based' service for the MoD. Athena wants to encourage a wider range of smaller companies supplying into the 'team'. This approach should have the effect of further encouraging the UK New Space industrial base and providing some insurance against technical and commercial risks associated with the more speculative space markets.

Meanwhile, an Airbus Defence and Space consortium, including QinetiQ, Northrop Grumman, KBR and Leidos UK, which was announced last December, is looking to provide a range of space-based assets and services. It also aims to place 30% of the work in the UK space SME community. The group accounts already for £5.8bn worth of UK space business. Its primary target will be MoD's secure communications market.

All of this activity, new and old, is a long way from the UK space backwater of the 1980s, and in many respects, it puts the British space industrial base in the forefront of the new space markets of the 21st Century. Whether the UK will attain the goal of doubling its market share by 2030 remains to be seen but even a near miss will be well worth the effort.

Afterburner

www.aerosociety.com

Wg Cdr R D Romanis shows Queen Elizabeth II and the Duke of Edinburgh a de Havilland Firestreak infrared, air-to-air guided missile on Gloster Javelin F(AW) 2, XA633, in 1957. A tribute to HRH The Prince Philip, Duke of Edinburgh is published on p 60. RAeS (NAL).

Message from RAeS

OUR PRESIDENT

Prof Jonathan Cooper

It was very sad to learn of the death of His Royal Highness The Prince Philip. As a keen pilot and supporter of aviation, science and technology, industry and young people, the Duke will have influenced many Society members' lives. He made a substantial contribution to our community. Awarded an Honorary Fellowship in 1954, Prince Philip was the Society's Honorary President during our centenary in 1966 and chaired the Society's 1,000th Council meeting in 1990. In 1976 he initiated the Fellowship of Engineering, now the Royal Academy of Engineering, which promotes engineering excellence and education, and was also Chair of the Originating Committee for The Queen's Award for Industry, as it was then known. His passion for aerospace and encouragement of young people will be missed by us all.

It has been an absolute honour to have been the President of the Royal Aeronautical Society. When I took up the role in May 2019, I thought that Brexit would provide the major challenge to our sector, and of course there are still issues to be resolved (for example with the UK's access to EGNOS Safety of Life Service). It is worrying to see reports that the UK government is likely to miss its target R&D spend. A gap between allocations and commitments will have a big effect on research programmes, and the associated technical expertise and jobs across the UK aerospace industry, that can't simply be put 'on ice' to be continued at a later date.

Little did I know that, in footballing parlance, I was going to have an extended presidency of two halves, with the past 12 months being very much dominated by the Covid pandemic. Not only has there been much hardship and loss at a personal level but the effects across our community, and the Society itself, have been immense. The Society and its membership have responded fantastically to the challenge and I am proud to see how all our activities have continued to function and that we continue to support our entire membership. I am sure that the RAeS will prosper once we move out of lockdown.

There were many instances of Society members and Corporate Partners responding to the pandemic. Examples included: Airbus flying shipments of face masks across Europe, 'Project Wingman' setting up mini-airport lounges for hospital staff and many companies, universities and individuals using their facilities and expertise to design and manufacture ventilators and PPE. It was a particular pleasure to bestow the second ever President's Award to the VentilatorChallenge UK Consortium in recognition of their achievement and contribution to the fight against Covid-19.

> THERE WERE MANY INSTANCES OF SOCIETY MEMBERS AND CORPORATE PARTNERS RESPONDING TO THE PANDEMIC

Our international reach continues to expand, with a representative organisation established in China, the inaugural meeting of the RAeS Singapore Branch Student Chapter and an MoU signed with the AIAA. There has been a much closer interaction with our accredited universities. Several academic forums were held, enabling HEI staff to share best practice in these strange times and also for the RAeS to share resources and accreditation guidance.

The move towards virtual delivery has had some positive consequences. We have maintained our conference and lecture programme using our enhanced digital capability, providing an improved offering to our members. Attendance for Society and Branch lectures is much greater and I have been able to attend many events hosted by our Specialist Groups and local Branches worldwide. For the first time all Divisional Presidents have been able to participate in Council meetings. Other highlights for me include: the award of Best PEI Prize in the Engineering Talent Awards, presenting the first Sir Ralph Robins Medal, being a signatory to the Society's Black Lives Matter statement, introducing the inaugural Mary Jackson Lecture and attending the NAL garden party on a hot June afternoon what seems a lifetime ago.

I would like to thank the volunteers who tirelessly support RAeS activities via the local Branches, Specialist Groups, Corporate Partners and our many boards and committees. The Society is defined by its membership and I am constantly impressed by our many devoted members. It was a pleasure to meet some of you during my term of office. Further thanks also need to go to the Society staff, led by Sir Brian Burridge, Council and the Board of Trustees, without whom the RAeS would not function and for their support of my presidential term. I have no doubts that the incoming President Howard Nye is going to make a great success of his year in office. I hope that he finds the experience as rewarding as I have and wish him all the very best.

Very early in my presidency, I spent an enjoyable two-day visit hosted by the Hamburg Branch. On the second morning, the plan was for me to catch a ferry across the Elbe and then get a lift to my first appointment. Unfortunately, I missed the ferry but I didn't have the contact number of the person I was meeting. Hamilton Place reputedly received a somewhat panicky phone call saying that the President had been lost. The past two years might have been very different!

OUR CHIEF EXECUTIVE

Sir Brian Burridge

- With the very poignant funeral of HRH The Prince Phillip executed with great precision still sharp in our memories, it is fitting that we pay tribute to his contribution to the Society over almost seven decades. The president rightly records this through the engineering lens but His Royal Highness was also a gifted and avid aviator. With 65 types in his logbook, he flew civil aircraft from the Constellation to Concorde, military aircraft from the Vampire to the Vulcan and helicopters from the Whirlwind to the Apache. This wide experience fuelled his curiosity and made him an authority on the Society's areas of interest, not least in encouraging young people to recognise the excitement and professional satisfaction inherent in flying (see p 60).
- As anticipated, the three follow-on publications to the *Integrated Review* covering the detail of defence posture, industrial strategy and the MoD's approach to climate change, have all added considerable texture. It is striking that there is now strategic convergence between defence and civil interests in areas, such as science and technology, research and development and in space. This is underpinned by a more pragmatic approach to the importance of on-shore, end-to-end capability in a range of segments from complex weapons through shipbuilding, combat air, rotary and space. There is also recognition of the value of defence manufacturing to the economy. In terms of air power, the matter of F-35 numbers remains unresolved: Typhoon and Tempest get additional funding but perhaps at the expense of a hollowing-out of surveillance capability, at least until the creation of a constellation of satellites fills the gap. More detail will come in next month's *AEROSPACE*.
- While more defence satellites might be welcome, space is becoming very crowded. Earlier in April, a SpaceX and OneWeb satellite came perilously close to colliding, missing each other by little more than 50 metres. Apart from their potential destruction, the collateral damage from the subsequent debris would have been enormous. Having run a related conference last year, the Space Specialist Group is taking steps to increase awareness of these hazards. More broadly, this issue of *AEROSPACE* is dedicated to space as a precursor to the incoming President's Space Conference, 'UK in the 2020s – An Emerging Space Power' on 19-20 May. This is a rich topic given the rapidly expanding market and the *Integrated Review*'s focus on space. So, if your interest has been kindled by this magazine, do register and join the impressive range of international speakers.
- On the careers front, the new Career Flightpath platform has got off to a great start with hundreds of users doing career assessments, e-learning courses and honing CVs. The platform is free, as is our ongoing personalised 1-2-1 advice from our dedicated careers team. Also, the team is holding a 'one-year-on' Careers Support and Advice virtual afternoon on 5 May with expert panellists from the 2020 event returning to give updates and advice as the impact of the pandemic continues. There will be other guest speakers and a 'meet the Careers team' open room. For more information contact **careers@aerosociety.com**.
- We have also partnered with World Skills UK to support the UK Aero Mechanical Competition 2021. The competition offers a tremendous opportunity for aerospace maintenance apprentices to demonstrate their knowledge and practical engineering skills and win a place in the national competition. Registration is open until 19 May. Please contact Rishi Radia in the Careers team if you would like more information. Also, our young member video competition AeroTube is now open for submissions. We are asking young members to show off their creative skills and share their knowledge by producing an informative video on an aerospace or aviation-related topic. The competition closes 31 May 2021, for more information contact **YPN@aerosociety.com**.
- As you read this, there is less than a week left in which to vote in the 2021 Council election. Meanwhile, members should have received their log-in details from Lumi to join the Society's Special General Meeting and the Annual General Meeting which takes place on the 6 May 2021 at 1100 (BST). Members will be aware that, after the formal business of the AGM, we will mark the presidential handover. I should like to place on record our thanks to Professor Jonathan Cooper who has so generously given of both his time and his wisdom over an extended period of two years. An extremely active president but also with a busy and responsible day job, Jonathan has represented the Society at numerous real and virtual events, maintained engagement with the Branches and Specialist Groups and made a success of chairing virtual Council meetings. The Society is grateful for Jonathan's contribution, commitment and flexibility during this exceptional and unprecedented time.

> WHILE MORE DEFENCE SATELLITES MIGHT BE WELCOME, SPACE IS BECOMING VERY CROWDED

Book Reviews

AMERICAN SECRET PROJECTS 2 and 3

US Airlifters 1941 to 1961

By George Cox and Craig Kaston

Crécy Publishing, 1a Ringway Trading Estate, Shawdowmoss Road, Manchester M22 5LH, UK. 2019. 303pp. Illustrated. £27.50. ISBN 978-1-91080-916-7.

US Airlifters since 1962

By George Cox and Craig Kaston

Crécy Publishing, 1a Ringway Trading Estate, Shawdowmoss Road, Manchester M22 5LH, UK. 2020. 256pp. Illustrated. £27.50. ISBN 978-1-91080-933-4.

These two volumes (published by Crécy) complement Vol 1 of the series which dealt with fighters and bombers of WW2 and two previous publications by Midland which dealt with post-war combat aircraft.

The first volume begins with a brief history of US airlifters and then outlines the specific requirements of the genre, including the ability to load large heavy items onto a spacious cargo deck. While the requirement for substantial airlift capability first came to the fore during WW2 this was largely met by adapted civil designs, most famously the Douglas C-47, although the first purpose designed projects did appear in prototype form. It was in this era when the requirement tended to divide into tactical and strategic, with the latter projects including influences from strategic bombers, as well as the burgeoning long-range civil market.

Some more exotic approaches were also attempted, such as flying wings and canard designs, which reappear several times during this story. Several other innovative approaches were also proposed, including swing tails and gull-wings to ease loading, turboprop and turbojet propulsion, as well as pod carriers, although none of these reached production.

The tactical requirement did result in a few successful designs, notably the Fairchild C-82, which were evolved over several iterations. However, by the mid-1950s, a competition between several manufacturers to provide a medium-lift capability resulted in the award of the contract to Lockheed for the C-130 Hercules. The strategic requirement followed a similar progression, with perhaps more effort to draw on civil designs, which resulted in the Douglas C-133, although longer-term success was minimal compared to the C-130.

During this period the requirement for a tanker/transport to support SAC's bombers also emerged but despite several optimised tanker proposals, budget and time constraints resulted in the Boeing KC-135, which drew heavily on cross-fertilisation with the civil B707. Moving on towards the 1960s saw many efforts to produce a better airlifter, by using as much as possible of civil designs, as well as going for more innovative solutions, resulting in the Lockheed C-141 which employed the same fuselage cross-section as the C-130. Other designs were aimed at producing greater lift, VTOL capability and even supersonic cruise.

Above: A C-2 Greyhound carrier on-board delivery aircraft from the Providers of Fleet Logistics Support Squadron (VRC) 30 prepares to make an arrested landing on the flight deck of the aircraft carrier USS Nimitz *(CVN 68).* US Navy.

The final chapter of Volume 2 deals with a number of proposals to meet the light airlifter needs of the US Army, which included adaptations of civil designs and fairly conventional new designs, as well as STOL and VTOL proposals.

Volume 3 continues with the attempts to produce a more effective strategic airlifter, capable of carrying outsized loads, while faced with budget constraints, which pushed constructors once again to draw on existing civil types and even for Boeing to propose a design utilising the wing of the B-52. However, it became clear that a new design would be required and a series of competitions and proposals followed, which eventually resulted in the Lockheed C-5.

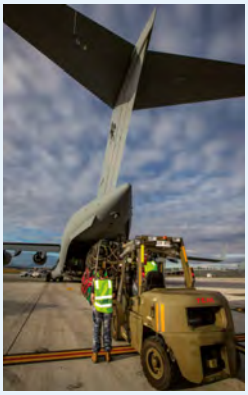
At the other end of the scale the pursuit of a VTOL capability spawned a myriad of designs and proposals, including some unsolicited, which produced some prototypes but no production items, for the army support role or for the larger air force Hercules replacement. Efforts in the latter case were to continue, with emphasis moving away from VTOL to STOL and, after multiple proposals, resulted in a competition between prototypes of the Boeing YC-14, utilising the Coanda effect, and the Douglas YC-15 employing externally blown flaps.

However, a further change of emphasis saw resources being switched to strategic lift, which, after rejection of derivatives of the C-5 and the Boeing 747, eventually produced the McDonnell Douglas C-17, which is currently in service with the USAF and several foreign air forces. Meanwhile, efforts to modernise the tanker/transport fleet again saw the rejection of optimised designs in favour of the cheaper solutions of modifying a civil design, to produce the KC-10A and the upgrading and re-engining of the existing KC-135s.

These books display outstanding editorial standards, including many pictures and diagrams, many of which are attributable to the originating companies

One of the longest chapters charts the history of Carrier On-board Delivery (COD), starting in the 1950s, involving a myriad of designs employing much of the V/STOVL techniques examined elsewhere but with an equal lack of success. Alternatives of adapting existing carrier-capable types and modifying civil designs, including the Boeing 727 and Fokker F-28, were also proposed over the decades but with only limited success.

The following chapter looks at proposals to use large airlifters as strategic missile launchers, the use of nuclear propulsion, span-loaders, pod carriers and other innovative approaches, that have yet to achieve success. Another chapter addresses the problem of out-sized loads, originating with the need to transport the large rocket boosters used in the US Moon programme. One of the proposals involved the use of the wings and other components of the British Saunders-Roe Princess flying boats, while another bizarrely employed two sets of wings and engines from Douglas DC-7s. Later efforts saw the use of a Boeing 747 to transport the Shuttle and of transport aircraft to launch rockets carrying satellites into orbit. The latter has had some success, including the launch of satellites from a Lockheed L1011 TriStar.



Royal Australian Air Force (RAAF) movements personnel from No 23 Squadron load a C-17A Globemaster prior to it departing RAAF Base Amberley to participate in Exercise Shaken Fury in the US. Commonwealth of Australia 2021.

There is also a chapter that deals with the many projects based on the C-130 Hercules, including various test beds, stretched and wider fuselages, STOL variants with a selection of propulsion options, including rockets, and even a flying boat version. The final two chapters deal with the emerging airlift requirements and the technology likely to be available to meet them, although actually not that much has changed since the 1960s. The need for a special operations V/STOL capable airlifter, incorporating stealth features, has generated many proposals, without actually producing any hardware "at least as far as is known".

These books display outstanding editorial standards, including many pictures and diagrams, many of which are attributable to the originating companies. There are also numerous tables of technical data, and performance information, although much of this is also contained in the text. Finally, both books are rounded off with a comprehensive glossary, a reference bibliography section and indexes.

All-in-all, the authors should be congratulated for completing what must have been a monumental task.

Colin Frazer
AMRAeS

SUKHOI Su-25

By Yefim Gordon and Dmitriy Komissarov

Crécy Publishing, 2020, 496pp, £44.95.

In 1970 the Soviet armed forces badly needed a modern ground attack aircraft to support their ground forces. Two of the famous Soviet design bureaux made proposals: The Ilyushin OKB with the Il-40 and the Sukhoi OKB with the Su-25. The Su-25 was chosen as the winner and made its first flight in 1972.

Following further development, the aircraft went into service in 1980 in support of the Soviet forces in Afghanistan, having been identified by NATO and given the reporting name 'Frogfoot'. Subsequently the aircraft was also exported to a number of nations in Europe, Asia, Africa, South America and the Middle East, with more than 1,000 aircraft being produced. It has seen active service in a number of different theatres, including the recent Russian involvement in Syria, and is still in operational use today.

The book under review, which is the latest in the 'Famous Russian Aircraft' series, studies every aspect of the life of the Su-25 in great detail. Starting with a review of the competition, it then describes the testing and development of the aircraft, before giving a very detailed view of the aircraft structure and the wide variety of weapons that the aircraft is capable of carrying.

Sukhoi Su-25 of the Russian Air Force landing at Vladivostok. Leukhin Fedor.

...as a 'go to' reference book on any aspect of the Su-25, it is unbeatable

Moving on, the book describes the aircraft's involvement in various battlefield actions and then discusses its service with the various export customers. Finally, in a number of comprehensive appendices, the authors list the details of every single aircraft produced, together with the accident attrition data.

This is a 'big' book in every sense of the word. It has 500 pages, measures 29cm x 21cm x 4cm, and weighs 2.5kg! Despite this, it is a very readable book, which contains a lot of fascinating detail and more than 600 photographs and drawings. It is probably unlikely that anyone would sit down to read the book from cover to cover but, as a 'go to' reference book on any aspect of the Su-25, it is unbeatable.

Sir Donald Spiers
CEng HonFRAeS

Book Reviews

JOHN HOUBOLT

The Unsung Hero of the Apollo Moon Landings

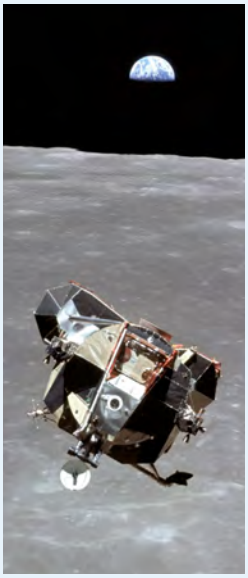
By William F Causey

Purdue University Press, Stewart Center, 504 W. State Street, West Lafayette, IN 49707-2058, USA. 2020. xxiii; 347pp. Illustrated. $29.99. ISBN 978-1-55753-946-5.

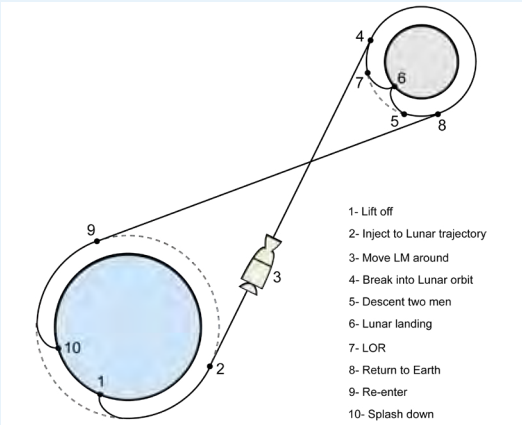
Have you ever watched an hour-long TV programme and thought to yourself that the story could have been told in half the time? That's how I felt by the end of this story about one of the design decisions that led to the success of the Apollo Moon landings. NASA put together the first rough estimates of how much it would cost to put men on the Moon in 1959. There was not much detail behind the estimates but, in general terms, they assumed that a rocket would fly from the Earth direct to the Moon and then return – the concept popularised by Jules Verne in *From the Earth to the Moon* (1865) nearly a hundred years earlier. It was recognised that there might need to be a variation of that involving two or three launches from the Earth in order to assemble the giant Moon ship before leaving Earth orbit – a variation that was felt to be within the (very wide) error margins of the estimates.

The idea of assembling a Moon ship in orbit around the Earth was promoted by Wernher von Braun who, as head of NASA's centre in Huntsville, Alabama, led the development of America's largest rocket motors. Building on his experience with the V2 in Germany during WW2, he developed first the Jupiter C rocket that put America's first satellite, Explorer 1, into orbit in 1958 and then got the go-ahead to develop a heavy lift rocket that would eventually become the Saturn V used in the Apollo Moon missions. His vision was to have a space station orbiting the Earth that would be a factory for assembling spaceships bound for the Moon, Mars and beyond.

The Jules Verne and the von Braun approaches both required landing a large vehicle on the Moon's surface, containing a rocket motor powerful enough to escape from the Moon's gravity along with the necessary rocket fuel. Working backwards, the size of the rocket leaving the Earth would have to be enormous. By early 1960, a US industry team at Chance Vought Corporation (working on a self-funded study) had shown a way to significantly reduce the size of the required rockets: park the main spaceship in orbit around the Moon and send a small ferry down to the Moon's surface. The ferry would later return the astronauts to the mothership for the trip back to Earth – this part involved rendezvous of the ferry and the mothership in orbit around the Moon. The whole scheme eventually became known as the Lunar Orbit Rendezvous (LOR) concept.



Above right: Lunar orbit rendezvous (LOR). Jooja. *Above: Earth, Moon and the ascent stage of the Lunar Excursion Module* Eagle, *in lunar orbit after return from the Moon and before rendezvous with the Apollo 11 Command Module* Columbia. NASA.



By early 1960, a US industry team at Chance Vought Corporation (working on a self-funded study) had shown a way to significantly reduce the size of the required rockets

John Houbolt at NASA's centre in Langley, Virginia, became the main promoter of LOR within NASA and persevered in detailing its advantages in the face of opposition from many quarters, not least from von Braun. The main factor that eventually persuaded the critics to adopt LOR was that it allowed the Apollo mission to be undertaken with a single launch of a rocket whose development was just about affordable. This reduced the development time to within the timeframe set by President Kennedy ("before the decade is out"), as well as holding down the costs. Von Braun and others were eventually persuaded by these cold hard facts to accept LOR, leading to the Saturn V rocket and the Command Module/Lunar Module architecture of Apollo.

We will never know if NASA would have switched to the LOR approach without the advocacy of John Houbolt. It is certainly possible that the schedule and cost implications of the alternatives to LOR would have eventually led hard-nosed NASA managers, such as George Low and Joe Shea, to adopt it anyway. However, Houbolt's actions as LOR 'champion' clearly helped.

The book's subtitle (Unsung Hero of Apollo) is something of an exaggeration, since many histories of Apollo have described Houbolt's efforts to have LOR adopted as the basis for Apollo. In this book, the details of numerous meetings and reports described by the author tend, if anything, to hide the wood for the trees, with the result that Houbolt's contribution gets somewhat lost. The story stops in 1963 once LOR has been accepted by NASA, so that the remainder of Houbolt's career and life is left untold.

The subject of LOR is curiously timely given current attempts by the US to return humans to the Moon's surface by 2024. Meeting that schedule affordably is forcing NASA to look at alternatives to the baseline approach (that would use a vaguely defined Lunar Gateway) including assembly on the Moon's surface and assembly in Earth orbit, as well as the proven LOR approach. *Plus ça change.*

Pat Norris CITP FRAeS

Library Additions

BOOKS

AIRCRAFT

Bristol Fighter: Frank Barnwell's ubiquitous multirole masterpiece by Ray Sturdevant, Gordon Page, James J Halley and Philip Jarrett, Air-Britain, 472pp, 2020.

After a look at the aircraft's development by the British and Colonial Aircraft Company, this book explores the role the aircraft played in WW1 and beyond. As is expected of an Air-Britain title, this is accompanied by histories of each aircraft produced. The book also contains a beautiful selection of photographs, line drawings and colour profiles, together with technical details reproduced from government publications.

Vickers VC10 & Super VC10 by L Cole, Pen & Sword Aviation, 2020, 84pp.

An illustrated guide to the aircraft, together with advice and colour schemes aimed at helping those building models of the aircraft.

75 years of the Lockheed Martin Skunk Works by J C Goodall, Osprey, 2021, 384pp.

A beautifully illustrated photographic record of the aircraft, missile and UAV programmes built and proposed at Lockheed Martin's factory, starting with the XP-80 Shooting Star and finishing with the proposed SR-72 Son of Blackbird.

Nomad 22: A new approach to STOL from Australia by Australian Department of Trade and Industry. Trade Publicity Branch, [1972?], 20pp.

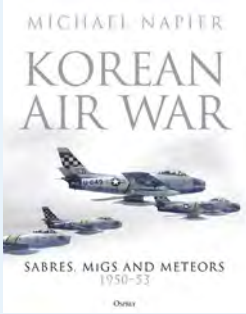
A marketing brochure, including descriptions of the aircraft and its systems. Includes diagrams showing typical layouts, a simple three view general arrangement drawing, a list of general characteristics and a performance summary, together with a number of graphs illustrating the aircraft's performance.

Selected flight test reports by R E Clear CEng FRAeS, Deputy Chief Test Pilot of Airspeed, on the AS57 Ambassador 48-seat transport aircraft, 1948-52, 1 file.

Hawker: Aeroplanes that have set a new standard by H G Hawker Engineering Co Ltd, [1929?], 31pp.

A marketing brochure giving brief details of their main aircraft types, printed in both English and Chinese.

AIR POWER HISTORY



Korean air war: Sabres, MiGs and Meteors, 1950-53 by Michael Napier, Osprey, 2021, 319pp.

This beautifully illustrated book on the Korean War explores the different phases of the air war and the major campaigns of the land war. It also examines in detail the air power of the major combatants, which included North and South Korea, the UK, Australia, Canada and South Africa, as well as China, the US and the USSR.

AIR TRANSPORT

Telling aircraft tails: A history of Britain's airlines in 40 aircraft by G Halford-MacLeod, History Press, 2021, 239pp.

Civil aviation's beautifully illustrated answer to 'The history of the world in 100 objects', highlights 40 individual aircraft to tell the wider story of Britain's airliners.

The civil applications of helicopters: Report on a visit to the USA in April 1947 by R H Whitby, 1947, 67pp.

A thorough report looking at the full range of options being explored in the US for the use of helicopters. Includes information from operators, details of potential uses including for air mail and agriculture, draft air traffic rules and details of operating costs.

FLUID MECHANICS

Annual Review of Fluid Mechanics edited by P Moin and Howard A Stone, Annual Reviews, 2021, 644pp.

The annual review of fluid mechanics exploring subjects such as fluids at the nanoscale, designing multicellular engineered living systems, Leonardo da Vinci and Fluid Mechanics, Levitation and Self-Organisation of Droplets, Predicting the Drag of Rough Surfaces, The Fluid Dynamics of Disease Transmission Cleaning and Decontamination of Surfaces.

The Comet racers uncovered by Guy Inchbald, Steelpillow, 2021, 48pp.

A study of the development of the de Havilland DH88 Comet and the stories of the five racing aircraft produced. It also contains details of the derivatives, replicas, copies and models made over the years.

SERVICE AVIATION

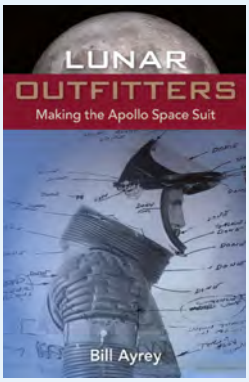
Air Transport Auxiliary at war: 80th anniversary of its formation by Stephen Wynn, Pen & Sword Aviation, 2021, 133pp.

An exploration of how the newspapers reported the ATA together with information on their pilots who died during the war.

RAF maintenance: planning & organisation, 1939-45, [1939-46?], 1 file.

A file of papers including proposals for maintenance organisation in 116 Wing, and notes on training and supplies from British South African Airways. It also contains analysis of the state of C-87s and Halifax IIIs of 216 Squadron for December 1944 and January 1945, Yorks in 246 Squadron in January 1945, Yorks in 511 Squadron for November 1944, December 1944 and January 1945 and Dakotas in 525 Squadron for November 1944, December 1944 and January 1945.

SPACE



Lunar outfitters: Making the Apollo Space Suit by Bill Ayrey, University Press of Florida, 2020, 407pp.

The Model A-7L pressure suit worn by the Apollo 11 astronauts, and the Model A-7LB that replaced it in 1971, originated at ILC Industries (now ILC Dover, LP), an obscure Delaware industrial firm. ILC space suit test engineer Bill Ayrey draws on original files and photographs to tell the dramatic story of the company's role in the Apollo programme.

HISTORY: AIRCRAFT FIRMS

Secret Spitfires: Britain's hidden civilian army by Karl Howman, Ethem Cetintas and Gavin Clarke, History Press, 2020, 191pp.

The Supermarine factory in Southampton was all but destroyed by enemy bombing in 1940. This book tells the story of how Spitfire production was dispersed and is packed with photographs and reminiscences from those who contributed to production.

BIOGRAPHIES & AUTOBIOGRAPHIES

Limitless: The autobiography by Tim Peake, Century, 2020, 478pp.

The story of Britain's first European Space Agency astronaut, including an account of his time training for and working on the International Space Station and his time training and serving as a helicopter pilot in the Army Air Corp.

Fighters in the blood: The story of a Spitfire pilot & the son who followed in his footsteps by 'Black' Robertson, Air World, 284pp, 2020.

This book explores the career of Air Marshal Graham 'Black' Robertson, including his RAF training, squadron commands during the Falklands conflict, service in Bahrain, Germany, and at RAF Wattisham and his time at the Ministry of Defence. Air Marshal Robertson's memoir is interwoven with accounts of the wartime service of his father, 'Robbie' Robertson.

Mother of the few: The aviation interests of Lucy, Lady Houston DBE by Charles E Mac Kay, 2020, 287pp.

A look at the life of Fanny Houston and the two major aeronautical projects that she supported: the British entry to the 1931 Schneider Trophy and the Houston-Mount Everest Flight Expedition of 1933.

C C Walker CBE HonFRAeS, 1877-1968: A centenary appreciation by David R Newman, 1977, 10pp.

A paper on one of the key figures from Airco and the de Havilland Aircraft Company, comprising of the text and slides of a lecture presented to the Royal Aeronautical Society's Hatfield Branch on 26 October 1977.

Save me an egg by Geoff Copeman, 1976, 20pp.

An unpublished account of a RAF serviceman based at East Kirkby, Lincolnshire, during WW2.

Memories of visiting Short Brothers and flying at Eastchurch before and during World War I by Alec Ogilvie, 1954, 8pp.

Includes memories of visiting Short Brothers in 1909, being one of the first Britons to fly their own Wright aircraft and how Eastchurch's club entered WW1.

To borrow these and thousands of other titles contact the National Aerospace Library. E nal@aerosociety.com W www.aerosociety.com/catalogue

Celebration of Life: His Royal Highness The Prince Philip, Duke of Edinburgh KG KT

The Duke of Edinburgh's contribution and passion for aviation have been well emphasised and His Royal Highness made a significant contribution to the sector. In celebration of his life and, following the sad news of his death, the Royal Aeronautical Society would like to share some of our favourite memories, alongside some exclusive photos, audio and articles.

His Royal Highness The Prince Philip, Duke of Edinburgh gained his RAF wings in 1953, his helicopter wings in 1956 and his private pilot's licence in 1959. He achieved 5,986 hours in 65 types of aircraft and continued to fly until he was 75. Soon after gaining his licence, he began to fly a de Havilland Heron on loan from the Navy to fly himself to engagements. He also took opportunities to take the controls of Concorde, an Avro Vulcan and sat in the co-pilot seat in an English Electric Canberra during a visit to RAE Bedford in 1959. In the Boeing family, he flew the Stratocruiser, the 707, 727 and 757.

On 16 December 1954, HRH The Prince Philip, was presented with his Honorary Fellowship scroll by Sir Sydney Camm, RAeS President 1954-1955, at the Assembly Hall, Church House. Honorary Fellowship is the highest distinction for aerospace achievement and is awarded to only the most exceptional contributions to the aerospace profession.

On the same night that he received his Honorary Fellowship, the Duke of Edinburgh delivered the Society's tenth British Commonwealth and Empire Lecture entitled 'Aviation and the Development of Remote Areas'. In the lecture, the Duke explores the vital and integral role of aviation for the benefit of agriculture, surveying, freight and much more. He challenged aircraft designers by saying:

"Aircraft must be simple, robust, and easy to maintain….. this does not mean that aircraft have to be slow. If high speed makes them more economical to operate, so much the better."

HRH The Prince Philip, Duke of Edinburgh KG KT HonFRAeS, RAeS Honorary President 1966
10 June 1921 - 9 April 2021

Below left: The Duke of Edinburgh is presented with his Honorary Fellowship scroll by Sir Sydney Camm CBE FRAeS, RAeS President 1954-1955, at the Assembly Hall, Church House, Westminster, 16 December 1954.
Below: Later that evening he delivered the tenth British Commonwealth and Empire lecture, 'Aviation and the development of remote areas'.
Below right: The Duke of Edinburgh, left, and Sir Frank Whittle view a Whittle jet engine at a dinner given by the Royal Aeronautical Society at the National Westminster Tower in 1987 to commemorate the 50th anniversary of the first running of the world's first jet engine.

The first Royal Aeronautical Society Handley Page Memorial Lecture was delivered by the Duke of Edinburgh at Cranfield on 21 May 1963, entitled 'Education for Technology'. The lecture, focusing on technical education, was delivered in front of an audience of some 1,500 people.

Lord Brabazon of Tara gave an after-dinner speech at his 80th Birthday Dinner, organised by the Royal Aero Club, February 1964. The toast was proposed by HRH the Duke of Edinburgh and has been digitised.

His Royal Highness went on to become the Royal Aeronautical Society's Honorary President in 1966. In this capacity, he chaired the Society's AGM on 5 May 1966. In the same year he attended the RAeS Centenary Congress and Fifth ICAS Congress on 12 September 1966 at the Royal Garden Hotel, London, delivering the address 'Influences on the Development of Aviation' and the Banquet at Grosvenor House the same evening. In the address, the Duke sets out the history and influence of the Royal Aeronautical Society, and more broadly of the developments in aviation over the years.

On 2 June 1973, the Royal Aeronautical Society was proud to host the Duke of Edinburgh at the RAeS Rotorcraft Section Helicopter Rally and Garden Party at Dunsborough Park.

HRH The Duke of Edinburgh attended a dinner given by the Royal Aeronautical Society at the National Westminster Tower in 1987 to commemorate the 50th anniversary of the first running of the world's first jet engine. Sir Frank Whittle HonFRAeS was in attendance also.

30 October 1990 marked the 1,000th Council

Meeting of the Royal Aeronautical Society, held in the Council Room at No.4 Hamilton Place. His Royal Highness attended the meeting and then inaugurated the then Rolls-Royce Suite in the basement of No.4.

To celebrate the centenary of the Wright brothers' first flight, the Duke attended the Society's Wilbur and Orville Wright Gala Dinner held in the Flight Gallery of the Science Museum on 17 December 2003.

The Duke of Edinburgh was present at a celebratory lunch on Friday, 19 October 2012, at No.4 Hamilton Place to formally inaugurate the Marshall of Cambridge Room, which now hosts a plethora of Royal Aeronautical Society events, meetings and STEM outreach work.

The Royal Aeronautical Society has been honoured by His Royal Highness' infectious passion for aviation and deep interest in aerospace engineering that was constantly displayed throughout his life. His words and work have gone on to inspire many in our sectors and for this and his many contributions, he will be greatly missed.

Our statement can be read on the Society's website and is included below:

It was with enormous sadness that the President, Trustees and Council Members of the Royal Aeronautical Society learned of the death earlier today of His Royal Highness The Prince Phillip, Duke of Edinburgh, KG, KT.

A passionate aviator who gained his RAF wings in 1953, he flew 65 types of aircraft and maintained an abiding interest in aerospace engineering, His Royal Highness was awarded an Honorary Fellowship in 1954, the Society's highest distinction for achievement, awarded only to those who make the most exceptional contributions to aerospace. He went on to become the Royal Aeronautical Society's Honorary President in 1966, chairing the Annual General Meeting of that year and returned to the Council Room in 1990 to mark the Society's 1,000th Council meeting.

Above left: The 1,000th Council Meeting of the Royal Aeronautical Society on 30 October 1990. Clockwise from centre back: G C Howell, President; The Prince Philip, Duke of Edinburgh, Hon Past-President; G M McCoombe, President-Elect; AM Sir Frank Holroyd, Dr G G Pope, D J Williams, D Stinton, Prof M G Farley, AM M K Adams, P J Bennington, H McK Cowan, K S Danisman, A R Sharp, N Falconer, R J Forrester, Dr J E Green, J B Groves, AM Sir Donald Hall, D J Harper, Capt R L Jones, Prof M V Lowson, P G Richards, G Roe, Capt M C Russell, P R Sampson, I R Yates, D G Yeomans, Prof J L Stollery, Dr P H Calder, Dr H Metcalfe, A W L Nayler, Council Officer and R J Kennett, Director.
Above: HRH The Duke of Edinburgh, right, is introduced to Sir Brian Burridge, then Chairman of the Air League, by Phil Boyle, then RAeS President, prior to the celebratory lunch to mark the inauguration of the Marshall of Cambridge Room at No.4 Hamilton Place on 19 October 2012.
Left: The Duke of Edinburgh at the controls of a Hawker Siddeley Andover CCMk2 of the Queen's Flight.
Below left: HRH The Prince Philip, Duke of Edinburgh, Honorary President, Royal Aeronautical Society, proposes the toast at the Luncheon given by the President and Council on 5 May 1966 at the Europa Hotel, London.
All photo RAeS (NAL).

Throughout his extended period of involvement with the Society, His Royal Highness delivered a number of the most prestigious annual lectures, often with a theme of the importance of education and the need to encourage young people into careers in aviation and aerospace engineering. The Society is indebted to His Royal Highness for his personal encouragement, infectious enthusiasm and sustained curiosity about aviation which have acted as an example to all.

The Royal Aeronautical Society sends its deepest condolences to Her Majesty The Queen and all members of the Royal Family.

This celebration is also available on the Society's website with links to Journal articles, audio and video.
https://www.aerosociety.com/news/celebration-of-life-his-royal-highness-the-prince-philip-duke-of-edinburgh-kg-kt/

Diary

EVENTS

www.aerosociety/**events-calendar**/

4 May
Air Race E – Propulsion Futures
Richard Glassock, Research Fellow, Hybrid and Electric Propulsion Systems for Aircraft, Nottingham University
Loughborough Branch online lecture

6 May
RAeS SGM and AGM

6 May
UK Space Command
AVM Paul Godfrey OBE, Commander, UK Space Command
Bedford, Cambridge, Hatfield and Stevenage Branch online lecture

11 May
The Rolls-Royce Ultrafan Demonstrator Programme
Andrew Geer, Chief Engineer, Ultrafan Demonstrator
Farnborough Branch online lecture

12 May
The Development of the Jaguar Jet Fighter
Brough Branch online lecture

12 May
The Fresson Story
Highland Branch online lecture

12 May
Team Tempest – the Future of Combat Air
Michael Christie, Director Future Combat Air Systems, BAE Systems – Air
Preston Branch online lecture


UK MoD

13 May
Sharpening the Claws of the Wildcat!
Lee Evans, Senior Test Pilot, Leonardo Helicopters UK
Online lecture

17-18 May
Maintaining Wellbeing: Opening up in the maintenance environment
Online RAeS conference

19-20 May
RAeS President's Conference: UK in the 2020s – An Emerging Space Power
Online RAeS conference

The Solid State Phased Array Radar (SSPAR) at RAF Fylingdales, North Yorkshire, UK, is one of the assets under the control of the UK Space Command. AVM Paul Godfrey will discuss the new UK Space Command at a joint lecture of the Bedford, Cambridge, Hatfield and Stevenage Branches on 6 May. Cherubino.

19 May
Branch AGM followed by Drone Operations
Andrew Chadwick, Chair, RAeS UAS Specialist Group
Hatfield Branch online lecture

27 May
Trenchard Lecture: Torn Curtain – How Bomber Command Pioneered Electronic Warfare
Dr Thomas Withington, defence analyst and writer
Online Named lecture

9 June
Typhoon Shaping the Future Battlespace – Keeping Typhoon Relevant and Effective Out to 2050
Piers Dudley, BAE Systems Aircrew Advisor
Preston Branch online lecture

10 June
Introducing ATI FlyZero
Chris Gear, Project Director, FlyZero
Online lecture

15 June
The ethics and legality of UAV operations
Anthony Gillespie, Visiting Professor, University College London
Farnborough Branch online lecture

15 June
Loughborough University MEng Final Year Aircraft Design Projects – series short lectures
Loughborough Branch online lecture

22 June
Pilot Training, is it time to revisit the basics?
Dr Kathy Abbott, Captain Wayne Morgan, Captain John Leahy and Nick Goodwyn
RAeS webinar

For further information and booking:
www.aerosociety.com/events-calendar/

NEW MEMBER SPOTLIGHT

Name: Lisa Sasse FRAeS, 55

Location: Warwick, New York

Job title: Chief Executive Officer, FlightStart Solutions and Vice President, Safety & Security CellBlockFCS

What inspired you into aviation? When I was six years old, on my first flight, I decided I wanted to be a Flight Attendant. Oddly enough, it wasn't just the cute uniform or the friendly faces, it was what I interpreted flying to be, a way to transport people safely. Even the demonstration of the oxygen masks was very serious in my young mind. As we hit some turbulence during the flight, I remember thinking, they have rules to follow to keep themselves safe too, instinctively instilling confidence due to their training, I didn't give the turbulence a second thought. That is where my passion began, in that moment in time. My passion grew every time I heard the roar of a helicopter overhead. After studying for business, I plunged into aviation, both fixed and rotary wing, starting with commercial aviation and then settled into business aviation. I have had the privilege to work with numerous Fortune 50 flight departments, large fleet helicopter organisations and critical response aviation companies. I have enjoyed close relationships with the OEMs and governing entities.

What is the best thing about your current role? Effecting and influencing safety in aviation. Each opportunity to educate and train for safety and security procedures is invaluable. Especially lithium battery thermal runaway concerns.

What made you join the Royal Aeronautical Society? The leadership that is represented

to the aviation community and my personal experience working with the Royal Aeronautical Society, through my work with the Flight Safety Foundation for over 20 years.

What do you hope to get out of your membership? The ability to utilise and influence protocols set forth by the Royal Aeronautical Society to growing membership.

What three items would you take with you to the space station? Aside from the necessary items, pictures of my loved ones, a journal to capture thoughts and experiences and inspirational reading.

What's your favourite aircraft? I love them all but I am partial to business aircraft.

Who is your biggest inspiration? I find inspiration in several people and things. I have to say one person specifically is a very important person in my life. She inspired me in numerous ways throughout the years. Her level of authority in a non-female environment, demonstrated the ability to be the very best regardless of the circumstances. Challenges that come into our lives, can sometimes be perceived as negative or distracting. When this has happened, I try to choose hope and inspiration to become better.

Piece of advice for someone looking to enter your field? There is nothing more gratifying than reaching altitude, looking out, above the clouds and being at complete peace. Those of us who are fortunate enough to fulfil that dream, have the responsibility of ensuring the most stringent safety practices. I would encourage that a person embrace that and make it their number one focus.

2021 RAeS COUNCIL ELECTIONS

HAVE YOU VOTED IN THE RAeS COUNCIL ELECTION 2021 YET?

Thank you for taking the time to vote in the 2021 Council Elections

The Royal Aeronautical Society Council Election 2021 is open for voting. All voting members who have an email address registered with the Society will have received an email notice enabling you to vote. If you believe that you are a voting member but did not receive an email, or you do not have a valid email address registered with the Society, then please contact our election provider, mi-voice, on +44 (0)845 241 4148 (we would advise that you check your email account's junk folder, in case your email settings determine the email as being spam).

Please note that the voting will close at 9.00am BST on Thursday, 6 May 2021.

Elections

FELLOWS

Jarrah Aldhafiri
Jorge Barata
Ian Barton
Keith Barton
Saptarshi Basu
Paul Begley
John Brindle
Marcus Chivell
Moogega Cooper
Wayne Davis
Marcelo De Lemos
Anthony Dogherty
James Feeney
Mitchell Fox
Roger Gardner
Jeremiah Gertler
Marius Gilmore
Steve Gladston
Justin Goatcher
Mohammad Hasnain
Robert Holland
Robert James
Pauline Jorgensen
Christos Kalogirou
Sergey Karabasov
Mohammed Karim
Suzanne Kearns
Robert Lewis
Raymond Lim
Richard Lowe
Christopher McKie
Robert Moffatt
Alan Quigley
Michael Riegel
Adam Sansom
Afen Sena
Christopher Shaw
Paul Shopland
Hadi Sirika
Andeon Siu
John Sowden
Willard Strandberg Jr
Mike Taylor
Christopher Tutill
Robert Veron
John Wighton
Thomas Wilson
George David Young

MEMBERS

Shokri Amzin
Adriano Argiolas
Adam Bakos
Callum Beal
Thomas Bennett
Eleftherios Bokas
Kirsty Boyd
James Burch
Mark Caven
Romilly Close
Michael Coetzer
Jonathan Conway
William Davey
Jane Dawes
Adam Dobson
Kenneth Douglas
Aaron Duke
Marie Edwards
William Ellis
Ahmet Erik
Tom Fisher
Andrew Foster
Ben Fox
Stuart Fox
Robert Galvin
Edwin Grimshaw
Luke Horner
Lucky Imarhiagbe
Parissram Jaggernath
Zuber Khan
Kevin Kidd
Andrew Lawrie
Errikos Levis
Rebecca Lougheed
Timothy Mackley
Jamie Malcolm
Shawn McCormack
Robert McGivern
Scott McQuaid
Ciara Meadows Miller
James Middleton
Andrew Milligan
Robert Moore
Carlos Moran
David Morris
Ian Mortimore
Patrick Mullan
Lewis Norris
Ricardo Nunes
Andy Paterson
Jaime Pelayo
Franz Savio Pereira
Tom Perry
Athanasios Polyzos
Harry Price
Alistair Roberts
Joseph Roberts
Nicholas Robinson
Mark Rogerson
Shane Ryan
Robin Saaristo
Sanjeet Singh Sidhu Brar
Alex Smee
Dan Smith
Steph Smith
Andrew Spencer
Sophia Stanford
Caitlin Stephenson
Vladimir Stoicescu
Owen Stuart
Luc Sturtzer
Paul Tedder
Derryck Telfer
Tanmay Tipnis
Blair Turner
Andrew Waldron
Joanna Watkinson
Carrie Wilson
Oliver Wilson
Ka Chun Nicholas Wong
James Yardley
Abiodun Yusuf
Adelino Bastos Da Silva
Catherine Cretni
Joyce Oyewole
Luke Pollock
Michael Price

ASSOCIATE MEMBERS

Alexandros Alexopoulos
Kai Barnett
Ryan Brand
Stuart Christie
Kay Davies
Christopher Edwardson
Tom Hinkin
Ciarán Morrison
Joshua Otter
Amile Ratnasiri
Allan Richardson
Witharanage Chaminda Rodrigo
Subitai Sidey
Rishabh Singh
Adam Taphouse
Daniel Teszka
William Thorne
Thomas Tyrell

ASSOCIATES

Aiden Coffey
Patryk Demkowicz
Daniel Ferriday
James Frankland
Josh Gibson
James Lewis
Umer Mahmood
Aaron Murphy
Scott Porter
Bilal Zia

WITH REGRET

The RAeS announces, with regret, the death of the following members:

HRH The Prince Philip, Duke of Edinburgh KG KT HonFRAeS 99
Graham Barry Atkinson CEng MRAeS 76
Frank Bennison CEng MRAeS 95
Michael Ennis CEng MRAeS 92
Ronald Patrick Gadd MBE FRAeS 87
Badshah Gul FRAeS 80
David Denver James CEng FRAeS 87
Frank Ralph Jones FRAeS 77
Robert Wynne Jones MRAeS 90
David Kolodziej FRAeS 84
Alan Marshall MRAeS 75
Kenneth William Newby CEng FRAeS 97
John Walton Saull CEng FRAeS 85
William Albert Squibb MRAeS 87
Alan Vincent Suffell Affiliate 82
Keith Ronald White MRAeS 90
Francis Brian Whitehall CEng MRAeS 90

E-ASSOCIATES

Miguel Aresta
Zayd Aslam
Mohamed Elshazly
Kevin Eskay
Mai Fadeni
Singo Gavi
Dulmin Jayasinghe
Grace Kenamu
Zeinab Khaksar
Alexander Megginson
Riley Purcell
Aeed Sanjania
Sebastian Syncerz
Ugyen Wangchuk
Marco Yeung

AFFILIATES

Ho Yin Chan
Rebecca Hidgcock
Anna Lamond
Julian Porter
Michael Waddington
Tomas Webster

RAeS CHIEF EXECUTIVE OFFICER

Announcement on the retirement of the RAeS CEO

After more than 50 years in the aerospace and defence sector and three years as Chief Executive Officer of the Royal Aeronautical Society, Sir Brian Burridge has indicated to Trustees that he intends to retire from his post in October of this year.

The Trustees are considering the appropriate recruiting strategy by which to appoint a replacement and, over this time, there will be greater opportunity to thank Sir Brian more fully for his excellent and valued contribution to our sectors.

Corporate Partners

NEW CORPORATE PARTNER

RICARDO
Shoreham Technical Centre, Shoreham-by-Sea,
West Sussex BN43 5FG
United Kingdom
http://www.ricardo.com

Ricardo plc is a world-class environmental, engineering and strategic consulting company and specialist niche manufacturer of high-performance products.

Ricardo develops clean, efficient and integrated propulsion systems for future aircraft in fixed wing, rotary, eVTOL and UAV platforms for commercial and defence applications. Ricardo's experienced manufacturing and technical teams deliver seamless low to medium volume manufacturing solutions from the company's state-of-the-art facilities.

Ricardo is the trusted engineering services provider for electrification, hydrogen fuel cell technology and defossilised fuels, and from its List X technical centres in the UK designs, develops and delivers innovative projects to the UK Ministry of Defence across land, sea and air environments.

Find out more about RAeS Corporate membership and advertising:
E partners@aerosociety.com
T +44 (0)20 7670 4346
www.aerosociety.com/corporate

The Last Word

COMMENTARY FROM

Professor Keith Hayward
FRAeS

The Right Stuff

The death last December of Chuck Yeager, combined with the 60th anniversary of Yuri Gagarin's 110 minutes of history, triggered a number of memories of historical reflections. Yeager became a popular legend primarily as a result of Tom Wolfe's book and subsequent film The Right Stuff. The book perhaps more than the film, focused on pilots and piloting and emphasised the bravery of chaps usually flying beyond the envelope for a basic salary. There was no PR machine to publicise the Bell X-1, or many of the other dangerous products of the early supersonic era. Times would change with the advent of the X-15 and especially with the selection of the Mercury 7 astronauts – 'spam in a can' to true pilots like Yeager – but increasingly part of an ambitious NASA publicity campaign. Gagarin was always part of a Soviet ideological campaign, but the nail-biting nearly lethal first flight showed real courage – and the last leg by horse and cart an earthy touch for a son of the proletariat.

Memories

As a boy growing up in the 1950s, the aircraft magazines were full of this sort of derring-do: I recall the glamour of test pilots like Neville Duke and 'Bee' Beamont. These were the 'top link' engine drivers of my generation. It was a risky career. Some of the experimental vehicles flying over American deserts were true death traps. Several British prototypes and their pilots were lost – memorably the young de Havilland probably beating Yeager unofficially to Mach 1+ in the DH108. Moreover, 'Winkle' Brown lost his chance of supersonic stardom with the cancellation of the Miles M.52 in 1946.

Not so glamorous in an age of computational fluid dynamics

Today's advanced aircraft are less likely to push into totally unknown territory by the time they make a first flight. Computer analysis, extensive simulation and other test regimes have removed some of the peril from the trade. Nevertheless, there have still been enough test pilots thankful for the work of Messrs Martin and Baker.

The riskier end of the testing spectrum is now largely to be found in the crewed space business. The Virgin Galactic accident was a dramatic case in point. Statisticians will underline the point that, despite reaching orbit on a routine basis, cumulative astronaut hours are still somewhat short of airliner levels of predictability. Indeed, that the shuttle only had two fatal accidents was a statistical quirk – the Congressional Office of Technology Assessment had predicted more than two over its lifetime. Personally, looking at the probabilities, I shall not be including space tourism on my 'bucket list'.

Respect where respect is due

The point of this rare venture into discussing piloting – I prefer to be drinking while flying – is to underline the importance of inspiration as part of the modern messaging process. There is a niggling awareness that an old political economist, such as this writer, will grumble about the poor cost-effective returns of human spaceflight. I still think there is more to do to reduce the cost side of the equation before we routinely inhabit rather than just visit space. Nevertheless, if aerospace is to compete for scarce STEM students, there is merit in lauding the likes of Tim Peake (and never to overlook Helen Sharman) as inspirational role models.

Yeager into the wide blue yonder

Bean counting is an important quality in an industry that has a well-earned reputation of burning its way through a lot of money but value for money has, for too long, had something of a narrowly defined meaning in some quarters. Remember Oscar Wilde's dictum that "to know the price of everything is to know the value of nothing"; there is something to be said for applying a premium for inspiration and emphasising quality over quantity. In another context, there are evident dangers in cutting corners for the sake of a better bottom line or a balanced defence budget. So, wherever Chuck Yeager's final flight has taken him, thanks for the 'Right Stuff' combination of bravery and inspiration.

> "CUMULATIVE ASTRONAUT HOURS ARE STILL SOMEWHAT SHORT OF AIRLINER LEVELS OF PREDICTABILITY. INDEED, THAT THE SHUTTLE ONLY HAD TWO FATAL ACCIDENTS WAS A STATISTICAL QUIRK

AVAILABLE TO ALL MEMBERS

ROYAL AERONAUTICAL SOCIETY

Learn, develop and elevate with Aeroversity

Introducing **Aeroversity**, our brand new integrated learning and professional development system, now exclusively available to all members. As a member of the Society, Aeroversity enables you to continue to develop your knowledge through informative courses, lecture videos and insightful podcasts along with specialist materials suited to your industry.

Resources include:

- Webinars
- Lectures from our network of branches and divisions, available by video and podcast
- eLearning modules and courses
- eBooks library
- Advanced Technologies and Aerospace Database
- Briefing papers ..and much more!

As a member of the Society, Aeroversity is the ideal place for you to record your initial and continuing professional development using MAPD - My Aero Professional Development. MAPD is a 2-way professional development platform, enabling members to access their CPD record and share with their mentors, colleagues and management for comments and feedback.

Download the app or access via your desktop to explore the full range of resources available.

Use your Society login to access here:

www.aerosociety.com/aeroversity