Stratospheric green growth

How the UK space sector could deliver a sustainable jobs revolution

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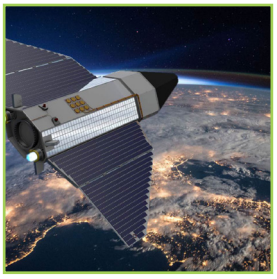

UKspace

UKspace is the trade association of the UK space industry and has been its leading voice for over 30 years. We represent the interests of industry with the UK government, parliament and national and international stakeholders. To achieve the best business framework to promote growth, UKspace works alongside the UK Space Agency, Innovate UK, the Satellite Applications Catapult, the Satellite Finance Network, Ofcom and government departments.

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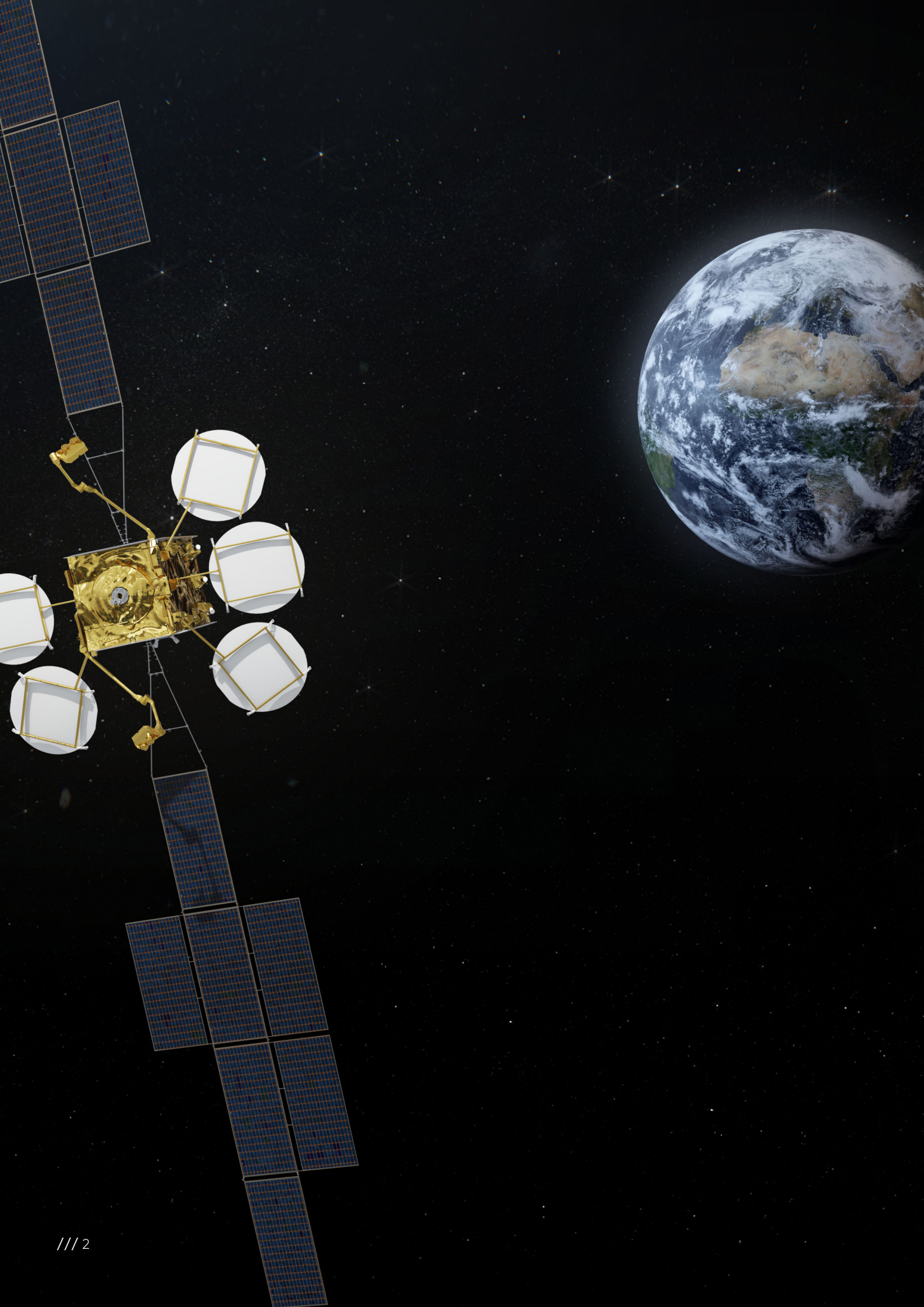

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Foreword

Fifty years since Neil Armstrong planted his foot on the surface of the moon, we still often think of space in terms of the quest to reach new frontiers. Every week there seems to be a new breakthrough to marvel over: the first discovery of water on a potentially habitable planet, the first image of a black hole, or the first plans for a sustainable base on the moon.

Over the next 50 years, there is almost certainly more to come. With technological leaps forward and a new generation of entrepreneurs emerging, we look set for a bold new era of space development. However, it is the critical importance of the space sector to peoples' everyday lives, and the big potential of the UK to lead the world in developing new practical and commercial opportunities, that the Government cannot afford to ignore.

The UK space sector powers the hundreds of communications satellites in orbit that mean that radio, television and telephone transmissions can be sent live, anywhere in the world. It is behind the navigation satellites that do not just help us to travel around our cities and towns; they also underpin our emergency, aviation and logistics systems. And it underpins the Earth observation satellites that are both a vital element of national security and an increasingly important weapon in the fight against climate change.

The sector has trebled in size, in real terms, since 2000 and in many respects, it is thriving. But what happens next? Whether the UK space sector continues to move forward in the future will depend on the political choices made today. Brexit presents opportunities for the UK but there are also multiple risks that need to be carefully managed. Meanwhile the global space market is growing exponentially, and other nations are waking up to the huge opportunities this offers.

Across this backdrop, the UK space industry is calling on policymakers of all parties to support the sector as a key national asset that delivers both taxpayer and political value. This report shows, in hard facts, the potential the UK space sector has to be the best in the world, bringing about serious gains for British jobs and industry.

In particular, we have an enormous opportunity to lead the way in using satellite technology to tackle climate change. As the world wakes up to the devastating impact of climate change, the UK has taken a lead in committing to reach net-zero carbon emissions by 2050. But, as many have since pointed out, tougher targets are meaningless without new ideas and practical plans to deliver them.

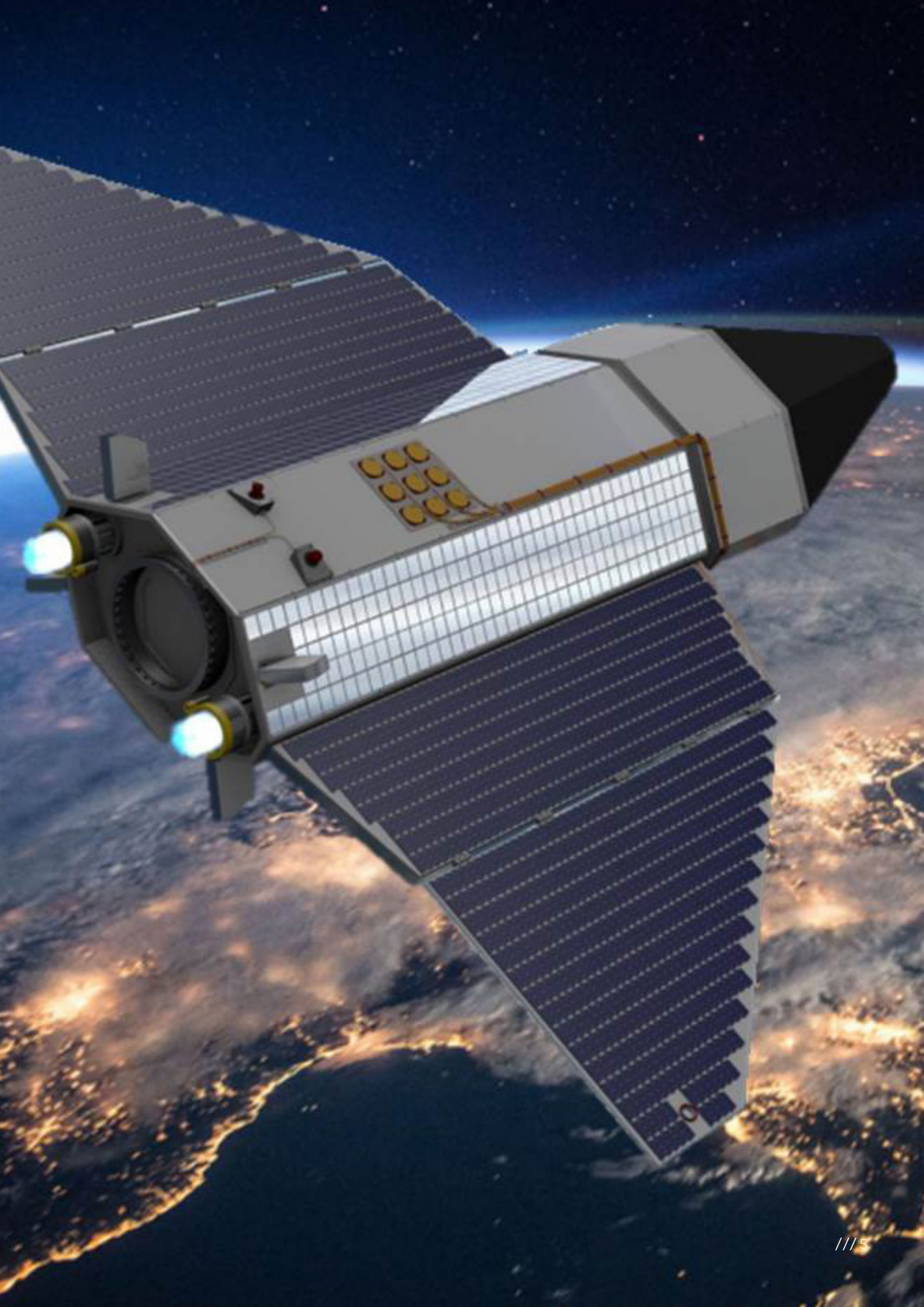
The space industry is already equipping policymakers with tools to help monitor and improve the environment as never before. The UK Space Agency's 'Space for Smarter Government' Programme has demonstrated the feasibility of an "Air Quality Hotspot Mapper" which could help the NHS manage the health fallout of poor air quality. On a global level, we are using this expertise to monitor forests, rivers, lakes, oceans, volcanoes, deserts, coast lines, ice caps, atmospheric changes and conditions such as the El Nino climate cycle in the Pacific Ocean, which has a global impact on weather patterns.

By properly investing in the UK space industry, the UK could yet assume the position of world leader in action as well as words – capitalising on a massive global market in environmental protection and monitoring. It would mean a new industrial revolution right here in the UK, creating thousands of new green jobs spread across all our regions, while helping to deepen our trading relationships with partners outside Europe.

The 1969 moon landing came after John F. Kennedy boldly set out to overtake the Soviet Union in the space race. In 2020, there is an entirely different contest occurring as rival nations set their sights on the rapidly growing global spacetech market. By investing in satellite technology to tackle climate change, the UK can be a big winner in the new space race.

Graham Peters

Chair, UKspace



Executive summary

With impressive growth and a constellation of innovators, the space sector has become a jewel in the UK's industrial crown. Space-related organisations are growing in number and workers are both highly skilled and highly productive, generating billions for the UK economy.

But we are now at a crossroads. Brexit has presented hurdles, as well as potential opportunities for the sector. While the sector does well at selling overseas, the global market is becoming more competitive. As a result, there is mounting pressure on the UK space sector to maintain its global presence. While other countries are growing their space sectors, the risk is that the UK has to expand just to retain its current position in the global market.

Against this backdrop, we are setting out a bold new vision for the future of UK space. It is a vision that takes account of the growing political appetite for environmental progress, as extreme weather events and climate related disasters becoming more frequent and difficult to deal with.

Our vision also neatly fits with the fact that the UK space sector is the unsung hero of attempts to improve our natural environment. Revolutionary new techniques in computing and artificial intelligence mean that satellites already have the potential to offer policymakers the ability to take specific and radical action to improve the environment.

Building on Prosperity from Space, our blueprint sets out how we can utilise the strengths of the UK space sector to grow a genuinely world-beating market in satellite and environmental protection services.

- We are forecasting up to 15,100 additional new "green jobs" within the space sector by 2030. This will be one fifth of all the forecast new green jobs within the UK economy, from just one sector.
- These green jobs will be some of the highest value in the country, delivering output rates to match the most productive industrial sectors in the UK economy.
- Creating these kinds of jobs would be the equivalent of adding the workforce of four Google UK HQ's to the economy, spreading growth and innovation across the UK.

In this report, we have anticipated some of the green jobs that are set to be created in new 'trailblazer' areas like sustainable finance and natural disaster relief. These new sub-sectors are already taking shape and could create roles ranging from quantitative analysts focused on measuring the impact of particular investments to data scientists tasked with monitoring the patterns of extreme weather events on the natural environment.

Looking further into the future, a new wave of green technologies are set to take off. As a result, a host of new jobs could be created ranging from solar power transmission technicians and robotic engineers to space telecommunications specialists and highly-qualified space debris removal physicists.

The new jobs will only be created in the UK if the Government is prepared to invest in the space sector. Policymakers must support our critical national infrastructure and security, while simultaneously setting a more ambitious agenda for this vital part of our economy. We are therefore calling on policymakers to support a number of specific actions and recommendations.

Most urgently, we are calling for the establishment of a National Space Programme, which includes a new £150m-a-year Innovation Fund. The NSP's primary objective would be to ensure that the UK space sector plays an increasingly prominent role in the global space market, with a specific focus on funding new R&D.

We also need to secure post-Brexit participation in a new satellite navigation system programme. The UK space sector must be able to bid to lead future missions by the Copernicus programme post-Brexit. The National Space Council must be given the powers and funding required to drive the sector forward.

And, looking further ahead, we need policy-makers to boost spending through the European Space Agency (ESA). With the recent funding increase, policy-makers recognised that ESA is a fantastic platform upon which to build an ambitious national programme to drive developments of sovereign capability, global collaborations and international trade. But the UK can still do much more to exploit the opportunities offered by ESA.

We are calling on policymakers to prioritise these pressing issues. The UK space sector has significant untapped potential. We could have a green jobs revolution in the UK. But the enormous promise of the sector will only be realised in years to come if the right political choices are made now.

Space data - the key to understanding climate change

Climate change threatens to have a catastrophic impact on ecosystems and the future prosperity, security and well-being of all humankind. The potential consequences extend to virtually all aspects of sustainable development, from food, energy and water security to broader economic and political stability. Global observation systems, including those from space, play an important role in helping to gauge these threats. Information provided by space-based technologies are used to monitor the Earth's climate system and support decision-making about climate change adaptation, prediction and mitigation, including addressing the needs identified under the United Nations Framework Convention on Climate Change.

Space has become an undisputed diagnostic tool for detecting and predicting climatic and environmental changes on a planetary scale. Space-based systems offer a unique viewpoint of the Earth and as such have become unparalleled in enabling us to understand our planet as a whole.

Space-based technologies and space-derived information play a key role in climate knowledge, science, monitoring and early warning. Space-based information can contribute to assessments of the vulnerability of communities to climate change and can help monitor the effectiveness of adaptation strategies. In addition, carbon sequestration areas - such as forests, woodlands, wetlands - can be monitored.

Earth observation in particular has not only revolutionised the way we perceive our planet, but it has also changed the way we comprehend our profound impact on the environment. Satellite missions build a long-term archive of essential data for local and international policy and planning.

35 of the 45 essential climate variables defined by the heads of UN Climate Change are measured from space.

Space data also play a key role in providing supporting information to aid organisations in dealing with the impacts of climate change, such as flooding and drought. Space delivers data with regular, uniform and global coverage, and reliable assessments of trends over time for specific variables. It also observes remote regions that are under-sampled by conventional networks.

Satellite measurements of Earth's changing temperature, sea levels, atmospheric gases, declining ice and forest cover for example, are one of the main ways of providing the scientific community with the data they need to improve our understanding of the Earth system and predict its future.

Space instrumentation has delivered consistent climate data for over 30 years. Traditionally this data is delivered via international organisations such as EUMETSAT, the European Space Agency, the EU or the American body NOAA. As climate targets become key for nations and essential to global manufacturing companies, the monitoring of climate emissions is becoming a commodity and space plays a vital role in this.

The UK can enhance and grow its capability leadership in the domain of space and climate not only in upstream satellite instrument technology developments, but also in the science and exploitation of the data for national purposes, and with other nations in international partnerships and agreements. This includes building and enhancing big data management and analytics (AI) techniques to enable new applications to be developed and delivered by UK companies into the growing climate services marketplace. Bilateral projects would also lead to follow on export missions and services further demonstrating the UK's ambition to be a leader in tackling climate change, cutting net greenhouse gas emissions in the UK to almost zero by 2050, and exporting UK climate services into the global economy.

Introduction

The space sector is of increasing importance to the UK economy. Space-related organisations are increasing in number, generating high-skilled employment and high-quality economic output in the process. Many parts of the sector export their unparalleled knowledge and expertise across the world. The space sector has tripled in value since 2000 and year-on-year growth is five times greater than the wider economy since 1999.

Prosperity from Space, published by the Space Growth Partnership, has set out a vision for enhanced growth in the UK space sector over the next decade. The blueprint aims to double the value of space to wider industrial activities from £250 billion to £500 billion, generate an extra £5 billion in exports and attract £3 billion of inward investment.

In his first speech as Prime Minister on the steps of Downing Street, Boris Johnson appeared to acknowledge the powerful potential of the industry when he gave prominence to the space sector. "Let's get going now on our own position navigation and timing satellite and earth observation systems – UK assets orbiting in space, with all the long term strategic and commercial benefits for this country," he declared.

When setting its legislative agenda three months later, the Government turned this rhetoric into a statement of intent, committing to making the UK a world-leader in space technology with an "ambitious national space strategy".

Time to get serious about space

The ambitious attitude we are now seeing is encouraging, after successive governments have failed to treat the sector as a high priority. Responsibility for space policy currently represents only one item in the very broad remit of the Science, Research and Innovation Minister. Moreover, UK Government funding for the sector as a proportion of GDP pales in comparison to that of other rich nations.

In the last 18 months the ideas of a space 'sector deal' and a National Space Council have both been put on the table. These are welcome developments, with the space sector keen to play its part, but the feeling is that positive statements now need to be turned into serious investment and concerted action.

The UK space industry was encouraged by the 2019 ESA funding increase. This means that – for the next three years - the UK will account for 11.5 per cent of the total funding committed to ESA. But we still have further to go to match our European counterparts. The largest contributions to ESA come from Germany (22.9 per cent), France (18.5 per cent) and Italy (15.9 per cent). Without a similarly big commitment to ESA, many firms based in the UK could yet face very serious challenges in future years.

Looking ahead, the importance of the Government and the UK space sector working together cannot be understated. Given the headwinds that the sector faces, it is imperative if the sector is to continue to flourish in the future.

One threat to the UK space sector is greater competition. While it is impossible to pinpoint by how much the global space market will grow in the coming years, all indications are that it will grow rapidly. Other nations are increasingly recognising the opportunities that this presents and are nurturing their own space sectors in response. In the period 1957 to 2008, just over 50 countries had successfully launched a satellite into orbit; in the period 1957 to 2018 the figure had grown to just over 80 countries.

Another threat is the uncertainty facing the sector related to Brexit, with examples of uncertainty being:

- The EU's decision to exclude British companies from the delivery and design of the Galileo satellite navigation programme. Without our own capability, the danger is that UK firms will be excluded from the encrypted system, overlooked for lucrative new global deals and become dependent on other nations for position, navigation and timing services that underpin our critical national infrastructure.
- The ability of the UK space sector to lead future missions by the Copernicus programme. As things stand, there is around $1bn of future work the industry can bid for and agreeing that the UK can be part of the Copernicus deal is crucial.

Gearing up for green jobs

In light of greater global competition and industry uncertainty, the UK needs to think strategically to avoid missing out on major economic and social gains. We must constantly be looking for new growth markets that will not just provide market opportunities, but opportunities that create the potential for lasting value to be created which will sustain the kinds of high-quality, secure employment people need.

One of the next major frontiers of this kind of opportunity will come from addressing the world's most pressing environmental challenges. Climate change is a global phenomenon and increasingly a major problem for all nations, with extreme weather events and climate related disasters becoming more frequent and difficult to deal with.

The UK space sector already plays a major role in monitoring climate change. Space-based technologies and space-derived information are central to climate knowledge, science, monitoring and early warning. Indeed 35 of the 45 essential climate variables defined by the heads of UN Climate Change are measured from space. And UK engineers play a key role in manufacturing the equipment that is delivering environmental data today. While the Copernicus programme has often led the way, new entrants to the market could still deliver yet more. These include NovaSAR, the first all-UK radar spacecraft that was developed jointly by Surrey Satellite Technology and Airbus in Portsmouth and launched to orbit in September 2018. Its pictures are now being assessed for use in diverse applications, including crop analysis, flood and forestry mapping, and maritime surveillance.

Space itself also has strong green credentials. Satellites are powered by the sun using solar arrays and are built to last from a few to over 20 years. Space launches have a significantly smaller environmental impact than many other industrial sectors. For example a flight by European heavy-lift launch vehicle Ariane 5, with six to eight launches a year, produces roughly the same level of emissions as a standard long-haul flight by a Boeing 747.

The UK Government has already set much stall on leading the fight against climate change. Protecting and improving the environment featured in both the Prime Minister's first speech and the Government's legislative agenda. Reference was made to creating the 'green jobs' that will contribute to better environmental outcomes. Commitments were made to improving air and water quality and tackle plastic pollution. The government has also acknowledged that satellite technology can play a major role in combatting climate change. In 2019, it was announced that new £5m government-backed virtual satellite data centre will analyse the impact climate change is having on the UK, shape policies on reducing carbon emissions, and contribute to reaching net-zero targets. "This new satellite data centre will give us instant images showing us the true impact of climate change and in doing so, help us develop innovative new ways of tackling it," stated former Business Secretary Andrea Leadsom on 30 December.

Such initiatives are to be welcomed but much more could be done to harness the power of the UK space sector in the fight against climate change. The organisation PUBLIC has argued that the Government should increase the use of "challenged-based" procurement processes. The idea being that the space sector's knowledge and expertise can be tapped into to provide innovative new ideas to public sector challenges. Such an approach could be used to focus specifically upon improving environmental outcomes.

It is now clear that countries across the world are increasingly looking for solutions to negative environmental outcomes. Our scientists and engineers are often leading the way and this presents exciting opportunities. By taking urgent action to retain and build our space capability in the UK, we could be a global leader on addressing the world's environmental challenges.

This report argues that the objective of making the UK a world-leader in space technology neatly compliments the parallel objective of protecting and improving the environment. It provides an illustrative analysis of how the UK space sector could provide swathes of new 'green jobs' over the next decade. It also sets out how case studies of the sub-sectors of the space industry will help the environment and future innovations in space and it provides a blueprint for how the government and the UK space sector can work together over the coming years.

The UK's space economy: high-growth and going green

The UK space sector has the characteristics of an industry that has huge economic potential. The publication Size & Health of the UK Space Industry 2018 sets out how space companies are contributing to economic growth and how the sector is changing.[1]

In almost every sense, the sector is high growth. Space-focused companies have generated levels of income that have grown at rate faster than the growth in the UK economy as a whole. The numbers employed in the sector have grown at more than three times the rate of the wider economy (a rate of 4.3%, compared to 1.3%). Annual R&D expenditure growth has averaged 16% over the last two years, even after taking inflation into account.

The sector does well at selling overseas. Almost two-fifths of its income is generated from abroad, an export share that outstrips the performance of the UK economy; 37% of space sector income is generated via exports, compared to 28% in the wider economy.

Workers in the sector are highly skilled and highly productive. Its labour productivity is 2.6 times that of the UK average. The average level of qualification is higher than in any other sector, with three-quarters of employees holding at least a primary degree.

The sector's activity is spread across the country. Activity is skewed towards the Greater South East – as with the rest of the economy – but all 12 of the UK regions are home to companies that undertake space-focused output. Further afield, there are also space companies operating out of the crown dependencies.

These attributes combined to create a sector that in 2016-17 generated income of £14.8bn, continuing the trend of strong annual real-terms growth, which has been uninterrupted since estimates of the sector's income began. The sector also accounted for 5.1% of the global space economy and contributed £13bn of Gross Value Added to the UK economy, a figure which incorporates both direct effects and the effects it has within its supply chain.

A critical piece of context for the space sector's economic impact is the economic activity that relies upon its services. Like the fibre optic cables that provide internet access, or the pylons that deliver electricity, space technology should be regarded as part of the nation's essential infrastructure. Space technology – and in particular satellite services – support industries with a combined turnover of at least £698 billion and that contribute £302bn to GDP.

Space sector ambitions for the end of the next decade:

- Grow sector income to £40bn by 2030.
- 60% of the space industry's income to be generated by exports by 2030.
- The UK's space industry workforce to be up to 119,100 by 2030.

Looking to the immediate future, the UK space sector has big ambitions for increasing the income it generates, the exports it sells and the jobs it creates. Meeting the ambitions – set out in the box above – will see the space sector become even more important to the UK economy.

The growth of the space sector will be driven by some parts of the industry more than others. As discussed in the previous chapter – there is a good case to say that satellite technology will be instrumental in improving environmental outcomes. And as we show in case studies in the next chapter, the technology will enable us to be better at fighting pollution, encouraging sustainable investment and implementing emissions-reducing

transport policies.

But the headline figures are the numbers of high quality green jobs that we could see in the UK space industry. An analysis undertaken for this report has looked at how many green jobs we might expect to be created by advances in satellite technology in the space sector (the details of our analysis can be found in a technical appendix at the back of this report). The projected green jobs growth is consistent with the industry ambitions for overall sector jobs by 2030. We found that:

- The growth in use of satellite technologies could create up to 15,100 green jobs within the space sector by 2030. If this number of jobs were created, it would be the equivalent of roughly one-fifth of all the forecast new jobs that relate to the protection of the environment and the management of natural resources.
- These green jobs will be some of the highest value jobs in the country. Indeed, output rates per worker exceed those of workers in motion picture, video and television programme production, computer programming and advertising – among the most productive industrial sectors in the UK economy.
- Creating these jobs would be the equivalent of adding the workforce of four Google UK HQ's to the economy. Moreover, these jobs would be spread across the country.

Environmental trailblazers of the UK space sector

If the UK is to experience a green jobs revolution in the next 10 years, then the UK space sector can make a significant contribution to making it happen. Specifically, it has the potential to help us rise to the increasingly urgent challenges of protecting our natural environment and tackling climate change.

The previous chapter stated that the growth in use of satellite technologies could create up to 15,100 green jobs within the space sector by 2030. These green jobs will be some of the highest value jobs in the country with higher productivity than that of a worker in the overwhelming majority of other industries.

But what will these new roles look like? As satellite technology develops, four 'trailblazer' sub-sectors in the space industry look more likely than others to grow and create green jobs in serious numbers.

These sub-sectors are already taking shape. As they develop further, we expect that these four sectors will create roles ranging from quantitative analysts focused on measuring the impact of particular investments to data scientists dedicated to monitoring the patterns of extreme weather events on the natural environment.

Sustainable finance

The financial system has a big role to play if the serious environmental and social challenges that we all face are to be addressed. It will finance big investment projects, such as large-scale renewable energy initiatives. It will be a leader in understanding the environmental and social impacts of what it is financing, as many major investors have begun to do. It will have to manage the risk created by environmental and social change to protect people's savings and wealth.

Hence, the term 'sustainable finance' – whilst broadly defined – represents how the financial system interacts with and recognises environmental and social issues.

The space sector can support the development of sustainable finance. It can do this by providing quality information that will allow investors to better judge how they can allocate capital sustainably. Encouraging this new market in information from space is a key feature of the activity undertaken by Satellite Applications Catapult, which is tasked with boosting UK productivity by helping organisations harness the power of satellite-based services. The company argues that "geospatial data, including earth observation and climate data can provide key elements of the information that is needed to evaluate risks, opportunities, and impacts of (un) sustainable investment opportunities to deploy sustainable finance effectively".

Some clues as to how geospatial data could underpin a new approach to financial services may be given by the growth of the FinTech sector. This sector, comprised of providers of financial services using software and modern technology, has an internationally mobile and highly skilled workforce. It is disrupting and complementing established parts of the financial system, further technological advancements are opening up new possibilities for it and growth is fast. Recent evidence suggests that annual growth rate in the FinTech workforce has been just under 19% a year.[2]

If this new market were to fully develop, what would this mean for jobs in the space sector? Once sustainable finance takes off, there are all types of specialisms that could arise. For instance, there may be data scientists dedicated to monitoring the patterns of extreme weather events or quantitative analysts measuring the impact of particular investments on the natural environment.

Sustainable agriculture and development

The fusion of satellite technology and agricultural processes – part of the emerging 'Agri-tech' sector – has been heralded as a major breakthrough in realising more sustainable, efficient and cost-effective methods of farming. There are plenty of examples that back this statement up.[3]

Satellite data and analysis has enabled farmers to implement new water management systems, contributing to 18-30% reductions in a farm's water usage. As agricultural irrigation is the world's large consumer of water, more efficient usage could help to prevent future water shortages.

In the past, the agricultural sector has come under sustained criticism for pollution arising from pesticide and fertiliser runoff. The natural environment and ecosystems of birds, aquatic life and even humans have been negatively affected. Satellite technology has enabled a reduction in the instances of over-fertilisation by monitoring the requirement for fertiliser.

It is for these reasons that satellite-enabled agri-tech is one of the world's fastest growing sectors. Although, there are barriers to the expansion of the sector. Consultancy London Economics has found that costs, reliability of mobile internet signal where farming occurs, a lack of technical knowledge, and the benefits of the technology being unclear, all contribute to lower take-up.

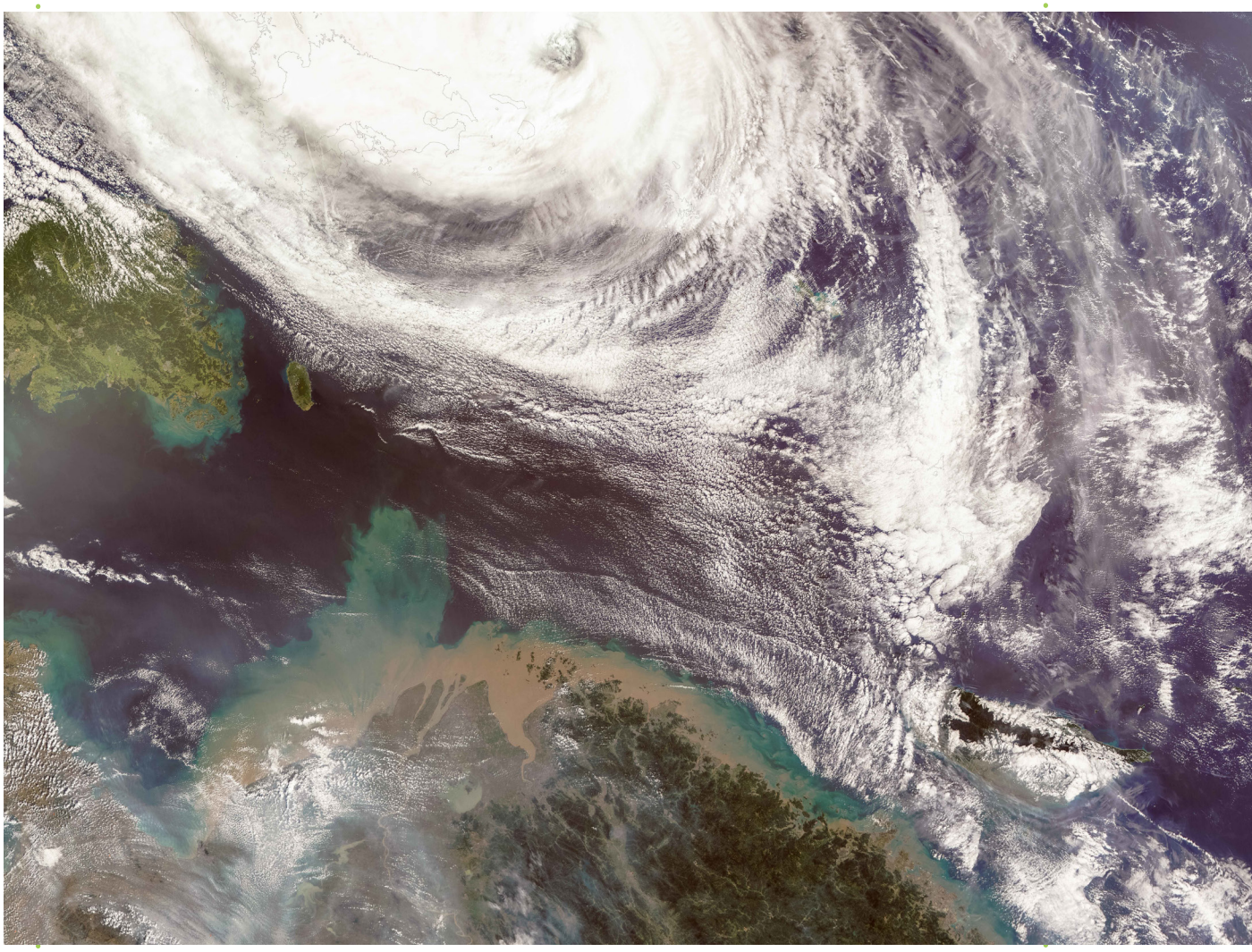
The establishment of satellite applications in agri-tech could lead to the creation of new job roles entirely. For instance, there could be roles for space-data enabled crop managers, agricultural satellite advisers for farms and technicians who retrofit equipment to enable old farm machinery to interpret satellite data.

Natural disaster observation and relief

Since the launch of the Landsat-2 in 1975, satellites have revolutionised the way we understand natural events occurring on Earth. A principal application of the ground-breaking Earth observation technology has been its ability to help us understand, prepare and respond to a wide range of natural disasters, such as cyclones, earthquakes, volcanoes, wildfires, floods and oil slicks. The orbital positioning of satellite enables far superior observation capabilities than traditional land-based weather and environmental monitoring.[4]

For example, satellites are capable of providing early-warning signs of areas at risk of wildfires. This includes rapid real-time observation of hotspots, including dry biomass and drought affected areas. The real-time monitoring enables emergency services and fire response teams to deploy at a faster rate than ever before, containing wildfires that can eviscerate entire ecosystems.

The accuracy of satellite imagery also means it is now possible to detect minor changes to the Earth's surface, which can act as an early indicator of earthquakes.[5] This technology continues to evolve, giving earthquake protection authorities an even greater ability to protect lives and reduce damage in the future. The export potential of advancing this technology is high, due to the potential damage mitigation new technology could deliver to nations regularly affected by earthquakes and tsunamis.



Additionally, further development of satellite technology focused on volcanic activity and science may enable a new era of preparedness for volcanic eruption. The ESA's Sentinel-1 satellite has been pivotal in helping developing nations monitor volcanic activity, with it aiding Indonesian authorities during the eruption of Mount Agung in 2017.[6]

In addition, satellites can help us to monitor infrastructure that manages our natural resources. For instance, satellites are used to monitor the strength of dams in South America, providing an early warning system where there are risks to dams failing.[7]

As the various technologies are developed further by high-level natural disaster preparedness programmers, we should expect that there will also be new job opportunities in the field of real-time natural disaster hotspot monitoring and software engineers applying AI and satellite data to better understand risks and consequences of natural disasters.

Transport

Space and satellite technologies will change how all modes of transport are used and facilitate the integration of logistics systems.

In the future, satellite technology promises to revolutionise public transport. Buses may become on demand through use of smartphone apps. Trains will be better maintained as sensors send live data about the performance of rolling stock.

Private transport will also be transformed. Satellites will be able to warn of adverse weather conditions, telling drivers how their vehicle will react in such an environment. Where congestion occurs, satellites will be able to divert cars to quicker routes.

More specifically, satellites will aid transport to help the environment. The aviation industry is a prime example. With the 2050 net-zero carbon emissions target being adopted by the UK government and the sector, it is imperative for the aviation industry to improve its environmental record by reducing emissions. Improvements to engines and use of biofuels will help in the medium to long-term. But in the short-term satellite technology already offers some environmental benefits – navigation tracking technology has enabled tailored flight plans, which provide ideal routing to pilots and air traffic control, saving time and fuel.[8]

The shipping industry has also experienced satellite-enhancing benefits. There has been significant progress in safety, emissions reduction and security since the introduction of advanced space technology. Specifically, satellite monitoring of ships and maritime activity has enabled the introduction of real-time routing, which has produced marked improvements to fuel efficiency and emissions reduction.[9]

As well as environmental advantages, there are other, more niche benefits. Space technology has also provided new breakthroughs in the age-old battle against piracy, which even today costs the global economy $6bn per year.[10] By deploying tracking and monitoring technology, it is now possible to observe shipping lanes, navigate potential high-piracy danger spots and recover commandeered ships rapidly. All of this collectively enables greater risk mitigation and faster emergency response to piracy incidents.

It is easy to see how job roles will emerge from these innovations. There are likely to be space data traffic control operatives, space data emissions reduction professionals and shipping logisticians, all of which will be relying on assets in space for their jobs.

Future innovations in space

At satellite technology develops, it is not only the four trailblazer sectors highlighted in the last chapter that could create new green jobs across the UK. Looking further into the future, there are at least four more innovation areas that look set to lay the foundations for a further employment in the new-look space-based environmental services economy.

In all of these fields real progress is being made and projects are beginning to shape. Over the next few decades, the new wave of green technologies will be developed further, a host of new jobs will be created ranging from solar power transmission technicians and robotic physicists to space telecommunications specialists and highly-qualified space junk removal astrophysicists.

It is impossible to say when any of these new innovation areas will realise their full potential but those countries leading the way in creating these new employment opportunities could reap very significant rewards.

Manufacturing in space

Whilst the last 50 years of space manufacturing have seen great technological advancements on Earth, the future could see part of this manufacturing move into orbit itself. Several space companies have been developing the capability of producing equipment using machinery in orbit.

Manufacturing in space could produce a variety of benefits – to companies, space programmes and the Earth's environment. New products will be able to be produced which were previously impossible due to the constraints of the Earth's atmosphere. This includes flawless fibre optic cable, which has the capacity to transmit communication signals at previously unimaginable speeds, and 3-D printing, which has the capability to turn waste plastic into high-quality 3D printing "ink" to create new tools and materials. Last year, the first integrated 3D printer and recycler was part of a cargo sent to the International Space Station.

Blindness could yet be cured thanks to new protein-based retinal implants being built on board the International Space Station.[11] Freed from gravity, the hope is that protein cells can develop and generate retinal implants that are more stable and perform better than any made on Earth. Environmentally friendly 'astroplastics' could be also be produced in orbit, these would recycle waste to produce 3D printing material.

Space programmes will benefit from the ability to produce equipment in space – which avoids the costly requirement of sending up new equipment from Earth. The planet itself will also benefit from the reduced need to undertake satellite launches, which require high-levels of fuel usage to successfully escape the Earth's atmosphere and enter orbit. With manufacturing in space, the efficiency of launches could be increased, as satellites and spacecraft are better sustained and developed by orbital factories.

Manufacturing in space could therefore be a reality in years to come with several companies already developing the capability to use machinery in orbit. As ambitious innovations in space-based manufacturing take off, we could see the creation of a host new jobs in advanced robotics engineering. These robotic engineers would be responsible for developing robots capable of producing high-tech machinery autonomously whilst in the confined area of a spacecraft in the orbit of Earth.

Space-based solar power

Since the mid-20th century, physicists and astronomers have worked on the concept of developing the ability to harness solar power in space and transmit it to Earth.

Theoretically, space-based solar power would work through sending reflectors and solar panels into orbit to collect the thermal energy emerging from the sun. In space, solar energy is approximately 144% more intense than the maximum attainable on Earth and is a constant power source due to the sun being ever-present. Once collected, the energy would be transmitted to power stations on Earth by microwaves or laser beam.[12]

Whilst the concept of space based solar power is still in the developmental phase, other major national space programmes – including China, Russia and Japan - have begun to work extensively on it.[13]

One primary challenge is the effective transmission of energy to Earth and in 2018, California Institute of Technology achieved a significant breakthrough – with a new lightweight prototype using microwaves to transmit energy back.[14]

Another barrier is the cost of access to space. Here, a novel airbreathing/rocket propulsion system being developed by the UK-based firm Reaction Engines could be a gamechanger. This largely down to the precooler heat exchanger which can deal with the extreme temperatures associated with travelling at five times the speed of sound.[15]

The new engine is specifically intended for propelling reusable spaceplanes into orbit. Compared to existing rocket launchers these reusable spaceplanes will reduce costs by a factor of 10 at entry into service and a factor of 100 as the flight rate grows. Based on current funding levels these spaceplanes will enter service around 2035-2040 and Reaction Engines is currently identifying potential partners to join the project.

On numerous fronts, the development of space-based solar power is promising. Solar power is already the primary source of energy for powering satellites and space stations. As technology improves, costs go down and the world steps up efforts to wean itself off fossil fuels space-based solar power could ultimately signal a new era in energy generation. The result could be a new industry of solar power transmission technicians, charged with capturing the sun's thermal energy and sending it back to the Earth.

Space debris removal

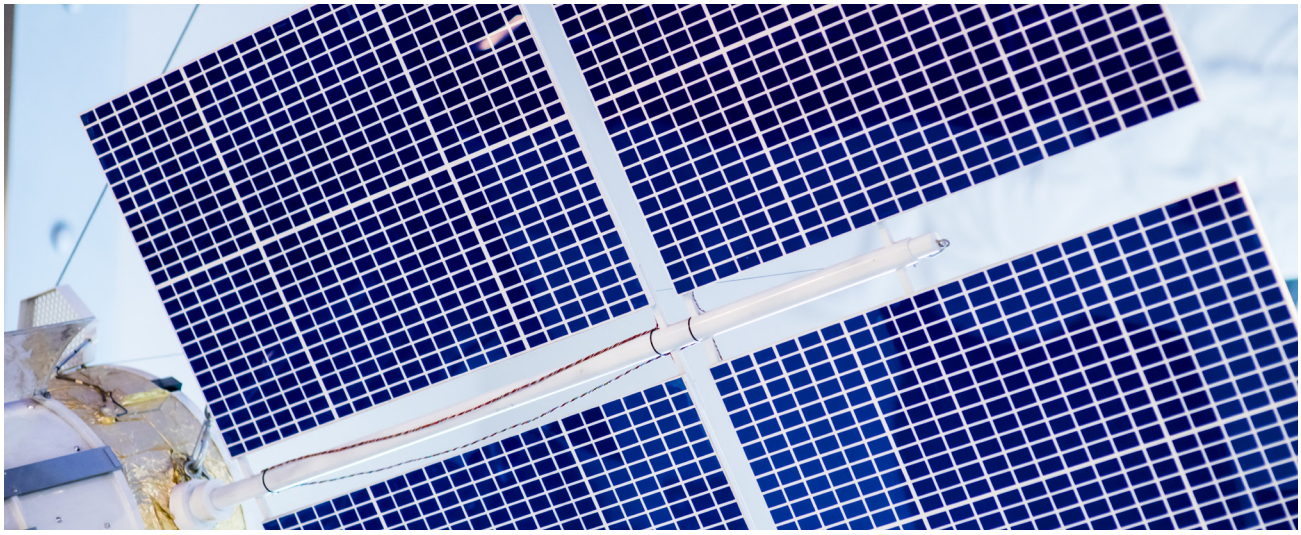
It is not just the Earth's immediate environment that space industry can help to clean up. There are presently around 500,000 pieces of debris in the Earth's orbit which are large enough to be tracked. On top of this, there are many millions of smaller pieces of debris orbiting the Earth at speeds of around 17,500mph – causing damage to spacecraft and satellites.

This so-called space junk is composed of both natural (meteoroid) and artificial matter and the damage incurred can lead to the loss of vital communications infrastructure, which can be extremely difficult and costly to replace. Space debris also hinders humanity's ability to undertake further space exploration on both manned and unmanned spacecraft, which can be severely damaged and knocked-off course by debris.

There have been four major collisions already in near-Earth orbit. The most serious of these occurred in 2009, involving a defunct Soviet satellite and a US-built commercial satellite. And the problem is getting worse. Experts now speak of a collisional cascading effect in which the potential for future collisions between space junk could ramp up in an alarming way.

Consequently, there is a growing market for space debris monitoring and removal, with the market research firm Technavio projecting that the market for these services will be worth $2.9bn by 2022.[16] Several British-based space firms have been world-leading in their development of space debris removal technology.[17] Chief among them is Airbus, who have developed the RemoveDebris spacecraft, which utilises several different forms of debris removal technology. Advanced engineering done in conjunction with Surrey Satellite Technology Limited has produced a space net and a space harpoon, which are capable of capturing debris in orbit.

With Airbus' space harpoon being developed at their factory site in Stevenage, the UK has a clear opportunity to emerge a world leading manufacturer of anti-space debris technology. But other nations also have big ambitions in this area. For example, Astroscale was founded in 2013 by Japanese IT entrepreneur Nobu Okada, who proposed using a start-up mentality to address the business of orbital debris mitigation. Its ELSA-d demonstration mission, scheduled to launch in 2020, will be the company's first mission to demonstrate the core technology necessary for debris docking and removal. The ELSA-d will be operated from the National In-orbit Servicing Control Centre Facility in Harwell, Oxfordshire. As this kind of technology develops, it is likely to result in numerous highly-qualified space junk removal physicists tasked with analysing the most effective way of collecting debris in the harsh, vacuum environment of space.



Secure and ubiquitous internet

The concept of ubiquitous internet has been in circulation for over a decade and is getting ever closer to becoming an everyday reality. In the future, the resulting improved digital connectivity could drastically drive down carbon emissions by reducing the need for physical travel by road or air.

To make it happen, several major space companies have been working on the deployment of broadband internet from space. They include the British firm OneWeb, whose satellite constellation is being developed in conjunction with Airbus.[18] It will initially consist of 650 satellites, in the largest launch campaign in history, and is the world's first network aiming to provide a global internet broadband network by 2021.

Another world leader in this field is Inmarsat. The UK-based firm has already developed Global Xpress, a satellite constellation which delivers seamless global connectivity to Governments and organisations across the world.[19] It is now in the process of developing a pioneering new generation of satellites that are optimised for real-time mobility and feature thousands of dynamically-formed beams that direct capacity with laser-like precision over high-demand areas.

Integrated with 5G mobile networks, satellite will provide the basis for ubiquitous internet, fully unlocking the power of the Internet of Things. With the advent of ubiquitous computing, people will be able to access the internet across platforms and devices, including everyday objects such as refrigerators and cars.

The implementation of these technologies will mean everyday tasks become more seamless, enabling productivity gains which can generate economic growth and improve operational efficiency. The introduction of 'smart homes' technology – which will rely on ubiquitous computing technology – will instigate substantial gains in energy efficiency in buildings, thereby enabling the rapid reduction of fuel usage and carbon emissions. And given that satellites are powered by sunlight, the new technologies provide an environmentally sustainable route to spreading the new technology far and wide.

But in order to benefit from these advances it is also essential that our digital networks remain safe from criminals and cyberattacks. Satellites will play a key role in the next generation quantum internet, helping to keep our country safe and British firm ArQit has already pioneered the development of 'quantum key' technology, bolstering the security of private and public sector online networks.[20] In future years we can therefore expect to have satellite broadband engineers and quantum key cryptographers in the jobs market.

Next steps - our 2020 vision

The preceding chapters have set out the transformative potential of the UK space sector. But if this potential is to be fulfilled then concerted action is needed. The following five recommendations make up our 2020 vision, setting out what this concerted action could look like now the new government is in place.

1. National Space Programme and Innovation Fund

The Government should establish a National Space Programme, which includes a new £150m-a-year Innovation Fund. The National Space Programme's primary objective would be to ensure that the UK space sector plays an increasingly prominent role in the global space market, building cross-country partnerships and exporting knowledge and equipment.

Space is a research and development intensive sector and requires co-investment from government. Hence, the £150m a year Innovation Fund would focus specifically on R&D. The allocation of Innovation Fund resources would be agreed between government, the space sector and other relevant bodies to the sector (such as universities). Some ideas for what the resources could be allocated to are as follows:

- Commercialisation of R&D. This would help the sector to make the most of opportunities to lead in the world in areas from space application of Quantum technology, AI, robotics and advanced manufacturing.
- Exploring space sector priorities. The space sector has identified a number of programmes that it thinks could be areas of focus within a National Space Programme. These include:
    - Sovereign geospatial data. Creating a step-change in the storage, maintenance, fusion and analysis of big, complex EO data sets to accelerate real-world applications.
    - Ubiquitous, resilient and secure connectivity. Ensuring that space networks are fully integrated into emerging mobile networks.
    - Resilient position, navigation and timing security solutions. Developing UK supply chains for new technologies that will underpin future resilient Position, Navigation and Timing and security solutions, supporting the UK's critical national infrastructure.

2. Joined-up National Space Council

The new National Space Council must be given the powers and funding required to drive the sector forward. Once implemented, this body should join up space strategy across Whitehall and help to ensure that public money is used to benefit government services and support industry growth. The National Space Council should have appropriate engagement with industry and academia to enhance its knowledge and credentials.

3. UK Global Navigation Satellite System

The UK should commit to funding its own sovereign Global Navigation Satellite System (GNSS) post-Brexit. The 2019 Spending Review committed to continuing to provide £191m of funding to support Brexit-related activities "including the development of a UK Global Navigation Satellite System option and delivering business stability for company law and audit". However, the estimated cost of the programme is £5bn. This needs to be reflected in long-term budget lines to sustain key precision, navigation and timing skills in the industry.

4. Copernicus

The UK space sector must be able to bid to lead future missions by the Copernicus programme post-Brexit. This would be through either ESA or a post-Brexit agreement with the EU on space and science cooperation. As things stand there is around $1bn of future work the industry can bid for – but we need a seat at the table.

5. Increased ESA funding

The Government must commit to increasing space funding from all current sources, including through the European Space Agency. The ESA funding increase announced in December 2019 means that – for the next three years - the UK will account for 11.5 per cent of the total funding committed to ESA. This is a step in the right direction, but we still have further to go to match the contributions of Germany, France and Italy. Being strong in ESA gives a fantastic platform upon which to build a national space programme to drive development of sovereign capability, global collaborations and international trade. Crucially, ESA has also always delivered excellent returns for UK business , with the UK getting an average £10 return for every £1 invested. In the medium-term, it therefore makes strong economic sense for us to step up our involvement in ESA.

Annex – the space sector and green jobs

The starting point for the analysis was to ask the following questions:

1. **What is a 'green job'?** There is no single, agreed definition. We used two that we felt were the most credible frame our analysis, as follows:

- The definition used by the International Labour Organisation (ILO). The ILO makes a distinction between production of environmental goods and services and involvement in environmental processes[21]:

> ***"At the enterprise level, green jobs can produce goods or provide services that benefit the environment, for example green buildings or clean transportation. However, these green outputs (products and services) are not always based on green production processes and technologies. Therefore green jobs can also be distinguished by their contribution to more environmentally friendly processes".***

In the context of the space sector, we interpret this to mean that those people employed to build a satellite for the specific purpose of monitoring the environment are in green jobs; so too are those people that interpret the data from said satellite to improve environmental outcomes.

- The definition used to measure the environmental goods and services sector. There is an emerging international approach to measuring the environmental goods and services sector, which is defined as follows[22]:

> ***"The environmental goods and services sector comprises all entities in their capacity as 'environmental producers', i.e., undertaking the economic activities that result in products for environmental protection and resource management. Producers in the EGSS may or may not be specialised in the production of environmental goods and services, and may produce them as principal or secondary activities or produce these products for own use. Consequently, the scope of the EGSS may overlap with existing legal definitions or statistical classifications of units only to a certain extent."***

Again, in the context of the space sector this may mean that a company that interprets satellite data does so for environmental purposes only some of the time. The resources utilised by the company for that specific purpose would constitute green jobs.

2. **How many green jobs are there currently in the space sector?** There are estimates for the number of jobs within the space sector, but little indication for how many would meet the definitions of 'green jobs'. We therefore used different scenarios to understand more about the potential green jobs within the sector. Our central scenario assumed that all -sub-sectors of space that focus on satellites (other than direct-to-home broadcasting) will include some employment that meet the definitions of green jobs that we have identified. The proportion of total overseas development expenditure going on satellite-related environmental projects in Africa is used as a proxy for the proportion of green jobs there are in the satellite industry*. This is the most relevant proxy we could find from the literature that we reviewed.[23]

From answering the above questions, we had baseline scenarios for the current number of green jobs within the space sector.

The next step was to look at the growth patterns in employment – both realised and expected - of other small, but high growth and innovative industries, which could be seen as comparable to the space sector The industries that we looked at were FinTech and Offshore Wind.*

The calculation we then used was simply applying the growth patterns of these industries to our baseline figure for green jobs within the space sector. We also added a green jobs growth pattern which matched the industry ambition for overall jobs. The average of these growth patterns gave us our final results. This gave us the projections for green jobs within the UK space sector up until 2030. The following results give our low, central and high scenario results for the growth in green jobs up until 2030:

- On the low scenario, where we included just the Satellite Applications sub-sector of the space industry (excluding direct-to-home broadcasting), we project a growth in green jobs of 7,500 to 2030.

- On the central scenario, where we included sub-sector of the space industry that are directly related to satellite technology (excluding direct-to-home broadcasting), we project a growth in green jobs of 15,100 to 2030.
- On the high scenario, where we include the whole space sector (excluding direct-to-home broadcasting), we project a growth in green jobs of 38,500 to 2030.

The figure for the proportion of environmental jobs that our central scenario would constitute is taken from the UK's EGSS accounts, where we projected past jobs growth in the sector forward to 2030..

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With thanks to the Satellite Applications Catapult for their generous support

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