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| <b>Institution:</b> University of Liverpool                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                     |                                                                                                                               |
| <b>Unit of Assessment:</b> 9 (Physics)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                     |                                                                                                                               |
| <b>Title of case study:</b> Liverpool particle physics research enables AIMES Grid Services Ltd. to generate economic impact, and improve NHS health service design, practice and operations                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                                                                                                                     |                                                                                                                               |
| <b>Period when the underpinning research was undertaken:</b> 2000 - 2008                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                     |                                                                                                                               |
| <b>Details of staff conducting the underpinning research from the submitting unit:</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                     |                                                                                                                               |
| <b>Name(s):</b><br>Prof Themis Bowcock<br>Prof Tara Shears<br>Prof Jon Goff<br>Dr Andy Washbrook<br>Dr Juan P. Palacios                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | <b>Role(s) (e.g. job title):</b><br>Professor<br>Professor<br>Professor<br>Research Associate<br>Research Assistant | <b>Period(s) employed by submitting HEI:</b><br>1991 - Present<br>2000 - Present<br>1999 - 2005<br>2001 - 2007<br>2000 - 2005 |
| <b>Period when the claimed impact occurred:</b> April 2014 - March 2020                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                                                                                                     |                                                                                                                               |
| <b>Is this case study continued from a case study submitted in 2014?</b> No                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                     |                                                                                                                               |
| <b>1. Summary of the impact</b><br><p>AIMES Grid Services Ltd. was founded in 2005 on the basis of Liverpool's particle physics research and the IP generated by Liverpool in the development of the MAP2 computer for CERN. Since 2014, AIMES has generated economic and healthcare impacts that include:</p> <ul style="list-style-type: none"> <li>Increasing the company's annual turnover by <b>96% to £4.5M</b> in 2019/20, <b>significantly exceeding the UK's national average</b> turnover for small companies, and <b>creating 21 new jobs</b>, representing a 70% increase in the company's headcount</li> <li>Contributing to the <b>improvement of health service design and commissioning</b> through its data centre and the deployment of Trustworthy Research Environments (TREs) in 2016</li> <li><b>Delivering improvements for NHS cost and resource efficiency</b> through the use of TREs</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                     |                                                                                                                               |
| <b>2. Underpinning research</b><br><b>2.1 Construction of MAP1 and MAP2 computers for CERN at the University of Liverpool</b><br><p>At the end of the 20<sup>th</sup> century, the computing infrastructure at CERN required to support its next generation of particle physics experiments represented a formidable challenge. In 2000, this challenge was partially addressed by the University of Liverpool through the construction of Europe's first commodity off-the-shelf computer – MAP1 in Liverpool's Department of Physics.</p> <p>MAP1's novel architecture incorporated high-density packing of computing hardware whilst enabling easy access and efficient cooling. MAP1 enabled the creation of a grid of low-cost computer centres with a huge compute cycle capability and was, in part, a catalyst for the £120M UK e-Science programme in late 2000.</p> <p>In 2003, as part of e-Science programme developments, Bowcock's research team at Liverpool was awarded a Science Research Investment Fund grant of £1.3M to further develop MAP1 into MAP2, which was commissioned in 2003. MAP2 comprised of 940 computation nodes, 100 terabytes disc space and had 30 times the computing power of MAP1. In November 2003, MAP2 was ranked as the 22<sup>nd</sup> most powerful academic computer in the world and the 86<sup>th</sup> most powerful computer worldwide.</p> <p>The benefits of MAP2 compared to MAP1, included:</p> <ul style="list-style-type: none"> <li>Improved (custom) Flow Control Software (FCS) enabling the integration of many thousands of PC's. Software included queue management and system maintenance.</li> <li>Use of a centralised telecommunications grade network switch (Force10) with over 100's of additional commodity switches compared to MAP1. This design and architecture was incorporated in the LHCb particle physics experiment at CERN.</li> </ul> <b>2.2 Application of Liverpool's MAP2 computer to research at CERN's LHCb experiment</b><br><p>MAP2's original scientific purpose was to design a revised Vertex Locator (VELO) detector for the LHCb experiment at CERN [3.1], as well as for processing in condensed matter physics</p> |                                                                                                                     |                                                                                                                               |

**[3.2].** MAP2 facilitated detailed optimisation studies into the VELO detector geometry layout and detector strip resolution, as well as investigations into optimum thickness of support structures. From 2010-2018, LHCb relied on the VELO modules for its primary tracking **[3.3]** (Bowcock, Shears, et al.). MAP2 was used to underpin other essential aspects of particle physics experiments such as providing the CPU requirements of full event simulation for the ATLAS and LHCb experiments at CERN **[3.3, 3.4, 3.5]**, including the trigger design of LHCb **[3.3, 3.4, 3.6]**.

### **2.3 Establishment of AIMES Centre to assist SMEs with computing technology adoption**

MAP2 demonstrated that - using its software and networking stack, and mechanical and cooling configuration - it was possible to create world-class computing facilities for private sector organisations. This level of computing technology had previously been out of reach for SMEs and many large companies. Time-to-solution for computing technology was a significant problem for UK industry in the early 2000s. This was recognised by the North West Development Agency (NWDA) and the European Commission as the technical justification for funding the formation of the **Advanced Internet Methods and Emergent Systems (AIMES)** Centre.

The AIMES Centre was established as a collaboration at Liverpool between the Department of Physics and the Management School, and secured funding of £7.8M (£2M from ERDF, £5.8M from NWDA) in 2003. Bowcock was the founding Technical Director of the Centre. The AIMES Centre focussed on assisting SMEs with the adoption of new computing technology and on creating business start-ups capable of exploiting new markets. Its objectives included the optimisation of supply chains within the automotive and aerospace sectors, as well as the optimisation of intensive care resources and delivery of care for Alder Hey Children's Hospital.

### **2.4 Formation of AIMES Grid Services Ltd and development of Trustworthy Research Environments for the healthcare sector**

In 2005, the AIMES Centre became a standalone commercial operation and was renamed AIMES Grid Services Ltd. In 2012, AIMES developed the *Health Cloud* – a dedicated virtual environment that enables NHS Trusts to use cloud computing technologies and manage sensitive data in a secure governed environment. In 2016, AIMES extended its Health Cloud capability to create digital infrastructures known as Trustworthy Research Environments (TREs) – secure platforms, where sensitive health data can be ingested.

The TRE provides a secure, computational powerful and stable platform to store, access and analyse confidential data. Importantly, it also meets common data standards, information governance and legal requirements for the storage and use of health data, which allows users to perform detailed data analysis using bespoke analytics tools. Without the TRE, data analysts will have no other choice but to download a snapshot of some data on their own local hard drives; this can be risky and insecure due to data confidentiality; data volumes can be large, change quickly and be out of date very soon after.

The development of the TRE infrastructure by AIMES builds upon the original research work undertaken by the University of Liverpool's Particle Physics group in three important areas:

- Research and technical expertise required to build cloud-based high-performance computing services. The first AIMES cluster was the MAP2 computer system at Liverpool and facilities were part-funded by AIMES Grid Services.
- Technical expertise required to deploy commercial applications on AIMES' facilities. Washbrook from Liverpool's Particle Physics group was employed by AIMES and utilised the MAP2 middleware for the deployment of commercial cloud services.
- Data science expertise required to analyse and compute large data sets. This collaboration continued with the input of Liverpool particle physicists who supported the development of hospital episode data analysis and geo-mapping against population changes.

### **3. References to the research**

**3.1** T. Bowcock et al., VELO Geometry Optimisation - An Update, LHCb 2001-071/VELO

**3.2** M. Roger, J.P. Goff, et al., *Patterning of Sodium Ions and the Control of Electrons in Sodium Cobaltate*, Nature 445 (7128):631-634 · February 2007 [DOI: 10.1038/nature05531](https://doi.org/10.1038/nature05531)

**3.3** The LHCb Collaboration et al 2008 *JINST* 3 S08005. [DOI:10.1088/1748-0221/3/08/S08005](https://doi.org/10.1088/1748-0221/3/08/S08005)

- 3.4 Shears, T & Anderson, J & Kechadi, Tahar & McNulty, R & Smoker, A & A. Barczyk, Ireland & Jost, B & Neufeld, N. (2004). *Simulations and prototyping of the LHCb and HLT Triggers*. DOI: [10.5170/CERN-2005-002.148](https://doi.org/10.5170/CERN-2005-002.148)**
- 3.5 R. Sturrock, D. Calvet, S. Albrand, J. Collot, J. Fulachier, A. Washbrook, et al. ATLAS data challenge 1. 2003, pp.56. in2p3-00020508. <http://hal.in2p3.fr/in2p3-00020508>**
- 3.6 J.P. Palacios. VELO vertexing and tracking algorithms of the LHCb trigger system LHCb Collaboration. 2006. 5 pp. Nucl.Instrum.Meth. A560 (2006) 84-88. DOI:[10.1016/j.nima.2005.11.239](https://doi.org/10.1016/j.nima.2005.11.239)**

#### 4. Details of the impact

Founded on the basis of and underpinned by Liverpool University's particle physics research and IP, AIMES has generated economic and healthcare impacts since 2014 that include:

- Increased the company's annual turnover by 96% to £4.5M in 2019/20, significantly exceeding the UK's national average turnover for small companies, and created 21 new jobs
- Contributed to the improvement of health service design and commissioning through its data centre and deployment of Trustworthy Research Environments (TREs) in 2016
- Delivered improvements for NHS cost and resource efficiency through the use of TREs

##### 4.1 Economic impact of AIMES – increased revenue generation and new job creation

Since its foundation based on and underpinned by Liverpool's particle physics research, AIMES has developed into an award-winning and industry-leading commercial data centre service provider based in the Liverpool City Region. Securing £1M Development Funding from Santander in May 2018 allowed AIMES to create a new 10,000 sq. ft. Health Informatics Centre at Kilby House Facility in Liverpool [5.1]. The new centre provides state-of-the art digital accommodation, specifically designed for advanced health informatics with connections to the Kilby House data centre and to the new Health and Social Care Network.

The annual turnover of AIMES increased by £2.2M (96%) to £4.5M in 2019/20 from £2.3M in 2014/15 [5.1], underlining the economic impact of AIMES which was founded on the basis of and underpinned by Liverpool's research. This is an average year-on-year growth of more than 14% [5.1], significantly exceeding the UK's national average turnover figures for small UK companies with 10-49 employees of £3M per annum, as outlined by the UK government's Department for Business, Energy & Industrial Strategy (BEIS) in 2019 [5.2]. Between 2014 and 2020, AIMES created 21 new jobs in the Liverpool City Region, bringing its current headcount up to a total of 30 staff employed [5.1]. This represents a significant increase of 70% from 2014 to 2020, and demonstrates the growth and viability of AIMES Grid Services' business.

##### 4.2 Healthcare impact of TREs – improved health service design and commissioning

In the healthcare sector, when dataflows cross organisational boundaries, including the NHS, social care, universities, police and industry, there is a need for a trustworthy infrastructure to link data while preserving the needs of the data owners, citizens, and researchers. AIMES Grid Services took on the task of addressing this challenge by using research expertise from the Department of Physics' MAP2 computer to develop the Trustworthy Research Environment (TRE) - a secure platform to analyse data and satisfy common data standards, information governance and legal requirements for the storage and use of data.

In 2016 AIMES Grid Services pioneered the TRE infrastructure in a number of project initiatives in collaboration with industry, the NHS and universities. AIMES' digital services have had significant impact on improving the design and commissioning of healthcare services in the North of England through the Connected Health Cities programme. Three examples of the impact of TREs on healthcare services (4.2a, 4.2b, 4.2c) are described below.

###### 4.2a The Connected Health Cities programme – “Healthcare Project of the Year”

AIMES Grid Services was awarded a contract to host the infrastructure for the Connected Health Cities programme to unite regional health data with advanced technology. AIMES used its cloud computing expertise to build two TREs: the North West Coast, and the North East and North

Cumbria TREs which enabled local adaptation to governance, data and research requirements [5.3]. The pan-northern Connected Health Cities programme was named “*Healthcare Project of the Year*” at the 2018 Bionow Awards [5.4], recognising Connected Health Cities’ innovative use of TRE technology and NHS data in creating and embedding learning health systems across 20 care pathway projects in the North of England. “*The key element in selecting the winner was that through bringing together a complex number of partners and organisations, the project has been able to harness and make use of clinical data. It is a project of magnitude and truly connects the North.*” - Technology Director at Trustech [5.4].

#### 4.2b Design and commissioning of healthcare services in the North of England

AIMES’ deployment of a TRE with the Connected Health Cities programme was pivotal in improving the design and commissioning of healthcare services in the North of England. The Great North Care Record created one shared care record for patients. Using the TRE infrastructure, the Great North Care Record now gives care records access to 100% of General Practices across the North East and North Cumbria, involving 400 practices, 25 NHS and Local Authorities, and 12 NHS Clinical Commissioning Groups, saving at least £8M per year [5.3].

By running newly developed algorithms on the TRE infrastructure, an extra 66% of epilepsy-related admissions were identified when compared to just using the primary diagnosis code, capturing more accurate average length of stay [5.3]. An application of these findings enabled paramedics to access epilepsy care records from secondary care to inform decisions about conveyance and immediate care [5.3]. “*By making additional information accessible for our ambulance clinicians, they will be able to make more informed decisions based on the patient’s medical history. This means that if the patient could benefit more from care in the community, unnecessary A&E admissions can be avoided which in turn will free up vital emergency resources.*” - Chief Consultant Paramedic, North West Ambulance Service NHS Trust [5.3].

#### 4.2c Detecting cases of Alcohol-Related Liver Disease

The North West region of England has one of the country’s highest rates of alcohol-specific deaths and Alcohol-Related Liver Disease is the dominant cause. Early inpatient intervention has the potential to save lives, however, reports show fewer than half of patients received ‘good care’ and mortality rates are high [5.5]. Using the TRE infrastructure through the Connected Health Cities programme, an extra 40% of cases of Alcohol-Related Liver Disease were detected when compared with standard approaches for capturing data on emergency admissions. The detection of extra cases of Alcohol-Related Liver Disease resulted in improved knowledge of disease burden and better monitoring of inpatient and post-discharge outcomes [5.3]. “*Our goal is to link, analyse and visualise data in ways that reflect the complexities of alcohol-related conditions and the wide variability in local service provision and organisation across the region – bringing local context to the interrogation of data*” - Consultant Gastroenterologist at Aintree University Hospital, North Mersey HIS and Connected Health Cities Clinical Lead for Alcohol [5.6].

### **4.3 Impact of TREs on NHS practice and operations – improved cost and resource efficiency for health services**

Current practice in large-scale, multi-centre clinical trials are often wasteful, resulting in significant costs and overheads. Trial protocols, staff records, training and governance information are typically maintained by participant sites in paper form which is not efficient practice within NHS operations. Poor recruitment for clinical trials can not only have financial ramifications, owing to increased time and resources being spent, but can also adversely influence the clinical impact of a study if it becomes underpowered [5.7].

In response to this problem, AIMES and the Liverpool Heart and Chest Hospital NHS Foundation Trust partnered to design and build a secure cloud-based platform, a TRE called “Streamline”, to manage research data capture and document workflows. The benefits of Streamline include: reduced administration costs to keep protocols up to date, increased visibility of the research data for adaptive trial designs, easier data collection for medical professionals, making clinical trials paper-free and guaranteeing failsafe access to current documents and

legacy versions, appropriate access from any web-enabled device, allowing remote-view and monitoring of research governance, for cost efficiency and assurance.

Streamline enabled a reduction of almost 50% in the time taken to recruit patients into cardiac clinical trial programmes at the Liverpool Heart and Chest Hospital NHS Foundation Trust. When first deployed, a three-year recruitment target was met within 18 months [5.1]. *“The online trial system is a sea-change in trial governance. It relieves individual trial staff of the burden of site file management and provides many useful tools to the system administrators”* - Research IT and Systems Lead at the Liverpool Heart and Chest Hospital NHS Foundation Trust [5.7].

Having worked together in the deployment and implementation of TREs, the partnership between AIMEs Grid Services and the Liverpool Heart and Chest Hospital NHS Foundation Trust was one of the three finalists for the “*Best Industry Partnership*” award at the North West Coast Research & Innovation Awards 2017 [5.8], recognising the significant impact of their partnership on cost and resource efficiencies in the provision of healthcare services for the NHS.

## 5. Sources to corroborate the impact

**5.1** Testimonial from the CEO of AIMEs Grid Services Ltd., evidencing the impact of Liverpool’s research on AIMEs Grid Services and the economic and healthcare benefits of AIMEs.

**5.2** Statistical release from the UK’s Department for Business, Energy & Industrial Strategy, “[Business population estimates for the UK and the regions 2019](#)”, Table A, page 4, evidencing the impact of AIMEs exceeding the UK national average turnover of small UK companies with 10-49 employees of £3M pa. [Accessed 11 December 2020].

**5.3** Impact Report (PDF) published by Northern Health Science Alliance, “*Impact Report on Connected Health Cities 2016-2020*”, evidencing the impact of AIMEs’ TRE infrastructure on healthcare services in the North of England.

**5.4** News story by Connected Health Cities, “[Connected Health Cities wins Healthcare Project of the Year award](#)”, published 3 December 2018, evidencing the pan-northern CHC programme being named Healthcare Project of the Year at the 2018 Bionow Awards. [Accessed 11 December 2020].

**5.5** Journal article. Kallis C, Dixon P, Silberberg B, et al. Reducing variation in hospital mortality for alcohol-related liver disease in North West England. *Aliment Pharmacol Ther.* 2020;52:182–195. <https://doi.org/10.1111/apt.15781>, evidencing the impact of alcohol-specific disease across the North West, the potential for early inpatient intervention to save lives, and the rates of ‘good care’ for patients and mortality. [Accessed 11 December 2020].

**5.6** News story by Connected Health Cities, “[Connected Health Cities puts alcohol treatment and support services on the map](#)”, published 5 December 2017, evidencing how Connected Health Cities is using data to help understand and improve services for alcohol misuse across the North West Coast. [Accessed 11 December 2020].

**5.7** Article on AIMEs website, “[AIMEs Health Cloud: Streamline](#)”, evidencing the challenges in the healthcare sector and the impact of AIMEs on the cost and resource efficiency in the provision of health services. [Accessed 11 December 2020].

**5.8** Finalist supplement for the [North West Coast Research and Innovation Awards 2017](#), held on 9 February 2017, evidencing AIMEs and the Liverpool Heart and Chest Hospital NHS Foundation Trust as one of the three finalists for their ‘Best Industry Partnership’ award. [Accessed 11 December 2020].