

# INNOVATE, ACCELERATE, COLLABORATE

## A West of England Space Strategy





# CONTENTS

<b>Executive Summary</b>	<b>4</b>
<b>Section 1: The West of England – The Place for Space</b>	<b>7</b>
A Successful and Innovative Region	8
The West of England's Space Legacy	9
Building on a Strong Base	9
Space Manufacturing	10
Bringing Space Benefits Down to Earth	15
Bridging Upstream and Downstream	17
Impressive Research Capability	19
Space Sector Strengths in the West of England	25
<b>Section 2: Shaping the Future</b>	<b>28</b>
The West of England Space Vision	28
Grand Ambitions	28
Future Space Market Opportunities	40
<b>Section 3: Strategic Pillars and Priority Actions</b>	<b>42</b>
Capability – Capitalise and Create	42
Talent – Educate and Inspire	45
Enterprise – Accelerate and Grow	48
Beyond our Boundaries – Communicate and Collaborate	50

## Cover images:

Engineer working on Advanced Low Emission Combustion (ALECSYS) Engine in Bristol © Rolls-Royce

Earth from the International Space Station © Thales Alenia Space

# EXECUTIVE SUMMARY

The UK space sector is at a pivotal moment. Both Government and industry recognise that it will be an engine for growth post-Brexit, powering the recovery from the impact of COVID-19 and delivering key strands of Government policy.

Central to the achievement of national ambitions is the growth of space innovation and enterprise at local and regional levels. Seizing the opportunity to play a leading role in the future success of the space sector and the wider space-enabled economy, the West of England was successfully named as one of seven new Space Hubs established by the UK Space Agency (UKSA) in November 2020.

With leadership being provided by the West of England Combined Authority, in partnership with the National Composites Centre, the Centre for Modelling and Simulation, the University of Bath and the University of Bristol. Reinforced by strong endorsement from industry champions, the Space Hub has provided the momentum for the development of this ambitious and timely regional space strategy.

## The West of England

The West of England is fortunate to have a unique and diverse space sector. Our region supports both multi-national space companies and innovative small and medium-sized enterprises (SMEs), with space-specific expertise spanning upstream (earth observation, space science and exploration, propulsion), downstream (satellite data to support climate change monitoring and mitigation, security and defence, COVID-19 response and space weather), engineering consultancy (military satellite communications, systems architecture, requirements, reliability and supportability engineering) and financial and professional services (space-specific legal, recruitment and start-up financing services). In addition there is significant science, technology, engineering and

mathematics (STEM) outreach and community engagement.

This is supported by world-class universities and research centres undertaking an impressive breadth and depth of space-related research activity, and a wide range of organisations supporting inspirational outreach and community engagement.

This is further complemented by exceptional world-renowned aerospace and advanced engineering expertise, with the region being home to major global players and a dynamic supply chain. Strong capabilities in technologies of high relevance to space – including artificial intelligence, autonomy, robotics, quantum technologies, high performance computing, composite materials, digital engineering and augmented and virtual reality, also add to the unique strength of the region.

## Our Strategy and Action Plan

With a vision of becoming an internationally-recognised space region, our engagement with space stakeholders has identified four Grand Ambitions which aim to address key challenges in the sector and are essential in setting the direction to achieve our vision.

- **Space for Climate, Environment and Net Zero;**
- **Space Infrastructure, Safety and Sustainability;**
- **Space for National Security and Defence;**
- **Space for Smarter Local Government.**

These Grand Ambitions will unlock a host of future market opportunities for our region, while simultaneously drawing on our region's unique and diverse strengths and capabilities. We will prioritise market opportunities that will bring us closer to achieving our Grand Ambitions, with an initial focus on:

- **Downstream applications;**
- **Safety of Space, including Space Situational Awareness, Space Debris and Space Weather;**
- **Defence Satellite Communications.**

Achieving our vision requires a step change in our approach to space. Consequently, we have set out a number of strategic enabling pillars, along with priority actions, so we can successfully address our Grand Ambitions and take advantage of emerging and future market opportunities from a position of strength.

- **Capability** – we will capitalise on our existing space and non-space strengths and create new capabilities through cross-sectoral innovation and technology convergence;

- **Talent** – we will prioritise space education, skills and workforce development, while undertaking inspirational outreach activity;
- **Enterprise** – we will provide the dedicated support required to enable space businesses to accelerate and grow;
- **Beyond our Boundaries** – we will proudly communicate and promote our space strengths, capabilities and ambitions, while welcoming collaboration with other UK regions and developing international relationships.

Delivering our space strategy will transform the space sector in the West of England, act as a catalyst for growing the space economy, increase our visibility on the world stage and drive cross-sector innovation and economic growth.



© Thales Alenia Space

Artist impression of a human in spaceflight







## Vision

The West of England to be an internationally recognised space region, inspired by local, national and global challenges to improve the economy, the environment and wider society.





## Grand Ambitions

We arrived at our Grand Ambitions through identifying our region's space strengths, key challenges for the sector and market opportunities.

 <p>Space for Climate, Environment and Net Zero</p>	 <p>Space Infrastructure, Safety and Sustainability</p>	 <p>Space for National Security and Defence</p>	 <p>Space for Smarter Local Government</p>
Downstream Applications	Safety of Space	Defence Satellite Communications	
Priority Market Opportunities			

## Strategic Pillars and Priority Actions

To realise our Vision and Grand Ambitions, actions under four Strategic Pillars will be delivered.

<b>Capability</b> 	Deliver flagship collaborative research and development projects to work towards our Grand Ambitions, our priority market opportunities and driving cross-sectoral innovation
	Stimulate engagement between the space sector and the aerospace, defence, cyber, high-tech, digital and creative communities, particularly with respect to the development of downstream applications
	Establish a Space Living Lab to undertake real-world testing and demonstration of space-enabled applications
<b>Talent</b> 	Identify and address skills gaps based on how existing STEM skills and workforce mechanisms in the region can support the space sector
	Maximise benefits from national skills and diversity initiatives, and contribute to the development of the National Space Skills Academy
	Establish international educational partnerships and enhance collaboration between the space industry and the digital, creative and cultural community
<b>Enterprise</b> 	Promote space-specific business support and sources of finance widely and effectively within the West of England
	Provide access to affordable space incubation and acceleration support and facilities
	Establish frameworks and mechanisms for space entrepreneurs, start-ups and SMEs to undertake collaborative research, development and solutions testing with larger companies and academia
<b>Beyond our Boundaries</b> 	Develop a compelling space proposition and suite of space-specific marketing materials to showcase the West of England's strengths and capabilities
	Host a major space conference/expo in the West of England and participate in internationally-significant space shows
	Collaborate with other UK space hubs and clusters to develop competitive advantage and build international relationships to drive a step-change in space-related exports and inward investment

# SECTION 1: THE WEST OF ENGLAND – THE PLACE FOR SPACE

Space technologies are woven into the fabric of everyday life in the UK and the space sector's value to life on Earth is difficult to overstate. It is a highly strategic sector, providing social, environmental and economic benefits, while forming part of the UK's critical national infrastructure. Space technology provides weather forecasts, location-based services and accurate time sources, live television broadcasting and rural broadband connectivity. Space enhances our lives and enables an increasingly diverse range of business and commercial applications, as well as supporting the public sector, aviation, geological exploration, climate change and environmental monitoring and measurement, communication connectivity, telecommunications, financial services, emergency services, national security and defence.

The UK has extensive space capabilities, both in terms of science, engineering and manufacturing (upstream) and satellite-enabled products, services and applications (downstream). The direct economic benefit of the space sector is important and growing, making a contribution to UK GDP of £5.7bn. The most recent studies show that the UK space sector generated revenues of £16.4bn, has a growth rate of 2.8% per year, represents 5.1% of the global space economy and employs a growing workforce of 45,100 people (Size and Health, 2020). Nationally, the ambition is to grow sector income to £40bn by 2030. Remarkably, satellite services facilitate and enable wider UK GDP of over £300bn in areas such as telecommunications, navigation, earth observation (EO) and meteorology.

The UK space sector is at a pivotal moment, with both Government and industry recognising that it will be an engine for growth post-Brexit, powering the recovery from the impact of COVID-19. The Government's Build Back Better Plan for Growth and 2021 Integrated Review of Defence, Security, Development and Foreign Policy both acknowledge the significant role of space in the future of the UK economy.



© Rolls-Royce

Artist impression of a moon station

A National Space Council has been established; the Government has procured a 45% share in the OneWeb constellation and Spaceflight Regulations have been launched. Additionally, recent defence announcements have made commitments to create a new Space Command that will protect the UK's interests in space and control the UK's first satellite launched from the UK in 2022. Furthermore, the Space Growth Partnership (SGP) is moving into a new phase – SGP 2.0 – focused on market intelligence, capability alignment (including skills and space clusters) and innovation and investment.

Central to the achievement of national ambitions is the growth of space innovation and enterprise at local and regional levels. Seizing the opportunity to play a leading role in the future success of the space sector and the wider space-enabled economy, the West of England was successfully named as one of seven new Space Hubs established by the UK Space Agency (UKSA) in November 2020. With leadership being provided by the West of England Combined Authority, in partnership with the National Composites Centre, the Centre for Modelling and Simulation, the University of Bath and the University of Bristol, reinforced by strong endorsement from industry champions, the Space Hub has provided the momentum for the development of this ambitious and timely regional space strategy. With a vision of becoming an internationally-recognised space region, we are bringing together space stakeholders to work with a common purpose to generate economic, social and environmental benefits for the West of England and beyond.

## A SUCCESSFUL & INNOVATIVE REGION

The West of England is an economic leader. With an economy worth over £40bn a year, a population of over 1.1 million people, one of the highest rates of employment in the country and over 46,500 businesses, our region competes on a global scale. It is a place where highly skilled people work, where ideas flourish and where businesses grow. It is also a place that a diverse population of people call home.

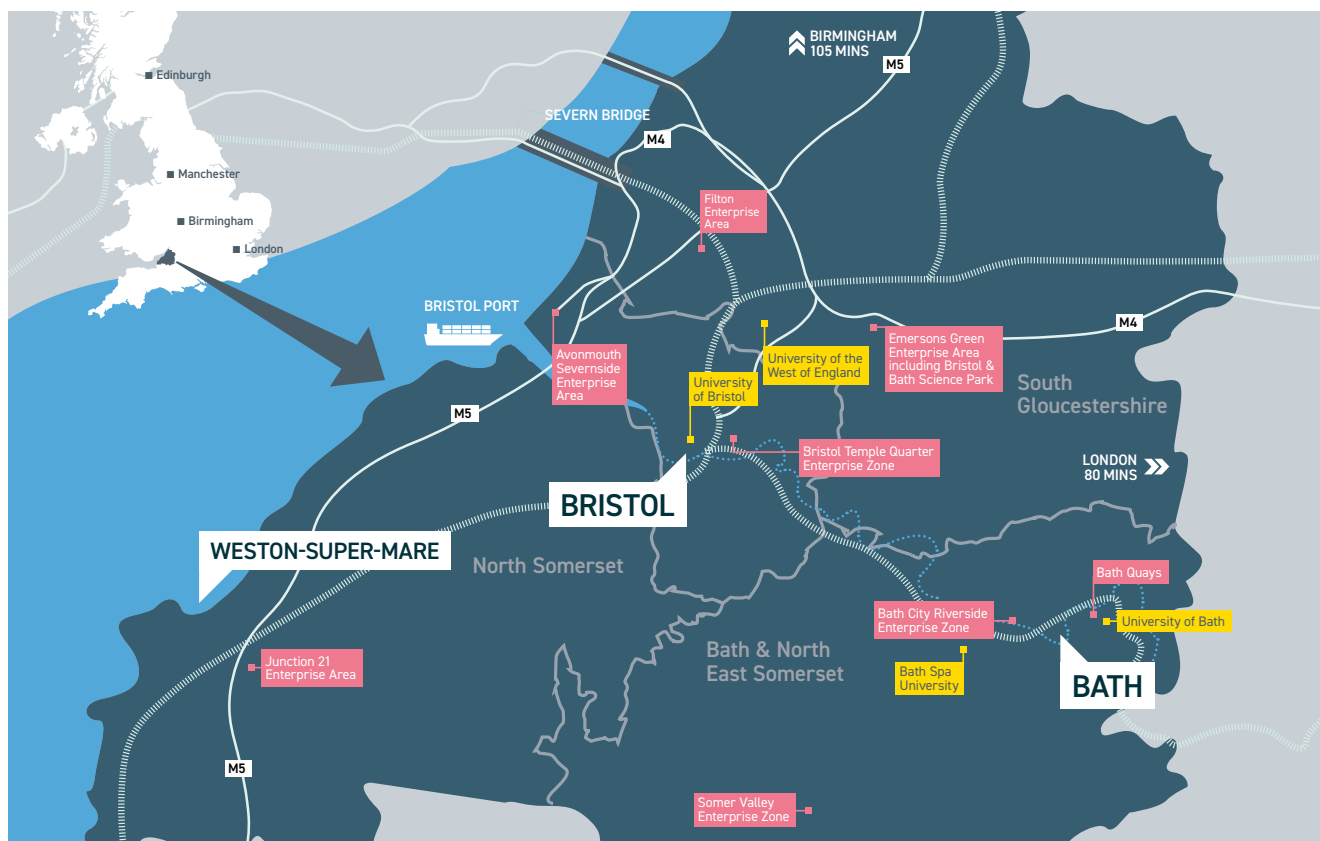
The West of England Combined Authority is made up of three councils in the region – Bath & North East Somerset, Bristol and South Gloucestershire. It also supports the Local Enterprise Partnership (LEP), which is business-led and covers the four West of England local council areas, including North Somerset. The aim of the organisation is to deliver economic growth for the region and address some of our challenges, such as productivity and skills, housing and transport.

The West of England Combined Authority, in partnership with the LEP, provides strategic leadership, particularly through the Local Industrial Strategy (LIS), complemented by the Climate Emergency Action Plan (CEAP) and the Regional Recovery Plan. The LIS draws on the unique strengths of our region and sets out an over-arching ambition for driving clean and inclusive growth. At its heart are four key priorities: cross-sectoral innovation, inclusive growth, productivity and innovation in infrastructure.

The LIS highlights three distinct and overlapping sector strengths that drive innovation in the region:

- advanced engineering including aerospace;
- creative, cultural and digital industries;
- financial, business and legal tech services.

They are supported by their supply chains and the region's four world-class universities.



The West of England Area



Underpinning this is a strong emphasis on digital transformation, with ambitions to create a high quality, effective digital infrastructure with consistent connectivity and speed. A perfect platform for space cluster development, the LIS looks to build on the region's strengths to support further cross-sectoral innovation, setting the strategic direction for growth and productivity, which is even more important as the region embarks upon its path to recovery from COVID-19 in the wider context of the climate emergency.

Space technology, data and services are fundamental to the delivery of LIS ambitions and underpin key priorities, including net zero, future transport and mobility, smart and connected cities, digitalisation, sector development, innovation, trade and inward investment, enterprise, skills and workforce development. Therefore, it is the opportune time to set out our space strategy for the West of England, building on a long and proud space legacy, an impressive existing space industrial and research base, and a host of adjacent technology and innovation strengths.

## THE WEST OF ENGLAND'S SPACE LEGACY

The West of England has a long history in the space sector. The Filton Enterprise Area which is usually connected with aerospace, especially civil aerospace, was also once the home of BAe Dynamics, and its subsidiary BAe Space Systems. The Filton site specialised in the design and construction of scientific satellites, and had a long pedigree in that discipline. Satellites and spacecraft as varied as Ulysses (solar observatory), Giotto (comet chaser), Envisat (polar-orbiting environmental satellite) and Cluster I, show the depth of international collaboration that is required for missions of this scale.

The first concerted effort to develop a horizontal take-off and landing launch vehicle concept was jointly carried out by Rolls-Royce and BAe in the 1980s at Filton. HOTOL (for Horizontal


Take-Off and Landing) was a single-stage-to-orbit (SSTO) space plane that was to be powered by a hybrid air-breathing rocket and jet. Although this concept never developed further than a design study, this concept led to the formation of Reaction Engines Limited and their Skylon concept which utilises a Synergetic Air Breathing Rocket Engine (SABRE) for propulsion.

When the Filton site was closed, several other companies were spawned, including Systems Engineering and Assessment Ltd (SEA), which focussed on hardware, and Science Systems (SciSys), with a software focus. Both of these companies were acquired in recent years – SEA by Thales Alenia Space UK (TAS UK) and SciSys by CGI UK – and continue to operate in the West of England.

A strong legacy in neighbouring areas also contributes to the history of the space sector in the West of England. The space division of Saunders-Roe was based in Yeovil, and it was there that the Blue Streak, Black Knight, Black Arrow and Black Prince rockets were designed. Black Arrow remains the only UK launch vehicle to have lofted a satellite, Prospero X-3, into orbit. The development of these launch vehicles formed the basis for the first joint European launch vehicle called Europa.

## BUILDING ON A STRONG BASE

The West of England is fortunate to have a diverse space sector, complemented by exceptional aerospace and advanced engineering capabilities, as well as a vibrant and highly innovative digital and high-tech sector. Our robust mapping of the West of England space landscape reveals that there are at least 52 organisations actively involved in space activities in the region. These include companies participating in exciting space missions, delivering innovative downstream applications and providing essential services to the space sector. We have world-class universities and research centres undertaking an impressive breadth and depth of space-



related research activity, and a wide range of organisations supporting inspirational outreach and community engagement. Encouragingly, a further 50+ companies have strong potential and ambitions to work in the space sector.

Our space-specific expertise spans upstream (EO, space science and exploration, propulsion and avionics), downstream (satellite data to support climate change monitoring and mitigation, security and defence, COVID-19 response and space weather), engineering consultancy (military satellite communications, systems architecture, requirements, reliability and supportability engineering) and financial and professional services (space-specific legal, recruitment and start-up financing services), as well as significant STEM outreach and community engagement. This is complemented by exceptional world-renowned aerospace and advanced engineering expertise. Strong capabilities in technologies of high relevance to space, including artificial intelligence (AI), autonomy, robotics, quantum technologies, high performance computing, composite materials, digital engineering and augmented and virtual reality (AR/VR), also add to the unique strength of the West of England.

## SPACE MANUFACTURING

The West of England hosts two multi-national space companies – Thales Alenia Space and CGI Group – who are playing a leading role in some of the most exciting and inspirational civil space missions of our time. These are enveloped by a remarkable community comprising innovative space manufacturing start-ups and SMEs, large internationally-recognised aerospace and defence businesses, and a critical mass of engineering consultancy expertise.

Thales Alenia Space, a joint venture between Thales Group and Leonardo Group, delivers cost-effective solutions and designs satellite-based systems for telecommunications, navigation, EO, environmental management, exploration, science and orbital infrastructures. The company established a presence in the UK

in 2014 and the UK business (TAS UK) leads in the design and manufacture of satellite propulsion systems, satellite sub-systems and system design studies, as well as the assembly, integration, test and manufacturing of new experimental payloads for both civil and military use. The company's largest UK site is based in Bristol and focuses on EO and space exploration activities robotics, AR/VR and specialises in scientific studies, technology demonstrators, flight hardware, instrument prime contracting and systems integration.

Projects to which the Bristol site has contributed include:

- CO2MAP Copernicus mission;
- European Space Agency (ESA) Bepi Columbo Mission to Mercury which launched in 2018;
- ESA's Earth Cloud Aerosol and Radiation Explorer (EarthCARE) satellite mission for which it designed the Broadband Radiometer (BBR);
- Design of the Double Walled Isolator (DWI) and Remote Manipulation (RM) for Mars Sample Return Handling;
- Rosalind Franklin ExoMars Rover.

Recent announcements include TAS UK's participation in ESA's TRUTHS satellite mission, which will improve the ability to track and monitor climate change from EO data, and NASA's Lunar Orbital Platform-Gateway which is a pillar of the Artemis programme designed to return humans to the Moon by 2024.

CGI Group is a Canadian multi-national IT consulting and systems integration company. In the UK, CGI works with clients to harness technology with practical innovation to transform, enable, protect and deliver mission critical systems.

CGI UK has a 30 year history in the West of England and its activities here focus on civil space in two key areas – ground segment software and on-board software.

## Space Activity in the West of England

There are 52 organisations actively involved in space activities in the West of England, and a further 50+ companies with strong ambitions and potential to work in the space sector.



**The South West is home to 11% of the UK's Space Organisations, and 25% of these are in the West of England.**

UK Space Industry: Size and Health Report 2020



With respect to ground segment software, the company develops mission planning systems and control systems for ESA missions and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). It has also provided planning systems for OneWeb, which has now been partially acquired by the UK Government, as well as being involved in Galileo. In the area of on-board software, the company supports space missions and science exploration, has led many of the prestigious and high-profile autonomy and AI elements of Mars exploration and space science programmes such as Aurora, Rosalind Franklin ExoMars Rover mission and Sample Fetch Rover, EarthCare and Aeolus.

As a result, the Bristol site has developed highly specialist capability in autonomy, robotics and AI-based technology that is unique in Europe and undertakes high-profile research and development (R&D) activity in these fields. For the future, CGI in the West of England will continue to build on the previous heritage in order to grow its presence in markets such as on-board and ground segment software domains and autonomous robotics in both domestic and international markets.

## Innovative start-ups and SMEs

Space manufacturing innovation and entrepreneurship is flourishing in our region. One of the earliest space start-ups - Bristol Spaceplanes – was established almost 30 years ago to advance a vision of low cost spaceflight and space tourism. The company has produced designs for three spaceplanes, both sub-orbital and orbital, using existing technology. Over the years, the company has attracted funding for feasibility studies, flown a remote-controlled scaled-down version of its sub-orbital Ascender spaceplane and conducted bench testing for the Ascender's rocket engine designs. While this market is moving at a slower pace than others, Virgin Galactic continues to pursue its ambitions in this field and is a market of interest for Japan.

Where Bristol Spaceplanes has started, others have followed. In recent years, B2Space and Space Forge have emerged, both with a presence in Bristol and South Wales. B2Space is developing a reliable, flexible, low-cost access to Low Earth Orbit (LEO) for small and micro satellites, based on a "rockoon" concept, which combines rocket and balloon technologies. It plans two programmes – Colibri for the launch of small and micro satellites and Hawk for near space testing – a flying lab in the stratosphere.

Space Forge is developing a reusable manufacturing satellite which aims to produce new materials in space that are not possible to make on Earth. It is one of only three companies the world which is working in this field, is attracting investment funding and is currently expanding in both Bristol and South Wales to bring its satellite project to test launch position.

LENA Space, an early-stage business headquartered in Bath with operations in the wider South West, is developing low-cost space rocket propulsion technologies. The aim is to provide an off-the-shelf solution to rocket developers, based on the aerospace model of providing engines separate to the airframe. The company has previously received funding from ESA and the UKSA, has tested sub-systems to TRL3-4 and is currently in the process of designing and testing additional systems and components.

Based at the Bristol and Bath Science Park, HiETA specialises in additive manufacturing, design engineering and materials development. The company works across a range of sectors including aerospace, automotive, defence, energy and motorsports. HiETA has also undertaken projects for various space customers, including rocket and thruster manufacturers, and fabricated parts for CubeSats.

There are also a variety of innovative start-ups not currently working in space who have significant potential to contribute positively to

# CASE STUDY

## Thales Alenia Space – Earth observation instruments

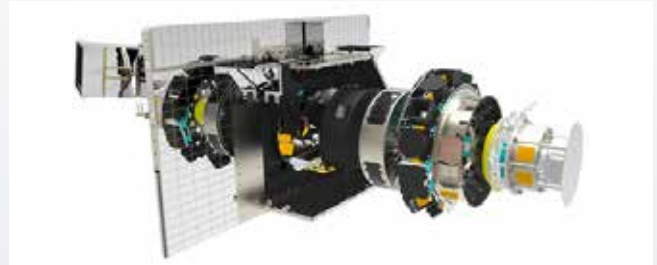
**Building satellites that make important contributions to environmental space missions, improving our understanding of our changing climate.**

Satellites built by Thales Alenia Space make important contributions to Observation and Environmental space missions to better understand our planet and its environment. Thales Alenia Space is a major contributor to Europe's Copernicus mission, an ESA programme which flies a suite of Sentinel satellites to track the health of the planet. These satellites observe and monitor for environmental protection, climate monitoring and natural disaster assessment and response services.

Several Earth Observation scientific instruments which, amongst other things, support climate research are being designed and built for space flight in Bristol by Thales Alenia Space. Here, dedicated teams design remote sensing instruments, build technology demonstrators and test electronic systems for on-board space flight hardware. Here are two examples:

Designed for the European Space Agency the Broad Band Radiometer (BBR) is currently awaiting launch on the EarthCare Satellite. This complex instrument, consisting of an Optics Unit and an Instrument Control Unit, overcame a significant engineering challenge and has set a new standard in global satellite radiometry. The EarthCARE mission, developed in co-operation with JAXA in Japan, aims to improve our understanding of the relationship between clouds, aerosols and radiation and their combined effects on the Earth's climate system.

Thales Alenia Space in Bristol are also leading the development of another important scientific instrument called a Multi Angle Polarimeter (MAP) dedicated to the measurement of atmospheric carbon dioxide produced by human activity. MAP is one of three sensor instruments that makes up the Copernicus Anthropogenic Carbon Dioxide Monitoring (CO2M) mission. MAP



Broad Band Radiometer scientific instrument

is an innovative, simple and compact instrument for aerosols retrieval. The data from this mission will contribute to increasing understanding of the impact of aerosols on both climate change, human health and be targeted at the design of new health applications, monitoring adherence to pollution level goals, as well as better understanding of climate generally.

As is typical of such important and complex projects these scientific instruments are being developed in collaboration with a team of UK and international scientists working in a consortium of industrial and partners. In the UK, the MAP airborne demonstrator project will fly one camera of the instrument on an aircraft, to flight-test the MAP instrument. Working with the University of Leicester, Thales Alenia Space will develop an aerosol retrieval algorithm for the data. This flight follows a previous mission a few years ago, which delivered a "High-resolution Anthropogenic Pollution Imager" (HAPI) to measure discrete spectra for detecting NO<sub>2</sub>.

MAP retrieves the key observation parameters: radiance and Degree of Linear Polarisation of scattered sunlight over a number of near InfraRed wavelength bands, and over a range of angles, to obtain much more detailed information on aerosols. It achieves this via an innovative focal plane, using pixel scale micro polarizers and multispectral filters. A MAP instrument can characterise the aerosol field across a wide swath. This technology enables a small sized instrument, which in turn means that it could be optimised for accommodation in future on lighter satellite and lower cost missions.





Artist Impression of astronaut on moon station

the sector. These include INSPHERE, which specialises in metrology, Smartia and Mesmerix, supporting Industry 4.0 and Internet of Things, enabled by AI and AR, and inward investor Vocavio, whose speech recognition technology could be applied in space environments.

### Close aerospace connections

The upstream space sector is complemented by one of the most diverse and capable aerospace clusters in the world, employing 31,000 people directly in the West of England area, accounting for 5% of employment (ONS Business Register, 2020) and supporting up to 98,000 jobs in the wider South West and South Wales economy (SIA, 2016). From a civil aerospace perspective, the three key players in our region are Airbus, Rolls-Royce and GKN Aerospace. While Airbus Defence and Space dominates the UK space landscape, Airbus' activities at its Filton site in the West of England primarily relate to commercial aircraft (specifically wing design, landing gear and fuel system testing). There is, however, the potential for facilities such as the innovative Airbus Wing Integration Centre (AWIC) to be used for the benefit of the space sector. Rolls-Royce is entering the space sector with the announcement of the first UKSA study into nuclear-powered space exploration, in

partnership with the UK Space Agency. The company's specialist capabilities in power and propulsion, high-temperature materials, complex manufacturing of composites and nickel alloys, as well as design, systems integration, repair and maintenance, are a strong basis for its future work in space. GKN Aerospace's Swedish facilities have participated in the European Ariane launcher programme from its inception. This is set to continue with the development of the next generation Ariane 6 rocket, with GKN developing a new nozzle for the Vulcain 2.1 engine, using the latest technology like laser welding and additive manufacturing. In the West of England, the recent opening of GKN's £30m GTC positions the company to take advantage of future space opportunities here, particularly with respect to the manufacture of metallic and composite integrated space structures.

The dynamic aerospace and advanced engineering supply chain is highly capable of contributing to the space manufacturing sector, particularly as many are exploring diversification opportunities in response to the COVID-19 pandemic. Examples of supply chain companies in our region that have the potential to serve the upstream space sector include Avon Dynamic Calibration, AVPE Systems, Cross Manufacturing, Dynamatic (Oldlands), Ipeco Composites, Ravenscourt Engineering, RPI UK, S2 Aerospace, TE Connectivity, Third Dimension and YED Avionics.

### Defence and cyber synergies

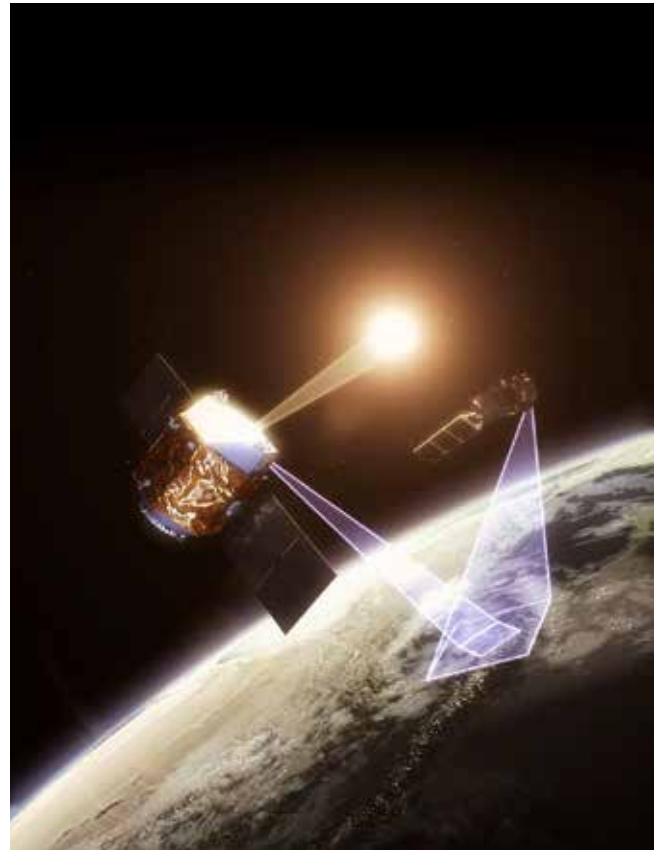
The South West has a large and highly sophisticated defence sector, closely interlinked with aerospace, marine and cyber. The Ministry of Defence (MoD) supports over 30,000 jobs in the region, including the Defence Equipment and Support (DE&S) organisation, which is based in the West of England with an annual budget of £10bn and employing 11,500 people (Ministry of Defence Website, Defence Equipment and Support, 2021).

Additionally, the MoD's Defence Digital, cyber security and Skynet satellite activities are located in Corsham, Wiltshire, in very close proximity to the West of England geography.

Major defence contractors in the region include Babcock, BAe Systems, Boeing Defence UK, MBDA, QinetiQ, Leonardo Group, Rolls-Royce and Thales Group. Additionally, Airbus has a significant presence in close proximity to the West of England, in both Newport with a leading cyber security centre and Wiltshire, to support Skynet activities at MoD Corsham. Much of the activity undertaken by defence contractors in the region is highly classified.

Companies such as Babcock and MBDA have indicated an interest in collaborating with respect to space-related activities, including Space Situational Awareness (SSA), data science, artificial intelligence, communications and autonomous systems. Additionally, the major engineering consultancy businesses in the region – including Atkins, BMT Global, Frazer-Nash, Nova Systems and PA Consulting – are all involved in defence space activities, particularly related to Skynet. For example, PA Consulting, with a regional office in Bristol, leads a consortium of partners in the West of England region (Frazer-Nash, SVGC Ltd, IMD Group) and beyond the region (Inmarsat, e2E Services, TP Group, Sirius Analysis), to work with the MoD on the Skynet 6 secure military telecoms satellite system at MoD Corsham.

In addition, Nova Systems has been successfully solving complex challenges in the UK, Australia and around the world for more than two decades. Nova Systems has signed a Statement of Strategic Intent with the Australian Space Agency (ASA), serves the Agency as a Technical Advisor for Space Launch, and separately serves the industry as a Suitably Qualified Expert (SQE) in launch and facility safety. The Nova team based in Filton are leading the support for the UK launch with a focus on systems engineering, system safety, test and evaluation, logistics and asset management, range services, weapons engineering, certification and design.



© Thales Alenia Space

Artist Impression of satellite observing Earth's climate

Further reinforcing the synergies with defence and space, the Western Gateway geography, which includes the West of England, Gloucestershire, South Wales, Swindon and Wiltshire, is home to one of the world's strongest cyber clusters with hundreds of companies responsible for one-third of all UK cyber patents and a GVA per employee three times the UK average. Complementing this exceptional capability even further, the field of quantum computing and technologies is an additional strength, with expertise at the University of Bristol and within spin-out companies, such as KETS Quantum Security, and early stage companies, such as Duality.

## BRINGING SPACE BENEFITS DOWN TO EARTH

There is a vibrant digital and high-tech community in the region. In 2017, the Bristol and Bath area was cited by Tech City as the most productive tech cluster in the UK, with a digital tech turnover of £8.1bn and employing 36,000



people. Bristol is acknowledged as being among the top 20 cities in Europe for tech investment (Tech City, 2018). Companies in the West of England have expertise in AI and machine learning, VR/AR and immersive technologies,

computer vision, software engineering and data analytics, and are well positioned to combine space technologies and satellite data with emerging technologies to develop innovative products, services and solutions.

Some of the companies doing just that include:

<b>4 Earth Intelligence (4EI)</b>	Provides intelligence about the Earth to aid decision-making, enabled by satellite imagery and spatial data. Projects include city heat mapping, air quality, habitat mapping and mangrove monitoring.
<b>CACI</b>	CACI's Information Intelligence Group (IIG), headquartered in Bristol, provides secure software and Cloud development, including space weather operations support to the Met Office protecting the UK's critical infrastructure.
<b>evriINSIGHT</b>	Enables evidence-based decision-making in high-value complex projects, including projects for the MoD and Foreign and Commonwealth Office (FCO).
<b>Geollect</b>	Specialises in geospatial analysis and intelligence in the fields of maritime technology, defence and security, as well as more recently using geospatial intelligence for COVID-19 response.
<b>Landmark</b>	Using satellite enabled geo-location, space assets and space data to deliver and enhance end-user experiences within marketing campaigns. Powering campaigns for world renowned brands across the entertainment, retail, travel and sports sectors.
<b>Riskaware</b>	Providing actionable intelligence and incident modelling utilising satellite data in the fields of defence, cyber security, marine and bio-environments, as well as COVID-19 response activities.
<b>UCHU</b>	Enables remote operations and collaborative working in aviation, aerospace, maritime and manufacturing using data fusion and a digital user-experience approach, making use of space assets and satellite imagery.
<b>Urban Hawk</b>	Specialises in transforming spatial data into commercial intelligence by combining satellite data and imagery with street-level data to create innovative solutions, such as Urban Digital Twins.
<b>Zeetta Networks</b>	Provides software tools to improve the monitoring, control and management of heterogeneous networks and has been involved in several national and European projects related to the convergence of terrestrial and satellite 5G.

## BRIDGING UPSTREAM AND DOWNSTREAM

Working across both the upstream and downstream space domains are three of the region's prominent engineering consultancies – Atkins, BMT Global and Frazer-Nash.

Atkins operates across a wide variety of markets, with its aerospace and defence activities being led from the Bristol office. Space capabilities and expertise are shared across the Glasgow, Bristol, Aldershot and London offices. The company has historically undertaken space activity but is now seeing this as an even more important aspect of its future growth strategy and is investing heavily in this area. As a result, the company is currently clustering activities in Advanced Air Mobility (AAM), Remotely Piloted Aerial Vehicles (RPAV)/drones, sustainable aviation and New Space alongside its traditional aerospace and defence activities.

Atkins has undertaken projects with AAC Clyde Space, Airbus and Thomas Keating, providing mechanical engineering, systems engineering and test expertise. With respect to defence space, the company works with many companies in the West of England area providing expertise in secure communications, high level systems architecture and availability and reliability engineering. The company also has related cyber security expertise. In the

downstream area, the company is both a user and a developer in the field of EO/geospatial data, using its intelligence capability across the portfolio of its interests, eg. in construction, oil and gas.

BMT Group is a global engineering consultancy with a strong presence in Bath. It is well-known for its defence marine activities, including the design of the Queen Elizabeth class aircraft carriers, and has extensive expertise in cyber security, virtual and augmented reality training solutions, port and critical infrastructure design, environmental risk assessment, Electronic Warfare (EW), Intelligence, Surveillance, Target Acquisition, and Reconnaissance (ISTAR), Position Navigation and Timing (PNT), and Global Navigation Satellite Signals (GNSS), program management and autonomy. In recent years, the company began to proactively grow its space business, drawing on its diverse R&D and engineering capabilities which were highly applicable to the space sector. The company provides specialist technical expertise and has been designated a high-growth company by the Satellite Applications Catapult. It has undertaken ESA contracts with 4 Earth Intelligence and the University of Exeter, as well as having staff members who were involved at high level with the Galileo and Skynet 5 programs respectively.

Frazer-Nash employs approximately 800 people, primarily in offices around the UK, including a hub in Bristol that is home to its newly announced Innovation Centre. Frazer-Nash's space team is led from Bristol and works virtually across a number of offices, including Bristol, Dorking and Glasgow, with the Plymouth office engaging with Spaceport Cornwall. The company is actively growing its space business and is investing heavily in this area. Frazer-Nash primarily works with Government agencies, with the company providing the MoD's DE&S organisation with systems and requirements engineering and supportability expertise. eg. a large Bristol-based team is working on Skynet 6 military strategic communications satellite activities. Frazer-Nash also works with industry, for example, undertaking work for a significant



Artist impression of satellite in orbit



# CASE STUDY

## Riskaware – Marine Watch

**Downstream satellite applications are used for smarter government decision making, preventing an oil spill disaster.**

The Malaysian government has been using the Marine Watch system from Riskaware for several years, and in that time the system has detected major spills and hundreds of potential smaller slicks. This information has been key to helping the government monitor and respond to oil spills, avoiding disastrous consequences for the local environment and economies.

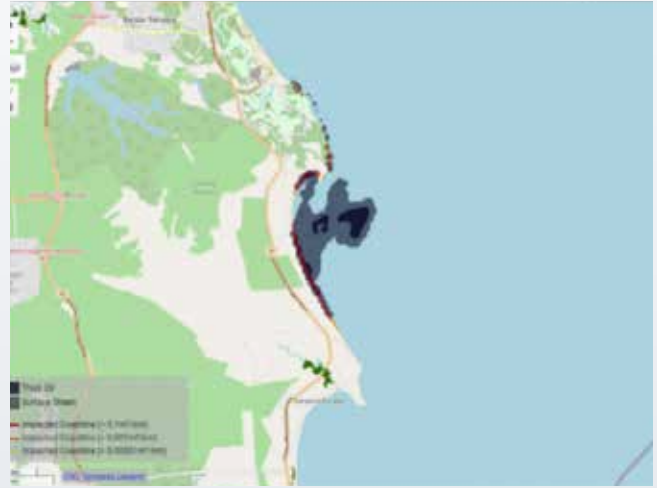
On the morning of 2nd May 2019, authorities were alerted to one such oil spill by Marine Watch's automatic notification system. It identified the spill was located roughly 11km off the coast of Johor, measuring around 5km<sup>2</sup> in area, and integrated modelling predicted that the oil could reach the coastal town of Bandar Penawar within days

An oil slick of this size can cause significant damage to the marine environment, affecting the livelihoods and health of the local people, so urgent response was needed. With support from Marine Watch's in country partners, the KASI Group, the Malaysian government were able to quickly deploy response ships, locate the spill and successfully contain the slick before it reached the coast.

Marine Watch provided the following critical situational awareness data:

- Automatic identification and sending of alerts of the potential presence of oil spillage.
- Modelling of the transport and dispersion of the oil spill forward in time from the point at which it was identified.
- Source identification modelling to show the areas where the oil could have originated.

Marine Watch's satellite oil detection capability, developed by PML and integrated into Riskaware's modelling platform, allows the Malaysian authorities to do this remotely,



© Riskaware

Computer images of Marine Watch mapping software

and without the need of patrols by ships and planes. Satellites regularly monitor Malaysian waters and, in this event, identified the potential slick before it had been seen from the coast or passing ships. This sent an automatic alert to the authorities, enabling them to initiate a timely response.

As collaborators and innovators, Riskaware will keep growing partnerships to continue creating better solutions for real world applications.



UK rocket propulsion company, as well as having expertise in the technical aspects of control systems, cyber security and satellites.

Notably, in November 2020, Frazer-Nash was commissioned by the Department for Business, Energy and Industrial Strategy (BEIS) to undertake a study on the feasibility of space-based solar power that would use a constellation of very large solar powered satellites in orbit to collect solar energy, convert it into high-frequency radio waves and safely beam it back to ground-based receivers connected to the electrical power grid.

## IMPRESSIVE RESEARCH CAPABILITY

The sheer depth and breadth of space engineering and science research in the West of England, combined with research strengths in space related fields, is awe inspiring. From our four world-class universities to our cutting-edge research centres, ground-breaking research projects are being undertaken in a wide range of disciplines, taking inspiration from global societal, environmental and economic challenges and driven by the requirements of the space industry and wider space-enabled economy. Taken together with our strong industrial base, this provides a compelling case to accelerate space sector growth and ambitions.

### World-class universities

All four of our universities have space expertise to offer. The **University of Bath's** space capabilities span a wide range of disciplines, from core Faculties of Science and Engineering to Social Sciences and the School of Management. The university has had a long history of engagement with industry in the region and the wider UK, including relationships with Leonardo, Spirent Communications, Chronos Technology, Airbus, Reaction Engines and others. In addition to these strengths, the university has expertise in high frequency (HF) radar and GNSS technologies, data assimilation, in-space additive manufacturing,

4D (time dependent) tomography, composite materials, finite element analysis and design of commercial control centres. The nationally-significant Centre for Space, Atmospheric and Oceanic Science studies the environment of the Earth and near-earth space and their effects on advanced technological systems. Likewise, the Astrophysics Group, a founding member of the Copernicus Academic Network, is very active in global collaborations, with strong industry connections at national and international level and together with the Institute of Mathematical Innovation has a focus on image and signal processing of EO data. In addition, the University of Bath is co-founder and an active member of the Global Network of Sustainability in Space (GNOSIS).

The **University of Bristol** is home to a strong multi-disciplinary community of space researchers across all faculties, moving beyond the Faculties of Science and Engineering to Life Sciences, Social Sciences, and Arts. The university is at the forefront of industrial space research and innovation, with strong engagement and long-standing partnerships with companies including TAS UK, CGI Group, Airbus, Virgin Galactic and several telecoms companies, including BT. The key strengths and capabilities of the University of Bristol cover a host of areas, including EO, communications, materials and components, payloads, space exploration, health and life sciences, as well as related fields such as data science, artificial intelligence, cyber security and quantum technologies.

In the field of EO, the university boasts huge numbers of academics in a range of disciplines who use satellite data and technologies to monitor greenhouse gases, volcanic plumes, ground deformation and earthquakes, flood and climate modelling, meteorological processes and Arctic ice melt. Partnerships within this group of academics exist with NASA, ESA, Rolls-Royce, the British geological associations, Qioptic, and the Alan Turing Institute, to name a few. From a communications perspective, the university is the location for the Smart Internet Lab, where extensive investment is being made in 5G and

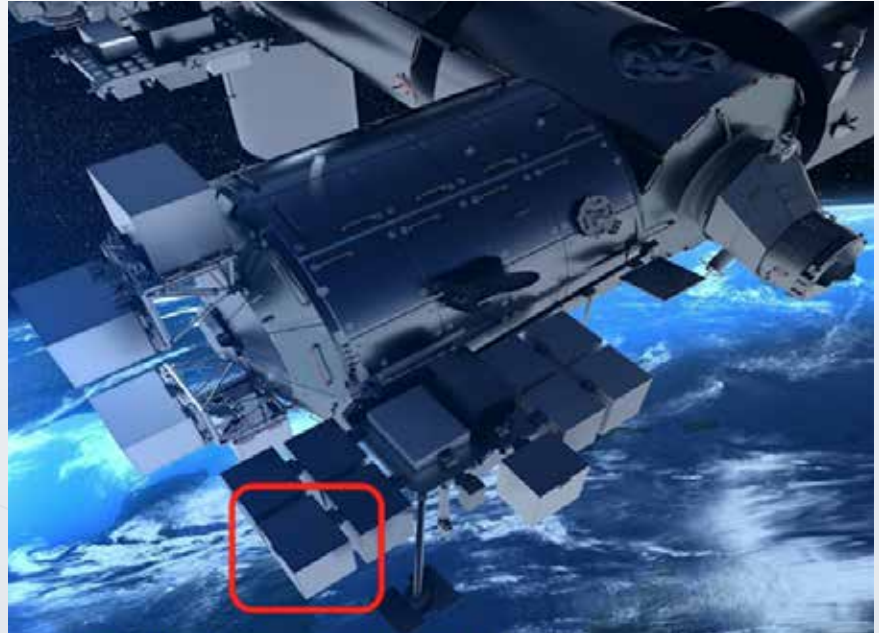
# CASE STUDY

## University of Bristol – SESAME

**Experimental research at the International Space Station and digital modelling tests how composite materials could be used to make space technologies more durable and sustainable.**

In July 2020, a University of Bristol team (led by Prof. Ian Hamerton and comprising Prof. Fabrizio Scarpa, Dr Mark Schenk, and Prof. Kate Robson-Brown) together with the industrial partner Oxford Space Systems, participated in a highly competitive, open European Space Agency/ French Space Agency call (AO Euro Material Ageing 2020) to select participants for the SESAME project. Following an international peer-review process, lasting 5 months, 46 proposals were whittled down to 15 and the University of Bristol team was one of those selected.

SESAME (the experimental compartment involves a door opening on command to expose the samples) is a 6 month, £3.5M mission to expose 45 material samples on the Bartolomeo platform, mounted on the exterior of the International Space Station's Columbus module, to assess their capability for survival in low Earth orbit (LEO). The space environment is a highly aggressive one: high vacuum (10<sup>-4</sup>–10<sup>-5</sup> Pa), UV radiation (100–200 nm), thermal cycling (–150 to 150 °C), charged



© University of Bristol

Artist impression of the Bartolomeo platform in space and the expected location of SESAME equipment

particles, high velocity dust, electromagnetic radiation, micrometeoroids, and engineering debris, literally eat away existing composite materials. When deployed in LEO, satellites are particularly prone to atomic oxygen (AO) exposure (with kinetic energy of 5 eV and AO flux of 10<sup>14</sup>–10<sup>15</sup> atoms/cm<sup>2</sup> s), which plays a major role in the degradation of composites.

Composites made from novel high performance polymers, developed in the Bristol Composites Institute within two PhD projects by Dr Desmond He (of the ACCIS CDT) and Ms Mayra Rivera Lopez (Department of Aerospace Engineering), will be flown in this prestigious mission in 2022. The physical and mechanical data acquired

before and after exposure in the SESAME mission will be used to develop a computational model, a 'digital twin', and provide information about the novel composite performance in extreme environments which will support ever more ambitious deployment for new space composites.

which is involved in defining next generation 5G architecture enabling the convergence of terrestrial 5G networks with satellite 5G, as part of the ESA HydRON programme. In the area of materials and components, the Bristol Composites Institute is at the leading-edge of space-related research including the development of lightweight space structures, eg. for launch vehicles using advanced composite materials. Other research activities include the development of payloads for NASA's Chandra satellite, development of CubeSat technology, contributions to NASA's InSight mission to Mars and the design of experiments with Zebrafish to take to the International Space Station to test how the musculoskeletal system responds to microgravity.

Similarly, the **University of the West of England (UWE)** has wide-ranging space-related expertise. Key specialities include robotics, materials and manufacturing, space propulsion and access to space, mission design trajectory optimisation, space debris and renewable energy applications for space. The University is exploring in-space servicing, manufacture and assembly, including manufacturing techniques for producing novel alloys and robotics for in-space autonomous manufacturing. In the field of propulsion, computational fluid dynamics (CFD) modelling is being used for the design of launchers, nozzles and low-gravity liquid propellant management, as well as exploring air breathing propulsion systems. The university is also undertaking work in the increasingly important field of space debris, including detection, recognition, tracking and removal. Mission design activities are also being undertaken, using a range of techniques including model-based systems engineering (MBSE), for small and nano-satellite missions, as well as observation and remote sensing payloads.

**Bath Spa University** has very specific expertise relating to GIS mapping. This expertise has been used to undertake the mapping and computer modelling of peatlands, consultancy projects for Natural England and coastal models for the British Nuclear Authority. More recently, research and consultancy has been undertaken for the NHS and the Royal United Hospital, Bath,

as well as companies requiring the use of GIS and/or (other) automation applications. This expertise is particularly relevant with respect to environmental sustainability and climate change. Other strengths at the university include digital, creative and cyber.

## Leading-edge research centres and assets

Strengthening our research base even further is the presence of our world-leading research centres which are actively increasing, or planning to increase, their space activities.

Part of the High Value Manufacturing Catapult, the **National Composites Centre (NCC)** is a world-class research centre, where companies of any size and across industry sectors, can access cutting-edge technology and specialist engineers, to drive innovation in the design and manufacture of composites. The NCC accelerates product development, stimulates innovative collaborative R&D and drives digital transformation in engineering and manufacturing. It develops solutions for highly complex problems, working with the most strategic and advanced end-user sectors, including aerospace, defence, energy and automotive.

The NCC is already accelerating its activities in the space sector and has a strong ambition to raise the Centre's profile within the space community and make a significant contribution to national space ambitions. The NCC's capabilities are ideally suited to space manufacturing technology research across all relevant space markets, particularly in the area of small satellites which is a national space sector priority and a high growth market. The Centre is currently producing a complex Class 5 liner-less showcase propellant tank based on a design for a geo-stationary satellite. The NCC's ultra-high temperature ceramic matrix composites (CMC) capability is receiving interest from several space companies. The Centre is working with the small satellite launch community which have plans to launch satellites in 2022 onwards. It is also supporting the development



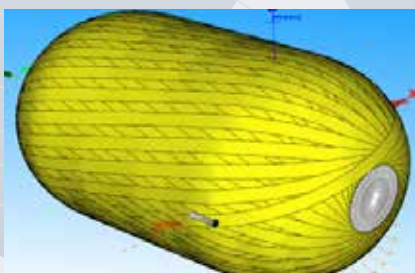
# CASE STUDY

## The National Composites Centre – Type V (liner-less) cryogenic tank demonstrator

**Expertise in manufacturing proves how light weight composite materials can be used in future space manufacturing.**

Launch vehicles and satellites can carry an array propellants such as cryogenic fuels (Liquid Kerosene, Methane, Hydrogen), oxidising agents (Liquid Oxygen, Nitrous Oxide) and pressurized inert gasses (Nitrogen, Helium) the use of which is a necessity for these vehicles to successfully complete their missions. Metal-bodied propellant tanks are heavy, which increases the global mass of the launcher or satellite, which ultimately increases the cost of launch or deployment. However, using lightweight advanced composite materials instead of heavier alternatives can play a vital future role to improve the economic viability of launches.

In response to this lightweighting challenge, the NCC has demonstrated the manufacture of a Carbon Fibre Reinforced Polymer (CFRP) composite Type 5 'liner-less'



Computer graphic of cryogenic tank design



A cryogenic tank in the laboratory

tank demonstrator, using Automatic Fibre Placement (AFP) with toughened epoxy unidirectional carbon prepreg tape and an in-house developed removable internal tooling. The tank has been inspected using coordinate measurements (CM) and has been tested by ultrasonic and thermographic non-destructive inspection (NDI) methods as a means of validating the process and assessing the part quality.

The aim for the NCC is to become a world leading RTO for composite tanks research and development. By completing this demonstrator, the NCC has now developed design approaches and manufacturing knowledge that can be used to support a future UK supply chain for composite tanks.

# CASE STUDY

## The Centre for Modelling and Simulation – Open Source Satellite Programme

### Using novel aviation design capabilities and industry 4.0 technologies to optimise the design and engineering of new satellites.

As part of its work with small to medium enterprises in the Digital Engineering Technology & Innovation (DETI) programme, CFMS is supporting KISPE Space Systems Limited (“KISPE Space”) with their Open Source Satellite Programme (OSSAT), which aims to democratise access to space by making systems more affordable and accessible. This vision will be enabled through leveraging holistic systems engineering practices and Industry 4.0 technologies to reduce programme costs and durations for space missions; and the OSSAT spacecraft platform design will be released as an open source resource for all to freely use. Collaborating within the DETI programme enables early access to enhanced digital engineering capabilities for KISPE Space, whilst CFMS gets a “real-world” test case against which to validate new technologies.

One of KISPE Space's objectives is to minimise Non-Recurring Engineering (NRE) costs by developing a generic satellite structure that can accommodate a wide range of payloads for diverse missions and with different launch vehicles. The structure must also be optimised to avoid adding unnecessary mass to the satellite, which would increase launch cost. With such a variety of often conflicting requirements, conventional design methods would require physical prototypes and repeated design iterations. As a result, the traditional design process is lengthy, consumes materials & resources, and demands significant funding.

CFMS is in an ideal position to generate solutions for KISPE Space, using a generative design optimisation approach. This uses digital engineering tools and methods to create multiple different designs and test each one virtually against performance criteria. By automating this process using multi-objective optimisation (MOO), coupled with high performance computing, an optimised satellite structure is created faster.

The process starts with the creation of a model of the satellite, which is constructed in an automated way and with minimum input requirements from a human operator. This

allows for a dramatic reduction of design time for any future mission requirements. The process of optimization is conducted algorithmically by varying the geometry (thickness, positions) of the structural elements, the manufacturing methods and materials used to make the structure, and the overall layout of components within the satellite. The vast array of models created are then tested against key environmental conditions, such as vibration and the forces experienced during launch, restrictions applied to centre of gravity and total mass. The end result will be a structural design that achieves the mission requirements. A stretch goal will be to include radiation shielding parameters into the structure optimization, which exploits work conducted by one of CFMS' recent interns as part of their industrial placement in the CFMS Model Based Engineering team.

Originally developed in an ATI funded project (DAWS) for the generation of aircraft structures, the research with KISPE Space demonstrates how CFMS can transfer investment in other engineering domains to solve problems in the space sector. CFMS is assessing its portfolio of solutions for application to other challenges in space.



© CFMS HPC

Cray Computer Hardware





of large all-composites launch rocket systems. Furthermore, NCC has undertaken a study for ESA and is working in close partnership with the Satellite Applications Catapult to identify other space-related opportunities. Another activity of relevance is the £9m DCMS and industry funded 5G-Encode project, led by Zeetta Networks [including Siemens, Telefonica and Toshiba] with NCC acting as the host for the UK's first open-access 5G factory test bed.

The **Centre for Modelling and Simulation (CFMS)** is a not-for-profit specialist in digital engineering. As a trusted and neutral provider, its vision is to be the recognised, independent, digital test bed for the design of high value engineering products and processes. Facilitating a greater understanding of how a product will perform throughout its lifecycle, its digital capabilities form the foundation for Through-Life Engineering Services, creating a virtual replica of systems and processes used for investigation of options and opportunities, in advance of physical development. Through its digital engineering experience across the aerospace industry, CFMS has pioneered new approaches in data science, AI, advanced simulation, model-based engineering and engineering computing. CFMS will exploit these approaches to create new opportunities in the space sector, building on decades of experience which its engineers have obtained in the UK and European space industry.

**Bristol Robotics Laboratory (BRL)** is the largest academic centre for multi-disciplinary robotics research in the UK, comprising a vibrant community of 300 academics, researchers and industrial practitioners. It is a collaborative partnership between UWE and the University of Bristol and is an internationally recognised Centre of Excellence in robotics. Its fields of interest include aerial robots, assistive robotics, bio-energy and self-sustaining systems, bio-mimetic and neuro-robotics, connected autonomous vehicles, human-robot interactions, medical robotics, robots for hazardous environments, robot ethics, robot teleoperation, robot vision, smart automation, soft and tactile

robotics and swarm robotics. Many of the projects within the centre are aligned with space innovation. Additionally, both TAS UK and CGI UK have a relationship with the BRL and navigation methods for the Mars Rover have been developed in collaboration with CGI UK.

In addition to the centres highlighted above, there are a number of other key research initiatives and assets of relevance in the region. The highly significant **Digital Engineering Technology and Innovation (DETI)** is a strategic programme of the West of England Combined Authority, delivered by the NCC, in partnership with CFMS, Digital Catapult, UWE, the University of Bristol and the University of Bath. Bringing together advanced engineering companies, digital technology pioneers and the research community, it is pushing the boundaries of digital engineering for the future and helping UK businesses to maintain engineering leadership, and has clear synergies with the space sector.

The **Institute for Advanced Automotive Propulsion (IAAPS)** is a centre of excellence for research, innovation, enterprise and education supporting the future direction of the automotive industry. Its focus is on smarter and cleaner engines, powertrain and driver technologies and it aims to accelerate the transition from low carbon to zero carbon vehicles. IAAPS propulsion expertise could feed into high power density electric machines, drives and energy storage systems; new developments in hydrogen fuel cell technology which could be applicable to space power and mobility applications. Synergies with future flight and advanced air mobility have already been identified and there are likely to be synergies with space propulsion.

Additionally, there are a number of industry-based assets of relevance to space, including TAS UK's advanced testing facilities, the Airbus Wing Integration Centre (AWIC), the GKN Aerospace Global Technology Centre (GTC) and Hewlett Packard Enterprise (HPE)'s high-performance computing (HPC) centre for the Met Office which is operated from Bristol.

## SPACE SECTOR STRENGTHS IN THE WEST OF ENGLAND

The financial and professional services sector is of vital importance to the space sector in areas such as technical space law and health & safety, as well as providing expertise to support growth in the space sector, including venture capital funding, employment law, intellectual property rights (IPR) and contractual matters. At the present time, in the UK, a lot of this activity is centred in London. However, the West of England is home to a strong financial, legal and professional services sector, employing 64,500 people (ONS Business Register and Employment Survey, 2020) and interest in the space sector is growing.

For example, Foot Anstey, a law firm with offices

across the South of England, including Bristol, is one of the only legal companies outside London which provides specialist legal support to businesses and organisations in the space sector, both upstream and downstream. In the upstream, the firm has been supporting the world renowned Goonhilly Earth Station with a range of commercial legal services and advice, it has worked with precision waveguide manufacturer Flann Microwave, and it has been supporting Spaceport Cornwall by advising on the legal and regulatory framework for launch under the Space Industry Act 2018, covering areas such as state aid, planning and environmental, property and infrastructure, and health & safety. In the downstream, the firm recently entered into an agreement with AeroSpace Cornwall to deliver IPR and commercial legal advice to 15 downstream space sector businesses, ranging from start-ups to SMEs. Foot Anstey has developed a good relationship with UKSA, hosting a number of UKSA space law plenaries and Launch UK events in the firm's Bristol office. Through its Truro office and connections in the region, Foot Anstey has established itself at the heart of the rapidly growing Cornwall Space Cluster. By combining its space law expertise,



Earth from the International Space Station



defence sector experience and specialist sector approach, Foot Anstey has ambitious plans to grow its business in this field, including in the West of England.

In parallel, Deloitte is in the process of developing further its unmanned aviation and space propositions in Bristol led by TechWorks - a technology hub that brings Deloitte's global expertise and capabilities to the region. TechWorks is home to a team of 60 technologists, engineers, digital architects and multi-skilled consultants based in the region who understand the local market.

The team recently worked with drone delivery service provider Skyports and Vodafone to collaborate on drone deliveries for the NHS. Using mobile connectivity and space-based technology, the drones take medical supplies to hard-to-reach healthcare sites. Deliveries that previously took up to 48 hours now take 30 minutes.

Deloitte is also the delivery partner for Gravity

Challenge which businesses in the region can benefit from - a programme which supports the space start-up ecosystem in the UK, particularly with respect to the use of EO, remote sensing, Positioning, Navigation and Timing (PNT) and satellite communications to develop downstream applications in a range of areas, including air traffic control and unmanned aviation, climate and environment, IoT, space science, precision agriculture and healthcare, among others.

Additionally, there are two space-specific recruitment agencies in the region - Cosmic Futures and EVONA. Cosmic Futures serves both established players and start-ups in the New Space market to identify suitably qualified professionals, thereby addressing the talent deficit in the industry. EVONA specialises in global space sector recruitment. Its founders have expertise in engineering, data science, AI and machine learning and are passionate about shaping the space industry.

Space-specific Strengths	Space-related Strengths
<ul style="list-style-type: none"> <li>• Earth observation</li> <li>• Space exploration</li> <li>• Space science/instrumentation</li> <li>• Satellite communications, especially military</li> <li>• Space weather</li> <li>• Safety of space operations</li> <li>• AI, autonomy and robotics for space</li> <li>• Downstream applications, particularly with respect to climate change, defence and disaster response</li> </ul>	<ul style="list-style-type: none"> <li>• Advanced engineering and manufacturing, especially aerospace</li> <li>• Propulsion technologies</li> <li>• Artificial Intelligence/Machine Learning</li> <li>• Augmented/Virtual Reality/Immersive technologies</li> <li>• Autonomy</li> <li>• Composite materials</li> <li>• Structures and structural analysis</li> <li>• Additive Manufacturing</li> <li>• 5G</li> <li>• Robotics</li> <li>• Internet of Things (IoT)</li> <li>• Cyber Security</li> <li>• Quantum Computing</li> <li>• High Performance Computing</li> <li>• Advanced Simulation &amp; Design</li> <li>• Digital Engineering</li> <li>• Data Science and Analysis/Big Data</li> <li>• Metrology</li> </ul>

Space-specific Strengths



## SECTION 2: SHAPING THE FUTURE

### The West of England Space Vision

The West of England to be an internationally-recognised space region, inspired by local, national and global challenges to improve the economy, the environment and wider society.

Our vision aims to transform the space sector in the West of England, act as a catalyst for growing the space economy and increase our visibility on the world stage. The West of England space sector has no single “signature space strength”. Rather, the region is blessed with a diverse range of space-specific activities and adjacent non-space capabilities, the combination of which provides an extraordinary opportunity to realise our ambition to become a world-leading space region.

Building on this strong base, a challenge-based approach has been taken, resonating with local strategic ambitions, national space priorities and global transformational trends in the space industry. Our intention is to draw on the full breadth of skills and capabilities in the region, responding flexibly to solve complex problems with innovative solutions. This will involve leveraging the broad and deep space expertise in our region, and exploiting mature and traditional space activities to unlock commercial New Space opportunities, thus driving innovation, increasing the numbers of companies that are active in the space domain and enhancing the competitiveness of the region.

### GRAND AMBITIONS

Our engagement with space stakeholders to date has identified four Grand Ambition themes which address key challenges in the sector and will be central to achieving our vision:

- **Space for Climate, Environment and Net Zero;**
- **Space Infrastructure, Safety and Sustainability;**
- **Space for National Security and Defence;**
- **Space for Smarter Local Government.**

#### Space for climate, environment and net zero

We are focusing on two distinct aspects of this ambition:

- Maximising the use of space assets and satellite data to monitor and mitigate climate change and contribute to net zero ambitions;
- Reducing the environmental impact of the space industry itself, particularly with respect to space launch activities.

Companies and universities in the region are already at the forefront of efforts to enhance climate knowledge, science, monitoring and early warning systems, as well as to enable Governments and other key stakeholders to make informed decisions and to manage climate change. TAS UK is participating in the European Space Agency (ESA) TRUTHS satellite mission which will improve the ability to track and monitor climate change from EO data, Frazer-Nash has been commissioned by BEIS to undertake a study on the feasibility of space-based solar power and the leadership for the Department of Environment, Food and Rural



Affairs (DEFRA) and the Environment Agency's EO virtual centre of excellence is located in Bath, supporting flood forecasting, monitoring and management at national level. Additionally, companies such as 4 Earth Intelligence and Riskaware provide intelligence about earth, enabled by space data and imagery, to monitor environmental indicators and inform policy and decision-making. In the academic world, a vast array of research is underway in this area.

The University of Bristol is a participant in the Met Office Academic Partnership which brings together world-class expertise in a formal collaboration to advance the science and skills of weather and climate prediction. Additionally, researchers at the university are using satellite data and technologies to monitor greenhouse gases, volcanic plumes, ground deformation, earthquakes, meteorological processes and Arctic ice melt. Ground-breaking research is also being undertaken by the University of Bath, in partnership with the University of Oxford, to use satellite imagery to count elephants from space, thus contributing to the protection of vulnerable and endangered species.

The space industry, therefore, plays a critical role in addressing climate change and environmental impact. However, some space activities themselves have an adverse impact on the environment, in particular, spacecraft and satellite launch activities. During launch,

carbon and micro-particles are released and it takes a lot of energy to generate and store propellants, especially cryogenic propellants such as hydrogen and oxygen. Additionally, first stage boosters often end up in the oceans. With respect to satellites, a high reliance on composite structures involves the use of a lot of plastics, exotic metal and ceramic materials. Spent satellites and waste from the International Space Station are disposed of by burning them up in the atmosphere, thus releasing more pollutants and increasing the risk of large components impacting population centres.

The West of England is ready to rise to the challenge – utilising the full breadth of its space-related capabilities to mitigate climate change, enhance the environment and achieve net zero, while simultaneously taking concrete action to reduce the environmental impact of the space sector. Our region has declared a climate emergency and published a Climate Emergency Action Plan (CEAP). There is a golden opportunity to clearly articulate the relationship between space and the environment, and to showcase the essential role that space technologies are playing in climate monitoring, mitigation and informing decision-making at local, national and international levels. This would lay a strong foundation for coordinating space activities across industry, academia and the public sector to explore how the space industry can directly contribute to net zero ambitions within the West of England and specifically how it can help to deliver the CEAP.

Stimulating growth in the downstream applications of satellite data is also a key mechanism for accelerating the journey towards net zero, eg. using satellite and geospatial data to optimise delivery routes for couriers to reduce vehicle emissions; monitoring traffic movements and emissions to optimise route planning for peak emissions, seasonal variations, major events and minimise disruption on local populace and commerce; monitoring inner city pollution levels resulting from planning changes, such as congestion charges,



Earth anchor satellites



urban restriction of diesels etc; monitoring of weather for the planning of green energy sources (including wind, wave, solar).

There are opportunities for our region to lead the way in making space more environmentally-friendly, in areas such as designing satellites and their components to burn up completely on re-entry, developing environmentally-friendly composite materials, designing and

developing reusable launch vehicle structures and components, and investigating new launch propulsion fuels. The West of England's proximity to Spaceport Cornwall and close working relationship with AeroSpace Cornwall provides an excellent opportunity to explore these possibilities in more depth.

### Early Priorities

- Capture and promote the contribution that the space sector in the West of England is making to mitigate climate change, enhance the environment and achieve net zero ambitions at local, national and international level;
- Map existing space capabilities and activities against the priorities of the West of England Climate Emergency Action Plan with a view to accelerating net zero ambitions locally while simultaneously stimulating space sector growth, particularly in downstream satellite applications;
- Bring together key stakeholders in the West of England and wider South West to focus minds on advancing the technologies required to reduce the environmental impact of space activities on Earth, particularly with respect to space launch and satellite operations and disposal.

# CASE STUDY

## University of Bath – TOPCAT II

**Applying research on space safety, sustainability and infrastructure to satellite technology, making GPS more accurate and reliable.**

TOPCAT II are two Global Positioning System (GPS) based satellite instruments developed by the University of Bath for the upcoming US-UK joint space weather science mission, CIRCE. Each CIRCE satellite will carry University of Bath's TOPCAT II payload and four additional instruments from NRL (US), UCL (UK) and SSTL (UK) that will measure the electron density, optical UV, ionised and neutral atmosphere and radiation of the region. The satellites are expected to be launched into Low Earth Orbit (LEO) in 2021.

TOPCAT II – TOPside ionosphere and plasmasphere Computer Assisted Tomography II – consists of a triple frequency GPS receiver that will measure the electron density between the GPS satellites and the CIRCE satellites at LEO. It is controlled by an interface board that ensures the correct operation and communication between the receiver and the main satellite. The full design, development and test cycle of TOPCAT II from prototype to space qualified payload was all carried out within a short development time of eight months.

One main error source of



© University of Bath

GPS instruments being developed

satellite navigation signals such as GPS is the ionosphere, which is affected by space weather. Space weather can be considered to be analogous to normal atmospheric weather, but the source of this is emissions from the sun – both radiation and particles. When these emissions interact with the Earth's magnetic field, it causes variations in the ionosphere. These variations can disrupt the GPS and other similar GNSS, which can result in navigation and timing errors for satellite navigation users.

This can be illustrated using an example such as automated landing of aircraft using GNSS. Variations in the ionosphere can result in GNSS signal scintillation, effectively fluctuating the signal rapidly. When this happens, the aircraft receivers can lose the signals from some satellites and therefore will not be able to use GNSS for automated

landing. Disturbance in the ionosphere due to space weather can also disrupt other radio signals such as High Frequency (HF), Very High Frequency (VHF) and Ultra High Frequency (UHF) signals that are used for communication.

TOPCAT II and other instruments of CIRCE will allow us to measure and study the ionosphere and improve our understanding of the region and related space weather dynamics, thereby helping us mitigate their effects on systems such as GNSS and HF communications.

## Space infrastructure, safety and sustainability

Space infrastructure, safety, and sustainability relates to the ability of all humanity to continue to use outer space for peaceful purposes and socio-economic benefit over the long-term. The increasing complexity of space missions, the emergence of large constellations of small satellites and the increased risks of collision, particularly from space debris colliding with satellites, all affect the long-term sustainability of space activities. Additionally, ambitious plans are emerging which will extend earth's economy into space, eg. increasing the use of space resources by mining on the Moon, undertaking in-orbit servicing, manufacturing and assembly, and establishing human habitation and settlements in space. There is an opportunity for the West of England to take a leading role in ensuring that space is exploited in a sustainable and socially just manner and that space resources are used responsibly, particularly given the very recent agreement between the United Nations and the UK to promote space sustainability.

The combination of our region's space-specific capabilities and our advanced engineering and manufacturing capabilities place us in the ideal position to support sustainable and responsible in-orbit servicing, manufacturing and assembly. Complementing our expertise in space exploration and satellite missions, the region has exceptional aerospace, composites and propulsion expertise in major companies, research centres and universities. A pioneer of in-orbit manufacturing, innovative start-up, Space Forge, which operates from Bristol and Newport, is developing a reusable manufacturing satellite which aims to produce new materials in space which cannot be made on earth.

A critical aspect of ensuring the sustainability of space involves developing a deep understanding of the space environment and knowing the exact location of space assets and space debris. Therefore, the development of Space Situational

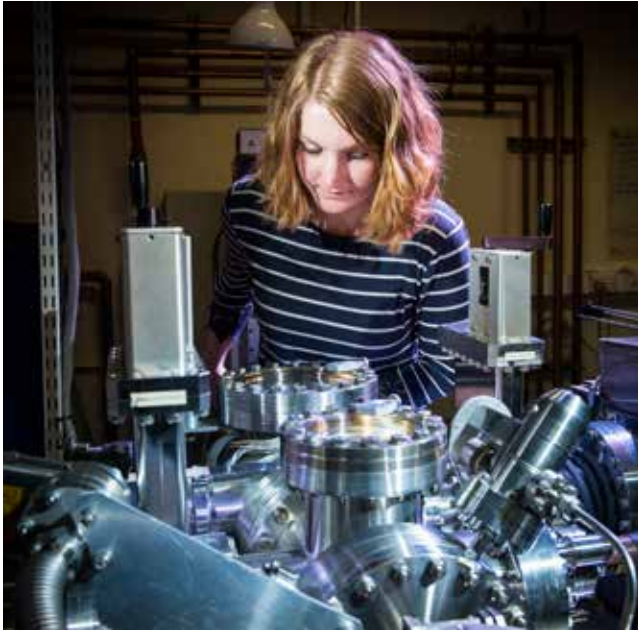
Awareness (SSA) technologies is becoming increasingly essential. Space debris comprises both failed & retired satellites, which are often large but easy to track, and smaller items resulting from routine space operations and from the disintegration of objects that are much harder, yet arguably more important, to locate and track. The major threat from space debris is known as the Kessler Syndrome, which is essentially a cascading avalanche of collisions. The probability of such an eventuality will rise exponentially as the mega-constellations become a reality.

In addition to space debris, space weather, including solar storms, can disrupt satellites and could have an enormous adverse economic impact, even on terrestrial systems such as power grids. Therefore, space weather forecasting and the development of space weather applications and services for spacecraft/satellite owners and operators would be valuable in terms of improving the safety and sustainability of space operations.

Our data science, artificial intelligence, machine learning, high performance computing and cyber security expertise enables us to make a major contribution to the development of SSA policies and technologies, as well as space debris tracking, mitigation and remediation/removal. Additionally, space weather is an area of expertise which we can build on. For example, CACI's Information Intelligence Group (IIG) has enhanced the Met Office space weather forecasting system to reduce the risks associated with space weather which can disrupt modern technology, radio communications and satellite operations, including GPS. Further expanding the relationship with the Met Office in the area of space sustainability would create synergies with the **Space for Climate, Environment and Net Zero Grand Ambition**.

In addition, ethics and sustainability are important components of space activities. Ethics is already well developed in EO applications and it will develop exponentially in space-





Researcher with machinery

based activities. Safeguarding space operations includes adopting designs and practices that limit, or ideally, prevent generation of space debris. Understanding and mapping space debris, responding to key questions such as who is responsible for collisions, as well as the development of laws and practice, along

with space traffic management are all critical concerns if humanity is to prevent a “tragedy of the commons”.

Space activities might eventually include extraction of resources, eg. from the Moon and from asteroids, adding issues of territoriality, cross-pollution between operators (eg. from mining debris) and safety of operations in increasingly congested and contested environments. With increased cadence and simultaneity of space operations, reliance on AI is seen as an enabling capability, which only adds to the reasons for including ethics and traceability in decisions and applications. The University of Bath hosts the only UKRI Centre for Doctoral Training in Accountable, Responsible and Transparent AI, providing academic and industrial collaborations to build from in this area. Ethics and sustainability are increasingly important to the wider public and policy-makers. They have a strong economic rationale and it is fast becoming a moral obligation. It is therefore important to showcase the West of England leadership in these areas.

### Early Priorities

- Signal our interest in being a key player in the development of national and international Space Sustainability policies, capabilities and technologies, including SSA, space debris (identification, tracking and removal) and space weather;
- Start to orientate our phenomenal strengths and capabilities in engineering, manufacturing and through-life services towards the future requirements of in-orbit servicing, manufacture and assembly;
- Build on existing links with the Met Office to be at the forefront of flagship projects aimed at developing systems for protecting spacecraft and satellites (and therefore the world economy) from the risks of space weather, and on international links with individual space players and international space agencies to address the increasing problem of space debris.

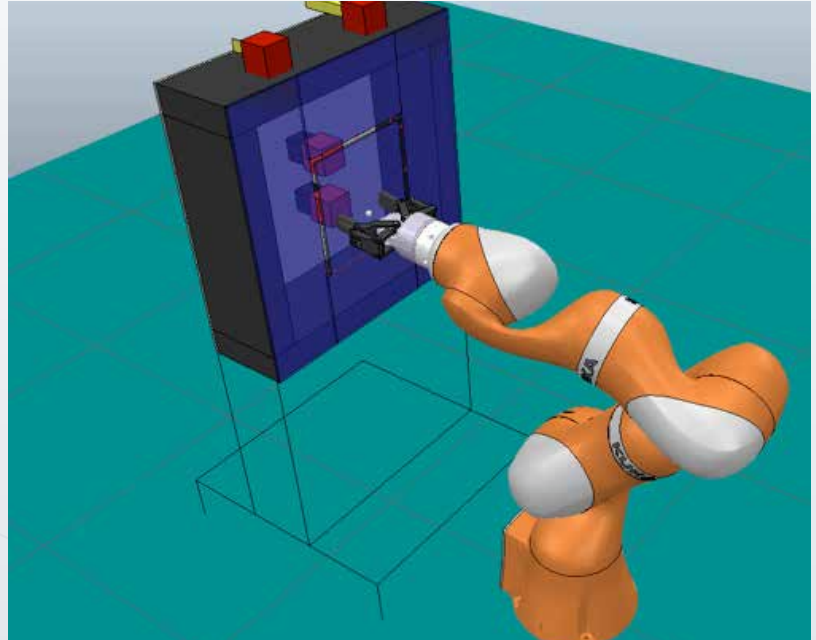
# CASE STUDY

## Bristol Robotics Laboratory – Haptic Teleoperation for space applications

**Exploring how research in robotics can contribute to space safety when faced with time delays in communicating in space technology.**

Teleoperation for space applications has been researched over the past 60 years, allowing us to bring human decision-making to previously inaccessible locations. The problem, still yet to be overcome, is how to perform tasks with the inherent high time delays as dictated by the large distances and the speed of light (Earth-Mars round-trip signal time is 6 - 44 mins). During teleoperation with delays of this level, there is an unavoidable delegation of responsibility from the operator to the robot. For this to occur smoothly, the operator must have confidence that the robot will carry out the desired task as instructed. However, operators are still reluctant to relinquish full control to the robot in space applications due to a lack of trust in the system. One way to address this may be to improve communication between the operator and the robot, through haptic feedback.

The focus of this project is to determine whether, and how, haptic feedback can be beneficial in developing trust for high latency teleoperation applications, i.e., Earth-Orbit, Deep Space Gateway-Moon, Deimos-Mars (delays in the several seconds range). Taking a task-specific approach, two additional lines of research will



be investigated: Human-in-the-loop modelling for complex, non-deterministic environments, and the effects of 'Human Factors'.

### Team:

**Phd student:** Joe Louca (University of Bristol)

**Supervisors:** Antonia Tzemanaki (University of Bristol), Kerstin Eder (University of Bristol), John Vrublevskis Thales Alenia Space, UK

### Funding:

EPSRC ICASE, Thales Alenia Space, UK

## Space for national security and defence

There is an increasing focus on defence space at the very highest levels of Government, with the recent defence announcements committing an additional £24bn of funding to the MoD over the next four years, including the creation of a new Space Command which will be capable of launching its first rocket in 2022, a new agency dedicated to AI and a new national cyber force. There are also calls from across industry for increased convergence between the civil, commercial and military space sectors, and a new National Space Strategy, which covers all aspects, is eagerly awaited.

Being home to the MoD's DE&S and being in close proximity to MoD Corsham, our region has formidable defence and cyber security expertise. A range of major defence players are located here, including Babcock, BAe Systems, Boeing Defence UK, MBDA, QinetiQ, Leonardo Group, Rolls-Royce and Thales Group. Airbus has a strong presence in the wider Western Gateway geography, which includes the West of England,

and that region boasts one of the world's strongest cyber clusters. Complementing this exceptional capability even further, the field of quantum computing and technologies is an additional strength, with expertise at the University of Bristol, including the Heilbronn Institute for Mathematical Research which is a partnership with the UK's Government Communications Headquarters (GCHQ), and spin-out companies, such as KETS Quantum Security, and early stage companies, such as Duality Quantum Photonics.

There is an extensive amount of defence space activity underway in the region. In particular, the major consultancy businesses – Atkins, BMT Group, Frazer-Nash, Nova Systems and PA Consulting – are heavily engaged in defence, cyber and space-related activities, primarily to support military satellite communications. Additionally, a number of downstream businesses, including CACI IIG, evriINSIGHT, Geolcollect, Urban Hawk and Riskaware, are using satellite data to provide defence and security intelligence.



IT programmer working on computer



As a result, the West of England is perfectly placed to make a positive contribution to the defence space domain, both in terms of supporting defence space activity, such as military satellite communications products, services and expertise, and responding to security threats. Complementing our strong civil space strengths and emerging commercial space capabilities, our region can also play its part in the defence space arena, in line with future defence space priorities to be outlined in the forthcoming National Space Strategy.

There are enormous opportunities to spin-in wider defence, cyber and quantum technologies into the space sector, as well as increasing the utilisation of satellite data to support national security and defence intelligence requirements. Activities in the defence space arena will complement the **Space Infrastructure, Safety and Sustainability Grand Ambition** by preventing in-space warfare and deliberate aggressive acts, such as the destruction of satellites.

### Early Priorities

- Recognise the strategic contribution of the West of England to national defence space activities and seek to strengthen and grow capabilities in this field particularly with respect to Skynet 6;
- Facilitate the spin-in of defence, cyber and quantum technologies into the space sector, as well as the increased utilisation of satellite data to support national security and defence intelligence requirements;
- Contribute to national and international dialogue with respect to the peaceful use of space and the prevention of in-space warfare and deliberate aggressive acts, thus simultaneously reinforcing Space Sustainability goals.



# CASE STUDY

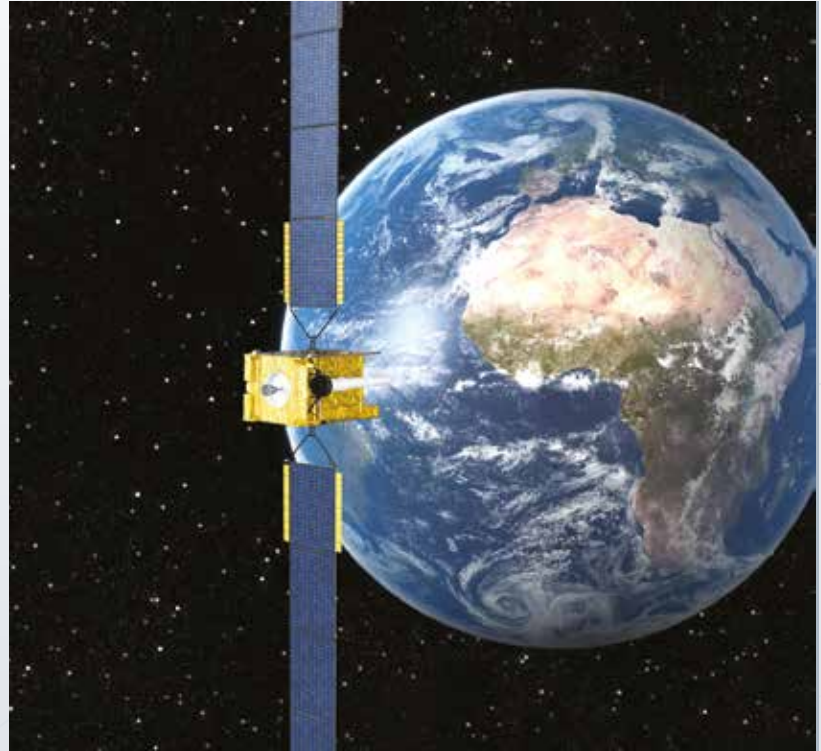
## Airbus – Skynet 5

### **Operating secure space communications services for national security and defence.**

The Skynet 5 programme, managed by Airbus since 2003, has provided the UK MoD with a suite of highly robust, reliable and secure military communications services, supporting operations in Iraq, Afghanistan and the Balkans. It was the largest MoD PFI contract to have been awarded at the time, and sustained over 2000 industry jobs working in partnership with the UK MoD, the programme commenced by using the legacy Skynet 4 satellites and then augmenting them with a fully refurbished ground network before launching the Skynet 5A, 5B, 5C and 5D satellites between 2007 and 2012.

Airbus provides 24/7 customer and technical support and Service Level Agreements with binding commitments to resolve issues quickly and efficiently – guaranteeing 99.9% availability. This support includes a large number of additional services, supplied to the MoD at short notice and includes UK, naval and remote deployments and support of secure communications solutions.

Through the many years of Airbus delivering an exceptionally reliable Skynet service the programme has reduced or removed many of the



© AIRBUS

Artist impression of satellite in orbit

technical and service risks for the MoD, whilst ensuring unrivalled secure satellite communications to UK forces delivering both operational and information advantage at the greatest time of need.

Airbus sites at Hawthorn and Colerne, near Corsham, deliver both Network Operations and Spacecraft Operations for the Skynet programme, as well as Service Management and a 24/7 customer support centre.

## Space for smarter local government

The West of England is committed to enabling clean and inclusive economic growth. The region has strategic programmes and investment in digital transformation, cross-sectoral innovation, employer-led skills and workforce development, business growth and improved transport connectivity. With its broad spectrum of products, services and applications, space is essentially a “golden thread” running through our region’s aspirations, ambitions and strategic imperatives. Central to delivering the LIS, CEAP and Regional Recovery Plan, there is huge scope to explore how space and satellite data, capabilities, assets and strengths can be used more effectively by both the West of England Combined Authority and the local councils it represents.

A synergistic relationship between the West of England’s priority sectors has the power to add significant value to the regional economy. The space industry forms an integral part of the aerospace and advanced engineering sector. Not only is there potential to boost space activities within this sector but there is also the potential for increased collaboration, innovation and co-creation across the advanced engineering sectors for mutual benefit and to stimulate further growth. Space is also embedded to a significant degree within the creative, digital and high-tech sectors and there are major opportunities to expand downstream space activities, to spin-in technologies from the digital and high-tech world and to leverage the creative and cultural sector to support promotion, skills and outreach activities. From the financial and professional services perspective, there is a rapidly increasing need for space investment, legal and regulatory services, which at present are mostly served from London but could be expanded in the West of England.

However, the possibilities do not end there. In addition to enabling growth in priority sectors, the space industry can facilitate growth in the wider economy and facilitate the activities

of end-user communities, from broadcasting to transport, from healthcare to emergency services. There are a range of companies in the region, eg. 4 Earth Intelligence, Geollect, Urban Hawk, are already utilising satellite data and imagery, often in combination with other data sources, to develop innovative applications and provide valuable services, in line with public sector ambitions and sustainable development goals. There is enormous potential to further expand the use of space technologies and satellite data to support the delivery of services, to address local challenges and to improve the lives of the local community. For example, satellite data can drive improvements in the quality and efficiency of transport, housing, air quality, congestion, environment, spatial planning and infrastructure, as well as adding value to strategic investments and ambitions, eg. DETI, Future Transport Zone, Future of Flight, Smart Cities and 5G.



Artist's impression of new Temple Quarter Enterprise Campus

© Feilden Clegg Bradley Studios

Combining space and non-space data opens up a wealth of new and innovative applications and services which can be used for pollution monitoring, climate change mitigation and adaptation, environmental compliance, cultural heritage, protection of natural resources, crisis management, safe transport, sustainable and smart mobility, building and renovation, sustainable/clean energy and vital societal functions, including healthcare, policing, energy, public services and logistics. With respect to future transport and mobility, space and satellite technologies will be critical to the development and successful deployment of Connected Autonomous Vehicles (CAVs) and Advanced Air

Mobility/Future of Flight, as well as enabling mobility-as-a-service solutions, ensuring transport system safety and security, and integrating drones, autonomous and unmanned platforms into the existing transport systems.

There is a great opportunity for West of England Combined Authority and local councils to play an instrumental and tangible role in the growth of the space sector by acting as customers, users and first adopters of innovative space-based applications, as well as supporting the growth of the sector through their economic development activities.

### Early Priorities

- Consider a review of strategic programmes in the West of England to determine how space technologies and applications can add value to these programmes, accelerate their delivery and further improve the lives of people in the region;
- Undertake more detailed research into non-space end-user communities in the West of England that are benefiting from, or could benefit from, space and satellite applications with a view to understanding their requirements, matching them with applications developers and providers, and enabling wider economic growth;
- Explore the potential for West of England Combined Authority and the local councils to act as customers, users and first adopters of innovative space-based applications, particularly to facilitate net zero goals, while also supporting the growth of the sector through their economic development activities.



## FUTURE SPACE MARKET OPPORTUNITIES

The Grand Ambitions that are inspiring our space-related aspirations in the West of England not only set the strategic future direction but unlock a host of future space market opportunities for the region, closely aligned with both the space and non-space capabilities of the region. Our intention is to:

- Remain competitive in existing areas of civil and defence space strengths, eg. EO, space exploration, scientific instruments, AI, autonomy and robotics for space missions, and military satellite communications;
- Stimulate rapid growth in New Space activities, both upstream and downstream, including support for space launch, in-orbit servicing, manufacturing and assembly, next generation launch and space propulsion, payloads, data handling, processing, storage and transfer;
- Spin-in a vast array of non-space capabilities into the space domain, particularly from other sectors such as aerospace, defence and cyber security and related to technology areas such as AI/machine learning, autonomy, AR/VR, advanced materials, engineering and manufacturing, particularly composites and additive manufacturing, robotics, digital engineering, quantum technologies and advanced data management.

The space industry in our region has traditionally focused on the civil space market (space science and space exploration missions), as well as defence space (military satellite communications), primarily driven by ESA and MoD requirements. Over the past ten years, the commercial space sector – or “New Space” – has been gathering pace and is now growing exponentially. The full scope of these markets is, as yet, unknown. However, the private space sector in the US reported global revenues of \$385bn in 2017 (US Chamber of Commerce, 2018), \$5.7bn was invested in New Space in 2019 (Bryce Space & Technology, 2020) and the small satellite (smallsat) launch market is forecast to

generate \$69bn in revenue by 2030 (Frost and Sullivan, 2018/19).





The West of England is ready to embrace this new era of space, inspired by our Grand Ambitions, building on our space, aerospace and advanced engineering legacy, and taking maximum advantage of our space and non-space capabilities and strengths. We will prioritise future market opportunities that will bring us closer to achieving our identified Grand Ambitions, including:

- Consolidating and growing existing markets – space exploration, space and climate science, defence space communications, EO, small satellite manufacture (structures and components), downstream EO products, applications and services;
- Identifying and capturing emerging markets – small satellite and commercial space launch (R&D, design engineering, structures and components manufacture, through-life support and services, payloads, financial and professional services), satellite constellation operations, SSA, space debris (identification, tracking, remediation, removal), space weather services, extending downstream products, applications and services to new end-user communities, particularly the public/para-public sectors;
- Preparing for new markets – in-orbit servicing, manufacture and assembly (R&D activity, market analysis), space-based solar power (feasibility studies).



## Market Opportunities

A wide range of growing markets link to our Grand Ambitions.





 <b>Space for Climate, Environment and Net Zero</b>	 <b>Space Infrastructure, Safety and Sustainability</b>	 <b>Space for National Security and Defence</b>	 <b>Space for Smarter Local Government</b>
<ul style="list-style-type: none"> <li>• Earth observation (EO)</li> <li>• Space exploration/ space science missions</li> <li>• Small satellites/ constellations</li> <li>• Environmentally-friendly space launch, including next generation propulsion</li> <li>• Climate science payloads/instruments</li> <li>• Space-based solar power</li> <li>• Downstream applications</li> <li>• Space manufacturing</li> </ul>	<ul style="list-style-type: none"> <li>• In-orbit servicing, manufacture and assembly</li> <li>• Safety of Space</li> <li>• Space Situational Awareness</li> <li>• Space debris (identification, tracking, mitigation, remediation/removal)</li> <li>• Space weather</li> <li>• Spaceflight/space tourism</li> <li>• Microgravity Manufacturing and Research</li> </ul>	<ul style="list-style-type: none"> <li>• Positioning, Navigation and Timing (PNT)</li> <li>• Defence satellite communications</li> <li>• Surveillance</li> <li>• Defence Intelligence</li> <li>• Cyber</li> <li>• Ground Segment</li> </ul>	<ul style="list-style-type: none"> <li>• EO/PNT to support Smart Cities</li> <li>• Mobility-as-a-service</li> <li>• Urban Air Mobility</li> <li>• Downstream applications to deliver public services</li> <li>• 5G applications</li> </ul>

Based on engagement with stakeholders of leading organisations working in the space sector in the West of England, we prioritised three market opportunities to focus on in the first instance:

- **Downstream applications;**
- **Safety of Space;**
- **Defence Satellite Communications.**

## SECTION 3: STRATEGIC PILLARS & PRIORITY ACTIONS

Central to achieving our vision of being a world-leading space region, making a tangible contribution to the space Grand Ambitions that we have identified and unlocking the market opportunities that we intend to target, are four strategic pillars:

 Capability	 Talent	 Enterprise	 Beyond our Boundaries
<p>We will capitalise on our existing space and non-space strengths and create new capabilities through cross-sectoral innovation and technology convergence.</p>	<p>We will prioritise space education, skills and workforce development, while undertaking inspirational outreach activity.</p>	<p>We will provide the dedicated support required to enable space businesses to accelerate and grow.</p>	<p>We will proudly communicate and promote our space strengths, capabilities and ambitions, while welcoming collaboration with other UK regions and developing international relationships.</p>

### CAPABILITY – CAPITALISE & CREATE

The West of England has superb capabilities which are fundamental to the future development of the space sector and to the growth of the wider space-enabled economy. Maintaining, strengthening and reorienting these capabilities is of paramount importance as we focus our efforts on our Grand Ambitions, playing a leading role in positioning the UK at the centre of the global space economy and taking advantage of emerging and future space market opportunities. We are in the enviable position of having unique, cutting-edge space capabilities and adjacent world-leading engineering, manufacturing and through-life services capabilities, as well as being at the forefront of a range of disruptive technologies which have clear space applicability. These capabilities readily lend themselves to making a

tangible contribution to all aspects of the future space industry and economy. Consequently, we will prioritise our capability focus around three key areas in order to capitalise on our strengths while creating new cross-sectoral synergies:

- Advanced engineering and manufacturing**
  - the rich legacy of aerospace, defence and space activities in the region provides a solid foundation for further enhancing and reorienting these capabilities to meet the challenges of the New Space era. Our world-leading capabilities in composites materials and additive manufacturing are of particular relevance to a wide range of emerging and future market opportunities, including structures and components for launch vehicles, spacecraft and satellites, next generation launch and in-space propulsion, in-orbit servicing, manufacturing and assembly, and spaceflight and space tourism. Making

best use of expertise within centres of excellence, such as the NCC, AWIC, GKN's GTC and Rolls-Royce's Composites Hub, to support space activity is highly desirable. In parallel, our advanced and digital design engineering, systems engineering and test capabilities, as well as our extensive experience in through-life support and services are critical to the successful development of these markets. Organisations such as CFMS and our high-calibre engineering consultancy businesses are perfectly positioned to apply these capabilities in the space domain, complemented by the DETI initiative. We have the power to harness these capabilities to improve the functionality of space platforms, enhance the performance and productivity of the space industry, and reduce the environmental impact of space launch and operations, while lowering the barriers of entry and opening up space possibilities to a wider range of companies.

- **Robotics and autonomy** – the West of England is internationally-recognised for its capabilities in the robotics field, both in industry and academia. In particular, CGI UK's Bristol facility is at the frontier of developments in this field, having developed highly specialised capability in autonomy, robotics and AI-based technology which has been used to support prestigious and high-profile space missions. Industrial capability is complemented by expertise in BRL, many of whose projects are closely aligned with space innovation. Continuing to break the boundaries in the field of robotics and autonomy will enable us to continue to facilitate space exploration and space science missions, while unlocking new opportunities related to in-orbit servicing, manufacture and assembly, and space debris removal, thus making a tangible contribution to the long-term sustainability of space.

- **Data and computer science** – with our cutting-edge capabilities in AI, machine learning, high performance computing, quantum technologies, cyber security, data analytics, IoT and digital technologies, the West of England is ideally placed to add value to the space sector, both upstream and downstream, as well as enabling the use of space data and applications to grow the wider economy and provide beneficial products and services to end-user communities. Much of the business of space is about data – gathering data about the Earth, the Moon and other planets, transmitting data from satellites to facilitate telecommunications for civil and military purposes, interpreting and translating data so that it can be used to inform policy and decision-making. We have a whole host of opportunities to build on these capabilities to grow our space sector and improve our community – data capture, data downlink, data storage, processing and management, data security, data analysis and data-enabled products and services, including mapping, location and tracking, and insight and monitoring. Developing our data and computer science capabilities will help us to address all of our Grand Ambitions while also opening up market opportunities in SSA, space debris monitoring and tracking, defence space and secure communications, and a multitude of downstream applications.

Collaborative research, technology and development, as well as cross-sectoral innovation, are central to capitalising on our existing strengths and capabilities, and to creating new space-oriented capabilities through convergence and creative collisions between technologies. We will leverage the collaborative environment that already exists in the region, which is home to an excellent mix of private and public sector organisations, including SMEs and start-ups, universities,



space companies (upstream and downstream), and large aerospace primes and their supply chains. We are “thinking big” – coming together across the space and non-space spectrum to develop flagship propositions to enhance our

capabilities, unlock new market opportunities and ultimately make a tangible contribution to some of the most pressing challenges of our time. Our ambitions will require large-scale long-term research and innovation funding.

### Early Priorities

- Bring forward a number of flagship collaborative R&D projects to work toward our Grand Ambitions and capture new market opportunities by leveraging the collaborative culture in the West of England, driving cross-sectoral innovation and aligning with the ambitions of the West of England LIS and the Innovation for Renewal & Opportunity programme;
- Stimulate engagement between the space sector and the aerospace, defence, cyber, high-tech, digital and creative communities, particularly with respect to the joint development of flagship projects, the spin-in of relevant technologies and the development of downstream applications, while maximising the use of research facilities and assets in the region for space purposes;
- Establishing a Space Living Lab to undertake real-world test and demonstration of space-enabled applications to support the West of England CEAP, thus showcasing capabilities, stimulating research and innovation, demonstrating public sector leadership and improving the lives of people in the local community.



## TALENT – EDUCATE & INSPIRE

We recognise that diverse, highly talented people are fundamental to our ambition to be a world-leading space region. At national level, proactive steps are being taken to ensure that the talent pipeline and workforce skill levels are keeping pace with the growth of the sector. The Space Growth Partnership's Skills Advisory Panel has ambitions to establish a virtual National Space Skills Institute/Academy which will aggregate skills demand at national level and provide a strategic perspective on future skills requirements. The findings of the latest UKSA Space Skills survey have recently been published. This is particularly aimed at determining the skills requirements at the mid-senior levels within the industry where it is acknowledged that there is a lack of suitably qualified people due to the speed at which the industry has grown in the UK over the past 10 years. Additionally, an industry census is also being undertaken to determine the demographic characteristics of the industry and ensure that it is attracting a diverse workforce. Furthermore, a Level 4 Space Technician apprenticeship has recently been announced, there are plans for a Level 6 apprenticeship and the feasibility of aerospace and aviation professionals transitioning to the space sector is being explored. The UKSA also runs a Space Placement in Industry (SPIN) programme to enable undergraduate and postgraduate students to undertake a summer placement and holds four careers events during the year, one of which is held at Ashton Gate, Bristol.

We are aware through our engagement with the space sector to date that companies are experiencing problems recruiting graduates with the requisite skills and interests. A range of key technical skills are required to support space sector activity, including data analytics, software programming, systems engineering, digital design and engineering, robotics and manufacturing, including additive manufacturing and composites materials. There are also distinctions between the requirements of upstream and downstream

companies. Difficulties attracting and recruiting graduates with the appropriate technical skills are mirrored at the national level. In addition to technical skills, commercial space industry management has also been highlighted as a key skills gap. Therefore, an understanding of local space skills needs in the context of the wider national picture is desirable, complemented by raising awareness of national skills activities and initiatives, increasing participation levels and maximising benefits for the region.

Notwithstanding the recognised skills shortages and gaps, locally and nationally, there is an impressive array of space-related and STEM skills activity underway in the region, generating a future talent pipeline, up-skilling the existing workforce and inspiring the next generation.

- **Generating the talent pipeline** – the four prestigious universities in the region are supplying high calibre graduates in a wide range of relevant disciplines, including engineering, computer science, climate science, life sciences, social sciences and management. Many students are engaged with UK Students for the Exploration and Development of Space (UKSEDS), the national student space society, and there is an opportunity to establish a branch here in our region. Additionally, the new multi-million pound West of England Institute of Technology, led by Weston College will revolutionise digital, engineering and manufacturing technology education across the South West and is responding specifically to the high-level technical skills needs of local industry. The West of England Careers Hub is another important initiative working with schools and colleges to improve career opportunities and work experiences for young people.
- **Upskilling the existing workforce** - The West of England Combined Authority has a wide range of skills and workforce development initiatives in place which have synergies with the requirements of the space industry, including up-skilling and re-skilling existing workers. This approach is integral to the



region's Employment and Skills Plan and other initiatives, such as the skills and workforce element of DETI, the region-wide Workforce for the Future programme and the Digital Skills Investment programme. Additionally, similar to exploratory discussions at national level, there is the potential to investigate the feasibility of transitioning aviation and aerospace professionals adversely impacted by COVID-19 into the space sector by acquiring space domain knowledge.

- **Inspiring the next generation** – an incredible amount of space and STEM outreach is being undertaken in the West of England, with our companies, universities and cultural attractions all having a role to play in inspiring young people and attracting them into the sector. From the “Future Martians” programme delivered by Thales Alenia Space UK to the planetarium at We The Curious, from CGI UK's contribution to the Bristol Technology Festival and to the University of Bristol's “Zebrafish in space” exhibition, the commitment to outreach and community engagement is remarkable. It also demonstrates the close synergies between the space sector and the region's world-class creative and cultural industries, bringing science, engineering, art and immersive experiences together in a unique and inspirational way. Enhancing the co-ordination of this excellent space and STEM outreach activity and increasing school engagement by leveraging local creative and cultural assets would go even further towards improving the lives of people in our region, particularly young people.

The region also commands significant influence in the space skills arena, well beyond the West of England. Our universities are well-connected into the national Space Skills ecosystem and are expected to play a key role in the delivery of the National Space Skills Academy, as well as potentially contributing to the delivery of any future Level 6 apprenticeship. They are also well-positioned to address existing skills gaps in the industry, including PNT data, cyber

security and AI. The University of Bristol hosts and chairs the Space Universities Network (SUN), chairs the UK Space Life and Biomedical Sciences Association (UKSpaceLABS) and participates in the Space Academic Network (SPAN), all of which inform the Space Growth Partnership (SGP), including the development of the proposed National Space Skills Academy.

The West of England can be proactive in developing its space skills and talent needs alongside the anticipated growth in the space sector. With the findings of the national Space Skills Survey and Space Industry Census due to be published, now is time to seize the opportunity to really understand the space skills requirements at local level in more detail, to determine how this can be served by existing local and national initiatives and to identify outstanding gaps. Aligning a space skills review with the LIS ambition of inclusive growth, the region's Employment and Skills Plan, the Green Skills agenda and the recently published Government Skills for Jobs White Paper with its proposal for Local Skills Improvement Plans, would give this work added impetus. It would also ensure that we can continue to contribute to the national space skills conversation from a position of strength and increase the attractiveness of the region with respect to developing international educational linkages, for example, with the International Space University (ISU).

### Priority actions

- Undertake a comprehensive review of space skills, workforce and outreach activities in the region with the aim of identifying and addressing skills gaps, understanding how existing STEM skills and workforce mechanisms can support the space sector, and determining what additional actions need to be taken to support space sector talent, now and in the future;
- Consider the findings of the national Space Skills Survey and the Space Industry Census, understand the implications for space skills and diversity at local level, and ensure that the West of England can maximise benefits from national skills and diversity initiatives, as well as contributing to the development of the National Space Skills Academy;
- Explore opportunities for collaboration to enhance space skills and STEM outreach activities, including cross-sectoral collaboration between the space industry and the digital, creative and cultural community, and the establishment of international educational partnerships.





## ENTERPRISE – ACCELERATE & GROW

The West of England has a sophisticated business and innovation support landscape, orientated to support high-growth, high-tech, innovative businesses. Space businesses can benefit from a wide range of business and innovation support mechanisms, trade associations, incubators and accelerators including (but not limited to) Business West, local Department for International Trade and investment teams; Engine Shed; the West of England Growth Hub; Quantum Technology Enterprise Centre (QTEC); SETsquared Bath and Bristol; TechSPARK; Unit DX and the West of England Aerospace Forum (WEAF). Additionally, the West of England Combined Authority provides funding mechanisms which can be accessed by space and satellite applications companies, eg. the Business Innovation Fund (BIF), which is a three-year project to award R&D grant funding, alongside wrap-around business support, to SMEs in the West of England.

In parallel, West of England businesses can take advantage of national-level space support initiatives delivered through UKSA, UKspace, the Satellite Applications Catapult, the Satellite Finance Network (SFN) and the KTN Space team. This includes the recently-launched Space Accelerator programme being delivered by Entrepreneurial Spark on behalf of UKSA and the Airbus “Open Innovation – Space” initiative.

Despite this attractive business support ecosystem, we acknowledge that space-specific support at local level needs to be boosted and that increased visibility and awareness of what is on offer, both locally and nationally, would prove highly beneficial. There is also scope to maximise the utilisation of the wider business support and economic development ecosystem in the region to highlight space-related opportunities to the wider SME, start-up and scale-up community. We are committed to creating an environment that enables space and space-related businesses to flourish. This environment will emphasise:

- **Incubation and acceleration** – recognising the exponential growth rates in the commercial space arena, an emphasis on the provision of space-focused incubation and acceleration facilities is vital. In the short-term, the existing ecosystem can provide support for bid preparation, access to finance and assistance with business development, as well as mentoring and coaching. We are keen to see our businesses taking advantage of Geovation, the Ordnance Survey’s open innovation arm, which has a presence at Engine Shed, facilitating access to geospatial expertise, supporting start-ups and offering accelerator programmes. In the longer-term, the creation of dedicated space incubator and accelerator facilities, covering the whole spectrum of space technologies and applications, is desirable. This can build on the expertise of SETsquared, who work in Bristol and Bath and supported the UK Space Incubator Network programme between 2016 and 2020.
- **Supply chain strengthening and diversification** – the space sector has enormous potential to open up new markets and unlock diversification routes for the well-established aerospace supply chain, particularly those that have been adversely impacted by the COVID-19 pandemic. In the short-term, the provision of supply chain support aligned with Made Smarter has the potential to benefit of the upstream/space manufacturing community, while the replication of the highly successful National Aerospace Technology Exploitation Programme (NATEP) in the space sector, with a pilot being conducted in the West of England, should be given serious consideration. From a downstream perspective, there is much to be learned from the South West Centre of Excellence in Satellite Applications (SWCoESA), based in Exeter, which helps businesses to exploit the use of satellite data, technology and applications and to develop new satellite applications concepts. Exploring the feasibility of adopting this Centre of Excellence model to cover the West of England geography (and

possibly neighbouring areas) would also be a worthwhile endeavour.

- **Boosting innovation** – facilitating opportunities for entrepreneurs, start-ups and SMEs to collaborate with other industry players and universities is hugely important. Our region already fosters a high degree of collaboration and this can be further enhanced by maximising engagement with research centres and universities with respect to technology pull-through and exploitation into industry. Other ideas include the establishment of frameworks for space sector ambitions, managed by industry on behalf of the UK Space Agency and MoD, to which SMEs and start-ups can compete for funded bids and partner with larger exploitation partners if needed. A similar approach could be taken with respect to space Grand Ambitions, for example, to support net zero ambitions, nationally and regionally, through space technologies, with open calls to enable SMEs to pitch for funding to develop and test solutions.

- **Accessing finance and facilities** – in order to scale-up and grow, access to funding from a variety of sources is essential. We want our businesses to benefit from the expert guidance and support of the ESA Business Applications Regional Ambassador for the South West region to a greater extent than ever before, thus attracting higher levels of ESA funding. Increasing the visibility and ease of access to space-specific venture capital and other sources of finance, such as Deloitte Gravity Challenge (London/Bristol), Seraphim Capital (London) and the Starburst Accelerator (international), would benefit businesses in the region. Given the strength of the financial and professional services sector in the West of England, in the longer-term, the establishment of a local space investment community would be very welcome, potentially as a node of the Satellite Finance Network. Alongside access to finance, access to facilities is another challenge for smaller businesses. Enabling access to affordable space engineering facilities such as clean rooms, thermal-vacuum and vibration testing, as well as access to affordable office, warehouse and commercial/manufacturing space is a priority.

### Priority actions

- Promote space-specific business support and sources of finance widely and effectively within the West of England, maximise the use of the existing business support ecosystem to enable SMEs to grow their space-related activities and advocate for the establishment of a new Satellite Applications Centre of Excellence to cover the West of England geography;
- Explore options to provide access to affordable space incubation and acceleration support, space-specific test facilities and office, warehouse and commercial/manufacturing space to drive the growth in space start-ups and scale-ups with a view to establishing a West of England Space Campus, including dedicated space incubator and accelerator facilities, in the longer-term;
- Establish frameworks and mechanisms for space entrepreneurs, start-ups and SMEs (and those wishing to enter the sector) to undertake collaborative research, development and solutions testing with larger companies and academia, including the creation of a "NATEP for Space", a UK Space Agency/MoD space pitch process delivered by industry and a local space fund.





## BEYOND OUR BOUNDARIES – COMMUNICATE & COLLABORATE

The West of England has a compelling space story to tell – building on our rich legacy of space activity and our existing knowledge-intensive space industry and research community, while shaping the future by harnessing the power of advanced sectors, such as aerospace, and a wealth of digital and disruptive technologies. As an outward-looking region, we will proudly increase the visibility of these space strengths and capabilities, in order to enhance the region's influence nationally and internationally, attract future funding and investment, grow the space sector and increase its productivity and competitiveness, and demonstrate how space is actively contributing to local and global challenges, such as the drive for net zero.

We recognise that our phenomenal capability can be deployed to work toward our Grand Ambitions even more effectively through partnership with others. Consequently, we are keen to have a close working relationship with other Space Hubs and clusters around the UK, particularly where such relationships can stimulate collaboration and develop a critical mass of expertise, thus providing competitive advantage. In the first instance, developing close relationships with areas in close geographic proximity are viewed as the highest priority. Strengthening our close relationships with the Cornwall & the Isles of Scilly and Heart of the South West LEP areas would enable opportunities related to Spaceport Cornwall, Goonhilly Earth Station and the Met Office to be identified, developing a relationship with the Midlands Space Hub would foster links related to the use of quantum technologies for space applications, and partnership working across the Western Gateway would leverage capabilities related to defence and cyber security. However, we are proactively participating in the regional networking activities facilitated by the Satellite Applications Catapult on behalf of the UK Space Agency and are open to building mutually beneficial relationships with other areas of the

UK, including OxLEP, Enterprise M3 LEP and Scotland.

With our ambition to be recognised globally as a leading space region, we also recognise the importance of maintaining a strong international profile and strengthening international relationships, with respect to inward investment, trade, R&D collaboration and educational exchange. The space community in the West of England already boasts strong international links. Thales Alenia Space and CGI Group are multi-national companies, as are the major aerospace and defence companies in our region that have the capability of expanding into the space industry (Airbus Filton, Babcock, GKN, Rolls-Royce, MBDA). The universities have close links with international institutions, including ESA, NASA and JAXA. Additionally, a number of downstream companies, including Riskaware and 4 Earth Intelligence, are active in overseas markets, such as the Middle East and South East Asia.

Invest Bristol & Bath, the inward investment team within the West of England Combined Authority, already seeks to attract space-related inward investment as part of its aerospace and advanced engineering (AAE) campaigns and activities, in partnership with colleagues from the Department for International Trade (DIT). Additionally, the West of England Combined Authority remit is increasingly focusing on trade in addition to inward investment.

Target markets include:

- Well-established space nations which closely align with existing priority markets for Invest Bristol & Bath's AAE activities (eg. USA, France, Germany, Spain);
- Markets where there are plans to consider increased international activity in the near future (eg. Canada, India, Japan, UAE);
- Other markets which have synergies with the West of England region (eg. Australia/New Zealand, Indonesia, Ireland, Luxembourg).

### Priority actions

- Develop a compelling space proposition and suite of space-specific marketing materials to showcase the West of England's strengths and capabilities, increase the region's sphere of influence within Government and the national arena, and act as a catalyst for collaboration and international engagement, within the context of the Space Sector Covid Support Plan, published by DIT in February 2021;
- Increase the profile of the West of England as a leading space region by hosting a major space conference/expo in the West of England and participating in internationally-significant space shows, in partnership with the UK Space Agency, Satellite Applications Catapult, DIT and other stakeholders;
- Collaborate with other UK space hubs and clusters to develop competitive advantage and build international relationships to drive a step-change in space-related exports and inward investment.



## SPACE HUB PARTNERS & CHAMPIONS



## SUPPORTING INDUSTRY ORGANISATIONS INCLUDE:



West of England Combined Authority, 3 Rivergate, Temple Quay, Bristol BS1 6EW  
**T:** 0117 428 6210 **E:** [innovation@westofengland-ca.gov.uk](mailto:innovation@westofengland-ca.gov.uk)  
**W:** [www.westofengland-ca.gov.uk](http://www.westofengland-ca.gov.uk)