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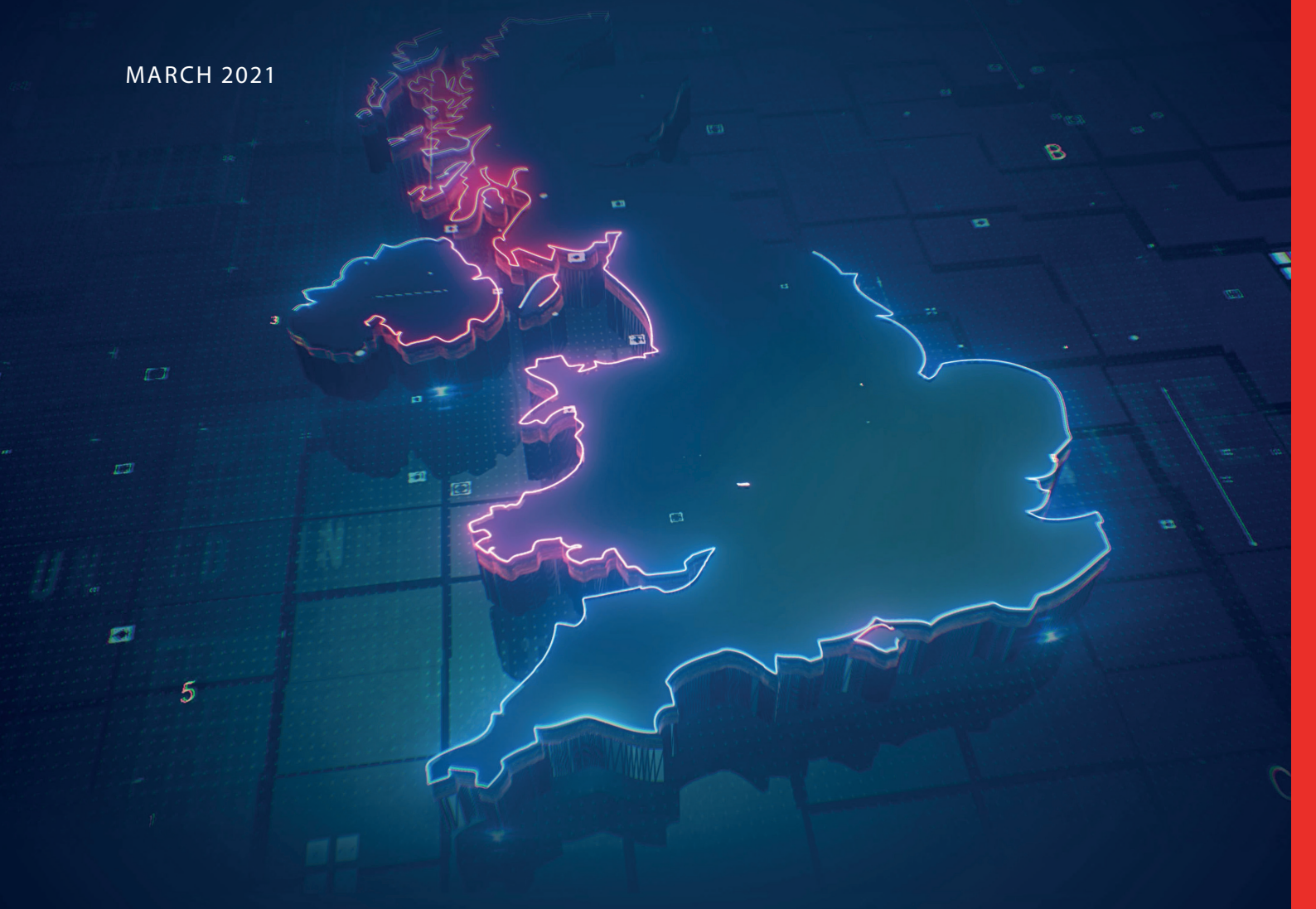
Developing the Space Sector in the Oxford-Cambridge Arc

MARCH 2021



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RED KITE
MANAGEMENT CONSULTING

Developing the Space Sector in the Oxford-Cambridge Arc

Full Report

Prepared for the Satellite Applications Catapult and the UK Space Agency by Red Kite Management Consulting

March 2021

This is the full report of an independent review of themes and capabilities in the space and related sectors in the Oxford-Cambridge Arc, setting out a vision and action plan to maximise the potential of space-related activities across the Arc.

It shows how the Arc space sector can collaborate with other Arc strengths to solve societal challenges, lift a globally significant space cluster to an even higher orbit, and export its capability and value nationally and internationally – Rising to the Challenge.

Contents

The Red Kite Team

Red Kite Management Consulting	Connected Economics	Commercial Space Technologies
• Lead: Robin Tucker • Strategy, marketing, public policy • Knowledge of space application markets: telecoms, transport, agri/environment • Arc base and knowledge	• Lead: Dominic Walley • Economics, Data and Public policy • Experience with space and related markets; stakeholders in LAs, LEPs	• Lead: Alan Webb • Launch and satellite industry experts since 1983 • Contacts through space & supplier industry

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Introduction

The Oxford-Cambridge Arc is a globally significant area for innovation and has great potential for economic growth, but it also faces challenges. The Satellite Applications Catapult and UK Space Agency asked us to review the themes and capabilities in space and related sectors in the Arc, and to set out a vision and an action plan to maximise the potential of space-related activities in the Arc.

The study was led by Red Kite Management Consulting, with economics and public policy input from Connected Economics, and space sector expertise from Commercial Space Technologies.

We found that the challenges faced by the Arc are a concentrated version of UK national challenges: challenges of clean growth, environment, transport and health. The Arc has strong capabilities to address those challenges, and its space sector can link with these capabilities to tackle Arc and hence national challenges.

This insight underpins our vision, and to enable it we propose a problem and market focused approach to innovation. The Arc's space sector has achieved great things over the last decade, and it can continue this success and growth with investment in space technologies and clusters, improved collaboration across the Arc, and foundational capabilities (e.g. skills and workspaces). With the approach we describe, the Arc's space sector can solve some of the biggest challenges we face locally in the Arc, nationally, and across the world. These breakthroughs will deliver benefits, develop capabilities and build businesses across the UK, to both support national growth and cement the Arc as a global centre of research and problem solving in the emerging global space economy.

Part 1: Existing Recommendations and Activities

Introduction to Part 1

In this Part 1, we review existing Recommendations in two main sections, first the 'vertical' Space sector which strongly features recommendations of the collaborative 'Space Growth Partnership' that spans business, academia and the public sector. We also cover National Space Policy and recommendations from the space trade association. In the second main part, we cover national and regional strategies including the National Industrial Strategy, relevant Science and Innovation Audits, the Arc's 'founding documents' leading to the Arc LEPs' Local Industrial Strategies and delivery plans. We also review current activities in the Arc that support the space sector and other technology sectors.

There are many recommendations and strategies across these documents, which comprise over 1600 pages in total. We have edited many for brevity, duplication and relevance, but have left many in that are not directly in the Arc/Space cross-over, partly to give a full flavour of these strategies, but mostly because there are opportunities for the space industry in the crossovers. For example, using satellite solutions in Health 'Living Labs', ensuring that skills programmes both benefit from the inspiration of space and produce people with skills useful for space, and using satellite applications for infrastructure planning or environmental monitoring.

After each main section, we examine the main themes across the recommendations and strategies in that section. Finally, we examine the synergies between the between Space-sector, National and Regional strategies and recommendations.

1. Relevance Ratings

We rate each of the recommendations on its relevance to the Arc Space Sector.

Space-sector recommendations	Rating	Arc/National recommendations	Rating
Specific to or high-impact for the Arc	H	Specific to space	H
Advantage for Arc, or Arc version possible	M	Advantage for Space, or Space version possible	M
Benefits space sector in general	L	Benefits the Arc or industry in general	L

As an example Medium relevance, we give this rating to Growth recommendations in the Space IGS because although these were recommended on a national basis, many of them had strong Arc impact due to the space sector presence in the Arc, and looking ahead many of them could be taken forward on an Arc or LEP area basis. e.g. an Arc-wide initiative to develop geospatial markets linked to natural capital, or existing LEP-led business support schemes with an enhanced focus on space-related and other priority sectors.

2. *Space-sector strategies, recommendations and activities*

The recent development of the UK space industry can be traced back to the **Space Innovation and Growth Strategy** of 2010. A joint initiative between government, industry and academia the Space IGS set out the importance of the space sector for the UK, and a 20-year vision and growth strategy for the UK to become a world lead in space. It covered five key areas: Markets, Capabilities, Public Policy, Skills and Awareness, and Finance.

The Space IGS led to renewed interest and investment in the UK space sector, and it was no coincidence that the UK Space Agency was formed in the same year and the Satellite Applications Catapult in 2012. We won't note its recommendations here as they are superseded by the Space Growth Action Plan.

The **Space IGS 2014-2030: Space Growth Action Plan** (SGAP) followed on from the Space IGS in November 2013 and set the target for the UK space industry to achieve 10% market share by 2030. It was again produced by a cross-sectoral team and had 5 main recommendations with 40 actions. Progress on these actions was reported to the Space Leadership Council, which comprises senior representatives from IGS stakeholders and the government minister.

The detailed actions are not listed because they are superseded by the 2015 Update Report below.

Space IGS Space Growth Action Plan – Recommendations	Theme	Relevance
Develop the high-value priority markets identified to deliver £30 billion per annum of new space applications by promoting the benefits of Space to business and Government and engaging service providers (7 actions to develop markets) 35 potential markets identified.	Markets	M
Make the UK the best place to grow existing and new space businesses and attract inward investment by providing a regulatory environment that promotes enterprise and investment in the UK (6 actions on regulation)	Regulation	L
Increase the UK's returns from Europe by continuing to grow the UK's contributions to European Space Agency (ESA) programmes and securing greater influence in large European-funded programmes (7 actions on Europe)	Europe	L
Support the growth of UK Space exports from £2 billion to £25 billion per annum by 2030 by launching a National Space Growth Programme and defining an international policy that will improve collaboration with nations across the world, enhance the UK's competitive edge in export markets and enable targeted and market-led investments in leading edge technology. (11 actions on a National Space Growth Programme)	International+ Government Investment	M

Stimulate a vibrant regional space SME sector by improving the supply of finance, business support, information, skills and industry support. (9 actions on SMEs and Skills/Education)	Finance + Business Support	M

The Government Response to the SGAP in April 2014 acknowledged the opportunity and welcomed the ambition of the sector and the strategy. It set out recent Government actions: the definition of a Civil Space Strategy, a National Space Security Policy and the establishment of the 'Space for Smarter Government Programme'. It committed the Government, through the UK Space Agency, to work with the industry towards implementing the growth strategy.

The **UK Space IGS 2015 Update Report** provided a progress update on the Space IGS Space Growth Action Plan recommendation, and simplified the structure into five Themes and ten Priorities.

In parallel, the Satellite Applications Catapult, KTN and other stakeholders were developing market analyses and roadmaps for some of the high-priority markets identified in the 2013 SGAP and Technology Roadmaps to identify key technologies and skills that the UK should be investing in.

Space IGS 2015 Update – Priorities	Theme	Relevance
1. Address high value market opportunities for UK businesses by developing and implementing growth roadmaps. To engage stakeholders, and identify, validate and map out opportunities.	Innovation + Markets	M
2. Increase the use of space applications and infrastructure to meet the UK's security and defence needs	Security	L
3. Further develop analysis of the economic impact of the space sector	Strategy	L
4. Promote relevant regulatory and spectrum regimes to maximise UK business growth	Regulation	L
5. Implement the European Space Engagement Plan	Europe	L
6. Drive UK exports. Industry and Government working to encourage and coach businesses to take their products to export.	International	M
7. Access High Value Market Opportunities through an increased investment in the National Space Growth Programme. Increased national investment to complement the UK's investment in ESA.	Government Investment	M
8. Encourage space-related businesses, especially SMEs, to maximise opportunities for growth. Including Networks, finance, skills, export and scale-up assistance.	Finance, Skills, Bus. Support	M
9. Grow regional space clusters, including Harwell.	Clusters	H
10. Ensure skills are in place for the UK to develop space related opportunities. From STEM subject entry to skilled graduates.	Skills	M

The **National Space Policy of 2015** was focused on broad policy, but many of its policies can be linked to recommendations and actions in the sector.

It has 4 main policy areas, all of which support the growth of the space sector, and areas 1 and 3 are most relevant. We have identified some of the wording that supports specific actions to support the sector that could be applied in the Arc.

National Space Policy 2015 – Policy Areas	Theme	Relevance
Government will drive the use of innovative services from space where they are the most cost effective solution to improve public services, through coordination across departments and in partnership with the wider UK space sector. For instance, Government will use space to bridge the digital divide.	Government Procurement	M
Government will continue its efforts to increase the supply of a skilled workforce on which the space sector depends by investing in education and outreach programmes.	Skills	M
Government will ensure that new space technology and knowledge is transferred to other sectors.	Innovation	M
2. Government commits to preserving and promoting the safety and security of the unique space operating environment, free from interference.	Security	L
3. Government supports the growth of a robust and competitive commercial space sector, underpinned by excellent academic research.	Markets, Skills	M
Government will continue to make finance markets work better for innovative, smaller businesses, centred around the British Business Bank.	Finance	M
Government will support innovation, entrepreneurship and private-sector investment in space, for instance through the Satellite Applications Catapult	Innovation investment	M
Government will also fund a range of technology support programmes, spanning blue skies research through to near-market applications, with differing financial models	Innovation investment	M
Government will develop further clusters around existing and new space assets in industry and academia, replicating the "Harwell effect"	Clusters	M
Government will support companies that utilise space to deliver innovative products that align with local smart specialisations.	Markets	H
Government will drive adoption of space solutions for the delivery of public services, acting as a customer where space provides the optimum solution	Government procurement	M
4. Government commits to cooperating internationally to create the legal frameworks for the responsible use of space and collaborate with other nations to deliver maximum benefit from UK investment in space.	Regulation	L

In January 2019, the **Size and Health of the UK Space Industry 2018** study was published. While this does not contain recommendations for the sector, it does allow the respondents to identify high-level 'enablers to growth'. These are at a high-level, and most would have to be national, but 'encouraging STEM uptake' could be local and there could be a local space investment programme or 'sector deal'.

Size and Health 2018 – Enablers to Growth	Theme	Relevance
UK-EU partnership deal for UK exit from EU	Europe	L
UK National Space programme	Government Investment	M
Encouraging STEM uptake	Skills	M
UK sector deal	Government Investment	M
Business-friendly legislation	Regulation	L
Enhanced export support	International	M
Regulation of spaceflight	Regulation	L

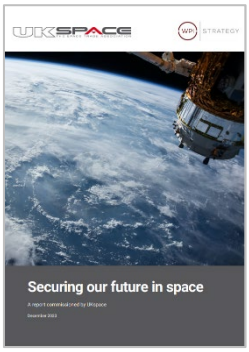
In May 2020, the Space Growth Partnership, led by the industry published **Prosperity from Space: A Partnership Strategy for the UK**. This document set out a strategy of co-investment by Government and industry, working in partnership with academia and entrepreneurs to develop the sector. It proposed focusing national effort on four sector market priorities to build on the UK's strengths:

- Earth Information Services;
- Connectivity services;
- In-space robotics;
- Low cost access to space;

There were four pillars to 'Prosperity from Space' strategy.

Prosperity from Space – Four pillars of strategy	Theme	Relevance
1. Creating a National Space Programme to unlock increased private investment	Government Investment	M
building new global partnerships and exports	International	M
maintaining world-class excellence in stand-out UK strengths	Innovation investment	M
and combine capabilities in space data and AI to drive productivity in sectors across the UK economy	Markets	H
2. Creating the right environment for success by securing and building on existing strengths / market position	Markets	M
Improve the entrepreneurial pathway and access to finance	Finance	M
Setting up a cross-Government working group to secure high value inward investment	Finance	M
Using Government procurement to stimulate commercial investment with UKSA as a procurement agency	Government Procurement	M
Find a new mechanism to encourage operators to deliver 100% UK communications coverage	Government Procurement	M
Develop a UK national capability in Earth information to benefit UK businesses and Government	Government Procurement	M
Delivering a competitive and progressive regulatory regime	Regulation	L

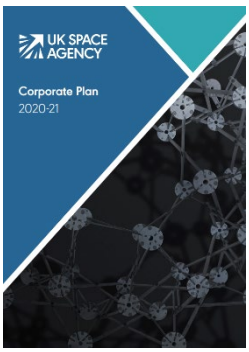
3. Investing in people and places	Skills + Clusters	M
attracting and training up to 30,000 additional skilled people by 2030	Skills	M
actively encourage diversity and inclusion	Skills	M
Showcase scientific achievements and undertake 1,000,000 interactions with young people each year	Skills	M
Spread the benefits across the UK by developing locally led regional technology hubs	Clusters	M
4. Continuing to drive growth from our investment in ESA, Eumetsat and EU programmes	Europe	L
Enhance UK's relationship with ESA maintaining at least the current level of investment. (L relevance but high impact due to ESA presence in Harwell).	Europe	L
Enhance UK's relationship with Eumetsat continuing the currently planned levels of investment	Europe	L
Support UK / EU partnerships on current and planned EU space programmes, or compensating opportunities	Europe	L



UKspace, the industry's trade association followed this in December 2020 with a report which put numbers on the desired Government investment and procurement. Their **Securing our future in space** report had 3 simple recommendations to begin "the execution of a well-funded National Space Programme."

Securing our future in space – Recommendations	Theme	Relevance
1. Set up a National Space Innovation Fund at £150m per year, sustained over 10 years, to be matched by industry. This would advance research and technology to commercial viability and create huge new value for the UK.	Government Investment	M
2. Create a National Procurement Fund of £250m per year, sustained over 10 years, for the procurement by Government of UK space products and services, to accelerate commercialisation of the space sector and encourage R&D.	Government Procurement	M
3. Establish a Space Delivery Agency to drive the national space programme, complementing the UK Space Agency's role in policy, international relations and regulation, but focused on pushing a complex commercial hi-tech programme forward.	Government Investment	M

Current national activity to develop the sector, beyond the space industry itself, is focused around the UK Space Agency, and the Satellite Applications Catapult.



The UK Space Agency's activities are captured in its **UK Space Agency Corporate Plan 2020-21**, which runs to March 2021. However, it does include work towards a 'National Space Strategy'. This identifies 8 Priority Programmes, 5 of which are major areas of Government investment in space. Of those, the NSIP and the International Partnership Programme have potential local analogues.

UK Space Agency Corporate Plan 2020-21 – Priority Programme	Theme	Relevance
Sector Resilience: providing dedicated sector advice and support to help resilience and recovery	Business Support	L
National Space Innovation Programme: set up and deliver a pilot for new national and international programmes. (£15m fund, £200,000 to £2m per project)	Government Investment	M
UK Spaceflight Programme: a £50 million programme to kick-start small satellite launch and sub-orbital flight from UK spaceports	Government Investment	L
UK Space Based PNT Programme (SBPP): Discovery to Mar 21 and Options Assessment to OBC by Nov 21	Government Investment	L
Transformation: Ensuring an effective UKSA which is a great place to work	(Internal)	L
A UK Space Strategy: bringing together the newly formed National Space Council to take ownership for developing the UK Space Sector	Strategy	L
International Partnership Programme: using the UK Space sector's strengths to deliver space-enabled Development Assistance that provides measurable and sustainable economic or societal benefit	Government Investment	M
European Space Agency: Our shared investment in ESA programmes, £374m this year	Europe	L

The **Satellite Applications Catapult Delivery Plan 2020** identifies 7 market opportunities for satellite applications where it will focus on building demand and applications. It then describes initiatives to develop disruptive technologies and unique facilities, international markets, and regional space activities. This built on the Catapult's Strategy 2018-2023 – the main difference being that this also included the 'blue economy' and 'local governments services' beyond health as key potential markets.

Satellite Applications Catapult Delivery Plan 2020 – Plan	Theme	Relevance
Build demand for, or develop satellite applications in: • Agriculture • Extractive Industries • Climate and Sustainability • Intelligent Transport • Health and Wellbeing • Geospatial Intelligence • Ubiquitous Connectivity	Markets	M

Access to Space: Grow UK community of disruptive space technology providers. Including In-orbit demonstrator programme, Manufacturing for Space, Commercialisation of Space	Innovation	M
Emerging Technology: Identify and catalyse exploitation of disruptive technologies. Including Future Mega-constellations, New architectures for embedded AI, V-band	Innovation	M
Facilities: By 2030 provide ten unique facilities across UK. Including Access to R&D, DISC (Harwell, Westcott), Westcott Space Cluster	Innovation	H
International Strategy: Closer collaboration of SA Catapult with FCO and DIT, Leverage EASOS and other technologies in accessing international markets, Explore opportunities in China, Take the Joint Centre approach in other key geographies, e.g. Australia, Gulf, Expand activity in Latin America, building on current presence	International	M
Placemaking: Continue to support, grow and evolve Centres of Excellence. Develop Cluster approaches, including Westcott	Clusters	M
Business Support, current and new future: Sprint, Commercialisation and aim to develop a Scale-up programme	Business Support	M
Over the next few years, to enable UK success: Communities and engagement, Partnerships, Commercialisation	Business Support	M

Space sector activities in and beyond the Arc – The sector is thriving and is very cooperative, which perhaps comes from a shared endeavour of open up the 'final frontier' together, and the need for cooperation to assemble all the skills required for a complex and expensive mission or commercial venture.

Before the Covid pandemic there were frequent meetings of the space community, both to network in general and to work on specific topics. Half probably came from the Arc, and another quarter from nearby, e.g. the M3 corridor. But, even before the pandemic people would travel from further afield and some events were linked by video to other locations – the Satuccino 'Extra Shot'. Events focused on a specific topic (e.g. agriculture or rail) drew from a wider geography due to their longer length and subject relevance. Since Covid, events have gone online, which has enabled a wider range of attendance from around the UK and even internationally.

Beyond the Arc, there are many events: large conferences such as the biannual UK Space Conference, Reinventing Space, Space to Connect, and many more general and specific conferences and meetings.

Space sector activities in the Arc	Theme	Relevance
Business Support (see also SA Catapult Delivery Plan above)		
ESA Business Incubation Centre – Harwell hosts one of 4 ESA BICs in the UK. Support is offered to selected space-related startups including £43,000 for product development and IPR, access to STFC facilities, business support and funding, collaboration and network access.	Business Support	H

SFN Surgeries – Monthly advice, SMEs can book an hour with the Satellite Finance Network panel of experts. Some of these surgeries used to be at Harwell, most in London. Now they are online.	Business Support	M
Regular Events		
Satuccino – Monthly information sharing and networking event at the Satellite Applications Catapult, Harwell (currently online).	Networking	H
ESA Space Cakes – Monthly information sharing and networking event at ESA Business Incubation Centre, Harwell (currently online)	Networking	H
Westcott Space Innovators – Monthly information sharing and networking event at Westcott Business Incubation Centre (currently online)	Networking	H
Specific Events – July 2020 to January 2021		
Space: The New Manufacturing Frontier	Innovation	M
Space Technology in Extreme Mining Environments	Markets	M
Researcher in Residence Q&A Session	Markets	M
Unlocking the potential of UK satellite enabled Agri-Tech products & Services – with the Agri-EPI Centre	Markets	H
Driving Space Business in a Changing World: Financing, Investment and M&A	Finance	M
Emerging Technology for Space Webinar - Solar Energy, In-Orbit Fabrication and Robotic Assembly	Innovation	M
Precision Livestock Farming and Sensing Technology in Extensive Grassland Systems	Markets	M
Satellite Technology Addressing Social Challenges in Mining – Webinar	Markets	L
5G for Content Acquisition and Distribution – Webinars by Cambridge Wireless	Markets	M
UK-Australia Cyber Security in Space – Workshops	Markets	M
Cyber-security Workshops (UKSA / SA Catapult)	Business Support	M
Funding Grants, Calls and Opportunities – Examples promoted at recent events		
Space Applications to Advance Innovation on Circular Cities (ESA)	Innovation	M
National Space Innovation Programme (NSIP) (UKSA – see above)	Innovation	M
Marine Southeast projects: UFO, Space2Waves	Innovation	L
Astropreneurs mentoring (EU H2020)	Innovation	M
ESA Business Applications including Covid-19, Space & 5G, Space4Rail, Intelligent Transport, Food and Beverage Fraud, Digital Health, Pollution…	Innovation	M
Knowledge Transfer Partnerships (KTP) (Innovate UK)	Innovation	M
International Space Pitch Day (Allied Defence Accelerator)	Innovation	M
Space Placements in Industry (SPIN)	Skills	M
Cross-Cluster Proof of Concept Grant (STFC)	Innovation	M
OrbAstro payload opportunity	Innovation	M

2.1 Themes of Space-sector strategies, recommendations and activities

The clear theme of most of these activities is a drive to **create and commercialise innovation** in both 'upstream' space and 'downstream' space applications.

Starting with creating the innovation, much of this is with **Government investment** through Innovate UK, UKSA and ESA – almost all match-funded. These are approaches which have shown then ability to create new applications and businesses, for example Rezatec and Open Cosmos. Some is driven by **Government procurement**, with the SSGP as the best example. But the industry's trade association is calling for dedicated space innovation investment and procurement programmes of £150m and £250m a year, far larger than the £15m NSIP, £8m NSTP and £1m SSGP[1].

To link innovations to **markets**, there is a theme of activity in exploring space application markets, mapping out the opportunities, bringing people together, developing concepts and running demonstration projects. This activity reduces risks and enables partnerships, increasing the chances that businesses or entrepreneurs will pick up the baton to exploit an opportunity.

Skills was noted as an important enabling theme requiring action for the industry, with the sector creating up to 100,000 jobs nationally by 2030.

Several themes are clearly helpful to developing technology businesses of all kinds: **Finance**, **Business Support** and **Networking**. **International** trade and investment, with a particular focus on exports, is an important theme with the space sector highlighted as having great opportunity. **Europe** is a theme in itself due to the size of the ESA programme, in which UK and Arc-based academia and businesses play a key role, and the two ESA facilities at Harwell.

Two themes are mostly dealt with by central Government, but with implications throughout the space industry. **Security**, including defence, ensures that space and related assets can operate free from interference. **Regulation** enables the responsible and collaborative use of space and the benefits that can come from it.

A final theme is not written in the recommendations of the reports, but is implicit in their development. This is the **shared national leadership** by industry, academia and the public sector in forging a strategy for the space sector, over a decade from 2010's Innovation and Growth Strategy to 2020's 'Prosperity from Space'. The collaboration, effort and leadership demonstrated by people who share a vision for the potential of commercial space has set the sector on an upward trajectory.

[1] The UKSA International Partnership Programme is larger, funded at £152m over 5 years.

3. National and Regional strategies, recommendations and activities

Three national strategic initiatives have come together to shape the economic strategy of the Oxford-Cambridge Arc and its emerging Delivery Plans.

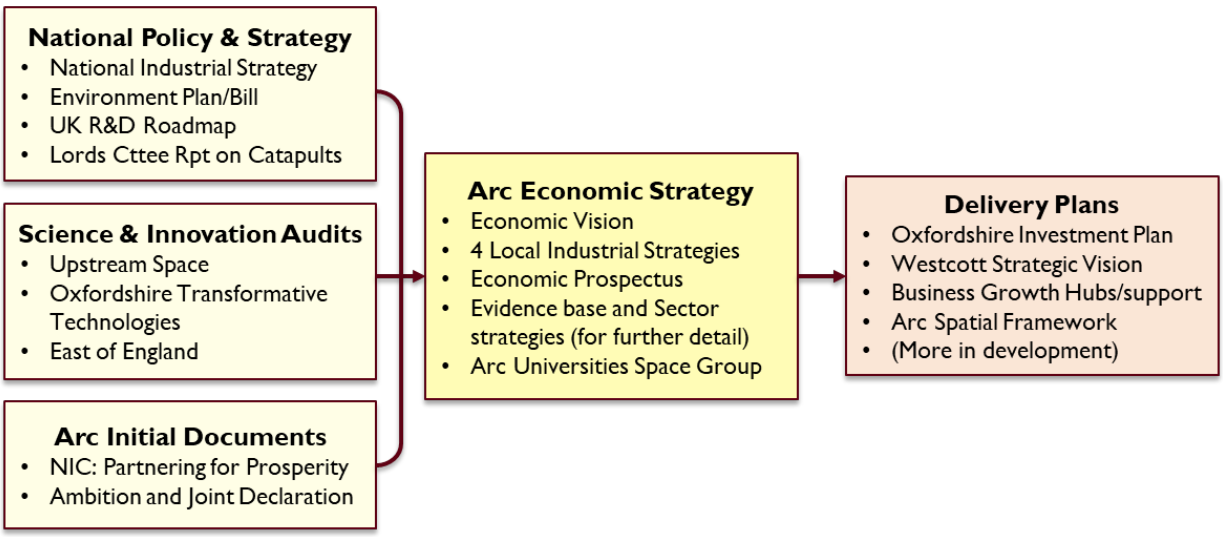


Figure 1-1: National and Regional Strategies and Plans

The National Industrial Strategy, relevant Science and Innovation Audits and Partnering for Prosperity were published in late 2017 and were based on many months of work starting from different perspectives. But they have mesh together to create a vision of potential that the LEPs and Local Authorities have recognised. The 4 LEPs worked together to develop an Economic Vision, their own 4 detailed Local Industrial Strategies – which are consistent across the Arc, and to summarise them in an Economic Prospectus. These are now being discussed with Government, individually and together, and specific strategies and Delivery Plans being developed by LEPs, sectors and locations. A space sector strategy for the Arc could clearly fit into this picture.

In this section we step through these strategies and plans, capturing the recommendations that are most relevant to the space sector. These include many that are not directly space-related, but create opportunities for satellite applications.

3.1 National Policy and Strategy

The National Industrial Strategy was published in November 2017, a comprehensive strategy aiming to improve the nation's productivity and competitiveness – adding to skilled jobs, earnings and living standards. It introduced 4 Grand Challenges that will define the industries of the future – each of these is an opportunity for the space sector. It sets out 5 Foundations of Productivity – all of which apply to the space sector, some very directly and some less directly. In one of those it introduced the concept of Sector Deals – Space has not yet achieved a sector deal, but it remains an ambition.

National Industrial Strategy	Theme	Relevance
4 Grand Challenges		
AI & Data Economy: We will put the UK at the forefront of the artificial intelligence and data revolution	Innovation	M
Clean Growth: We will maximise the advantages for UK industry from the global shift to clean growth	Innovation	M
Future of Mobility: We will become a world leader in the way people, goods and services move	Innovation	M
Ageing Society: We will harness the power of innovation to help meet the needs of an ageing society	Innovation	M
5 Foundations of Productivity		
Ideas - To be the world's most innovative economy. Raise total research and development (R&D) investment to 2.4 per cent of GDP by 2027. Increase R&D tax credit to 12 per cent and a £725m Industrial Strategy Challenge Fund.	Innovation investment	M
People - To generate good jobs and greater earning power for all. Establish a technical education system that rivals the best in the world. Invest an additional £406m in STEM education. Create a National Retraining Scheme.	Skills	M
Infrastructure - A major upgrade to the UK's infrastructure. Increase the National Productivity Investment Fund to £31bn, supporting investments in transport, housing and digital infrastructure, including EV charging, fibre and 5G.	Enabling Infrastructure	L
Business Environment - To be the best place to start and grow a business. *Sector Deals* – partnerships between government and industry aiming to increase sector productivity. First Sector Deals in life sciences, construction, AI and automotive. Drive over £20bn investment, including £2.5bn Investment Fund via British Business Bank. Review actions that improve productivity and growth of SMEs.	Innovation, Finance, Business Support	M
Places - To have prosperous communities throughout the UK. *Local Industrial Strategies* building on local strengths to deliver economic growth. Transforming Cities fund: £1.7bn for intra-city transport. £42m to pilot a Teacher Development Premium for areas that have fallen behind.	Enabling Infrastructure, Skills	L

The **Industrial Strategy Council** was established as an independent body to assess progress towards the aims of the Industrial Strategy. It produced its first **Annual Report** in February 2020, which stated that the Industrial Strategy was a positive force and progress had been made, but after 3 years the Industrial Strategy needed updating and reprioritisation. Some of the recommendations are relevant to the space sector.

Industrial Strategy Council Annual Report Recommendations	Theme	Relevance
Increase focus, financing and policy co-ordination on the Grand Challenges, particularly Clean Growth / Net Zero 2050	Innovation	M
£2.5bn Industrial Strategy Challenge Fund needs to be scaled up if it is to support significant progress on the Grand Challenges	Innovation, Finance	M
A strategic overhaul of training policies and institutions is needed to meet the future skills challenge in the UK	Skills	M
An expansion in the number of businesses benefiting from the BBB's support	Finance	M
A strategic review of the apprenticeship system, introducing greater flexibility	Skills	M

Government environmental policy also points to opportunities for satellite applications. The **Natural Environment White Paper 'The Natural Choice'** of 2011, made the commitment for this "to be the first generation to leave the natural environment of England in a better state than it inherited". This included consideration of 'Natural Capital' concepts, which recognise the value of the assets that nature provide, and in 2012, the Natural Capital Committee was founded to advise Defra.

The **25 Year Environment Plan 'A Green Future'**, launched in 2018, embedded natural concepts and recognised that a long-term view was necessary. This was followed with the introduction of the **Environment Bill introduced 2019**, third reading expected later in 2021, to deliver "urgent and meaningful action to combat the environmental and climate crisis we are facing". Many of these could be supported by satellites – the Natural Capital Committee highlights the need for "asset-based metrics and a comprehensive baseline census to effectively report on progress" for example.

3.2 Science and Innovation Audits

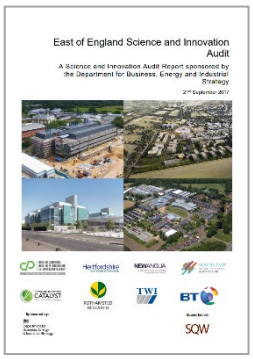
The Science and Innovation Audits (SIAs) were initiated in 2015 by the then Universities and Science Minister Jo Johnson to map local scientific strengths, both existing and emerging, to identify the most promising areas of potential. Since then, there have been 25 reports in 3 waves, of which 3 are relevant to the space sector and the Arc.

The **Oxfordshire Transformative Technologies Alliance Science and Innovation Audit** was delivered as part of Wave 2 in 2017, although like all the SIAs it had taken some time to prepare. It highlighted 4 technologies, chosen because they had the potential to be transformative of the economy and/or society, were co-dependent, and that they were similar in that they needed similar skills and approaches and had large opportunities at the intersections.

The report identified both specific and cross-cutting enablers investments that would be required to realise the potential of these sectors. It also noted that other sectors could have been chosen for high potential transformative technologies within Oxfordshire. This report has a strong read-across to the Local Industrial Strategy.

Oxfordshire Transformative Technologies Alliance Science and Innovation Audit	Theme	Relevance
Technology 1: Connected and Autonomous Vehicles (CAVs): Public engagement and responsible research to improve public acceptance; Invest in more CAVs to enable the UK to compete; Invest in research, testing and local supply chains	Innovation	M
Integrate CAVs into housing development and transport infrastructure	Innovation	M
Technology 2: Digital Health: Increase clarity in regulatory and procurement processes; Improve access to clinical and economic data for the NHS; Accelerate timescales for uptake and procurement processes; Improve adoption beyond initial test bed sites	Innovation	M
Establish a regional Data Lake, across care pathways enabling improvements in health treatments and outcomes in partnership with the NHS	Innovation	M
Provide access for companies to a treatment test-bed	Innovation	M
Technology 3: Space applications: Focus on end user solutions; Increase capacity to work with Universities and STFC and transfer knowledge to commercial applications; Support local space related companies to promote solutions nationally and to develop export capability	Innovation	H
An application focussed geospatial data analytics Centre *(created as SEDAS & CEMS)*	Innovation	H
A Disruptive Innovation for Space Centre to develop new sensors and platforms *(created as DISC)*	Innovation	H
Continue to focus and promote the Harwell Space Cluster *(has happened)*	Innovation	H
Technology 4: Technologies underpinning Quantum computing: Work towards a blueprint for a quantum computer; Identify use cases for small quantum computers; Create a dedicated institute to develop quantum software tools; Develop more impact case studies	Innovation Investment	M
Establish a dedicated National Quantum Computing Technologies Centre *(done)*	Innovation	M
Gap to fill: Attracting top talent. Requires training engineers, addressing cost of living and transport constraints	Skills, Enabling Infrastructure	M
Gap to fill: Growing businesses to medium size is challenging due to lack of facilities and skilled staff	Skills	M
Gap to fill: Translating new technologies to scale-up by testing and demonstration	Innovation	M
Invest in Hardware development centres e.g. DISC, Quantum computer, AV testing	Innovation	H

Invest in data and software e.g. a health 'data lake'; geospatial analytics data centre	Innovation	H
Invest in test facilities e.g. end-to-end health pathways, AV testing, Satellite testing	Innovation	H
Invest in Technology integration – connectivity of data and communication networks	Innovation	L
increase training in specialist skills nationally, as well as in Oxfordshire. Increase the availability of generic skills (e.g. digital, data analytics) and for new courses (e.g. quantum computing or AI)	Skills	M
Implement Local Plans to build more housing in Oxfordshire, to enable more people to afford to live close to their work	Enabling Infrastructure	L
National housing investment should include 21st century 'smart technology'.	Enabling Infrastructure	L
Support and preserve science and innovation through funding, and as far as possible continue engagement in European programmes	Innovation Investment	M
Overcome traditional cultural barriers for inter-disciplinary collaboration, with an open innovation environment that brings together customers with challenges, solution providers and academia in affordable and flexible space	Innovation Investment	M
Place-based living lab model to address the identified gap of collaboration between sciences, to accelerate innovation	Innovation Investment	M
Cross-cutting: ask existing networks to develop better cross-sector linkages (e.g. OxLEP Network Navigators which have worked well)	Networking	M
Improved marketing of the region and its assets and capabilities	Networking	M
Retain medium-sized companies with availability of facilities as they grow	Business support	M

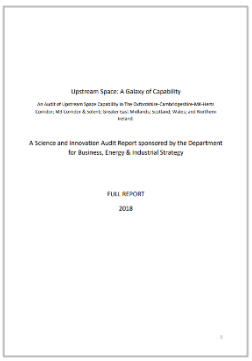


The **East of England Science and Innovation Audit** was also delivered as part of Wave 2. Like the Oxfordshire SIA this identified 4 sector themes as areas of both strength and high potential for the region, but it differed by focusing on a wider geographic area – an East of England area involving 4 LEPs, but only CPCA being in common with the ARC. CPCA is important for all 4 sectors, and the same 4 later appear in the CPCA Local Industrial Strategy. The EoE SIA identified 4 'Gaps' and 8 'Key Interventions' focused on two key challenges, one of commercialisation, and one of collaboration across the region and beyond.

East of England Science and Innovation Audit	Theme	Relevance
4 Sector Themes		
Life Sciences	Innovation	M
Agri-Tech	Innovation	M
Advanced Materials & Manufacturing	Innovation	M
ICT	Innovation	M
4 Gaps		
Unlocking investment in the process of convergence	Innovation	M
Providing skills, particularly relating to data (echoed below)	Skills	M
Enabling co-location and clustering - "serendipity can be engineered"	Clusters	M

Increasing connectivity for large volumes of data	Infrastructure	M
8 Key Interventions		
Building Innovation Capacity - Cross-cutting venture to build innovative capacity, particularly among SMEs in the ecosystem	Innovation investment	M
East of England Innovation - Initiative to encourage technology transfer, particularly for SMEs outside the main clusters	Innovation investment	M
Smart Enabling Technologies Testbed - Infrastructure project to achieve high speed and high capacity connectivity	Enabling infrastructure	M
Centre for AgriFood automation - Venture to provide a regional resource in automation, at Holbeach (not Arc)	Innovation investment	L
MedTech Hubs - Project to accelerate the development of emerging Hubs and to build synergies	Innovation investment	M
Microbiome Hub - Innovation Centre anticipating the opening of the new Quadram Institute, on Norwich Research Park (not Arc)	Innovation investment	L
Precision medicine cancer ecosystem - Radical new approach to precision medicine, building on foremost science	Innovation investment	L
Cell & Gene Therapy R&D Centre - Provision adjacent to the Cell and Gene Therapy Manufacturing Centre, at Stevenage Bioscience Catalyst (not Arc)	Innovation investment	L
Other Recommendations		
Cross-cutting: Address major issues relating to skills – particularly those relating to data science and computer science	Skills	M
Life Sciences, 2 imperatives: the region's existing ecosystems must be allowed to evolve and grow; the more sophisticated and consistent use of data must become commonplace – and the concept of "open innovation" must evolve to something more like "open sourcing".	Innovation process	L
Agri-tech: Notes Pressure for sustainable intensification, producing more food on less land with fewer inputs and Increasing use of technology such as IT, satellites, remote sensing and proximal data gathering to optimise returns	Innovation, Markets	H
Agri-tech Opportunities in Robotics, Rhizosphere (soil near roots) modification, Sensors and Diagnostics	Innovation, Markets	M
Data and ICT, genomics, genetics and plant breeding and microbial research will act as a foundation for the discovery and translation of technology and innovation	Innovation, Markets	M
New surveillance technologies arising from genomics linked to sensors and diagnostics will enable development of new plant varieties and plant protection products	Innovation, Markets	M
Link is made between Agri-tech in the East of England and the "space-led data applications" in the Oxfordshire SIA.	Innovation, Markets	H
AM&M: The challenge is to find methods of growing world class research and innovation capability while at the same time improving linkages to regional industry	Innovation, Markets	M
This would involve strengthening links between academic centres, supporting these with enhanced IT capability and making the resulting expertise and innovation potential available to technology hungry companies.	Innovation	M
ICT: Availability of local talent, despite the range of initiatives, there is much more to do and all parts of the supply side – from schools through to universities – have a role to play, as indeed does central government.	Skills	M

ICT businesses must also engage much more consistently if the shortages are to be addressed effectively.		
Possibilities for greater collaboration across the region. Targeted collaborations around Big Data Analytics and Machine Learning, High Performance Computing, and Scalable Network Test-bed	Innovation, Collaboration	M


Upstream Space: A Galaxy of Capability

An Audit of Upstream Space Capability in The Oxfordshire-Cambridgeshire-M4-Harm Corridor; M3 Corridor & Solent; Greater Sao; Midlands; Scotland; Wales; and Northern Ireland.

A Science and Innovation Audit Report sponsored by the Department for Business, Energy & Industrial Strategy

FULL REPORT

2018

A **Science and Innovation Audit for Upstream Space: A Galaxy of Capability** was produced in 2018, as part of the third wave of SIAs. This described upstream space as a 'UK Nationwide Cluster' with an innovative, strong and collaborative sector reaching from Glasgow to Goonhilly.

Many opportunities and recommendations echo those in the Space IGS. In addition, it recommends building connections across the 'Nationwide Cluster' while increasing activity in regional clusters. Beyond 'conventional' innovation investment, three themes are strong: the need for skills (both general STEM and space-specialist), the potential of cross-fertilisation with other sectors, and the opportunity in the ground segment.

Upstream Space Science and Innovation Audit Recommendations	Theme	Relevance
Interact with 1 million young people per year to increase interest in STEM careers	Skills	M
Build the connections across the 'UK Nationwide Cluster'	Networking	H
Earth observation and telecoms are seeing a step change, so UK should build on competences to take advantage of coming growth	Markets	M
Reinforce UK leadership in science missions to maintain academic links, support UK reputation and provide inspiration and development of the next generation of engineers, technicians and scientists	Skills	M
Be ready for opportunities in in-orbit servicing and manufacture, debris removal and other space environment protection	Markets	M
Address the gap in UK launch capability	Innovation - Launch	M
Showcase the economic benefits of Upstream Space to potential inward investors	Finance	H
Increase investment in new infrastructure, such as test centres and spaceports, and fundamental and applied R&D	Government Investment	H
Continue to build connectivity and mutual support across the whole UK upstream sector, including established global players and the wider 'UK Nationwide Cluster'	Networking (space sector)	H
Ensure activity in regional clusters is increased and retains focus	Clusters	H
Maintain R&D intensity through a dedicated and stable funding base for space manufacturing and ground segment technologies, and create the conditions in which companies are able to confidently re-invest in R&D.	Innovation Investment	H
Raise awareness of emerging technologies that will plug the gaps in the UK's value chain and drive down satellite manufacture costs to drive down the cost of downstream services	Innovation	M

Develop unique, strategic, industrially focused infrastructure with the potential to anchor business investment, and accelerate UK technical and manufacturing / production capability for 'new space' markets	Innovation Investment	M
Fill gaps in technical education: space materials, magnetics, radiation, environmental vacuum conditioning, safety, RF, research engineers	Skills	M
industry to work with universities more closely to keep them informed of needs, even specific ones such as space-grade product specifications	Skills	M
Encourage AI skills development with reference to the 2017 'Growing the Artificial Intelligence Industry' report	Skills	M
Increase the desire for and quality of STEM education in secondary school	Skills	M
Cross-fertilise between upstream space and other innovative sectors to enable innovation, and understand cross-sector synergies (or lack of)	Networking (cross-sector)	M
New models of collaborative R&D, such as the Strategic Research Cluster model, could be explored to help add focus and commercialisation to upstream space research at a national level	Innovation Investment	M
Non-traditional investment models, including PPP, are already emerging. Further alignment between industry and Government to help de-risk developments is highly likely and recommended	Finance	M
Regulators and insurers ought to work closely with Government and industry to reduce barriers to successful market entry	Regulation	M
Upstream ground platforms and control stations must evolve to meet future needs, and this is a huge opportunity. Ground segment needs to include Acceleration, compression, virtualization and other applications to stay competitive. The ground segment must be more strategically aligned with satellite manufacturing, and geographical proximity helps.	Markets – Ground segment	M


HM Government

UK Research and Development Roadmap

July 2020

In July 2020, the Government, through the Department for Business, Energy and Industrial Strategy (BEIS) published its **UK Research and Development Roadmap**. Despite being published in the middle of the pandemic, this confirmed the Chancellor's March Budget commitment to increase public investment in R&D to £22 billion a year by 2024/25, and the goal to increase overall UK investment in R&D to 2.4% of GDP by 2027, from about 1.7% today.
Its overall tone was bold and forward-looking.

UK R&D Roadmap Recommendations	Theme	Relevance
Increase investment in research. Supporting long-range, fundamental, underpinning science and research, and Supporting innovation, application and deployment	Government innovation investment	M
Delivering "moonshot" ambitions and proposing the key challenges we want to Address. "Ambitious, measurable goals which could have a significant impact on an important societal issue"	Government innovation investment	M

Creating an ARPA style body to boost transformative research in the UK. (Announced in Feb 2021 as ARIA, the Advanced Research & Invention Agency	Government innovation investment	M
Develop a comprehensive new R&D People and Culture strategy. To put the UK at the forefront of attracting, retaining and developing diverse, talented people.	Skills	M
Create a new deal for funding postgraduate research – increasing the investment in research training, numbers, supported, models of delivery, stipend levels	Skills, Innovation	M
Increase support for early career researchers	Skills	M
Set up a new Office for Talent	Skills	M
Global Talent Visa Reform	Skills	M
Develop a new offer linking research and innovation talent to levelling up ambition	Skills	M
Continue Budget 2017 plan to unlock £20bn finance over 10 year	Finance	M
Tackle regulatory barriers which inhibit pension fund investment in innovation firms	Finance	M
Work with finance industry to open finance opportunities	Finance	M
Capture the economic benefit of research through innovation. Increased Higher Education Innovation Funding, new Knowledge Exchange Framework and more.	Finance	M
Build on our innovation enabling infrastructure. Including the Catapult Network, Public Sector Research Establishments	Innovation Facilities	M
Incorporating pro-innovation voices from across the UK in innovation policymaking	Strategy	M
Taking greater account of place when making decisions	Strategy	M
Fostering greater co-creation and collaboration	Collaboration	M
Be at the forefront of global collaboration with a new, agile offer	International	M
Demonstrating the UK's leadership in existing key multilateral research and innovation organisations	International	M
Investing in infrastructure for the long term. World-class infrastructure and labs. We want to develop a National Digital Research Infrastructure	Innovation Facilities	M
Minimise bureaucracy in the public funding system. Increasing clarity and coherence in public R&D funding	Governance	L
Strengthening the role of our research and innovation institutions	Governance	M


HOUSE OF LORDS

Science and Technology Select Committee

2nd Report of Session 2019–21

Catapults: bridging the gap between research and industry

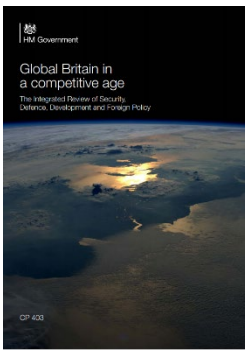
Ordered to be printed 28 January 2021 and published 5 February 2021

Published by the Authority of the House of Lords

HL Paper 118

The House of Lords Science and Technology Select Committee published a report on the Catapults in February 2021, entitled **Catapults: bridging the gap between research and industry**. This report said that the Government needed a more detailed plan and more investment to meet its R&D ambitions and that more strategic decisions are needed from the Government, UKRI and Innovate UK to maximise innovation and commercialisation, for example There does not appear to be a clear list of priority technologies for the UK. It said the UK's innovation system has the necessary components to be successful, and the Catapults were an integral part of this, but the network should be expanded and given more flexibility to achieve its potential.

House of Lords Committee Report on Catapults – Recommendations	Theme	Relevance
Government, UKRI, and Innovate UK should set out a clear plan for how public sector resources and private investment can match the ambition in the R&D Roadmap.	Innovation investment	M
UKRI allows Catapults to bid for Research Council funds where there are clear advantages in terms of both research and innovation.	Innovation investment	M
Innovate UK shows more flexibility in permitting public sector bodies to have a larger share of collaborative R&D funding, particularly when more than one such organisation is involved.	Innovation investment	M
Innovate UK and other funding bodies support transformative innovation more effectively, including by shifting the balance between public funding and industrial match funding, to reduce the risks to industry and encourage its participation in risky R&D projects. They should consider arrangements for more translational funding to increase the flow of projects from universities to Catapults and industry.	Innovation investment	M
Innovate UK ensures that Catapults' KPIs focus on delivery of effective collaborations and successful innovation and commercialisation, and reflect their contribution towards key policies such as the net zero economy and regional development.	Governance	M
UKRI ensures that universities' KPIs provide stronger incentives for commercialisation of research findings in relevant disciplines.	Governance	M
UKRI and Innovate UK address the imbalance between competition and collaboration in their frameworks such that Catapults and universities can work together more easily on innovation projects.	Governance	M
UKRI foster closer links between industry and universities and assist researchers to work at the interface between the two, including through supporting roles for academics at the Catapults.	Collaboration	M
BEIS uses its current review of the Catapults to give the Catapults assurance of long-term continuity, longer-term certainty over funding and reviews limited to once every five years, to match the five-year funding cycle.	Strategy	M
BEIS and UKRI develop a more strategic approach across policies for innovation and regional development—such as broadening access to the Strength in Places Fund.	Strategy	M
Government scales up the Catapult Network, without which it is unlikely that sufficient private sector investment will be committed and unlikely that the Government's R&D spending target will be met.	Innovation	M
In its response to this report, the Government provides a detailed strategic plan for delivering its R&D ambitions, including: milestones for increased private sector investment towards the overall spending target; a list of criteria to be used to select technologies and sectors for further support and an explanation of how these will be responsive to future challenges; and a list of technologies and sectors that are being considered for further support.	Strategy	M
We recommend that the Government makes the best possible use of the Catapult Network, promoting it as the UK's national innovation asset, and using it as the default mechanism for exploiting promising technologies and sectors. We recommend that the Government promotes its R&D strategy confidently, in the UK and internationally.	Strategy	M

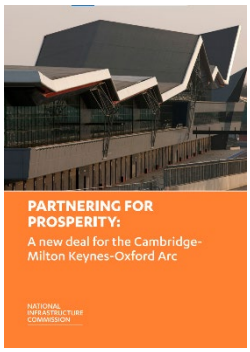


Global Britain in a Competitive Age: the Integrated Review of Security, Defence, Development and Foreign Policy was published on 16 March 2021, describing the government's vision for the UK's role in the world over the next decade. This had a four-part strategic framework to adapt to a more competitive and fluid international environment, and space has an important role to play in each one of the four. The Prime Minister's foreword emphasised the importance of agility and speed of action, and the soft power that comes from creativity in the arts and sciences, the need for cyber security and the importance of tackling climate change and biodiversity loss. This all points to space having an increasingly important role in national policy going forward.

Integrated Review Framework	Theme	Relevance
1. Sustaining strategic advantage through science and technology: Growing the UK's science and technology power; and Responsible, democratic cyber power	Policy	M
2. Shaping the open international order of the future: A force for good: supporting open societies and defending human rights; An open, resilient global economy; and Extending an open international order in future frontiers	Policy	M
3. Strengthening security and defence at home and overseas: Countering state threats: defence, disruption and deterrence; Conflict and instability; Homeland security and transnational security challenges	Policy	M
4. Building resilience at home and overseas: Building the UK's national resilience; Tackling climate change and biodiversity loss; Building health resilience	Policy	M
On Space: We will make the UK a meaningful actor in space, with an integrated space strategy which brings together military and civil space policy for the first time. We will support the growth of the UK commercial space sector, and ensure the UK has the capabilities to protect and defend our interests in a more congested and contested space domain – including through the new Space Command and the ability to launch British satellites from the UK by 2022.	Policy	M

3.3 Arc Initial Documents

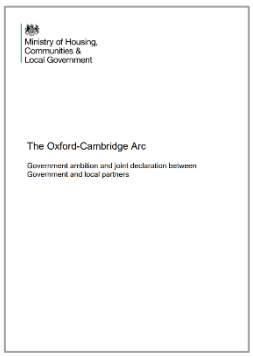
The Oxford-Cambridge Arc, corridor or the 'golden triangle' with London has been talked about for many years as an area of high economic performance and potential. Recent initiatives started when the Government asked the National Infrastructure Commission to report on how to maximise the economic potential of the Arc. Its 2017 report, **Partnering for Prosperity: A new deal for the Cambridge-Milton Keynes-Oxford Arc** is the start of the current Arc initiative. It set out a vision for the Arc as a powerhouse of "world-class research, innovation and



technology", but noted that it needed new homes, better infrastructure and new forms of governance to succeed.

Partnering for Prosperity Recommendations	Theme	Relevance
East-west infrastructure enabling new settlements (East West Rail)	Enabling Infrastructure	L
Delivering new places through Development Corporations	Infrastructure, Governance	L
Establish governance for infrastructure, community assets and net gain in biodiversity and natural capital	Infrastructure, Environment, Governance	L
Establish pipeline and long-term plans and deals for infrastructure including upgrading public transport, transport hubs and cycling infrastructure	Enabling Infrastructure	L
Change CIL and s106 to give LAs more powers and flexibility	Governance	L
Consider agreements for flexibility in land supply as long as land supply and protections from speculative development are ensured	Planning	L
Govt and LAs work to create Arc-wide spatial vision and plans	Planning	L
Robust Arc-wide and sub-regional governance	Governance	L
Publish a six-monthly update	Governance	L

The Government published a response to this document in October 2018, supporting the ambition that the NIC had set out.


Ministry of Housing, Communities & Local Government

The Oxford-Cambridge Arc

Government ambition and joint declaration between Government and local partners

In March 2019, the Government published **The Oxford-Cambridge Arc: Government ambition and joint declaration between Government and local partners**. As its names suggests, this recognised the Arc as "an area of significant economic strength and opportunity, which can further benefit its existing and future communities and businesses by realising its potential" and set out the ambition of Government and local parties to realise that potential. The document did not have Recommendations as such, but it had a record of 'Recent Progress' and 'Next Steps'. It established 4 Policy Pillars, and in each of these satellite applications can be seen to have a role to play.

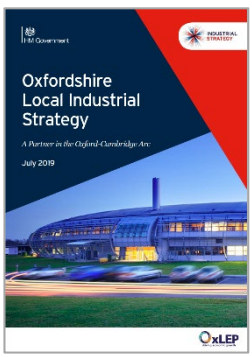
Ambition and Joint Declaration	Theme	Relevance
Governance • Established groups in Government departments chaired by MHCLG • Established Arc Leaders Groups and other Arc groups • Next Steps: Arc Business Group and Public engagement	Governance	L
Policy Pillar 1: Productivity • Government published National Industrial Strategy • Underway: LGF funding, Energy Hub, Enterprise Zones, Economic study	Strategy	M-

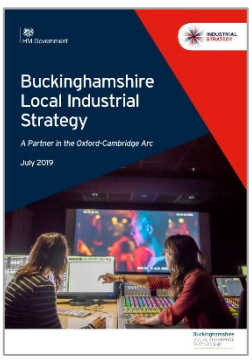
• Next Steps: Engage with universities, explore 4 Grand Challenges, Local Industrial Strategies		
Policy Pillar 2: Place-making • Oxon Housing & Growth Deal, Target to halve new home energy use by 2030, Green Communities prospectus • Next steps: Spatial framework *(due soon)*, approaches to housing supply	Housing	M-
Policy Pillar 3: Connectivity (Infrastructure) • Establish East West Rail, other rail, road and Transforming Cities projects • Next Steps: Expressway options *(now paused)*, Digital infrastructure options	Enabling infrastructure	L
Policy Pillar 4: Environment • Consulted on biodiversity net gain and committed to explore natural capital • Exploring opportunities for local delivery of 25-year Environment Plan • Next steps: Identify opportunities to explore biodiversity net gain, Develop plan for natural capital approach, Embed sustainability in place-making	Environment	M

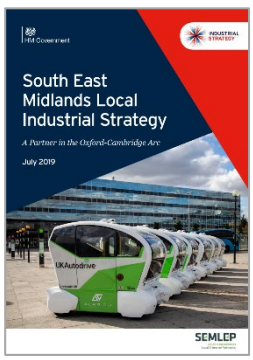
3.4 Arc Economic Strategy

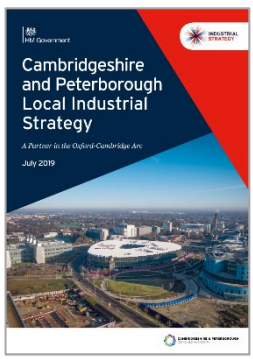
The 4 LEPs across the Arc jointly published and **Economic Vision** in April 2019. This set out a joint vision for cooperative growth, focus sectors and was a pre-cursor to their Local Industrial Strategies. We will not cover it in depth because the themes and recommendations all return in the Local Industrial Strategies and the later Economic Prospectus. The benefits of this joint document can be seen in the alignment between the themes and formats of the 4 Local Industrial Strategies from the 4 Arc LEPs.

The **4 Local Industrial Strategies** were published in July 2019 after many months of work in each of the LEP areas, across the Arc, and with central Government. Each of the 4 documents shares a common Arc context before describing its own region's economic situation and potential in more detail. Each sets out certain Sector Priorities for growth, relates the 4 Grand Challenges and sets out 'Commitments' linked to the 5 Foundations of Productivity in the National Industrial Strategy.









Arc-wide aspects common across all 4 Local Industrial Strategies	Theme	Relevance
Ideas		
Cross-Arc collaboration: Harness the collective strength of the Arc's research base	Networking	H

Strengthen ability to commercialise ideas from universities, use existing assets and develop emerging districts to support convergence of technologies across sectors	Innovation	H
Grow role as a global research and innovation hub	Innovation	H
Government investments in innovation. e.g. Harwell, Autonomous Vehicles,	Government investment	H
People		
Review labour market intelligence across the Arc, to gain a better understanding of how skills provision is currently delivered and funding utilised.	Skills	M
Work with local employers to increase apprenticeship uptake across the Arc	Skills	M
Work with local employers to support the effective role of T levels	Skills	M
Establish an Arc-wide skills marketplace using evidence from each Skills Advisory Panel	Skills	M
Government investments in skills. e.g. new Skills centres, Institutes of Technology	Skills	M
Infrastructure		
Improve transport links: EW Rail, major roads and first-mile/last-mile connections	Infrastructure	L
Develop shared evidence base for future energy needs of the Arc	Infrastructure	L+
Plan digital infrastructure across Arc to support roll-out of fibre and 5G	Infrastructure	M
Standardise public data where possible, with view to addressing Grand Challenges	Infrastructure	M
Work with government to explore new approaches to funding infrastructure	Infrastructure	L
Government investments in infrastructure, e.g. EW Rail, roads, Transforming Cities	Infrastructure	L
Business environment		
Develop improved, joined-up, business support across Arc	Bus. Support	L
Help SMEs to access finance, working with the British Business Bank	Finance	L
Encourage trade and inward investment	Finance	L
Develop an 'Arc Internationalisation Delivery Plan'	International	M
Government investments in business support, e.g. Growth Hubs, Enterprise Zones, British Business Bank	Government investment	L
Places		
Contribute to Clean Growth Grand Challenge and Halve energy use of new buildings across Arc	Housing, Environment	M
Embed 25 Year Environmental Plan and Net Gain across Arc	Environment	M
Co-design a local natural capital planning approach for Arc	Environment	M
Use intelligent design in new developments	Housing	L
Maximise environmental expertise across Arc, empower business community to champion the Arc's natural assets	Environment	L
Government investments in Places, e.g. LGF, HIF, Growth Deal	Housing	L

Oxfordshire Local Industrial Strategy	Theme	Relevance
Breakthrough Sectors		
Life sciences	Innovation	M
Quantum computing	Innovation	M
Space-led Data Applications	Innovation	H

Robotics and Autonomous Systems (RAS)	Innovation	M
Cryogenics	Innovation	M
Energy	Innovation	L
Digital and creative	Innovation	M
Motorsport (M due to materials/manufacturing links)	Innovation	M
Ideas		
Create more workspace and clusters. (Shortage esp. in growth stage.)	Workspace, Clusters	M
Drive up R&D investment and Prioritise Breakthrough technologies in local R&D investment	Innovation investment	M
Develop Oxfordshire internationalisation plan: Brand and Arc's international profile	International	M
Launch 'Connecting Globally' platform: showcase success, network globally	International	M
Launch IP acceleration to support firms to manage IP	Bus. Support	M
High Flyers programme to retain talent and develop future leaders	Skills	M
People		
New Skills Advisory Panel, Skills Priority Statement and Social Contract	Skills	M
OxLife to support people into more inclusive work	Skills	M
Inclusive Growth Commission	Skills	M
Advanced Skills Centre	Skills	M
Oxford Centre for Innovation	Skills	M
Infrastructure		
Scope options to accelerate gigabit fibre and 5G	Infrastructure	L
Work to progress Oxfordshire Infrastructure Strategy (OxIS)	Infrastructure	L
Work to realise Oxfordshire Energy Strategy with a low carbon energy grid	Infrastructure	L
Encourage innovation in low carbon solutions e.g. Garden Towns at Bicester & Didcot	Infrastructure	L
Business environment		
Establish a Scale-Up Programme across the Arc	Bus. Support	L
Address lack of space for business and innovation	Workplaces	M
Establish investment case for Arc infrastructure to attract institutional investors	Finance	M
Places		
Develop a Data and Mobility Living Lab	Cluster	M
Develop a Clean Growth Living Lab	Cluster	M
Develop a Health and Wellbeing Living Lab	Cluster	M
Adopt the principles of Healthy Place Shaping	Environment	M

Buckinghamshire Local Industrial Strategy	Theme	Relevance
Internationally significant assets		
Upstream Space		
Enhance networking across Space propulsion, launch UAV and Satellite applications	Networking	H
Raise UK profile in upstream space, esp. propulsion	Innovation	H

Develop export and inward investment plan, initially for Westcott assets (then creative sector)	Finance	H
Attract investment from finance community, large corporates, overseas investors	Finance	H
Enhance key education, research, development and test facilities across the Westcott Space cluster	Skills	H
Creative and Digital		
Consolidate capabilities and support exports and inward investment	International	M
Develop Screen Industries Global Growth Hub at Pinewood	Investment	L
Secure investment in key research facilities and programmes	Investment	L
Support skills development	Skills	M
Silverstone and Advanced Manufacturing		
Focus business investment and financial incentives on SME innovation	Innovation investment	L
Support development and application of emerging technologies at Silverstone	Innovation	M
Develop innovation ecosystem to improve connectivity between businesses and universities	Innovation, Networking	M
Attract interest from the finance community, large corporates and overseas investors	Finance	L
Continue to build the Silverstone Cluster to improve opportunities across wider Arc	Cluster	L
Health and social care model		
Support collaboration between businesses and health and care providers who will deliver Integrated Care using technology	Innovation, Networking	L
Position Buckinghamshire as the MedTech adoption accelerator to conduct product testing at-scale	Innovation	L
Use opportunities offered by housing growth in Aylesbury Garden Town to test new technologies and the Ageing Society Grand Challenge	Cluster, Market	M
Ideas		
Establish an Innovation and Enterprise Board comprising key local and national stakeholders	Governance	L
Set up the Living Labs	Cluster	M
People		
Establish a prestigious, structured careers offer which provides clear work pathways from school into work	Skills	M
Boost industry placements in disciplines befitting the Buckinghamshire economy, building capability ahead of T levels	Skills	M
Work with employers across the area to facilitate effective use of the apprenticeship levy through transfer flexibilities	Skills	M
Inspire the workforce of the future to work in Buckinghamshire's leading businesses in space, creative, high value manufacturing and digital health	Skills	M
Infrastructure		
Develop digital connectivity, working with developers and infrastructure providers	Infrastructure	L
Support work on surface connectivity to Heathrow Airport and resilience for rail access to London	Infrastructure	L

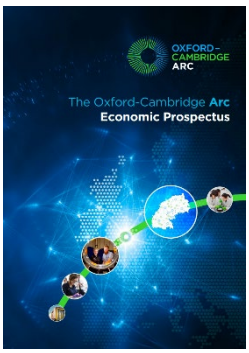
Work with EEH and emerging Sub-Regional Transport Body to progress local ambitions on connectivity	Infrastructure	L
Business environment		
Expand business growth programmes and encourage innovation	Bus. Support	L
Supply chain mapping and development driven by a detailed analysis of market need, trade flows and opportunities for investment at scale	Strategy	L
Incubation and co-working spaces: develop new and enhanced business spaces with services inc. 3D printers, ultrafast broadband and collaborative working	Workplaces	M
Collaboration tools: creating a new sharing platform where employers can share resources, facilities etc. to prevent down time and the risk	Business Support	L
Places		
Build on Aylesbury's garden town status by considering locally led options to deploy new technologies and disruptive housing delivery	Housing	L
Ensure new and existing growth areas are linked and serviced by sustainable infrastructure	Infrastructure	M
Develop the business case for a Productive and Healthy Places Programme	Environment	M

South East Midlands Local Industrial Strategy	Theme	Relevance
SEMLEP Area role in addressing the national Grand Challenges		
Future of Mobility – a leading role, trialling cutting-edge mobility enabling technologies	Innovation	M
AI and Data – the first STEM-skills focused university MK:U	Innovation	M
Clean growth – using area's energy, mobility, food, drink & logistics expertise	Innovation	M
Ageing society – 'Strengthening the Workforce' and 'Settlement of the Future'	Innovation	M
Ideas		
Continue to be at the forefront of the Future of Mobility Grand Challenge, with locally led development of new facilities and test beds to pilot solutions	Innovation	M
Develop advanced logistics hub of excellence	Innovation	M
Strengthen links between business networks, innovation centres, groups and sectors and help businesses access funding and support through SEMLEP's Growth Hub	Innovation, Networking	M
Work with local authorities and universities to support the development of new research and development assets and expertise within the SEMLEP area	Innovation investment	M
People		
Work with local businesses, stakeholders and education institutions through newly formed Skills Advisory Panel to support skills provision in the area	Skills	M
Drive greater business engagement with educators and students through the 'Growing Talent' campaign	Skills	M
Ensure employer-led talent pipeline through effective careers information, inspiration and advice in schools and colleges, promoting pathways based on employer needs	Skills	M
Place focus on the development of levels of digital skills and STEM	Skills	M
Infrastructure		
Identify, support and disseminate best practice from energy 'beacon projects' (those implementing early-mover future energy systems and technologies)	Infrastructure	L

Bring together major energy stakeholders to support the energy transition	Infrastructure	L
Support SMEs in energy-related innovation and to adopt energy-efficient practices	Infrastructure	L
Work with LAs and other partners to support strategic transport links, first-mile-last-mile connectivity, and EV infrastructure	Infrastructure	M
Continue to be at the forefront of the Future of Mobility Grand Challenge, with locally led development of new facilities and test beds to pilot solutions	Innovation	M
Work with local authorities and others to support full fibre connectivity	Infrastructure	L
Work with organisations involved in managing flood risk and water scarcity to develop plans for water infrastructure	Environment, Infrastructure	M
Business environment		
Develop pipeline of employment land and premises in the area	Workplaces	L
Increase promotion of the SEMLEP area to prospective investors (in property)	Workplaces	L
Continue business support through SEMLEP Growth Hub inc. scaling-up & peer groups	Business support	L
Work with DIT to attract inward investment and support exports	International	L
Places		
Work with local authorities and other partners to identify opportunities to pilot 'Settlement of the Future' concepts	Housing	L
Work with the area's Local Nature Partnerships and those leading on local developments to support and protect natural capital	Environment	M
Continue to support activity and other initiatives to bring people closer to, and into, the labour market, and to regenerate relatively deprived areas	Skills	L
Identify ways to support increased transport and digital connectivity for rural areas, and the rural visitor economy	Infrastructure	L+

Cambridgeshire and Peterborough Local Industrial Strategy	Theme	Relevance
Four strategic growth sectors		
Life Sciences	Innovation	M
Agri-tech	Innovation	M
Digital and IT	Innovation	M
Advanced materials and manufacturing	Innovation	M
Ideas		
Improve networking and linkages, with new and improved business networks and	Networking	M
Support collaboration between businesses, universities and others, and investment, including R&D funding in the four major growth opportunities	Innovation investment	M
Improve funding for Intellectual Property exploitation, including a Mayoral Investment Fund, Agritech Research and SME fund	Innovation investment	M
Improve the amount of physical space for businesses, at least 4 Launchpads inc. agri-tech, AI and advanced manufacturing, and start-up and scale-up space	Workspace	L
Introduce new programmes of support for businesses, across CPCA	Bus. Support	M
People		

Establish Skills Advisory Panel and a series of skills initiatives including Work Readiness, a Skills, Talent and Apprenticeship Hub, a Skills Brokerage Service	Skills	M
Look at scope to create a new university in Peterborough	Skills	M
Infrastructure		
Series of infrastructure plans: SE Local Energy Strategy, Connecting Cambridgeshire Delivery Plan, Local Transport Plan, Cambridge City Deal, Bus Review and rollout Smart Cities initiative to Market Towns	Enabling Infrastructure	L
Business environment		
Create a new Global Growth Service targeted at the places and firms that will have the most impact	Business Support	L
Introduce a new 'Trade & Investment Service' supporting exports and growth finance	International	M
Establish a Global Investor Service focused on landing new firms into the region	Finance	M
Create an Inaugural Growth Investment Fund to fill gaps in the finance market	Finance	M
Introduce a Global Growth Champions Programme, targeted at life science and digital sectors. (Business support).	Business Support	M
Places		
Prevent flood risk to Fens: economic risk £7.3-8.8bn	Environment	M
Work collectively to overcome the acute constraints facing Greater Cambridge and support innovation-led growth, with infrastructure and business growth schemes	Workplaces	M
Improve skills, growing the high productivity business base, and attracting investment in Greater Peterborough	Investment, Skills	M-
Deepen business networks and develop supported clusters to improve productive, business growth in The Fens, with business support and infrastructure	Business support	M-



The **Arc Economic Prospectus** was published in September 2020 as an integrated vision of the capabilities and potential of the Arc, setting an ambition to double the economy of the Arc by 2050, and outlining of the sectors, actions, government support and investment that would realise that potential, drawing on the LISs. It was developed by the Arc Leadership Group, with the Arc Universities Group and the Arc LEPs Group.

Arc Economic Prospectus	Theme	Relevance
Our ask of Central Government		
Increased focus on the Arc's strategic innovation infrastructure. Major innovation and R&D investment across our sector and industry strengths.	Innovation investment	H
Continued support for planned Arc-based projects – transport and digital infrastructure	Enabling Infrastructure	L/M
Establish Arc-governed investment channel – flexible funding for capital and revenue to build collaborative business cases and unlock public and private sector funding	Finance	M
Sector priorities		

Life Science innovation network (including health) – accelerate innovation, commercialisation and scale-up	Innovation, Markets	M
Sustainable aviation – towards zero carbon aviation	Innovation, Markets	M
Space Gateway – Harwell & Westcott including new space accelerator, AI Lab, DISCs	Innovation, Markets	H
Future mobility – CAV and underpinning technologies	Innovation, Markets	M
Zero-carbon energy – energy systems demonstrators, hydrogen, and fusion	Innovation, Markets	M
Recommended projects		
Business scale-up programme	Bus. Support	M
Arc investment fund	Finance	M
Internationalisation programme	Support, Finance	M
Digital infrastructure – fibre and 5G	Infrastructure	L
East West Rail	Infrastructure	L
East west road connectivity, including active travel and electric vehicles (+ for satellite role in enabling future mobility solutions)	Infrastructure	L+
First mile - last mile connectivity – mass transit and active transport at scale	Infrastructure	L+
A dynamic and responsive skills system, transferring unused Apprenticeship Levy resources to SMEs and creating employment pathways aligned with business needs	Skills	M
New STEM focused institutions, including 2 new universities	Skills	M
Skills capital fund, to develop new education facilities	Skills	M
Living labs, to integrate pioneering technologies in flourishing communities	Innovation	M
Settlements of the future, sustainable and affordable solutions for living and working based around green transport hubs and modern methods of construction	Spatial Planning	M
Green Arc, doubling the land actively managed for nature	Markets	M
Environmental enhancements, managing for resilience and water resources	Markets	M
Arc data lab, using data, AI and a 'digital twin' of the Arc to inform decisions	Innovation, Markets	M

Yet to be published due to Covid-related delays is the **Arc Universities and Space** report, by the Arc Universities Group. This reviews the space-related capabilities in the research-focused universities in the Arc, from West to East: the University of Oxford, The Open University, Cranfield University, and the University of Cambridge. It has four recommendations, all of which are relevant for this report – the first of which will be addressed by Part 3 of our report.

Arc Universities and Space - Recommendations	Theme	Relevance
Develop an Arc wide vision for the UK space sector	Strategy	H
Encourage the creation of an Arc Space Working Group	Governance	H

Champion space as a graduate career pathway and to develop the range of space-related teaching and training, outreach, talent, skills and apprentices	Skills	H
Support a dedicated space scale-up programme	Bus. Support	H

3.5 Delivery Plans

LEPs, Local Authorities and other bodies are now developing plans to deliver on the Industrial Strategies. A full set is not yet in place, and discussions are ongoing with Government about governance and funding – this situation is likely to develop over 2021 and Covid-19 has made the outcomes more difficult to predict. The Arc's basic case remains that investing in the Arc provides a strong economic return to the economy, plus a 'levelling-up' in the lower productivity areas of the Arc, and as Arc organisations collaborate with businesses elsewhere in the UK.

The **Oxfordshire Investment Plan** was published in August 2020. This was based on the LIS and contained 20 'investment ready' proposals worth over £4 billion to develop the physical, digital, financial and knowledge infrastructure of Oxfordshire, many of these feature in the Arc Economic Prospectus. Each of these has a business case for public sector funding, with private co-investment, to support economic growth. There are a further 17 'Projects Under Development'.

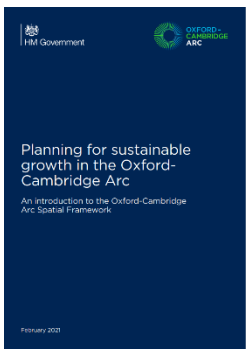
Oxfordshire Investment Plan Proposals	Theme	Relevance
ID1 The Energy Systems Accelerator	Clusters	L
ID2 Global Life Sciences Cluster	Clusters	M
ID3 Harwell International Space Cluster ID3A Gateway to the UK Space Sector: £80m for new 15,300m2 Space Gateway complex including Showcase, design, lab and office space ID3B Disruptive Innovation in Space Centre (DISC) Phase 3: £22m ID3C Space AI and Autonomy Lab (SAILAB): £120m for AI and autonomy facility	Innovation, Cluster	H
ID4 Oxford – Singapore AI Institute	Innovation	M
ID5 Locate Oxford: Global Innovation Campus	Innovation	M
P1 Careers Innovation Gateway	Skills	M
P2 T-Level Programme	Skills	M
P3 OxLIFE (longer and more flexible careers)	Skills	M
B1 Internationalisation Plan	International	M
B2 West's End Global Innovation District (Oxford)	Workplaces	M
B3 Creative and Cultural Industries Hub (Oxford)	Workplaces	M
B4 Facility for Industrial Scale-Up Support (FISUS): £52m scale-up centre including lab, office and networking spaces for space, health and energy SMEs at Harwell	Workplaces	H
B5 The Recovery and Investment of the Visitor Economy		L

Oxford City Science Area Sectors Infrastructure	Workplaces	M
Culham Science Park Infrastructure	Workplaces	M
Harwell Campus Infrastructure	Workplaces	M
Living Labs Testbed Infrastructure	Innovation	M
LO:GIC at Begbroke Science Park Infrastructure	Workplaces	M
PL1 Living Oxford (Oxfordshire's Living Labs)	Innovation	M
PL2 Howbery Park Centre of Excellence in Climate Change	Innovation, Workplaces	M
PL3 Culham-to-Harwell Mobility Corridor	Innovation	M
PL4 Global Energy-Technical Living Lab	Innovation	M

The **Westcott Strategic Vision** was produced in 2020 as a 10-year plan for a Space Innovation Business Park, building on the success on Westcott Venture Park in upstream space, 5G and business incubation. The vision was developed by Bucks LEP, Patrizia (the site owners) and Satellite Applications Catapult.

This vision would bring a strong skills development and manufacturing capability into the business park, to complement its current innovation role.

Westcott Strategic Vision	Theme	Relevance
Create a Space Innovation Business Park at Westcott by investing £380m over 10 years. 12 facilities. 2260 new jobs, 1000 apprentices, £1.9bn NPV.	Innovation, Clusters	H
Phase 1, 2020-25: DISC 1 (Upstream), DISC 2 (Downstream), Agri Zone, Health Zone, Apprentice School, Innovation Centre, Automated Drone Port, Data and Embedded Sensor Facility, AI and Robotics Centre, Intergenerational Training Centre	Innovation, Skills	H
Phase 2, 2023-26: Advanced Manufacturing Centres, Apprentice School Expansion,	Innovation, Skills	H
Phase 3: 2026-2030: Large manufacturing Facilities	Scale-up	H



The Ministry of Housing, Communities and Local Government (MHCLG) published on 18 February 2021 **Planning for sustainable growth in the Oxford-Cambridge Arc – An introduction to the Oxford-Cambridge Arc Spatial Framework**. This document is a policy paper that sets out how Government intends to work with communities and local partners to develop a spatial framework and plan for the Arc, to support long-run economic growth, and to make it a great place to live, work and travel in, with lasting benefits to the environment.

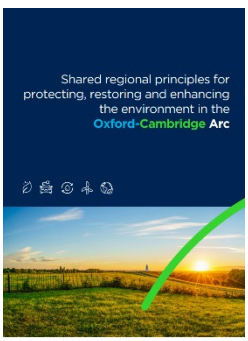
This document does not have recommendations as such, but it sets out a collaborative approach, that will take into account the environmental, social and economic impacts of policies, and using developing a common digital platform and robust evidence base to underpin the Spatial Framework. The

timescale is to develop a vision by summer 2021, policy options by spring 2022 and a draft spatial framework by autumn 2022, with consultations at each of these three stages before producing the final Spatial Framework. [The multifunctional nature of the problem, wide geography and short time-scale means that geospatial data approaches, enabled by satellites should be of value. – *Red Kite*]

The Sub-national Transport Body closely aligned with the Arc published the **England's Economic Heartland Regional Transport Strategy – Connecting People, Transforming Journeys** a week later on 25 February. This set an ambition "To support sustainable growth and improve quality of life and wellbeing through a world-class, decarbonised transport system which harnesses the region's global expertise in technology and innovation to unlock new opportunities for residents and businesses, in a way that benefits the UK as a whole." and to achieve Net Zero for the transport system by 2040 if possible, and certainly by 2050.

The strategy has a five-point plan of action, which emphasises that this is a shift away from 'business as usual. For example, the target is for private car use to reduce by 5-10% or more per decade.

EEH Transport Strategy Action Plan	Theme	Relevance
1. Focus on decarbonisation of the transport system by harnessing innovation and supporting solutions which create green economic opportunities.	Enabling Infrastructure	M
2. Promote investment in digital infrastructure as a means of improving connectivity.	Enabling Infrastructure	M
3. Use delivery of East West Rail and mass rapid transit systems as the catalyst for the transformation of our strategic public transport networks.	Enabling Infrastructure	M
4. Champion increased investment in active travel and shared transport solutions to improve local connectivity to ensure that everyone has the opportunity to realise their potential.	Enabling Infrastructure	M
5. Ensure that our freight and logistics needs continue to be met whilst lowering the environmental impact of their delivery.	Enabling Infrastructure	M



The Arc Leadership Group launched the Environment Principles for the Arc on 12 March 2021[2] in a document titled **Shared regional principles for protecting, restoring and enhancing the environment in the Oxford-Cambridge Arc**. These principles set a clear intent for a sustainable approach to economic development, in conjunction with net biodiversity and wider net environment gain, and the sustainable use of resources.

Arc Environment Principles	Theme	Relevance
The Arc will seek partners to:		

[2] https://news.oxfordshire.gov.uk/ox-cam-arc-leaders-put-environment-at-heart-of-all-decisions/

1. Work towards a target of net zero carbon at an Arc level by 2040. Ensuring all decisions about development and new infrastructure support this goal.	Environment	M
2. Protect, restore, enhance and create new nature areas and natural capital assets, including doubling the land managed for nature.	Environment	M
3. Be an exemplar for environmentally sustainable development, in line with the ambitions set out in the government's 25 year plan. This will incorporate a systems-based and integrated assessment and implementation approach and will fully recognise the associated health and wellbeing benefits.	Environment	M
4. Ensure that existing and new communities see real benefits from living in the Arc.	Environment	M
5. Use natural resources wisely.	Environment	M

With these recent documents: the Local Industrial Strategies and Economic Prospectus, the Spatial Framework (now underway), the EEH Transport Strategy and the Environment Principles, the strategic framework for the Arc to support the 'four pillars' is now rapidly coming together.

Delivery Activities

Business support is crucial to many new and growing firms' success. All of the LEPs have **Business Growth Hubs** and private support, networking and finance are also available. The LEPs have well developed business networks, but Oxford and Cambridge areas have better developed Finance networks – although these can spread their reach – so companies in at Westcott in Buckinghamshire would go to the Oxford investment networks to seek angel finance, for example.

Business Support Activities	Theme	Relevance
Business Support • OxLEP Business, Oxford Innovation • Buckinghamshire Business First • SEMLEP Growth Hub • CPCA Growth Hub, new service with £30m support There are many private advisors and consultants in each area, and specialist support such as accountancy, legal, IP, IT and HR.	Business Support	M
Business Networks • Oxfordshire: B4, Oxford Greentech, Natural Netwalking • Bucks: Buckinghamshire Business First Networking Events • SEMLEP: [TBD] • CPCA: Cambridge Network, Cambridge Cleantech, Agri-Tech East, Cambridge Wireless	Networking	M
Finance • Oxford Investment Opportunity Network (OION), Oxford Capital, Oxford Sciences Innovation • Central Arc Angels (launched Nov 2020)	Finance	M

• Cambridge Angels, Amadeus Capital, Cambridge Capital Group, Cambridge Agritech, Eastern Agri-tech Growth Initiative		

3.6 Themes of National and Regional strategies, recommendations and activities

The theme that stands out from the regional and Industrial strategies that interlock in the Arc is **investment in innovation with a return to the wider UK** economy.

Across each of the documents, **Government investment** is requested to add to private sector investment in buildings, equipment and R&D to enable **innovation** and **scale-up**. The Government's own R&D Roadmap is consistent with this approach, committing to invest in key fundamental and commercialisable areas (although not stating what the priorities are). There is a very strong **Cluster** approach, which each LEP area identifying areas of expertise that they wish to build on. But, they also note the value of cross-discipline working (or convergence) as there is much value in combining the expertise of one sector with another. Space applications are a clear example of this, the crossovers are noted for Agri-tech and Advanced Materials & Manufacture, and there are several others.

Skills are essential to innovation and have high emphasis, with plans for new strategy bodies, new qualifications, new career paths and even 2 new universities in the Arc.

Finance features in all of the Local Industrial Strategies, and this often includes a plan to attract inward investment from international sources. There is also an outbound **international** ambition for exporting.

As might be expected of LEPs, working closely with Local Authorities, the practical factors and **Enabling infrastructure** that enable businesses to operate feature heavily. **Workplaces** appear to be needed in many parts of the Arc, with a focus on flexible spaces for small but growing businesses, and in relevant clusters. **Housing** to support population growth with high quality of life. **Infrastructure** to ensure they can connect physically (and ideally not by driving), digitally and with their utilities. And the Arc places a large emphasis on the **Environment**, with ambitions and detailed principles for net biodiversity gain, and a wider range of environmental benefits backed by natural capital approaches.

Across each of the Local Industrial Strategies, and across LEP activities today there a range of **Business Support** and **Networking**, and the R&D-focused reports emphasise the value of **collaboration**. The theme here is to enhance this, and to make the networking linkages wider: between sectors, between business and academia, and across the Arc.

4. Synergies between Space-sector, National and Regional strategies and recommendations

It is immediately clear that the two sets of strategies have largely identical themes and several synergies.

The first area of synergy is in the overall themes: the space industry, Arc and national strategies all focus on **innovation** and strongly support the **'cluster'** approach. All envisage **Government investment unlocking private effort and co-investment**, and **co-operation with local academia** and research expertise. All note the importance of developing the **STEM skills** base, and while certain skills are highlighted in some reports, the main emphasis is on increasing the aggregate number of graduate and technician level people in the workforce. All have a similar picture of the other supports required by the 'innovation ecosystem': **finance, workplaces, business support and networking**.

We note that the general approach to clusters is local, and one SIA recommends a local space cluster approach, but the Upstream Space SIA identifies a 'UK Nationwide Cluster'. Some activities benefit from locality: from sharing facilities, from availability of expertise or from networking. But other activities you only need once in the UK (or in Europe, or the world) such as large testing or assembly facilities. By considering these factors we will be better placed to consider which activities should be placed at Harwell, which elsewhere in the Arc, and which are largely location-agnostic. We discuss what is present in each location in Part 2 (Capabilities) and review the cluster benefits seen and make recommendations in Part 3 of our report.

The second area of synergy is in the **markets** identified as opportunities for the space sector and those that are high-potential sectors in the Arc. There are five key synergy areas seen in the diagram below: Space itself – with connections into **aviation** and **advanced materials & manufacturing, Environment & agriculture, Transport, Health, and Digital & Connectivity**.

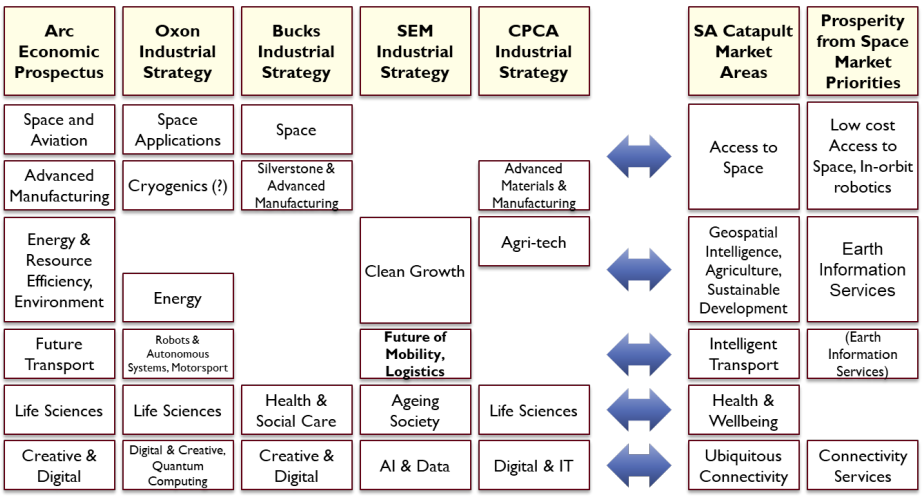


Figure 1-2: Synergies between markets in Arc strategies and Space strategies

Each of these areas of market synergy has some activity today, but potential for more.

There is a third area of synergy, also related to the markets for space applications, and that is that **these relate strongly to the national 'Grand Challenges' and the local challenges facing the Arc**.

- The Arc has a strong ambition for growth, both economically and in population ('Partnering for Prosperity' estimates 23,000-30,000 net new homes per year) in a region with precious natural assets and productive agricultural land. The Arc sets out an ambition for Net Biodiversity gain and using natural capital approaches. This fits strongly with the '**Clean Growth**' Grand Challenge. Satellite services can monitor the environment, aid flood prediction and planning, and monitor structures such as bridges and dams.
- The Arc's **transport** system is already congested and polluting in places and suffers particular problems in the 'first/last mile', this aligns with the '**Future Mobility**' Grand Challenge, and satellite services role in transport planning, monitoring and communications.
- **Life Sciences and Health** feature in the Arc's strengths and potential across all 4 LEP areas, and supports the '**Ageing Society**' Grand Challenge. Initial collaborations with the space sector have focused on emergency services communications, but there is possibly greater potential in monitoring activity to provide warning and encourage healthy lifestyles.
- Underpinning all of these, and other opportunities are data and connectivity, included in the '**Data and AI**' Grand Challenge. Satellites can provide more ubiquitous and secure connectivity, and applying AI and other emerging techniques to satellite data increases its potential availability and application in many spheres.

Part 2: Regional Capabilities in Space and Adjacent Sectors

Introduction to Part 2

In this Part, we review capabilities and organisations in the Arc's space sector and adjacent but aligned sectors, in 4 sections:

1. Broad capabilities across the Arc
2. Capabilities in the Arc Upstream Space Sector
3. Capabilities in Adjacent Sectors
4. Key Space and Space-related organisations

The Space Sector is commonly divided into 'Upstream' and 'Downstream'. For compatibility we follow the definitions used in the 'Size and Health' Report[3]

- Upstream includes the Design and Manufacture of Space Equipment (including software and ground equipment)
- Upstream also includes the Launch and Space Operations
- Downstream includes applications of space data and products
- Ancillary Services may apply to Upstream or Downstream. Some are very space-specific, like Space Insurance, but others are fairly general like general accountancy – but there is a range of specialisation in between (e.g. R&D grant support).

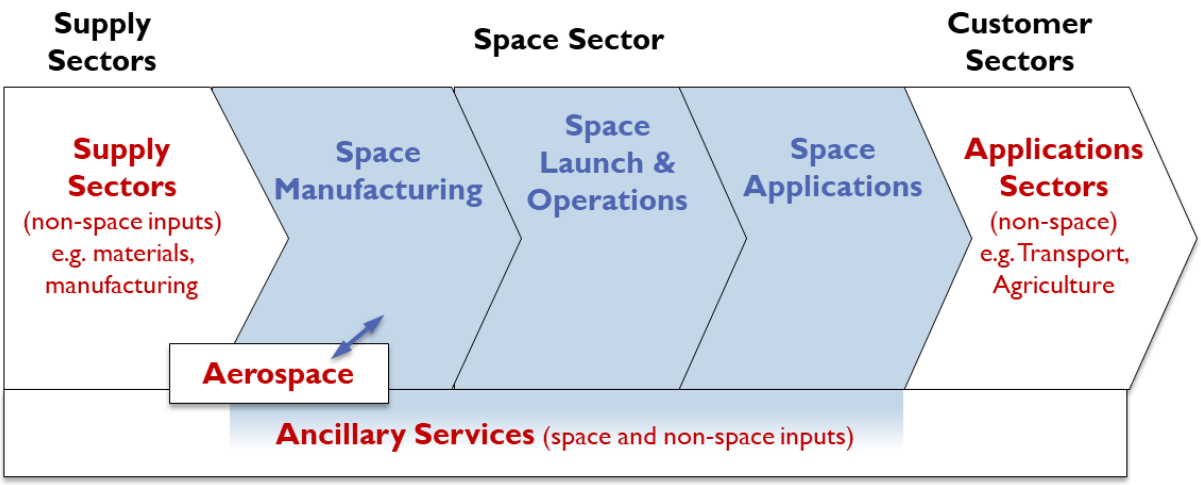


Figure 2-1: Space Sector (blue) and Adjacent Sector (red) simplified value chain

Outside the Space Sector, we are interested in 'Adjacent Sectors'. These can be considered as:

- Supply Sectors, including materials, manufacturing and electronics. Ancillary Services (both space and non-space) are also a Supply Sector
- Customer Sectors, mostly Applications Sectors such as Environment, Mobility and Health

[3] Size & Health of the UK Space Industry 2018, London Economics, January 2019 (The same segmentation is used by know.space in the 2020 survey).

- A few special cases. Aerospace and some other engineering sectors parallel the Space industry, and products or processes may exchange each way.

Within each sector we consider the capabilities: facilities, skills and knowledge, with a focus on those that are difficult to replicate. That could be because they were very expensive, required a lot of effort or time to develop, or embedded something unique.

In many cases capabilities in a sector are clustered together, with the most relevant example being the space clusters at Harwell and Westcott. This brings an extra layer of capability to organisations located at these sites as they can often access a wider range of capabilities. This is one of the cluster benefits that we discuss in Part 3 of our report.

Our research for this report included the documents reviewed in Part 1: Existing Recommendations and Activities – the Science and Innovation Audits, and the Local Industrial Strategies were particularly helpful. We supplemented this with our interviews, local knowledge, databases[4] and other research.

1. Broad capabilities across the Arc

The Oxford-Cambridge Arc is strategically situated at the heart of the UK, with the global centre of London on its doorstep and the UK manufacturing heartlands of the Midlands to its north.

The defining feature of the Arc is its role as powerhouse for education, research and knowledge. Home to 10 universities, including two of the world's best at Oxford and Cambridge, the region sees this concentration of knowledge and creativity reflected in the careers of its residents and the activities of its businesses. Across England and Wales, 27% of people have a degree level or above education (Figure 2), while in the Arc this is 30%. This outperformance in educational attainment is not distributed equally across the Arc, although it is quite widespread. In Oxford and Cambridge this rises to 43% and 47% respectively. Anecdotally, many people find work near their university, or return there in later life.

[4] In particular: KTN Space Landscape https://space.ktnlandscapes.com/ and
Satellite Applications Catapult Capabilities Catalogue https://sa.catapult.org.uk/uk-space-capabilities-catalogue/

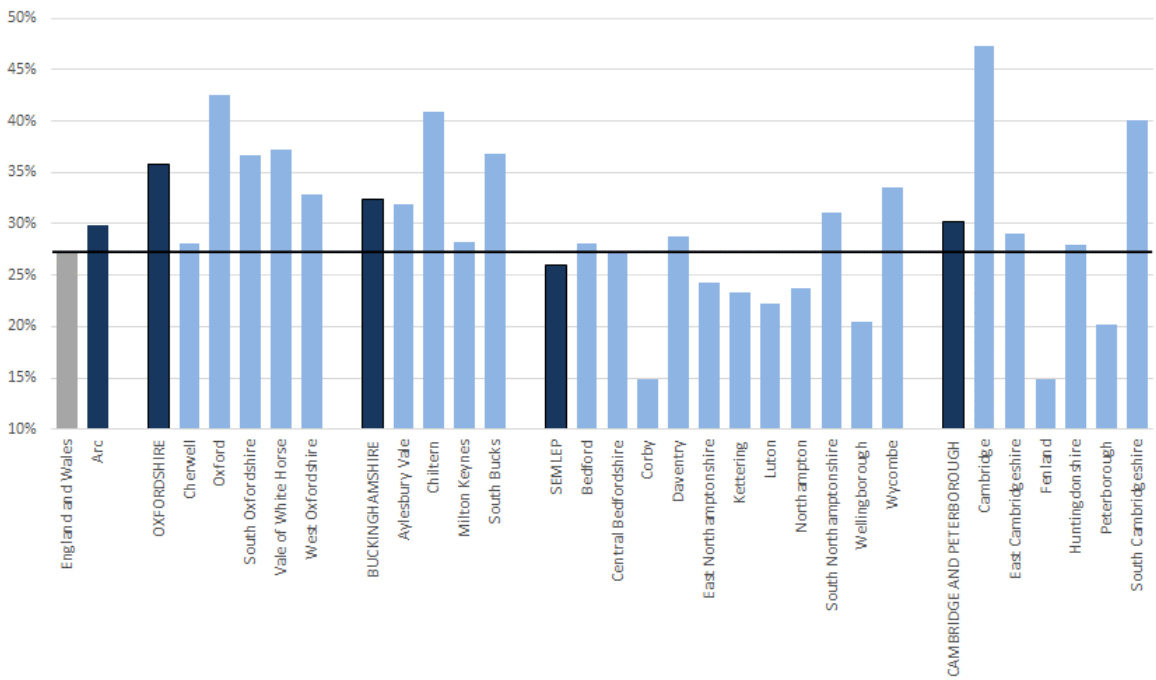


Figure 2-2: Share of population over 16 with degree level or higher qualifications (from census 2011)

While science, technology and research are central to its capabilities, the Arc also shows great spatial variation in activities and capabilities. Central and north eastern parts of the Arc tend to house a less highly educated workforce and host different economic specialisms (e.g. transport, logistics, manufacturing and utilities in Northampton and Peterborough).

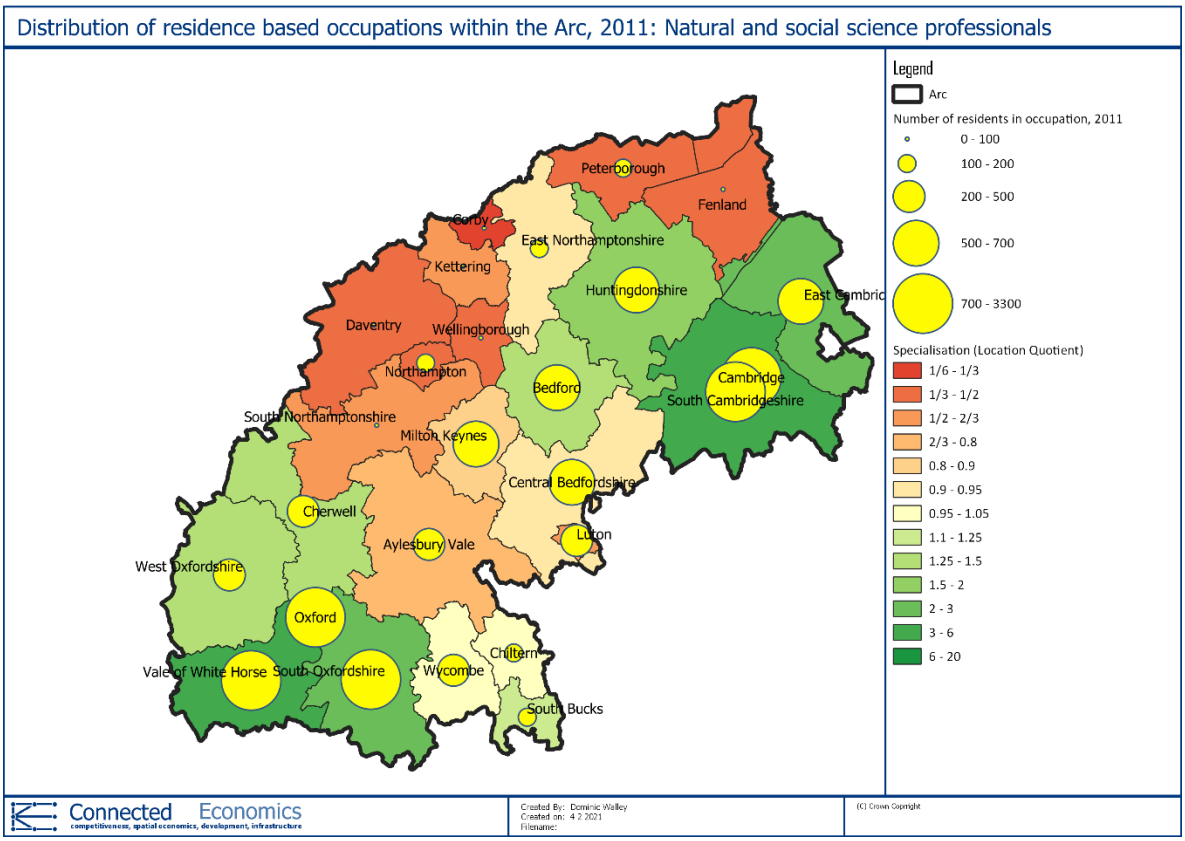


Figure 2-3: Specialisation in science professions (from census 2011)

Figure 3 shows the absolute number of people who work as natural and social science professionals across the Arc (in yellow circles) and the comparative level of specialisation in these professions compared to the UK average (in the background heatmap). Large numbers of people in these occupations cluster around the university cities and research clusters of Oxford and Cambridge, although there are also significant numbers in Bedfordshire, which benefits from Cranfield and other technology clusters in the county and nearby. However, the intensity of these professionals within the workforce is around 10 times the UK average in areas around Oxford and Cambridge while it is close to the UK average throughout Buckinghamshire. A chance meeting between two strangers in these places is around 100 times more likely to connect two scientists than in the UK as a whole.

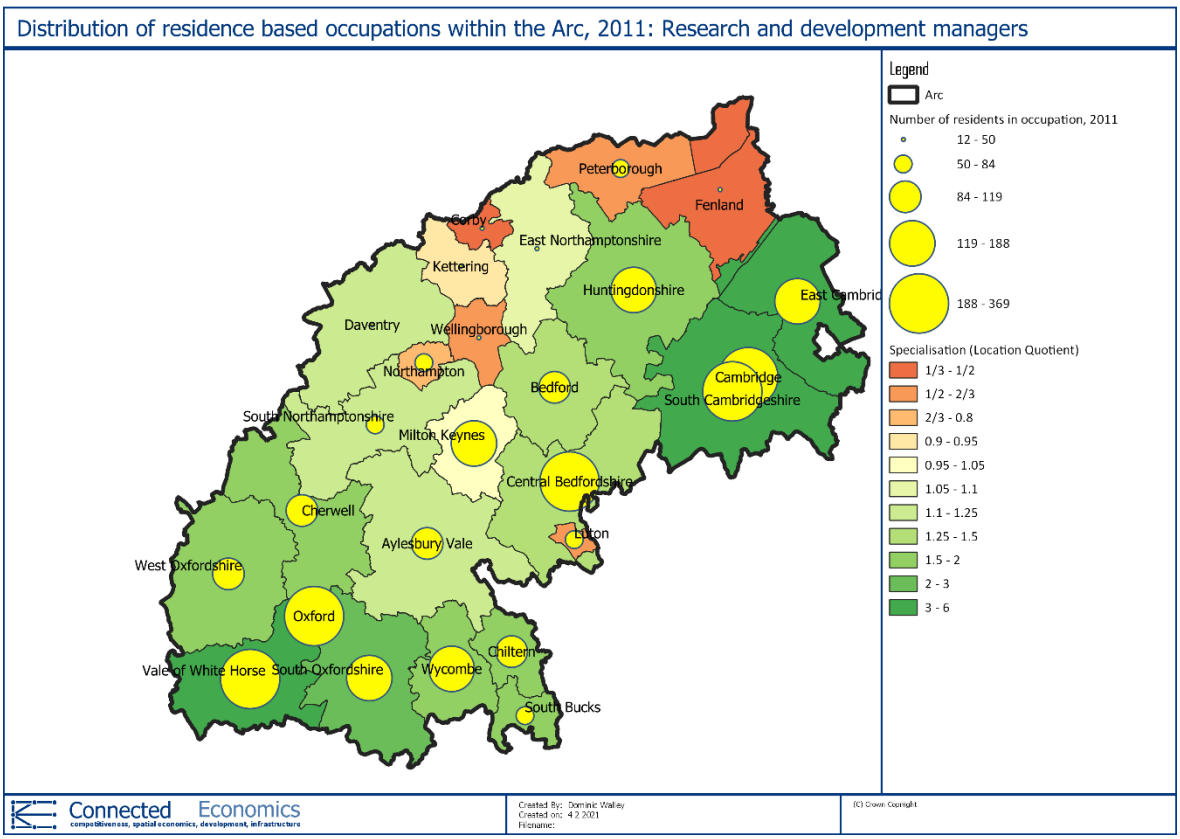


Figure 2-4: Specialisation in research and development manager occupations (from 2011 census)

Figure 4 shows the widespread capabilities of the Arc in applied research and development. Almost all parts of the Arc are more specialised in these occupations than the UK average.

The Arc's well-educated workforce supports a business landscape which is rich in technology companies, research institutes and innovation clusters. Figure 5 shows the size of sectors in the Arc on the vertical axis and the intensity of employment in them compared with the UK average on the horizontal axis (a measure of specialisation). The bottom right quadrant shows sectors where the Arc is highly specialised, but where the sectors themselves are relatively small. This includes sectors such as the manufacture of footwear (a particular specialism in Northamptonshire) and of breakfast cereals (for example Weetabix in Kettering). Conversely, the top left quadrant shows larger sectors, but where the Arc specialisms are not as deep. Temporary employment agencies, for example, employ an

enormous 64,000 people across the Arc (around 1.7% of employment, compared to 1.3% across the UK as a whole), so the Arc is only somewhat specialised in these activities.

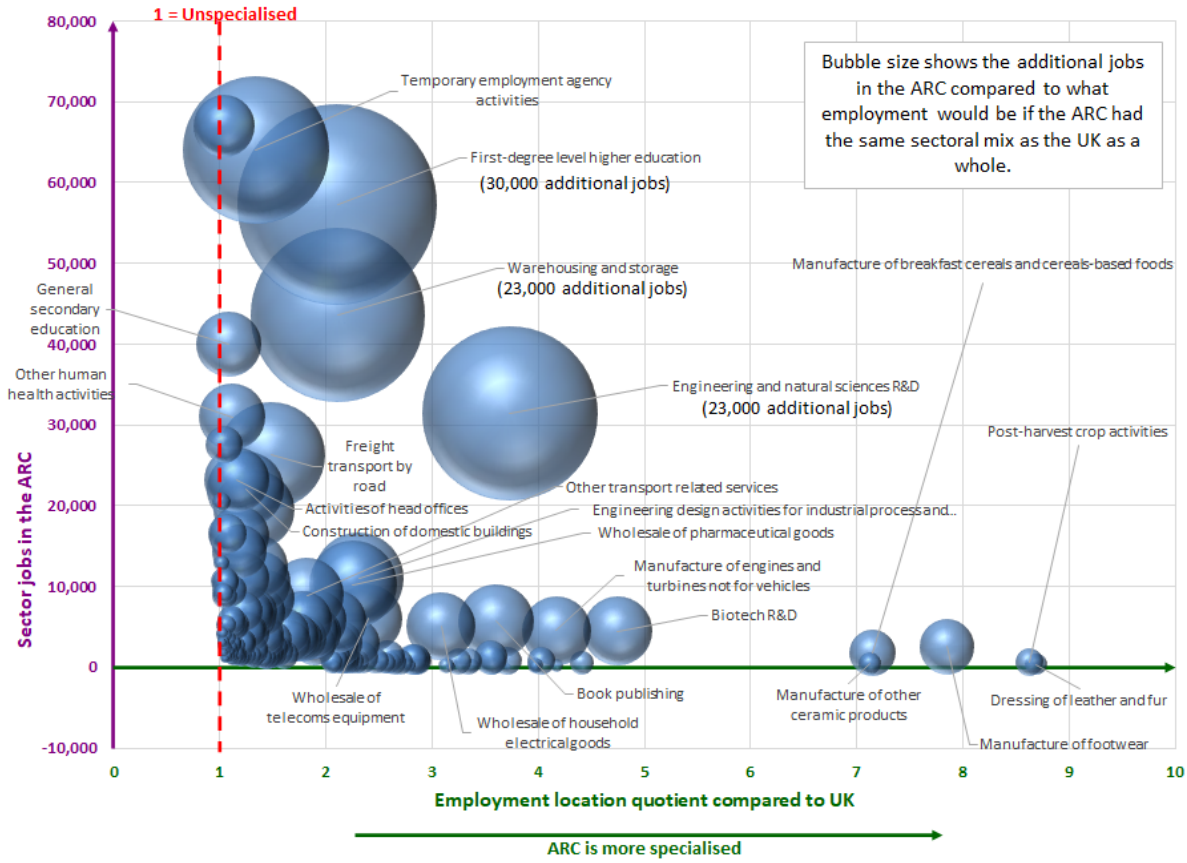


Figure 2-5: Arc sector specialisms (from Business Register and Employment Survey data, 2019)

The most interesting areas are where the Arc is both specialised and where the sectors themselves host substantial employment. In these sectors, the Arc hosts many more jobs that it would if it followed the average UK pattern of employment across sectors. This 'additional employment' is shown in the diagram by the size of the bubbles. The three sectors that stand out as the largest on this measure are:

Degree-level Higher education (reflecting the concentration of universities);

Engineering and natural sciences R&D; and

Warehousing and storage (reflecting the logistics specialisms of the central and northern parts of the Arc from Central Bedfordshire up to Northampton, Daventry and across to Peterborough).

Both higher education and engineering R&D provide critical inputs to upstream space, while higher education and logistics signal important resources from which to build larger-scale manufacturing and downstream space capabilities.

Although smaller, some other sectors are also well represented in figure 5 and highlight opportunities and capabilities to keep in mind while considering the potential for space and related sectors across the Arc: biotech R&D, transport, wider engineering capabilities (such as engineering design and technical testing and analysis), and wider logistics specialisms (such as road freight and transport related services).

The set of skills, occupations and the business environment of the Arc provides an excellent mix for developing both the upstream and downstream space sector economy. However, there are some areas where the Arc does not have the intensity of activity found in other areas of the UK, and which could provide important push towards developing space related products and services, in particular telecoms where many links could be made just outside the Arc.

2. Capabilities in the Arc Upstream Space Sector

The upstream space sector covers the development, delivery and operation of spacecraft. There are many organisations involved in the manufacture of satellites, components and subsystems in or around the Arc and this expanding as regional hubs, such as the Harwell Campus, encourage start-ups to establish with the help of business incubator schemes, grants and other support from entities such as ESA, Satellite Applications Catapult and STFC's RAL Space.

The existence and expansion of satellite testing and qualification facilities, such as the RAL R100 space integration and test facility and the new National Satellite Test Facility in Harwell, means that upstream companies save substantial costs from having to bring these expertise and facilities in-house. This has incentivised established companies, such as Airbus DS and Thales Alenia Space, to set up branches in the Arc. These facilities, which are operated by RAL Space, are targeted at national and international science partners, including the neighbouring universities of Oxford, Cambridge, Cranfield and the Open University.

Evidence from our interviews suggests that these facilities greatly support these four universities to develop space science instruments and payloads, enabling them to have a seat at the table for international 'Big Science' collaborations such as interplanetary probes (e.g. the OU led Mars Lander, Beagle 2) and astronomy missions (e.g. ESA's Gaia satellite that performed high precision measurements of 1.7 billion stars). Because of this focus, we describe the wider extent of these Universities' capabilities in section 2.3 on Payloads and Instrumentation below.

The proximity of academia and industry creates a fertile environment for innovation. Universities and research institutions, like RAL Space, perform a pivotal role in fundamental research, taking ideas that may not have a clear commercial application, or are too immature and risky to commercialise, up to a less risky TRL 4 status, although the volume of this research is limited. From this point there are various business support incentives, including grant co-funded by companies, to take these ideas through further TRLs and on to market.

Technology and services that support the operation of spacecraft are also featured in the Arc, with companies like Telespazio UK, based in Luton, providing ground systems support, while research institutions like RAL Space work on furthering fundamental communications technology both at Harwell and at their Chilbolton Observatory ground station facilities located outside the Arc, in Hampshire.

While there are no launch facilities in the Arc, there is launch vehicle development. This is an expanding area of interest, thanks to the highly publicised success in commercial launch of SpaceX, the following rush to market of others, and the rising demand for smallsat/cubesat launches.

The extreme conditions and requirements a launch vehicle must meet require specialised mechanical and electrical components, chemicals, materials, equipment and test procedures in its development and manufacture. This study group has found an intense amount of industrial and R&D activity in the Arc related to this branch of the sector, which may seem surprising considering the high population of the Arc and the geographic isolation these activities typically require for public safety and environmental reasons (such as noise pollution during rocket engine firings). There are historical reasons why a number of these entities are located within the Arc, which will be touched on later in this section. The uniqueness of being able to base such activities close to major transport links and other industry centres means there is good potential for expansion, and we already see the beginnings of this in certain areas of the Arc.

There are notable correlations with specific upstream activities clustering around specific hubs or regions of the Arc. The activities can be roughly divided into four sectors: satellite design, manufacture and assembly; payloads and instrumentation; propulsion and ground sector.

2.1 Propulsion

The majority of launch vehicle and satellite propulsion companies in the Arc are located within the 650-acre Westcott Venture Park, Buckinghamshire. Originally an airfield, the site has been used as a rocket motor development centre since 1946, leading to its maximum size in the 1970s where it was involved in the development of solid and liquid propellant rocket engines with labs for environmental testing, drop towers and hangers. Most of this activity has now ended and the site has changed hands multiple times, now being owned by German investment company Patrizia.

Case Study: European Astrotech

European Astrotech Limited (EAL) is a UK company with ~10 employees based at Westcott Venture Park in Buckinghamshire. The CEO and founder of EAL, Chris Smith, is an ex-MoD employee who was based at Westcott before it became the Venture Park. The company provides propellant services in all areas of the space industry. Their experience in liquid propellants and spacecraft propulsion subsystems enables them to support clients in all aspects of propulsion chemistry and engineering; from analysis, processing of components and assemblies; through to subsystem qualification testing and launch site services. EAL offer services in: Launch campaigns, Compatibility testing, Sub-system testing, Chemical analysis, Training and Consulting

Benefits for the Arc and greater UK Economy:

Upgrading and improving the Westcott site: Westcott's facilities were built for a very specialised purpose but fell into disrepair. EAL recognised their value and renovated some of the old facilities at their own cost, adding data acquisition and processing equipment, thus improving the value and capability of the site.

Offering unique and in-demand capabilities: The company is an example of the propulsion expertise that Westcott is reputed for. With an expanding satellite market, there is a surge in launch projects, two are based in the UK and others international launch providers are looking to operate from one of the UK's emerging spaceports. With this comes the need for expertise in fuelling and testing rocket engines and satellite thrusters and their propellants. EAL and Westcott are well positioned to benefit from this opportunity.

Education and Outreach: EAL recognise the growing STEM skills gap. To counter this problem, EAL arrange weather balloon experiments for schools for education and outreach. The children learn about GPS equipment and operations, presenting skills, costing projects, practical demonstrations and more.

Arc Benefits to European Astrotech Ltd:

Local Collaboration and Business Opportunities: There is a lot of local collaboration in this field enabled by location. EAL do propellant analysis for Nammo UK on their thrusters. Airborne Engineering Ltd. (AEL) worked for EAL providing and operating data acquisition equipment – all three are based at Westcott. EAL work with companies at Harwell, such as Thales Alenia Space and Astroscale UK, and with Airbus DS (despite its large size), an hour away in Stevenage.

Emerging Interest in Westcott: Westcott's unique status as a site for rocket engine tests in the southern UK is leading to increasing growth and investment from Innovate UK, UKSA and ESA. This has and will result in more business for EAL, and brings complementary services on to the site.

Local Skills: EAL have benefitted from local skills. They have been involved in ~£2,000 local apprenticeship schemes and generally see 10 applicants a year and good results from these programmes.

Conclusions:

EAL are an example of how a small space company can offer immense value to their customers through unique and highly specialised expertise. With creativity, these skills can also inspire and educate.

There is scope at Westcott to use the heritage features for a newly emerging market, but it will require deep technical knowledge and experience to exploit this in conjunction with other users. With a long-standing understanding of the technology and potential for the site, EAL are well positioned to offer this advice.

Most of the old facilities, although derelict, remain largely intact and structurally sound, preserved both for historical reasons and because they are solid concrete constructions (built to withstand blasts from rocket engine test failures). The principles of rocket engine design and testing have not fundamentally changed since Westcott's founding, so its facilities could be restored for their original purpose.

Some of the companies on site have already done this, for example, European Astrotech Ltd., who specialise in propellant analysis and fuelling satellite propulsion systems, renovated some of the old buildings as firing sites and control rooms for modest cleaning and redecorating costs. With predefined safety distances and features such as purpose-built earth mounds, ditches and reinforced concrete facilities already in place, the site is set up to host far more companies and activities related to rocket engine and satellite thruster development than today.

The most active and longstanding propulsion companies on the site include European Astrotech Limited (EAL), Airborne Engineering Limited (AEL), Nammo UK and Falcon Project Limited, there are

also a number of propulsion start-ups emerging through the Westcott Business Incubation Centre, such as Protolaunch and Smallspark Space Systems. Although there is overlap between these propulsion companies from working in the same sector, each appears to specialise in a particular niche that complements, rather than competes, with the activities of the others. There is therefore a notable level of collaboration between the companies on site that provides Westcott with a scalable capability to tackle higher value and more technically demanding projects as and when they arise. Despite most of these companies classifying as SMEs, their client base extends to some of the largest space companies in the UK and Europe, including Airbus Defence and Space (Airbus DS) and Thales Alenia Space. These relationships have emerged partly because small, specialised companies can often perform functions such as propulsion technology testing, qualification, fuelling and even development quicker and cheaper than larger companies.

Almost all these companies have benefitted from contracts and grants awarded by ESA and UKSA, although few from local grants. Some, however, have benefitted from small local apprenticeship schemes, as well as utilising CNC, 3D printing and other precision or advanced manufacturing from the local area. Some advanced manufacturing companies near Harwell were, however, unfamiliar or even unaware of Westcott, thus suggesting that publicity for the Venture Park could be improved. This may change once the National Space Propulsion Test Facility (NSPTF) is opened at the site in March 2021 – representing a £4m investment from UKSA that is expected to create around 60 jobs and boost the capabilities and opportunities for the propulsion companies on the site. NSPTF also represents the government's recognition of the potential for propulsion R&D as launch and satellite projects around the world continue to attract investment. Signs of future growth for the site are already emerging, as a large multinational manufacturer of science equipment, AVS UK, is currently building a sizeable facility, but at present the site still remains largely unused. Assuming the site continues to grow, it would benefit from a central canteen and networking area (similar to that found at Harwell) and additional accommodation in the local area. The lack of these basic facilities has been highlighted as limiting factors by those interviewed from the site.

The unique engineering capabilities and activities of some of the propulsion companies in Westcott have inspired collaborations with educational establishments inside and outside the Arc. This activity offers minimal, if any, financial return, but has a positive effect that could be amplified by modest local or national support. For example, Airborne Engineering have supported Cranfield University Masters projects with test equipment and expertise. Meanwhile, European Astrotech has ongoing weather balloon experiments to train and inspire local school children in STEM subjects (pro bono work not supported by grant schemes). It is also worth noting that most employees for two of the propulsion companies at Westcott are Cambridge engineering graduates who all took part in the same extracurricular rocketry group, which to the knowledge of those interviewed receives little to no official support.

Propulsion is a fundamental enabling technology for the space industry with extreme engineering demands, possibilities for spin-out applications in other industries, and transformative potential for the space industry. A leading example of this in the UK and the world is the R&D work by Reaction Engines Limited, at the Culham Science Centre, Oxfordshire.

Case Study: Reaction Engines Limited (REL)

Reaction Engines is a next-generation aerospace propulsion development company, founded in 1989 in Culham, Oxfordshire. It employs over 200 staff across sites in the UK and US, and has raised over £100m in the last three years from public and private sources. In 2013 the UK Government announced a £60m commitment to aid the design, manufacture and testing of SABRE demonstrator engines.

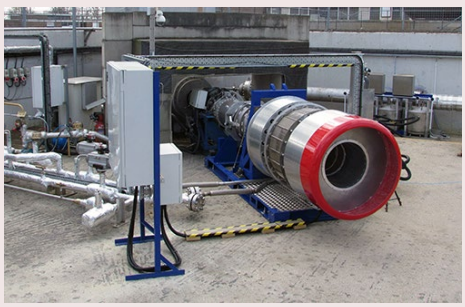
The SABRE (Synergistic Air Breathing Rocket Engine) is designed to switch from air-breathing mode in the lower atmosphere to rocket mode in space and has the potential to be truly transformative, enabling reusable spaceplanes and hypersonic transport. This is a unique technology worldwide.

The programme requires several high precision manufacturing and testing techniques and is tapping resources in motorsport (their CCO and Engineering Director both had long careers in Formula 1) and aerospace (partnerships with BAE Systems, which is also an investor, and Rolls Royce to help research high-speed aircraft propulsion systems).

Benefits for the Arc and greater UK Economy:

Benefits of REL's R&D have already been seen in the Arc and are expected to continue as Reaction Engines progresses. There have been direct benefits to local suppliers, such as Airborne Engineering in Westcott. There are indirect benefits as well, by improving standards in the local supply base. One of the core technologies is a compact heat exchanger, able to cool air from 1,000°C in less than 1/20th of a second, a 1.5MW energy flow unprecedented from a heat exchanger of this size.

To achieve this performance, Reaction Engines require unique and high precision manufacturing methods. Supplier standards for quality assurance (QA), timescales of manufacture, cost, etc. needed to be improved beyond what was available in the local area, so the company acquired local suppliers, Crossman Engineering and Bright Precision, to gain the necessary skills and improve standards in-house. Reaction Engines now offer vacuum brazing and other high precision manufacturing methods unique in the UK to the space, aerospace and defence sectors.



REL Heat Exchanger test, Culham

Thermal management is a challenge in many industries, making the spin off applications for this technology considerable. Examples currently being explored include heat management for batteries in electric vehicles, desalination plants, and aerospace gas turbines.

If successful, it is uncertain what Reaction Engines' business model would be, however it would be a huge value-creator for the UK and manufacturing of engines and airframes/spaceplanes would be required. The Arc has less experience in this field, but it provides an excellent opportunity for other areas of the UK such as Bristol, North Wales or Northern Ireland.

Arc Benefits to Reaction Engines:

Reaction Engines has benefitted from tapping into the Arc's academic and engineering experience, being able to access the Westcott propulsion test facilities only 40 minutes from their Culham base, and experienced suppliers in the cluster.

They have gained government investment through UKSA, and also improved their Quality Assurance through OxLEP funding used to fund local QA specialists.

Oxford University has been a valuable partner, with a large heat transfer laboratory in Osney, supporting discussions about heat transfer problems, and aerodynamics research.

Conclusions:

It is unclear whether special features of the Arc were responsible for Reaction Engines locating in Oxfordshire or whether this decision was coincidental (the founder, Alan Bond, originally worked on fusion research at the Culham site). What is clear however, is the benefit Reaction Engines is having on employment and capabilities in the Arc, as well as the significant economic advantages it could bring to the Arc if its SABRE programme successfully makes it to market. The demonstrates the benefits a high-profile R&D project can bring to the UK and the local area.

2.2 Satellite Design, Manufacture and Assembly

The Arc is home to a great depth and diversity in satellite development, some of the most prolific outside Airbus DS in Stevenage. A richness in supportive government facilities and academic activities has enticed larger companies to set up local bases to reap the benefits, as well as encouraging a growing start-up community.

Satellite activity in the Arc is centred on Harwell Campus, Oxfordshire. The site was founded on an old airfield because of the abundance of open flat land, which provides a starting point for facilities and expertise and room for growth (a similar story to Westcott). Harwell was originally home to atomic energy research, but after the relocation of Appleton Laboratory from Slough to Harwell, nuclear and space research were joined in one entity, Rutherford Appleton Laboratory (RAL). RAL Space remains a government research laboratory and one of the main catalysts for space activity in Harwell, the Arc (where it supports ~400 employees) and the wider UK.

A number of highly specialised facilities are provided by RAL Space, including satellite and payload manufacturing, assembly, integration and test facilities, which are some of the best in the country and able to host a wide range of satellite sizes. It has its own semiconductor fabrication or foundry, a rare capability that offers a unique level of autonomy and supply chain resilience. These facilities exist primarily to support academia and fundamental research. The number of partnerships and joint projects RAL Space has with UK academic institutes is too extensive to list for this study, but it includes all universities with a strong space focus, including Leicester, Glasgow and Edinburgh, as well as all research universities in the Arc. For example, there has been a lot of interest in space science missions (X-Rays, etc.) from Cambridge University, while the University of Oxford mostly works on Earth Observation (EO) missions.

RAL Space draws distinction between international, European and, sometimes, UK (e.g. they think of Airbus DS as Toulouse, France rather than Stevenage, UK and they have more collaborative work with the University of California than Cambridge University). This means that it facilitates international collaboration and is a strong force for UK academia getting involved in large international space science projects. The majority of the upstream academic activity is focused around the development of

scientific payloads and instruments – essentially representing the sensors and systems within a satellite that define and deliver a mission. This hardware is usually tailored to a particular mission, e.g. specially sized lenses and mirrors that constitute a bespoke telescope for a specific EO mission. Payloads and instrumentation will be discussed at greater length in the next sub-section.

Satellite manufacturing companies receive business from payload providers by building the power, communications and control systems that support the payload within a satellite – the satellite bus or platform. There are companies in the Arc that supply specific satellite components (e.g. Oxford Space Systems), ranging up to complete satellite buses, as well as providing full turnkey solutions that involve satellite design, assembly of systems with payloads and testing (e.g. Open Cosmos).

The majority of these activities are based on the Harwell Campus. On top of a general trend for suppliers to gravitate close to their customers (in this case the payload providers and grant bodies), there are also advantages in having the two upstream activities situated close to one another to facilitate the large volumes of information that often need to be exchanged during the design and manufacture of a satellite.

Finance and business support also encourage satellite suppliers to locate in Harwell. For example, Oxford Space Systems (OSS), a manufacturer of carbon composite deployable structures and antennas for satellites, was founded in Harwell in 2013. The company benefitted in early stages from business planning support and profile raising from SA Catapult and a Launchpad grant from Innovate UK. The company leveraged this support and demonstrator projects to secure a series of funding rounds, with Longwall Ventures first met through the Harwell Cluster at the Electron Building's Coffee Shop. OSS now has over 50 employees, a growing revenue book and is a shining success story on the Campus.

Other satellite companies that have found success at Harwell include Deimos UK and NanoAvionics UK. Both companies are headquartered outside of the UK, in Spain and Lithuania respectively, and have drawn on the resources of their parent companies in the early stages for business support and to secure grants. After moving to Harwell in 2019, Nanoavionics UK have now opened a larger facility for satellite assembly, integration and testing (AIT) in Basingstoke, joining other satellite providers in the M3 corridor (such as In-Space Missions, in Bordon and Surrey Satellite Technology, in Guildford). The facility aims to eventually support 400 jobs and the move was supported by the local LEP, Enterprise M3. One of the main reasons for the new facility was the need for space to install a cleanroom and all the necessary equipment for nanosatellite production, with an opportunity to scale. Meanwhile, Deimos UK, after 8 years at Harwell and after growing to 30 people with a turnover of £3m, is also expanding off campus for similar scaling reasons (although with satellite products centred mostly around flight system software, their scaling needs are arguably lower than hardware companies like Nanoavionics UK). Both of these examples highlight the underlying issue of workspace at Harwell, the Campus may be a good place for companies to start, but there is limited room for larger businesses. Other companies complained of high living costs resulting in difficulties attracting personnel (especially

in the larger companies), poor transport connections and low bandwidth internet as being further limiting factors that could be improved.

Despite these shortfalls, new companies are still gravitating to Harwell, like Tyvak, a US company that specialise in providing platforms and full turnkey solutions to payload providers. One reason consistently cited in interviews for this is Harwell's size. Despite limitations on workspace, it is recognised that the Campus has reached a 'critical mass' that attracts potential collaborators and customers to the site, as well as daily visitors and resulting business opportunities through hosted networking events (like Satuccino) and workshops.

Another unique factor of Harwell is the sheer range of activities from small to large satellite projects. A number of companies operating in the small satellite market have already been mentioned, however, larger satellites, although built and assembled elsewhere, are brought to Harwell for testing. An upcoming example is the Skynet 6a satellite (part of a UK MoD telecommunications constellation), the contract (over £500m) for this satellite was awarded to Airbus DS last year. Compared to small satellites that weigh hundreds of kilograms or less, satellites like Skynet weigh several tonnes and require large-scale facilities to test them, such as those hosted by RAL Space in Harwell. During these activities, the number of personnel on site, both for RAL Space and the on-site Airbus DS office grow considerably. This influx of personnel offers networking and business opportunities to the other companies based on site. Furthermore, larger satellite projects and companies also have supply needs, representing business opportunities for some of the suppliers in Harwell (e.g. OSS have supplied antennas to Airbus for some of their next generation 3-6 tonne telecommunication satellites).

Activity diminishes within the Arc for this portion of the upstream satellite sector as you move away from Harwell. There are a few isolated examples, such as ABSL/ Enersys, based in Culham Science Centre, Oxfordshire, which specialise in batteries qualified for the space environment, but no notable or intentional clusters of companies.

Outside the Arc, the main satellite manufacturing plant of Airbus DS in Stevenage, Hertfordshire has a significant influence. This is one of the largest of its kind in the world, with turnover topping nearly a billion pounds is only 15 miles from Arc resources of Telespazio in Luton or 30 from Cranfield / Milton Keynes. A significant portion of the staff for this facility also live in the nearby portion of the Arc, where the cost of living is affordable.

2.3 Payloads and Instrumentation

Unlike 'Propulsion' and 'Satellite Design, Assembly and Testing', activities related to the design, development, manufacture and testing of payloads and instruments are distributed a little more evenly across the Arc as it involves university projects with wider collaborations. Meanwhile, relevant commercial activity is again mostly clustered around the Harwell Campus.

As noted in Section 2, all of the research universities in the Arc are involved, to a greater or lesser extent, in space science projects. Monitoring and measuring novel aspects of celestial objects, or the Earth from space, require the development of specialised, and often bespoke, instruments that can be as much of an innovative challenge to develop as the science they support. The knowledge and skills imparted from these projects therefore have wide-reaching applications. Programmes such as the Space Research and Innovation Network for Technology (SPRINT) work between academics and SMEs to improve the space supply chain and apply space research to adjacent sectors. For instance, The Open University is working in partnership with the Scotch Whisky Research Institute and IBM Research UK (Milton Keynes) to apply space technology to develop methods to authenticate Scotch whisky. The Arc is therefore well positioned to benefit from these activities and transfer the technology from space instruments and payloads into 'terrestrial' applications.

Oxford University hosts unique space-related facilities, including the Infrared Multilayer Laboratory that has provided essential infrared filter components to many space missions (Earth observation, planetary and astrophysics). They are able to manufacture instruments, for example for earth observation satellites or planetary probes, and flight electronics. They can also test many most instruments at Oxford in a thermal/vacuum chamber and for vibration and shock, with a short trip to RAL Space at Harwell for bigger payloads.

Meanwhile, Cambridge University is more involved in the theoretical and observational aspects of astronomy, with a focus on astronomical instrumentation, but leaving other space hardware development to others.

Cranfield and the Open University have been involved in numerous high profile space science missions. For example, the Open University built parts of the spacecraft and Ptolemy instruments that are currently in orbit on the ESA ExoMars Trace Gas Orbiter. Open University does not appear to have many space-specific facilities, but it does have significant precision engineering and additive manufacturing capabilities on its Milton Keynes campus.

Cranfield's research areas include sensor technology, precision engineering, earth observation, spacecraft/ satellite design, and mission design, supported by clean room and CubeSat laboratory facilities. The University is very clear about its willingness to engage in partnership projects, from joint supervised research projects to larger strategic partnerships.

Despite the abundance of space science activity at OU and Cranfield, it is surprising to note that space technology clusters have not formed in the Milton Keynes area to benefit from the skills and facilities these academic institutions provide. Instead, the main convergence of academia and industry around payload and instrument R&D is on the Harwell Campus. The presence of RAL Space, as well as the other positive features of Harwell that are described in the previous sub-section, are most the likely reasons for this.

A good example of a company developing payloads at Harwell is Lacuna Space, a space technology and services company that's business centres on the emerging Internet of Things (IoT) market. Despite being an IoT services company, Lacuna also have a strong design and manufacturing capability and build all the receiver payloads that go into their spacecraft, developing IP that has made them competitive and unique. They have outsourced a lot of the other elements of their hardware and connectivity needs to companies in Harwell, the Arc, the greater UK supply chain and beyond. Some examples of suppliers from Harwell include OSS for antennas and Open Cosmos for (some of) their satellite buses. They also work with local company Mach-Tech Ltd. for some of the precision metalwork that goes into their payloads. As well as having their own lab and facilities for payload development, Lacuna have also benefitted from the test facilities on site (e.g. thermal vacuum chambers) and have a good relationship with RAL Space, which allows them to use RAL's staff time flexibly and in a cost-effective manner. Lacuna attribute a lot of their success to the support they've received from ESA and the ECSAT team on site, having graduated from the ESA BIC (Business Incubator) and received further funding through ESA ARTES (Applications, Telecommunications and Integrated Applications).

2.4 Ground Segment

The space ground segment refers to network equipment, software and personnel involved in sending, receiving and processing data from satellites, and distributing that data between sites on the ground. These activities ensure that satellites operate optimally and that data collected by (e.g. images of the earth) are received and processed into a useful format (e.g. data compression, adding georeferencing to raw EO data, etc.). As satellite numbers increase and the radio frequency spectrum becomes ever more crowded, the pressure on the ground sector and the importance for further advancements to keep up with demand will continue to grow. There may also be emerging commercial opportunities for satellite terminals in households and small businesses (such as farms) as satellite services delivering new forms of connectivity and IoT services become more common.

Fundamental research by RAL Space into future communications technologies (currently spread between their Harwell and Chilbolton bases) is currently poorly supported. Despite this technology becoming ever critical to unlock the full potential of upcoming satellite constellations, commercial entities are unwilling to commit resources because of the high financial risk for such 'exploratory research', which places the responsibility on academic institutions like RAL Space to raise the TRL to a point where industry can take over. Commercial activities around the space ground sector are relatively low in the Arc, meaning that there is potential opportunity and space for such a company to grow.

This study found little by way of facilities and equipment for this sector in the Arc, i.e. satellite dishes/antennas and control facilities for transmitting/receiving satellite data. There are instead activities of associated software and services. In Harwell, Deimos UK market proprietary services and software for satellite control and payload data processing, they also work with RAL Space on space surveillance

and tracking. Meanwhile, RAL Space have specialists on Harwell Campus with skills and knowledge in the ground segment (such as the award-winning Joint Science Operations Centre (JSOC), which plan and prepare all the commands for the instruments on board ESA's Cluster II satellite constellation), as well as a few antennas, however, the majority of their activities in this area are based outside of the Arc at Chilbolton Observatory in Hampshire. Among radio telescopes and space monitoring facilities, Chilbolton also hosts the RAL Space Satellite Ground Station that provides satellite communications services to the scientific community and undertakes work for commercial clients.

Telespazio UK (formerly Telespazio VEGA) and their parent company Leonardo (who are focused more defence), are based in Luton, Bedfordshire and include satellite systems and operations in their many space-related activities. Thales Alenia Space (TAS) own a 32% share of the company and have an arrangement for Telespazio to help operate the large telecommunications satellites built by TAS, thus offering their customers a full turnkey solution. Telespazio also perform similar satellite operations and data processing services for other customers, such as ESA and Europe's Copernicus Earth Observation (EO) Program.

Our focus is on commercial space sectors, but we note the military UK Space Command will be based in the Arc at RAF High Wycombe and staffed from all three branches of the armed forces and have a significant cyberspace component. This will bring more space ground operation capability and skill into the Arc, and draw on local expertise, even if the interaction is indirect (e.g. movement between civilian and military jobs).

2.5 New Upstream Markets

New markets in the space environment are emerging, including in-orbit inspection, servicing and debris removal. The most developed is the monitoring, management and removal of space debris, driven by the commercial and strategic importance of orbits to space nations. Global and UK licencing requirements for satellites are tightening, and now set a threshold of 25 years, after which satellites must de-orbit or move to less crowded 'graveyard' orbits and the requirement for collision avoidance capabilities. There is also increased funding and collaboration between government and industry to mitigate space debris and make space a sustainable environment for the future. This is fast-developing area, and two international companies active in Harwell: Astroscale and D-Orbit.

Astroscale, headquartered in Japan, have developed spacecraft that can attach to and de-orbit multiple satellites, as a prearranged 'End of Life' service, or as part of 'Active Debris Removal' for agencies who are taking on responsibility for debris already in orbit. The company is also focusing on 'Life Extension' missions for larger satellites in Geostationary orbit, because it is cheaper to extend the life of a large telecommunications satellite worth several hundred million US dollars than to replace it. Astroscale will launch their first demonstrator mission later in 2021 and have partnered with SSTL, based in Guildford, to produce the target satellite that will simulate space debris for their demonstrator satellite to capture.

D-Orbit, headquartered in Italy, have developed solutions covering the entire lifecycle of a space mission, including mission analysis and design, engineering, manufacturing, integration, testing, launch, and end-of-life decommissioning (de-orbiting). Their spacecraft both releases satellites (CubeSats) and recovers and deorbits them. D-Orbit launched their first spacecraft last year.

Both companies have received grants from ESA, and a share of a £1m UKSA grant for solutions to the space debris problem. Deimos UK, based in Harwell, was also a recipient of this grant, because of their work with RAL Space on Space Situational Awareness.

As the number of satellites ever launched is predicted to quadruple over the next 10 years, the market for companies like Astroscale and D-Orbit will inevitably grow. The Arc is well placed to host these and other companies by means of facilities and skills, but also because of space situational awareness research RAL Space is leading in the UK, from Harwell and Chilbolton Observatory in Hampshire, representing a potential partner, customer and facilitator for this market.

2.6 Conclusions on Upstream Space Sector in the Arc

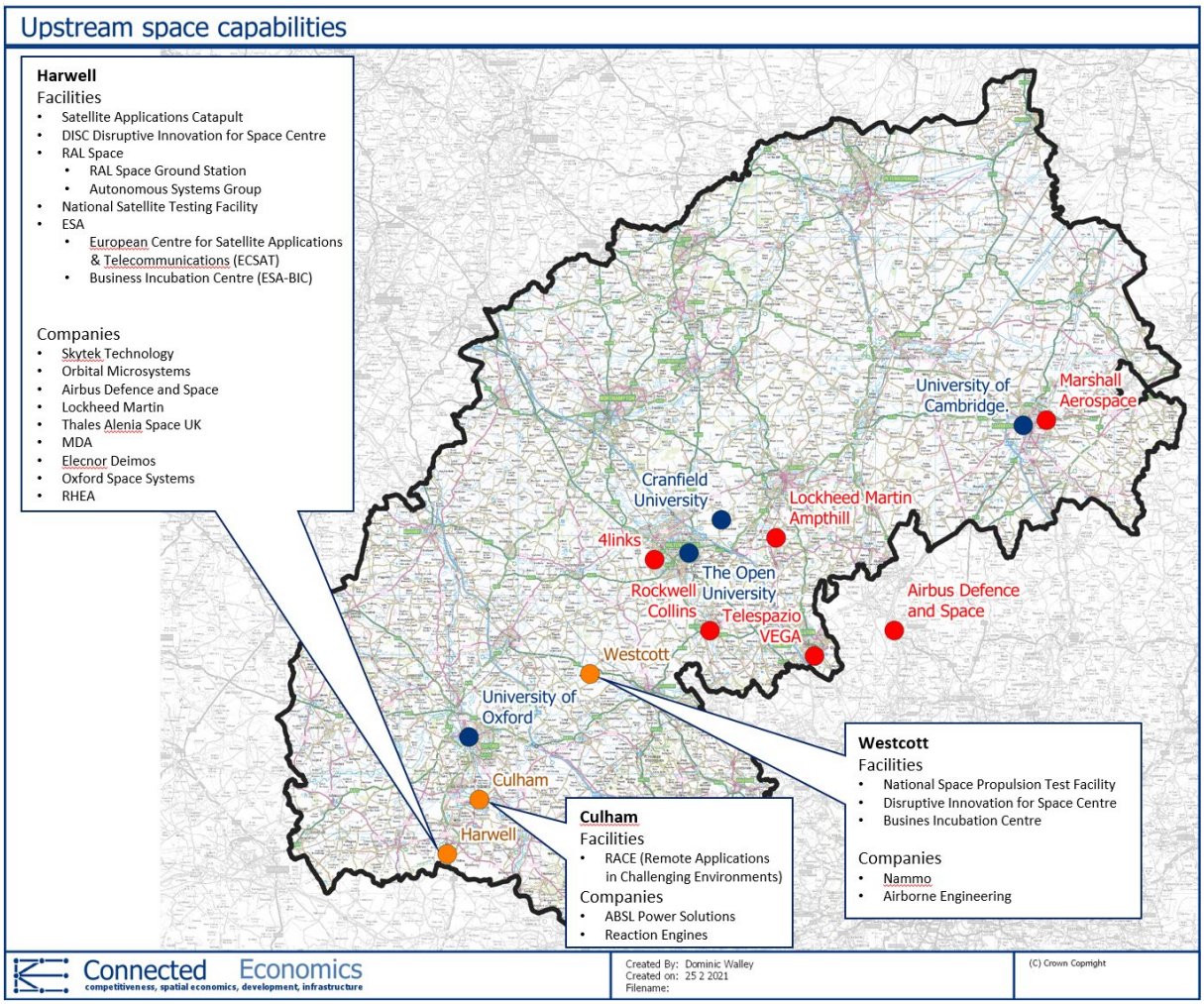


Figure 2-6: Upstream Space Capabilities in the Arc

Upstream space activities in the Arc are heavily focused in the Southwest, especially R&D and commercial activities at Harwell Campus, propulsion at Westcott Venture Park and Reaction Engines at Culham Science Centre. Towards the centre of the Arc, there is a focus on space research at The Open University in Milton Keynes and Cranfield University close by. Upstream space activities are less as one continues East towards Cambridge. There is a suggestion that Cambridge University opts for a more theoretical and less 'hands-on' approach, but this is perhaps a 'chicken and egg' situation as it does not have easy access to the testing facilities at Harwell and Westcott.

Overall, the Arc's capability in most areas of upstream space is very high. We believe this is because of a long-standing combination of world-leading academic institutions, research and test facilities and the proximity Airbus DS's main satellite plant just south of the Arc, coupled with more recent investment and effort to grow the Harwell (and to some extent Culham and Westcott) clusters.

3. Capabilities in Adjacent Sectors

To gain the full potential of the space sector, we need to understand adjacent sectors, both supply and customer side.

3.1 Prioritisation of Adjacent Sectors

To identify the most important adjacent sectors, we collected a list of sectors from source documents (including those used in Part 1) that are current or potential suppliers or customers for the space industry, that are strengths in the Arc, or that are national or Arc challenges.
We then identified six factors that would mark a sector out as a priority.

Synergy – Supply side	• How closely synergistic is the sector with the space sectors supply chain? How strong are the opportunities for performance enhancement or cost saving?
Synergy – Customer side	• How close is the sector aligned as customer of the space sector? Does it have a huge potential benefit from space (e.g. environmental monitoring) or not much?
Size – Current	• Is the market for the adjacency today large or small?
Size – Future	• Will the market for the adjacency in the future be large or small? Benchmarked against the largest opportunity.
Transformative Potential	• Does the sector, have the potential for "transformative solutions for the space sector", either by dramatic performance/cost improvements, or by enabling space to transform society, the economy or the environment for the better? (inc. 'levelling up')
Arc Advantage	• Is there a clear advantage to acting on this opportunity in the Arc? (Even if the action or impact spreads beyond the Arc.)

Figure 2-7: Sector prioritisation factors

We applied these factors to the initial list of sectors, initially taking it down to a list of nine. Then each member of the project team independently gave a score to each sector on each factor on a scale of 0 (no significant opportunity) to 4 (large / maximum opportunity). We then discussed the areas where we had significant differences (9 of the 54 scores) and came to a consensus view. This method has the advantage of benefitting from our individual knowledge without 'groupthink', focusing discussion on the more difficult judgements and turning a subjective view into a form of quantification, albeit on a very basic scale, which we choose to represent as 'Harvey Balls'[5]. The reasons for prioritisation are explored further in the sector sections below, but we will touch on the ones most important to the rankings here.

Sector	Synergy – Supply	Synergy – Customer	Size – Current	Size – Future	Transformative Potential	Arc Advantage	Overall Priority
Digital and Connectivity	◐	●	●	●	●	●	1 ●
Advanced Materials & Manufacturing	●	◐	◐	◔	●	◐	2 ◕
Aerospace / Aviation	◐	◐	◐	◕	◕	◕	3 ◐
Mobility and Logistics	◕	◕	◐	◕	◕	◕	4 ◐
Environment and Agriculture	○	◕	◕	◔	●	●	5 ◐
Health and Life Sciences	◕	◐	◕	◔	◕	●	6 ◐
Spatial Planning and Delivery	◕	◕	◕	◐	◐	●	7 ◔
Ancillary Services	◐	○	◐	◐	◕	◕	8 ◕
Energy	◕	◐	◕	◕	◐	◐	9 ◕

Figure 2-8: Adjacent Sector Prioritisation

Our top ranked adjacent sector was **Digital and Connectivity**. For digital, this is because of the growing need for data management and processing with cloud, AI and in future quantum techniques. For connectivity, it is because satellites will increasingly become an indispensable part of the global communications network. Communication is already the largest space market, and this will only grow.

The next two are on the supply side. **Advanced Materials and Manufacturing** has always been a driver of space industry progress and has transformative potential from new materials and methods. **Aerospace/Aviation** is similar, with untapped linkages on the aerospace side in the Arc and across the UK.

On the customer side, we think that **Mobility and Logistics** offers greatest potential. Exactly how the next 30 years of transport plays out is uncertain, but whatever the mix of autonomous cars, shared cars, smart roads, drone delivery or bike hire – satellites enable them all.

[5] https://en.wikipedia.org/wiki/Harvey_balls

Environment and Agriculture is close behind. This will be a smaller market, but with transformative environmental impact as satellites will enable verification, carbon prices and other mechanisms to implement UK laws on natural capital and Net Zero. The Arc has world-leading strengths in these areas.

Health and Life Sciences is an enormous opportunity with 'connected health' and technology transfer, and the Arc's expertise is undoubted. Currently health services linked to space are small however, so the priority is reduced for that.

Spatial Planning and Delivery relates space directly to the housing challenge in the Arc, so gives an opportunity to tackle that local problem. It is possible that the Arc Spatial Framework gives an even bigger transformational opportunity than we have considered here.

Energy is an opportunity for space applications, but we did not find it particularly large or well-linked to the Arc's energy strengths. We found **Ancillary services** particularly important to smaller businesses that have not been able to develop in-house capability in finance or IP for example, so they are a priority in the space sector with many new and small businesses.

3.2 Advanced Materials and Manufacturing

There are two overarching principles that guide the design and manufacture of all space hardware, from the very small (e.g. nanosatellites weighing a few kilograms) to the very large (e.g. geostationary telecommunication satellites weighing several tonnes).:

1. It has to work and continue to work for its intended design life, because once in space, hardware (unlike software that can receive updates and bug fixes from the ground) can no longer be accessed for repairs; and

2. It has to be as light and volumetrically efficient as possible; because space transportation is incredibly expensive (typical prices to orbit, depending on mission parameters, range from $5,000 USD per kg to $50,000 USD per kg).

Even if these principles are challenged in the future, with in-orbit servicing and lower cost launches, it will be a long time before they are set aside. With this is in mind, precision manufacturing and advanced materials are critical to the upstream space sector, for the design and manufacture of payloads and instruments, propulsion systems and general satellite hardware (e.g. components, sub-systems and structures).

When combined with the highly demanding space environment, space hardware requires materials with specialised and sometimes unique properties, including being:

- Light weight;

- Resistant to extreme temperature fluctuations;
- Resistant to extreme vibration (rocket launches have been described as 'controlled explosions' and can be quite violent);
- Less likely to produce secondary radiation when exposed to highly ionising radiation (radiation from the previous absorption of radiation in matter); and
- Not prone to "outgassing" (the release of gas trapped within a solid) in the vacuum of space.

One space component developer that has benefitted from the supply of advanced materials in the Arc is Oxford Space Systems (OSS), based in Harwell. The company develops and manufactures deployable space structures and antennas built from carbon composite materials. This need for high-quality composites, with rapid turnround times for prototyping, has been facilitated by a company that also made them for Red Bull F1. The proficiency in such materials is well represented in the Arc with a cluster of companies around Silverstone, Northamptonshire that service the needs of the motorsport industry. Like Space, Motorsport has similar needs from its materials with regards to being light weight and resistant to temperature changes and vibrations. There are therefore a few instances where both industries have interacted in the Arc, and there is scope for more collaboration in the future, with one side pushing the other towards further advancements in the field. Strong materials expertise also resides in Cambridgeshire, such as the Cambridge Graphene Centre and CP Composites.

There are also examples of space companies in the Arc sourcing local advanced and precision manufacturing companies to help build their hardware. One example is Lacuna Space, based in Harwell, who work with a local supplier located close to Harwell, called Mach-Tech Ltd., for some of the precision metal work that goes into their payloads. The manufacture of payloads and instruments must be highly precise, with narrow tolerances (such as the mounts for optics), which allow companies like Mach-Tech to cost their services at a premium (although this is still cheaper than the premiums charged within the space industry). Mach-Tech represent one of many similar high precision manufacturing companies based in the Southwest of the Arc, that frequently service the needs of the space clusters (Mach-Tech receives ~6 space manufacturing enquiries a year). The advanced and precision manufacturing companies in this area of the Arc also receive a lot of business for the manufacture of robotic tools to service the nuclear research clustered around the Harwell Campus and Culham Science Park. This study has found little evidence of crossovers between nuclear and space activities in the Arc, despite their proximity, but there is some potential for collaboration and advancements in the development of radiation hardened electronics.

Mach-Tech, and its local competitors, also receive a lot of work from F1 and the motorsport activity in and around Silverstone. The clustering of Advance Materials and Manufacturing (AM&M) companies around Silverstone has led to the formation of the 'Silverstone Technology Cluster', a non-profit organisation that represents and promotes businesses in advanced manufacturing, electronics and software within a one-hour drive of Silverstone (some of this branches northward outside the Arc).

There are approximately 4500 businesses of this description in this area, 130 of whom are direct members of the Silverstone Technology Cluster – their activities range from marine, medical, space, defence and more.

As well as the precision and quality of AM&M around Silverstone, the companies are also used to handling small batch productions (e.g. prototyping for the next racing season). This favours the high value but low volume orders of the space industry. The space industry is, however, trending towards larger constellations of hundreds or low thousands of satellites, so the demand for medium volume manufacturing (it is unlikely to reach the mass production scales seen in sectors such as the car industry) may also rise in the future. This is something that the AM&M suppliers around Silverstone are again prepared to accommodate.

The highly demanding requirements of the space industry have also led to advancements in the AM&M sector, and resulted in spin-off applications and supply opportunities to other sectors outside of space. A number of space companies in the Arc have found that, despite there being numerous advanced manufacturers and machine shops in the area, the quality of what is produced needs further improving to meet the requirements of space. OSS take it on themselves to improve this quality in-house. Meanwhile, Reaction Engines, based on the Culham Science Centre in Oxfordshire, chose to acquire local manufacturing companies and improve and add to their processes in-house. This has led to world-class manufacturing capabilities that are unique to the Arc and the UK, such as vacuum brazing, which Reaction Engines are now marketing to other sectors in and out of the Arc (see Reaction Engines case study in Section 2).

The Arc is also home to a high number of academic institutions, with 10 universities including the world-leading Universities of Oxford and Cambridge. Almost all of these institutions have AM&M departments, thus elevating the potential for advancements in the Arc compared to other areas of the UK. For example, a revolutionary process for the cleaner, greener, more efficient production of metal powders was invented by Professor Derek Fray and his research group in the Department of Materials Science and Metallurgy at the University of Cambridge. These advancements resulted in the founding of Metalysis Ltd. in 2005 to commercialise this game changing technology. The company now employs around 65 people and has since moved to Yorkshire – one of many examples where the Arc's innovation ecosystem has created employment elsewhere in the UK. The Loxham Precision Engineering Laboratory at Cranfield houses ultra-precision machines and is used for commercial and research purposes including space engineering.

The Cambridge region is also home to The Welding Institute (TWI), a 75 year old membership-based research and technology association founded on joining technologies, materials science and testing. TWI's client projects bring together experts from TWI and the Member to provide solutions directly focused on assisting the Member's business. TWI have over 600 industrial members, of which ~160 are Aerospace organisations, including RAL Space and several others involved in rocket and propulsion

manufacture, such as Relativity Space Inc., SpaceX (US), Gilmour Space (Australia) and the Arc's own Reaction Engines Ltd. There are also companies represented from a number of other sectors (e.g. oil and gas, equipment consumables and materials, engineering and fabrication, power, electronics and sensors and more). The presence of TWI in Cambridge offers a focal point in the Arc for international AM&M organisations to interact and for the cross-pollination of ideas and advancements between different sectors.

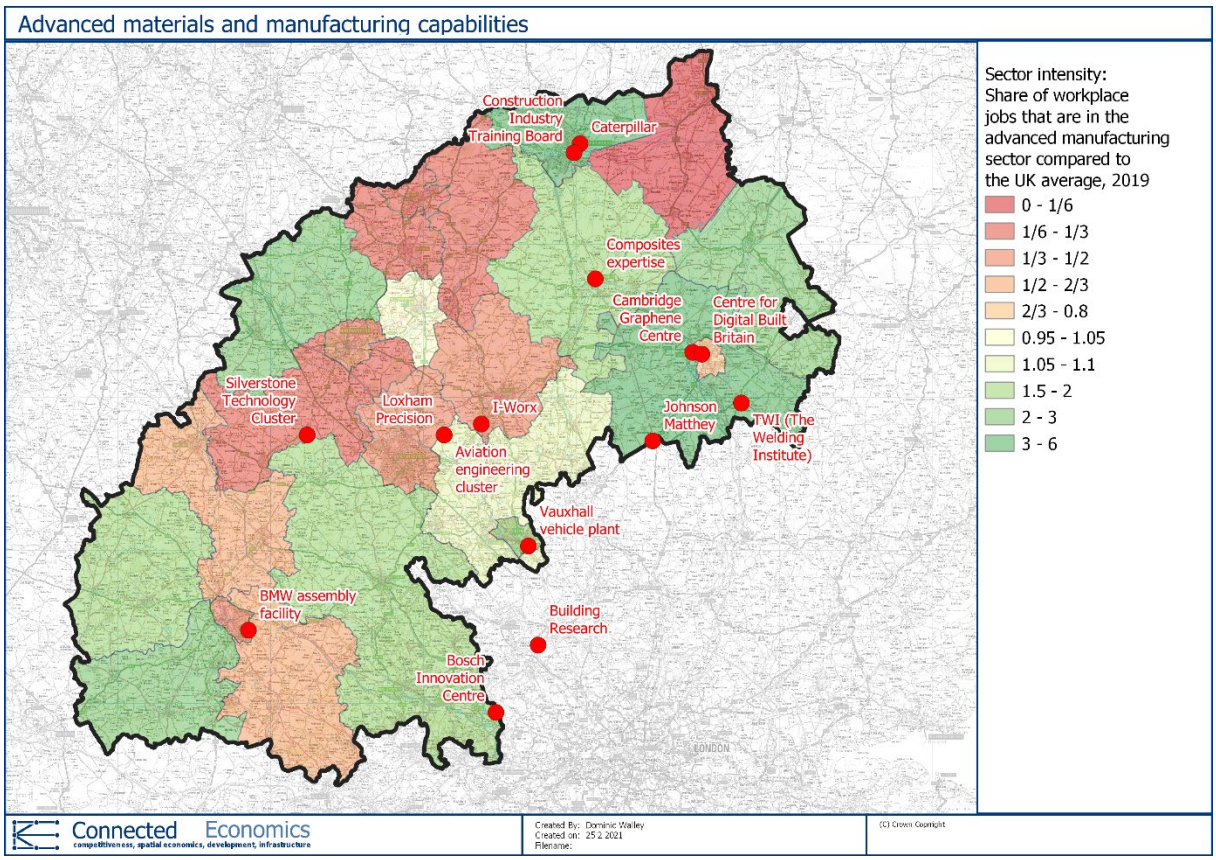


Figure 2-9: Advanced Materials & Manufacturing Capabilities in the Arc
(Sector intensity uses NESTA definition of hi-tech manufacturing based on high intensity of certain STEM occupations)

TWI has very large lab facilities that bring a number of unique and high quality manufacture and test capabilities to the area. These facilities include: friction stir welding, electron beam welding (one of the largest in the UK), hydrogen facilities for low temperature development and testing, high temperature fatigue rigs, additive manufacture and more. TWI also offer training, consulting and research grants to help take projects from TRL 4 to 8 (from concept to factory). This study was surprised to not find Westcott based propulsion companies in TWI's membership lists. This might be because most of the propulsion companies in Westcott are SMEs with narrow margins and TWI focuses on quality rather than low cost. However, if these companies grow similar in size to Reaction Engines, then the TWI could prove to be a valuable asset, because rocket propulsion in particular has a lot to gain from these manufacturing techniques. For example, many companies are now working towards fully 3D printed rocket engines, such as SpaceX in the US and Skyrora in Edinburgh. Propulsion companies in Westcott, like Airborne Engineering, do 3D print some of the parts for their engines, outsourcing to local

suppliers. There are several 3D printing contractors located in the Arc, but little evidence of their numbers or capabilities standing out above other areas of the UK (except possibly for TWI).

In conclusion, the Arc has a strong proficiency in AM&M which is aided by the highly demanding industries and research activities located within, primarily space, nuclear and motorsport. The concentration of these activities in the Arc is above the national average, which has also pushed the standards and state-of-the-art for AM&M in the Arc above the national average. This also pushes the potential for advancements in this sector higher in the Arc compared to the national average. This is especially true when factoring for the Arc's heightened academic presence in the UK, as well as the hosting of technical centres, such as TWI, which draw high profile international members to the Arc; through a combination of world-class facilities, expertise and a broad network of contacts that extend across multiple sectors.

3.3 Aerospace and Aviation

Ranking third in the world, behind only the USA and China, the UK is a big player in the aerospace industry. There are clear connections between aerospace and space, which is why several companies cover both spheres of activity, such as Airbus DS, Lockheed Martin and BAE Systems, all of whom have a presence in or near the Arc. This is partly because of the overlap in technical challenges that the hardware must meet in both industries. Like Space, Aerospace favours lightweight materials (e.g. carbon composites) and light but strong structures (e.g. 'lightweighting' techniques) and both need resistance to fatigue from vibrations and flexing. Engines for aircraft and rockets also have to withstand extreme temperature fluctuations, as well as there being some similar subsystems, such as turbo pumps.

The industries also start to coalesce as they get closer to defence applications, such as hypersonics research. For example, although aimed primarily at civil use, the air-breathing rocket engine technology being developed by Reaction Engines (in Oxfordshire) technically classes as hypersonics research and the US defence sector has expressed interest.

There are also overlaps in the design and manufacturing processes between the two industries. Knowledge of medium volume manufacturing in aviation could also support future satellite production in the UK as production rises to meet demand for future satellite constellations. A near-term example of this is the potential relocation of OneWeb satellite manufacturing, run by Airbus in Florida, USA to the UK, following the UK government's $500m USD rescue of the company last year.

There are advancements in both sectors to address these overlapping challenges, and with the close proximity of organisations from both sectors in the Arc, there is the opportunity for the region to be at the forefront of breakthroughs in novel technology applications and developments. There are a number of examples of clusters, universities and centres of excellence, such as The Welding Institute

(TWI), within the Arc that host and support both industries and can act as a bridge for interactions and ideas.

Cranfield University is one of the best examples of this. It represents a big hub for aerospace research, with strong research centres (such as the Aerospace Integration Research Centre, and the Digital Aviation Research and Technology Centre) in aircraft and engine design. As a university that is dedicated to aerospace research and education, it even has a runway on site capable of landing a Boeing 737 passenger aircraft. As discussed in Section 2. Cranfield University is also involved in a number of 'big science' space research projects that connects it closely to the space activities of RAL Space in Harwell and the Open University in Milton Keynes. Nearby is the cross-sector Aerospace Technology Institute. Cranfield therefore represents a melting pot of ideas for both space and aerospace.

Going broader, the Arc Universities Group is also collaborating on the government challenge of zero net carbon emissions for the aviation industry by 2050. This challenge ties together several different elements from the industry, combining research into environmentally friendly materials and manufacturing methods, green propulsion (such as electric and hydrogen) and how to manage and optimise distribution in the supply chain (such as airport operations) to minimise waste. There are opportunities for space to add value in this research, to improve efficiencies in the supply chain through smarter connectivity and to monitor emissions and environmental impact through EO data applications. There may also be ways to improve the efficiency of air traffic management and identify more efficient flight paths, something that space data is already supporting though ADS-B satellite surveillance technology in aircraft.

Another example of collaboration between the sectors comes from Reaction Engines. The air-breathing rocket engine it is currently developing, called SABRE, combines elements of rocket and jet engine design that has been hailed as the next game-changing technology in transport propulsion (as the jet engine was over the propeller). For this reason the company is closely partnered with BAE Systems (also an investor) and Rolls Royce. The company has also started a study looking at ammonia as a sustainable green fuel for the aviation industry, which supports the government's goals and efforts of the Arc's universities for zero net carbon emissions mentioned earlier.

While the space industry appears to be weighted towards the west of the Arc, Aerospace seems more evenly distributed, with activities already mentioned in Oxfordshire and Milton Keynes, there are also hubs around Luton airport and capabilities and skills in the Whittle Lab in Cambridge University (specialising in aircraft propulsion) and Marshall Aerospace Defence Group, an international aerospace company employing 1,700 that is headquartered in Cambridge. Marshall modified a Lockheed Tristar passenger jet in 1993 to carry and launch the Pegasus XL satellite launch vehicle. Until the successful launch of Virgin Orbit's Launch One vehicle from a Boeing 747 earlier this year, the Pegasus was the only operating example of an air-launch system. With Virgin Orbit looking to launch from (among

other places) Cornwall, there may be opportunities once again for Marshall Aerospace in the space sector.

In conclusion, the Arc has a very strong aerospace industry especially centred on academia and research. At present, aerospace manufacturing is distributed across the Arc and focused on R&D and niche areas rather than large scale manufacture. There are notable examples where space and aerospace reside in close proximity, but these links do not appear to have been fully exploited, which offers potential for each sector to develop services and products to support the other, and to collaborate on advancements for mutual gain.

The challenge to turn aviation carbon neutral in the UK by 2050 is one example where aerospace and space are working towards the same goal within the Arc. Meanwhile, Reaction Engines continue their development of the next stage in transport propulsion. If successful, international travel and space transportation may be dominated by spaceplanes designed and developed by Reaction Engines, with support from the aerospace industry in the Arc. However, if successfully developed, may be manufactured in areas of the UK with existing large scale aircraft production, such as Bristol, Broughton and Belfast.

3.4 Digital and Connectivity

The first internet traffic carried into the UK came across the Atlantic by satellite – connecting US seismic arrays across the world for the US Nuclear Monitoring Research Office monitoring at a snail's pace of 9kbps. Now satellite form a critical part of global communication networks.

Although declining, around half of space and space derived revenues still come from direct-to-home broadcasting, highlighting the strong links between space, broadcasting and media. Direct to home broadcasting flourished from 1989 following the launch of the Astra 1A satellite which enabled Sky TV. Historically, the interaction between media and satellite capability has been a driver of our media landscape enabling innovations such as HD and UHDTV, pay per view and interactive TV. This symbiosis has had a surprising range of wider consequences, such as the creation of the Premier League supported by satellite TV revenues – a reminder of the transformational shifts that can sprout from developments in satellite enabled connectivity.

Satellite communications make up another sizeable chunk of space derived revenues, with a wide array of different and specialised services from secure military communications, communications with aircraft and shipping, low latency specialist services (e.g. for banking and trading) and newly competitive satellite retail broadband services. The market for large broadcasting satellites is fading as pay-TV shifts to on-demand streaming services over fibre/cable broadband networks.

Now, a new wave of communications constellations is emerging, driven by three main factors:

- Consumers demanding ubiquitous broadband as an essential service;

- Technology that has allowed both miniaturisation and convergence between internet and broadcast applications; and
- A decline in launch costs which has attracted new entrants to the market.

In 2020, more than two thirds of all 1,200 satellites launched were part of SpaceX's new Starlink constellation, and another 100 joined the OneWeb constellation.

With lower launch costs and cheaper satellites, constellations from companies like Planet Labs and Spire Global are transforming Earth Observation as well. The deluge of data from these satellites needs managing, storing and processing. The capabilities of software, digital compression technologies, machine learning and artificial intelligence are revolutionising how we approach this ocean of new data – both onboard satellites and when that data reaches Earth.

3.4.1 Connectivity

There are some significant sat comms capabilities within the Arc such as Arqiva Ltd which provides satellite broadcasting services including broadcasting Freeview satellite TV. Arqiva has offices and ground stations across the UK, but is particularly represented across the Arc though offices in Daventry (Northants) and Chalfont (Bucks) and with ground stations at Bedford and Sandy Heath in Bedfordshire. Hughes Europe, a major provider of sat comms and part of the American Echostar Group, is headquartered in Milton Keynes. However, most of the largest sat comms operators tend to be located outside but close to Arc such as Sky UK which has a large campus at Isleworth in London, or Intelsat, Eutelsat and Inmarsat which are also headquartered in London. London and the M4 corridor also host clusters of media, comms and tech companies such as Vodafone (Newbury), Verizon (Reading), Huawei (Reading with research in Cambridge), O2 (Slough) and others. Overall, the share of employees working in satellite telecoms companies in the Arc is only half of that seen in the UK as a whole, and this under-representation is similar across telecoms activities as whole.

Several smaller niche satcomms providers are based in the Arc, for example Deos Europe (incubated at Harwell) provide connectivity and data management services for mobile medical screening vans while Vislink specialise in provide communications in challenging environments such as for military applications or providing comms to broadcasters at live events.

While the presence of communications companies within the Arc is limited, there are capabilities across the field of digital communications including firms like CCS (Cambridge Communication Systems) which is a specialist in self-organising wireless backhaul for small cell, Wi-Fi, CCTV, smart city and enterprise applications, Sierra Wireless, a pioneer in connectivity for IoT devices and Wyld Networks which has developed from 'mesh' technologies to low-cost satellite IoT for sensors. A strong networking community, Cambridge Wireless, focusses on wireless and mobile, internet, semiconductor and software technologies.

The Arc is also a leader in researching and developing the new communications technologies of the future. Cambridge Wireless is developing a 5G testbed with Huawei. The Westcott 5G Step-Out centre provides a testbed for testing and developing 5G technologies. In Harwell, a new engineering hub at ESA-ECSAT will show how 5G and satellite communications can be integrated.

Case Study: Lacuna Space

Lacuna Space is a space technology and services start-up that's business is centred on the emerging Internet of Things (IoT) market. They are based in Harwell, Oxfordshire, (employing 3 to 4 staff) drawn by the UK space start-up community and ESA's Centre for Space Applications and Telecommunications (ECSAT). Their office in the Netherlands works with The Things Network in Amsterdam and their network includes developers and collaborators all over the world.

Lacuna provides a low-cost service to connect IoT nodes that can't connect on a ground network. This competes with traditional models, such as Inmarsat, but in a lower priced niche. Lacuna's model uses onsite data processing (combining edge computing, AI and IoT) to send low bandwidth, yet highly relevant data, back to their customers. By lowering the price of space data and services, IoT companies like Lacuna are looking to increase the market for space applications.

Despite being a downstream supplier of IoT services, Lacuna also has a strong design and manufacturing capability and build all the receiver payloads that go into their spacecraft, developing IP that has made them competitive and unique. They are therefore a company with a unique blend of upstream and downstream capabilities that has a lot to benefit from the Arc, as well as a lot to give back.

Benefits for the Arc and greater UK Economy:

Despite their micro-SME size, Lacuna Space have brought business to several suppliers in their local area and exemplifies how companies can benefit from being in an industry focused cluster.

Other than their payloads, Lacuna Space has outsourced elements of their hardware and connectivity to companies in Harwell, the Arc and the wider supply chain. At Harwell, Lacuna rents office space, lab space and a clean room to build payloads. They buy antennas from Oxford Space Systems, also based in Harwell. They have sourced some of their satellite busses from Open Cosmos and NanoAvionics, also based on site.

The company also works with a local supplier located close to Harwell, called Mach-Tech Ltd., for some of the precision metal work that goes into their payloads. This company is not space focused, but was chosen because of the quality and affordability of their services. Although cheap by the standards of the space industry, this is considered premium work by Mach-Tech because the high quality and precision expected.

Arc Benefits to Lacuna Space:

After successfully raising funding and launching hardware into space, with more soon to follow, Lacuna Space aims to start commercial operations this year. The company attributes a significant portion of its success to the support it has received from Harwell.

Despite the site itself not having good transport links, it is a good place for collaborations with other companies and the start-up community has proven very useful;

There is a 'critical mass' of business contacts (both permanent companies on site and people travelling in) that makes networking events, such as workshops and Satuccinos, valuable;

The location of ESA ECSAT was one of the main motivations for Lacuna basing at Harwell. In Lacuna's view, ECSAT employs some talented people including 'New Space' staff from smallsat companies who understand those they support and advise, and they have been a consistent 'review pool' and support;

Lacuna graduated from ESA BIC and is part of the ESA ARTES programme, both of which offered vital financial and business advice support; and

As well as their own facilities, the company also use the test facilities on site (Thermal Vacuum Chambers, etc.). Their relationship with RAL allows them to use RAL's staff and facilities flexibly and cost-effectively.

Conclusions:

It is clear that Lacuna Space based in the Arc because of networking, organisations and facilities on Harwell Campus. The company has also benefitted from skilled and cost effective local suppliers.

The nature of Lacuna's business means they are looking globally for customers, targeting those that are remote and away from connections. They are therefore unlikely to sell their services within the Arc.

As they grow and find success, it is possible that the cost of living and work space near Harwell will lead them to look elsewhere for a new base.

In academia, the Arc strengths range from the philosophy of communications at the Oxford Internet Institute to the Digital Technology Group at the University of Cambridge which spans physical science research to applications – and prides itself that its projects are usually implemented in hardware and tested in real-world environments.

The near-term goal of the communications community is ubiquitous connectivity – providing connectivity to everyone and everything, everywhere, and with sufficient data speeds and at low cost. This goal will be achieved through a combination of wireless, satellite and terrestrial systems, and Arc capabilities and companies are well placed to play a role and could unlock the next wave of disruptive technologies. Small scale precursors of this already being developed and trialled by Arc companies. For example, Darwin in Oxford are connecting terrestrial and sat comms to deliver ubiquitous connectivity, and demonstrating a use case through trials of autonomous vehicles.

Overall, the Arc is not well represented in major communications companies, headquarters and facilities, but where it does shine is at the research end of the value chain.

3.4.2 Software, data and the products of NewSpace

The digital revolution is the backdrop for a dazzling collection of Arc capabilities in software, Artificial Intelligence and data science. Links with the space sector are numerous, including:

- Smart systems and decision making on board satellites to minimise power use, compress data and autonomously manage operations. Skytek Technologies, for example are a software company focussed on providing software for space based applications (spacecraft, EO platforms, etc) and have a presence at Harwell;
- Data hosting, data warehousing and data aggregation;
- Developing applications from EO Data.

The last of these areas quickly crosses over with other sectors explored elsewhere in this report such as agri-tech, geospatial intelligence or satellite enabled health applications. However, there are some core digital capabilities that sit between the satellite downlink and the application of this data. Good examples are GeoCento, an alumnus of the European Space Agency Business Incubation Centre and

located at Harwell, which provides software to georeference and combine images from different sources, or Agrimetrics which aggregates data to provide a one-stop-shop for geospatial intelligence. While Agrimetrics is focussed on the agri-tech sector, it does hint at the opportunities that will arise for innovative companies to collate, catalogue and improve access to EO data sources. The Data Discovery Hub managed by the Satellite Applications Catapult is a pathfinder in this emerging sector.

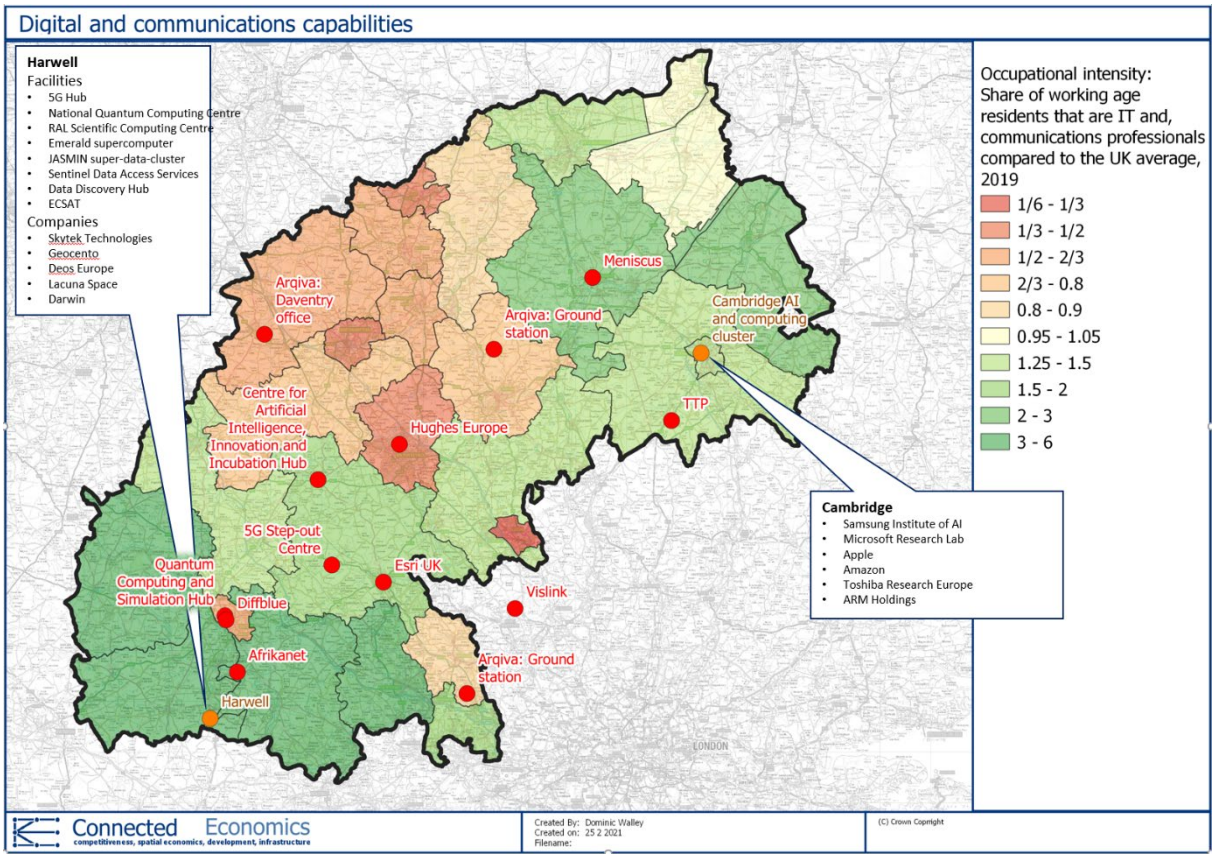


Figure 2-10: Digital and Communications capabilities in the Arc

The most prominent Arc capabilities in the digital and software fields are:

- ARM, the leading microprocessor design company. Based in Cambridge, but owned by SoftBank of Japan, with a $40 billion acquisition by Nvidia pending.
- The Cambridge AI cluster including, for example, the Artificial Intelligence Group at Cambridge University, the planned NVIDIA AI Research Centre at ARM's Cambridge campus, Microsoft's research lab, Samsung's AI Centre Cambridge and smaller companies like Intelligens which have developed software to train AI on sparse or noisy data;
- Dedicated facilities such as the STFC Scientific Computing Department, operating RAL Space's Centre for Environmental Data Analysis and JASMIN 'super-data-cluster';
- Wider research capabilities in computing, chips, wireless and low power computing such as Amazon Research Cambridge, Apple Research, Microsoft Research Lab and Toshiba's Cambridge Research Laboratory;

- A strong specialism in software and computing: across the Arc. The intensity of software and computing companies across the Arc is mapped in Figure 10;
- Looking further ahead a developing expertise in quantum computing including the University of Oxford's Quantum Computing and Simulation Hub and the National Quantum Computing Centre being set up at Harwell.

These fields are all fast-growing sectors globally with many competing centres across the world. While the Arc has some world leading capabilities in this area, it will need to work hard to stay ahead and claim a significant share of global markets.

Overall, the Arc has a greater intensity of jobs in software and computing than the UK as a whole and Figure 10 shows that this capability is distributed across the Arc. Concentrations are evident in Cambridge/South Cambridgeshire (represented by companies such as Coderus and Green Custard), Milton Keynes (such as Zizo, the data software and data analytics company and Pulsant, the Milton Keynes Data Centre) and the Vale of White Horse in Oxfordshire.

Much of this data and connectivity powers the global financial hub of London, only 0.0003 seconds from Milton Keynes at light speed. The Digital Catapult, based in London supports industries and technologies. While digital communication appear seamless, the proximity to London is an important enable of the benefits provided by the Arc's strategic location at the heart of the UK economy.

In conclusion, the communications and digital sectors are intimately connected to space from the development of software to support upstream space, to managing the flood of data from a rapidly growing EO sector. While the Arc is not well endowed with large communications companies, it does play a strategic role as a research hub for the communications industry. The Arc's key strengths in cutting edge research (particularly in AI, comms and chip design) and its strength in software and computing more generally, position it well to grow these markets and their links to space. However, this is a cutthroat area of dynamic global competition in R&D and new product development. The strength of the Arc's research base will once again underpin its future success in this critical sector.

3.5 Environment and Agriculture

Monitoring Earth's environment has been an important application for space since TIROS-1 sent back its first pictures of weather patterns in 1960. Now, in a climate crisis, with biodiversity loss threatening ecosystem collapses, and with air pollution causing thousands of early deaths in the UK alone, it has never been more important. Agriculture provides most of our food. It depends on natural environment, but productivity and resource efficiency are important as well as environmental impact.

These issues manifest all over the UK and the globe, but are particularly intense in the Arc where outstanding or sensitive environments like the Chiltern Hills or the Ouse and Nene Wetlands lie next to intensively farmed lands, and urban areas likely to see rapid further growth.

Satellites can help tackle these challenges and the Arc (and nearby) also has exceptionally strong capabilities in relevant satellite applications and the environmental and agricultural sectors.

Remote sensing satellites can image or measure many of the relevant things directly, with increasing physical, time and spectral resolution. Where they cannot, they can upload data from ground-based sensors – including a new generation of low cost Internet of Things (IoT) satellite services. Growth markets will include:

- Biodiversity/Environmental Net Gain monitoring. A commitment of the Arc and likely to become a national legal requirement in the Environment Bill, which will then require verification. It is likely that satellite data would be a cost-effective part of a LA or Arc-wide (or wider) monitoring plan.
- Soil Carbon. Verifying soil carbon so that farmers and land managers can be incentivised through carbon credits to adopt carbon sequestration practices.
- Natural Capital more widely. With the Arc and the 25 Year Environment Plan committed to Natural Capital approaches, there is a need to monitor the level and changes to its component assets.
- Air pollution. Estimated to cause 28-36,000 early deaths in the UK each year and exacerbate other conditions including Covid-19, understanding the sources and dynamics is rising up the agenda. Current satellites have resolutions around 5km, but this is improving with smart processing and bespoke sensors, and ground-based sensors can provide on-the-spot resolution.
- Water. As the climate crisis impacts us in coming decades, we will suffer more storms, floods and droughts. Satellites can help us prepare for, predict and manage these.
- Precision agriculture. Applications are already developing to help farmers understand where they should apply more or less water, fertiliser or pesticide to their fields, or optimise their livestock feeding, saving money, time and environmental impact.
- Farm automation. Satellites can support the longer-term move to farm automation, by providing reliable communications coverage in rural areas.

The Arc has globally competitive capabilities in the environment and agriculture. There is a general pattern of strength in broad environmental issues and water in the west of the Arc, and agriculture and food production in the east (although exceptions exist).

The Universities have strong departments including Oxford's Environmental Change Institute and Department of Atmospheric, Oceanic and Planetary Physics, Open University's strength's in flood and ocean science, Cranfield's National Soil Resources Institute, Urban Water Hub and expertise in sensors, Cambridge's Department of Plant Sciences and Sainsbury Laboratory, and the Global Sustainability Institute at Anglia Ruskin. Both Oxford and Cambridge have been active in climate science and environmental satellite missions from their beginnings.

Around these are a set of research organisations. On the environmental side these range from the Centre for Ecology and Hydrology and British Geological Survey near Wallingford, Oxfordshire, to the British Antarctic Survey in Cambridge. RAL Space in Harwell hosts CEDA an Earth observation and atmospheric data centre and JASMIN a supercomputer with petabytes of storage for environmental science. Natural England has a large office in Peterborough. There are also many environmental groups, ranging from Low Carbon groups to Wildlife Trusts and Local Nature Partnerships, often including people with strong skills who would be interested to get involved in projects that are positive for the environment.

In agriculture there are more: The Livestock Innovation Centre and CABI in Oxfordshire, the Agri-EPI Centre near Cranfield, the National Institute of Agricultural Botany near Cambridge. Looking a little wider shows the strength of the east of England as just outside the Arc is the John Innes Centre and the Institute of Food Research in Norwich, and Rothamsted Research in Harpenden – national centres of expertise and internationally respected.

The eastern Arc's commercial strength includes Bayer CropScience and Syngenta in Cambridge. The east of England's agricultural expertise is linked in Agri-TechE, a membership organisation that brings together farmers with scientists, technologists and entrepreneurs to create innovation.

Case Study: Rezatec

Rezatec is a geospatial analysis busines based at Harwell. It focuses on solutions for customers in industries that gain high value from managing their ground-based assets and critical infrastructure remotely, at scale, including water, utilities, forestry and agriculture.

Rezatec combines satellite data and imagery with other datasets, and applies AI techniques to create products that create value for its customers. Most of its customers are in North America, where the utilities, water and forestry sectors have seen the value in these approaches.

The business started in 2012, with academic founders and a strong climate change focus, but early on these were joined by co-founders with strong business experience, and the company pivoted to focus on markets with more immediate commercial potential. It was supported by several grants and raised seed funding in 2014 with rapid expansion following and in 2020 Gresham House Ventures invested £5m into Rezatec. At the start of 2021 it has about 50 employees, and its use of cloud computing has enabled them to expand rapidly, incorporate more datasets and tools, and work from home during the pandemic.

Benefits for the Arc and greater UK Economy:

Rezatec benefitted in early stages from grants from UKSA, ESA and Innovate UK and is already proving a good investment by growing to 'Medium' size with a considerable employment and export footprint. It is on the cusp of cashflow breakeven from operations and may seek additional investment to accelerate growth, depending on conditions.

It has been a valuable positive example for downstream businesses on the Harwell campus, and this has been an area of mutual benefit as Rezatec, Harwell and the Catapult have helped to promote eachother at various times.

Quad One, home of Rezatec, Harwell

Rezatec also has potential to bring value and environmental benefits of its services to the UK. However, while it has some UK customers, in general UK private utilities and public services have been slower to adopt geospatial services than their North American equivalents.

Arc Benefits to Rezatec:

Its position in Harwell has benefitted Rezatec by proximity to the other organisations and people that are present on or visiting the site. It initially set up within the Catapult building and this helped build relationships with UKSA and ESA that led to grants and referenceable case studies that were enormously valuable in gaining later customers and funding.

Being a part of the Harwell cluster also made it easier to meet with customers, funders and employees who could visit the cluster for a 'Harwell day' not just a specific company.

Now the company is well established, the location is less crucial, as their customers are elsewhere, but it is still a benefit for recruiting.

Conclusions:

Rezatec is an example of the innovation system working as it should. An academic idea, combined with entrepreneurship, nurtured with innovation grants, backed by business angels and then venture funding, now approaching profitability and still growing rapidly. The one thing that could have gone better is a UK market more ready for their services. Taking each of these successful elements and building on it gives us a good model for successes of the future,

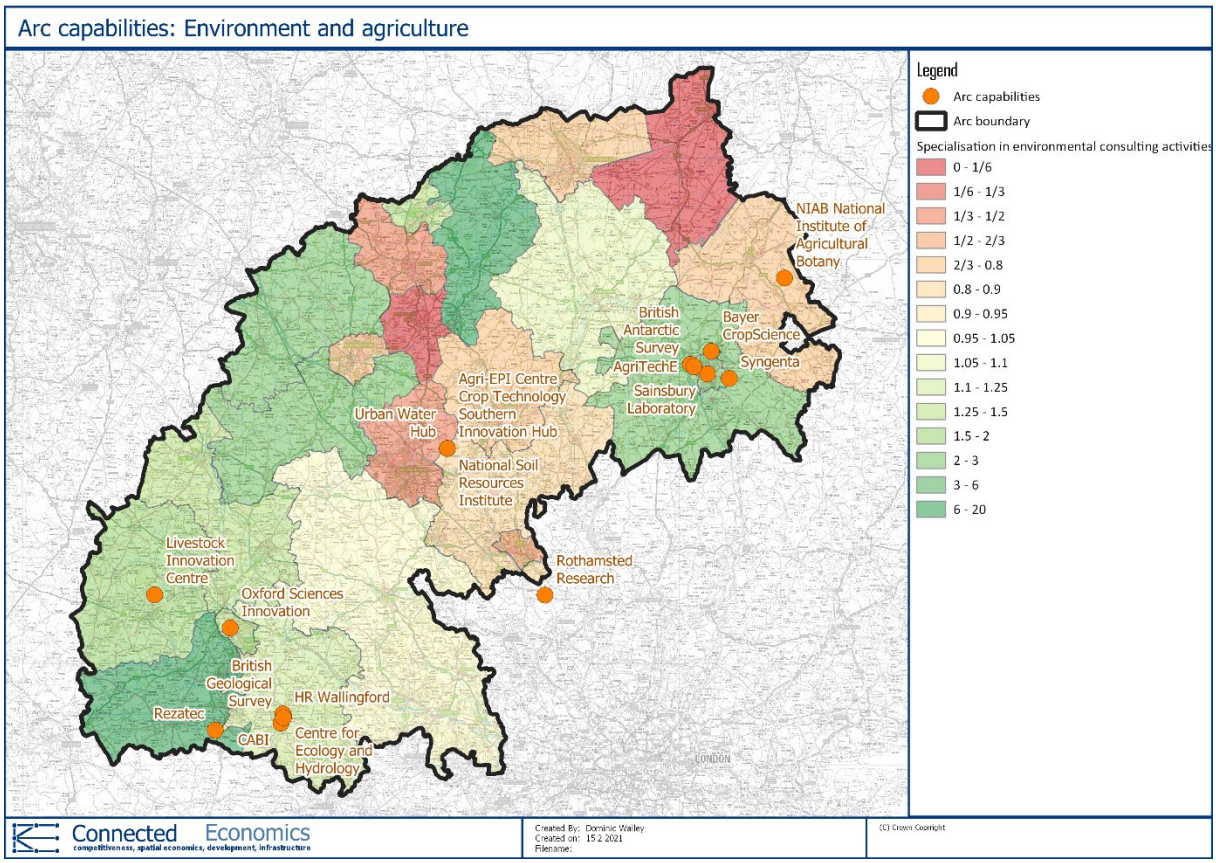


Figure 2-11: Environment and Agriculture capabilities in the Arc

In Oxfordshire, Deimos Space UK, a subsidiary of the Spanish Deimos Elecnor Group is strong in this field, for example with applications that allow farmers to monitor crop growth based on EO imagery and satellite data. Rezatec, also at Harwell, is growing rapidly with global sales as a business applying

satellite and other geospatial analysis to environmental issues. Esri, producers of industry-standard ArcGIS software, has its UK base in Aylesbury, and there are many small Earth data businesses in the region. Oxfordshire is heavily populated with consultancies that operate in environmental fields including HR Wallingford, Jacobs, Ricardo and RPS, but others spread across the Arc.

3.6 Mobility and Logistics

Satellites are so embedded in our journeys that we forget how they hover reliably behind our weather forecasts, mobile phone navigation apps, and sometimes satellite-enabled Wi-Fi. But our current transport system has problems – it is polluting, space-hungry and often causes delay. Recognising the need for decarbonisation, England's Economic Heartland, the Sub-national Transport Body that is slightly larger than the Arc announced in February 2021 a strategy from a net zero transport system as early as 2040[6].

There are three layers to tackling these problems, both for people (mobility) and things (logistics) and there are big opportunities for satellites to support each of them.

Layer 1: Reducing journeys

- Better spatial planning, for example mixed developments with workplaces near homes and the walkable '15-minute neighbourhood' (see Spatial planning section 3.8).
- Replacing journeys with digital. See Digital and connectivity section 3.4.
- Freight consolidation. Better information enables logistics providers to group freight onto fewer vehicles. This is particularly important in urban areas with an increasing use of home delivery – imagine a LA allowing only three delivery vans per street per day to force consolidation between operators, improving pollution and road safety.

Layer 2: Modal shift to Public, Shared and Active transport

- Better Transport Planning, using information about journeys, traffic by type, pollution which may be collected by sensors via satellite.
- Mobility-as-a-Service. Apps that suggest the best route by Public and Active modes are becoming common, and they are informed by satellite. To be most effective they need real-time information on traffic conditions and connections.
- Ticketing. Satellites can enable seamless ticketing and information, making public transport more easy.
- Road pricing. Some system will be needed to manage electric car use given low electricity prices, and to replace fuel taxes.

[6] http://www.englandseconomicheartland.com/transport/our-strategy/

- Car sharing (e.g. Zipcar) Journey sharing (e.g. Uber) and Micro-mobility (bike/scooter hire). Satellite data helps understand where the demand is, and is essential for tracking assets and directing customers.
- Home delivery and its automation – both ground-based and airborne. Satellites already play a role in home delivery. But in future, as we see this becoming partly then fully automated it will increase. Even in places with good mobile network coverage, satellite provides valuable resilience and security.

Layer 3: Improving efficiency and safety

- Satellite signal latency means it won't be used for *driving* an autonomous car, but its ubiquity makes it valuable for network management[7], which could manifest at 'network control' and in a vehicle (e.g. diverting to avoid a problem).
- 'Smarter satnavs' could improve emissions and safety through better route choice or enabling systems such as charging point locators, height warnings or speed limiters.

There are many other applications of satellites to transport. Aviation we cover in 3.3. Rail and maritime are important satellite markets, but not Arc strengths, so we do not focus on those.

The Arc's capabilities in mobility and logistics are strong, ranging from the cutting-edge of technology to leadership in practical logistics solutions.

The University of Oxford and Cranfield University have international reputations in transport, and the University of Northampton maintains a strong interest in logistics.

In Milton Keynes, the Connected Places Catapult is a hub for activity in transport and the built environment, connecting many universities, businesses and other institutions with a series of events, programmes and projects.

The Arc has several transport innovation capabilities. The first springs from 'Motorsport Valley', a name given to a £6 billion cluster high performance automotive activity along the Thames Valley that runs through the Arc and beyond. This centres on the Silverstone Technology Cluster and Circuit, but five Formula 1 teams and many other teams and suppliers are based in the west of the Arc. Many of them, like Prodrive in Banbury and Williams Advanced Engineering, at Grove in Oxfordshire transfer their motorsports technologies and processes to domains from aerospace to healthcare.

Allied to this is a strong vehicle testing infrastructure including Millbrook Proving Ground, Mahle's Real Driving Emissions test centre and Altitude test chamber and the new Catesby Aerodynamic Research Facility (CARF).

[7] Ofcom's Connected Nations 2019 report: 62% of motorways and A roads and 46% of B roads have 4G data in-vehicle coverage from all four operators – so 38% and 54% do not. (Voice coverage is 81%/68%).

The Arc is strongly placed for autonomous vehicles which will be enabled by satellites. Testing of these new vehicles is key and the Arc has The National CAV Testing Centre is at Culham, CAV Testing at Milton Keynes, the Multi-User Environment for Autonomous Vehicle Innovation (MUEAVI) at Cranfield and Millbrook. Culham, Millbrook and CAVWAY, planned junction testbed at Oakley Airfield in Bucks are part of the Zenzic autonomous vehicles collaboration, and Cranfield and the Connected Places Catapult are partners in the HumanDrive project. Also at Culham are Oxbotica, one of the leading businesses in autonomous vehicle development and RACE, UKAEA's team for Remote Applications in Challenging Environments. On a smaller scale, Harwell hosts Helix Technologies, who makes specialist antennas for navigation systems. Milton Keynes is also the testing ground for Starship home delivery by robot.

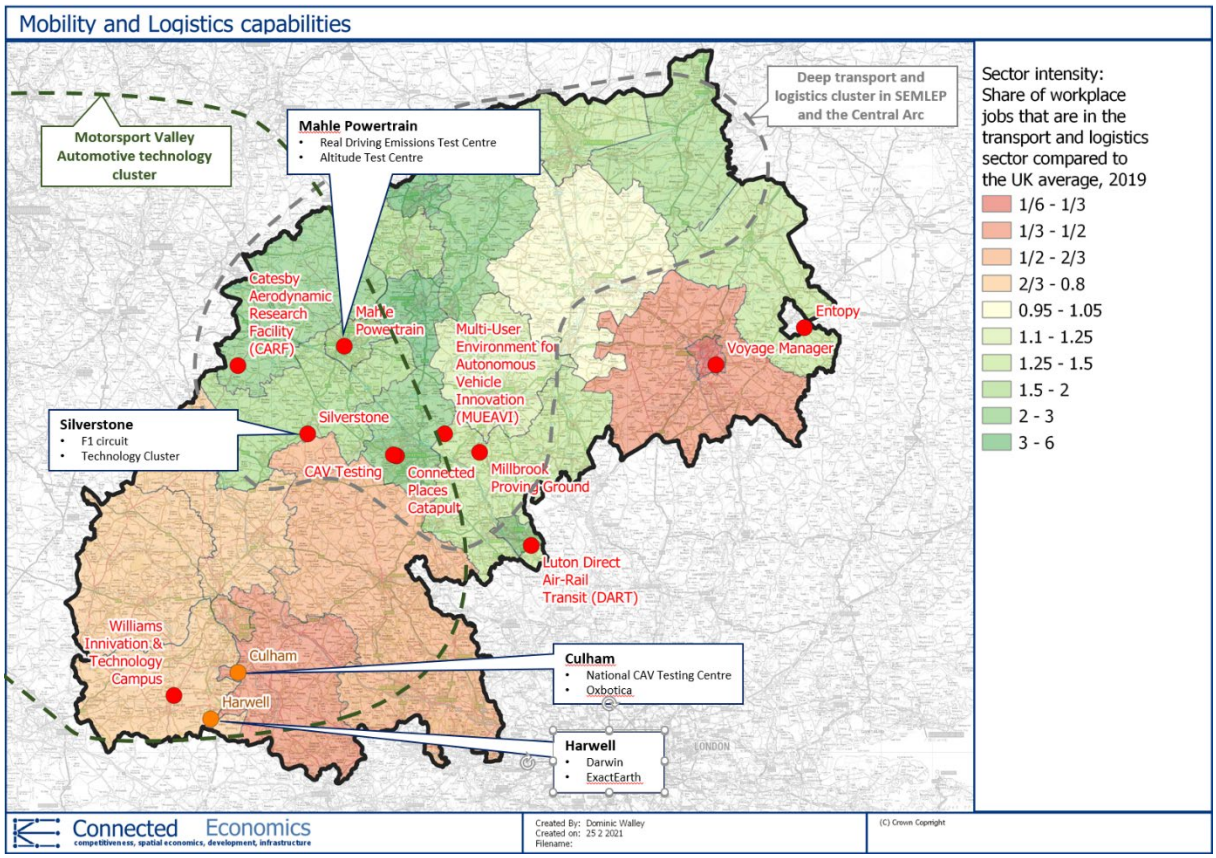


Figure 2-12: Mobility and Logistics capabilities in the Arc

The Arc is developing transport decarbonisation capabilities as well, some technological, some in transport planning. In technology, Harwell is the site of the Faraday Institute for battery development, and Oxford, along with Coventry, are set to become the first 'all-electric bus cities'. Cambridgeshire, Oxfordshire and England's Economic Heartland are adopting a proactive approach to transport decarbonisation through modal shift. Oxford has an ambitious plan for traffic restrictions and a Zero Emissions Zone. Cambridge and Oxford already have the highest fraction of journeys by cycle in the UK and are investing to increase this. Milton Keynes and Oxford have e-Scooter trials. CPCA is developing plans for a Cambridgeshire Autonomous Metro. All of these are enabled or could be enhanced by satellite data.

3.7 Health and Life Sciences

There are two main areas of benefit from satellites in health. The first is from data connection, which can work in many ways, all benefitting from satellite's ubiquity and reliability. The second is in technology, either developed for space or in space, that finds medical applications.

Health connections

- Emergency response. 'Always on' data or video communications for emergency vehicles including ambulances and paramedics. This enables coordinating of people and resources in an emergency situation, or remote monitoring of patients, possibly enabled by AI, or other medical experts to assist in diagnosis.
- Virtual home visits. GP or Nurse virtual visits would normally done over broadband, but broadband and even mobile do not cover all places, and satellites can cover the gaps. This applies just as much to the clinician as to the patient.
- Remote monitoring and diagnosis. Connection enables real-time or reliable medical monitoring of conditions like Type-2 Diabetes or during investigations or surgery. In future, this could be enhanced with real-time AI processing to detect patterns that indicate a problem worthy of attention (e.g. cancer cells).
- Activity monitoring. Subject to consent, monitoring physical activity enables a person to be nudged by technology or by their GP into a healthier lifestyle. Or this can be used to check that less able people are still active, raising an alert if they do not move in a day.

There are principles that underlie all of these. The advantages of satellite connections are its ubiquity, reliability and security. If you can assume a connection all the time you can change processes dramatically, for example including cloud-based data and AI processing in the loop. The reliability of a satellite connection can exceed that for a regular broadband connection, so it is better for some critical medical purposes even with a few-tenths of a second of latency. For mobile applications, it works best when it can be incorporated in the same device so the experience is seamless to the user. The reducing cost of satellite connections is making this more viable all the time, and the previous phenomenon of digital technologies widening health inequalities may be reversed in future.

Improving medical technology and medicines

- Space technology can improve life on Earth. RAL Space has worked with King's College London to develop a breath test for sepsis from a Laser Isotope Ratiometer designed to sense gases in the Martian atmosphere. Space technologies have also been used to develop better prosthetics, and treatments for wounds and restless legs.
- The zero-g environment of space can be used for pharmaceutical development, taking advantage of better mixing and crystal growth. Nanoracks and Space Tango of the USA are offering opportunities for this on the ISS, and SpacePharma of Switzerland in their own 'mini-lab' spacecraft (for $230,000 the time). All three have ambitions to develop their own small

space stations for pharmaceutical and materials science. While these companies are not Arc or UK-based, it is quite possible that their services are being used by the world-leading pharmaceutical firms based in the Arc.

The Arc's expertise in Health and Life Sciences has been highlighted on the world stage recently with the Covid-19 vaccine developed by the University of Oxford and Cambridge-based AstraZeneca. This however, is just the tip of the iceberg.

In Oxford, the Life Sciences Cluster has world-class R&D facilities with 180 R&D companies and another 150 in related businesses. Activity centres in the east of Oxford, and includes the Biomedical Research Campus with The Li Ka Shing Centre for Health Information and Discovery (including the Target Discovery Institute and the Big Data Institute with access to the UK Biobank) and the Wellcome Trust Centre for Human Genetics including the Oxford Genomics Centre. Nearby is the Oxford BioEscalator incubator, which provides lab space and support to help turn entrepreneurial ideas into businesses.

Only a few miles south is Oxford Science Park, home of Oxford Nanopore and tens or other biotech businesses. To the north of Oxford, Begbroke Science Park also has a strong biotech focus and opened the Begbroke Innovation Accelerator building in 2017. Outside Oxford, near Didcot is Milton Park with dozens of life sciences companies including Adaptimmune and Evotec. And alongside the space cluster in Harwell is a HealthTec cluster with over 1000 people in 40 organisations including the Medical Research Council, Public Health England and the Rosalind Franklin Institute. These and off-campus businesses such as AstraZeneca, GSK and Pfizer are able to access facilities like the Diamond Light Source, the Central Laser Facility and the ISIS muon and neutron source to probe molecular structures.

Cambridge is the centre of no less a Life Sciences Cluster, with over 400 companies and 15,000 employees. In the south of the city is Cambridge Biomedical Campus, which includes the city's main hospitals, the MRC Laboratory of Molecular Biology, Cambridge Institute for Medical Research, MedTech Accelerator, GSK's Clinical Research Unit and AstraZeneca's Global R&D Centre and corporate headquarters. To the north of the city, Cambridge Science Park hosts 100 businesses with a focus on health-related technologies and opened a new Bio Innovation Centre in 2020.

A few miles southeast is Babraham Research Campus, home to the Babraham Institute and 60 other organisations and bioscience facilities. Nearby this is the Wellcome Genome Campus, housing the European Bioinformatics Institute (EMBL), Wellcome Trust Sanger Institute and the BioData Innovation Centre with flexible space for genomics and biodata innovators.

There is strength in the centre of the Arc as well, particularly in the Stoke Mandeville Cluster near Aylesbury, Buckinghamshire. Stoke Mandeville Hospital is the UKs' national spinal centre and origin place of the Paralympic Games. With Buckinghamshire being an early mover in integrating health and

social care, it is developing this capability into a Living Lab to pilot the delivery of new products and services into an efficient health and care delivery model.

3.8 Spatial Planning and Delivery

The Arc is the epicentre of the most ambitious plan for physical development in the country. Over the next 20 years, plans for approximately 1 million new homes and 2 million new residents will place unparalleled pressure on the spatial planning and development community. The Arc aspires to do this while improving biodiversity, habitats and the natural environment and cutting carbon emissions to zero. Nowhere else are the challenges and opportunities of excellent spatial planning more significant or more pressing.

In February 2021 the government's Arc team headed by MHCLG published its first steps towards developing a spatial framework for the Arc. This followed Budget 2020's commitment to develop an Arc spatial framework and years of previous work by other organisations such as the National Infrastructure Commission. **Planning for sustainable growth in the Oxford-Cambridge Arc: An introduction to the Oxford-Cambridge Arc Spatial Framework**[8] sets out government's strategic approach to planning to realise that transformational opportunity presented by the Arc. The engagement and priority demonstrated by national government is a key strength in effective spatial planning. Another strength is the emerging Arc governance and leadership: The Arc Leadership Group, the Arc Universities Group, the Arc LEPs Group and the Arc Environment Group. Together these may unlock innovative approaches to spatial planning and delivery that could otherwise fail due to coordination failures, a lack of long-term vision, or a lack of understanding of what is possible using emerging innovative methods for spatial planning.

The spatial plan will set out land allocations for housing and commercial development as well as infrastructure and utilities requirements. Most importantly though, it offers a foundation that glues these together and offers the opportunity to develop transparent new mechanisms for delivering and monitoring development activities which are shared by central and local government, developers, utilities and communities. This is in the sweet spot of earth observation capabilities and the innovation potential of the Arc.

The main Arc capabilities that can be brought to bear on these challenges are:

- A vibrant and world leading geospatial intelligence capability. This is ESRI, 1Spatial, 2Excel Geo, Deep Planet, eOsphere, GeoCento, Rezatec and others.
- Emerging niche applications for geographical intelligence in spatial planning. For example, companies like Power Market, Spottitt and Vidrona have developed to support utilities in

[8] https://www.gov.uk/government/publications/planning-for-sustainable-growth-in-the-oxford-cambridge-arc-spatial-framework

developing new assets and managing existing ones, while HR Wallingford has capabilities in using geospatial intelligence for flood risk and water management.

- Capabilities in instrumenting and measuring. Companies such as Ground Data, for example, have developed autonomous remote sensors to instrument spatial features, and Arc companies Lacuna and Wyld Networks downlink IoT sensor data from satellites.
- A host of companies supporting spatial planning in agri-tech and environmental applications. See the agri-tech and environment section for more details.
- More generalist spatial planning actors that are beginning to use EO data as part of their normal activities. Geoger consulting, for example, position themselves as a new wave of spatial planning consultancy based on satellite derived geospatial intelligence. Others such as Urban Foresight are more generalist, but with clear strengths in using EO data in their work. More traditional spatial development practitioners are beginning to become aware of the possibilities opened up by EO data, for example 'digital twins' in spatial planning and construction, but its entry into the mainstream market is relatively slow.
- Academic strength in its universities, including the Faculty of Technology, Design and Environment at Oxford Brookes University, which is internationally recognised for its work in the built environment and linking it to public health.

These capabilities have reached the point where they can tackle significant challenges in spatial planning, and the linked issues of environment, transport and health. However, such methods have developed in niches but are yet to be adopted in the mainstream of planning. Most spatial planning decisions are based on traditional data sources such as static maps and land surveys. In transport planning, for example, patterns of transport journeys are still derived from census data, roadside traffic counts and broad data from mobile phone mast areas. Compare this with retail or finance, where rapid-cycle data from individual phones and from satellites is used to assess where people are moving in shopping malls, or factory outputs based on carpark occupancy, roof heat or visible storage. The spatial planning system to date has had no system to encourage innovation, and has generally discouraged it, by encouraging developers who reference long-established standards and approaches.

The ambitious Arc Spatial Plan and all its supporting agreements, frameworks and deals provide opportunities to reimagine spatial planning approaches. The Arc houses capabilities in each step of the process: collecting, processing, understanding the data; and using it in the planning process. This makes the Arc an excellent test bed or Living Lab for new approaches in Spatial Planning which we will discuss in Part 3.

3.9 Ancillary Services

Ancillary services are those that support the space sector without being specifically 'upstream' or 'downstream'. A few are specialised to space, such as space insurance and technical consultancies,

some specialise in a wider range of technology such as innovation advisors and venture capital financers, and some are generic to businesses such as office space and accountancy.

We did not see an opportunity for space to revolutionise these sectors, but it will stimulate their growth as the space sector grows – an economic multiplier. In some cases connectivity from space will allow professional services firms to operate from 'not spots' or on a mobile basis with reliable broadband connectivity where they would not be able to before.

There were several services that we identified as crucial to the start-up and scale-up businesses that have been a feature of the upstream and downstream space sector.

Legal and Accountancy

While prosaic these have a vital role in ensuring the company is set up correctly without problems in its shareholdings, legal structure, documentation or tax approaches that will manifest at a later point. Experienced accountants can help businesses navigate through the basics and more advanced aspects such the Enterprise Investment Scheme and R&D Tax Credits.

Some space companies have specialist legal requirements. This includes satellite licencing, frequency filing, export controls and international treaties (such as the Outer Space Treaty of 1967) and contracts like the Launcher Service Agreement (a core contract between the launch provider and satellite customer), which although mostly standard in construction, contains areas that require specialist space knowledge. Mostly these are provided by space specialists embedded in legal firms that cater for the general aerospace industry, and London rather than the Arc is the most common base.

IP Advisors and Patent attorneys – Ensuring that the company's intellectual property is protected and can be exploited effectively. These can be part of a legal firm, or a technology specialist.

Business advice and Market Research

Different companies we talked to had found different external advice useful, depending on what they needed to fill gaps in their own capabilities. This included business planning, marketing, bid support and access to finance.

The Arc is well provided with all these forms of professional service. The areas around each of the major cities and clusters in the Arc are well provided and many of the firms have strong experience in dealing with technology firms, and for example R&D Tax Credits or EU Horizon Grant applications.

Market research is valuable to help funding bodies and agencies understand emerging opportunities and under-resourced sectors, so they can more effectively and appropriately direct their support. Discussions between private industry and investors can also benefit from specialist independent market research, either to support a business case or scrutinise it.

In specialist sectors, such as space, that have peaks in activity (during a launch campaign for instance) and a high variance in project work, temporary capability gaps often emerge. There are therefore a number of freelance experts and specialist consultancies in the space industry that are ready to fill these gaps when needed. Hempsell Astronautics, in Bedfordshire, is one example of many small companies that provide consultancy services in specialist areas, in this case astronautical systems engineering, in the Arc.

The clustering of government space entities in the Arch, including the newly established Space Command based at RAF High Wycombe, generate a need for specialist consultancies to fill capabilities and advise on emerging opportunities or threats. Leonardo, based in Luton, and RHEA group, with a presence in Harwell, both supply specialist support and advice to the UK MoD. Meanwhile, civil contractors like Deimos UK, provide consultancy support and advice to UKSA on GNSS (following Brexit and the UK's exclusion from Europe's Galileo GNSS program) and to RAL Space on space weather, surveillance and tracking. Opportunities for the Arc in these areas are likely to grow as the UK develops national space capabilities and programs, like GNSS, that are independent from Europe and UK MoD (supported by increased military spending) take more of a forward-facing position on space issues.

Workspace

Everyone needs somewhere to work. Up to a few people this could be fairly ad hoc. Up to ten it seemed to be reasonably easy to find a place on a campus or business park in an 'accelerator' or 'incubator' building. Beyond this seemed to be a difficult phase with businesses often having a combination of rapid growth and uncertain cashflows. Above 30 or 50 employees, the growth rate was steadier and cashflows more secure so businesses could plan their space needs and put their name on a longer-term home.

In the middle range, 10-50 employees, there seemed to be an unmet demand for flexible space where companies could buy more space as they needed it, both for general office space and for cleanroom facilities for space hardware manufacture, assembly and testing.

At a larger scale here are many business parks and science parks across the Arc, space seems available, but price becomes a factor and we have seen this as a factor in some company's location decisions. Property markets are in flux after Brexit and Covid-19 and the outcome is not yet clear. The ideal solution may be to encourage the construction of larger workspaces within the 'wider cluster' where businesses can still share the skill and supply base, but spread the economic benefit.

Finance

Businesses need money to start up and to scale up. Many we talked to had found Innovate UK or ESA grants valuable at the start, and supplemented them with a combination of founder, 'friends' and angel

funding. In later stages, venture capital had been valuable for the few that had reached that stage. Bank loans are not relevant until a steady revenue has been achieved.

In the Arc there is quite a good early-stage finance capability, with established angel networks in Oxford (Oxford Investment Opportunity Network (OION) which reaches out to Buckinghamshire and Berkshire, and Oxford Capital) and Cambridge (Cambridge Angels, Amadeus Capital, Cambridge Capital Group). Cambridge also has two agri-tech focused groups: Cambridge Agritech, Eastern Agri-tech Growth Initiative. SEMLEP launched 'Central Arc Angels' in November 2020.

These networks attract a range of family offices and venture capital firms. In addition Longwall Venture Partners is based in Harwell and invests with a long-term view in start-up and early stage businesses in the healthcare, science and engineering, including space – past investments include Oxford Space Systems. Seraphim Capital is based in London, but invest in space companies in any geography including D-Orbit who have a presence at Harwell.

Space is a relatively unusual prospect, even in an Arc where investors and banks regularly see AI or Biotech companies. This could change and is addressed in one of our recommendations.

Insurance

Insurance is an important enabler in any industry to reduce risk to an acceptable level.

Third party liability (TPL) insurance is a prerequisite for satellite and launcher companies to receive the necessary government licences to operate. Depending on the value of their hardware, these companies may also choose policies that cover against loss of hardware or revenue. For example, many satellite companies insure against launch delays, because for every day a commercial satellite spends on the ground and not in orbit, it is not generating revenue. There are a number of space focused underwriters and brokers, either independently based in London or part of a Lloyds of London syndicate, that sell insurance products to space companies in the Arc.

Space technology companies partaking in potentially hazardous R&D projects and activities may also require specialist insurance. There are insurers that sell cover for a range of industrial accidents. For example, the propulsion companies at Westcott, and Reaction Engines at Culham, would have to take out such insurance to handle the toxic and cryogenic propellant they have to handle, and to conduct various (potentially explosive) rocket engine and satellite thruster tests.

Software and IT Services

The space industry is centred on data services, with satellites and spacecraft acting as data collection and delivery tools. Software and IT services are the glue that holds this all together.

There are several companies in the Arc that are involved in the distribution, processing and analysis of satellite data. Deimos UK in Harwell and Telespazio UK in Luton both market software applications that derive useful information and insights from EO satellite data, for crop management and monitoring the structural integrity of buildings respectively. Both companies also supply flight systems for satellites. Telespazio UK also run EO data quality programmes for ESA called QA4EO and are involved in data processing and archiving.

With a strong base of IT capabilities in Milton Keynes (such as IBM) and further expansion expected in this sector in the near future, the Arc has a foundation of skills and facilities to grow new opportunities in this area.

3.10 Other Opportunity Sectors

Energy

The Arc has considerable expertise in energy, and there are several space applications, however we did not rate it among the largest opportunity markets.

The Arc's energy expertise is widespread, including:

- Culham Centre for Fusion Energy, developing nuclear fusion reactors.
- Several renewable energy initiatives including Chelveston Renewable Energy Park and Energy Superhub Oxford, which links domestic solar cells to large-scale battery storage and electric vehicle charging to optimise usage.
- Oxford PV, who are developing perovskite based tandem solar panels for increased efficiency.
- The Faraday Institution, at Harwell, the UK's centre for battery research with a consortium of 21 UK universities and over 50 businesses.

The main uses use of satellites in energy (excluding extractive industries) are for inspecting utility networks (e.g. for tree incursion) and for the location and forecasting of renewables. Both of these are good sources of business for Earth observation or geospatial businesses like Rezatec or Spottitt. However, we do not consider them transformational for their sectors or the space sector.

It is possible that by 2050 we will have Satellite Solar Power Stations. It has not been possible to assess this technology in the scope of this study, but it is one that should be considered on the 'watchlist' for future UK investment.

Extractive Industries

Extractive industries, for example mining and quarrying, are one of the Catapult's market areas for satellite application. Within the Arc there is a significant amount of aggregates quarrying for construction, and with the pace of development this is likely to continue. Satellites can help identify

new sources and for larger operations are being used to automate quarry operations. They can also monitor quarries to ensure they remain within their agreed limits and conditions.

Overall, while there is some value in the Arc, it is not a large industry on the scale of other mining operations, and not an Arc strength, so we have not prioritised it.

4. Key Space and Space-related organisations

In this section, we list some of the main companies and organisational capabilities within the Arc space sector. These organisations have been identified and defined based on our understanding of capabilities and activities within the Arc gained during this project and drawn from several sources including:

- The Knowledge Transfer Network Space Landscape Map[9]
- The Satellite Applications Catapult Capabilities Catalogue[10]
- Analysis of proprietary company databases containing data from Companies House and other sources;
- Interviews and other interactions with members of the Arc space community.

To keep this relevant and to a manageable size have selected companies based on a size threshold (typically 20 employees or equivalent in turnover) plus those with an important or distinctive capability, particularly if it enables others – for example Open Cosmos or European Astrotech.

The companies and capabilities listed are not fully based on quantitative criteria or thresholds because data to support this is simply not available and judgement is required. There are several reasons for this:

- Standard classifications of company activities (SIC codes) are not well suited to identifying space companies in the wider space sector with many classified for example as engineering consultants or technical testing companies;
- Some companies have operations or customers that are both in the space and other sectors (for example engineering companies such as Mach-Tech, or geospatial intelligence companies such as ESRI);
- Companies have more than one location and their presence in the Arc may be only a small part of their operations (for example, Airbus DS or GMV);
- In many cases it is not clear where the boundary lies for defining a 'space company' and judgement is required, particularly in downstream applications markets. Urban Foresight, for

[9] https://space.ktnlandscapes.com/
[10] https://sa.catapult.org.uk/uk-space-capabilities-catalogue/

example, are a spatial planning consultancy that often use satellite derived data to support their activities, but for many of their clients such capabilities are not relevant.

- Data source challenges including, for example, that the KTN landscape map is based on self-reporting and therefore contains some smaller companies with limited space capabilities, and that the SA Catapult Capabilities Catalogue includes all identified space companies, many of which are small.

Finally, we note that any table in a report which lists capabilities will soon be out of date in a fast-changing sector such as space. We would therefore refer readers to sources such as the KTN Landscape Map and the SA Catapult Capabilities Catalogue which are regularly updated

Key Space and Space-related organisations

Organisation	Primary capabilities					
	R&D	Upstream space	Oper-ations	Satellite apps	Other	Notes
Companies						
Reaction Engines	✓	✓				Innovate SABRE propulsion and reusable SSTO launch system developers.
Telespazio UK	✓	✓	✓	✓		Large satellite system design, operations and applications capability (~100 staff) at Luton
Thales Alenia	✓	✓				Systems design, integration and manufacturing
Airbus Defence and Space	✓	✓	✓			Small presence at Harwell but very large upstream space facility (around 2,500 people) just outside the Arc at Stevenage
Lockheed Martin	✓	✓				Global space capability. Large facility at Ampthill, Bedford but more limited local space sector activity
MDA	✓	✓				Canadian company with significant space robotics capability in the Arc
Arquiva			✓	✓		National sat ops, broadcasting and media company with significant Arc facilities
Lacuna Space	✓	✓	✓	✓		Sensors and sat comms for IoT. Small, but near-unique capability.
Wyld Networks	✓			✓		Communications including satellite IoT. Based in Cambridge.
Hughes Europe			✓	✓		Sat comms
Oxford Space Systems	✓	✓				Developing deployable antennas for spacecraft. Around 40 staff at Harwell.
Rezatec				✓		Geospatial data analytics company, based at Harwell, about 50 staff
TTP	✓	✓				Communications scientists and designers
Vislink				✓		Communications for challenging environments
4links	✓	✓				Parts supplier for upstream space
GMV UK	✓	✓		✓	✓	Innovation and tech company. HQ in Madrid with UK subsidiary at Harwell.
Deimos UK	✓	✓	✓	✓	✓	UK subsidiary of Elecnor Deimos. Space systems design and consultancy. 30 employees at Harwell

Organisation	Primary capabilities					
	R&D	Upstream space	Oper-ations	Satellite apps	Other	Notes
Nammo UK	✓	✓				Design and manufacture of engines and thrusters for satellite orbit/altitude change. Around 30 employees at Westcott.
Marshall Aerospace	✓	✓				Aerospace and space
I Spatial						Large geospatial intelligence software developer (around 250 employees), based at Cambridge Business Park
ESRI UK				✓		HQed in the US with large UK subsidiary (around 300 staff) in Aylesbury. Key player in global geospatial community
ABSL Power Solutions	✓	✓				Design and manufacture of batteries or space and other challenging applications. Based at Culham with around 50 staff.
Open Cosmos	✓	✓	✓			Volume small sat designer, manufacturer and operator. Based at Harwell with around 50 employees
AgSpace, AgriMetrics and Crop Performance Ltd				✓		Three companies in the emerging space enabled agri-tech sector, based across the Arc in Harwell, Rothamstead and Cambridge respectively with around 60 staff between them
OceanMind				✓		Satellite applications to monitor fishing vessel compliance. Around 20 employees
RHEAtech Ltd	✓	✓			✓	Aerospace and security engineering services and solutions, system development, and technologies. UK subsidiary of Belgian company with around 25 staff at Harwell.
Focal Point Positioning	✓	✓				Tech to improve GNSS accuracy. Around 20 employees in Cambridge.
Astroscale	✓	✓	✓			On-orbit servicing and debris removal. Harwell based UK subsidiary (around 20 staff) of Tokyo, Japan headquartered company
MapAction				✓		Geospatial intelligence for global disaster relief. Around 20 staff in the Arc
European Astrotech		✓	✓			Westcott-based propulsion specialist. Only 10 employees but unique capabilities.
Airborne Engineering		✓				Westcott-based

Organisation	Primary capabilities					
	R&D	Upstream space	Oper-ations	Satellite apps	Other	Notes
Key public sector capabilities						
Satellite Applications Catapult				✓	✓	UK technology and innovation company (with public funding) focussed on commercialisation of space research. Around 150 staff at Harwell.
UK Space Agency					✓	Based in Swindon (just outside the Arc) the Government agency responsible for civil space strategy and regulation.
RAL Space	✓	✓	✓	✓		The space hub for UK research and innovation and part of STFC. 330 staff at Harwell and involved with around 210 spacecraft
STFC	✓				✓	STFC are the parent or RAL Space and manage the Harwell space cluster
ESA	✓	✓	✓	✓		ESA's UK base and HQ for telecoms and business applications is ECSAT at Harwell, the European Centre for Space Applications and Telecommunications. Harwell is also home to the ESA Business Incubation Centre (BIC)
UK Space Command			✓		✓	RAF High Wycombe is currently home to National Air and Space Operations Centre (NASOC) and will become home of Space Command in 2021
University of Oxford	✓	✓			✓	Strong engineering and upstream space R&D. Upstream space facilities include the Infrared Multilayer Laboratory and heat transfer laboratory.
University of Cambridge	✓				✓	Upstream space capability mainly focussed on theoretical and observational aspects of astronomy. World leading computing and AI capabilities.
Cranfield University	✓	✓			✓	R&D focussing on sensors, precision engineering, Earth observation, spacecraft/ satellite design, and mission design. Clean room and CubeSat laboratory facilities.
Open University	✓	✓			✓	Strong upstream space engineering pedigree. Built parts of the spacecraft and Ptolemy instruments on ExoMars Trace Gas Orbiter

Part 3: Vision, Recommendations and Action Plan for developing the Arc Space Sector – *Rising to the Challenge*

Overview – Rising to the Challenge

By 2050, we must overcome great national and global challenges, in environment, transport, health and other areas of our lives. Space will play a vital part in tackling those challenges, and by 2050, space applications will be everywhere, monitoring our environment, guiding our transport systems, checking our health. They will be an invisible part of our lives just as the satellites behind weather reports, TV broadcasts and mobile phone navigation are invisible today.

This transformation offers the chance for the UK to become a global leader in many new markets that will emerge, and that opportunity starts in the Oxford-Cambridge Arc.

The Arc is a unique place with a high concentration of the national and global problems, but also a high concentration of world-class problem-solvers. These problem-solvers work in space and other key sectors, in academia, business and public life. They will bring together their expertise to create transformational innovations, approaches and businesses that will enable the Arc to achieve its goals of green growth, and to bring economic, social and environmental benefits to other parts of the UK, and to the world.

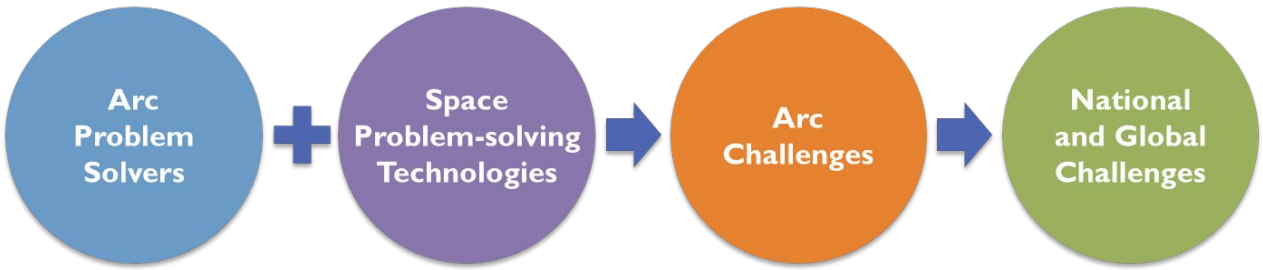


Figure 3-1: Red Kite's overview vision for how the Arc and its space sector can rise to the challenges in the Arc, the nation, and the world.

As examples, the Arc can innovate and pilot approaches to Net Biodiversity Gain and Net Zero climate change impact. It can start immediately by linking these to the Arc Spatial Framework and the EEH Transport Strategy.

The Arc's space industry will also expand. In addition to growing current activities, our vision is that national space strategy includes investments that draw on the Arc's skills and offer high scale potential, such as propulsion and in-orbit servicing.

The Arc's space sector has been doing many of the right things and should build on the success of the Harwell and Westcott clusters, working with the local hi-tech supply base. This should be supported

by collaboration with high-priority sectors and by investment in STEM skills and basic capabilities. Much of this can be started with a small investment focused on the big problems – setting the challenge for the innovators in the Arc.

Insight – Problems and Problem-solvers

In developing the earlier parts of this work, covering Existing Recommendations and Strategies (Part 1) and Capabilities in the Arc (Part 2) we reviewed documents comprising over 1600 pages. We were struck be a clear pattern to the themes that emerged.

The sectors in which problems are identified…:

- National and Global Challenges, for example the Grand Challenges of the Industrial Strategy, and more specific ones such as how to implement Net Biodiversity Gain or new mobility services.
- Local Challenges in the Arc, which due to the Arc's nature are often intensified versions of the national challenge. The Arc documents consistently identify environment, transport and spatial planning (space for housing), which are prime examples.

… are sectors in which two types of problem-solver are strong:

- Arc Problem solvers. The Arc has a high concentration of expertise in the priority sectors relevant to local, national and global challenges, as we have identified in Part 2, including businesses, universities and other institutes and organisations active in those sectors.
- The Space sector, which can bring new communication, data, insight, control signals and more with increasing resolution and timeliness that can transform the priority sectors.

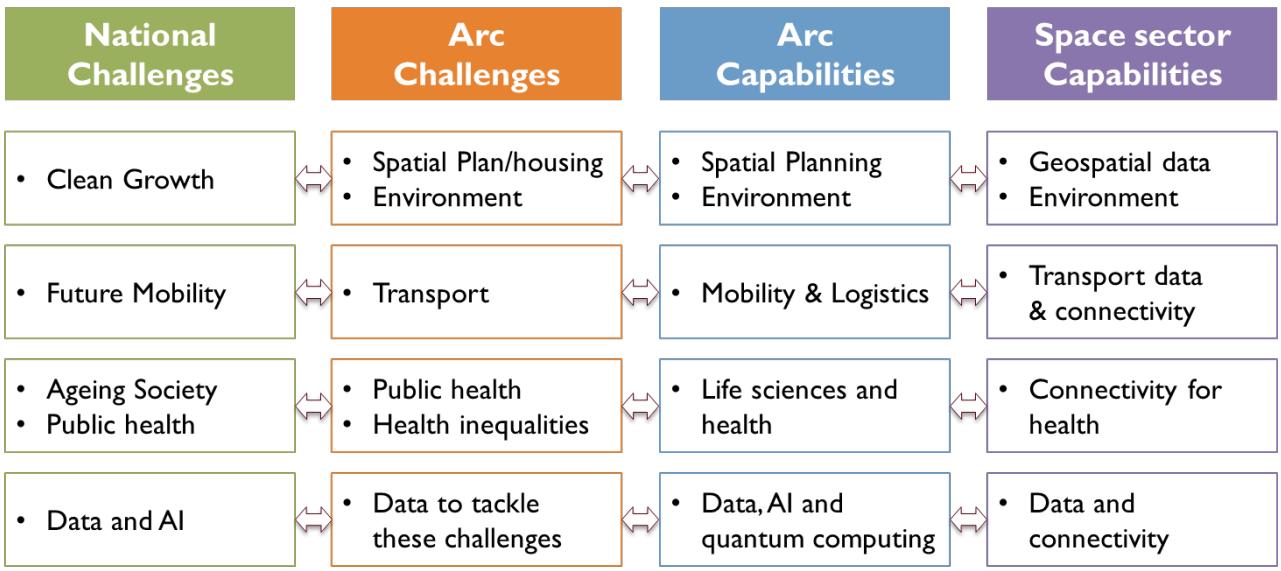


Figure 3-2: Challenges, and the problem-solvers in the Arc

This is clear when set out in Figure 2. As we discussed this, we brought together what we had learned, across documents, research and interviews, our experience of upstream space and downstream

applications, of economics and public policy, and of commercial markets and entrepreneurial innovators. We considered how the strengths of the Arc's sectors expertise and its space sector could best be combined to tackle these challenges, and what the impediments were. As a result we developed the 'Rising to the challenge' process.

'Rising to the challenge' process

The Space sector can work with adjacent sectors to tackle challenges in the Arc and then extend the benefits to the UK and worldwide. Innovation is the fire-starter of this process, but our research points to the importance of establishing markets – otherwise the fire goes out. This is why the 'valley of death', where new companies run out of funding before generating significant revenues, is high in the minds of the technology investors we have talked to. For commercial markets, investors can make a judgment based on research, but for public markets this is very risky, and most of the opportunities for space we described in Part 2 are created by the public sector, either by direct procurement or by regulation or other incentive.

This approach operates on individual problems, but its cumulative ambition is high. We propose an 'Arc Challenge Fund' and programme to tackle pivotal challenges in clean growth, climate change, air pollution, public health and sustainable transport. It would make use of a laboratory 100 miles long by 40 miles wide, staffed with some of the world's best scientists and engineers, training the next generation, and with entrepreneurs and investors ready to commercialise the ideas that spin out. It is not a 'big bet', but a series of smart bets – we estimate a fund of £3-10 million a year would fund one or two competitive, problem-focused innovation challenges each year, allowing the programme to start small and prove its worth to justify a total innovation investment of £100-300 million over 30 years.

This is the minority of the funding – the markets created will involve much higher levels, but will be good value as the each of target problems cost UK society many billions of pounds every year. Establishing a clear sight of the market at the innovation stage is a vital part of our proposed process. Showing this approach works in the Arc, would have enormous potential benefits to the UK, both in the societal and environmental benefits of solving the problems, and in the economic value of commercialising the solutions worldwide.

To address these big public challenges, and commercial opportunities, we need three stages, which in outline are:

1. **Innovation.** Creating a new idea or approach and bringing it to a viable technical reality.
2. **Market building.** Creating a market for the innovation, with clear funding paths to provide certainty for effort and investment and enabling the innovation to prove its benefits and its business model. This is often forgotten or fails, and leads to the 'Valley of Death'.

3. **Wider application.** The proven innovation will now be a good proposition for similar national and global situations. The business will have a revenue stream and a proven model, so is a good investment case for scale-up. Others will follow, and a new market will be created.

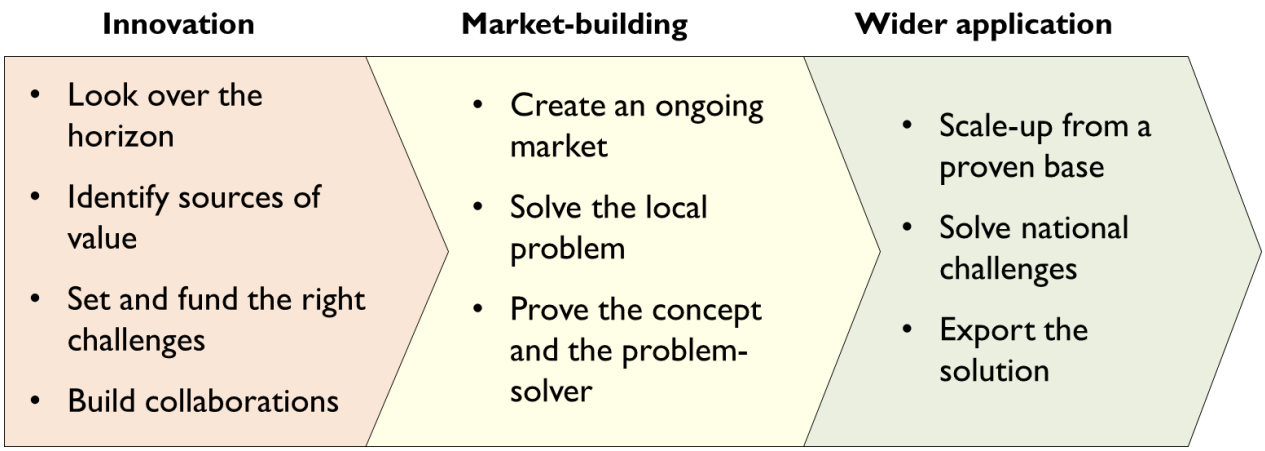


Figure 3-3: Rising to the challenge process

Innovation

- **Looking over the horizon** to the next big opportunities and challenges should be a regular collaborative activity in each major field. The thinking needs to be 'blue sky', engaging openly with a diversity of thinkers, but then applying knowledge to assess mid-term viability and judge the right time to invest. For space-related sectors, the Satellite Applications Catapult is in a good position to be the convenor of a cross-sectoral groups to do this.

- **Identifying the sources of value** is particularly important for the many challenges where the value manifests through the public sector. Thinking through the value chain can identify potential funding sources, we think there will be three types:
    - Commercial markets and existing public markets, for example communication services or utility network inspection where the market and value is already established.
    - New Public markets where a 'polluter pays'[11]. For example, Net Biodiversity/ Environment Gain verification funded from developer contributions; Carbon sequestration and verification funded by carbon pricing; Preventative health improvements funded knowing that they will make savings in future treatment costs, or by taxation of unhealthy products and activities. The government of the day may need to make difficult choices in implementing these, but there is precedent in Fuel Duty, Soft Drinks Industry Levy, the coming Environment Bill and increasing positivity in discussions of carbon prices.
    - New Public markets – government funded. Where there is public value, but there is no specific 'polluter', the government (i.e. the taxpayer) would pay, but with reference to

[11] 'Polluter' is used here in a general economic meaning of an entity that damages a public good. .

savings or benefits created. For example Transport system connectivity improvements might be funded with reference to the health and carbon savings they create.

- **Set and fund the right challenge**. Set an innovation challenge with an objective that is relevant to a future market – either commercial or public. For commercial markets this requires some research into current markets and what innovation might justify public investment. For public markets the relevant innovation agency (e.g. Innovate UK, ARIA[12]) should work with appropriate 'customers' such as the Arc Growth Body[13], Local Authorities, Natural England, DfT or NHS to create a 'customer/value-led' call with some commitment to a market to follow. To maximise innovation the challenge should focus on the functional objectives rather than specifying a particular technology.

  Traditional funding approaches specify a co-funding mix, usually requiring 50% from the innovator, sometimes higher (e.g. 60-75%) for low TRL[14] research. This puts off many potential innovators. 75-100% development funding could be more often used (as it is by ESA) for early stage or risky projects, but there is some risk that companies pursue grants without the intent of commercialising.

  An alternative would be a competitive tender approach. This works particularly well for the problem-focused approach we have outlined where it is solving the problem that matters, not the technology or approach. We propose an 'Arc Challenge Fund' of £3-10m is created in to launch one or two challenges each year with a fairly open functional brief. The offer need not be restricted to organisations in the Arc; local organisations may benefit from proximity and local insights, but they may form out-of-area partnerships to get the right skills mix (as we did for this project). The NASA COTS and CRS example below shows the approach, although here the challenge was upstream, where most of our challenges would be downstream.

- **Build collaborations**. Tackling these challenges will be most effective with business, academia, research organisations and others working to combine their knowledge and skills. Innovation agencies and the Catapults can bring these people together and foster joint approaches. This already happens with workshop sessions on, e.g. space and agriculture and space and rail freight, but could be extended into more active match-making directed at these calls. Problems that are too large for this process on its own may require collaboration on a wider scale – these 'transformational programmes' are described in the Foundations section below.

[12] The new Advanced Research and Invention Agency announced 19 February 2021
[13] Announced as intention by Government on 18 February 2021
[14] Technology Readiness Level – a measure of how close a technology is to market

Market-building

- **Create an ongoing market (Public markets)**. The customer now needs to follow-through with its commitment to a market, offering a contract that addresses its challenge. For example, the Arc Growth Body might offer a contract for three years of Net Biodiversity Gain verification. The contract would not need to be awarded to the winner of a preceding innovation grant, or to a business from the Arc, though these may have an advantage.

- **Create an ongoing market (Commercial markets)**. For commercial markets the business needs to communicate its proposition effectively to its customers. If the company cannot do this on its own, the business support community, including the space business incubators can help.

- **Solve the local problem**. The winning business delivers on its contract, solving the problem (or at least part of it) in the Arc.

- **Prove the concept and the problem-solver**. In solving the problem, the business proves its approach in a real-world situation. It also earns revenues, which validates its business model and makes it a much more viable prospect for investment.

The Market-building stage is so important because confidence in a market enables confidence in investment, both of money and of effort from innovators and business founders. This is a crucial factor missing from parts of the UK innovation environment today. The issue for space is that many of the opportunities we describe are managed by the public sector: environment, transport infrastructure, health, spatial planning. The public sector does not always adopt new technologies at rapid pace. So unlike commercial markets, innovators cannot develop a better mousetrap and offer it to consumers or businesses confident that it will prevail in the market. In this environment, they will be reluctant to invest time or money. This puts the onus on the public sector to create a clear market for innovation, where it would create benefits for the public.

This is not a completely new approach. A hugely successful example in the space industry was NASA's COTS and CRS programmes (see box). This was so successful they followed the same model with the Commercial Crew programme. There is a more extreme version in the 'Prize' approach, ranging from the Ansari X Prize[15] for a reusable crewed spacecraft to the SpaceNet Challenges[16] to apply machine learning to mapping challenges, but these do not usually establish an ongoing market so may leave the winners to struggle. The Ansari X Prize was won by SpaceShipOne in 2004, but its descendant, Virgin SpaceshipTwo, is still not in commercial service 17 years later.

[15] https://en.wikipedia.org/wiki/Ansari_X_Prize
[16] https://spacenet.ai/challenges/

Case Study: NASA COTS and CRS

COTS (Commercial Orbital Transportation Services) and CRS (Commercial Resupply Services) were NASA initiated programmes to develop and procure respectively commercial freight delivery services to the International Space Station (ISS). As NASA Administrator Dr Griffin stated, "With the advent of the ISS, there will exist for the first time a strong, identifiable market for "routine" transportation service to and from LEO." COTS and CRS used this market-building opportunity.

Under COTS, NASA initially signed development contracts with SpaceX and Rocketplane Kistler in 2006, however Rocketplane Kistler pulled out in soon afterwards and NASA re-awarded the contract to Orbital Sciences in 2008. The programme resulted in the development and demonstration flights of SpaceX's Falcon 9 launcher and Dragon capsule, and Orbital Sciences' Antares launcher and Cygnus capsule. Two new launchers and two capsules for a public investment of $821 million with commercial partners adding $1044m[17]. The remainder of the investment was made by the private companies, knowing that these assets would have commercial opportunities under CSR and in the open market.

SpaceX Dragon Capsule

NASA's Aerospace Safety Advisory Panel considers the COTS programme "extremely successful" and says "we would encourage NASA (and other Government agencies) to consider adopting similar approaches where possible."

The first CRS contracts were awarded in 2008, $1.6 billion to SpaceX for 12 Dragon cargo missions and $1.9 billion to Orbital Sciences for eight Cygnus missions to ISS. In 2016 CRS phase 2 contracts were awarded to SpaceX, Orbital ATK, joined by Sierra Nevada with their Dream Chaser lifting-body spaceplane. Similar approaches are now being used for Commercial Crew programmes and some aspects of the Artemis lunar programme.

Wider application

- **Scale-up**. With a proven product, reference customer and income stream, the business can approach other customers, and attract investment (UK and inward) and employees for expansion. Depending on the type of business, this may happen inside the Arc, perhaps in areas with more space for economic growth, or outside the Arc – a 'levelling up' opportunity.

- **Solve national challenges**. Having tackled challenges of environment, transport and health inside the Arc, successful space-related businesses are likely to be in demand in the many places across the UK with similar problems. The approaches will be quickly adaptable and generate local employment, economic, environmental and social benefits. UK Space Agency, UKSpace and the Catapult can help spread the word in the UK.

- **Export the solution**. Other nations also experience the same challenges. Arc-developed solutions can be applied, earning foreign income. UK Space Agency, UKSpace and the Catapult and UK DIT can help take the message internationally.

[17] https://www.nasa.gov/content/cots-final-report 2014

Foundations: Clusters, Collaboration and Capability

This vision requires expanding capability in the industry and a highly collaborative approach. The 'Three Cs' foundations of Clusters, Collaboration and Capability are crucial to enabling the vision.

Clusters, co-locating concentrations expertise and facilities, have long been considered as an important driver of innovation. We assembled academic and practical studies of this, combined with our interviews for this study and knowledge of the UK and overseas space and other technology sectors. The benefits of clustering can be summarised as three areas: Sharing, Matching and Learning as summarised in Figure 4 below.

Sharing

Indivisible facilities

In public goods: Rocket testing facilities, clean rooms, Etc.

In private production processes or outputs: The 'factory town'

Implies cluster size is driven by trade off between the cost of the facility and the transport cost of accessing it

Sharing gains from a wider pool suppliers

E.g. enabling a firm to get better value by being able to choose the right supplier from a wider pool

Implies cluster has the geographic scope of trade/transport distances

Enabling specialisation because of larger markets

E.g. enabling a specialist space engineering firm to thrive because of a large pool of local customers (Usually 'local' is defined by transport costs).

Sharing risk

With risky investments, and 'shocks' to demand, there are greater opportunities in a cluster to share labour and pool risk

Implies cluster operates at the scale of the local labour market

Matching

Better labour market matches

When Telespazio looks for an engineer, the candidate they find is likely to have more relevant skills

Better land and capital market matches

When selling assets and property they stay idle for less time

When Companies need bigger premises there are more suitable places available

Easier to bring new ideas to market when matches with specialised suppliers is easier and cheaper

Higher probability of matching

Fewer unemployed resources and capital when there are a lot of different activities that could use them

Engineers living in the cluster are likely to spend less time between jobs and so have less risk of being unemployed

Reduced risks from making 'partner specific' investments

Incentive to develop specialist skill is stronger because it can be used in many places

When making partner specific investments, there is a smaller risk of 'renegotiation' when alternative partners are available

Learning

Generation of knowledge

Process innovation is easier with more different local models to copy from, e.g. Duranton and Puga model where:

Diversity reduces process innovation costs so firms start up and experiment in more diverse areas

But economies of scale are larger where similar processes cluster, so once a product is mature the firm has an incentive to move to an area more specialised in the process that it uses where costs are lower

Skill acquisition: Younger workers learn their craft and experienced worker benefit from new ideas

Diffusion of knowledge

When market information is noisy, there can be benefit in seeing what others do. E.g. if firms gear up for anticipated new contracts, then other firms can see this market signal and follow. Can lead to 'inefficient herding'

Accumulation of knowledge

Long-term and sustained growth in skills and knowledge as we build on history

'**Spatial information externalities**' in other words 'the coffee shop effect'

Figure 3-4: Cluster benefits: Sharing, Matching and Learning

When we applied this to the Arc space industry, we could see the benefits occurring on 3 distinct geographic scales (Figure 5). Interestingly none of these are specifically the scale of the Arc. Two occur within the Arc and would be seen in many industries. The final one occurs on a much wider scale due to the high value products and collaborations of the space industry.

Our vision is to build on the existing space clusters at Harwell and Westcott, with a focus on the activities that need the closest cooperation: R&D and testing for upstream space, and applications that need the close integration with upstream.

Scale	On site (up to 1km)	One hour travel (up to 60km)	National (up to 1000km)
Cluster benefits observed	• Serendipitous meetings 'the coffee shop effect' • Easy to arrange meetings • Rapid repeat R&D/ testing use of facilities	• Regular suppliers • Employees (maximum commuting range) • Planned networking (maximum distance travelled to event)	• One-off journeys for a £100k or £100m satellite • Major collaborations e.g. Arc firm with University of Edinburgh • Major events e.g. UK Space Conference

Figure 3-5: Cluster benefits observed in the Arc Space sector

Other sector applications and other linkages such as aerospace should normally develop in clusters of expertise for the 'customer' sector and are discussed in the collaborations section below. This is not absolute, but it for any major cross-sector initiative is worth considering whether it should be located in the space cluster, in the application sector cluster, or near the actual customers – if more than one of these can be achieved, so much the better.

Around Harwell and Westcott, it is valuable to develop the wider cluster as some of the space businesses have already done by investing in their supplier base. We see a programme that reaches out to potential hardware and software suppliers and lists them as 'space-interested' or 'space-experienced' to make it easier for space companies to find inputs, accelerating the growth of the UK's space-capable industrial base.

Collaboration continually creates value in the space sector. Many of the of the successful ventures we talked to were the product of partnerships between a combination of academics, technologists and business-minded people, with the public sector providing a kick-start with funding or access to facilities or other needed capabilities.

Here the Arc offers its great advantage: **the high concentration of related sectors**. We see benefits to be unlocked by cross-pollinating space expertise with the priority sectors we have identified.

This collaboration will range from small to large activities. At the small scale are, for example, sector/problem focused workshops like those the Catapult hosts today.

At medium scale are collaborative research projects that advance knowledge but also allow time for informal knowledge exchange, we see great scope and value here. For example:

- Funding two geospatial data experts into the AI cluster at Cambridge to explore what is possible to advance town planning, with an input to the Arc Spatial Framework
- Placing an Earth observation expert in the Agri-EPI Centre in the eastern Arc agriculture cluster, working on a specific problem, but also serving as a resident expert on satellite data capabilities, and learning first-hand about farmer needs and attitudes on information systems.

- Bringing Local Authority Transport Planner into the Satellite Applications Catapult's Transport team for a three-month placement, to gain knowledge on their working practices and to leave them with an understanding of the current and coming capabilities of satellite data.
- Running a joint project with the Connected Places Catapult and the University of Northampton to see what can be achieved with satellite IoT in the SEMLEP logistics cluster.
- Embedding a satellite data expert with knowledge of Positioning, Navigation and Timing into the health cluster at Stoke Mandeville to develop activity 'nudge' apps for social prescribing.
- A technology transfer programme between the Arc's upstream space sector and the aerospace clusters at Cambridge and Cranfield, including advanced materials and manufacturing techniques that may be valuable across both sectors.

At the large scale would be transformative programmes to tackle aspects of Grand Challenges that are beyond the 'Rising to the challenge' process described earlier. This is where larger investment or wider collaboration is required over many years (e.g. £10-100m per year), either to solve a difficult problem, or to operationalise a solution. Cross-sector collaborations would be assembled across the Arc, between and probably beyond, requiring active collaboration building, not just serendipity, but it will be easier if cross-sector and cross-institution links are already in place through initiatives described above. Examples include the Faraday Institution for battery development and the Zenzic collaboration on connected and self-driving vehicles. Decisions on this scale would be national, but the Arc is well placed to host them in the sectors in which we have described its world-leading expertise.

Overall, this process of enhanced, directed collaboration increases the chances of spotting opportunities for innovation, and increases the chances that innovations can be turned into successful markets.

Capabilities cover the core of what is needed to deliver the vision, and these foundations must develop as the sector develops. Our work identified four areas particularly relevant to the Arc.

- **Skills** was a great concern across our research. By 2050, the children entering secondary school this year (2021) will be 40, so the choices they make at school will affect the skills available to the space industry. But we heard other issues as well: discontent with housing availability and pricing, transport (bus and bike more than car), and leisure facilities around Harwell. It is worth noting that the comments raised reflected the demographics of the younger workforce that will supply the industry (less likely to drive, more interested in nightlife) than the study team or most of the spatial planners and decision-makers we have met.

  The space sector can help to address its own problems. It can provide the inspiration for a child to choose STEM subjects at secondary school, or for an apprenticeship or degree with the additional knowledge that there are many good local jobs that need them. Great examples are the European Astrotech weather balloon GPS outreach described in Part 2, the OAS

training centre at Culham where Oxford Space Systems and Reaction Engines train apprentices, and the proposed STFC 'skills factory'.

Satellites can also provide the geospatial knowledge to improve spatial planning, so people live closer to work and transport systems are more usable and sustainable. Even at the draft stage of this project there was interest from the MHCLG Arc Spatial Framework team in finding out how satellite data and the latest geospatial techniques could help them in their task.

- **Facilities** need to keep pace with the industry. Following the recent opening of the National Satellite Test Facility at Harwell and the National Propulsion Test Facility at Westcott, there were no urgent calls from our interviewees for major new technical facilities, although more clean room space will be needed as volume increases. RAL Space is conducting a more thorough survey of future needs. The main area of need identified is for affordable, flexible workspace for small high-growth businesses of 10-50 employees. This is a tricky stage because growth is rapid but cashflows are usually not strong so the company cannot usually buy ahead. Harwell and other Science Parks try to facilitate growth by enabling such businesses to move between premises as they grow, but purpose designed flexible space (such as the Harwell Gateway proposal) would be ideal.

  Providing space to grow for high-value businesses is an important enabler for the space sector's and the Arc's success. We note again the value of clusters, and that does not mean everything should happen at Harwell, but that other sectors should be encouraged in other geographic clusters.

- **Finance** is essential for business growth and while Cambridge and Oxford have strong technology finance communities, space is still quite a new proposition. Longwall Venture Partners and Seraphim Capital are notable exceptions. The space community should be more visible in the financial and business community, and aim to be seen as a 'regular' business sector. Sometimes it is best not to talk about innovation (which a banker will read as 'risk') and talk about committed revenue contracts and a good cashflow record.

  The space industry can help itself here, by collecting and talking about business success stories, not just technical success stories. In the next few years, these should accumulate rapidly.

- **Business support** had proved essential for many of the businesses we talked to, allowing them to access skills not in their team when they were small. Key skills included legal and accounting to ensure that the company was founded in a way that would not cause problems later. Intellectual property to ensure the value of its knowledge assets were protected. Marketing for businesses who had got the technology right, but had not translated that into a proposition that resonated with their intended customers. Many UK space businesses have benefitted from ESA's Business Incubation Centre programme. Other programmes such as SPARK or LEP

support are valued by businesses that find and use them, although the offers vary and other businesses piece together their own support from local advisors.

The Arc's four Local Industrial Strategies propose improved business support and scale-up support across the Arc. The consistency of this would improve communication of what was available. There is a possible case for an Arc space business incubator to increase capacity, but we did not see an obvious gap that did not compete with ESA's programme, so this would essentially be doing more of a good thing.

A space-enabled Arc, a space-enabled nation, a space-enabled world

Rather than starting our detailed vision with rockets and satellites, we will start it with the challenges that face society, how they can be tackled, and how space can play a collaborative role in that. As we have shown in Part 2, the Arc has a unique combination of world-class skills in academia, in technology and in business, across the space sector and across the 'challenge' sectors: environment, mobility, health and ICT. If anyone can innovate to find solutions, the collaborating people of the Arc can, just as they innovated to create a low-cost vaccine to Covid-19 in record time.

The next thirty years must and will see a transformation in our approaches to environment, transport and health. We are in a climate crisis with the human and economic costs becoming more evident every year. Air pollution is a global and national problem, with over 4 million deaths worldwide, and 30,000 in the UK, every year. Physical inactivity is responsible for one in six UK deaths, but our current transport system makes walking or cycling unattractive for most people. These problems are starting to be tackled, and space, and the Arc have a big role to play.

Here we look at four areas of challenge and opportunity. These are closely aligned to the four 'Grand Challenges' of the National Industrial Strategy: Clean Growth, Future Mobility, Ageing Society and Data and AI. In our Vision, the Arc uses its capabilities, linking space with other sectors to tackle these

Clean Growth – Spatial Planning and the Environment

To gain the full economic benefits of the Arc will require substantial housing and business growth: 23-30,000 net homes per year according to the National Infrastructure Commission. This intensifies the need for good spatial planning, which is the process by which we decide what goes where, and on 18 February 2021 the Housing Minister Rt Hon Christopher Pincher announced the development of an Arc Spatial Framework by 2022 and the intention to establish an Arc Growth Body[18].

The cooperation in the Arc and between Arc and central Government, the vision in of the Arc Spatial Framework, some of the ground already laid in the Environment Bill, and the capabilities in the Arc in

[18] https://www.gov.uk/government/news/government-plan-to-transform-oxford-cambridge-arc-into-uk-s-fastest-growing-economic-region

the environment, in geospatial data and in satellites provide an unmatched opportunity for innovation and to chart the way forward to a planning system that finds better balances for nature, people and the economy – for all must co-exist.

We have identified several possible applications for this approach. The Arc is already committed to Net Biodiversity Gain on new development and this is likely to become a national requirement in the Environment Bill, so we use that as a detailed example of how the Arc 'Rising to the Challenge' process can work. Other beneficial outcomes include: permeable and navigable neighbourhood environments, good insulation and thermal characteristics of buildings, sustainable patterns of activity that promote health and minimise pollution, carbon emissions, noise and congestion, and many others. Emerging satellite-based capabilities offer the opportunity to measure and monitor these frequently and at detailed spatial resolutions. This kind of capability was previously unimaginable in spatial planning and opens the door to innovative approaches that could deliver better outcomes.

These markets and quasi-markets for spatial planning outcomes deliver societal benefits. The public sector is therefore the main customer, but money could be raised through environmental taxes with the 'polluter pays' principle. Innovation on the part of the public sector is likely to be a key driver for co-developing policies and satellite enabled products to support them. Examples could be:

- Verification of **Net Biodiversity Gain** from development. In our vision, this will be extended into a wider Net Environment Gain, a full natural capital approach. The Arc's planning authorities (or the Arc Growth Body) will keep track of natural capital across the Arc, with particular focus on development sites and compensation sites, ensuring that the developers' promises for compensation were delivered. Satellite data will play a key role in covering the richness of data across a wide area. (See box)
- An **outcome-based Environmental Land Management System**. With satellite verification there is the opportunity for a real market in ecosystem services where the government could incentivise landowners to provide beneficial environmental outcomes.
- Developer contributions based on measured **environmental performance of a development**. Monitoring of thermal and pollutant emissions from developments (either direct form satellite or via IoT sensors) enables contributions to be linked to the measured levels.
- Developer contributions or incentives linked to **travel and health outcomes**. Monitoring of induced traffic from developments can inform development design, and potentially drive incentive structures that nudge developers to deliver developments that deliver sustainable travel and healthy activity patterns.

'Rising to the Challenge' – Net Biodiversity Gain Verification example

The Arc is committed to the principle of Net Biodiversity Gain, but there is currently no easy way to verify the impact of the development or the compensation. Satellite technology could help and demonstrates the two steps of innovation and market-building. It is important that the need for this becomes large if the Environment Bill passes in its current form, so there is a large potential market to encourage innovators.

Stage 1: Innovation. We suggest starting with an 'Arc Challenge' tender for development of Net Biodiversity Gain verification approaches. A functional specification would be set by the Arc Growth Body with scientific advice. Development contracts might be awarded to two or three consortia who bring together the best combination of scientific and process skills. They would be funded according to a judgement of how risky the technology challenge is, 100% if the technology is at very low readiness level, but much lower if it needs less development.

Stage 2: Market-building. The market is built by offering a contract for say three or five years of monitoring services. This could be funded by a small part of the Arc's CIL or LGF funds on the principle that the 'polluter[19]' (in this case the developer) should ultimately pay. It is the coming of this contract that provides the main incentive for businesses to get involved.

Stage 3: Scale-up. The winner(s) of the service contract will have solved a significant problem for the Arc. This is also a national problem and there will now be a proven model for solving it, which will advance the Clean Growth Grand Challenge across the UK, particularly if the Environment Bill is passed making 10% biodiversity net gain a legal requirement. The model may be observed and adopted by other countries facing the same challenge. The winner(s) may or may not originate from the Arc, but the skills in the Arc favour this. They will certainly benefit from having a proven reference case, giving them a strong position for other opportunities to sell their expertise in the UK and worldwide. This proof of their business model will make them investable, and no doubt create imitators, and so a new small industry in natural capital monitoring and verification is created with the Arc and the UK as leaders.

Carbon pricing and carbon credits. The UK is legally committed to reducing greenhouse gas emissions to **Net Zero** by 2050, and EEH[20] and Oxford have already announced aspirations to reach that goal by 2040. To achieve this requires regulation, pricing or more complex schemes. The policy drive needs to come from Government, but the Arc is an ideal test-bed or 'Living Lab' with a combination of proactive thinkers, Local Authorities already consulting on Zero Emission Zones, transport, environment and satellite data experts to construct a pilot system. Over the next few years, the Arc's skills could be used to develop and test **carbon pricing and carbon credits** in transport, environment, agriculture and more – either in reality or in 'shadow' collecting data to support future national schemes. Satellites enable this through ubiquity of data collection, three examples are given below.

- Collecting **vehicle movement data for carbon and congestion-based road pricing**. Always-on connectivity and positioning allow sophisticated road pricing systems to be deployed, which could be linked to vehicle energy use or emissions through on-board sensors.
- **Measuring organic soil carbon for carbon credits**. Satellites, directly and with IoT ground sensors can measure carbon sequestration in soil and this can be used as the basis for payments to farmers and land managers for carbon credits, with a high assurance level.
- **Verification of carbon tax border adjustments**, for example if there is a carbon tax on beef and dairy products there should be a 'border adjustment' for imports to ensure a level playing field, and this would vary according to farming methods. Satellites can be used to monitor livestock numbers, grazing and feeding at farm level anywhere in the world to ensure the right tax levels are claimed.

[19] 'Polluter' is used in its general economic context as causing damage to a public good, in this case the natural environment.
[20] England's Economic Heartland, the Sub-national Transport Body that is slightly larger than the Arc

Other applications may not be suitable for live 'markets', but are still valuable. In the spatial planning process for example, planning new settlements and modifying existing ones so a high proportion of people live within a 15 minute walk of essential daily requirements, the '15-minute neighbourhood' principle that has been shown to reduce traffic and improve social cohesion in Paris and other places. Or flood modelling using satellite data, advanced processing techniques and high-performance computing to compare options for settlement location and water management options on a catchment scale. The Natural Capital approach provides an excellent framework to consider others, and our vision includes extending the satellite role to planning and monitoring across the full range of Natural Capital, in the Arc, the UK, and worldwide.

We cannot afford to wait before doing this. We need these environmental regulations and the systems to support them in place by about 2025, so they start having meaningful effects by 2030, to halt the damaging trends to our climate and ecosystems before they reach irreversible tipping points. Then 2030 to 2050 is the long haul of gradual repair to our natural systems, verified by satellite.

The Arc team within MHCLG are beginning their process with an audit of the data landscape within the Arc. This is a clear and immediate opportunity for the government Arc team to engage with the geospatial community to explore what data is available and how this could be used to position the Arc as a testbed for innovative spatial planning approaches.

Agriculture

In addition to the agriculture connections above, satellite data is increasingly used to increase farming outputs while reducing the use of costly or scare resources, and this will increase as services because cheaper and easier to use. Precision farming applications help farmers to apply just the right amount of water, fertilizer or pesticide to their fields, and link to weather forecasts to plan the best time to harvest. Other applications help to optimise grazing patterns for livestock. These applications are happening now, but the costs mean the early adopters are larger farms. Cost reductions from cheaper satellites and low cost IoT sensors will make them more accessible to a wider range of farmers.

Further out, as farms become more automated, reliable communications will be essential. Here satellites will be valuable as the main or backup communication channel for sensors in fields, on livestock and farm equipment. A further application is in food traceability, some applications already being able to link the food on your plate to the farm where it was grown, which can be valuable for branding or leisure economy opportunities.

Mobility

Our vision for mobility is transformative and based on discussions in the local strategic transport community. If growth continues with the same dominance of private vehicles, whether those are fossil-fuelled or electric, human-driven or autonomous, our roads and streets will be increasingly

choked. Building new roads has not proven a solution, as it creates more traffic. So, our vision is a multi-modal solution that aims to deliver EEH's target of a **net zero transport system** by 2040[21], but will still be developing in 2050.

As the Arc's growth is planned, we envisage a use of geospatial data in **transport planning** to reduce the need for motorised journeys. Satellite and other data will be used to model whether new homes will be near workplaces, shops and schools, perhaps aiming to create '15-minute neighbourhoods'.

Next is the enablement of **modal shift**, away from private cars towards public, shared and active transport. That will happen at the planning stage, where geospatial data may help to locate near public transport hubs, or the best places for bus stops or shared car pools. It will happen at the journey planning stage where people are presented with choices that show their best options for getting from A to B by bus, electric bike or car (or any combination), showing cost, time and maybe carbon and health impact as well. The car options may be their own, or it might be a fleet-operated car with some self-driving capabilities (limited in 2030, more advanced by 2050).

Finally, the journeys themselves will be made easier and safer. For **multi-modal journeys**, usually involving a public and an active stage that means effective real-time navigation through the stages and updates that might tell you about your next connection. For **road transport**, ubiquitous data will bring a minor revolution, real-time data and connectivity will improve network management, implemented through smart signage and in-vehicle systems that control speed and enable re-routing before traffic problems build up. Much of the data will travel directly Vehicle-to-Vehicle, Vehicle-to-Infrastructure, or via mobile networks, but satellites will provide coverage and resilience where other networks do not reach.

Satellite enables the electric vehicle revolution as well. Already electric car owners will use their sat-navs to find an en route charging point. This will become increasingly enhanced by linkages between the charging networks, prediction of when the charging points will be free, and matched to user journey requirements.

For **logistics** the story is similar, better communications, positioning and navigation enables **more efficient operation of logistics networks**, reducing costs and improving reliability and information to customers. In many cases certainty or cost more than absolute speed is required, and we expect to see more services like Starship's delivery service spreading across the Arc and beyond. This may extend to **flying 'drone' delivery services**, though these will have to prove their value against public concern and gain regulatory permissions, perhaps for specific services or locations.

The Arc already has excellent technical skills in transport systems, in academia, business and other national centres of expertise, and it has a forward-looking attitude to transport in some of the local

[21] http://www.englandseconomicheartland.com/transport/our-strategy/

authorities and England's Economic Heartland. Just as it is leading the way with connected and autonomous vehicles, Starship, Zero Emissions Bus City, and the Zero Emissions Zone, the Arc can lead other transport initiatives.

We are at a crucial stage and the DfT's Science Advisory Council recently recommended a five-year R&D programme to understand the energy vectors to deliver a Net Zero transport system by 2050[22] – it is essential that satellite capabilities are considered in this. The mid-2020s are then likely to see tests of different approaches, gradually a patchwork of new services will appear, some will prove popular and thrive. Here it becomes difficult to forecast: will new mobility services become popular and take over naturally due to their value and service? Will MaaS do to private cars what Spotify and Netflix did to CDs and DVDs? Or if it does not, will the environmental and health impact of private cars be reduced to a tolerable level, or will further action be required?

Health

A healthier society is being enabled by better information in many ways, and as capabilities increase and costs reduce, satellites will allow this to happen in more places more reliably.

The benefits of satellite connections are partly its ubiquity, but also in their reliability – being much less likely to suffer an outage than broadband.

Being able to rely on a steady connection any place, any time will enable us to use information to table a range of health problems that range from fundamental to highly sophisticated. In preventative medicine we can guide people towards healthier lives, by **tracking activity** and nudging them away from choices that lead towards physical inactivity or obesity. On a more sophisticated level, we will see rising use of **remote monitoring and diagnosis** of medical conditions, deployed both at home and in hospitals. Doctors and nurses will engage with patients in **remote consultations**, which should make it easier to bring specialists into the conversation earlier in the process. **Data and video for emergency vehicles** can be provided today.

One theme of these approaches is bringing **additional expert perspectives** to a complex case or surgery rapidly. Today those experts are human, but in future **AI-based systems** will be making judgements based on patterns in the data compared across thousands or millions of cases. Eventually this will enable remote surgery.

We will also see space technologies increasingly used in medicine, whether that is technology solutions such as advanced prosthetics, or pharmaceuticals developed in zero gravity.

[22] https://www.gov.uk/government/publications/research-and-innovation-to-support-transport-decarbonisation-2019/position-statement-on-transport-research-and-innovation-requirements-to-support-the-decarbonisation-of-transport

As we go into the future, medical technology will advance, but communications is likely to remain a benefit. We may have an array of sensors that communicate via our phone to look for pattens of trouble. After all, we already have smart watches with wrist sensors and the first 'radio pill' was developed in 1957.

Data and Connectivity

Studying these applications, and others, there are two key themes that shine through as enabling the advances and linking them to satellites.

The first is the use of data. With an increasing amount of data coming from and though satellites, it is an increasing challenge to process it. Satellite application companies will need to become increasingly skilled at data storage and processing, or work with partners who are. The current trend to cloud computing may be the solution, one of the geospatial companies we interviewed now hosts most of its data and processing in the cloud and has found this valuable for scaling up, and for allowing people to work from home during the pandemic.

Artificial Intelligence (AI) techniques such as Machine Learning will increasingly be used to extract value from the increasing amount of raw data. This will help to detect patterns, such as whether crops are growing healthily, whether the flexing of a building is the normal response to temperature or an early sign of trouble, whether traffic movements are the sign of an imminent jam, or whether your blood chemistry is in balance. The volume would make such tasks impossible for human eyes, but for AI it is a question of getting the data, the algorithms, and the processing power in the same place.

This points to big opportunities in **combining the Arc's space and digital expertise**. For downstream businesses dealing with large volumes of data, such as geospatial and transport, working with the digital experts in the Arc to be at the forefront of techniques for **storing, processing, visualising and applying data** will be vital for competitiveness. They can harness skills in hardware and software, in **cloud computing** and **bespoke coding**, in **machine learning and AI** – increasing applied to practical problems, and the emerging field of **Quantum Computing**.

For upstream space, there is a similar opportunity to use Arc **digital skills to improve satellite design and operations**. For example, **on-board processing** can enable more usable data to be transmitted, or inter-satellite links. **AI or autonomous systems** can reduce ground operation needs, which will become essential as near-Earth space becomes populated with more numerous constellations in addition to an already large debris challenge.

Not surprisingly then the second theme is connectivity. We have had commercial communications satellites since Intelsat 1 (also known as Early Bird) in 1965, in ever increasing number and power. With expanding fibre and mobile networks, it be expected for satellites to remain in their niche of high-priced coverage for inaccessible areas, plus broadcast coverage, but a revolution is on the way.

New Low Earth Orbit constellations are being launched and planned, with hundreds or thousands of satellites. These have several drivers that cannot be met by existing networks. They will be ubiquitous, and this matters not just globally, but even in a densely populated country such as the UK. Today, 43,000 UK homes cannot access good quality fixed *or* mobile services and even by 2025, Ofcom expects 5% of the UK's landmass will have no signal at all[23]. Satellite services such as OneWeb, Starlink and others planned, will fill this gap.

Mobile services backed by satellites will also improve mobility, with less chance of a break in service due to a 'shadow' or 'hand-over' effects and they generally offer greater security, being harder to intercept. Along with these inherent networks, a dual or triple network approach will provide resilience, removing many of the outages we experience and increasing our perception of network reliability.

Ubiquitous connectivity opens a wide range of opportunities, some already discussed in transport, health, agriculture, where being able to rely on a connection enables a solution that would not otherwise be possible. Many of these revolve around the safe operation of vehicles and diagnostic systems without human intervention – in other words, they will gradually enable a robot world, because the robots need wider awareness or information than from their immediate surroundings. We have recommended an approach to identify, fund and develop markets. Key to enabling this vision will be the **integration of satellite services with 5G and future mobile standards**, so that satellite links can be built into our vehicles, bus stops, routers and one day laptops and even phones.

Vision for the Arc Space Sector

Growth in the space sector will be powered by the application markets we have described above. The value created will justify the business cases for a rising number of satellites, the vehicles that launch them, and the businesses that operate them and process their data. The benefits of advances in processing power and connectivity, giving more functionality per kilogram are multiplied by those of reducing launch costs (thanks to companies like SpaceX) to radically shift the economics of satellite services and unleash their transformative potential.

Links to national space strategy

This growth can be accelerated with public investment in upstream space, in addition to the 'Arc/ national/global problem-solving' investment discussed earlier. This is mostly a question for national space strategy so not specifically a topic for an Arc study, but we note from our literature review that there are calls from industry and partnership bodies for a domestic UK space programme to run alongside the UK's ESA contribution. UKSpace proposes £150m/year investment and £250m

[23] Ofcom Connected Nations 2020

procurement[24], and that procurement could include a problem-solving challenge fund. Past returns on investment in space have been strong, with £1 returning £2-7 directly and £4-14 in spill-over benefits[25].

Such a strategy should be based on an analysis of potential technologies and markets, considering the market prospects and timing, and aiming to sort hype from reality. Talking to a wide range of people in and out of the sector is important – if you only talk to XYZ enthusiasts, you will get an enthusiastic view of XYZ (consider the optimistic forecasts for autonomous cars). Then the relevant agency(s) should work with funders (e.g. UKRI, ARIA, ESA) to invest intelligently. Public investment should be balanced with potential, but that potential should include both public benefit and commercial opportunity, and focus on areas where the UK has a good chance of sustained competitive advantage. These factors aim to maximise return on investment, but we also bear in mind the strong historic RoI from space and the need to invest in high-risk technologies and problem-solving for the best returns.

Applying these criteria to the Arc, areas that would be worth investigating are:

- **Propulsion**, with strength in Westcott and breakthrough technologies at Reaction Engines.
- **Materials and Life Sciences R&D**, two areas that are strong in the Arc, that can benefit from being taken into zero-gravity.
- **Robotics, sensors and autonomous systems**, where Arc capabilities developed for fusion reactor servicing, autonomous vehicles of all kinds, and advanced computing can be used in orbit or beyond for inspection, servicing and, one day, manufacturing.

Arc cluster development

Harwell benefits from having many organisations and facilities on site, but accommodation availability and pricing, and transport can be problematic – both for businesses and for the workforce. This makes it most attractive for organisations, or parts of organisations, which gain high value from the cluster such as intensive R&D, rapid cycle testing, start-ups that thrive on collaboration, business development that requires networking.

Developing Harwell in the right way can encourage this. Adding space for one or two very large companies might crowd out other possibilities, and it would be preferable to build spaces that encourage a larger number of smaller businesses (or parts of them) to retain their entrepreneurial activity. These businesses will often need shared facilities of the kind already provided, available on a 'pay-as-you-go' basis before they can afford their own investment. A plan for Harwell's future should consider the rate of expansion in space businesses and the physical space that can be allocated to this. It should also look at development in the wider area, aiming to make the local housing, town environment and transport infrastructure appropriate to a young, tech-savvy workforce.

[24] Securing our future in space, December 2020

[25] London Economics, Return from Public Space Investments, October 2015, confirmed by 2018 EO and Spillovers reports

Growing companies will want larger spaces, and if these are not available at Harwell companies may wish to retain a presence there for the collaboration and facility benefits, even as they expand elsewhere. **Westcott** has the space to develop a space cluster despite the propulsion testing on site. It has set out a bold strategic vision, and we particularly support the integration of skills development, with an intergenerational college in the plan. The propulsion testing is hard to replace, so should not be surrendered to other development plans unless an alternative is found that is viable for the UK space industry.

Other sites for **potential space clusters** could be identified across the Arc. Culham has a few space companies and could become a cluster near Harwell, with particular attraction for companies that would benefit from proximity to Reaction Engines, EnerSys ABSL, the nuclear site (e.g. radiation shielding), or the Oxfordshire Advanced Skills training centre. If Marshalls Aerospace complete their move from Cambridge to Cranfield, there will be some skilled aerospace workforce in Cambridge, to combine with the IT skills in the area, and perhaps part of the 800-acre airfield site. Cranfield itself may be another good location, benefitting from the University's involvement in space science, and the proximity of agricultural and environmental capabilities.

We noted that the cluster effect is stronger for Upstream companies than for Downstream, because of their greater need for collaboration, and to access facilities. **Downstream** companies have more need to be near their customer base in non-space sectors. This is illustrated by the increasing upstream presence in Satuccinos (pre and post-Covid, subjective view), and the wider dispersal of downstream businesses across the Arc. Downstream space businesses may come to Harwell (or Westcott) because the space incubators are there, and then set up closer to their customers or where rents are lower.

Clusters work for other sectors as well, and the space sector should support other sectors in their cluster-building. The upstream space sector should exchange knowledge with the aerospace cluster at Cranfield and the advanced materials and manufacturing cluster around Cambridge, as they already do with the motorsport sector. Just as satellites provide data for many applications, satellite data experts should be on tap to assist, for example, the sector experts in the logistics cluster in the north of the Arc, the agricultural cluster in the eastern Arc, and the AI cluster around Cambridge. This will accelerate the growth of the space-enabled economy more evenly across the region. This can be aided by coordinated networking events centred on the challenges space could address in other sectors and grants that encourage collaboration building.

Some businesses will incubate in the Arc and decide to leave at some point. We think this is particularly likely for a small number of businesses that grow to medium or large-scale manufacturing. These may move to areas of the UK that are lower cost, but with strong manufacturing expertise. Perhaps this would be places developing space manufacturing such as Leicester, Glasgow and the M3 corridor; perhaps those with aerospace expertise such as Bristol, North Wales or Northern Ireland; or

perhaps those with a more traditional engineering base that are looking to space for new, high-value opportunities such as the Northeast and West Yorkshire.

Quantifying the Vision

Quantifying the growth potential is difficult, in part because of the lack of a baseline. The Size and Health Study of 2018[26] did not use the 'Arc' in its geographic splits, just 'South of England' (which includes Guildford and Portsmouth alongside Harwell) and 'East of England' (which includes Stevenage alongside Luton). In round numbers, we estimate from this that the Arc had an income of £1 billion from space business in 2017, and 3000 employees. If the mix follows national patterns, this is about 80% Downstream applications and 20% Upstream space manufacturing and operations.

The UK has a target to grow to 10% of the global space market by 2030, an annual rate of about 7.5%. This is ambitious, because in 2014/15-2016/17 the growth rate had slipped to 3.3%, largely because of the diversification away from Direct-to-Home satellite TV services, which were reported as declining slightly. If the Arc reaches 8% growth in the space sector, this would triple space sector income and employment in 13 years – to £3 billion income and 9000 employees by 2030.

At the end of 2019 the Harwell space cluster consisted of 105 organisations and employed 1100 staff, with a target of 5000 people by 2030. This is consistent with our estimate, but the growth may be wider spread across the Arc, or the Arc growth rate may be higher. After 2030, we see space continuing to take an increasing role in our lives, but the growth rate must eventually slow, and we have speculated a 5% growth rate from 2030 to 2050.

	2017	2030	2040	2050
Income £m	1000	3000	5000	8000
Employment	3000	9000	15,000	24,000

Figure 3-6: Size of the Arc Space sector (Red Kite estimates)

Recommendations and Draft Action Plan

The space sector in the Arc has enjoyed success and growth in the last several years and these recommendations aim to build on that. A strong part of our message is to keep doing the same things that have delivered success so far. Many of our recommendations for the Arc apply equally well beyond it.

The recommendations and particularly the 'Who' and 'When' are initial views, for discussion with stakeholders.

[26] Size & Health of the UK Space Industry 2018, London Economics. A new 2020 Size & Health report is due shortly and may be possible to include in our Final Report.

Recommendation 0: Coordination

Ref	Action	Who	When
0.1	Establish an Arc Space Working Group to coordinate between the various organisations. This is partly established with the Arc Universities Space Working Group, but needs more commercial representation for a balanced third leg.	Arc space-related organisations	By 1 July 2021

Recommendation 1: Develop the **'Rising to the Challenge'** process where the Space capabilities in the Arc work with other sectors to solve problems of national and global importance.

Ref	Action	Who	When
1.1	Set up a collaborative horizon scanning process, to identify sectoral opportunities and challenges that are ready to solve with the power of satellites and other capabilities.	SA Catapult to lead a deliberately eclectic coalition of partners	Set up 2021, cycle through sectors over 3 yrs
1.2	Identify the 'sources of value' in public benefits and discuss with 'owners' to work out how to use them to fund innovation and new markets. e.g. Net Biodiversity/Environment Gain funded from developer contributions; Carbon sequestration verification funded by commission on carbon credit sales; Transport system connectivity improvements funded by Government (taxpayer) with reference to the health and carbon savings they create. (Several examples in sections above).	Arc Growth Body (in waiting)? (These are societal problems, space is a tool.)	Mar 2022 for first three. Then ongoing.
1.3	Set up an Arc Challenge Fund to enable the problem-solving process to start rapidly while long-term arrangements resolved. Our estimate is £3-10m/year to launch 2 challenges a year.	BEIS (perhaps via UKRI or ARIA) or Arc fund	2021
1.4	Identify potential legal or regulatory blocks for challenge and engage with Government to find creative ways around them, e.g. exemptions or local deals.	Arc Growth Body (in waiting)	2021
1.5	Launch first 'Arc Challenge' to innovate and develop solutions to the first problem. This would be a competitive tender, with a functional specification, probably open to companies in the Arc and outside, with collaboration encouraged. (Funding from UKRI/ARIA if Arc Growth funding not in place)	Arc Growth Body (in waiting)/ Innovate UK with SA Catapult/UKSA assistance	First Innovation challenge by March 2022. Market by Apr 2024
1.6	Launch subsequent Arc Challenges on further opportunities/challenges (7 listed as examples in Clean Growth section with possible market mechanisms, some of which have several components, others do not have identified market mechanisms but are still high value e.g. flood prediction, remote health diagnostics, ubiquitous connectivity.)	Arc Growth Body (in waiting)	One, ideally two per year
1.7	Actively build collaborations to tackle the challenges. Use themed workshops, and help people to join the dots and find partners to complement their own abilities.	SA Catapult, UKSA, Universities	Challenge launch to closing date.

1.8	Engage immediately with satellite/geospatial community to identify how they can assist with Arc Geospatial Framework. For example, organise a 'show and tell' of geospatial companies for the MHCLG team and local planning authorities. Base Arc spatial planning in the Arc.	MHCLG Arc Spatial Framework Team and LPAs, with help from SA Catapult	Mar-June 2021
1.9	Expert assessment of potential for satellites to deliver/improve Net Biodiversity Gain verification (selected as a priority)	Arc Environment Group and SA Catapult approach MHCLG and Defra	Mid 2021
1.10	Use competitive tenders, and/or 75% to 100% funding for high-risk / low-TRL projects. Latter is used for some ESA projects	UKRI/ARIA	With challenges
1.11	In the market stage, develop marketing strategies e.g. organise 'trade missions' to customers e.g. DfT, Local Government Association, National Farmers Union, etc.	SA Catapult	With challenges

Recommendation 2: Invest to develop the **space sector**, aligned with national strategy and areas of Arc expertise.

Ref	Action	Who	When
2.1	We support industry and academic calls for a substantial UK space programme, running alongside our ESA programme. A significant part of this should be directed at tackling the national challenges.	BEIS	2021
2.2	Track emerging upstream technologies and markets with respect to maturity and market prospects. Aim to sort hype from reality (and timescales).	SA Catapult	Ongoing
2.3	Work with funders (UKRI/ARIA) to invest intelligently. Aim to balance major public investment with potential and match it to areas where UK has realistic chance of advantage. e.g. for the Arc Propulsion, Micro-gravity materials/pharma R&D. In-orbit robotics/servicing.	SA Catapult, with UKSA, UKRI, ARIA	Ongoing
2.4	To support a substantial UK space programme, increase the number of space specialists within UK Space Agency.	UKSA	As funding grows

Recommendation 3: Build on the existing Harwell and Westcott **clusters**, and the nearby supply base.

Ref	Action	Who	When
3.1	At Harwell, continue to make space for cluster development with a focus on companies (or the parts of them) that gain and offer collaboration benefits. A particular need is office/lab/cleanroom space for growth stage (10-30 employees).	Harwell Campus/STFC, with partners	Ongoing
3.2	At Westcott, establish more of a 'cluster' feel by adding a central meeting point coffee shop and growth. Again, growth space office/lab/ cleanroom space is desired. Increase visibility of Westcott in local area (e.g. signage). Encourage nearby visitor accommodation.	Westcott partners	2022 and ongoing
3.3	At Westcott, encourage development of a space cluster but ensure this does not stop the ability to do propulsion testing unless a viable alternative can be found for the UK space industry.	Westcott partners, UKSA	Ongoing

3.4	Support Culham as a base for space companies as well, particularly if they benefit with interactions with the organisations there.	SA Catapult, UKSA	Ongoing
3.5	Improve links in upstream supply base around Harwell/Westcott by creating a 'Yellow Pages' or catalogue of 'space interested' and 'space experienced' suppliers. (Could be sub-set of Capabilities Catalogue).	SA Catapult	2021 1st Edition
3.6	Facilitate regular links between elements of the 'national space cluster' e.g. Joint Satuccinos, workshops, virtual guided tours, etc.	SA Catapult, UKSA	Ongoing

Recommendation 4: Develop the benefits of **collaboration** across the Arc and across Sectors, with small, medium and large-scale initiatives.

Ref	Action	Who	When
4.1	Continue to run sector/problem focused workshops. Aim to bring in more non-space people and focus on priority sectors and challenges.	SA Catapult	2021 and ongoing
4.2	Start a rolling programme of collaborative research projects putting a 'space person' in another sector or vice versa working on a challenge related project for an extended period to maximise both formal and informal knowledge exchange. Six examples are given in the 'Collaboration' section above, e.g. a geospatial expert in the AI cluster at Cambridge, working on spatial planning. We estimate a funding requirement of £100-200k per project, average duration 1 year with up to 10 projects running concurrently – so an annual budget of £1-2m.	SA Catapult to coordinate with partners	Plan in 2021. Launch in 2022 and ongoing
4.3	Develop knowledge exchange programme between space, aerospace and AM&M sectors including Cranfield and Cambridge.	SA Catapult ?	2022 and ongoing
4.4	Look for needs and opportunities for collaborative Transformative Programmes to tackle Grand Challenges. This approach would be selected where the efforts of several organisations need to be combined with substantial investment over a period. (The Faraday Institution for batteries, and Zenzic for autonomous mobility are examples). These will require a large (but currently uncertain) budget.	Arc Space Working Group recommend these to UKSA/UKRI/ Gov't for funding	From 2022
4.5	Foster collaborative opportunities in the supply chain. Look for places where technologies or skills can be combined to make something better or solve a problem.	SA Catapult	Ongoing

Recommendation 5: Develop the **STEM skills** required for the future of the space sector, using space as the inspiration.

Ref	Action	Who	When
5.1	Develop a STEM inspiration programme for Secondary School children drawing on individuals in local space-related organisations and materials to be developed by UKSA as an Arc-wide initiative contributing to the national 'Million interactions' initiative.	LEPs/ Future Arc Growth Body to lead, coordinating UKSA, delivery through LAs	2022
5.2	Identify current and future specialist needs and work with universities and colleges to put in place courses and apprenticeships to provide a regular flow of skilled people in the local area. E.g. cross-over courses for engineering/physics students and STFC's proposed 'Skills Factory'.	LEPs/Arc Universities Space Group with Government departments	2022

5.3	Foster interest in space by supporting community groups, university groups, school groups etc with interest in science.	All space organisations	2021 on
5.4	Input to local development because it is important to the workforce. We heard discontent with housing availability and prices, transport (non-car), and leisure facilities around Harwell.	All space organisations	Ongoing

Recommendation 6: Build the other critical **capabilities** for a healthy space ecosystem: Finance, facilities and business support.

Ref	Action	Who	When
6.1	Finance: Help to make 'space' a more normal proposition to the finance community. Reach out to where the general banking community meets in the Arc (e.g. business networking events) and communicate not innovation (which says 'risk') but business success and profit. Collect and publicise business success stories not just technical ones (e.g. positive cashflows and exits).	SA Catapult, UKSA	2021 on
6.2	Facilities: Expand facilities as needed to enable innovation in upstream and downstream. Current need is for flexible affordable office/lab and cleanroom space, particularly in growth stage (10-50 employees). We did not identify major technical facilities required, but RAL Space is conducting a survey. Business case evaluation would be required.	STFC / Site owners	Ongoing
6.3	Business support. Ensure that new companies understand the basic needs of accountancy, legal and marketing, and that programmes are in place with capacity to support promising new businesses. (As they are today)	SA Catapult, ESA, LEPs	Ongoing
6.4	Business Incubation Centres. Ensure a well-signposted network of business incubators across the Arc, with some loosely themed to priority sectors including space, environment, spatial planning, agriculture, mobility, health, communications, AI, etc. Each with relevant cross-sector networking and access to facilities such as EO data and DISCs.	LEPs/Arc Growth Body, SA Catapult	2022

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