Oxfordshire Transformative Technologies Alliance

Science and Innovation Audit

Summary Report

August 2017

Introduction and context

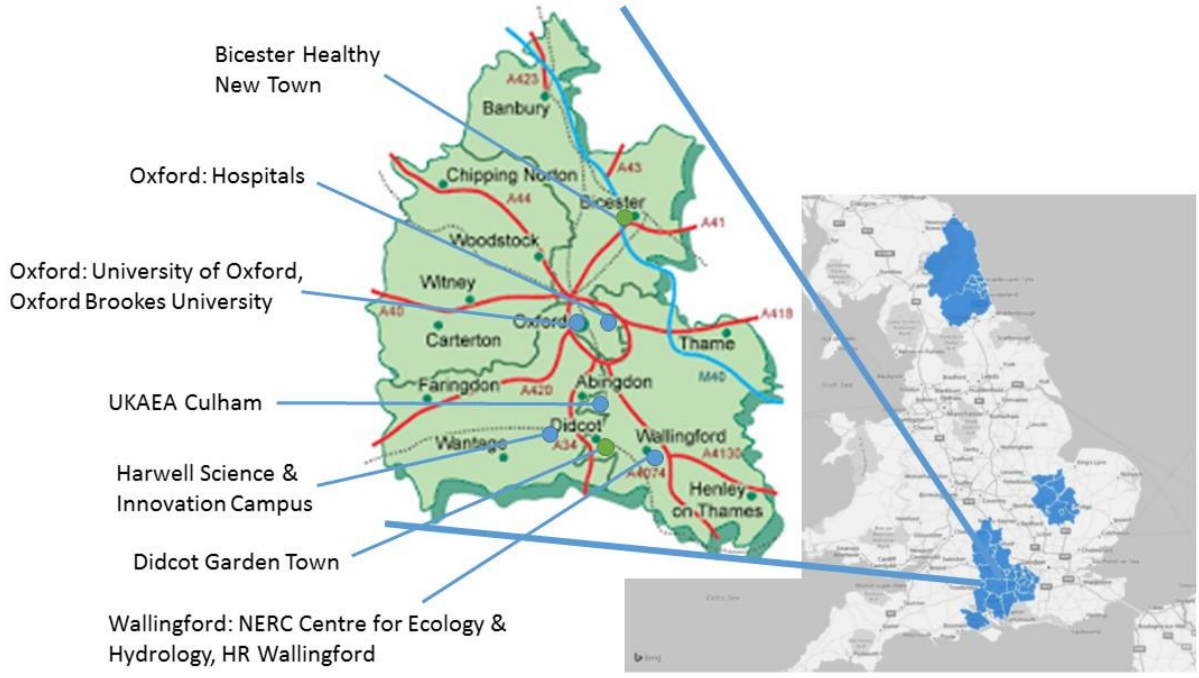
The Oxfordshire Transformative Technologies Alliance SIA focusses on 4 large scale, disruptive, inevitable, digital technologies, for which the UK has great need and world class strength, particularly in Oxfordshire. There is considerable consensus that business sectors and workforces globally will be significantly disrupted by the development and impact of these technologies. We have sought to think beyond 'business as usual' to identify opportunities and strategies to secure the UK's position in a global context as these technologies increase their market share, and their relevance and influence in policy, society and economies.

The technologies are fast-moving and competitive, and offer opportunities which require strategy and cohesive leadership and prioritisation if the UK is to maintain and develop a global position in the science and innovation and markets.
We consider maximising the value of investments through co-location and connectivity between complementary technologies, and delivery mechanisms and connectivity into the supply chain. The national purpose is to maintain and capitalise on the UK's narrow, and otherwise fragile, early mover advantage.

This SIA demonstrates both the scale and quality of Oxfordshire's science and innovation assets, and their potential to support implementation of the National Industrial Strategy, and have lasting transformational impacts on national competitiveness and productivity through 2030.

Place

The geographic focus for the SIA is on assets within Oxfordshire. There are links with three other areas of the UK: the M3 corridor, greater Cambridge, and the north-east of England, for technology development, manufacture and rollout.



Vision

The core vision of this SIA is for Oxfordshire to be a global leader in the development of transformative technologies that will underpin the future UK economy and provide lasting global competitive advantage.

Convergence of ubiquitous computing power, cloud data storage, and advanced decision making algorithms with mass consumer acceptance of increasingly smart digital devices, will continue to transform society.

The opportunity for the UK is to play a leading role by developing new products and services built on purposeful investment in appropriate skills and strategic support for cross-sector engagement. This will mutually reinforce the growth of these technologies, and their application to a wide range of market sectors. The selected technology areas are:

- Digital Health
- Space-led Data Applications
- Autonomous Vehicles
- Technologies underpinning Quantum Computing

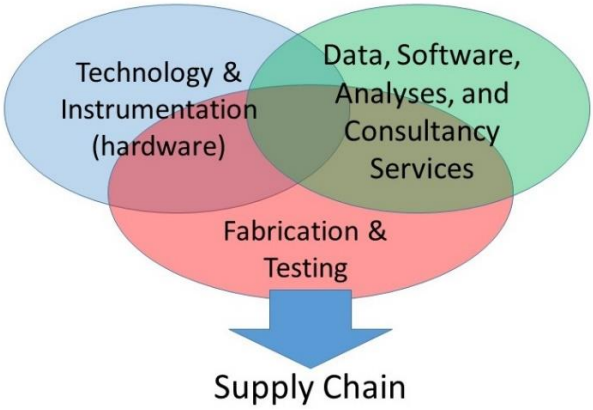
These are not the only themes in which Oxfordshire has highly significant or leading science and innovation capacity in the UK, and internationally[1].

These four technologies were selected because they are specific areas of technology and application development (rather than broad industrial sectors) which, combined, have the potential of driving innovation across many sectors and they share common aspects which make them a cohesive proposition:

1. They are all digital technologies, or are highly dependent on digital technologies. They are all developing rapidly and present long-term opportunities for significant growth and competitive positioning in the global economy.
2. They share co-dependencies, such as cybersecurity and machine learning, which are regional strengths.
3. They will extensively disrupt industry sectors and workforces: integration will require innovative governance. A place-based approach underpins the holistic nature of the opportunities, leading to economies of scale and other potential synergies across the value chain and in new market opportunities.
4. Opportunities for innovation (products and services) exist at the interfaces between these technologies (e.g. vehicle-based health monitors), which are more likely to be identified and exploited quickly if these technologies are co-located and strategized.

1 Leading strengths in, for example, Sustainability, Biosciences, and High Value Manufacturing, shown in 'Mapping England's Innovation Activity', Smart Specialisation Hub, June 2017. University of Oxford ranks 1st in UK in REF2014 for 12 of the 31 subject Units of Assessment by volume of world-leading research.

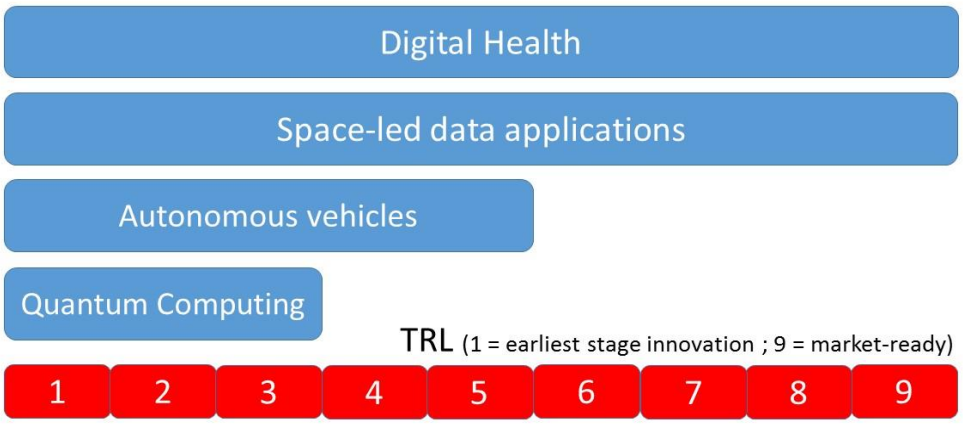
5. Their development suits Oxfordshire's highly skilled workforce, with a strategy to deploy the skilled workforce nationally and internationally as new products and services are manufactured and roll out to other regions and countries. A UK growth model would include manufacture at scale in other parts of the UK.
6. Many skills needs are common to all four technologies. A place-based approach creates a value proposition for training and workforce development.
7. The technologies share a development and economic model of having "hardware" (physical components and products), "software" (data and analysis), and data access and consultancy services:



Hardware, software and services are best developed together, to maximise the benefits of test beds, and rollout via Living Laboratories.

These four transformative technologies are at different stages of commercial maturity. Digital health and satellite applications technologies are in the market, and growing. Autonomous vehicles are beginning to be demonstrated. Quantum computers are in early stage research and development, and are part of a larger whole: the ability of the human mind to utilise the brute power of computing.

Human society is on the cusp of a 4th industrial revolution, in which automated systems and data connectivity change possibilities and society. The breadth and depth of research and innovation in Oxfordshire in these 4 transformative technologies should be recognised and supported as a strategic national asset.



Technology readiness levels for Oxfordshire Transformative Technologies

The Transformative Technologies

Connected and autonomous vehicles (CAV)

Oxfordshire is best placed to be a Living Laboratory for real world testing of CAV rollout. By retaining the UK's strong global position in Autonomous Vehicle development, revenue to the economy is expected to be at least £51bn by 2030, with 320,000 new jobs, 5,000 serious accidents avoided and 2,500 lives saved.[2]

Oxfordshire is a near perfect test bed. Vehicles can be tested geographically closely to the design, communications, navigations, and analytics facilities and workforces.

The Oxford Robotics Institute kick-started the UK's autonomous cars programme in 2010. Oxbotica was created in 2014 as a spinout of Oxford University, and now leads the UK consortium to develop and launch a fleet of driverless vehicles on public roads in 2.5 years. The research and development continues in conjunction with RACE (Remote Applications in Challenging Environments) at Culham, which provides testing conditions ready for rollout to public highways. New and expanded settlements across Oxfordshire can be living laboratories for the integration of Autonomous Vehicles, demonstrating transport solutions for further deployment nationally and in other countries.

Digital health

Digital technologies can transform healthcare, from prevention, through diagnosis and intervention, to ongoing monitoring.

The UK market for digital health is expected to grow to £2.9bn by 2018, driven primarily by high growth in apps (38%) and analytics (24%)[3]. The UK can do better than present at capitalising on innovation and bringing beneficial technologies to market more rapidly.

The Oxford Thames Valley region has over 160 digital health companies and 430 stakeholders across industrial, academic, NHS and third sector[4]: this region is a potential major growth cluster for developing and demonstrating high income, technology-based healthcare solutions[5]. Creating a closed loop of data and testing along the entire care pathway will vastly smooth the existing pinch points to market.

Developers with an end-to-end patient pathway and test-bed system can speed innovation, demonstration and rollout, and better evidence health benefits and cost systems. This can create 300,000 new jobs (33,000 in Oxfordshire) by 2030 and yield £1.8bn/year in savings[5] to the NHS.

Space-led data applications

The UK space industry's target is 10% of the global space market by 2030. This should mean £40bn/year and 100,000 jobs for the UK.[6]

2 *Connected and Autonomous Vehicles: The UK Economic Opportunity*, KPMG
3 *Digital Health in the UK. An industry study for the Office of Life Sciences*, Deloitte
4 *Digital Health in Oxford and the wider Thames Valley region*, Oxford Academic Health Science Network, Oxford University Innovation and the University of Oxford
5 Existing capacity and excellence makes the region a very strong choice for highly skilled workers and inward investment, and thereby for sector growth for the UK. 1% savings across the NHS through digital health technologies (conservative estimate). NHS budget 2030: £180bn (2017 budget: £123.7bn (source: King's Fund), 3% inflation)
6 *Building our Industrial Strategy: UKspace and Space Growth Partnership Response*, UKspace

Space data includes earth observation, satellite positioning and communications. To develop products and services space data is applied with other data sources to create real-world solutions.

Oxfordshire has over 75 organisations, Europe's largest Space Cluster, the Satellite Applications Catapult, world-class research, a rich innovation ecosystem, and international pull.

To at least maintain the UK's global position – and add value in conjunction with CAV and Digital Health's use of location data, and communication – the proposed interventions include a data analytics hub to develop applications, and work with Living Labs as demonstrators for data products, and to boost the value proposition for inward investment in UK Space.

Technologies underpinning quantum computing

Quantum technologies will profoundly change the world, and our lives, by 2030. The UK has a strong, but fragile, global position in the race to develop a quantum computing capabilities.

Oxfordshire leads a consortium of 34 organisations to build a quantum computer demonstrator by 2020, and to stimulate quantum industries.

Establishing a 'Quantum Valley' in Oxfordshire, to build a computer, will create 10,000 UK jobs across the supply chain. Oxford University ranks 1st in the UK for mathematics, physics and engineering[7]. Local companies are engaged, e.g. Oxford Instruments which is providing the cooling technology. Oxfordshire leads extensive high-level training programmes in quantum technologies.

Assembling a functional quantum computer will nucleate new companies, and attract inward investment for the UK.

Global USP: opportunities for innovation at the intersections between technologies, for added value and output

Our global USP is to facilitate innovations at the intersections between these four transformative technologies, situated with Living Lab testing and demonstrators. There is added value in combining these transformative technologies in a highly networked science and innovation setting which is excellent at shared features such as machine learning, cyber security, imaging and sensing.

Development of any one of the four technologies will yield economic and social benefits for the UK. There is a strong opportunity for additionality: more applications and products will arise by focussing the development and test sites of these four complementary technologies in a place of world-leading science – opportunities which investment in any of the technologies independently will not achieve.

7 REF2014: the Research Excellence Framework, HEFCE

Key strengths

Oxfordshire has long been a world-leading centre for research and innovation across a wide range of technologies and sectors. It contains Oxford University, ranked number 1 in Europe for both research and commercialisation, large government investments (>£2Bn in internationally leading scientific facilities), especially at Harwell and Culham, leading industry clusters in life sciences, scientific instrumentation and motorsport, and the largest investment fund for university spin-outs globally.

Growth opportunities

This SIA is focussed on four themes where rapidly developing digital capabilities are converging but where the industry is nascent and therefore has the greatest potential for growth, anchoring capabilities in Oxfordshire and securing the UK's global competitive advantage. Within the UK context, Oxfordshire will always be a location where new technologies are invented, developed and tested but most full scale manufacture and assembly will occur elsewhere.

The key to success is for the research, innovation and testing of technologies to be clustered such that national supply chains can be developed from this base and for the skills and services supporting this cluster to be of sufficient quality, scale and flexibility to enable the innovation, integration and translation processes.

Oxfordshire has a history of developing hi-tech clusters of this sort and its proximity to London and Heathrow airport together with its connectivity with the rest of the UK and a global outlook make it ideal for developing and commercialising new technologies. The approach requires building three core capabilities in the county:

- Technology & Instrumentation ("hardware"): linked to targeted sectoral goals in Harwell (satellites and quantum), Culham (autonomous vehicles) and Oxford Hospitals (digital health)
- Data & software: to take data analytics and science from the laboratory into practice, including machine learning, vision and imagery techniques, in the context of cyber security and privacy
- Fabrication & test facilities: Living laboratories where solutions can be deployed and tested together in real-world environments, whether at Culham for autonomous vehicles or smart communities at Bicester and Didcot garden towns

Common features required to underpin development include:

1. Digital skills development and attraction of global talent
2. Investment in supply chains which will grow across the UK
3. Consistent strategic funding for growth
4. National networking to strengthen complementary technical capabilities in other regions

Gap analysis

Through consultation with key players in the county and beyond, gaps have been identified which need to be addressed for innovation and growth to flourish:

1. Oxfordshire's principal challenge is to continue to attract and retain the top talent required for world-leading businesses. This requires significant investment in training of engineers (both software and hardware) and addressing critical issues of the cost of living (associated with the largest house price to salary ratio in the UK) and transport constraints.
2. Whilst the region boasts an enviable track record of start-ups, the ability to grow businesses to medium scale and beyond is challenging through lack of facilities and skilled staff and there is a need to grow "unicorns" and attract inward investment at scale from multi-nationals if the county is to rapidly seed the development of the UK's digital economy.
3. With the wealth of research expertise generating new solutions, the principal challenge with new technologies lies in their translation through integration of capabilities and rapid scale-up by testing and demonstration. Good examples exist with the Satellite Applications Catapult and healthcare translational pathways. These require further integration, and new facilities need to be developed for autonomous vehicles and quantum computing.

Key ambitions/proposals

The critical components of the system that require investment in order to maximise national opportunity in Oxfordshire, can be divided into four areas:

1. Hardware development - e.g.:
    - Space: Disruptive innovation centre to translate technologies from other sectors and platforms to accelerate innovation in the satellite sector
    - Quantum: Facility for the building of the first quantum computer
    - Autonomous vehicles: Accelerate fleet design and national testing
2. Data & software - e.g.:
    - Health: Create a data lake to enable development of new applications
    - Space: Geospatial analytics centre to translate new analytics research into tools to address business requirements with a geospatial context
    - Autonomous vehicles: agreeing frameworks to collate and share data to enable new services whilst addressing cyber-security and privacy concerns within regulatory frameworks
3. Test facilities - e.g.:
    - Health: An end-to-end patient pathway and test-bed system for new digital health technologies
    - Autonomous Vehicles: Development of a test facility to provide comprehensive testing of urban, intra-urban and rural services
4. Technology integration:

    Seamless connectivity between data and communications networks for satellites, autonomous vehicles, and aspects of digital health.

Living Laboratories

Within this SIA, the convergence of sectoral thinking was reflected in the over-arching desire to establish world class 'Living Laboratories' delivered with industry where several technologies can be deployed together to address common challenges (e.g. healthy living, efficient mobility, national productivity). These Living Laboratories have many layers: strategic planning and local politics; infrastructure and hardware including seamless networks for transport, housing, hospitals and industry; software systems, data management and system of systems control; integrated solutions that use big data to optimise service delivery to improve productivity within environment constraints; sales opportunities, local, nationally and internationally, to generate jobs and growth; and last but not least, deep and wide engagement with the public.

- This model can be built on existing opportunities with Didcot Garden Town and Bicester Healthy New Town, both of which are undergoing rapid development. Also at small scale in the putative Culham Smart Community.

For broader, more effective, national development and demonstration of these (and other) technologies and solutions, we propose involvement in a platform approach to connect development initiatives (such as Healthy New Towns) nationally. This proposal would integrate these transformative technologies further (for example, with environmental management, air monitoring systems, energy, and/or waste solutions being developed and tested in other Healthy New Towns), and accelerate the production of proven solution sets.

Such a national platform could be integrated further, with similar initiatives in other countries, offering more integrative solutions fit for broader application, and would develop more routes to market at international scale.

Networking/collaboration

The progression from hardware to software, and thence to Living Laboratories, suggests a movement from technology towards society. Whilst some would see the inevitable conclusion of digitalisation as being the rise of the machines, with artificial intelligence controlling our lives and robots invading our human spaces, our position is more optimistic. We see these new digital technologies as enhancing our lives - the next generation of smarter tools used by smart humans to improve health, mobility and prosperity.

To achieve this we need thorough and comprehensive conversations that engage all of society. This raises the need to network, collaborate, and communicate - perhaps in unprecedented ways - to ensure that our reliance on digital technologies does purposefully lead to improved quality of life for all.

Connecting across the UK, for global strength

The process of producing this SIA has involved close collaboration between members of the core consortium (OxLEP, Oxford Brookes University, University of Oxford, STFC, UKAEA, the Satellite Applications Catapult, Oxford AHSN and Oxford University Innovation) and the involvement of a wide range of industrial partners. In addition an Advisory Group, chaired by the Pro-Vice-Chancellor Research & Innovation at Oxford University and comprising senior representatives of the business, research and academic communities, has already met twice to advise on the SIA, and this Group will continue to meet in future in order to support and oversee resulting initiatives.

The work on the SIA has also stimulated increased networking between the four themes, and has identified opportunities for Oxfordshire to be *a living lab for the testing and roll out of new technologies*, leading towards a digitally-enabled world where healthcare and transport, as well as numerous other sectors (e.g. agriculture, financial services, energy) are revolutionised through the transformative technologies of satellites and quantum computing. Existing initiatives such as Smart Oxford, Barton Park and Bicester Healthy Towns, and Culham Smart Community provide small scale test beds which can be linked together to form a county-wide network.

To quote one member of the Steering Group: “Part of the process of the SIA for me has been the coming together of elements where I have been working with others and beginning to see how things fit together now and could do in the future”. The diversity, dynamism and tight geographical focus of the Oxfordshire high tech cluster means that interactions between researchers, businesses and residents are made possible by proximity, and the strength of the cluster also means that new ideas are more likely to secure funding and attract the technical and management skills needed to generate economic and social benefits from those ideas locally, nationally and internationally.

The SIA process has emphasised existing links with other SIA technologies, regions, and business sectors. Increased awareness of complementary activities across the UK has identified shared aspirations, and has increased willingness to collaborate for collective benefits and efficiencies. Beyond Oxfordshire, four other LEPs (Thames Valley Berkshire, Greater Cambridge Greater Peterborough, Enterprise M3 and North East) were included in a wider, active grouping because of the strong inter-relationships within the four themes between research and innovation organisations in Oxfordshire and these other areas.

Industrial participants and stakeholders

The production of this report, including its propositions and strategy, has involved intensive collaboration between the 7 members of the core consortium, and the close, dedicated involvement of 33 industrial partners and 18 non-business organisations (listed at Annex A of the full report), most of which have a business representation role and are in regular contact with business regionally, nationally, and internationally.

Examples of links between SIAs, and the importance of the themes to the wider UK economy

1. Agri-tech (East of England SIA) and 'Space-led data applications'

The East of England has a national leadership role in Agri-tech, resulting from the combination of a strong heritage in crop-based agriculture and horticulture and the depth and calibre of related scientific research in the region.

This SIA region is well-placed to apply, and benefit from, new technologies in precision and smart agriculture, including the application of robotics, sensors and diagnostics, to increase the efficiency, speed and precision of applying fertilizers and pesticides, and of harvesting. Precision and smart agriculture rely on the rapid processing of large amounts of data, much of which is gathered from satellites. There is strong complementarity between the OxTTA SIA proposition in space led data applications to dramatically increase the efficiency and environmental performance of agriculture. For example:

- The Satellite Applications Catapult is working with Cranfield University and the Agri-EPI Centre to exploit EO, weather and field data to support the precision management of grassland agriculture.
- Oxfordshire-based remote sensing consultancy Rezatec have been working with British Sugar to develop decision support tools to help optimise sugar production across the supply chain.

2. Offshore Renewable Energy (ORE Catapult, North East LEP, Midlands Engine SIA) and 'Autonomous Vehicles' and 'Space-led data applications'

The full range of satellite technologies are used to support the offshore renewables sector. In particular:

- Satellite communications and positioning are widely used in the building of offshore facilities; companies developing applications for this market have combined datasets such as weather information and sea conditions for use by offshore energy companies.
- Unmanned Autonomous Vehicles including drones are increasingly deployed; organisations including the Satellite Applications Catapult are using data from drones to complement satellite data, with the drones rely on satellite positioning. Through its Centre of Excellence in the North-East, the Catapult is linked into the drone supply chain in the North East and the Offshore Renewable Energy Catapult.

3. Quantum technologies (Innovation South SIA and Glasgow Economic Leadership SIA, in conjunction with Birmingham Hub)

The Quantum Enhanced Imaging (QuantIC) Hub at Glasgow and the Glasgow SIA HEIs are partners in all 4 EPSRC Quantum Technology Hubs. Their Consortium is particularly well-placed to drive productivity from the EPSRC's overall investment.

OxTTA's findings major on the potential in Central Scotland for rapid integration of quantum technologies with photonics, microelectronics, software/ big data interpretation at relatively low TRLs 3-5 into prototype devices that will support major strides in technology adoption (via our demonstrators) in industrial monitoring, process control, asset management, imaging/ visualisation and digital manufacturing at higher TRLs 5-7. The same capacity for integration of quantum technologies into composite devices at low TRLs will particularly complement the OxTTA aspirations in respect of quantum computing and the Innovation South SIA aspirations in quantum supply chain. It will also provide particular opportunity for rapidly increasing links with the Birmingham-based Quantum Hub in Sensors and Metrology.

These SIAs together illustrate the connected, national nature of the investment needed to drive UK-wide success. Investment in each of these regions will lead to spillover benefits in the others (and beyond), and we hope that these three SIAs, taken together will inform a national strategy for developing a UK lead in quantum computing.

4. Satellite technologies and data (Innovation South SIA)

Innovation South's strengths in satellite data are more widely distributed across a larger geography, including a number of excellent Universities, Pirbright and NPL's South Hub and a very large number of major industry partners and many diverse, and innovative SME clusters, including marine and coastal sectors.

The two regions are therefore complementary with Oxfordshire more intensely research-focussed and Innovation South providing more of a balanced and diverse portfolio between corporate R&D, academic and PSRE research and SME innovation across a much larger economic region. In the space sector, Oxfordshire's focus is downstream on satellite data and national testing laboratories whilst Innovation South's key strengths lie in upstream satellite innovation from Airbus, Surrey Satellite Technologies Ltd, NPL and the Universities of Surrey and Southampton with complementary satellite data analytical capability from the University of Portsmouth.

5. Catapults

Oxfordshire is already linked into the whole Catapult network through the Satellite Applications Catapult, which works across the whole network and on projects with High Value Manufacturing, Transport Systems and Offshore Renewable Energy Catapults.

6. Quantum technologies, AV, and compound semiconductors (South Wales)

Compound semiconductors are essential for the development of quantum computers, autonomous vehicles, electronic propulsion and satellite technology requiring advanced data-communications and energy generation. Oxfordshire has considerable expertise from academia to SMEs and larger companies. We anticipate close collaboration with the Compound Semiconductor Applications Catapult in South Wales, together with the other key facilities in the compound semiconductor cluster: the Institute for Compound Semiconductors, the EPSRC Compound Semiconductor Hub and the Compound Semiconductor Centre.

Investing in R&D in these areas will lead to economic growth within the Oxfordshire region, and will also lead to the expansion of the compound semiconductor industry in South Wales, creating economic growth and increased high-value employment in the region, and related industrial benefits elsewhere in the UK.

Diamond Light Source is the UK's national synchrotron science facility and is part of the Harwell Science and Innovation Campus, Oxfordshire