



Department for
Business, Energy
& Industrial Strategy

South West England and South East Wales Science and Innovation Audit

Annex G: Aerospace and Advanced Engineering Theme Report

A Science and Innovation Audit Report sponsored by
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Annex G Aerospace & Advanced Engineering Theme Report

1. Introduction

Aerospace & Advanced Engineering has been identified as a strength of the Audit region. This strength has been built over decades and has resulted in the rich landscape of Industrial Primes; Systems / Structural Suppliers; Research Centres and renowned Academic Institutes, all with related skills. This community has a long history of collaboration both within and outside of the region.

This truly world class and world leading capability has delivered iconic products that the UK has taken great pride in being associated with, such as the Westland Sea King Helicopter, Dyson cyclone vacuum cleaner and Bristol Proteus gas turbine engine which powered the Bluebird CN7 land speed record car.

Whilst these foundations are strong, much more remains to be done. Our international competitors are advancing and UK national momentum must be maintained. The overriding impression gained from conducting this audit is the strength of opportunity that the region can deliver, backed by evidence of achievement but mollified by the concern created by the risks and challenges faced related to loss of long established capability which threatens the Government's Industrial Strategy.

A lot of emphasis has been placed on developing high value manufacturing capability; this audit considers that a broader strategy to protect and enhance capabilities elsewhere in the Industrial Value Chain is essential. Specifically, **High Value Engineering Design** and **System Integration Skills** (e.g. whole structure, sub-structure and propulsion) are core to the region and core to the protection of longer term manufacturing, recognised by the AGP; ATI; APC and the CEO of the HVM Catapults. Additionally, opportunities exist in developing **Composite Capabilities** and addressing life-long learning to manage the transition into the 4th Industrial Revolution – Industry 4.0.

Proposals to protect and reinforce the regional capabilities can be categorised as **High Value Design & Systems Integration** and **Composite Materials & Manufacturing**:

High Value Design and Systems Integration:

- 1) A **High Value Design Institute** - a Catapult centre focused on Design Integration capabilities, initially focused on Aerospace. This could be translated to other sectors and regions.
- 2) Institute for Advanced Automotive Propulsion Systems **IAAPS** – delivering future generations of low carbon vehicles through efficient powertrain **design and integration**, which is also applicable to Aerospace and other sectors.

Composite Excellence:

- 1) National Composites Materials Centre **NCCM** - re-shoring the **Composites Materials Value Chain** by building on the existing capability at the NCC. Applicability across multiple sectors, all of which are forecast to grow.

Core to this outcome is the coordinated support that these developments will bring, along with projects addressing skills and training such as the South West Institute for Technology & Skills **SWIFTS** (which is aligned to the National College for Advanced Manufacturing agenda), to deliver the National agenda for industrial development.

The current Aerospace & Advanced Engineering activity in the South West of England and South East Wales is built on over 150 years of engineering pedigree. Advanced engineering strengths in the region fall into three broad sectors, aerospace, automotive and marine, each of which can be divided into defence and civil applications. The steel industry is also a further sector of national importance (AAE6).

Aerospace – companies are located throughout the Audit area from Cornwall to Gloucestershire, with the region being home to 14 of the 15 largest aerospace companies in the world. In particular, the West of England has been a cradle of aviation innovation since the British Empire and Colonial Aeroplane Company opened in Filton (near Bristol) in 1910. There has been over 100 years of continuous development, design and manufacture, which includes global companies such as Airbus, BAE Systems, GKN Aerospace, Leonardo Helicopters, MBDA and Rolls-Royce resulting in the largest aerospace cluster in the UK, and the second in Europe, with 20% of the UK aerospace workforce, many of whom are involved in advanced design and systems integration within prime contractors and major Tier 1 suppliers.

Automotive – industry is concentrated at locations along the M4, Swindon: Honda UK Manufacturing, South East Wales: Ford Engine Plant, as well as high-end manufacturers in Somerset: Ariel Motor Company and West of England: Bristol Cars. The region is also a home to a spoke of the Advanced Propulsion Centre UK with the internal combustion engine system efficiency (ICE-SE) centre based at the University of Bath which conducts technology development with automotive companies from across the UK and around the globe, such as Ford, JLR and McLaren, and their supply chains.

Marine – Strengths lie in marine engineering, historically through the Royal Navy and more recently firms such as Babcock, MSubs and Princess Yachts. Indeed, Plymouth has the highest proportion of its employment in manufacturing of any city in Southern England. Ship building is found in Falmouth (A&P is UK's largest ship-repair complex) and North Devon, (Appledore). Marine defence organisations are also located further east in the region e.g., BMT Defence Services, Bath.

The audit area's strengths in AAE have grown up alongside the **steel** industry in South Wales, which has historically served as a source of raw materials for many of the region's industries. Additionally, there is significant cross over between the Marine Engineering sector in the Aerospace & Advanced Engineering and Marine Renewables within the New Energy theme as well as Industry 4.0 in Digital Living Platforms and Sensors discussed in the Next Generation Microelectronics theme; with many AAE firms supported by common supply chains in these related areas.

The Aerospace & Advanced Engineering (AAE) audit references publically available as well as novel datasets and publications and has been informed by canvassing the views of academia, industry and local government connected to the Aerospace & Advanced Engineering sector. A workshop was held which attracted 48 delegates representing the

majority of academic institutions in the region as well as a cross section of Blue Sky start-up companies, SMEs and OEMs. The outputs from the workshop as well as further consultation with stakeholders throughout the audit process were used to add context to the data collected centrally. Further review of the outputs was carried out by a theme review panel representing a cross-section of stakeholders.

2. Regional science and innovation assets

Our region's physical and intellectual assets in AAE have breadth and depth, reflecting a rich heritage of innovation in aerospace, automotive and marine engineering. The region's AAE strengths are supported by numerous multi-million pound infrastructural investments that support key sector clusters. The Universities of Bath, Bristol, Cardiff, Exeter, Plymouth, West of England, South Wales and Gloucestershire are involved in research directly related to the theme with many of the region's major AAE assets are associated with these Higher Education Institutions.

R&D Assets (Appendix AAE1) – Facilities of note include The National Composites Centre (NCC)¹, owned by The University of Bristol, is part of the High Value Manufacturing Catapult and is based at the Bristol & Bath Science Park. Opened in 2011, the NCC is a key part of the Government's composites strategy and brings together dynamic companies and enterprising academics to develop new technologies for the design and rapid manufacture of high-quality composite products. The University of Exeter's Centre for Additive Layer Manufacturing (CALM)² was developed in partnership with Airbus Group Innovations. Funded by the European Regional Development Fund (ERDF) it has supported more than 200 companies and has created regional growth of £20m. The Morgan-Botti Lightning Laboratory³ at Cardiff University was established in 2011 as a collaboration between the Welsh Government, Cardiff University and Airbus Group Innovations (formerly EADS). It undertakes research including measuring the direct-effects of lightning strikes on structures and samples and investigating lightning protection mechanisms for the aerospace industry. The Electron Microscopy Centre (EMC)⁴ at Plymouth University has 30 years' experience working with AAE industries, supporting them through analysis of defects and quality control.

Capabilities in the automotive sector lie at the Powertrain & Vehicle Research Centre (PVRC)⁵ which builds on 50 years of research excellence focused on improving the systems efficiency of the whole vehicle powertrain (engine, transmission and control), which recently has been aimed at reducing CO₂ emissions of both diesel and petrol engines, and improving real world driving conditions. It partners with local companies, Ashwoods (Exeter) and HiETA Technologies (Bristol), and nationally Ford UK, Jaguar Land Rover, Lotus Engineering, TATA and McLaren Automotive, Ricardo, Honeywell, Shell, BP, and many more.

¹ National Composites Centre - <http://nccuk.com/>

² Centre for ALM - <http://emps.exeter.ac.uk/engineering/research/calm/>

³ Morgan Botti Laboratory - <http://lightning.engineering.cf.ac.uk/>

⁴ Electron Microscopy Centre - www.plymouth.ac.uk/your-university/about-us/university-structure/faculties/science-engineering/electron-microscopy-centre

⁵ University of Bath PVRC - <http://www.bath.ac.uk/mech-eng/research/pvrc/>

Further assets lie outside HEIs. Aerohub⁶ at Cornwall Airport Newquay is a designated enterprise zone that offers planning-free development and 100% business rate relief. Funded with £2.3m from the Homes and Communities Agency (HCA) and £3.9m from the European Regional Development Fund Convergence programme, with Cornwall Council providing the land, Aerohub is home to Advanced Engineering companies such as CIS UK Ltd and Apple Aviation as well as Bloodhound Supersonic Car which is attempting the UK's latest land speed record. Aerohub / Cornwall Airport Newquay is well placed to be the UK's first spaceport.⁷ With one of the UK's longest runways, available development land, uncongested clear airspace and access to segregated airspace. The Aerohub Enterprise Zone also incorporates Goonhilly Earth Station, a major satellite communications hub and location for a proposed Space Science Centre. This complementary expertise is covered in the Resilience, Environment and Sustainability Theme as Goonhilly is part of the Satellite Applications Catapult Centre of Excellence.

The marine technology focused Enterprise Zone at the 35 hectare Plymouth Devonport site (now named Oceansgate⁸) will provide further impetus to marine sector growth and the partnership between BMT and MSUBS to develop a test range, located off the Plymouth coast for testing UxV technologies. The facility features sensors within fixed buoys, environmental sensors, GPS, Wi-Fi (for tracking, communications and navigation) and will help developers test their technology in real conditions.

Skills & Training - In September 2009 Flybe announced its successful bid for Training Academy project at Exeter Airport. Funding included £4.3m from Learning and Skills Council's (LSC) new Capital Specialisation Fund (CSF) and £2.8m South West Regional Development Agency. The Flybe Training Academy⁹ offers a wide range of Pilot, Technical, Cabin Crew and Customer Service courses to airlines across the world, as well as a range of non-aviation training to other individuals and organisations in the South West.

Teaching related to the region's AAE strengths is also evidenced in the further education landscape with City of Bristol College offering courses in Aeronautical engineering and Aerospace engineering manufacturing¹⁰. Exeter College offers in partnership with Flybe at Exeter International Airport an Aircraft Engineering higher education foundation degree¹¹. Yeovil College provides post GCSE students with an opportunity to gain qualifications in Composites engineering (Level 3) as well as vehicle maintenance & repair¹². Cornwall College's Falmouth Marine School offers a range of qualifications in boat building and repair and marine engineering¹³. In the higher education space, a significant number of Centres for Doctoral Training (CDT) / Doctoral Training Entities (DTEs) are housed in the

⁶ Aerohub at Cornwall Airport Newquay - <http://www.aerohub.co.uk/>

⁷ http://www.cioslep.com/assets/uploads/documents/1463644707_AH_spaceport_v3.pdf

⁸ Oceansgate - <http://www.oceansgateplymouth.com/>

⁹ Flybe Academy - <http://www.flybetraining.com/>

¹⁰ City of Bristol College - <http://www.cityofbristol.ac.uk/courses/aeronautical-engineering/>

¹¹ Exeter College - <http://www.exe-coll.ac.uk/Course/engineering-flybe-diploma/>

¹² Yeovil College -

<http://www.yeovil.ac.uk/Apprenticeships/Engineering/AdvancedCompositeEngineering.htm>

¹³ Cornwall College - <https://www.cornwall.ac.uk/boat-building>

region's universities including those in Advanced Composites for Innovation & Science¹⁴ and Composite Manufacture¹⁵ (Bristol), Catalysis¹⁶ (Bristol, Bath and Cardiff), Autonomous & Robotic Systems¹⁷ (Bristol and UWE), Metamaterials¹⁸ (Exeter) and Sustainable Materials and Manufacturing¹⁹ (Exeter).

3. Excellence in science and research

Research Excellence Framework 2014 (REF)

Approximately 250 academic staff based at the region's Universities are involved in AAE research (Appendix AAE3). Since 2008 the AAE academic community have trained over 750 PhD students with 90% of the research activity was classified as world-leading or internationally excellent (4 & 3*, respectively). Researchers are drawn from 10 Units of Assessment (UoA) as defined by the REF, with the majority associated in UoAs 12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering and 15 General Engineering.*

21 REF Impact Case Stories are directly associated with academics from this theme, pointing to excellence in:

- Design and manufacture processes: e.g. composite wing structures, light-weighting and performance enhancement of aerospace structures, and improving car production processes
- Decarbonisation through improvements in engine fuel efficiency
- Modelling, simulation and testing of new materials (composites, steel & alloys, concrete) and structures applicable across AAE

An audit of research income associated with AAE shows that in the period 2008-2015 the total research income across the consortium was over £210m, with 2014/15 representing the academic year with the highest research income. This is reinforced by the region's Universities being awarded eight further recent AAE projects worth over £1m each and all involving at least one commercial partner.

Publication data

SciVal analysis of publication data for the period 2011-15 shows the combined publishing output of the Universities in the audit region out-performs the UK, Europe and the World in Aerospace and Automotive Engineering. 23% of the University of Bristol's papers on this topic are highly cited (compared to 20% UK, 17% Europe, 10% World) and 84% of the University of Bath's articles are found in high impact journals (76% UK, 73% Europe, 53% World). The region's universities also outperform the UK, European and World averages for publication citations and impact in the area of Automotive Engineering with 63% of the

¹⁴ Advanced Composites for Innovation & Science - www.bristol.ac.uk/composites

¹⁵ Composites Manufacture -

www.epsrc.ac.uk/skills/students/centres/profiles/compositesmanufacture/

¹⁶ EPSRC CDT in Catalysis - <http://www.catalysis-cdt.ac.uk/>

¹⁷ EPSRC CDT in Future Autonomous & Robotic Systems - <http://farscope.bris.ac.uk/>

¹⁸ EPSRC CDT in Metamaterials - <http://emps.exeter.ac.uk/metamaterials/>

¹⁹ Sustainable Materials & Man. -

www.exeter.ac.uk/doctoralcollege/fundedcentres/materialsmanufacturing/

University of Bristol's output being in highly cited papers, compared to 21% for the UK, 16% Europe and 12% World.

Further analysis of these data on topics central to AAE indicates that universities in the audit region out-perform the Russell Group (which includes Universities of Bristol, Cardiff and Exeter) and the UK as a whole on citation impact, publishing in high impact journals and co-publishing with industry in the subject area of composites. The University of Bath's publications on wing aerodynamics and The University of Bristol's publications on laminates and composite materials are more than twice as likely to be highly cited and 1.5 times more likely to be published in high impact journals than other articles in this topic area. In the areas of Composite Materials, Laminates and Delamination, Buckling, Fibres and Textiles, the University of Bristol is world-leading in terms of number of publications, overall citations and field-weighted citation index.

Cardiff University is the leading UK institution for publishing on supply chains and is among the top 10 most active universities worldwide for this topic. University of Bath, University of Exeter, University of Plymouth, University of Bristol and University of the West of England are also significant contributors to publishing in this area²⁰.

Patents

Based on named inventors, over the period 2004-2013 companies in the consortium area and associated with AAE filed over 1,500 patents. Across South West England & South East Wales eight of the ten most active companies in terms of protecting their intellectual property are associated with the theme. This includes firms such as Dyson, Airbus, Rolls-Royce, Renishaw, BAE Systems, Vecto Gray Controls and Edwards. Furthermore, The Universities of Bath, Bristol and Cardiff all appear in the top 40 organisations in terms of number of patent filings²¹.

4. Innovation strengths and growth points

In 2015, across the consortium area there were 7,775 enterprises operating within Aerospace & Advanced Engineering. This represents an increase of 29% over the past 5 years, with much of this growth occurring after 2012. This is more than twice the average rate of growth in number of enterprises across industries in the Audit region (13%)²².

Approximately 475 companies are associated with the aerospace sector with a value to the economy of £3.2bn and Gross Value Added (GVA) of £2.3bn²³, 190 are within the automotive sector, 150 with the marine sector and 140 with steel. Furthermore, 14 of the 15 largest aerospace companies in the world have a presence in the South West and sector exports from the region are estimated to account for between 50 – 65% of sales²⁴. 1015, 1385, and 3805 companies were classified under Engineering Design for Production & Process, Technical Consulting in Engineering and Other Engineering codes, respectively. However, over 90% of these companies employed fewer than 10 people.

²⁰ SciVal Analysis at University of Bath Library July 2016 - www.scival.com

²¹ Technopolis patent data - World Intellectual Property Organization 2004-2013

²² Business Register and Employment Survey 2014, NOMIS Official Labour Market Statistics

²³ ADS Group UK Aerospace Outlook 2011

²⁴ South West & Wales, Spotlight, Autumn 2015 - <http://sites.southglos.gov.uk/wp-content/uploads/sites/241/2015/09/2015-bristol-spotlight-autumn.pdf>

Between October 2013 and May 2016 the region's SMEs population had the highest uptake of NATEP projects (35) and highest predicted growth in jobs. Moreover, a significant number of these projects undertaken in the region were in Innovative materials for aerostructures and components, particularly composites. This links directly to the ATI pillars and themes and support the national AGP strategy²⁵.

When expressed as location quotients (LQ), the consortium area has particularly high concentrations of enterprises in the Aerospace sector (LQ - 2.62). Indeed the Audit region boasts largest aerospace cluster in the UK, and the second in Europe, with 20% of the UK aerospace workforce. Further analysis indicates that companies engaged in these activities are clustered in the South East Wales and West of England Local Enterprise Partnership (LEP). South East Wales also has high LQ scores, 2.75, for Manufacture of basic iron and steel and of ferro-alloys. Similarly concentrations of companies involved in the building of watercraft and structures are found in Cornwall & the Isles of Scilly LEP (LQ - 5.15) and Heart of the South West (LQ - 2.75). Swindon & Wiltshire LEP area has particularly high location quotients (4.23) for the manufacture of transport equipment and associated equipment for motor vehicles (LQ - 2.64)²⁶.

Jobs

According to the Business Register and Employment Survey (BRES) 98,100 people are employed in AAE in the region, representing over 12% of all those in employed in this sector in Great Britain (812,600). Employment in AAE has been rising locally and in 2014, was 9,800 (10.9%) higher than it was in 2009. This is a much larger percentage increase than employment across all industries in the Audit region (0.6%) and is higher than the industry average across Great Britain (6.6%)⁵.

Jobs in AAE are high value. Productivity throughout the aerospace sector is estimated at £54,000 per FTE, rising to £73,000 amongst the major aerospace companies, and as compared to a regional productivity average of £43,000 per FTE. More than 30% of UK aerospace employees are educated to degree level or above, compared to a national average of 21% for the total working age population²⁷. Despite a projected decrease in the total number of people employed in AAE in the region between 2010 and 2020, the replacement demand, will be roughly twice the scale of the employment decline; a net requirement for 2,500 additional employees in advanced engineering over the next ten years²⁸.

These sectors are underpinned by technical engineering services, materials and component supply chains and research and experimental development in the region, with over 42,000 jobs classified under general engineering activities, engineering design activities for industrial process as well as engineering related scientific and technical

²⁵ NATEP Analysis and Statistics May 2016- issue 005

²⁶ Business Register and Employment Survey 2014, Nomis Official Labour Market Statistics

²⁷ Aerospace & Advanced Engineering Sectors - South West Region's Inward Investment Strategy

²⁸ West of England Strategic Economic Plan 2015-2030

consulting activities⁵. Approximately 65% of workers engaged in these industries are qualified to at least NVQ Level 3 or above⁶.

Strengths by Local Enterprise Partnership

West of England⁷

Advanced Engineering is recognized as being vital to the economy of the West of England as it makes intensive use of capital or knowledge; has high levels of R&D and technology expenditure; requires strong specialist skills particularly in science and technology; and is likely to compete nationally or internationally. Aerospace is the single most powerful sector in the West of England, with one of the largest concentrations of aerospace activities in Europe. The cluster acts as a magnet for further inward investment but the LEP also recognizes the accretion of strength and resilience in the local economy by virtue of having a broad spectrum of advanced engineering companies that include, robotics, automotive, white good manufacturing, general advanced engineering.

Manufacturing in the LEP contributes to a GVA of £58,800 per full-time equivalent employee, with output in the West of England approximately 20% higher than it is nationally, and 30% above the West of England economy as a whole. These high productivity levels are largely driven by the aerospace cluster comprising Airbus, GKN Aerospace, Rolls-Royce, BAE Systems, Honeywell, Claverham, MBDA and associated supply chain, as well as luxury car maker Bristol Cars.

Gloucestershire²⁹

The composition of the AAE sector in Gloucestershire comprises precision engineering sub-sector (50% of employees) and an even split between the Automotive (26%) and Aerospace (24%) sub-sectors. The picture differs in South West Gloucestershire with the Aerospace sub-sector accounting for 56% of employees. The strong advanced engineering cluster in Gloucestershire means that the proportion of employees engaged in the sector stands 50% higher than the national average.

Significant AAE employers in Gloucestershire include Spirax Sarco, Safran Landing Systems UK, Messier-Bugatti-Dowty, Renishaw, Kohler Mira, Bond Aviation Group, Oberthur Technologies, L-3 TRL Technology, Avon Metals, Glatfelter Lydney, Moog Controls, Corin Group and Relyon. The manufacturing sector accounts for a greater than average proportion of both employment and GVA; accounting for 11.9% of total employment (8.8% nationally) and contributing £1.88bn to the local economy or around 16.2% of total GVA (11.6% nationally). The percentage of young people attempting 'Triple Science' in Gloucestershire is increasing which has been shown to lead to a greater uptake of STEM subjects at A-level and University. DoE data indicates that pupils in Gloucestershire achieve better than average maths and science results.

Heart of the South West³⁰

Advanced Engineering, with its principal sub-sector Aerospace and other important components, Automotive, Advanced Electronics/Photonics, Defence and Marine, employs over 23,000 people across the LEP and contributes over £1bn to the economy. Many leading AAE companies are situated in Somerset and Devon, including Leonardo

²⁹ Strategic Economic Plan for growing Gloucestershire

³⁰ Heart of South West Strategic Economic Plan 2014-2030

Helicopters - Britain's only helicopter manufacturer that retains a complete indigenous design, development, production, manufacturing and support capability, Honeywell Aerospace, BAE International, SC Group (former Supacat), Centrax, MB Aerospace, Alcoa Howmet, Helitune, Beran Instruments, Ashwoods Automotive, Hymec, Aero Stanrew, Anglo-Krempel, Babcock, Thales, Aerosystems International, Ariel Motor Company, and Numatic International as well as links to major Ministry of Defence sites at Yeovilton and Abbey Wood. Interestingly, Somerset company, Ascenta, was acquired by Facebook to develop solar powered drones to supply wireless broadband to the developing world. Furthermore, Brecknell Willis has its UK centre for manufacturing and its global innovation centre in railway electrification systems located in Chard.

Such a robust and varied industry cluster generates a highly skilled, experienced and eminently "transferable" workforce with many supply chain companies being dual or multi-sector oriented. Indeed over 1/3 of the population in Devon are educated to degree standard or above. This makes for a highly diverse AAE base which the LEP is keen to secure and to grow both in size and scope.

Swindon & Wiltshire³¹

The LEP is home to some of the best known Advanced Engineering companies in the world including Dyson's global HQ in Malmesbury as well as Johnson Matthey Fuel Cells, Herman Miller, Torin, Knorr-Bremse, Tamura Europe, Honda and Wavin Plastics. Siemens Rail Automation formed after the acquisition of the control, command and communications divisions of Westinghouse Brakes & Signals, has its UK centre for manufacturing and its global centre for R&D in Chippenham. Swindon & Wiltshire is an internationally recognised centre of innovation in Automotive, Mechanical, Electrical and Process Engineering and has a growing Manufacturing cluster with the sector employing 11.8% of the county's workforce.

Wiltshire has a tradition of defence-related research and manufacturing with QinetiQ and Defence Science and Technology Laboratory (DSTL) at the Porton Down facility and Chemring Countermeasures. The automotive and rail systems sectors are also well represented in the LEP with Invensys Rail, BMW Group and an extensive automotive supply-chain network, including DTR VMS. Honda UK's fully integrated manufacturing facility currently produces the Civic, CR-V and Jazz range. Acknowledging the diverse Advanced Engineering capability as pivotal to the success of the local economy, the LEP is keen to foster cross-sector collaboration between Automotive and Aerospace.

Cornwall & Isles of Scilly³²

C&IoS has very low levels of business investment in R&D. In 2012 R&D spend was 0.22% of GDP, the lowest of any LEP area, compared to a national figure of 1.63% and an EU average of 2.09%. In the period 2010-2013 only 20 companies in C&IoS (out of 5,464 nationally) successfully applied for Innovate UK funding - with only £4 million of grants being secured out of £922 million nationally.

³¹ Swindon & Wiltshire Strategic Economic Plan – Aligning local innovation with Government ambition

³² Cornwall and Isles of Scilly Research, Development and Innovation Framework

The LEP has identified agri-tech, digital economy, e-health and e-wellbeing, marine technology, and, space and aerospace as markets where C&IoS has an existing asset base and where there is potential for global growth and development in that market. The LEP contains AAE companies including Lockheed Martin UK, Leonardo Helicopters, British International Helicopters, Western Aviation, A&P, Babcock and Princess Yachts. Consequently, investment will focus on these areas with for example €20-25M of ERDF funding earmarked for the space³³ & aerospace sector with marine technologies supported through schemes such as the Devonport Dockyard development under the Plymouth and South West Peninsula City Deal.

South East Wales

The region is centre of excellence for aircraft Maintenance, Repair and Overhaul (MRO) with British Airways Maintenance Cardiff, the world's only licensed dual bay facility capable of maintaining and overhauling Boeing 747, 767 and 777 aircraft³⁴. Furthermore the audit region is part of the wider steel industry cluster in South Wales (including Tata, Port Talbot) and contains companies such as Celsa Steelworks UK, Liberty Steel and Tata Steel Service Centre. The automotive industry is also represented by the Ford Bridgend Engine Plant which produces 750,000 engines per annum including the Ford SI6 engine for Volvo and Jaguar Land Rover and the Ford 1.6 L I4 EcoBoost. In March 2015 it was announced the "Dragon" designed petrol engines would be built at Bridgend following a £15m investment grant by the Welsh Government³⁵.

5. National and international engagement

Industry Bodies & Networks - *As well as being connected nationally and internationally, organisations in the Audit region can boast strong local networks involving industry, academia and government.* Aerospace Wales, provides a membership trade service for AAE companies in their geography³⁶. Similarly, the West of England Aerospace Forum (WEAF)³⁷ is a regional membership trade organisation representing the aerospace and defence sectors from SMEs to global corporations. As one of the largest aerospace and defence associations in Europe, WEAF provides a strong voice, representation and access to prominent regional, national and international decision makers in industry and government. It also serves as the regional coordinator for National Aerospace Technology Exploitation Programme (NATEP) activities.

The Exeter Initiative for Science and Technology (ExIST)³⁸ is a subgroup of Exeter Chamber of Commerce and Industry. Founded in 2011 by a group of business leaders in Exeter and the surrounding area, the initiative aims to optimise interaction between science, technology, engineering, mathematics and medicine (STEMM) businesses

³³ http://www.cioslep.com/assets/uploads/documents/1463644707_AH_spaceport_v3.pdf

³⁴ British Airways Engineering - http://www.britishairways.com/baemro/assets/download/BA_Engineering.pdf

³⁵ Brdigend Council - <https://democratic.bridgend.gov.uk/documents/s7098/151007%20Council.pdf>

³⁶ Aerospace Wales - <http://www.aerospacewalesforum.com>

³⁷ West of England Aerospace Forum - <http://www.weaf.co.uk/>

³⁸ Exeter Initiative for Science & Technology - <http://www.existexeter.co.uk/>

trading in the area. Further South West the Torbay Hi-tech forum³⁹ is a membership group dedicated to industry-led development, collaboration and promotion across the tech and advanced manufacturing sector. The Growth Acceleration and Investment Network (GAIN)⁴⁰ was founded by Plymouth University, Plymouth City Council and Tamar Science Park to accelerate the creation, growth and investment in high quality businesses, creating wealth and jobs in the South West

The Audit region has national Advanced Engineering links through bodies such as the Advanced Propulsion Centre (APC) UK⁴¹. The APC was established by the Automotive Council as the delivery hub for a joint industry / Government strategy to help the UK accelerate its leadership and excellence in advanced low carbon propulsion development and production. It will channel £1bn into the UK automotive industry over the next decade. The Centre's hub and spoke model, with the "internal combustion engine system efficiency" spoke based at the University of Bath, provides access to the UK's leading expertise and facilities in key strategic technologies for the automotive industry.

Collaborative Projects - The Audit area Universities all undertake significant collaborative research in AAE (Appendix AAE2) with companies of various sizes (SME to OEM / Multinational) and universities across the UK, Europe and further afield. Highlights include the £26m Advanced Combustion Turbocharge Inline Variable Valve-train Engine (ACTIVE)⁴² project with Ford, Continental, Schaeffler, Unipart Eberspacher Exhaust Systems, BP, Cambusion, AP Raicam and the Universities of Bath, Bradford, Loughborough and Nottingham. Its objective is to further improve the already class leading 1L Ford EcoBoost car engine.

Significant aerospace collaborations include Agile Wing Integration (AWI)⁴³ lead by Airbus with Marshalls, AGI and The Universities of Bristol, Cranfield and Loughborough. The £16m project will develop rapid, world-beating, wing design and integration capabilities for use during the early phases of an aircraft product development cycle with the aim of cutting aircraft carbon emissions. Aeroelastic Gust Modelling (AEROGUST)⁴⁴, is a €4.3m EU Horizon 2020 Research and Innovation programme. The project seeks to drive the competitiveness of European Aviation through cost efficiency and innovation, maintaining and extending industrial leadership. Led by The University of Bristol with The Universities of Liverpool and Cape Town, Airbus, Dassault Aviation, DLR, INRIA, NLR, NUMECA, Optimad, Piaggio Aerospace, VALEOL it will also transfer technology to the wind turbine industry.

Connectivity in the composites area is exemplified by projects such as High Performance Ductile Composite Technologies (HiPerDUCT)⁴⁵. The £6.4m project involving University of

³⁹ Invest in Torbay - <http://www.investintorbay.com/our-networks/hi-tech-forum/>

⁴⁰ Growth Acceleration and Investment Network - <https://gaininbusiness.com/>

⁴¹ Advanced Propulsion Centre UK - <http://www.apcuk.co.uk/>

⁴² Advanced Propulsion Centre UK -

<http://www.apcuk.co.uk/wpcontent/uploads/2014/10/APC1-Ford-ACTIVE-Overview.pdf>

⁴³ Research Councils UK - <http://gtr.rcuk.ac.uk/projects?ref=113041>

⁴⁴ European Commission Horizon 2020 - <http://www.aerogust.eu/>

⁴⁵ Research Councils UK - <http://gtr.rcuk.ac.uk/project/94A87C82-2284-4E27-A6DA-5BA06996E2C6>

Bristol, Imperial College London, BAE Systems, DSTL Porton Down, Halliburton Energy Services, Hexcel Composites, Mouchel, Rolls-Royce, Vestas, aims to design, manufacture and evaluate a range of composite systems with a ductile or pseudo-ductile response, while maintaining the strength and stiffness for which composites are so highly prized. The two-year, £4m ENABLES project supported by BEIS, ATI and Innovate UK assisted Rolls Royce in establishing a Composite Technology Hub in Bristol. The partnership between Rolls Royce, the NCC, University of Bristol and Advanced Manufacturing Research Centre in Rotherham, and the Manufacturing Technology Centre, Coventry, as well as the SME bf1systems, who brought experience from the automotive and motorsports sector, developed composites for fan housings with the new Hub central to the development of the next generation CTi (carbon/titanium) fan blades.

The highly innovative £1.9m Language of Collaborative Manufacturing (LoCM)⁴⁶ project in the areas of digital manufacturing and Industry 4.0 involves The University of Bristol, University of Bath, Airbus Operations, CIMPA S.A.S., Delcam International, Dyson Appliance, FBM Babcock Marine, Jaguar Land Rover, National Centre for Text Mining NaCTeM, Ove Arup and Partners, Shapespace, and Volvo.

Collaborative Publishing - *Collaboration between industry and academia is further evidenced through publications data (Appendix AAE4) with the percentage of highly cited articles by universities' in the Audit region that are co-authored with industry partners being over twice that of similar publications from the Russell Group and the UK as a whole.*

This is exemplified by University of Bristol being Airbus's top UK academic publishing partner. University of Bath, University of Exeter & Cardiff University are also in Airbus's top 10 UK academic publishing partners. University of Bath is a major publishing partner for Lotus Engineering being Lotus's second most frequent academic publishing partner and joint publications between University of Bath and Lotus have a strong citation impact, receiving over twice as many citations as would be expected for publications of their age and subject field. University of Bath and University of Bristol are significant academic publishing partners for Jaguar Land Rover and Rolls Royce UK. Bath and Bristol are both in Jaguar's top 10 most frequent academic publishing partners. Bristol is Rolls Royce's 7th most frequent UK academic publishing partner and Bath is in Rolls Royce's top 20 UK academic publishing partners, achieving a strong citation impact for co-published works⁴⁷.

The data also indicates the desire for companies outside the region to participate in the world class research being carried out by academics at universities in South West England and South East Wales.

6. Developments in science and technology – international markets and opportunities

National & International Comparators - To build on the region's strengths in AAE by retaining and attracting future research intensive and innovative companies which provide high skilled jobs, the activities, infrastructure and initiatives across the UK, Europe and around the globe should be considered for context and comparison (Appendix AAE7).

⁴⁶ Language of Collaborative Manufacturing - <http://locm.org.uk>

⁴⁷ SciVal Analysis at University of Bath Library July 2016 - www.scival.com

UK - Along with WEAFA and Aerospace Wales, other regional aerospace alliances (RAAs) represent clusters in different parts of the UK. This includes Farnborough Aerospace Consortium (FAC)⁴⁸, Midlands Aerospace Alliance (MAA)⁴⁹ and North West Aerospace Alliance (NWAAs)⁵⁰. These RAAs work closely with the national aerospace sector body, ADS, and are recognised as the Federation.

Automotive research facilities include the National Automotive Innovation Centre (NAIC)⁵¹, a £150m investment between Jaguar Land Rover, Tata Motors European Technical Centre, Warwick Manufacturing Group (WMG) and the University of Warwick. Ford's Dunton Technical Centre⁵² in Essex houses one of the largest automotive technical centres in the UK, employing approximately 5000 staff.

Marine clusters within the UK including Belfast Harbour⁵³ a trustee port covering an estate of over 2,000 acres which has invested over £60m to create new facilities to support the deployment and assembly of offshore wind farms, Lowestoft/East of England and the Southampton / Portsmouth region, which is supported by the £115m Portsmouth Southampton City Deal⁵⁴.

In March 2015, the £14.5m UK Research Partnership Investment Fund (UKRPIF) funded Advanced Steel Research Centre (ASRC)⁵⁵, housed in the Advanced Manufacturing and Materials Centre, was announced. Developments in skills training include the Airbus Defence and Space £2.5m science, technology, engineering and maths (STEM) centre⁵⁶ at its Exomars Rover facility in Stevenage. The centre hopes to attract more than 5,000 students a year.

Europe - Toulouse Aerospace Valley (TAV)⁵⁷, created in 2005 has 859 members from industry and academia. It employs 124,000 staff and 8,500 researchers representing 1/3 of the French aerospace workforce. To 2015 its 450 R&D projects had a value of €1.1bn. By 2025 TAV aims to create 35-40,000 new jobs. The model has been replicated across Europe, if on a smaller scale at locations such as Andalucia Aeropolis⁵⁸, Italian Aerospace Research Centre (CIRCA)⁵⁹ and Poland's Aviation Valley⁶⁰.

⁴⁸ Farnborough Aerospace Consortium - <http://www.fac.org.uk/>

⁴⁹ Midlands Aerospace Alliance - www.midlandsaerospace.org.uk

⁵⁰ North West Aerospace Alliance - www.aerospace.co.uk

⁵¹ National Automotive Innovation Centre -

<http://www2.warwick.ac.uk/fac/sci/wmg/research/naic/>

⁵² Dunton Technical Centre - https://en.wikipedia.org/wiki/Dunton_Technical_Centre

⁵³ Belfast Harbour - <https://www.belfast-harbour.co.uk/>

⁵⁴ Southampton / Portsmouth City Deal -

http://solentlep.org.uk/strategic_priorities/strategic_sectors

⁵⁵ Advanced Steel Research Centre -

http://www2.warwick.ac.uk/fac/sci/wmg/research/steel_processing/asrc/

⁵⁶ Airbus Defence & Space Centre for STEM -

<https://airbusdefenceandspace.com/newsroom/news-and-features/airbus-defence-and-space-to-build-stem-centre-at-its-uk-exomars-rover-test-facility-in-stevenage/>

⁵⁷ Toulouse Aerospace Valley - <http://www.aerospace-valley.com/en>

⁵⁸ Andalucia Aeropolis - <http://aeropolis.es/en/>

⁵⁹ Italian Aerospace Research Centre - http://www.cira.it/en?set_language=en

Advanced automotive research centres are located in Germany including The BMW Group Research and Innovation Centre⁶¹. Home to 9,200 staff working across the Group this unique setup reduces development time and is regarded as a pacesetter in the car industry. The International Centre for Turbomachinery Manufacturing (ICTM)⁶², established in 2015, constitutes the Fraunhofer Institute and RWTH Aachen University. Working together with industry partners the Institute aims to speed up innovation and provide specialist training related to turbomachinery.

Brest commercial port is located on the northern coast of France in the Brittany region and is an important gateway to France and continental Europe. The port is managed by the chamber of commerce and industry of Brest and is owned by the Regional Council of Brittany. The Port of Brest is the leading French port for military fleet maintenance and for civil naval repair⁶³.

Global – Aerospace, automotive and marine clusters are spread globally in traditional manufacturing locations such as Detroit, Centre for Automotive Research (CAR)⁶⁴ and San Diego⁶⁵ but with the emergence of new activity particularly in Asia. Examples include Asia Aerospace City⁶⁶, Korea Aerospace Research Institute (KARI)⁶⁷ as well as, China Automotive Technology and Research Centre (CATARC)⁶⁸, Pan Asia Technical Automotive Centre (PATAC)⁶⁹.

Market trends - *AAE companies face a crossroads of immense importance over the coming years. The extended design, build, test, implement cycles in advanced engineering industries require technologies to meet future policy demands to be developed today. This necessitates careful analysis of the policy and technology landscape in order to ensure the direction of travel remains relevant and opportunities aren't missed.*

Policy & Socio-Economic Drivers

Legislation – One of the most important issues currently shaping the aerospace, automotive and advanced engineering industries globally is fuel economies and emissions standards required under Government legislation. The Climate Change Act (2008) set a long-term legally binding framework for greenhouse gas (GHG) reduction in the UK⁷⁰. The Act requires Government to reduce GHG emissions by at least 34% by 2020 and 80% by

⁶⁰ Poland Aviation Valley - <http://www.dolinalotnicza.pl/en/>

⁶¹ BMW Group Research and Innovation Centre
www.bmwgroup.com/forschung_entwicklung/

⁶² International Centre for Turbomachinery Manufacturing - <http://www.ictm-aachen.com/>

⁶³ RegenSW - Plymouth Marine Industries Demand Study

⁶⁴ Centre for Automotive Research - www.cargroup.org/

⁶⁵ San Diego Maritime Cluster - <http://www.sandiegobusiness.org/industry/maritime>

⁶⁶ Asia Aerospace City - <http://www.asiaaerospacecity.com/>

⁶⁷ Korea Aerospace Research Institute - <http://www.kari.re.kr/eng.do>

⁶⁸ China Automotive Technology and Research Centre - www.catarc.ac.cn/ac_en/

⁶⁹ Pan Asia Technical Automotive Centre - <http://www.patac.com.cn/>

⁷⁰ The Climate Change Act 2008 (c 27)

2050 from 1990 UK levels. In 2013, domestic and international transport accounted for 26% of all UK GHG emissions⁷¹.

Skills - The Royal Academy of Engineering calculates that the UK needs an annual minimum of 100,000 graduates in STEM just to maintain the status quo in UK industry. It says more would be needed if the sector were to expand and help grow the economy. Currently only 90,000 STEM graduates are produced each year – around ¼ of whom go on to work in non-scientific careers⁷². Larger companies appear not to suffer from serious skill shortages. Their size and resources make it possible for them to either attract the very best staff and graduates, or to develop dedicated training schools to up skill their workforces. However, SMEs highlight the need for upskilling of the current “technical” workforce. Additional concern centres on an ageing workforce⁷³.

Devolution - Devolution of regional infrastructure budgets is current Government policy with deals so far agreed across the country including Cornwall in the audit region. Further devolution deals in are planned, including The West of England. The agreement negotiated would see the creation of a West of England Single Investment Fund distributing £30 million per annum over 30 years to boost growth and support infrastructure (roads and superfast broadband), skills (19+ adult education budget from 2018/19) & business (increased support for key growth sectors and the Bristol & Bath Science Park)⁷⁴.

Sector Analysis

Aerospace - The UK aerospace sector is expected to grow at a rate (CAGR) of 5% over the coming years⁷⁵. To 2031 there is an estimated global requirement for over 27,000 new passenger aircraft worth circa \$3.7Tn. Over the same time period, the global market demand for new commercial helicopters is expected to be in excess of 40,000 units, worth circa \$165bn⁷⁶. The MRO market is growing rapidly and represents a significant opportunity for the future⁷⁷.

Intriguingly, the commercial space market is forecast to be worth a trillion dollars globally by 2020 and the global market for Unmanned Air Vehicles (UAVs) was worth ~\$5bn in 2010 and is projected to increase to more than \$11.5bn per annum over the next decade⁷⁸. Aerohub Enterprise Zone / Cornwall Airport Newquay has the potential to be the UK's first space port.⁷⁹

⁷¹ Department for Energy & Climate Change - 2013 UK Greenhouse Gas Emissions, Final Figures

⁷² Royal Academy of Engineering - Jobs and Growth: the Importance of Engineering Skills to the UK Economy

⁷³ WEAFF Members' Skills Survey

⁷⁴ West of England Devolution Agreement

⁷⁵ ADS UK Aerospace Outlook 2015

⁷⁶ Lifting Off – Implementing the Strategic Vision for UK Aerospace

⁷⁷ Commercial Aircraft Maintenance, Repair & Overhaul (MRO) Market Forecast 2015-2025

⁷⁸ Aerospace & Advanced Engineering Sectors - South West Region's Inward Investment Strategy

⁷⁹ http://www.cioslep.com/assets/uploads/documents/1463644707_AH_spaceport_v3.pdf

Automotive - Britain is the fourth largest vehicle producer in Europe, making 1.6 million vehicles in 2014. Every 20 seconds a car, van, bus or truck rolls off a UK production line. Approximately 4 in 5 cars produced in the UK (78%) are exported to more than 100 countries. It is expected that the global light vehicle sales will hit 100m units by 2017 and 111m by 2020⁸⁰.

Furthermore, The Government has launched a consultation to explore factors around implementation of autonomous vehicles. Automated vehicle technologies will have a profound impact on the UK transport system and deliver major benefits: fewer crashes, greater freedom to travel, more efficient transport networks and new high value jobs in the technology and automotive sectors⁸¹.

Marine - The global marine market is estimated at £3Tn, especially with high value opportunities across emerging economies. As well as offshore renewables manufacturing (Cross Ref – New Energy Systems), naval export of high tech systems and class leading capability in leisure craft can capture the rapid growth of middle classes in other countries, building on the UK's reputation for quality⁸².

Steel - In 2014 the contribution of the UK steel industry to the economy totalled £2.2bn, 0.1% of the total output and 1% of manufacturing output, a decline of 24% since 1990. By way of contrast, world steel production increased 96% between 2000 and 2014, mostly driven by Chinese steel production. China produced 779m tonnes of steel in 2013, 48% of the world total. The UK produced 12m tonnes⁸³.

Technology Developments

High Value Engineering Design – “High Value Design” is the intellectually-intensive activity associated with the architectural definition of a complex product, its major components and its systems. Studies such as that by The Ford Motor Company⁸⁴ have shown that “product design” has the greatest influence on productivity improvement and downstream costs. Correcting the effects of “poor design” can be prohibitively expensive and have tangible impact on market share and/or business performance. Global excellence in “high value design” capability will ensure that the UK is able to deliver world-leading technologies and product solutions, delivering maximum competitiveness to customers. Leadership in design quality and productivity will ensure that the UK is an attractive supplier for product solutions and analysis/validation services.

Composite Materials - The global market for composite products in 2013 was worth \$68.1bn and is expected to grow at around 6.5% CAGR over the next 7 years to about \$105.8bn in 2020. The Composites Leadership Forum (CLF) estimates the size of the UK composites industry to be worth £1bn in terms of finished parts. Consultation with the UK composites supply chain has shown that the UK has the opportunity to grow its current £2.3bn composite product market to £12bn by 2030⁸⁵. If fibre and materials manufacturing

⁸⁰ Statista - Worldwide light vehicle sales - outlook 2011-2020

⁸¹ Centre for Connected & Autonomous Vehicles - Pathway to Driverless Cars

⁸² UK Marine Industry Alliance: A strategy for growth for the UK Marine Industries

⁸³ UK steel industry: statistics and policy Briefing Paper Number 07317, 11 July 2016

⁸⁴ Sandy Monro (Ford Motor Company) – Lean Design Philosophy, 1988:

⁸⁵ Composites Leadership Forum, UK Composites Strategy 2016

is successful on-shored it would bring ~£2bn of additional exports from the UK, and save up to £5/£7bn of imports by 2030.

The strong growth in the short to medium term will be driven by the production of composite components for the new civil and military aircraft and adoption of composites in the automotive and marine sectors with a major driving being the need to reduce weight for fuel efficiency. Aerospace, Automotive, Construction, Oil & Gas and Renewables all have a potential market size of over £1bn each by 2030⁸⁶.



Percentage figures are Compound Annual Growth Rate (CAGR). The forecast figures reflect the view of UK supply chain companies in research carried out by the NCC in mid-2015.

Figure AAE1 Opportunities in composite materials by market

Automation, Smart Factories & Industry 4.0 - A report by McKinsey estimated that the application of advanced robotics could generate a potential economic impact of \$1.9Tn to \$6.4Tn per year by 2025⁸⁷. This would result in new products and transformation in the way in which products are built and services are delivered. Robotics and Autonomous Systems (RAS) was identified by the UK Government in 2012 as one of the Eight Great Technologies that support the UK Industrial Strategy⁸⁸.

Industry 4.0 is a current trend that represents the application of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things and cloud computing to create a "smart factory". Here cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make

⁸⁶ Aerospace & Advanced Engineering Sectors - South West Region's Inward Investment Strategy

⁸⁷ McKinsey & Co: Disruptive technologies: Advances that will transform life, business, and the global economy

⁸⁸ RAS 2020 Robotics and Autonomous Systems: A national strategy to capture value in a cross-sector UK RAS innovation pipeline through co-ordinated development of assets, challenges, clusters and skills

decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and humans in real time, allowing services to be offered and used by participants of the value chain⁸⁹.

Propulsion - Despite the promise of new, cleaner technologies, the automotive sector still believes downsizing the traditional internal combustion engine is likely to yield the best results in the short-to-medium-term. Furthermore, when it comes to alternatives, fuel cells have moved ahead of battery electric systems to become the number two priority for investments until 2020⁹⁰. As shown in the Automotive Council's technology roadmap⁹¹, whilst electrification of the powertrain remains a goal for national governments, a mixtures of technologies, including internal combustion, will remain for decades to come.

The increasing divergence in requirements combined with the large array of possible technologies creates new challenges for the vehicle industry with the future holding uncertainty around preferred powertrain platform technologies and more specialized powertrain platform(s) to meet competition. The challenge for the UK economy is therefore to be ahead of any market preferences, across sectors and technologies, in order to secure the long-term future of propulsion in this country.

Additive Layer Manufacturing (ALM) - ALM involves the production of three-dimensional parts directly from computer aided design data (3D-printing). Objects are constructed from deposition of material (resin or metal) in layers as little as 0.05mm thick. The benefits include: lower manufacturing costs; shorter time to market; greater flexibility and the potential to create innovative and complex components that previously could not be manufactured. ALM is likely to have wide-ranging uses across advanced engineering.

Exeter's Centre for Additive Layer Manufacturing has identified around 1,000 components used by Airbus that could be built using ALM, saving 3,000 tonnes across Airbus' forecast of 25,000 new aircraft and resulting in end users saving to the tune of \$300bn over the next 20 years⁹².

Testing, Certification and Metrology - Industrial metrology is integral part of advanced engineering manufacturing processes, with the use of laser tracker systems and coordinate measurement machines used for inspection, tooling, part mating and reverse engineering tasks, achieving single-micron accuracies. Innovative manufacturing processes and materials must also be amenable to this rigorous inspection with their suitability established at the earliest possible TRL. To achieve this the testing and characterisation of materials in silico as well as at component and sub-structure level is essential. Moreover, evolving existing and developing new testing regimes that mirror real world operation, for example in light of the vehicle emissions testing scandal, will be crucial to development of new technologies.

⁸⁹ McKinsey & Co: Manufacturing's next act

⁹⁰ Warwick Economics & Development Report – University of Bath IAAPS

⁹¹ Technology Roadmap - <http://www.automotivecouncil.co.uk/wp-content/uploads/2013/09/Automotive-Council-Roadmaps.pdf>

⁹² Centre for ALM - <http://emps.exeter.ac.uk/engineering/research/calm/>

7. Conclusions

Capital investments already in place or currently being developed are competing to provide companies and countries with market and economic advantage in all these areas. Globalisation is moving at such a pace that it is becoming irrelevant where the supply base sits and many 'Primes' (first tier manufacturers) are moving their manufacturing nearer to emerging customers - especially the Far East and China. Furthermore, UK manufacturers often require the majority of materials to be sourced from outside UK, increasing risk especially in times of economic turbulence. This can be compounded by, increased cost, poor availability and variable quality and consistency from manufacturers and suppliers. For UK supply chains to compete in this global market it is important to stem the trend to offshore. The region's advanced engineering sectors: aerospace, automotive, steel & marine, display synergies which can be underpinned by common, sector agnostic, technology developments. With appropriate investment the region's competitive advantage, over the clusters in the UK, Europe and globally, in AAE can be secured and developed.

Stakeholder Workshop – The workshop helped identify a number of actions that would help the region to realise these opportunities, or that without action have the potential to inhibit success:

- Programmes or structures to enable cross-sector participation in knowledge-exchange, mediated by Universities; particularly to enable SMEs to work collaboratively with each other, Universities and, crucially, OEMs /major suppliers
- Coordinated incubator facilities with lab/experimental/test space and in-house innovation support
- Establishment of a “Digital Factory” or “Catapult” for Advanced Engineering
- Long-term investment for teaching of STEM subjects in schools and beyond
- Increased and innovative “quick and easy” funding mechanisms: Increase in NATEP-type funding, an “Innovation Fund” i.e. offering tax incentives, management education, and start-up capital. Fund offering financial incentives to implement sustainable/circular manufacturing.

In addition, several specific capital investments have been identified which help support the workshop outputs and will enable the region to capture and maximise market share in growth areas. These projects (Appendix AAE7) are at various stages of development.

The £37m **Airbus Wing Integration Facility** has been funded by the joint industry and government aerospace R&D funding programme. Scheduled to open in 2017, and located at Airbus' existing Filton site but with an “open door” policy where external organisations can make use of the equipment and laboratory space, it will be delivered as a partnership between the Department for Business, Innovation & Skills (BIS), the Aerospace Technology Institute and Innovate UK. The advanced testing centre for large structural components will enable Airbus and its partners to develop new and cutting edge ideas in wing design & manufacture, an area in which the region is world leading academically and in industry.

In the Marine sector, the **Marine Industries Production Campus (MIPC)** at the ex-MoD site at Davenport will see Princess Yachts expand their superyacht manufacturing facility to include a £35m investment in new production hangers and office accommodation. The

rest of the site will see phased development between April 2015 and April 2017. Successful delivery of this strategy has the potential to deliver 1800 jobs and £85m of investment.

The Bristol & Bath Science Park already hosts the NCC, The Centre for Modelling and Simulation (CFMS)⁹³ and HiETA Technologies (leaders in additive manufacturing for aerospace and automotive propulsion). Its central location, proximity to many of the major advanced engineering companies in the region and the GW4 Universities, coupled with its excellent transport links, make it an ideal focal point for further investments to realise, together with the Airbus Wing Integration Facility, MIPC and existing assets, many of the opportunities identified in this submission. Moreover, the West of England devolution deal includes additional investment for the Bristol & Bath Science Park with the concept of an **Advanced Engineering Campus (AEC)** supported by South Gloucestershire Council and Bath & North East Somerset Council. Serving as the regional hub *The AEC constituents will deliver world leading **High Value Engineering Design** and **Systems Integration** capabilities, **Composite Materials** technologies, as well as the teaching, CDTs and life-long learning to position the UK as a global leader as we transition into the Industry 4.0 revolution.*

Projects that would deliver this regional advanced engineering competitive advantage include the **High Value Design Institute**. *Initially focussing on the Aerospace sector and built on the Catapult model, the Institute will develop and demonstrate high value engineering skills as well as securing a “corporate memory” for UK aerospace.* The extended period between new aircraft development programmes, combined with retirement of experienced Engineers, is leading to a growing “capability gap”. The aerospace industry’s continued success depends on retaining excellence in design and competitiveness in the face of growing international competition. Supported by partners including Airbus, Rolls-Royce, Leonardo Helicopters, GKN, Dowty Propellers, together with West of England Aerospace Forum, regional universities and the National Composites Centre, the HVDI will collaborate closely with the existing and planned assets at the Bristol & Bath Science Park and will provide a collaborative workspace creating a magnet for Advanced Design Capability. It will bridge the key gap between academia and industry offering a safe environment to demonstrate new technologies – whole aircraft modelling; digital manufacturing; materials applications; propulsion / systems integration; sub-structure concepts. As a mechanism to assist in delivering iAero, the Institute would develop High Value Design capability outside the OEMs and would enable the supply chain to better understand the whole value chain and move up it by developing integrated solutions.

The learning from Aerospace challenges would be applicable across advanced engineering sectors where “system of systems” focus and integration challenges are paramount as well as being the prototype for a UK High Value Design network. Crucially, overseas investment in HVD capability is increasing in response to recognition of the need for action, threatening the competitiveness of the UK. Without immediate action, there is a real danger that vital HVD capabilities will be lost making it difficult, if not impossible, for the UK to bid for future high value opportunities. The HVDI seeks to address some of the fundamental challenges articulated in the AGP Means of Ascent, Industrial Strategy for UK

⁹³ The Centre for Modelling and Simulation - <http://cfms.org.uk/>

Aerospace 2016 which states that ‘HVD is essential to high value manufacturing’. Current indications are that a HVDI would be an effective means to co-ordinate a programme of capability development and demonstration. Such an environment would give the “next generation” (of Engineers and businesses) a chance to learn from experienced practitioners, but also allow them the opportunity to explore innovative ideas that can form the basis for future products and services relevant to evolving market demands. The UK must also proudly demonstrate its proven capability if it is to influence the investment and procurement decisions of international stakeholders.

The automotive propulsion **systems integration** expertise at the University of Bath’s Powertrain & Vehicle Research Centre (PVRC), the internal combustion engine system efficiency spoke of the Advanced Propulsion Centre UK, is sought after by UK and global automotive companies, e.g. CLEVeR project. The Centre boasts 40 years of collaborative industrial research excellence but has outgrown its current location. Costing £50m, **The Institute for Advanced Automotive Propulsion Systems (IAAPS)** will be a 10,000m² world-leading facility at the Bristol & Bath Science Park that delivers transformational R&D for low carbon propulsion systems development and integration, enabling UK industry to define the next and future generations of powertrain technologies while helping Government meet its environmental policy commitments. R&D facilities will emulate and exceed those housed in other research facilities in Europe (e.g. ICTM Aachen) and globally, allowing technology options to be researched, developed and brought to market more quickly and at lower cost; benefiting the entire propulsion systems market.

IAAPS is being backed by a cross section of AAE companies who have committed £67m additional R&D to 2025, including the majority of automotive and aerospace SMEs surveyed. The Advanced Propulsion Centre, Local Enterprise Partnerships, Local Authorities, Government Officials, The Department for Business Innovation & Skills, Innovate UK and the GW4 grouping of Universities (Bristol, Cardiff, Exeter & Bath) are also supporters. *IAAPS will generate over £800m additional turnover (NPV) & £221m GVA, respectively and create 1,900 new jobs while protecting 21,000 UK engineering jobs.* Through training increased numbers of PhD, MSc students and Apprentices, IAAPS will help meet the pressing skills need for higher level engineers and will enhance knowledge transfer to improve UK productivity.

The global composite materials market is large and growing rapidly. *The region is in a nationally unique position to take advantage of this growth, with the National Composites Centre, which houses unique facilities for high volume composites manufacturing for the automotive industry, world-leading academic strength in the University of Bristol’s ACCIS and a large concentration of companies involved in composite materials manufacture. However, there is no current UK capability to produce the constituent elements of Carbon Fibre based products. The NCC together with the Centre for Process Innovation (CPI), have therefore identified the strong potential for a **National Composites Materials Centre (NCMC)** to anchor a composite materials supply chain in the UK.* Operating on a Hub and Spoke arrangement and seeking to partner with excellence wherever it is located in the UK, NCMC aims to enhance the investment (via academia, HVM Catapult, industry) and drive the development of new fibres, resins, textiles, and the associated component high volume manufacturing process technologies.

As part of the proposed £115m investment near Avonmouth, Bristol, the NCMC would enhance the NCC's current offering and capabilities by expanding the NCC's influence on the complete value stream of composites systems design and manufacturing, including sustainability. Specific programmes of work would cover activities under its £2m Catapult REACH project engaging with SME's to launch projects such as National Product Verification Programme (NPVP), to improve data driven manufacturing in the regions SME population. This would ready them for High Value Design and Industry 4.0 with a regionally enhanced NATEP programme to assist the regions SME's investigation of new technologies; facilitated by the NCC acting as the gateway to the rest of the HVM Catapult network.

In the wider context of the Government's National Aerospace Strategy "Means of Ascent" to 2026, **Innovation Aero (iAero)** is intended to act as the "SW regional delivery mechanism" of the Aerospace Growth Partnership (AGP) strategy. Supported by OEMs and local LEPs, iAero addresses the future capabilities required to sustain and grow the region's AAE sector through collaborative investments, interventions and developments. Infrastructure enhancements necessary to realise the iAero ambition include the innovation centres in Yeovil and Filton, Bristol. Scheduled for May 2018, the 2,500m² "iAero Centre at Yeovil" facility in the Heart of the South West LEP will cost approximately £9.6m with investment sought from the ERDF, LEP Growth Deal 3 and business in the region. The iAero Innovation hub at Filton costing £16m and generating £8m GVA, will provide a 4,000m² facility within the Filton Enterprise Area.

A key challenge identified in the National Aerospace Strategy and the AGP and ATI Technology Strategy, is the validation of the performance before final assembly and full integration, i.e. at pre-production TRL4-6. Wing integration is at the core of the region's aerospace manufacturing and design capability, drawing together structures, propulsion and systems integration elements of aircraft design and delivered through an industrial base represented by Airbus, GKN, Rolls-Royce, Cobham, GE and Leonardo Helicopters. The formation of a South West **Aerospace Substructure Wing Integration Centre (ASWIC)** aligns directly with this strength national strategy. Flight test and validation are a certification requirement for aircraft development, however, the process is not only expensive, but also structural changes revealed by flight test late in development are difficult to implement. ASWIC will provide the technical capability to integrate, test and analyse (hardware-in-the-loop) for individual components or assembled sub-structures at a pre-production phase adopting techniques from the partner Universities and components from early stage design to test and validate static and dynamic flight performance before full wing integration, thus mitigating these risks.

Locating ASWIC on at the Bristol & Bath Science, adjacent to the NCC and CFMS develops the synergies at the Advanced Engineering Campus and links it directly with the HVM Catapult and the South West's aerospace industry which is key to knowledge exchange from academia. Furthermore, Initiatives such as the Testbed for Robust Integration of MAterials and STructures (TRI-MAST) and Aerospace Substructure Wing Integration Centre (ASWIC) underpin the work at the Airbus Wing Integration Facility and will, in collaboration with regulatory bodies, expedite the adoption of these new materials (e.g. composites) and manufacturing processes (e.g. ALM) across advanced engineering sectors.

To help address the identified challenges around skills & training, the South West Institute for Technology & Skills **SWIFTS** is a collaborative model for skills development and technological education that seeks to align with regional employment requirements, integrate existing activities and providers, such as the National Colleges for Advanced Manufacturing and build upon the opportunities offered by new developments (devolution of adult education budgets) and projects within the region. The model for SWIFTS is based on the Learning Factory model where a blended industrial and educational environment modernising the learning process by bringing it closer to the industrial practice and allowing training in realistic manufacturing environments. Partners include the regions Universities and Further Education Colleges, employers, regional business networks as well as the LEPs. SWIFTS will embed facilities/capacity within in the existing regional educational network. This will maximize the benefit from any capital/revenue investment by complementing existing investment and avoid duplication.

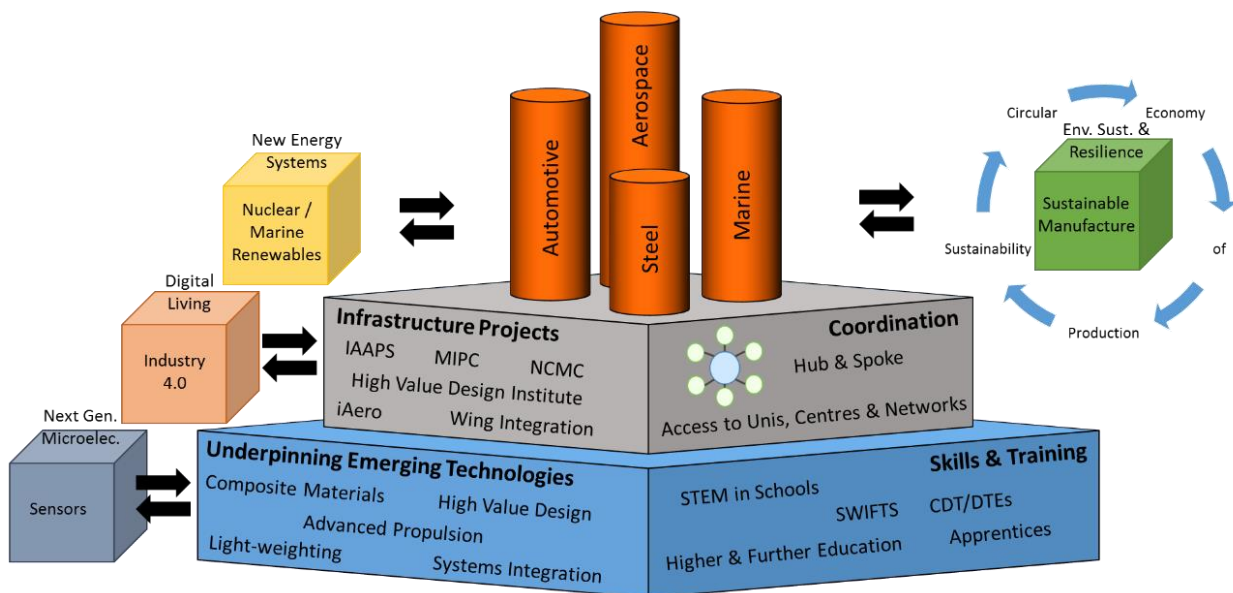


Figure AAE2 Development in the Aerospace & Advanced Engineering sectors (orange cylinders) is underpinned by emerging technologies and areas such as High Value Design, Systems Integration, Composite Materials, Advanced Propulsion and Light-weighting. These must be aligned with appropriate skills and training from school/college to University and beyond e.g SWIFTS (South West Institute for Technology & Skills). The sectors are further strengthened by research centres and infrastructure projects described in the text. Although, these require better coordination and ease of access. The AAE theme interacts with the other Science & Innovation Audit themes either through sector (Nuclear), an underpinning technology (Sensors) or more general process and engineering themes (Circular Economy, Industry 4.0).

The UK incumbent position is at risk from growing international competition and substantial changes in product and manufacturing technologies. However, AAE industry and academia in the South West of England and South East Wales already have a strong base in these markets and are well positioned to take advantage of future growth. The projects identified above and others yet to be conceived are critical to capitalise on the market opportunities outlined in Sections 6 & 7 and deliver the regional and UK growth agenda. Their coordination under an Advanced Engineering umbrella, encompassing the unifying

areas of High Value Engineering Design, Composites technologies and Systems Integration capabilities, will link the present and future assets at the Bristol and Bath Science Park (NCC, CFMS, IAAPS, NCAM) with the nearby Airbus Wing Integration Facility and iAero project at Filton, NCMC at Avonmouth and also The MIPC in Plymouth, iAero in Yeovil and Aerohub in Newquay.

Appendices

Appendix AAE1 List of Assets

Asset	Value	Host/Lead	Descriptor
Flybe Training Academy	24M	Exeter Airport	In September 2009 Flybe announced its successful bid for Training Academy project at Exeter Airport. £4.3m from Learning and Skills Council's (LSC) new Capital Specialisation Fund (CSF) £2.8m South West Regional Development Agency. The Flybe Training Academy offers a wide range of Pilot, Technical, Cabin Crew and Customer Service courses to airlines across the world, as well as a range of non-aviation training to other individuals and organisations in the South West
National Composites Centre (NCC)	55M	University of Bristol	Part of the High Value Manufacturing Catapult, the NCC is based at the Bristol & Bath Science Park. Opened in 2011, the NCC is a key part of the Government's composites strategy and brings together dynamic companies and enterprising academics to develop new technologies for the design and rapid manufacture of high-quality composite products. The founding members of the NCC were GKN Aerospace, Airbus, Leonardo Helicopters, Rolls-Royce, General Electric and QinetiQ. Current membership extends to 25 companies spanning the complete Advanced Engineering spectrum as well as a further 18 associate member firms
Aerohub	6.2M	Cornwall Airport Newquay	Aerohub is a designated enterprise zone that offers planning-free development and 100% business rate relief. The site has uncongested and unrestricted airspace, one of the UK's longest runways, direct maritime access and superfast broadband. Funded by £2.3m from the Homes and Communities Agency (HCA) and a grant from the ERDF Convergence programme (£3.9m), with Cornwall Council providing the land. Aerohub is home to AAE companies such as CIS UK Ltd and Apple Aviation as well as Bloodhound Supersonic Car which attempts the UK's latest land speed record. Aerohub / Cornwall Airport Newquay is well placed to

			be the UK's first spaceport. ⁹⁴
Morgan-Botti Lightning Laboratory	1.6M	Cardiff University	The lightning research facility was established in 2011 as a collaboration between the Welsh Government, Cardiff University and Airbus Group Innovations (formerly EADS). It undertakes research including measuring the direct-effects of lightning strikes on structures and samples and investigating lightning protection mechanisms for the aerospace industry
Centre for Additive Layer Manufacturing	2.6M	University of Exeter	Airbus Group Innovations partnered with Exeter University to develop the Centre for Additive Layer Manufacturing. Funded by European Regional Development Fund (ERDF) it has supported more than 200 companies and has created regional growth of £20m
Centre for Systems, Dynamics and Control		University of Exeter	Research in robust and fault tolerant control laws, validation and verification is undertaken
Cardiff Catalysis Institute	6.1M	Cardiff University	The Cardiff Catalysis Institute (CCI) was created in 2008 with an initial investment from Cardiff University of £2.8m. Its focus lies in the fields of photocatalysis and renewable fuel synthesis, including considerable expertise in the catalytic synthesis and decomposition of hydrogen peroxide, which has applications as a fuel for remote energy generation and in propulsion technologies and exhaust after-treatment. It was upgraded to Institute status in 2012 and granted a further investment from the University of £3.3m.
Centre for Power Transmission and Motion Control (PTMC)		University of Bath	The University of Bath's Centre for Power Transmission and Motion Control (PTMC) was founded as the Fluid Power Centre in 1968. The Centre's scope has grown beyond the original fluid power field, to include electromagnetic and piezoelectric systems and other technologies motivated particularly by challenges in automotive and aerospace engineering
Innovative Design and	10M	University of	The Innovative Design and Manufacturing Research Centre (IdMRC) was established in

⁹⁴ http://www.cioslep.com/assets/uploads/documents/1463644707_AH_spaceport_v3.pdf

Manufacturing Research Centre (idMRC)		Bath	2001 and received two major funding awards from EPSRC totalling more than £10m. The IdMRC undertakes world-leading research into the design and manufacture of machines, systems and processes. The Centre is unique in combining a design focus with a strong emphasis on manufacture in a closely integrated group.
Turbomachinery Research Centre		University of Bath	The Gas Turbine Research Unit has secured grants and funding from both the Engineering and Physical Sciences Research Council (EPSRC) and from multinational engineering conglomerate Siemens as well as local firm Cross Manufacturing
Materials & Structures Centre		University of Bath	The Materials and Structures (MAST) Centre is as a multidisciplinary centre that simultaneously develops and designs innovative materials with unique properties, whilst targeting the technological and manufacturing applications in which they will be employed, thereby revolutionising performance and production process.
Gas Turbine Research Centre (GTRC)	10M	Cardiff University	In 2004, Cardiff University took ownership from QinetiQ of their large-scale gas turbine combustion research facility. The GTRC was established with the support of a £3.85m grant from the European Union's Objective 1 Programme and £350k from the Welsh Assembly Government's Knowledge Exploitation Fund. With this funding the equipment was moved from Farnborough and re-instated in Port Talbot at the Welsh Assembly Government's Energy Research Building. The GTRC consists of two major combustion rigs each designed for detailed investigation of combustion and emissions in gas turbines. The rigs are designed for the study of different facets of the combustion process.
Advanced Composites Centre for Innovation and Science (ACCIS)	3.1M	University of Bristol	ACCIS brings together composites activities across the University of Bristol, based in the Faculty of Engineering and linking to the Science and Medical Faculties. Their vision is to be a world leading centre for composites research and education, combining cutting edge fundamental science with strong industrial links for exploitation and technology

			transfer. ACCIS is a focus for collaboration internally, nationally and internationally, with over 100 active researchers and doctoral students under the themes of Multifunctional composites and novel microstructures, design analysis & failure, intelligent structures, and composites processing & characterisation. ACCIS labs have state-of-the-art testing capabilities from single fibres to bridges
Rolls Royce Technology Research Centre (RR-UTC)		University of Bristol	The Composites University Technology Centre (UTC) at the University of Bristol is a research centre supported by Rolls-Royce plc to provide a validated analysis capability for the response of composites that can be used to design and manufacture composite components. It aims to act as a focus for composites research activities, liaising with other universities to provide a coordinated programme to meet the needs of Rolls-Royce. The Composites UTC was established in 2007 and in 2012 entered into a partnership with the Lightweight Structures UTC at TU Dresden to form the Rolls-Royce Composites University Technology Partnership (UTP).
Powertrain & Vehicle Research Centre (PVRC)	5M	University of Bath	The PVRC at the University of Bath encompasses 40 years of research excellence focused on improving the efficiency and emissions of both diesel and petrol engines. The PVRC currently has 17 active research projects, all of which are collaborative in nature, with a total value in excess of £40M. The growing research portfolio supports 60 researchers and over 200 students from undergraduate to PhD level. It partners with local companies, Ashwoods, HiETA Technologies, and Ford UK as well as nationally and internationally with firms such as Jaguar Land Rover, Lotus Engineering, BMW, Tata and McLaren Automotive.
Centre for Low Emission Vehicle Research (CLEVeR)	2M	University of Bath	The newly installed Dynamometer, commonly known as a rolling road aims to bridge the gap between the lab and the real world by allowing vehicles to be analysed in a series of real-world driving conditions, but within a precisely controlled laboratory

			environment.
Centre for Automotive Powertrain and Systems Engineering (CAPSE)	2M	University of South Wales	CAPSE is Wales' only independent research, development, test and certification house which undertakes cutting edge research and knowledge transfer activities within the advanced automotive and power systems engineering sectors, particularly relating to hybrid and electric vehicles. CAPSE has helped develop, supply and test all the batteries for the McLaren P1 sports car, homologated the Smart Electric Car, life tested and improved the 1000hp motor that won Le Mans and works with JLR, Tata, Johnson Matthey and Williams.
South Yard Plymouth		HM Naval Base, Devonport	The Royal Navy Dockyard consists of fourteen dry docks (docks numbered 1 to 15, but there is no 13 Dock),[2] four miles (6 km) of waterfront, twenty-five tidal berths, five basins and an area of 650 acres (2.6 km ²)
Boscombe Down			QinetiQ, whose airfield at Boscombe Down in south Wiltshire benefits from the 2 nd longest landing strip in the UK, is essential to sovereign capability having a long term partnering agreement under which it provides the UK MOD with innovative and realistic test and evaluation of military and civilian platforms, systems, weapons and components.
ACMC Advanced Composites Manufacturing Centre		University of Plymouth	Founded in 1987, ACMC is a leading composites R&D facility at the University of Plymouth. Based in the School of Marine Science and Engineering (SMSE), ACMC is active in a wide range of projects, and aims to bridge the traditional gap between academic R&D and the needs of industry
Electron Microscopy Centre	Recent upgrade 1.3M	University of Plymouth	EMC houses light microscopes, electron microscopes, imaging processing and analysis software providing support to a range of disciplines within Plymouth University, external research organisations and industry clients. Recent upgrades to capability funded by ERDF, JEOL (UK) Ltd and Plymouth University.
Wales Space Academic Partnership (WASP)		Welsh Government, Cardiff University and pan-	WASP is pan-Wales, and SE Wales has strengths represented by both major blue chip companies such as Airbus and specialised SMEs such as QMC Instruments Ltd. which designs, develops and

	Wales	<p>manufactures instrumentation.</p> <p>Cardiff University's School of Physics and Astronomy develops astronomical instrumentation, especially at millimetre and sub-millimetre wavelengths, supporting ground and space-based observatories and studies of the Cosmic Microwave Background. The School played a major role in the first recorded observation of gravitational waves early in 2016 and also led the team which built the camera for Europe's Herschel Space Observatory.</p>
Astrophysics Research and Electronics & Electrical Engineering	University of Bath	Focus on real-time, autonomous and robotic systems; the exploitation of ESA and NASA space-based data; and the exploitation of Global Navigation Satellite Systems (GNSS) and Earth Observation satellite data for specification of the space-weather conditions (ionosphere), for atmospheric measurements (dynamics) and for satellite-to-ground and ground-to-satellite communications.
Centre for Device Thermography and Reliability; and other related research centres	University of Bristol	<p>Development of new technologies (e.g. robotics, deployable structures, low-power electronics), but also fields that rely on satellite-derived data (e.g. navigation, earth observation and geosciences), as well as fundamental physics (e.g. astrophysics, planetary science).</p> <p>CDTR aims to understand and improve the reliability and thermal performance of semiconductor devices such as GaN and other power electronic devices used in satellites, switches and radars, and to develop new materials such as borides for neutron detectors.</p>
Satellite Applications Catapult Centre of Excellence	Goonhilly, Met Office Universities of Exeter, Falmouth, Plymouth and other partners	Detailed in the Resilience, Environment and Sustainability Theme, but with clear linkages to AAE (e.g. space) and Digital Living (e.g. satellite communications) themes

Appendix AAE2 Collaborative Projects

Project	Value (£)	Lead (Partners)	Descriptor
Advanced Combustion Turbocharge Inline Variable Valve-train Engine (ACTIVE)	26M	University of Bath (Uni of Bradford, Loughborough, Nottingham, Ford, Continental, Schaeffler, Unipart Eberspacher Exhaust Systems (UEES), BP, Cambustion, AP Raicam)	The ACTIVE project is supported by the Advanced Propulsion Centre (APC). Its objective is to further improve the already class - leading 1L EcoBoost car engine
Future Fast Aeroelastic Simulation Technologies (FFAST)	€3.7M	University of Bristol (Institut National de Recherche en Informatique et en Automatique, Council for Scientific and Industrial Research, Delft University of Technology, Deutsches Zentrum für Luft- und Raumfahrt, International Research Institute for Advanced Systems, The University of Liverpool, Politecnico di Milano, Numeca International, Optimad engineering, Airbus UK, EADS Deutschland. Military Air Systems DE, Institute for Information Transmission Problems)	The project aims to improve the speed and accuracy of unsteady load calculations which play an important role in the design and development of aircraft components
Agile Wing Integration (AWI)	16M	Airbus (Marshalls, AGI and The Universities of Bristol, Cranfield and Loughborough)	The project will develop rapid, world-beating, wing design and integration capabilities for use during the early phases of an aircraft product development cycle with the aim of cutting aircraft carbon emissions
Aeroelastic Gust Modelling (AEROGUST)	€4.3M	University of Bristol (Unis of Liverpool, Cape Town, Airbus Defence & Space, Dassault Aviation, DLR, INRIA, NLR, NUMECA, Optimad Engineering, Piaggio Aerospace, VALEOL	Funded by the European Union's Horizon 2020 Research and Innovation programme. The project seeks to drive the competitiveness of European Aviation through cost efficiency and innovation and has taken inspiration from FlightPath 2050 whose goals include

			maintaining and extending industrial leadership. Further transfer of technology to the wind turbine industry will increase the renewable energy sector.
Aircraft Loads Prediction using Enhanced Simulation (ALPES)	€1.3M	University of Bristol (LMS International, Airbus)	EC FP7 Marie Curie European Industrial Doctorate Training Network. The aim of the network is to improve the prediction accuracy and efficiency of the loads experienced by an aircraft in-flight and on the ground. The ALPES network involves five PhDs combining a novel research programme with industry focused training, including placements at Airbus in the UK and/or France
Centre for Innovative Manufacturing in Composites (CIMComp) and the Future Manufacturing Hub	5.2M	University of Nottingham (Unis of Bristol, Cranfield and Manchester)	Established in 2011, the EPSRC funded CIMComp underpins the development of next-generation composites manufacturing processes based on low cost, short cycle times, efficiency and sustainability. Current activities involve 32 industrial partners and four Technology Centres, with a portfolio of 25 interrelated projects and an Industrial Doctoral Centre, with a total portfolio value of over £16 million; forming a key link in the UK Composites infrastructure strategy
Modelling of Adaptive Wing Structures (MAWS)	€0.2M	University of Liverpool, (University of Bristol, Aircraft Research Association, and Stirling Dynamics)	Adaptive wing tip concepts have the potential to improve fuel efficiency towards achieving the

			Vision 2020 ACARE Agenda, represented by: 80% cut in NOx emissions, halving perceived aircraft noise, 50% cut in CO2 emissions per passenger km. The project, closely aligned with the Control and Alleviation of Loads in Advanced Regional Turbo Fan Configurations (CLAReT)
Experimental TRansonic Investigations On Laminar flow and Load Alleviation (ETRIOLLA)	€4.2M	IBK-Innovation, (University of Bristol, Revoind Industriale and Totalforsvarets Forskningsinstitut)	Wind-Tunnel-Model capable of assessing the extent of laminarity on the wing and evaluating the performance of load control and alleviation (LC&A) systems in the trailing edge of the wing, thus reducing development costs and associated energy usage for operation of wind tunnels
Experimental Subsonic Investigation of a Complete Aircraft Propulsion system Installation and Architecture power plant optimization (ESICAPIA)	€2.6M	IBK-Innovation, (University of Bristol, Revoind Industriale and RUAG Schweiz)	ESICAPIA focused on the experimental optimization of a regional aircraft configuration and a subsequent optimization of take-off/ landing configuration.
Gust Load Alleviation techniques assessment on wind tUnnel MOdel of advanced Regional aircraft (GLAMOUR)	€2.6M	Politecnico di Milano (TECHNION - Israel Institute of Technology, IBK-Innovation, University of Bristol and Revoind Industriale)	The aim of the project is a technological optimisation and experimental validation through an aero-servo-elastic innovative wind tunnel model of gust load alleviation control systems for advanced Green Regional Aircraft through increases in

weight saving.

High Performance Ductile Composite Technologies (HiPerDUCT)	6.4M	University of Bristol (Imperial College London, BAE Systems, DSTL Porton Down, Halliburton Energy Services, Hexcel Composites, Mouchel, Rolls-Royce, Vestas)	The aims of HiPerDuCT are to design, manufacture and evaluate a range of composite systems with a ductile or pseudo-ductile response, while maintaining the strength and stiffness for which composites are so highly prized
Language of Collaborative Manufacturing (LoCM)	1.9M	University of Bristol, University of Bath (Airbus Operations, CIMPA S.A.S., Delcam International, Dyson Appliance, FBM Babcock Marine, Jaguar Land Rover, National Centre for Text Mining NaCTeM, Ove Arup and Partners, Shapespace, Volvo	The vision of this research will be realised through a suite of ICT tools that embody new methods and approaches for capturing and analysing the content and evolution of engineering communication and digital objects, and new methods and approaches for generating, representing, interacting with, and interpreting what are defined as signatures of in communications and digital objects. The term signature is used to represent a meaningful relationship between one or more dimensions of communication and/or digital objects at a point in time or over a period of time.

Appendix AAE3 Research Excellence Framework (REF) 2014 data

The Aerospace & Advanced Engineering theme covers a broad range of academic disciplines from Supply Chain Management to Heavy Engineering. The research of academics associated with the theme was submitted to 10 REF units of Assessment (UoAs), as outlined in the table below:

UoA	Submitted staff associated with theme	No of Institutions	Doctoral awards 2008-16	UoA overall profile (% 3 or 4*)
8.	Chemistry	2	8	97%
9.	Physics	1	47	90%
10.	Mathematical Sciences	3	1	87%
11.	Computer Science and Informatics	2	61	72%
12.	Aeronautical, Mechanical, Chemical and Manufacturing Engineering	1	145	89%
13.	Electrical and Electronic Engineering, Metallurgy and Materials	1	11	91%
14.	Civil and Construction Engineering	1	-	97%
15.	General Engineering	4	509	89%
19.	Business and Management Studies	2	7	79%
25.	Education	1	8	85%

Appendix AAE4 Publication data

An analysis of data pertaining to academic publications related to the AAE theme was undertaken, based on the 250 academic staff identified by consortium institutions that are active in the field. The following three SciVal subject categories were used to profile and benchmark the South West Region's research publishing for the theme: Aerospace Engineering, Automotive Engineering, Ceramics & Composites. Publications (articles, reviews and conference proceedings) for the five year period 2011-15 are reported.

Publication metrics for the SIA Universities' combined publishing:

	Aerospace Engineering	Automotive Engineering	Ceramics & Composites
Scholarly Output (publications)	431	104	629
Authors	412	149	818
Field-Weighted Citation Impact	1.29	1.87	1.83
Citations	1,526	594	6,397
Citations per publication	3.5	5.7	10.2
Outputs in Top Percentiles % (publications in top 10% most cited worldwide for their year of publication and subject area)	17	21	24
Publications in Top Journal Percentiles (Publications in top 10% journals by SNIP)	40	37	48
Academic-Corporate Collaboration % (Publications with both academic and corporate affiliations)	8	19	6
Citations per publication for Academic-Corporate co-authored publications	3.4	6.8	9.6

Aerospace Engineering

	SIA Universities	World	UK	Russell Group
Scholarly Output	431	100689	4447	2342
Field-Weighted Citation Impact	1.29	0.9	1.57	1.83
Outputs in top 10% of subject area (%)	17	10	16	18
Publications in Top Journal Percentiles (%)	40	27	45	51
Academic-Corporate Collaboration (%)	8	2	6	6
Citations per publication for Academic-Corporate co- authored publications	3.4	3.2	3.9	4.2

Automotive Engineering

	SIA Universities	World	UK	Russell Group
Scholarly Output	104	46,051	2,253	1,041
Field-Weighted Citation Impact	1.87	1.16	1.57	1.85
Outputs in top 10% of subject area (%)	21	14	19	23
Publications in Top Journal Percentiles (%)	37	25	44	53
Academic-Corporate Collaboration (%)	19	4	8	10
Citations per publication for Academic-Corporate co- authored publications	6.8	3.8	3.6	4

Ceramics & Composites

	SIA Universities	World	UK	Russell Group
Scholarly Output	629	95,737	5,129	3,762
Field-Weighted Citation Impact	1.83	1.38	1.68	1.79
Outputs in top 10% of subject area (%)	24	16	20	22
Publications in Top Journal Percentiles (%)	48	30	36	38
Academic-Corporate Collaboration (%)	6	2	5	5
Citations per publication for Academic-Corporate co- authored publications	9.6	8	9.9	10.2

Aerospace Engineering

Aerospace Engineering publications from ...	Highly cited (top 10% most cited for year & subject area)	High impact journal (top 25% of journals by SNIP)	% Academic – industry co- authored papers	Average citations for academic- industry papers
University of Bath	21.4	84.3		
University of Bristol	23.1	80.8		
SIA South West Universities United Kingdom	20.9	78.5	8.5	5
Europe	20.4	75.8	6.1	4.8
World	17.4	73.3	3.9	5.7
	10.2	53.4	2.3	4.5

Automotive Engineering

Automotive Engineering publications from ...	Highly cited (top 10% most cited for year & subject area)	High impact journal (top 25% of journals by SNIP)	% Academic – industry co-authored papers	Average citations for academic-industry papers
University of Bristol	62.5	81.3		
SIA South West Universities	29.1	78.2	18.2	11.1
United Kingdom	20.7	76.4	7.1	4.8
Europe	16.1	61.9	5.5	7.1
World	12.3	52.2	3.9	6.1

Ceramics & Composites

Ceramics & composites publications from ...	Highly cited (top 10% most cited for year & subject area)	High impact journal (top 10% of journals by SNIP)	% Academic – industry co-authored papers	Average citations for academic-industry papers
Cardiff University	32.9	47.1		
University of Exeter	23.9	82.5		
SIA South West Universities	24.6	49.9	5.7	8.8
Russell Group	21.7	39.1	5.4	9.2
United Kingdom	20.3	37.9	5.2	9
Europe	15.9	37	2.9	7.5
World	16	33.5	2	7.5

Wing Aerodynamics

Publications group	# Publications	Highly cited (top 10% most cited for year & subject area)	High impact journal (top 25% of journals by SNIP)
University of Bath's publications in wing aerodynamics (SciVal competency)	30	30	90
All publications in wing aerodynamics (SciVal competency)	637	13.8	56.5

Laminates and composite materials

Publications group	# Publications	Highly cited (top 10% most cited for year & subject area)	High impact journal (top 25% of journals by SNIP)
University of Bristol's publications in laminates & composite materials (SciVal competency)	143	24.5	73.4
All publications in laminates & composite materials (SciVal competency)	1,351	12.6	53.2

Supply chains (publications group defined by keywords)

SIA South West universities' publishing on supply chain, 2011-15.

University	# Publications	Field-weighted citation impact
University of Bath	33	2.04
University of Bristol	23	1.48
Cardiff University	99	1.95
University of Exeter	26	5.07
University of Plymouth	22	1.96
University of the West of England	24	0.86

Top 10 universities worldwide most active in publishing on supply chain management

University	Country	# Publications	Field-weighted citation impact
Islamic Azad University	Iran	126	1.61
Hong Kong Polytechnic University	Hong Kong	115	5.04
Michigan State University	United States	63	2.95
Syddansk Universitet	Denmark	56	9.01
University of Arkansas	United States	50	2.12
Arizona State University	United States	48	2.59
Universiti Teknologi Malaysia	Malaysia	47	2.74
Cardiff University	UK	46	2.57
University of Tehran	Iran	43	2.28
The Ohio State University	United States	43	2.74

Number of publications each university has in the broad subject area 'Engineering' for the 5 year period 2011-15 and the number of engineering publications co-authored between each pair of universities over this 5 year period. For example: University of Bath has 1,642 engineering publications, 47 of which were co-authored with University of Bristol.

	Bath	Bristol	Cardiff	Exeter	Plymouth	UWE
Bath	1642	47	4	18	9	12
Bristol		3050	32	40	11	35
Cardiff			1708	7	10	4
Exeter				1068	13	1
Plymouth					687	3
UWE						577

Number of researchers each university has who have published in the broad subject area 'Engineering' in the 5 year period 2011-15 and the number of these authors involved in co-published engineering publications between each pair of universities. For example: 1,081 University of Bath affiliated authors have published engineering papers; 52 of these have been authors on papers co-authored with the University of Bristol, while 53 University of Bristol affiliated authors have been involved with papers co-authored with the University of Bath.

	Bath	Bristol	Cardiff	Exeter	Plymouth	UWE
Bath	1081	52	6	20	10	16
Bristol	53	2030	65	68	16	37
Cardiff	6	49	1229	10	7	4
Exeter	18	40	7	643	15	1
Plymouth	8	10	11	27	464	1
UWE	9	37	6	1	3	350

Corporate collaboration. Number of academic publications co-authored between South West region universities and major industry partners, 2011-15.

	Bath	Bristol	Cardiff	Exeter	Plymouth	UWE
ABB	1	1		1		
Airbus	7	32	7	5		4
BAE Systems	1	10		5		
Boeing	2					
BP	3	1	1	1		
Finmeccanica		1				
Ford	1	1				
GKN Aerospace	1					
Jaguar	16	10	2			
Lockheed Martin				1		
Lotus	4	1				
QinetiQ	3	12	6	4	2	2
Rolls Royce	8	38	5	1	1	1
Thales	1	12	1			

Appendix AAE5 Theme income data

Research Income for AAE based on funder type for period 2008 – 2015

HESA funder type	Total research income as related to theme £(k)							
	Code	2008/ 09	2009/ 10	2010/ 11	2011/ 12	2012/ 13	2013/ 14	2014 /15
Research Councils	1	9089	8012	8626	8281	9075	1022 6	1152 1
UK based charities (Open competitiveness)	2	61	102	157	143	194	255	133
UK based charities (Other)	3	53	99	130	152	138	188	287
UK central government & local authorities	4	3318	3575	3790	2983	9419	1053 5	1494 7
UK industry, commerce, public corporations	5	3458	3405	3895	5619	4447	4331	4633
EU Government Bodies	6	2282	2528	3374	4692	4803	5207	5150
EU-based charities (open competitive process)	7	0	2	0	0	3	0	0
EU industry, commerce and public corporations	8	191	610	535	653	358	525	351
EU other	9	0	11	11	19	26	17	75
Non-EU-based charities (open competitive process)	10	0	0	0	0	0	56	34
Non-EU industry, commerce and public corporations	11	862	414	175	661	444	215	93
Non-EU Other (Other overseas)	12	31	77	174	187	244	363	392
Other sources	13	34	78	26	4267	7202	4437	5291

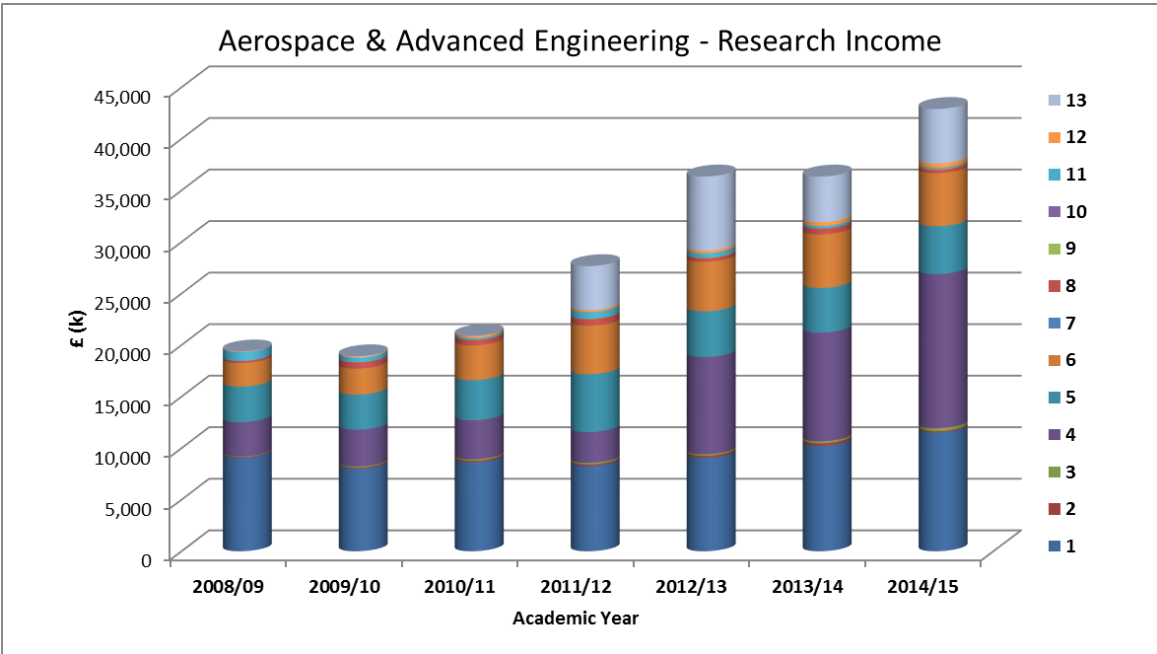


Figure AAE3 New Energy Research Income

Appendix AAE6 Major Clusters, Present and Planned Infrastructure

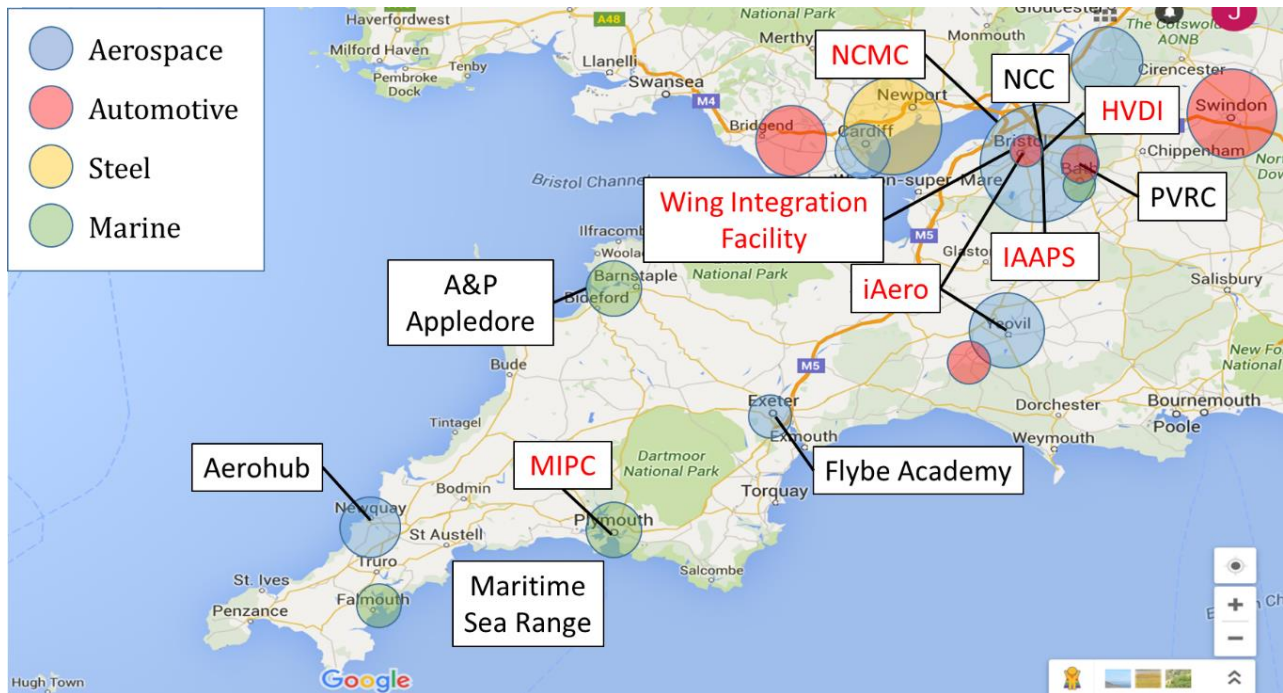


Figure AAE4 Major Clusters, Present and Planned Infrastructure

Aerospace – companies are located throughout the Audit area from Cornwall to Gloucestershire, with the region being home to 14 of the 15 largest aerospace companies in the world with a major cluster around Filton (near Bristol). The 2014 Top aerospace companies report from pwc⁹⁵ give the global top 15 as:

Company	Where?	Company	Where?	Company	Where?
1. Boeing	WoE	6. Raytheon	Glos.	11. Honeywell Int.	WoE
2. Airbus	WoE SE Wales	7. General Electric	Glos. SE Wales	12. BAE Systems	WoE
3. Lockheed Martin	C&IoS	8. Leonardo (was Finmeccanica)	HoSW C&IoS	13. L-3 Communications	Glos.
4. United Tech. Group		9. SAFRAN	Glos.	14. General Dynamics	S. Wales
5. Northrop Grumman	Glos.	10. Rolls Royce	WoE	15. Bombardier	HoSW

Automotive – industry is concentrated at locations along the M4, Swindon-South East Wales. The region is also a home to a spoke of the Advanced Propulsion Centre UK with the internal combustion engine system efficiency centre based at the University of Bath (PVRC). **Marine** – is concentrated in Plymouth and Falmouth (A&P is UK’s largest ship-repair complex) and North Devon, (Appledore). Marine defence organisations are also located further east in the region. The audit area’s strengths in AAE have grown up alongside the **steel** industry in South Wales, which has historically served as a source of raw materials for many of the region’s industries.

⁹⁵ <http://www.pwc.co.uk/industries/aerospace-defence/top-100-aerospace-companies-2014.html>

Appendix AAE7 Project Portfolios

The table shows current and proposed initiatives in AAE 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
Airbus Wing Integration Facility	Funded - BIS Aerospace Technology Institute & Innovate UK	The £37m Airbus Wing Integration Facility is scheduled to open in 2017, and located at Airbus' existing Filton site but with an "open door" policy where external organisations can make use of the equipment and laboratory space. The advanced testing centre for large structural components will enable Airbus and its partners to develop new and cutting edge ideas in wing design & manufacture, an area in which the region is world leading academically and in industry.
Marine Industries Production Campus (MIPC)	Funded - Plymouth and South West Peninsula City Deal	From April 2015, key areas of South Yard are being transferred from the Ministry of Defence to Plymouth City Council. The site will offer 25,000m ² of flexible employment space and deep water testing facilities suitable for the marine and advanced manufacturing sector. South Yard has recently been awarded Enterprise Zone status and will benefit from incentives such as reduced business rates, simplified planning rules and super-fast broadband.
iAero (South), Yeovil	Business Case - ERDF, LEP Growth Deal 3 & business	Scheduled for May 2018, the 2,500m ² "iAero Centre at Yeovil" facility in the Heart of the South West LEP will cost approximately £9.6m
iAero (North), Filton	Business Case -ERDF, LEP Growth Deal 3 & business	The iAero Innovation hub at Filton costing £16m and generating £8m GVA, will provide a 4,000m ² facility within the Filton Enterprise Area.
Institute for Advanced Automotive Propulsion Systems (IAAPS)	Full Business Case -BEIS, LEP Growth Deal 3 & business	Costing £50m, IAAPS will be a 10,000m ² world-leading facility at the Bristol & Bath Science Park that delivers transformational R&D for low carbon propulsion and will enable UK industry to define the next and future generations of powertrain technologies while helping Government meet its environmental policy commitments.
National Composites Material Centre	Outline Business Case -	The £115m NCMC will provide open-access facilities to industry to support innovation in the production of all of the constituents of composite materials. Operation

(NCCMC)	Treasury, BEIS	will be based on, and expand on, the current HVM Catapult model. The NCC would lead on R&D Hub and Spoke Programme Management, building relationships with OEMs and industrial sponsorships, skills and training, standards development.
Advanced Engineering Campus	Concept - West of England Single Investment Fund, Local Growth Fund	Bristol & Bath Science Park is close to many of the major advanced engineering companies in the region and the GW4 Universities. Coupled with its excellent transport links this makes it an ideal focal point for further investments to realise the West of England devolution ambitions in AAE. The devolution deal includes additional investment for the Bristol & Bath Science Park with the concept of an Advanced Engineering Campus and CDT in Industry 4.0 being supported by South Gloucestershire Council and Bath & North East Somerset Council.
Aerospace Substructure Wing Integration Centre (ASWIC)	Concept	ASWIC will provide the technical capability to integrate, test and analyse (hardware-in-the-loop) for individual components or assembled sub-structures at a pre-production as well as validating static and dynamic flight performance before full wing integration. Locating ASWIC on at the Bristol & Bath Science, adjacent to the NCC and CFMS develops the synergies at the Advanced Engineering Campus and links it directly with the HVM Catapult and the South West's aerospace industry which is key to knowledge exchange from academia into industry.
Aerohub / Spaceport	LEP Growth Deal 3	Aerohub / Cornwall Airport Newquay is well placed to be the UK's first spaceport. ⁹⁶ With one of the UK's longest runways, available development land, uncongested clear airspace and access to segregated airspace. The Aerohub Enterprise Zone also incorporates Goonhilly Earth Station, a major satellite communications hub and location for a proposed Space Science Centre.

⁹⁶ http://www.cioslep.com/assets/uploads/documents/1463644707_AH_spaceport_v3.pdf