Department for
Business, Energy
& Industrial Strategy

South West England and South East Wales Science and Innovation Audit

Annex J: Digital Living Innovation Theme Report

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

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Annex J Digital Living Innovation Theme Report

1. Introduction

As a recognised and evidenced powerhouse of Electronics and Computing both in industry and in academia, the region has taken a leading role in developing the digital technologies that have transformed our lives over the past 20 years. The region fully intends to continue in that mission through strong established partnerships with corporates, SMEs and universities. Based on recent experience we can expect the impacts of these technologies on society to be complex and subtle - the huge socio-economic and cultural diversity of the region makes it an ideal test bed for the responsible development of new digital technologies that meet the needs, embrace the aspirations and understand the concerns of local communities and businesses, large and small.

As defined by Michael Hill-King, Huawei Collaboration Director, UK R&D Centre: *"Digital Living is the way in which our lives are affected by digital products and services. Digital means connectivity; digital means storage; digital means computation. But digital enables much more. Digital means applications become possible to offer new experiences for living, new ways of living and more convenient ways of living"*

Numerous reports have been published highlighting the strategic importance of the Digital Industries sector for the UK economy, a number identifying the audit regions strengths and clusters of national importance, including for example the 2016 Tech Nation report[1] and the 2014 Centre for Cities report "Industrial Revolutions: capturing the Growth Potential"[2]

Through the audit process, convergence occurred around the following top level thematic subsets and technical underpinning of Digital Living:

Thematic subsets

- Digital Health
- Digital Creative Economy
- Smart Cities & Transport

Underpinning technology themes

- Cloud Computing (Including Communications & IoT).
- Digital Media (including Virtual/Augmented Reality, Creative Media)
- Robotics / Autonomous Systems

Appendix DL7 gives a definition for each of these thematic areas.

It should be noted that digital technologies related strengths and opportunities in both Environmental Risk and Resilience and in Aerospace and Advanced Manufacturing were identified and mapped. These are underpinned by many of the same technologies but are covered elsewhere in the audit report.

[1] www.techcityuk.com/wp-content/uploads/2016/02/Tech-Nation-2016_FINAL-ONLINE-1.pdf
[2] www.centreforcities.org/wp-content/uploads/2014/07/FINAL_Centre-for-cities-report2014.pdf

Underpinning technologies encompass a wide number of areas of technical capacity including: *cloud computing, cyber security/cryptography, quantum technologies, data analytics, machine learning, sensors, radio frequency, wireless/5G, high performance computing, autonomous systems, digital media production, wired and photonic networks, machine vision*

The region is home to a significant population of companies both small and large, local and international, operating at both the applications and underpinning technology levels. Its major conurbations have been highlighted as digital technology clusters of national and international significance in a range of informed reports, which stress the economic impact of the clusters[3].

The region's Universities have a strong track record of cutting edge research being translated into real application with the Digital Living theme covering a wide group of researchers across 29 different areas of research (REF Units of Assessment).

The region punches massively above its weight in this space; for example as described herein despite representing just 9.5% of the UK's population, the region produces 25% of the UK's patents in Digital Communications and was identified as the home of one of the UK's two leading smart cities.

2. Regional science and innovation assets

Our nationally recognised strengths are built upon a long history of academic and industry excellence and innovation in underpinning digital technologies and of innovative companies, large and small, delivering applications across many sectors. The region has a large number of research and innovation assets related to this theme, including academic research centres and groups, industry innovation, development capacity and focused innovation support, which we are harnessing to maintain and grow our world leading position.

Science and innovation assets of scale are described by sub theme in Appendix DL1.

Given the nature of the theme, with applications areas underpinned by fundamental technologies the academic assets are spread across a large number of Schools and Departments in all of the region's Universities. The region is home to the Universities of Bath, Bristol, Cardiff, Cardiff Metropolitan, Exeter, Falmouth, Gloucestershire, Plymouth, South Wales and UWE with research and innovation activities related to this theme.

The relevant research assets are to be found in University Departments of Electrical and Electronic Engineering and of Computer Science. The region is home to seven Electronic and Electrical Engineering Departments (Bath, Bristol, Cardiff, Plymouth, Exeter, UWE and University of South Wales) which produce 435 graduates, 175 postgraduates and 55 PhD students per annum. Approximately 50% of the research within these schools aligns with this theme, including particular strengths in fixed and mobile communications. Total research income is £18m per annum.

The region hosts nine University Computer Science Departments (Bath, Bristol, Cardiff, Cardiff Metropolitan, Exeter, Gloucestershire, Plymouth, UWE and USW), producing 849 graduates, 300 postgraduates and 55 PhD students per annum and with total research

[3] www.duedil.com/technation/2015

income of £12m per annum. More than 90% of research activity within these Departments is of relevance to this theme, including for example the £12m digital health-care project, SPHERE.

Bristol hosts the EPSRC Centre for Doctoral Training in Communications. Bath, together with Bournemouth, hosts the Centre for Digital Entertainment, the EPSRC Centre for Doctoral Training in Games, Visual effects and Animation. The EPSRC Centre for Doctoral Training in Future Autonomous and Robotic Systems: FARSCOPE is delivered jointly by the University of Bristol and the University of the West of England through the Bristol Robotics Laboratory.

3. Excellence in science and research

We have identified a total of 634 researchers (at Principal Investigator level) working in fields directly related to the Digital Living theme at in the region's Higher Education Institutions. Of these 431 were submitted to the 2014 Research Excellence Framework.

Research Evaluation Framework 2014

Researchers active in the Digital Living theme were submitted to the 2014 REF across 29 different Units of Assessment (UoA) of the 36 defined in the REF. The large number of UoAs is indicative of the very wide footprint that the Digital Living theme has across academic disciplines. In order to better analyse the REF submission a threshold was used of greater than 10% of the regional researchers submitted directly identified with the theme. This reduced the UoAs under consideration to 10 (Appendix DL2). Submissions to these UoAs included 322 researchers directly identified with the theme from a total of 1363 FTE researchers submitted in these UoAs (33% of all regional researchers submitted). 79.2% of the overall REF quality profile for the 10 UoAs rated as world-leading (4*) or internationally excellent (3*). 86.5% of the related impact case studies were rated as having outstanding (4*) or very considerable (3*) impact.

Publications Analysis. (Appendix DL3).

Analysis of publications data undertaken using SciVal and Scopus identified a total of 3,899 research publications in the broad area of digital living for the period 2011-15 (defined via institutional publication competencies in SciVal). Regional publications represent 5% of world research outputs and 25% of UK outputs in this thematic area.

Further analysis shows that regional publications in the digital living thematic area outperform the UK as a whole, in terms of publications in the top citation percentiles (27% vs. 23% in the top 10% most highly cited publications worldwide) and in terms of publications in the top journal percentiles (32% vs 28% in the top 10% most highly cited journals worldwide). The Field Weighted Citation Index (which measures how the citations received by the region's publications compare with the world average) is also considerably higher (2.47 for the region vs. 2.13 for the UK).

In addition, 3% of papers have industry co-authors (UK = 2%) and 52% have international co-authors (UK = 45%), which can be used as a proxy for collaboration, recognising that it will under report the levels of collaboration with industry as, in a number of technology fields, companies do not allow employees to co-author academic publications.

University Research Income

Research grants and contracts income in fields related to the Digital Living theme totalled £52.6m in 2014/15, and shows a steady upward trend from £29.6m in 2008/9. Total research income for the period 2008-2015 totalled £261.7m. This increase of 78 % for Digital Living compares with a 43 % increase over the same period for the sector.

The region's research income in Digital Living shows a healthy balance of funders with Research Councils making long-term investments in strong underpinnings alongside funders of more applied work.

Appendix DL4 provides further details of research income by institution and funder type.

4. Innovation strengths and growth points

Using standard measures of economic activity, employment data and counts of active enterprises is challenging in this field. Many companies that are connected with the theme will identify themselves across a range of product and service sector industrial classifications which in themselves struggle to represent the changing business models and new technologies in this area.

As digital technologies are seen as nationally critical this has led to experimentation by a range of bodies such as NESTA in new ways of capturing data about the broad sector.

These methods and the associated reports identify that the audit region has a number of well-established and nationally significant high tech/digital clusters. The 2016 Tech Nation report highlights digital technology clusters in Bristol and Bath, Cardiff, Exeter and Truro & Redruth. Clusters were identified using quantitative indicators such as the density of digital tech companies in an area, economic performance and growth rates and the level of community activity (networks, meetups etc.) Figure 1 in Appendix DL8 gives key data from this report.

Patents

Technologies underpinning the Digital Living theme make up a significant proportion of the patenting activity in the SIA region. Regional patenting in Digital Communications makes up 20% and Computer Technology 12% of the UK total in these fields. With Telecommunications they are also within the top 5 areas for patent activity in the region, each representing more than 10% of total patents in the SIA area. Companies in the region hold significant global patents pertaining to the underpinning technologies such as cloud computing, business intelligence/analytics, high performance computing and machine learning. See Figure 2 in Appendix DL8.

Digital Health

The region is unusually well endowed with health related data collected on its citizens whether as individuals, within households and across the wider population. In Bristol, for example, this data is collected routinely as part of people's clinical care and through monitoring airborne exposures (pollutants, allergens), via existing major research projects such as ALSPAC, the MRC Integrative Epidemiology Unit, and the EPSRC funded SPHERE project, or through other programmes such as Bristol City Council's Quality of Life Survey.

Distinctive Regional Demographics: Our stable and ageing population presents a significant opportunity to develop health and life science industries in the region. In particular the South West peninsular has a significant over-representation of older people with 49.5% of the population aged over 45 and 22% above the age of 65; 6% higher than the national average[4]. In Wales, the Public Health Wales Observatory highlighted in early 2016 that the number of people aged 65-84 has increased by 17% between 2005 and 2014 and the number of people aged 85+ has increased by 27% over the same period. Between 2016 and 2036 the number of people aged 65-84 is expected to increase by 40% and those aged 85+ is expected to increase by 145%.

A number of regionally commissioned reports[5,6] highlight the opportunities for economic regeneration arising from this demographic and the resulting changing nature of healthcare provision, including an increased focus on prevention, early intervention and community-based service models with an older population providing a test bed for digitally enabled innovations which can help support the health and care of older. Significantly, the diversity of the region (e.g. ethnicity, income, occupation, connectivity, urban/rural) makes the region an ideal location for proving new technologies that can ultimately be marketed worldwide to the majority of developed nations that face the same demographic challenges.

Further analysis of these findings by the SW Academic Health Science Network (AHSN) in 2014 suggests these demographics, alongside the regions strength in leading the development of integrated care systems presents an opportunity to catalyse innovation, including attracting businesses to research, pilot and test innovations[7] in the region, alongside catalysing the region's hi-tech SME cluster and the broader entrepreneurial community to respond to clearly defined challenges in the health system identified through the increased investment into health research.[8]

An exceptional capability in population health research provides companies with access to world-leading expertise in evaluating the performance of digital technologies in improving population and individual health in the region. When combined with underpinning world leading capabilities in fields such as designing and evaluating complex health interventions wireless and optical communications technologies, data security and encryption and other major projects that are integrating data across, for example, primary, secondary and social care this provides a unique proposition to SMEs and larger corporations and will attract them to develop and grow in our region.

E-Health and E-Wellbeing is a priority in the Cornwall and Isles of Scilly LEP SMART specialisation framework. Healthy Ageing is identified for Cornwall and the Isles of Scilly and the Heart of the South West LEP areas, capitalising on regional assets and the distinctive demography of the SW Peninsula

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[4] ONS LEP Profiles (2012) www.neighbourhood.statistics.gov.uk/HTMLDocs/LEP/LEPD/atlas.html

[5] The Old and the New: New opportunities for education, research and economic regeneration arising from the needs of older people (2012).

[6] www.erdfconvergence.org.uk/_userfiles/files/GrowthProgramme/3C&IoSRD&IFramework.pdf

[7] Bain & Company (2013): Opportunities in Integrated for Pharma and Medtech- When, Where and How Should Manufacturers get involved?

[8] Ibid.p49

- NHS England - two Academic Health Science Networks (AHSN) cover the audit region. They are very active in supporting the development of the digital health sector and linking it into the NHS – the primary customer for digital interventions and into the local authorities who now have responsibility for public health in England.
- In Wales, the Welsh Government digital health and care strategy was announced in November 2015. NHS Wales is working with companies in the audit region to develop and trial services and products, working with innovators, entrepreneurs and suppliers in a digital health network and increasing NHS access to future technologies and innovations.

TechSPARKs Cluster map[9] (Appendix DL7) identifies that the regional Digital Health sector is made of 70 companies in the region. The UK digital health sector is estimated to be worth £2bn, forecast to rise to £2.9bn by 2018, with a 2015 turnover of £886m and 7,400 employees.[10] The global market value is estimated to be €17.6bn in 2017[11].

Innovation support mechanisms include:-

- **Development programme to support healthcare innovators in the West of England**. - SETsquared & West of England Academic Health Science Network (AHSN) - The Programme is an intensive four day course that is open to healthcare professionals, health and life science academics, small businesses and public contributors. It is focused on innovators with a clear business proposition, or with an innovative idea that has an application in the healthcare sector and can bring substantive benefits. These are frequently in the Digital Health field
- **South West Interactive Healthcare Programme**, Announced in July 2016 the South West Academic Health Science Network, Creative England, West of England Academic Health Science Network and SETsquared – Fund of £500,000 for creative and digital companies to develop innovative healthcare technology and solutions
- **Webstart**[12] is developing a specialist e-health accelerator
- **University Enterprise Zone,** University of the West of England – A Health Tech Hub has been proposed by UWE with the West of England AHSN focusing on innovation for independent living and citizen-centric health, bringing together expertise in robotics, biosensing, microelectronics, data analytics (for healthcare) and communications to provide businesses with a comprehensive suite of advanced R&I facilities and specialist expertise to improve their rate of innovation, reducing time to market, cost and risk associated with product development
- **Assisted Living Action Network,** a platform for businesses, healthcare professionals, service user groups and academic researchers to stimulate the development of innovative assisted living products and services in the South West. ALAN is managed by executive members, Designability, the University of Bath Innovation Centre, and Bath Research & Development (NHS BANES, Swindon, Wiltshire)
- The EPSRC-funded **SPHERE** programme is now making available health-focussed IoT devices and platforms available to a number of companies and academic consortia nationally and internationally for the purposes of conducting clinical trials of

[9] techspark.co/cluster-map/
[10] http://www.sehta.co.uk/wp-content/uploads/2016/06/Stephanie-Parker-Office-for-Life-Sciences.pdf
[11] https://ec.europa.eu/digital-single-market/news/mhealth-what-it-infographic
[12] www.webstartbristol.com/

interventions and self-management tools. As SPHERE matures its technology and pool of 100 researchers will naturally underpin regional aspirations in this space.

Digital Creative Economy

The creative industries, based on digital technology, is the fastest growing sector of the UK economy at 8.9% a year (against an average of 4.6%), and makes up 5.2% of the economy as a whole.

According to the Department for Culture, Media and Sports January 2016 economic estimates[13,14] in the South West creative industries grew 21.5% in 2013-14, overtaking the North West. Bristol and Edinburgh are the only UK cities outside the London/SE region to appear in the top 20 for their concentration of both creative industries and technology, defined by location quotient.

The Geography of the UKs Creative and High Tech Clusters Report[15] demonstrates that Bristol is one of only five clusters in the UK that demonstrate high concentrations of employment in both the creative economy and in high tech, making it well positioned to lead in creative digital applications and technologies.

According to research[16] published in 2015 by the Creative Industries Council, Bristol is one of three UK cities outside London identified as having the best prospects for future growth in the creative industries. The Cardiff and South East of Wales area has been increasingly recognised as a significant cluster in this thematic area and in particular the subset of activates around the film industry. This sub theme is dominated by small SMES or sole traders, who come together to deliver particular projects or programmes of work. Film and video post-production companies, who are typically very heavy users of digital technologies have grown up, in particular in Bristol and Cardiff, originally driven by the presence of the BBC in both cases.

TechSPARKs Cluster map[17] (Appendix DL7) shows a Digital Creative economy which is made of 500 companies in the region, totalling revenues of £660m with 15,900 employees.

- **Aardman Animations,** based on two sites in Bristol, and employs 250 people is celebrating its 40th year in 2016. In 2015 it purchased a majority stake in US animator Nathan Love creating its first overseas production facility.
- The **BBC** has a very strong TV and media production presence in Cardiff, with 1300 staff and Bristol with 1000 staff.
- Cardiff is home to a significant proportion of BBC creative output (such as *Doctor* Who and many other popular programme making). It hosts Roath Lock Studios, the BBC's 17,000 m^2 drama production studio complex in Porth Teigr

[13] www.gov.uk/government/uploads/system/uploads/attachment_data/file/523024/Creative_Industries_Economic_Estimates_January_2016_Updated_201605.pdf
[14] www.gov.uk/government/publications/digital-sector-economic-estimates-january-2016/digital-sector-economic-estimates-2016-key-findings
[15] www.nesta.org.uk/publications/geography-uks-creative-and-high-tech-economies
[16] www.gov.uk/government/groups/creative-industries-council
[17] techspark.co/cluster-map/

- Bristol is the home to the BBC Natural History Unit (300 staff), and part of the following teams are also based in the city - Arts programming, Factual formats, features and daytime, Documentary production
- **Pinewood Studios**, in Cardiff has a 7,000 m^2 site. It collaborates with Bath-Spa University on degree programmes in Film, Television and Digital Production

The region hosts a number of innovation assets to support this activity

- **Launchpad** is a major games and creative tech incubation model in Falmouth, designed to respond directly to market needs.
- **Pervasive Media Studio** – Hosted by Watershed, PMS is a world leading open innovation centre and a community of over 100 artists, creative companies, technologists and academics exploring experience design and creative technology. Projects can be cultural or commercial and span play, robotics, location-based media, food, connected objects, interactive documentary and new forms of performance.
- The **SETsquared centres** in Bristol, Bath and Exeter[18], along with the **Welsh ICE: Innovation Centre** for start-ups in Wales[19] and the **Alacrity Foundation**[20] in Newport, Europe's only charitable technology incubator, are notable business incubator assets.
- The **Formation Zone** (Plymouth) has supported 180 businesses to develop, mainly in the Digital Creative Economy,
- Plymouth University operates a network of **Innovation Centres** (Pool, Tremough and the Health and Wellbeing Innovation Centres) on behalf of Cornwall Council. Plymouth Science Park is host to some 43 Digital and Creative companies
- The new **Devonport Market Hall**[21] – RIO (Real Ideas Organisation, an ACE funded body), due to open in June 2018 is a new digital hub, with 3,000 square feet of bespoke, quality office, lab for digital creative companies and organisations; a cultural, corporate events space with a seating for up to 350 people and an expo capacity of 600, and a digital visitor experience of touring programmes, screen and installation based work and programmed activity.
- **GloWorks**, Cardiff - 3200 m^2 Creative Industries Centre in Cardiff. Opened in 2014 and now fully let with tenants including leading television production company Boom Pictures and digital agency Sequence.
- **Cardiff Start** - a network of entrepreneurs, start-up founders, creatives, students and investors. Founded by creative/digital industries experts.
- **Bristol Media** - Industry led organisation, whose primary role is to facilitate collaboration and growth within the region, delivering projects, events and opportunities for over 550 members. Its mission is to drive creativity and innovation across the southwest creative and media sectors.
- **Digital Exeter** and **Tech Exeter** – networks supporting the grassroots development of digital creative, visualisation businesses
- **Gloucestershire Growth Hub,** operated by the University of Gloucestershire for GFirst LEP is working with the University's **School of Media and School of Computing and**

[18] www.setsquared.co.uk/
[19] welshice.org/
[20] alacrityfoundation.co.uk/
[21] themarkethall.co.uk/

Technology to support business incubation and development of creative economy enterprises.

- **The Imagarium** - Europes leading motion capture studio and production company based in Bath, in partnership with **CAMERA** – motion capture facility and researchers at the University of Bath

Smart Cities/Regions and Smart Transport

In the May 2016 Huawei sponsored UK Smart City Index Report[22] Bristol was identified as one of two UK leader cities, alongside London. The report identified that when it comes to technologies, strategies and visions, Bristol shows unique characteristics. Whilst London, as a global megacity, operates on a different scale than any other UK centre and benefits from its global financial centrality, Bristol's competitive advantage lies in its vision and its world-leading city-networking project, **Bristol Is Open (BIO)**. Other city strengths included its deep understanding of the open data revolution, energy-management innovations and community engagement. The report highlighted the importance of **playable city** ideas – a Bristol innovation - a reminder of the need for smart cities to be attractive, engaging and efficient.

In May 2016, **BIO** was awarded the global 'Smart City Innovator' award at the TM Forum 2016 – Digital World Awards[23]. TM Forum is the global member association for digital business. BIO[24], is a city networking project with the potential to emerge as a world-leading large-scale environment for the testing of technological, social and urban innovation. **Monmouthshire Made Open**, and **MonmouthpediA**, are examples of digital-social innovation built on co-creation approaches. **Exeter City Futures** a public private partnership is driving forward a smart city ambition for the Exeter region.

The West of England is host to **Venturer** and **Flourish**, two of the UK pilot connected autonomous vehicle (CAV) projects. Exeter hosts the Innovate UK funded **Engaged Smart Transport project**, led by NTT Data, which aims to better understand and influence real time travel behaviour through traffic management systems and individual smart technology. The audit region has strengths in rail automation and control systems. **Siemens Rail Automation** has its UK centre for manufacturing and its global centre for R&D in Chippenham, Wiltshire. **Knorr-Bremse Rail Systems** is based in Melksham, Wiltshire and **Brecknell Willis** has its UK centre for manufacturing and its global centre for innovation in railway electrification systems in Chard, Somerset.

There is an emerging group of companies specialising in smart cities or transport related products and services in the audit region. Corporates such as **ARUP**, **Atkins**, **Buro Happold Engineering** and **Altran** are developing regional high level expertise in both smart cities and connected autonomous vehicles, and Bristol is Open (BIO) is attracting international corporate partners including major automotive manufacturers, **NEC** and **Nokia**.

Demonstrator programmes, such as **BIO** and **Smart Islands** (Scilly Islands), offer allow companies already active in digital applications opportunities to enter this emergent market area.

[22] www.huawei.com/en/news/2016/5/UKs-leading-smart-cities
[23] www.tmforum.org/about-tm-forum/awards-and-recognition/digital-world-awards/
[24] www.bristolisopen.com/

Underpinning Technologies: Cloud Computing, Communications and IoT

The underpinning technology theme is dominated by number of key corporates with assets in the region, together with a network of SMEs and start-ups.

Toshiba, Cray, Google, Huawei, ORACLE, IBM UK, Hewlett Packard Enterprise, Amazon, PCS, Intel and **Amdocs** all have a digital R&D and innovation oriented presence in the region. Specialist areas include Infrastructure as a Service (IaaS); Platform as a Service (PaaS) – including Data/Analytics, IoT; Software as a Service (SaaS) applications; high performance communications, storage and compute; machine learning; human computer interaction/immersion; chip design and cyber security.

Cray – in 2015 the US advanced supercomputer manufacturer chose to set up its European, Middle East and Africa (EMEA) R&D Centre in Bristol following its acquisition of Gnodal, an HPC technology company that has been supported by SETsquared.

Hewlett Packard Enterprise – Product Development teams in Bristol lead HPE's global investment in IaaS – storage and compute – products and are one of the most significant contributors to the OpenStack cloud computing initiative. HP also have product development teams in Bristol focussed on Data/Analytics R&D.

IBM UK – Cloud Data Services product development team in Bristol. IBM led the Network and Information Sciences International Technology Alliance, involving Cardiff University, along with other leading academic and industry partners such as Airbus UK Ltd. & Systems Engineering and Assessment UK Ltd.

Intel – Swindon, Intel's UK headquarters, hosts the Intel High Performance Computing Lab which gives partners early access to Intel processors and HPC technologies, and the Memory IP Lab which creates designs for Intels silicon processes to be used on Intel's system on a chip products. It also hosts the Internet of Things Ignition Lab, designed to work with innovators to develop end to end IoT solutions.

Intel Graphics and Media Lab - algorithms and software for Intel's processor graphics hardware. It focuses on 3D, media and Android core software and has extensive expertise in low power devices such as tablets and smartphones.

Oracle – Strategic product development centre and innovation centre in Bristol hosting Oracle's Analytics/Business Intelligence, Data Visualisation, Cloud (IaaS and PaaS) product development teams. In 2014 Oracle announced Bristol as one of four globally strategic product development centres.

Toshiba Telecommunications Research Lab - Bristol – since its inception in 1998 TRL has been at the cutting edge of research into technologies such as next generation wireless networking, reconfigurable architectures, and smart systems for energy, mobile and medical applications

The innovation support infrastructure for growth oriented tech companies is well developed, examples include:

- **SETsquared**, the University business incubator partnership with centres in Bath, Bristol and Exeter is now ranked no1 globally.
- Network/meetups groups are widespread and very active, examples include **TechSPARK**, **Digital Plymouth**, **TechSouthWest**, **Tech Exeter** and **Software**

Cornwall. I**nnovation Point**, Newport - provides services to help companies develop new and disruptive technology ideas that deliver growth

- **National Software Academy,** a new technology hub in Newport led by Cardiff University, trains industry-ready software engineers in partnership with industry and local businesses.
- **The Gloucestershire Science and Technology Park at Berkeley** is developing state of the art facilities for cyber and computing, including dirty lab and secure testing facilities for businesses. The Park is being developed in partnership by South Gloucestershire and Stroud College, the University of Gloucestershire and Gfirst LEP.
- **The Cheltenham Cyber Business Park** is a proposed Local Growth Deal 3 development adjacent to GCHQ in Cheltenham. The proposal builds on the county's strengths in computing and cyber security, and the announcement last year by the then Chancellor of the Exchequer of a new Cyber Innovation Centre in Cheltenham.
- **Exeter Science Park** hosts the Met Office collaboration space and new supercomputer.

Underpinning Technologies: Digital media, Virtual and Augmented Reality

The region has a significant track record pioneering innovation in digital media including for media production, virtual and augmented reality, simulation, 3D modelling and moving image research.

Hewlett Packard in Bristol has led significant advances in animated film production technologies in collaboration with Pervasive Media Studios, Bristol University and regional film production companies. SMEs such as YellowDog are pushing the boundaries of high performance cloud computing to establish a new generation of film production techniques.

Virtual and Augmented Reality are emerging technology areas, with significant economic development potential. As a set of creative design practices and skills this area draws heavily on CGI, vision technologies, immersive media (such as Data/Fulldomes) and a history of simulation and 3D modelling.

VR and related digital content is a major opportunity for the UK's world leading creative industries. The UK, as one of the world's leading creative sectors (film, TV, games, theatre and fashion), built on strengths in both creative talent and technology, is well positioned to lead in this area. VR is commonly applied to the games industry, but visionary start-ups in the region such as Interactive Scientific, Opposable group and ZUBR are applying VR to scientific and educational applications with broader citizen focused use cases. The region is host to aerospace, high tech digital and nuclear clusters. All these sectors have on their agenda the use of virtual or augmented reality to improve their operations and lower the cost of maintenance.

Airbus, GKN and EDF Energy have a strong interest in virtual and augmented reality applications to their businesses. EDF - *"VR/AR is firmly on our top level requirements list for improving the preparation of operations"*. This applies to both the nuclear new build agenda, and decommissioning. **Intel** Swindon hosts the Intel Wearable IP Lab which focuses developing the building blocks for a range of applications areas including Virtual and Augmented Reality.

The ecosystem is primarily based within the Bristol and Bath High Tech cluster and in Cardiff with clusters of computer games related activity and innovation support in Devon and Cornwall. The West of England has a connected group of firms that are already integrating VR into their businesses or products, from health, engineering, aerospace, training, education, film and media related content producers including digital and games. Recent investments including the high speed data connections through Bristol is Open and the Bristol Data Dome allow experimentation that cannot occur anywhere else, and the high profile VR World Congress conference further focuses attention on Bristol as a location for the future of VR and AR development

The Bristol Games Hub has been bringing the community together in the West of England, and organises the annual VR world congress conference, attended in 2016 by 750 delegates. Six companies make up the driving force behind this industry in the West of England: Opposable games, Auroch Digital, Big Robots Games, Evil Twin Artworks, Force of Habit, Esportsify and Yogscast. Notable Cardiff companies include On Par, Atticus, 4Pi Production and Orchard.

Prominent regional organisations with a role in supporting these technologies and content development include:

- The Pervasive Media Studio
- @Bristol
- Bristol Games Hub
- The Centre for Modelling and Simulation
- Games Wales South - a meetup for video-games developers in Cardiff
- The Games Academy, Falmouth University
- i-DAT at Plymouth University
- Formation Zone, Plymouth University
- The Interactive Systems Studio, an open innovation R&D studio, hosted by Plymouth University
- Oracle UK
- Plans are developing for a Bristol based VR Hub to support this emergent area (Appendix DL6)

Underpinning Technologies: Robotics and autonomous systems

Robotics and Autonomous Systems was identified by the previous Government as one of the 8 Great Technologies[25] in which the UK has the potential to be a global leader.

This theme has a strong concentration of activity around the West of England area with notable Plymouth based activity in marine autonomous systems research and innovation. The EPSRC knowledge map[26] highlights the West of England and the **Bristol Robotics Lab** as the main national research cluster in autonomous systems with additional presence in Plymouth, Exeter and Bath.

[25] www.gov.uk/government/uploads/system/uploads/attachment_data/file/249255/eight_great_technologies_overall_infographic.pdf

[26] www.epsrc.ac.uk/research/ourportfolio/knowledgemap/

The West of England LEP Strategic Economic Plan identifies robotics as a key strength of West of England's High Tech Cluster. The TechSPARK cluster map highlights twenty six companies working in this sector in the region, with economic revenues of £40M and one thousand three hundred employees.

This sector is underpinned by the regional presence of major corporates within the aerospace and advanced engineering sector (**Airbus, GKN, Rolls-Royce)** with an interest in robotics and autonomous systems. A number of other large companies and organisations are focused on sectoral applications including **Renishaw** in medical robotics, the **National Nuclear Laboratory** (NNL) who recognise that Robotics and Autonomous systems will play a key part in tomorrow's new build programme and decommissioning challenges and **GCHQ** Cheltenham which has identified the vulnerabilities in autonomous systems, including vehicles as a key risk in their deployment and is developing programmes to work with systems developers in this area. The region also hosts a number of large specialist engineering services companies with robotics domain expertise, such as **Altran.**

As identified previously The West of England is host to **Venturer** and **Flourish**, two of the UK pilot connected autonomous vehicle (CAV) projects and **ARUP** and **Atkins** are developing regional higher level competencies in autonomous vehicles. A number of smaller specialist companies have been successful, such as **OC Robotics**, who specialise in robotic systems for confined and hazardous environments and companies, such as **Applied Automation** and **MSubs**, who specialise in marine autonomous vehicles New companies are emerging such as **5AI** (Bristol and Cambridge) created by successful Bristol silicon entrepreneurs who are focusing on applications of AI in autonomous vehicles, **Imetec**, a Bristol University spinout company focused on remote monitoring for nuclear sites by autonomous UAV and **Open Bionics**, who are developing robotic prosthetics.

A range of organisations provide innovation assets to support organisations developing or using robotics and autonomous systems:

- The Bristol Robotics laboratory runs a business incubator[27], hosting currently ten start-up companies.
- Futurespace – the University Enterprise Zone at the University of the West of England provides start-up and grow-on space for technology/knowledge based businesses in robotics and autonomous systems and other related fields. Services will include provision of facilities and advanced tools for academic and industry innovators, collaborative projects and technology companies.
- The National Composites Centre is a centre of excellence in industrial robotics as applied to composites manufacture

5. National and international engagement

Digital technologies and applications are highly international with academic expertise and leading companies spanning many countries. As described in Section 4 many of the

[27] www.brl.ac.uk/businessengagement/technologybusinessincubation/brlincubatee companies.aspx

world's leading digital technology companies have innovation related operations in the audit region.

A total of 3,899 academic research publications were identified in the broad area of Digital Living for the audit region for the period 2011-15. Using SciVal, these papers were compared with UK, European and World publications in the same fields.

This analysis shows that the academic papers from the region's researchers have higher levels international co-authors than for the UK as a whole (52% vs 47%) and match that for corporate/industry co-authors (3%). Authorship can be used as a proxy for collaboration, recognising that it will under report the levels of collaboration with industry as in a number of technology fields companies do not encourage employees to co-author academic publications. A SciVal analysis indicated that the region's researchers collaborated most frequently with researchers from the USA, followed by Australia, Canada, Germany and France.

Academic research income data for the theme highlights that 22% is received from European Union research programmes and a further 3.3% from other international funders (Appendix DL4). The majority of this income is related to collaborative multinational research, and demonstrates significant levels of international collaboration and, given the competitive nature of this funding, regional excellence for researchers in the theme.

6. Developments in Science and Technology - international markets & opportunities

The UK digital economy contributes 7% of national output, 5% of jobs and 9% of businesses. This is similar to the US, but behind South Korea which leads the world at 11% of national output[28].

The UK Digital Catapult has recently refreshed its strategy to focus on technology layers offering UK businesses significant global opportunities. The audit region's research and innovation strengths map well onto this revised strategy. These layers are **Data** – including cyber security and privacy, **Connected** – Internet of Things and 5G, **Intelligent** – machine learning and artificial intelligence and **Immersive** – virtual and augmented reality and new forms of human machine interfaces. It highlights **Creative industries** and **Health** as sectors to target, alongside **Digital Manufacturing** which is addressed under the Aerospace and Advanced Manufacturing theme in this audit.

Clear market and technology opportunities have been identified across the main Digital Living themes and underpinning technologies.

Digital Health

NESTA published "The NHS in 2030"[29]in July 2015. This document offers a vision for the NHS in the medium–term future. It clearly identifies that the digital sector can play an important part in addressing the issues linked to an ageing population along with the reduction of the costs of care and the provision of better care, empowering the individual in term of access to their data and self-diagnosis.

- New improvements in digital technologies will enable an explosion in the use of personalised medicine

[28] The Economist , 11 June 2016
[29] www.nesta.org.uk/sites/default/files/the-nhs-in-2030.pdf

- New digital technologies also allow people to track and analyse their own health data, and to share this and other health knowledge with others in ways that will aid prevention and management of long–term illnesses

Precision medicine will be improved, for example machine learning could be a way to discover new signals of illness or monitor the effects of treatment.

Health knowledge and support, in the form of citizen empowered data access would be able to be delivered, leveraging on the following technologies/applications:

- Microelectronics & silicon design
- Cloud computing, infrastructure, bespoke platforms
- Vision
- Robotics/autonomous systems
- Communications

Virtual and augmented reality will play a role in diagnostics and other interventions, including robotic and remote surgery.

All of these opportunities will be enabled by advances in high speed communications, new sensors development, security and data analysis. As key customers and stakeholders the NHS and associated organisations will be drivers of an active UK supply chain, positioning UK industry as competitive on the world stage. In a report[30] for the UK Office of Life Sciences, Monitor Deloitte segments Digital Healthcare into four areas – *Telehealthcare* – where the UK (and the region) has high penetration rates but risks losing competitive advantage as we remain at the demonstrator stage, *mobile (m)health* - with predicted growth rates of c.35% in the UK (2014-18) but challenges in monitising developments due to the NHS reimbursement models, *Analytics* – where growth rates of c 24% are predicted up to 2018 with a strong UK academic base and the NHS offering a single data source and purchaser opportunity and *Digital Health Systems*, the largest and slowest growing segment, with particular challenges in driving the adoption of electronic health records into the secondary acute NHS hospital market and where US suppliers dominate.

The report identifies a total UK market size of £2bn (£23bn worldwide) in 2014 rising to £3bn (£43bn worldwide) in 2018, with Digital Health Systems representing 50% of this market.

Digital Creative Economy

A significant overlap and convergence exists between two significant UK sectors, 'digital/high tech' and 'creative industries' giving rise to the term 'Digital Creative Economy'. NESTAs report "Geography of the UK's creative and high tech economies"[31] highlights that the UK's creative economies sector has been growing more than three times faster than the workforce as a whole. The part of the UK workforce which straddles both the creative and high tech economies has been particularly dynamic growing at 8 % per annum

Digital Economy

[30] Digital Health in the UK: An industry study for the Office of Life Science, Sept 2015, Monitor Deloitte

[31] www.nesta.org.uk/publications/geography-uks-creative-and-high-tech-economies

- The Digital Sector accounted for 7.3 per cent of the UK Economy in 2014, the highest proportion recorded, up from 6.9 per cent in 2009
- The value of goods exported by the UK Digital Sector in 2014 was £15.9bn, a 3.3 per cent increase on the 2013 value of £15.4bn
- In 2009, GVA of the Digital Sector was £93.7bn, and accounted for 6.9 per cent of the UK economy. Between 2009 and 2014 it increased by 26.3 per cent, compared to an increase of 20.0 per cent for the UK economy as a whole over the same period
- In 2014, there were 2.0 million jobs in the Digital Economy, an increase of 1.7 per cent compared with 2013 and 6.4 per cent of the total number of jobs in the UK
- The number of jobs in the Digital Economy has increased by 7.1 per cent since 2011 to 2.0m, representing 6.4% of UK jobs, which increased by 4.2 per cent.

The Creative Economy

- The GVA of the Creative Industries was £84.1bn in 2014 and accounted for 5.2 per cent of the UK economy
- It increased by 37.5 per cent between 2008 and 2014, compared to an increase of 18.2 per cent for the UK economy as a whole
- IT, software and computer services continued to be the largest constituent part of the Creative Industries, accounting for 43.5 per cent of the Creative Industries GVA

Smart cities/region & transport

In a 2013 report for BIS[32] ARUP identified the market for Smart Cities products and services at greater than $400bn in 2020 with Smart Transport valued at $150bn and with a growth rate of greater than 20%. The ARUP report also suggests that the UK's main opportunities will be in design, finance and engineering services, which it estimates could constitute 25% of the global annual spend.

IoT and Smart Cities are clearly linked opportunities. The integration of data analytics with the cloud, sensors, software development, data storage, security and cryptography and resilience is ready to happen, and the convergence of different strands of technologies coming together will underpin future services and products. Bristol is Open is now at the stage of proving the concept of a truly smart city, where citizen could be empowered. The programme was featured in the Innovate UK commissioned report on Smart Cities[33].

The technologies are today ready for use and integration, as evidenced in the "Era of Living Services" produced by Fjord[34]. The audit region, from Bristol, to the Isles of Scilly through the Smart Islands programme is deploying test beds and running demonstrator projects (such as in connected autonomous vehicles) and is ready for the next revolution.

Underpinning Technology: Cloud Computing (including IoT & Communications)

This theme underpins all applications and sub-themes listed. In communications, trends in video consumption especially mobile video, new formats such as 4K and 8K, cloud computing and storage have driven an exponential growth in data transfer. The trend for all devices to be connected (IoT) and the emergence of new services and content are

[32] www.gov.uk/government/uploads/system/uploads/attachment_data/file/249423/bis-13-1217-smart-city-market-opportunties-uk.pdf
[33] https://issuu.com/senatepublishing/docs/smart_cities?e=24164424/36469903
[34] www.fjordnet.com/conversations/the-era-of-living-services/

driving communications and cloud computing research in a wide range of fields to achieve the required performance, scalability and agility.

Quantum engineering represents a promising emergent technology. From the development of a quantum computer to the improved cryptography using quantum key (QKD) methods, this is recognised at Governmental level as a UK's priority with £275m committed to fund developments. It is one of the EPSRC defined research themes.[35]

The 2016 Ericsson Mobility Report predicts that Internet of Things is expected to surpass mobile phones as the largest category of connected devices in 2018. Additionally it differentiates the two major emerging markets, each one with different requirements: massive and critical applications.

- Examples of massive applications include smart buildings, transport logistics, fleet management, smart meters and agriculture. All of these are characterised by the need for high connection volumes, low cost, low energy consumption and small data traffic volumes.
- Critical IoT connections, instead, require ultra-reliability and availability, with very low latency. This category includes traffic safety applications, driverless cars, industrial applications, remote manufacturing and healthcare applications.

The aerospace engineering industry, which is very strong regionally, offers a route to market for many of these technologies. For example IoT, cyber security and embodiment of high level of security / encryption from the design stage are at the forefront of Airbus Group strategic thinking. The company relies heavily on its specialist supply chain. Accelerating the product development cycles for regional SMEs and other suppliers would be of clear interest for the group.

Underpinning Technology: Digital media (including VR/AR)

Digi-Capital[36] highlights that the major VR /AR segments which will be generating revenues in the future are:

- Content (gaming, film and TV, healthcare, education and social)
- Hardware and distribution (headsets, graphic cards...)
- Software platforms and delivery services (content creation tools, B2B and enterprise uses).

Across these three segments VR and AR are expected to generate total revenues of about $150Bn 2020. As a comparison the film industry, generates content revenues of $104bn today.

The demands VR/AR applications and services place on data transfer is also driving many of the developments that will underpin 5G mobile wireless standards and will leverage future developments in cloud computing and storage, areas of strength for this region.

Other industrial applications of AR and VR have been proposed and researched including for example maintenance and operations support in aerospace and other advanced

[35] www.epsrc.ac.uk/research/ourportfolio/themes/quantumtech/

[36] www.fastcompany.com/3052209/tech-forecast/vr-and-augmented-reality-will-soon-be-worth-150-billion-here-are-the-major-pla

manufacturing fields. The technologies also offer opportunities to enhance workplace learning across a wide range of sectors. To date few applications have reached regular use and significant opportunities exist for content producers and end user companies. IHS[37] predicts that 14 million headsets will be sold in 2016 and 22 million by 2017. Juniper Research forecasts that wearable VR head mounted display shipments will approach 30 million globally by 2020.

Whilst headset and other high level hardware development is unlikely to take place in the UK, much of the content for such devices could and will come from this region, with our creative industries already significant players in the creation of mobile content, games, experiences and installations. The demands VR/AR applications and services place on data transfer is also driving many of the developments that will underpin 5G mobile wireless standards and will leverage future developments in cloud computing and storage, areas of strength for this region.

Other industrial applications of AR and VR have been proposed and researched including for example maintenance and operations support in aerospace and other advanced manufacturing fields. For example Airbus / Endeavr runs the SCADA/ICS Cyber test lab in Newport and are working on AR/VR directly with Microsoft as a Hololens early adopter. The technologies also offer opportunities to enhance workplace learning across a wide range of sectors. To date few applications have reached regular use and significant opportunities exist for content producers and end user companies.

The Centre for the Analysis of Motion, Entertainment Research and Applications (CAMERA) at Bath is working with Headley Court to use 3D scanning techniques to advanced gait analysis for the development of next generation prosthetic limbs for amputees. They are also providing a training platform for those who board naval ships, recreating the stress of such environments through realistic VR content is of high importance.

VR/AR is an emerging area, but there is a strong cross-sectorial case to be made for developing further capabilities in the region. As an example, operational VR capabilities are currently being imported into Airbus in the UK from other parts of the Airbus group, especially in the areas of maintenance and training. Thanks to the regional critical mass in the gaming industry detailed earlier, there is a strong case for ensuring the aerospace and advanced engineering and gaming industries work collaboratively on the development of VR/AR technologies transferrable across sectors.

Underpinning Technology: Robotics/Autonomous Systems (RAS)

A 2013 McKinsey study[38] into disruptive technologies estimates that by 2025 RAS technologies will have an impact on global markets of between $1.9 and $6.4 trillion per annum. Current estimates from Europe and Japan indicate that the market for RAS products and technology, for non-military sectors, will be in the order of £70 billion by 2020-2025.

The RAS sector is made up of a large number of sub sectors. Industrial robotics markets make up the majority of the current and future market. This sector is forecast to be valued

[37] technology.ihs.com/551073/virtual-reality-and-entertainment-bubble-or-next-big-thing
[38] Disruptive Technologies – advances that will transform life, business and the global economy, McKinsey Global Institute, May 2013

at $80bn by 2022 but is unlikely to be addressable to any degree through the regional science and innovation base. There are however many opportunities in niche and emergent sectors[39] that can and will be addressed. Examples include in nuclear decommissioning, where the audit region has leading research and commercial strengths in UAVs and in robotic manipulators and vehicles, RAS is projected to make up 20% of the £50bn per annum global decommissioning costs by 2020. In offshore energy and oil recovery autonomous underwater vehicles (a regional strength) are poised to revolutionise the sector.

In health and social care a 2010 study forecast that annual UK public expenditure on long-term care will increase from £11.3 to £31.1 billion by 2032, with private expenditure due to rise from £7.3 to £22.4 billion in the same period. RAS technologies are emergent in this sector with very significant potential impact on how a future aging population lives and how its healthcare is delivered.

The economic benefit in terms of national costs avoided thanks to the use of RAS as part of the intelligent mobility solutions in transportation over the next 20 years is estimated to be in the order of £1tn for the UK. The world connected autonomous vehicles (CAV) market alone has been valued at $30bn by 2030 by Frost and Sullivan, dominated by vehicle sales. Whilst the region will not capture the majority of this market, systems, communications and control form a significant part of the value add and science and innovation challenges in these areas are being addressed in the region.

7. Conclusions

Investment Opportunities

In both the applications areas and key elements of the underpinning technology base the region has considerable strengths. It has an attractive mix of leading large globally leading companies and innovative and high growth oriented smaller companies that can take advantage of rapidly moving markets with significant economic potential.

The region has also invested in a wide range of innovation resources to support particularly the smaller innovative companies in the fields highlighted. These include Innovation Centres and incubation support, demonstrator platforms and development funds. These resources are somewhat fragmented and investment has tended to be focused at the local (LEP) level with local economic growth as the focus, without considering the regional context. Project and support mechanisms continue to be developed and Appendix DL5 shows a portfolio of digital innovation projects currently under development at the regional level, targeting a range of sources of public investment.

An opportunity exists to better link these innovation support mechanisms, so as to ensure that each is adopting best practice and to link them to existing regionally based companies, large and small, with direct market related interest and technologies to bring to bear. Whilst Universities are frequently hosts or major partners in such initiatives there remains more to be done to integrate science base expertise and those organisations with the potential to collaborate with the researchers, exploit the research outcomes and identify the new research challenges and opportunities.

[39] RAS 2020 Robotics and Autonomous Systems National Strategy, July 2014

A significant opportunity exists to integrate the regional science base with the industry base to bring early stage underpinning research together with the demonstrator phase required to support transition and adoption, and the companies who are leading in the field.

Building on models that have operated both at the regional level in different applications areas (e.g. the National Composites Centre) and internationally in digital innovation (e.g. the Qualcomm Centre at the University of California San Diego) a business case is being developed for a hub-and-spoke based open innovation approach.

At its centre will be a **Digital Innovation Hub (DIH)**, a physical facility that reinvents for the 21st Century the concepts of university-industry partnership and of postgraduate-level education. The DIH will be embedded and integrated within a vibrant and nationally-leading digital technology industry cluster, housing academic researchers in a broad range of disciplines related both to underpinning digital technologies (e.g. cloud computing and HPC; digital media; robotics & autonomous systems; etc) and also to specific application-areas (e.g. digital health, smart cities, and transport systems). The DIH facilities will allow companies to base their employees in the DIH's dedicated office and lab spaces, and to use the DIH's specialist digital infrastructure. But, most significantly, the DIH will offer companies year-round access to working with the University's DIH students engaged in novel postgraduate degree courses with a focus on project-based and problem-based learning, where the content of the education courses is tailored via co-creation and co-delivery with industrial partners. Such courses will also likely be of great value for in-work skills re-training of existing employee. In this sense the primary focus of the DIH will be on the generation of "talent", the highly skilled workers needed for the digital technology companies in underpinning technologies and applications-related areas.

It is envisaged that large companies would wish to base programme or project teams in the building, making use of world leading digital infrastructure and that early stage companies may base themselves in the building from start-up through to the fast growth scale up stage (20-30 employees), supported by world class business advice from **SETsquared**. The Hub building design will recognise the need for commercial confidentiality but would also be designed so as to catalyse and accelerate informal communication between postgraduate students, academic researchers and company employees.

Rather than being an isolated ivory tower, the DIH will build on the region's expertise in community co-production and real world technology evaluation. A defining characteristic of Digital Living is the need to consider the impact of new technologies on daily lives. Recent months are replete with expensive examples of the unanticipated side-effects of digital technologies on the privacy, safety and livelihoods of individuals. There is both a moral and commercial imperative to ensure that acceptability and value are an inseparable part of digital research and development of the design and evaluation of pilots and of the training of young innovators, engineers and scientists.

The Hub will also act as a host location for collaborative project teams, specialist innovation support such as the cross sectoral **VR Hub** referenced previously and as a major demonstrator site in specific digital applications areas, showcasing technologies and applications to a wider audience and allowing early stage technology development to be

accelerated. Figure 4 in Appendix DL8 gives a graphical illustration of a city or region scale demonstrator, integrating many aspects of underpinning technologies with applications level integration.

Finally the Hub will be the home to new and novel postgraduate education programmes, with the focus being on technology project and challenge based learning delivery (normally in conjunction with partner companies), combined with underpinning enterprise education. This format is designed with the objective of producing highly skilled future employees for the digital technologies sector and ensuring they are equipped to be productive at a much earlier stage of their employment that conventional post graduates.

As a Hub it will also have a responsibility to link to other specialised Digital Centres at the regional and national level, (e.g. the 5G Centre at Surrey University), including those focused on supporting start-up and growth technology companies and to offer underpinning technology support to those working in specific application areas regionally, such as Environmental Resilience and Risk (see outline business case for the **Institute for Environmental Risk**- Appendix N), Robotics and Autonomous Systems and Digital Manufacturing.

It will work closely with Catapults at a national level particularly Digital, Future Cities, Energy Systems, Transport and Advanced Manufacturing, acting as a regional focal point or node as appropriate. In order to best link to the innovative SMEs around the region it will partner with Innovation Centres and incubators around the region, best placed to support and develop such companies.

The outline business case for the **Digital Innovation Hub** can be found in Annex N.

Appendices

Appendix DL1 - List of Assets

Digital Health

Asset	Host / Lead	Descriptor
Corsham Institute	Wiltshire	Citizen led data initiatives, Ark Data Centre which securely stores the majority of NHS Biobank/Genomics data.
Connecting for Care consortium	WoE AHSN, 3 Local Authorities, 100+ GP Practices	Around 1 million citizens so far on an NHS interoperability platform and growing is also significant. This is now starting to provide base for R&D activities, which are becoming exploitable
Anchor Robotics Personalised Assisted Living (ARPAL) facility	Bristol Robotics Lab – UWE, Univ. Bristol JV	Living lab that enables robotics researchers, elderly people with assistive needs and those supporting them, to work together to devise and test new robotic solutions in a home environment -
Neuro-Cognitive Research Centre	Plymouth Univ.	Designs and develops new computerised measures of cognitive functioning in neurodegenerative diseases and Health solutions for various diseases or conditions
South West NHS Genomic Medicine Centre	RD&E, Exeter	The South West GMC works with a number of national organisations to achieve the aim of sequencing 100,000 genomes.
SPHERE programme	Univ. Bristol	£ 12M programme - A synthesis of Digital Living technologies being brought together to deliver against the healthy ageing agenda, focusing on employing data-fusion and pattern-recognition from a common platform of largely non-medical/environmental networked sensors in a home environment. Uses local area as a test lab.
West of England Genomic Centre	WoE AHSN	Links longitudinal citizen data sets on over 20,000 individuals over 20 years.
The Diabetes Digital Coach Test Bed	WoE AHSN	NHS IoT Testbed Programme to link mobile health self-management tools (wearable sensors and supporting software) with the latest developments in connecting monitoring devices. Will enable people with Type 1 or Type 2 diabetes to self-manage their condition & encourage more timely and appropriate interventions from peers, healthcare professionals and carers.
MRC Integrated Epidemiology Unit	Univ. Bristol	Conducts some of the UK's most advanced population health science research. It uses genetics, population data and experimental interventions to look for the underlying causes of chronic disease.

ALSPAC	Univ. Bristol	A world-leading birth cohort study. Between April 1991 and December 1992 more than 14,000 pregnant women were recruited and these women, the children arising from the pregnancy, and their partners have been followed up intensively over two decades. It is the most detailed study of its kind in the world and a rich resource for the study of the environmental and genetic factors that affect a person's health and development.
Centre of Excellence - part of the Precision Medicine Catapult	Cardiff Univ.	Providing diagnostic tests and data-based insights into a patient's disease. Led by a consortium headed by Welsh Government, NHS Wales and the University, the Centre will collaborate with local, national and global stakeholders including Welsh Government, academia, health systems and SMEs, to identify and resolve barriers to building a leading UK precision medicine industry
Clinical diagnostics	Cardiff Univ.	Focus is obtaining pathophysiological information from members of the population as a means of providing data for digital processing or remote monitoring
CLIMB project	Cardiff Univ. (partner)	Cloud Infrastructure for Microbial Bioinformatics - develops and will deploy a world leading cyber-infrastructure for microbial bioinformatics; providing free cloud-based compute, storage and analysis tools for academic microbiologists in the UK.
Wellcome Trust Centre for Biomedical Modelling and Analysis	Univ. Exeter	Brings together scientists from quantitative disciplines including mathematics, computer science and physics with those from biology, biomedicine and clinical sciences to enable breakthroughs in biomedical and clinical research
EPSRC Centre for Predictive Modelling in Healthcare	Univ. Exeter	A world leading team of mathematicians, statisticians and clinicians with a range of industrial partners, patients and other stakeholders to focus on the development of new methods for managing and treating chronic health conditions using predictive mathematical models.
SMART lab	Univ. Exeter	Study of Maladaptive to Adaptive Repetitive Thought - work includes development of digital tools to support patient self-management and reporting.
EXTEND	NIHR Clinical Research Facility Exeter	Provides a database of nearly 10,000 people who have agreed to participate in healthcare research carried out at the University of Exeter and have donated samples to a biobank.
European Centre for Environment and Human Health	Truro, Univ. Exeter	Leads the Medical & Environmental Data Mash-up Infrastructure (MEDMI) project which aims to connect diverse databases to improve our understanding of the links between climate, environment, and human health.

Telecare & Telehealth	Cornwall College	Delivery of qualifications for telecare and telehealth practitioners for well over 10 years strong links with the Telecare Services Association (TSA) - the industry body for telecare and telehealth. extensive links with local business
National Centre for Excellence in telehealth and telecare	Cornwall, BT	
Centre for Robotics and Neural Systems	Plymouth Univ.	Ambient intelligence and robotics to support young patients and elderly users.
Interdisciplinary research initiatives	Plymouth Univ.	E-Health: health decision-making; telehealth (e.g. e-Caalyx and LiveWell); “big data” (e.g. BioPattern); user-led e-health (e.g. SharpTalk and Diabetes App Challenge); social robotics (e.g. ALIZ-E and ROBOT-ERA); computer-aided diagnosis (e.g. ACEmobile); development of novel eHealth interventions (e.g. Face It); and e-health implementation studies (e.g.Superfast evaluation, Plymouth SeniorNet)
Cognition Institute’s CogNovo	Plymouth Univ.	Exploring different methods of iterative and bidirectional communication and engagement with communities to understand the barriers and enablers of technology to deliver prevention, health and social care;); Establishing the full impact of technology-based health and wellbeing social care throughout a person’s life in home, workplace and community; Extending the application of gaming technology to the health and wellbeing sector; Understanding the impact on other health and social care services of prolonged use of assistive and innovative communication and delivery technologies;
Institute of Health and Community	Plymouth Univ.	VOYAGE is an inter-disciplinary initiative that harnesses research and innovation in the field of ageing across Plymouth University and its many external partners.
NHS Digital Exemplars	NHS Foundation Trusts	Taunton and Somerset NHS Foundation Trust and University Hospitals Bristol NHS Foundation Trust have been selected as two of twelve “digital exemplar” sites in England to lead the use of digital technology to drive radical improvements in the care of patients. They will each received £10m from NHS England in a bid to inspire a digital revolution across the health service.

Digital Creative Economy

Asset	Host / Lead	Descriptor
Knowle West Media Centre	WoE	Develops opportunities for a wide range of people to 'imagine' the future, by testing ideas and digital technology within communities, public spaces and homes
REACT Hub	UWE, Bristol, Cardiff, Exeter	One of 4 knowledge exchange hubs funded by the AHRC, which connected arts and humanities researchers to creative technology businesses to make new prototype products or services. REACT has been bringing together a local cluster of micro-companies around the Persuasive Media Studio, which acted as a Hub
Digital Cultures Research Centre	UWE	Concerned with the meaning and uses of media technologies in everyday life, focusing upon Pervasive Media, Play, and User-Generated Content.
iDAT	Plymouth Univ.	Vehicle for world-class research and development activities alongside commercial and cultural projects which extend the University's cultural and arts programmes and support the delivery of the enterprise agenda.
Digital Humanities	Univ. Exeter	The Digital Innovation Lab will offer to create labs and research space for the examination and preservation of important historical, literary and visual artefacts.
Creative Arts & Games	Falmouth Univ.	UK's highest ranking Arts University, leading in the creation of the future talent pool for the creative industry sector. Falmouth Launchpad (Games) is designed to prove an innovative methodology, building high-growth/high-value businesses to market demand, meeting challenges set by industry partners in the digital games sector
Playable City	Watershed	An initiative that brings creatives and smart cities technologies together to create connections and play, exploring the implications of embedding technologies within city infrastructure and developing imaginative prototypes that rethink public spaces
Connected Performance	Falmouth Univ.	Building on EU research programmes, Falmouth conducts leading edge research into connected performance, which is applied to areas such as immersive games and telehealth. Projects such the "Online Orchestra" have utilised the internet to provide opportunities for children and practitioners in remote communities to participate in a combined dance or orchestral performance.
School of Media	Cheltenham,	The School covers the full range of creative media,

	Univ. of Glos	including film, TV, radio, popular music, animation, with strong professional links to the media industry. The School supports the University's Research Centre for Innovation, Design and Technology, which includes VR/AR/Digital solutions in design, music technology and digital innovation.
Gloucestershire Growth Hub	Gloucester, Univ. of Glos	The Hub was established by the University in October 2014 in partnership with Gfirst LEP. It provides a wide range of business services for creative media and other sectors. With investment from Growth Deal 1, it will be moving to new, purpose built premises in 2018, co-locating the Growth Hub, the University Business School and the LEP.
Creative Cardiff	Cardiff	A network connecting people working in any creative organisation, business or job in the Cardiff region. Runs events and initiatives that support increased collaboration and innovation.
CAMERA	Bath	Motion capture facility and researchers at the University of Bath**,** in close partnership with The Imagarium, Bath, Europe's foremost motion capture studio.
Digital Innovation Fund for the Arts in Wales	Cardiff, Arts Council of Wales/ NESTA	Supporting arts organisations to explore digital technology uses to enhance audience reach and engagement and to embed and scale demonstrators
DC Labs	Falmouth, RCUK	Digital Creativity Labs (DC Labs) is a major (£18 million) investment by three UK research councils, four universities, and over 80 collaborative partner organisations to create a world centre of excellence for impact-driven research, focusing on digital games, interactive media and the rich space where they converge. Based at The University of York, with "spoke" sites at the Cass Business School, Goldsmiths (University of London) and Falmouth University.

Smart Cities/Regions and Transport

Asset	Host / Lead	Descriptor
Bristol is Open / Open Programm-able City	JV Co - City Council & Univ. Bristol	World leading city scale digital research infrastructure with: fibre in the ground; a mesh bouncing from lamppost to lamppost across the City; and a mile of experimental wireless connectivity along Harbourside. The networks are controlled in Software – creating a Software Defined Network. It uses Network Function Virtualisation to make the infrastructure super-fluid, sliceable, and usable by many different projects at once. Extension across the WoE is planned.
REPLICATE	Bristol – 1 of 3 Light-house Cities City Council / Univ. Bristol	£29m euro H2020 project developing and validating a Sustainable City Business Model; enhancing transition to smart cities in the areas of energy efficiency, sustainable mobility and ICT infrastructure. The main purpose is to accelerate the deployment of innovative technologies, organisational and economic solutions to significantly increase resource and energy efficiency, improve the sustainability of urban transport and drastically reduce urban greenhouse gas emissions
High Performance Network Group	Univ. Bristol	Specialises in the application of advanced hardware and software technologies, targeting future optical communication networks for data centres, cloud based applications and distributed technologies including in smart cities applications
Communica-tions and Networks Group	As above	At the forefront of world research and development for more than 25 years with many major technological achievements to its credit including: Wireless LAN technology, Wideband CDMA for 3G, SMART Antennas, Smart Grid/Smart Metering, Sensor Networks, Wireless Network Coverage CAD software and power efficient RF transmitters for Digital Video Broadcast (DVB) and cellular communications. Now focused on developments in 5G technologies and applications areas from smart cities to connected trains and road vehicles
Flourish/ Venturer		Funded by Innovate UK the VENTURER consortium is trialling autonomous vehicles in the Bristol and South Gloucestershire council areas to explore the feasibility of driverless cars in the UK. The trial is being funded by Innovate UK to investigate the legal and insurance aspects of the new technology and explore how the public react to such vehicles. FLOURISH focuses on the core themes of wireless

		connectivity, security and customer interaction. The three-year project, worth £5.5 million, will develop products and services that maximise the benefits of connected and autonomous vehicles (CAVs) for users and transport authorities. By adopting a user-centred approach, it will achieve a better understanding of consumer demands and expectations, including the implications and challenges of an ageing society.
UK Collaboratorium for Research and Infrastructure in Cities (UKCRIC)	Univ. Bristol, Cardiff Univ.	Urban areas are serviced by complex, interdependent systems provided by a number of interacting infrastructures at high density. Digital infrastructure is increasingly enabling real-time, in situ testing of infrastructure performance. UKCRIC will establish a network of interlinked urban infrastructure observatories at sites across the UK including Bristol and Cardiff for the digital capture, mapping, sensing, monitoring and testing of real urban infrastructure systems over the long-term.
Centre for Transport and Society	UWE	Research to understand the inherent links between lifestyles and personal travel in the context of continuing social and technological change
The Bristol Urban Area Diagnostics Pilot	UWE/ Univ. Bristol	One of 5 pilots under the new Innovate UK/RCUK (UKRI) URBAN Living programme looking at complex problems across four 'Challenge Themes': Mobility & Accessibility, Health & Happiness, Equality & Inclusion and the 'Carbon Neutral' city
SMART Islands	Council for the Isles of Scilly	Proposed smart grid/smart energy programme to meet the islands energy objectives energy cost reduction, renewables and low carbon vehicles
Exeter City Futures	Exeter City Council	A private-sector led initiative to grow the region's economy, safeguard its natural resources and improve quality of life through the innovative use of data. It has links to investors creating a fund of up to £100m to invest in enterprises with growth potential.

Underpinning Technologies: Cloud Computing, Communications and IoT

Asset	Host / Lead	Descriptor
The Bristol Vision Institute	Univ. Bristol	Host to the EPSRC's only Platform Grant in Vision Science and Engineering, which brings together BBC, ARRI, QinetiQ, Thales, and The Academy of Motion Pictures, Arts and Sciences.
Jean Golding Data Institute	As above	University Research Institute focusing on interdisciplinary research involved in creating, processing, investigating and exploring big data
Smart Internet Lab	As above	Strategic and applied research on key communications and digital technologies, a hub for Internet Research, fusing research expertise and innovation in a range of areas such as Smart Cities, Autonomous Vehicles, IoT and eHealth; 200 experts across the boundaries of wireless, networks and photonics.
Advanced Computing Research Centre	As above	World-leading research into the efficient use of many-core parallel computer architectures and open parallel programming standards.
Communication Systems & Networks (CSN) Group	As above	Addresses topics such as the Internet of Things (IoT), Massive MIMO, robust vehicular communications, dynamic mmWave networks, full duplex communications, wearable wireless technologies and wireless/optical network integration. Many of these subjects are critical in the development of efficient and cost-effective 5G networks.
Cryptography and Information Security Group	As above	Conducts research into cryptography, the underlying hard problems on which it is based and the hardware and software needed to implement secure systems including techniques for proving security of cryptographic systems, the efficient implementation of such systems on small computing devices and the verification that such implementations do what they say they do. Unique in its combination of theoretical and practical work it is a world leading research group. The University hosts a GCHQ/EPSRC Academic Centre of Excellence in Cyber Security Research.
Heilbronn Institute	Univ. Bristol / GCHQ	The Heilbronn Institute is a partnership between the University and GCHQ. Each member of the Institute spends half their time pursuing research directed by the Government Communications Headquarters, and the other

		half doing personal academic research. Fields of expertise include topics in number theory, algebraic geometry, algebra, combinatorics, probability, quantum information, computational statistics and statistical learning
Bristol Interaction and Graphics (BIG) Group	Univ. Bristol	BIG acts as a hub for collaboration between social scientists, artists, scientists and engineers to combine efficient, aesthetic and innovative design. Research areas include human-computer interaction, visual, auditory and haptic perception, visualisation and sonification, touch and gestural input, tangible interfaces, augmented and virtual reality, wearable and on-body computing, sustainable interaction design, digital engagement, interactive fabrication as well as flexible and actuated devices.
Intelligent Systems Group	As above	Extraction of information and knowledge from data. Research includes machine learning, pattern recognition, web technologies, data mining, bioinformatics, semantic image analysis and natural intelligent systems.
Bristol Robotics Lab	Univ. Bristol/ UWE joint venture	Research Themes Aerial robots Assisted Living Bioenergy & Self Sustainable Biomimetic and neuro-robotics Control for HRI Medical robotics Nonlinear control in robotics Robot vision Safe human robot interaction Smart automation Soft robotics Swarm robotics Unconventional computation Verification & validation
Bristol Is Open	Univ. Bristol/ Bristol City Council joint venture	brings together many technology strands from the Internet Of Things to the cybersecurity, block chain, big data management and communications
High Performance Computing Wales	All Wales initiative led by Bangor but with a hub in Cardiff (and three	Wales' national supercomputing service provider and host to the UK's largest distributed general purpose supercomputing network. a multi-million pound investment that

	other locations)	gives businesses and researchers access to world-class, secure and easy-to-use high performance computing technology
Data Innovation Institute	Cardiff Univ.	Fundamental research into the aspects of managing, analysing and interpreting massive volumes of textual and numerical information
Crime & Security Research Institute	As above.	Internationally-recognised research that generates new evidence and insights to help reduce crime and increase security, in partnership with organisations such as IBM, WHO, What Works Centre for Crime Reduction
Cardiff Social Data Science Lab	As above.	ESRC strategic 'Big data' investment to support real-time social data analytics for research, policy and practice. The Lab forms part of Cardiff University's Data Innovation Institute
Exeter City Futures	Exeter City Council	A private-sector led initiative to grow the region's economy, safeguard its natural resources and improve quality of life through the innovative use of data. It has links to investors creating a fund of up to £100m to invest in enterprises with growth potential.
Coelition	Devon	An independent not-for-profit company which supports a global ecosystem for the responsible use of behavioural data
Open Data Institute Nodes	Bristol, Cardiff, Cornwall & Devon	1/3 of total UK ODI Nodes - connect, equip and inspire people around the world to innovate with data, led by local experts.
Centre for Security, Communication and Network Research (CSCAN).	Plymouth Univ.	Leading the commercialisation of a novel security appliance aimed at Schools, working in collaboration with Devon and Cornwall Police, the South West Grid for Learning and the Internet Watch Foundation, with a nationwide rollout in September 2016
Microelectronics Research Group	Univ. Bristol	Research spanning the mobile/embedded and high performance computing spaces including parallel and reconfigurable computer architectures, energy efficient computing, fault tolerant systems, design verification, and next generation technologies, such as 3-D chip design and NEMS
Quantum Engineering Technology Laboratories	As above.	A globally significant centre for research, development and entrepreneurship in the emerging quantum technology industry and is an international node for collaboration with industrial and academic world leaders, and the EPSRC UK Quantum Technology Hub

		Network.
Met Office	Exeter	Europe's largest environmental High Performance Computer in the world at the Met Office, with its Informatics Lab and new collaborative space, based at Exeter Science Park
i-DAT	Plymouth Univ.	Co-creates and shares technological prototypes and practices that push and challenge the boundaries of digital arts and creative media practice. Main focus is on making 'data' tangible, playable and readily available as a material, to generate new meaning and inform participation, audience engagement and innovation in the arts.
School of Computing and Technology	Cheltenham and Berkeley University of Gloucestershire	Hosts teaching, research and business support facilities in Cheltenham and Berkeley. Covering computing, cyber and games, it has strong partnerships with the growing cluster of computing/cyber related agencies and businesses in Cheltenham, Gloucester and Malvern
Gloucestershire Science and Technology Park	Berkeley; University of Gloucestershire with South Gloucestershire and Stroud College	The Park is based on the former nuclear power station at Berkeley and continues to house nuclear research facilities. It is benefiting from Growth Deal investment to build construction and engineering skills, advanced computing and cyber facilities, a University Technical College specialising in computing and engineering. It is also the site for approved future Growth Deal investment in renewable energy
Human Computer Interaction Group	Univ. Bath	Research into issues related to understanding human tasks and activities, including collaboration, how these are influenced by Information and Communication Technologies and the associated implications for the design of future interactive systems
SW Centre of Excellence in Satellite Applications.	Goonhilly Earth Station	One of 5 CoEs under the Satellite Applications Catapult, this brings together the expertise of the Met Office, the Universities of Exeter and Plymouth, Falmouth and Rothamstead Research. Key initial themes are: Marine/Maritime industry, Agritech/food supply, eHealth/eWellbeing

Underpinning Technology: VR/AR

Asset	Host / Lead	Descriptor
Games Hub		Physical space and network bringing together developers and academics to create and study games. Regional VR/AR champion.
VR World Congress	Industry	UK's biggest VR trade event
AIRBUS Wing Integration Centre	AIRBUS	Includes VR engineering suite
CAMERA - Centre for Analysis of Motion, Entertainment Research and Applications	Univ. Bath	Motion Capture, Visual Effects and Video Game Research, Virtual and Augmented Reality, and Performance Analysis for elite sport, health and rehabilitation
@Bristol Datadome	@Bristol, BIO, Univ. Bristol	UK's only 3D 4K immersive presentation space (120 seats). Connected to a dedicated High Performance Computer & used to explore how new technologies can be used to visualise and manipulate data and information with engineering, medical and smart city applications
CFMS – the Centre for Modelling and Simulation		Independent not for profit specialist in high value engineering design capability underpinned by high performance computing, advanced modelling and simulation
Visual Information Laboratory	Univ. Bristol	Undertakes innovative, collaborative and interdisciplinary research resulting in world leading technology in the areas of computer vision, video communications, 3-D visual mapping and navigation, image and video communications, content analysis and image-sensor processing.
Intelligent Systems Group	Univ. Bath	Research into the two-way relationship between natural and artificial intelligence, with an emphasis on constructing and modelling complete systems.
The Immersive Vision Theatre at i-DAT	Plymouth Univ.	Research tool for simulation, VR and gaming
Bristol-BBC Immersive Technology Laboratory	Univ. Bristol/BBC R&D	In association with partners including Aardman Animations. An innovative research collaboration in Immersive Technology spanning engineering and psychology with application to the creative arts. Provides key underpinnings for future consumer and professional technology and services.

The Centre for Research in Applied Cognition, Knowledge, Learning & Emotion (CRACKLE)	University of Gloucestershire Cheltenham	The Centre specialises in psychology-driven research into neuroergonomics; situation awareness; virtual and augmented reality systems; impact of emotion on decision making in safety critical and pressured environments; application of VR in training for care settings / forensic settings. Current projects include psychological aspects of crime, decision-making in high-risk contexts such as the foreground, health psychology and counselling
Interactive Systems Studio	Plymouth University	An open innovation R&D studio, investigate current technologies, platforms and working processes to innovate in the field of interactive systems and 3D environments. This ranges from entertainment systems on mobiles through to serious games simulations, virtual and augmented reality environments. The studio team investigates new approaches and develops real world solutions both for undergraduate programme and working in collaboration with external partners.

Underpinning Technology: Robotics/Autonomous systems

Asset	Host / Lead	Descriptor
Bristol Robotics Laboratory	UWE/Univ. Bristol JV	Leading UK centre with research in a wide number of themes:- Aerial robots, Assisted Living, Bioenergy & Self Sustainable, Biomimetic and neuro-robotics Control for HRI, Medical robotics, Nonlinear control in robotics, Robot vision, Safe human robot interaction Smart automation, Soft robotics, Swarm robotics, Unconventional computation, Verification & validation, Intelligent Systems
Centre for Robotics and Neural Systems	Plymouth Univ.	Interdisciplinary research cluster, with international collaborations in robotics, machine learning and artificial intelligence
Communication Systems & Networks (CSN) Group	Univ. Bristol	Wireless communications – research into connected (train and car) vehicle systems
National Composites Centre	Univ. Bristol	Part of HVM Catapult - national centre of excellence for the development and application of robotics in composites manufacture
Autonomous Marine Systems (AMS) research group	Plymouth Univ.	Artificial intelligence (AI), advanced control systems engineering theory, multi-sensor data fusion, dynamics, thermodynamics and fluids, SMART materials, marine power plant, marine vehicle performance prediction, propulsors, integrated navigation systems and marine renewable energy.
Venturer, Flourish	Bristol	Industry led programmes - Autonomous and Connected Vehicles – see Smart Cities
SW Nuclear Hub	Univ. Bristol	Autonomous drone based monitoring of nuclear sites, spinout company created
Medical robotics	NHS Bristol	Research in the application of robotics in urology/prostate surgery & deep brain stimulation
ASTREA programme	AIRBUS South Wales	The programme focuses on enabling the routine use of Unmanned Aircraft Systems (UAS) in all classes of airspace without the need for restrictive or specialised conditions of operation.

Appendix DL2 Research Evaluation Framework

The Digital Living theme covers a broad range of academic disciplines, spanning 29 REF units of Assessment (UoAs), with 10 with greater than 10% of staff specialising in Digital Living related research:

UoA		Submitted staff associated with theme	No of HEIs	Doctoral awards 2008-16*	UoA overall profile (% 3 or 4*)	>10% related staff
1	Clinical Medicine	18.5	3	18	83%	10%
2	Public Health, Health Services and Primary Care	3	2	12	84%	
3	Allied Health Professions, Dentistry, Nursing and Pharmacy	26	4	63	85%	11%
4	Psychology, Psychiatry and Neuroscience	41	4	67	85%	19%
5	Biological Sciences	7	3	21	85%	
6	Agriculture, Veterinary and Food Science	3	2	4	73%	
7	Earth Systems and Environmental Sciences	13	3	40	86%	
8	Chemistry	5	1	22	96%	
9	Physics	11	2	50	89%	
10	Mathematical Sciences	4	2	12	74%	
11	Computer Science and Informatics	103.8	6	336	81%	80%
13	Electrical and Electronic Engineering, Metallurgy and Materials	7.8	1	24	65%	28%
14	Civil and Construction Engineering	1	1	5	97%	

15	General Engineering	64.5	5	251	90%	26%
16	Architecture, Built Environment and Planning	10	2	26	73%	
17	Geography, Environmental Studies and Archaeology	10	3	19	77%	
19	Business and Management Studies	12.7	3	54	74%	
20	Law	2	2	11	84%	
21	Politics and International Studies	1	1	6	81%	
22	Social Work and Social Policy	10	3	6	76%	
23	Sociology	7	2	46	82%	10%
25	Education	3	2	7	69%	
26	Sport and Exercise Sciences, Leisure and Tourism	4.2	2	9	89%	
28	Modern Languages and Linguistics	4	2	2	66%	
29	English Language and Literature	2	2	15	78%	
30	History	2.8	1	12	73%	
34	Art and Design: History, Practice and Theory	27.8	4	45	57%	28%
35	Music, Drama, Dance and Performing Arts	19	4	21	55%	17%
36	Communication, Cultural and Media Studies, Library and Information Management	7	2	16	80%	18%

Appendix DL3 - Publication data

An analysis of data relating to academic publications related to the Digital Living theme was undertaken, searching by a comprehensive list of keywords/phrases to focus the search on areas of particular relevance.

Regional Publications = 3899	No Publications	Regional Share
World	78,411	5%
Europe	40,739	10%
UK	15,312	25%

	FWCI	Outputs In Top Percentiles (10%)	Publications In Top Journal Percentiles (10%)	Academic-Corporate Collaboration	International Collaboration
World	1.71	18%	24%	2%	26%
Europe	1.73	18%	24%	2%	39%
UK	2.13	23%	28%	2%	45%
Region	2.47	27%	32%	3%	52%

Digital Living - Region:

	FWCI	Outputs In Top Percentile (10%)	Publication In Top Journal Percentile	Academic Corporate Collab	Intl Collab
Big data	2.3	28%	29%	1%	62%
Comms	2.12	14%	31%	0%	43%
Creative digital	2.39	30%	31%	1%	53%
Crypto	5.34	16%	14%	19%	63%
Digital health	1.91	14%	35%	5%	45%
Elec	2.34	23%	37%	5%	45%
Quantum	2.97	23%	25%	7%	72%
Robotics	1.91	14%	35%	5%	45%
Vision	1.17	7%	51%	0%	56%
Average	2.494	19%	32%	5%	54%

Digital Living: UK

	FWCI	Outputs In Top Percentile (10%)	Publication In Top Journal Percentile	Academic-Corporate Collab	Intl Collab
Big data	1.94	21%	27%	3%	51%
Comms	1.86	15%	29%	0%	40%
Creative digital	2.09	22%	26%	1%	43%
Crypto	3.88	11%	20%	18%	59%
Digital health	2.13	24%	28%	2%	37%
Elec	2.09	22%	38%	4%	47%
Quantum	2.64	28%	27%	5%	70%
Robotics	1.83	16%	37%	3%	48%
Vision	1.91	8%	47%	5%	50%
Average	2.263	19%	31%	5%	49%

Digital Living: Europe

	FWCI	Outputs In Top Percentile (10%)	Publication In Top Journal Percentile	Academic-Corporate Collab	Int. Collab
Big data	1.65	15%	22%	2%	40%
Comms	2.12	13%	34%	7%	35%
Creative digital	1.74	20%	22%	1%	42%
Crypto	3.22	10%	23%	10%	46%
Digital health	1.69	20%	22%	2%	33%
Elec	1.78	18%	36%	5%	38%
Quantum	1.83	23%	24%	4%	57%
Robotics	1.63	12%	31%	2%	32%
Vision	1.42	8%	36%	3%	36%
Average	1.898	15%	28%	4%	40%

Digital Living: World

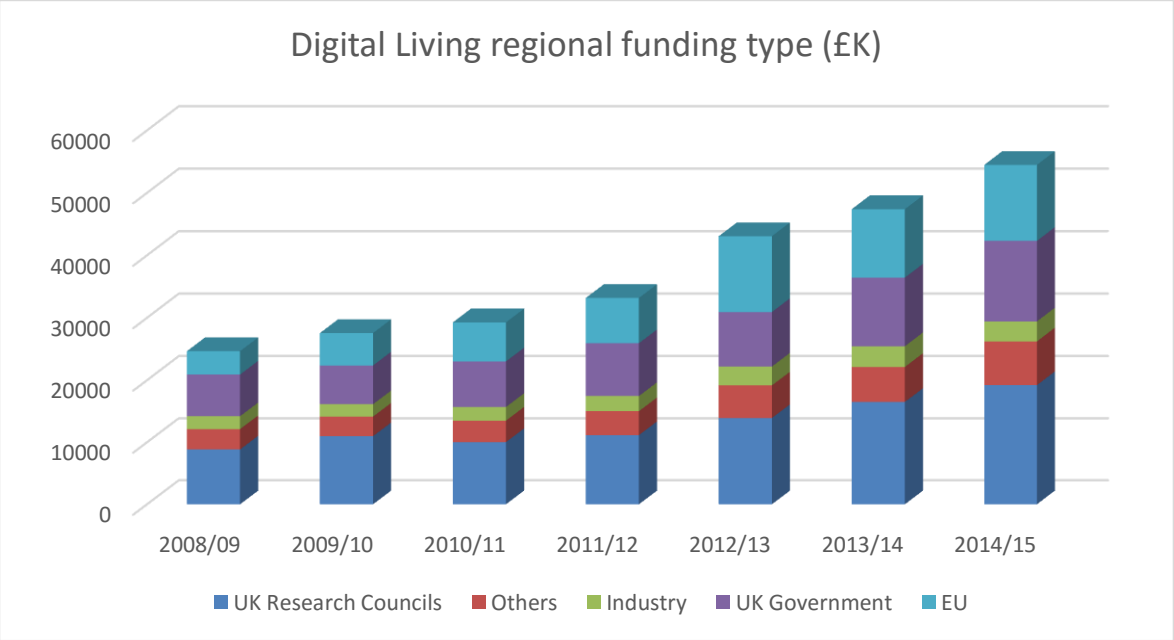
	FWCI	Outputs In Top Percentile (10%)	Publication In Top Journal Percentile	Academic-Corporate Collab	Int. Collab
Big data	1.49	14%	21%	2%	26%
Comms	1.75	9%	31%	5%	22%
Creative digital	1.6	17%	19%	1%	28%
Crypto	2.84	8%	21%	9%	27%
Digital health	2.19	27%	26%	2%	25%
Elec	1.47	15%	29%	4%	23%
Quantum	1.57	19%	23%	4%	36%
Robotics	1.48	10%	28%	3%	19%
Vision	1.12	7%	31%	4%	20%
Average	1.723	14%	25%	4%	25%

Appendix DL 4 - Theme income data

The tables below present the total research income related to the Digital Living theme since 2008, by HE institution and funders' type.

HESA funder type	Total research income as related to theme (£k)						
	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
University of Bristol	10,137	11,713	12,123	15,232	17,599	22,195	24,139
Falmouth University	163	18	650	285	3,169	847	212
Bath University	1,316	1,344	1,614	1,511	1,911	2,406	2,930
Exeter University	348	336	318	295	1,266	2,936	2,347
Plymouth University	3,155	3,719	3,238	2,654	3,656	3,727	6,935
University of West of England	5,069	5,664	5,516	5,920	7,815	6,381	6,366
University of South Wales	57	42	162	712	277	152	892
Gloucester & Cheltenham University				12	32	32	125
Cardiff University	4,401	4,707	5,634	6,556	7,360	8,737	10,647
Regional Total income (£k)	24,645	27,542	29,255	33,176	43,085	47,413	54,593

HESA funder type	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
1 BIS Research Councils, Royal Society, British Academy and Royal Society of Edinburgh	8,847	10,976	10,031	11,158	13,912	16,498	19,203
10 Non-EU based charities (open competitive process)	84	55	109	67	153	271	261
11 Non-EU industry, commerce and public corporations	189	107	122	210	53	67	74
12 Non-EU other	245	171	292	386	722	961	1,312
13 Other sources	127	272	161	217	339	265	491
2 UK-based charities (open competitive process)	2,642	2,534	2,743	2,895	3,478	3,641	4,398
3 UK-based charities (other)	180	122	145	289	555	485	542
4 UK central government bodies, local authorities, health and hospital authorities	6707	6223	7313	8472	8743	11,001	12,956
5 UK industry, commerce and public corporations	1,887	1,896	2,089	2,243	2,990	3,268	3,192
6 EU government bodies	3,332	4,813	5,417	6,859	12,051	10,763	11,902
7 EU-based charities (open competitive process)	0	3	35	168	8	39	8
8 EU industry, commerce and public corporations	351	233	703	142	69	117	165
9 EU other	55	137	95	70	12	37	89
Regional Total income (£K)	24,646	27,542	29,255	33,164	43,053	47,381	54,468


Digital Living regional funding type (£K)
60000
50000
40000
30000
20000
10000
0
2008/09
2009/10
2010/11
2011/12
2012/13
2013/14
2014/15
UK Research Councils
Others
Industry
UK Government
EU

Appendix DL5 - Major Companies in Theme

Major Digital companies

Aardman, Andromeda Capital, ATASS, Black Swan, BBC (Creative output in Cardiff & National History Unit in Bristol), Broadcom, Roath Lock Studios, Pinewood Studios, Launchpad, ClusterHQ, Cisco, Cray, Play Nicely, Auroch Digital, Opposable VR, BMT Defence, BDH Productions, the R Index, 422South, Zubr VR, Fourth reality, 360 Virtual Tours, VRGO, Motion Impossible, CRMS, Dashboard, Dyson, ForgeRock, Future Cities Catapult, Hitachi, Hewlett Packard, Huawei, IBM, Google, Nokia Networks, Oracle, Renishaw, Toshiba, Ultra, PCS, NFC, Nokia (Through BIO), Sift, E3, Zone, Mubaloo, Aerian, Complete Control, True Digital, Nomensa, Bristol Games Hub, Amdocs, Zynstra, Eden Ventures, Future Publishing

Companies with digital related applications on their top requirements list

EDF Energy, the Met Office, Airbus, Ashwoods Automotive, Leonardo (AgustaWestland), Avanti, BAE Systems, BMW, Boeing, Broadcom, Claverham, Cobham, Doncasters, Dowty, GE Aviation, GKN Aerospace, Goonhilly Earth Station, HiETA Technologies, Honda, Honeywell, Ipeco composites, JLR, Johnson Matthey, MBDA Systems, McLaren, Messier Dowty, Pall Aeropower, QuEST Global, Rolls-Royce, Renishaw, SKF Clevedon, Smith Industries, Thales, Horizon/Hitachi, Western Power Distribution, Toshiba, National Grid and Ofgem, Alstom, Atlantis, BAE Systems, Carnegie, Fugro, Marine Current Turbines, Met Office, Seabased, Seatricity, Searaser, Simply Blue, Sonardyne OWEL, QinetiQ, Tocardo, Valeport, Viper Subsea, Wello, Endeavr, Cassidien, ARUP, Atkins. The National Nuclear Laboratory, Buro Happold Engineering, Altran, BMT Defence Services, Babcock, IPL

Next generation of micro-electronics companies

Present in the region are: Avanti, BlueWireless, Broadcom, Cray, Dialog Semiconductor, General Dynamics, Gooch & Housego, Imagination Technologies, IQE plc, HP, Huawei, Plessey, Raytheon, Silicon Basis, Toshiba and Xmos, Intel.

Appendix DL6 - Project Portfolio

Projects in progress are outlined in the table below, which shows current and proposed initiatives in Digital Living related areas across the region. This includes funded programmes and those looking to access funding through a variety of routes including Research Councils, Local Growth Fund LEP round 3 submissions, City Deals and other Government programmes.

Project/Scheme	Funding Source	Description
QUTIC	Local Growth Fund 3 – business case under development	Quantum Technologies Incubation Centre – offering facilities to support early stage companies developing products and services utilizing emerging quantum technologies. Aligned with the Quantum Technologies Lab at the University of Bristol
Futurespace	BIS Univ. Enterprise Zone pilot, Local Growth Fund 2	First phase opened Aug. 2016 - The 4,000 square metre building provides laboratory space, offices and workshops, share start-up 'studio' space, communal space for networking and meeting, access to specialist equipment and technical support and business services.
Health Hub – UEZ Bristol	ESIF – applied for	Focused on innovation for independent living and citizen-centric health, bringing together expertise in robotics, biosensing, microelectronics, big data (for healthcare) and communications
Devonport Market Hall		A new digital hub, with 3,000 square feet of bespoke, quality office, lab for digital creative companies and organisations; a cultural, corporate events space with a seating for up to 350 people and an expo capacity of 600, and a digital visitor experience of touring programmes, screen and installation based work and programmed activity.
National Cyber Security Centre for Wales	City Deal proposal	National Cyber Security Centre for Wales (NCSCW) could be based in Newport. The vision is to advise, protect and secure businesses within the region.
Economics Centre of Excellence and Data Science Campus	ONS	A hub for the whole of Government to gain practical advantage from the wider investment in data science research and help cement the UK's reputation as an international leader in data science. By partnering with academia, the ONS will develop more 'real-time' economic statistics so that emerging issues and trends are

		spotted more quickly and understood in greater detail
Institute for Data Science – University of Exeter	Internal investment	A hub for development and use of innovative methodological data science approaches across the University, with a focus on four thematic areas: (1) environment and agritech (2) health, bioinformatics and the life course, (3) business innovation, and (4) security, ethics and governance.
SMARTLINE: Smart technology, linking innovation and needs for wellbeing in communities – University of Exeter, European Centre for Environment and Human Health	Cornwall & Isles of Scilly ESIF – applied for	SMARTLINE will identify the requirements and market potential for new eHealth/eWellbeing products and services, identify skills gaps, and create jobs. To achieve this it will investigate how new technology promotes improved health and wellbeing ("eHealth/eWellbeing") for individuals, their families and communities. This project will collect new data, and connect previously unlinked data and use innovative data analytical techniques to enable timely and targeted interventions, involving existing and new service providers. It will also provide a more efficient and effective lettings and asset management model for social housing, develop more resilient communities, and address issues of social isolation.
LABSTER Cornwall Centre of excellence for virtual laboratory simulations	ESIF – stage 2 bid due 30th Aug 2016	The project delivers new business-led innovations based on Labster's pioneering Virtual Laboratory Simulations that immerse users in real-world digital environments to enhance their learning, knowledge and experience in scientific experimentation and practice. Labster will work with the Exeter and Plymouth Universities to achieve: - the co-creation of new Virtual Laboratory Simulations: - R&D and innovation through product market testing and development intended to expand the product range to develop products that support.
Cheltenham Cyber Park	Local Growth Fund 3	A proposed business park, adjacent to GCHQ in Cheltenham, focused on incubation and support for companies related to computing and cyber; building on the 2015 Government announcement of a new Cyber Innovation Centre in Cheltenham

Environmental Futures and Big Data Impact Lab	Heart of the SW LEP	Recent proposal for an Environmental Futures and Big Data Impact Lab, which recognises the opportunity in the region to become a national centre of excellence for environment-related Big Data analytics, an underpinning technology / approach that is: key to understanding and addressing environmental issues; a driver for innovation; and central to productivity-led growth across the UK economy as a whole.
Bristol VR Lab		Private sector led proposal for the creation of a Lab which will deliver working space for VR/AR researchers and developers, access to latest technical innovation and hardware with introductory services to investors. It will have strong ties to the @Bristol Science centre, which will provide test space for VR content and hardware to be trialled with the public.
Bath Hacked	Bath	A joint council/community initiative that aims to put open data and smart thinking at the heart of the city. The primary mission is to bring bright people and quality data together to do useful things for the community.
National Arts and Technology Innovation Centre	Watershed /Arts Council Stage 1 Feasibility Study	Developed by the Watershed, the innovation centre will combine expertise in arts and technology, film and media, robotics and materials, education and engagement, business and entrepreneurship. Alongside the reknown Watershed cinemas, events suite, café/bar and Pervasive Media Studio the new centre will add facilities for showcasing, seminars, meetings, prototyping, collaboration and networking workspace for 100 people at early start-up and initial grow on stages

Appendix DL7 - Theme Definitions

Digital Health: Better use of data and technology has the power to improve health, transforming the quality and reducing the cost of health and care services. It offers patients and citizens more control over their health and wellbeing, empowers carers, reduces the administrative burden for care professionals, and supports the development of new medicines and treatments. A recent study[40] for the UK Office of Life Sciences segments Digital health into Telehealthcare, mobile (m)health (apps and wearable devices), health analytics and Digitial health systems (including electronic health records).

Digital Creative Economy: Creative Industries are those which have their origin in individual **creativity**, skill and talent and which have a potential for wealth and job creation through the generation and exploitation of intellectual property through the use of digital technologies[41].

Smart Cities & Transport: A Smart City will enable every citizen to engage with all the services on offer, public as well as private, in a way best suited to his or her needs. It brings together hard infrastructure, social capital including local skills and community institutions, and digital technologies to fuel sustainable economic development and provide an attractive environment for all.[42] Smart transport (or intelligent mobility) infrastructure is technology-enabled and demonstrates interconnectivity, with assets in a network that can communicate as well as respond to and shape demand and economic behaviour. For example, smart utilities and intelligent transport systems that use real-time traffic information to adjust traffic signal timings demonstrate these capabilities. Transport infrastructure that leverages big data analytics and data mining of user patterns is also smart.[43] Smart transport also encompasses the concept of connected and autonomous vehicles – the driverless car of the future.

Underpinning Technology: Cloud Computing (including Communications and IoT): The identified thematic areas are all underpinned by core technologies such as Infrastructure as a Service (Compute, storage and networking), Platform as a Service (including Application Development, Data/Analytics, Big Data, Identity Management, Business Process/Workflow Management, Event management and correlation, Internet of Things infrastructure), fixed and wireless communications, cyber security & cryptography, and sensing - from low cost distributed sensors through machine vision to satellite imaging. Collectively these technologies also form the underpinnings for the term of Cloud Computing.

Underpinning Technology: Digital Media, Virtual and Augmented Reality: Digital Media includes media production and storage, audio recognition and analysis, augmented and virtual reality, Augmented reality is about showing the user additional information or cues over and above what they can see in the real world, while virtual reality is used to project an entirely different environment from wherever the user is actually situated.

[40] Digital Health in the UK: An Industry Study for the Office of Life Science, Monitor Deloitte, Sept 2015
[41] From a definition developed by the former Department of Culture Media & Sport
[42] BIS Background Paper – Smart Cities - Oct 2013
[43] Routes to Prosperity, Ernst & Young, June 2016

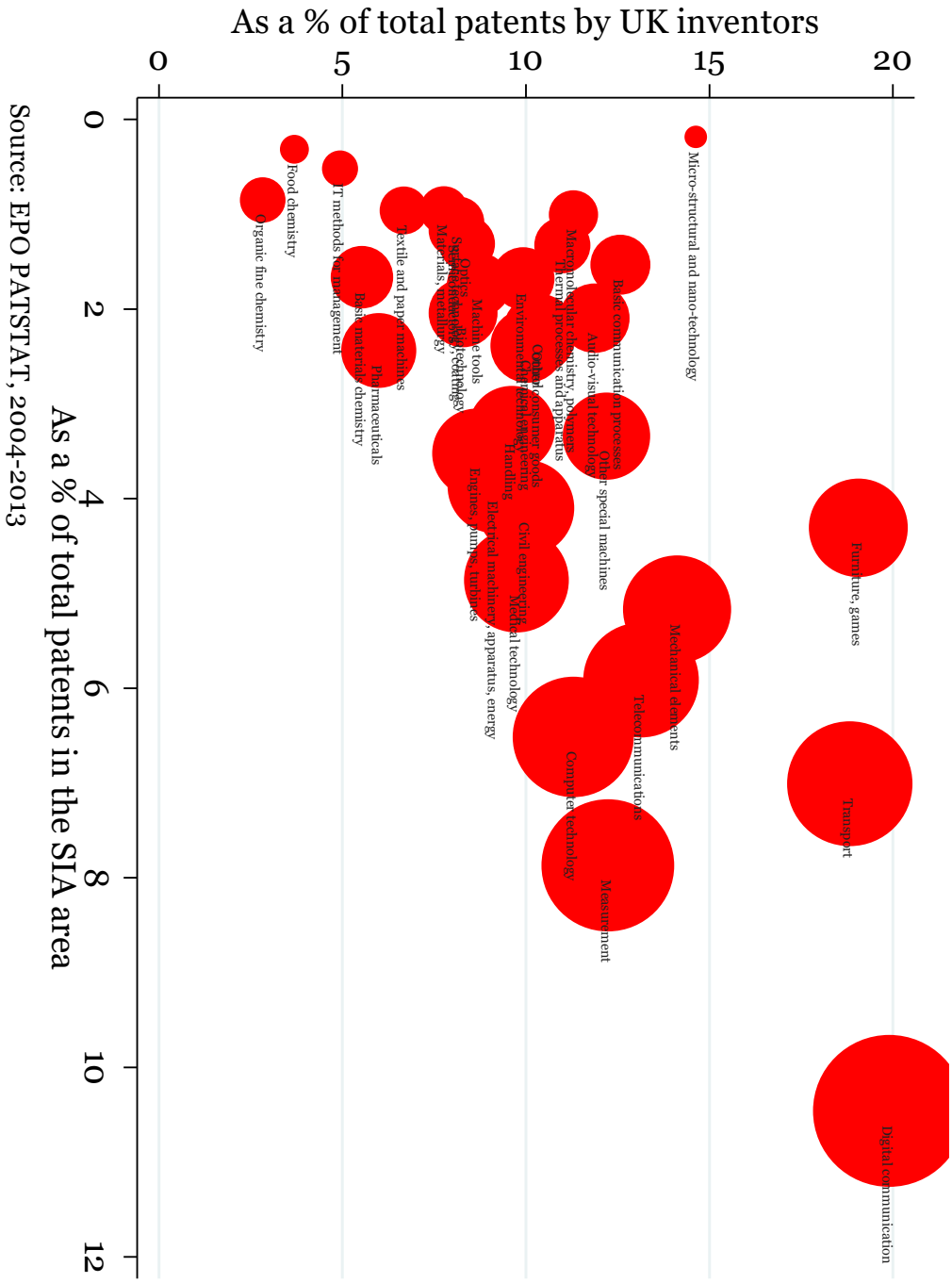
Underpinning Technology: Robotics / Autonomous Systems: Robotic and Autonomous Systems (RAS) are interconnected, interactive, cognitive and physical tools, able to variously perceive their environments, reason about events, make or revise plans and control their actions. They perform useful tasks in the real world, extending human capabilities, increasing productivity and reducing risks. In the future, RAS will be used to enhance almost every aspect of our lives. They will be part of the response to national challenges: an ageing population, safer transport, efficient healthcare, productive manufacturing, and secure energy.

Appendix DL8 - Tables & Figures

Figure DL1: Tech Nation 2016 Cluster data

	Data				Growth		
	Jobs	**Digital salary**	**Density**	**GVA (£bn)**	**Employ-ment**	**Turn over**	**GVA**
UK	1,560,000	£50,000	18%	87	11%	32%	27%
London	328,223	£58,978	20%	35.9	13%	101%	127%
SW England & SE Wales							
Bristol & Bath	36,547	£45,501	18%	1.8	9%	53%	26%
Exeter & Newtown Abbot	11,412	£39,695	16%	0.133	161%	41%	84%
Truro, Redruth, Camborne	1,380	£34,367	17%	0.031	1%	153%	127%
Cardiff	18,925	£42,926	17%	0.369	21%	15%	94%
Our Area Total	68,264			2.33			
Density = Digital Tech businesses as % of total							

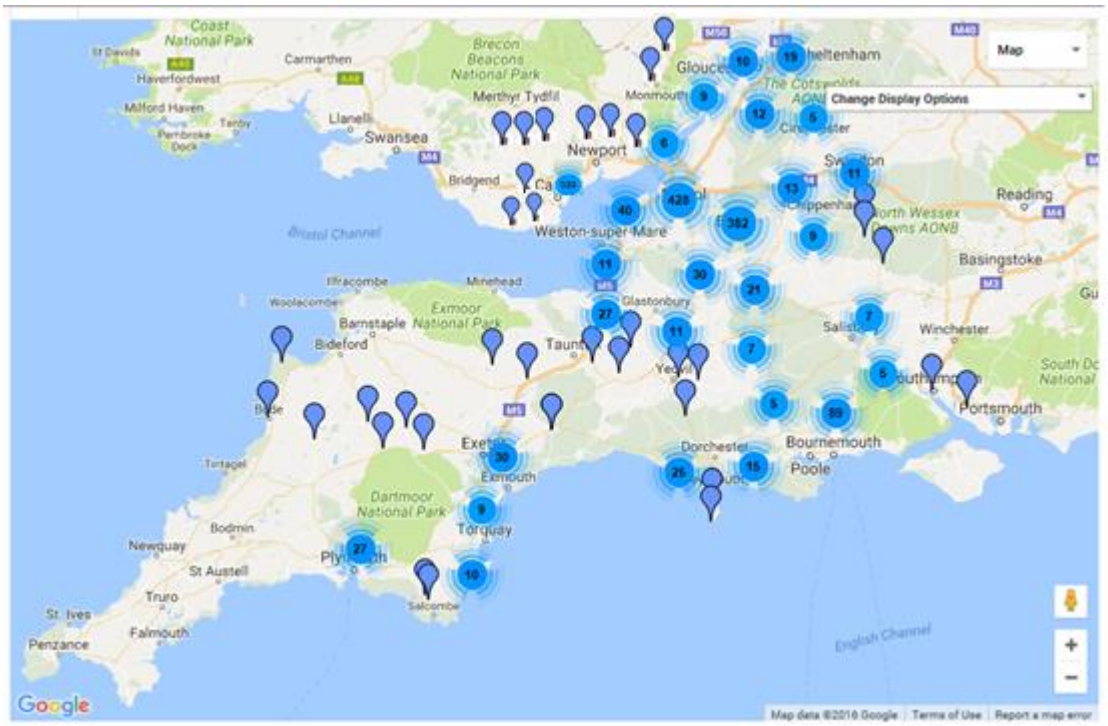
Figure DL2: Regional Patenting



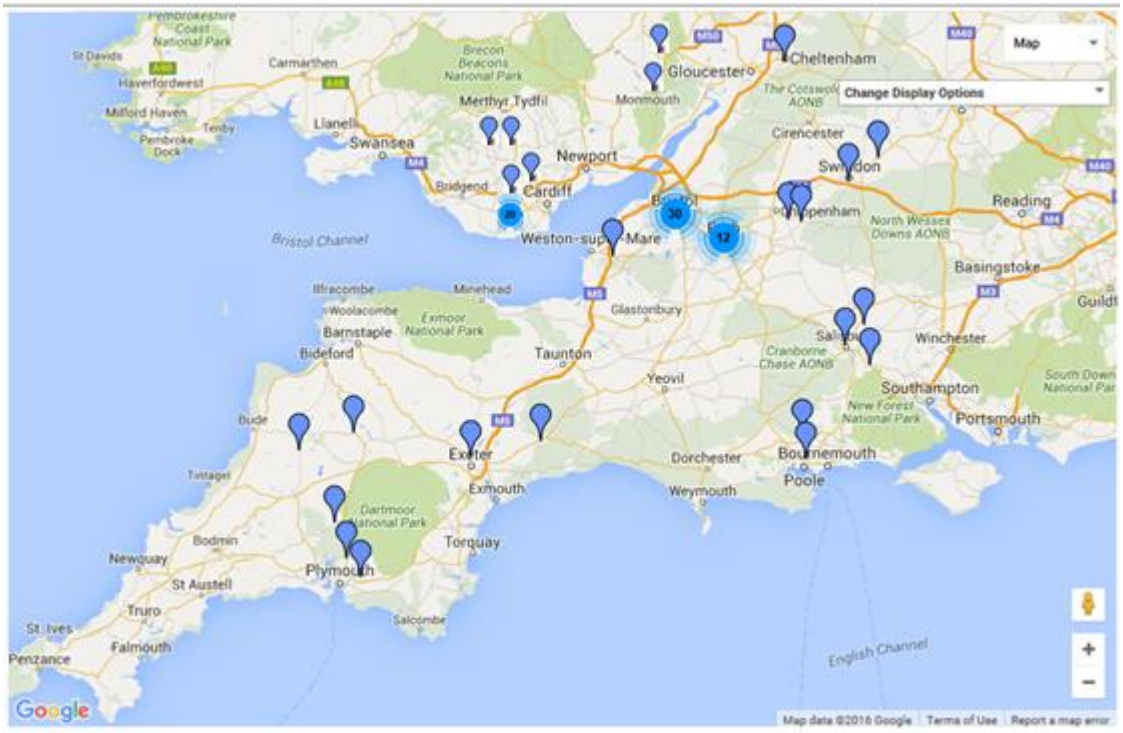
Source: EPO PATSTAT, 2004-2013

Figure DL3 a, b + c: Digital / High Tech Sector Cluster Maps

Using the TechSPARK Cluster map (*http://techspark.co/cluster-map/*) and the Electronic and Software technologies Network for Wales map (*http://www.estnet.uk.net/estnet-connect*) we estimate that the Digital/High Tech sector is worth £117.8bn in the region (data excludes South East Wales and Cornwall, but includes Dorset) with 1311 companies employing in excess of 129,000 people.



Digital Health Sector: 70 companies



Digital Creative Economy: 500 companies, estimated revenues of £660M with 15,900 employees

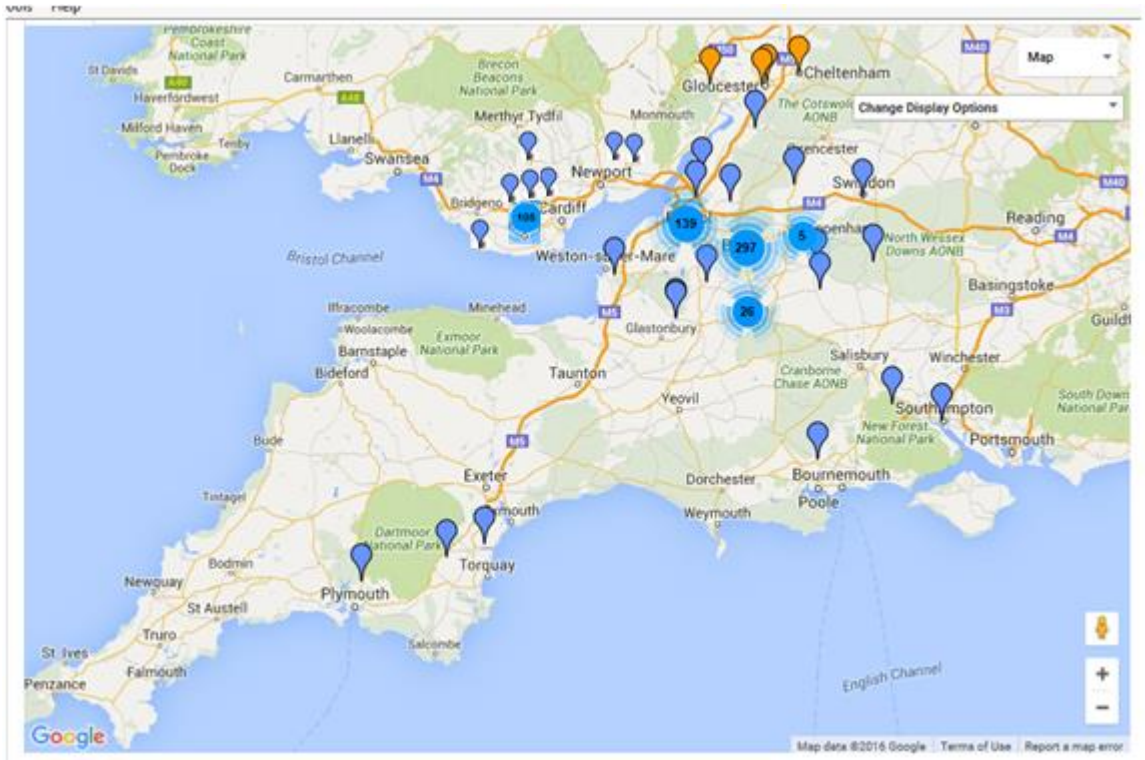
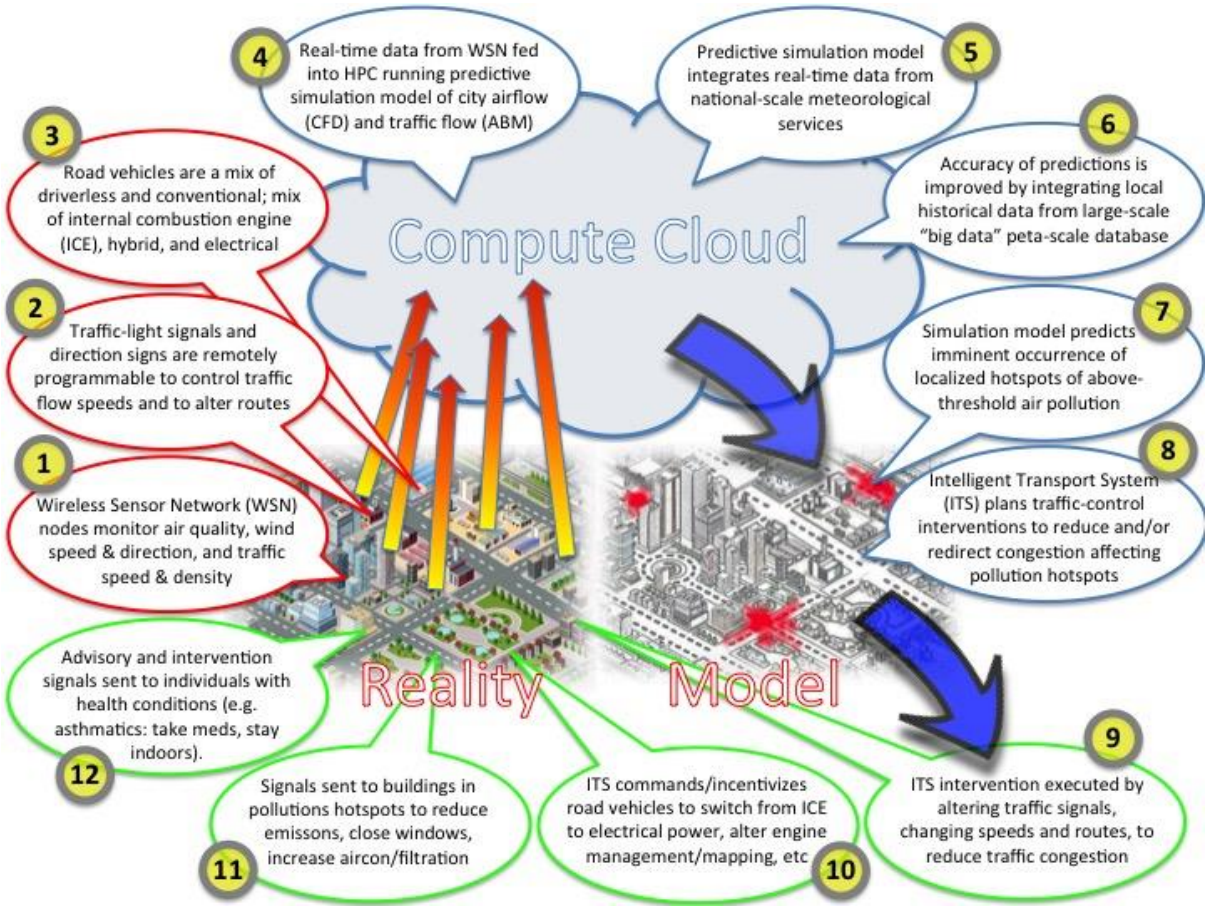


Figure DL4: Digital City Scale Demonstrator Use Case


4
Real-time data from WSN fed into HPC running predictive simulation model of city airflow (CFD) and traffic flow (ABM)
5
Predictive simulation model integrates real-time data from national-scale meteorological services
3
Road vehicles are a mix of driverless and conventional; mix of internal combustion engine (ICE), hybrid, and electrical
6
Accuracy of predictions is improved by integrating local historical data from large-scale "big data" peta-scale database
Compute Cloud
2
Traffic-light signals and direction signs are remotely programmable to control traffic flow speeds and to alter routes
7
Simulation model predicts imminent occurrence of localized hotspots of above-threshold air pollution
1
Wireless Sensor Network (WSN) nodes monitor air quality, wind speed & direction, and traffic speed & density
8
Intelligent Transport System (ITS) plans traffic-control interventions to reduce and/or redirect congestion affecting pollution hotspots
Reality
Model
Advisory and intervention signals sent to individuals with health conditions (e.g. asthmatics: take meds, stay indoors).
12
9
ITS intervention executed by altering traffic signals, changing speeds and routes, to reduce traffic congestion
Signals sent to buildings in pollutions hotspots to reduce emissons, close windows, increase aircon/filtration
11
ITS commands/incentivizes road vehicles to switch from ICE to electrical power, alter engine management/mapping, etc
10