Institution: University of Southampton

Unit of Assessment: 11 Computer Science and Informatics

a. Context

The UoA 11 return from the University of Southampton is from the Electronics and Computer Science (ECS) Academic Unit. ECS is the leading unit of its kind in the UK, with an international reputation for world-leading research across computer science, electronics, and electrical engineering. Research takes place in a multidisciplinary, collaborative environment, with over 550 researchers from many different subject backgrounds, leading to significant innovation and impact. The outstanding quality of our research, together with the enormous global market in software and web-based services, has led to a broad range of high-value impact whose beneficiaries include ***commercial businesses***, ***policy makers*** and ***the general public***. Our impact achievements can be grouped into five types as follows:

(i) ***Five spin out companies*** have been created to exploit our Computer Science research (Aerogility, Arkivum, ePrints Services, Garlik and SEME4). In 2012, ECS founded the Open Data Institute, a catalyst for open data start-ups with £10M from UK Government.

(ii) ***Benefits to industry*** through improved engineering and operating processes in key sectors, including aerospace, security, defence, software services, energy management and healthcare.

(iii) ***Public policy and national bodies*** have been influenced through our collaboration with a range of agencies including UK National and Local Government, European Union, UK funding councils, UK Met Office, Ordnance Survey, National Archives and the Library of Congress.

(iv) ***Professional bodies and standards*** have been influenced through our involvement in international standards bodies (e.g. WC3) and influential learned societies (ACM, BCS, IET, RAEng and the Royal Society).

(v) ***Public engagement and education*** has been achieved through social media, web-based citizen advice, radio, TV news and documentaries, newspaper coverage, school and college networks, open days, industrial days and public science events.

Staff from four ECS research groups are returned via UoA 11: *Agents, Interaction and Complexity (AIC)*, *Communications, Signal Processing and Control (CSPC), Electronic and Software Systems (ESS)* and *Web and Internet Science (WAIS)*. AIC and WAIS research has had impact covering each of these types. CSPC and ESS impact primarily covers types (ii), (iv) and (v).

b. Approach to impact

Fully supported by the University, ECS adopts a pro-active approach to identifying and exploiting the commercial and non-commercial impact of its research and benefits from embedded support at all levels to enable staff to engage with impact activities. Our approach to impact is as follows:

1. Engagement with Key Beneficiaries and Audiences

(i) Dissemination: Open dissemination of research findings to potential end-users helps to raise awareness leading to mutual benefit. To this end, we have long been committed to the concept of open access; our ***ePrints*** publications repository has over 15,000 publications (November 2013).

(ii) Alumni Links: Leveraging impact from alumni who are in key positions in industry is an important part of our strategy. To grow such links, ECS holds an annual alumni reception; the most recent was held at the IET in London in May 2013, with ~300 alumni from across the globe. There is a LinkedIn group for ECS alumni with over 1000 active members and growing (November 2013).

(iii) Public Engagement (PE): We pursue a policy of interacting with the public and key stakeholders to influence public attitudes to science and engineering. A highlight of our PE was Tim Berners-Lee's participation in the opening ceremony of the London 2012 Olympic Games. Nigel Shadbolt was series consultant to the 2010 BBC Virtual Revolution TV series and has given talks on open data at significant government events including the White House Smart Disclosure Summit, 2012, the EU Ministerial Conference, Posnan, 2012 and the 2012 EU Health Data Futures Summit. Wendy Hall spoke on Web Science at the 2011 Davos World Economic Forum. Berners-Lee has given public lectures on linked data at major public events such as TED (2009) and Campus Party Brazil (2009). Other examples of our PE activities during the REF period include Hall as guest Director of Cheltenham Science Festival (2013), lectures at science fairs by Shadbolt (Cheltenham, 2009) and Hall (Winchester, 2013). Alex Rogers and others have demonstrated ECS multi-agent research at the Big Bang Science Fair (2012), Farnborough Air Show (2012), Big Bang Solent (2013) and the ORCHID Industry Day (Farnborough, 2013). Gopal Ramchurn participated in the 2013 "*I'm a Scientist, Get Me Out of Here*" national public engagement competition, covering AI and agent technology.

2. Developing and Maintaining Relationships

(i) Business Relationships: Our full-time Partnership Manager, Joyce Lewis, coordinates ECS business relationships. A key mechanism for relationship building is our Careers Hub and annual Careers Fair which involves over 300 companies. While graduate employment acts as an opening attraction for these companies, as the relationship develops, many also seek collaboration with ECS researchers. The ECS Industrial Advisory Board (IAB) includes senior representatives of technology-focused companies (e.g. Alstom, ARM, Captec, BAE, DSTL, IBM, Selex ES, Synopsys, Meggitt and Chemring). These representatives are mainly senior R&D leaders and, through our annual IAB workshop, they contribute directly to our research strategy helping us identify trends and opportunities. Members of the IABs of our two Doctoral Training Centres (Web Science and Complexity Science) contribute directly to research through funding and mentoring of PhDs.

(ii) Public Bodies: Leading ECS researchers hold key UK Government policy roles. Berners-Lee and Shadbolt were appointed by the Coalition Government to the Public Sector Transparency Board, responsible for setting open data standards across the public sector and developing the legal Right to Data. As well as securing significant changes in Government policy, they oversaw the design and implementation of data.gov.uk which hosts over 2500 public datasets. Nick Jennings is a Chief Scientific Advisor (CSA) to the UK Government with the national security portfolio and is an active member of Sir Mark Walport's network of CSAs. Hall was a member of the UK Prime Minister's Council for Science and Technology until 2008 and is currently a member of the Board of DSTL. Kieron O'Hara chairs the Transparency Sector Panel for Crime and Criminal Justice, an expert panel that advises the Home Office and Ministry of Justice about open data releases. O'Hara's recommendations on collating best practice on anonymising data has been pursued by the Information Commissioner's Office leading to www.ukanon.net. Work with Hampshire County Council by Ramchurn on multi-agent disaster simulation led to changes in emergency evacuation procedures on the road network in Hampshire.

(iii) User Communities: Luc Moreau plays a key role in WC3 standardisation as co-chair of the W3C Provenance Working Group. ECS supports the impact provided by open source software projects by providing dedicated hosting services to support user communities; we host the ePrints open repository system led by Les Carr (www.eprints.org, adopted by over 500 institutions worldwide) and the open source Rodin/Event-B formal methods toolset led by Michael Butler (www.event-b.org, over 13,000 downloads). The Web Science Trust, hosted at Southampton, promotes the global development of Web Science enabling researchers to share research data collected about the Web and its evolution. The LexDis service (lexdis.org.uk), which assists educators in enhancing the attainment of disabled students, receives over 500 visits/month and won the 2009 IMS Global Learning Impact Leadership Award. The ESS group have provided training on Event-B to over 40 industrial engineers from systems companies such as AWE, Thales and General Motors. The AIC group have provided training on agent-based techniques to over 45 engineers from Chemring, BAE, MBDA, Rolls-Royce and Selex ES.

3. Exploitation of Research Outcomes

(i) Commercial Contracts*:* During the REF period, we held industrially-funded contracts worth a total of nearly £4.6M that exploited ECS Computer Science research. These were with major companies such as AWE, BAE, Secure Meters UK, IBM, Microsoft, BT, General Dynamics, Sharp, Thales, QinetiQ, Hitachi, National Grid, Xerox, ABB, ST Micro. For example, AWE contracted Butler's team to adapt the Rodin toolset to enhance their in-house process for embedded system design with verification capability and AWE engineers are now deploying the adapted toolset. BAE contracted Jennings' team to apply agent technology to improving autonomous vehicle mission planning, supply chain logistics, military logistics and autonomous power management.

(ii) ECS Partners Ltd, led by a full-time Business Development Manager, John Darlington, provides consultancy services to industry with the objective of exploiting the value of our expertise through short, focussed work. Since its inception in 2004, it has worked with a wide range of organisations, from the small enterprise, to FTSE 100 and global companies, to apply our expertise to solving industrial problems. Examples of industrial consultancy include contracts with ARM, AWE, BAE, BBC, General Motors, Orange and Thales. Revenue at ECS Partners has grown from £462k in 2008 to ~£2M in 2013. Short consultancy contracts have led to larger on-going relationships (ARM, AWE, BAE).

(iii) Startups: As well as providing consultancy to industry, ECS Partners acts as a vehicle for incubating start-up activity. For example, the Garlik semantic web startup arose out of ECS

Partners consultancy and was incubated by offering temporary employment to key research staff until start-up funding came through. Garlik had 500,000 users, 18 employees and turnover of £2.3 million when acquired by Experian in 2011. ePrints Services, another spinoff that evolved from ECS Partners consultancy, is now a business unit employing 7 staff providing hosting services, training and consultancy around the ePrints open access repository software from ECS. Other commercial start-ups based on our Computer Science research include Aroxo (agent negotiation for comparison websites), Aerogility (agent negotiation for project management, 20 employees), Arkivum (assured archiving, 10 employees, VC funding of £2.3m) and SEME4 (4 employees).

(iv) Embedded Enterprise Fellow: ECS appointed Reuben Wilcock to the role of Senior Enterprise Fellow with a remit to maximise the commercial impact of ECS research by taking research demonstrators through to commercial products. For example, the MyJoulo domestic heating monitor, based on AIC energy management research, was developed into a commercial product by Wilcock, winning first place in the 2013 British Gas Connecting Homes competition leading to trials and the potential for deployment in the homes of millions of British Gas customers.

(v) IT Innovation, part of ECS and based at the University Science Park, is an international leader in applied research and innovation leading to the deployment of information-based technologies in industry, commerce and the public sector. It has taken part in 42 major projects in collaboration with business in the last five years and has worked with over 100 companies as project partners and clients. A notable success was technology for decision support in crises such as environmental disasters, which was recognised by receipt of an IRM Global Risk Award in 2013. Technology developed by IT Innovation for broadcasters, including BBC and RAI, was commercialised by our spin-off company, Arkivum Ltd, to provide assured archiving services.

4. Support and Reward

(i) Supporting Impact: Staff are supported in their efforts to shape public policy, contribute to standards bodies and build communities through travel funding and administrative support and through hosting of dedicated web sites. ECS Partners and the ECS Partnership Manager assist in managing contacts with industry. On top of these, the University **Research and Innovation Services (RIS),** with over 60 staff**,** provides comprehensive contract support, IP management and negotiation expertise to facilitate collaboration with our business partners and support incubation of new businesses. In addition, three RIS staff provide dedicated support to ECS. RIS provides access to local and national venture initiatives for new business development such as the SET Squared incubator on the Southampton Science Park.

(ii) Reward: ECS recognises the value of the University's Enterprise job family and rewards enterprise activity in promotion. For example, in 2011 Wilcock was promoted to Senior Enterprise Fellow for his enterprise work. Consultancy activities through ECS Partners provide a means for staff to be rewarded financially for deploying their expertise in industrial work.

c. Strategy and plans

We will ensure the sustainability of our impact success through systematic sharing of best practice and will grow the breadth and reach of our impact by embedding impact more deeply in our research activities. In addition to continuing with all of the impact mechanisms outlined in Section b), we will implement the following 10 strategic impact initiatives:

1) Create Commercialisation Fund: To encourage commercialisation activity covering a broader range of ECS research we will set up an annual fund to which ECS researchers will bid to support commercialisation of research results that are close to exploitation. We expect to support the 3 or 4 strongest activities per year through this mechanism.

2) Grow Embedded Enterprise: Our Enterprise Fellow has proved highly successful at converting research prototypes into commercial products. We will expand the enterprise activity to a team of 5 people, embedded within ECS, who will collaborate actively with researchers to turn results into products and services. In particular we will exploit the distinctive position of ECS as a joint unit to develop innovative products combining electronics and software.

3) Annual Impact Workshop: As part of our preparations for REF 2014, we received valuable feedback and advice from IAB members on our impact case studies. We will regularise this through an Annual Impact Workshop bringing together researchers and industrial partners with the aim of identifying new impact routes and developing exploitation strategies for on-going research.

4) Sustaining Policy Influence: Key ECS academics already play leading roles in shaping public policy (e.g. Berners-Lee, Hall, Jennings, Shadbolt). These leaders will mentor other ECS academics in developing similar national and international policy-shaping roles.

5) Strategic industrial Relationships: Our research has led to commercial contracts with leading UK businesses such as ARM, AWE, BAE, DSTL, Imagination and Secure Meters. We are developing strategic relationships with a handful of key businesses whereby we provide a single port of call for their R&D requirements across ECS research areas.
6) Exploit University Strategic Initiatives: The University has made major strategic investments in key areas including the Institute for Life Science (IFLS), the Southampton Marine and Maritime Institute (SMMI – a £120M investment in partnership with Lloyds Register). Our participation in these is providing opportunities for impact on other sciences as well as broader commercial and non-commercial impact, e.g. research in AIC will enable new discoveries in the life sciences through the IFLS. ECS will lead on the development of a new Aerospace Institute that will provide novel opportunities for our Computer Science and Electronics research (e.g. multi-agent systems and software engineering to enable new generations of dependable autonomous systems).
7) Relationship to Research Strategy: In making strategic decisions about our portfolio of research activities, we will be influenced by the impact potential of existing and new research areas. We have already identified Cyber-security and Big Data are areas for growth through appointment of new academic staff and these are areas with strong impact potential.
8) Appoint an Impact Manager: To ensure that we are making the most of the impact potential of our research and are using our resources effectively, we will appoint an Impact Manager whose role will be to coordinate impact identification and delivery mechanisms across ECS and to monitor and evaluate the resulting impact.
9) Comprehensive Public Engagement Programme: Our new Impact Manager will coordinate the planning and delivery of a comprehensive range of public engagement activities including web resources, school visits and participation in science fairs and similar public events. We see MOOCs (massive open online course**)** as an effective means of reaching a large audience so we will expand our MOOC offering (we already operate a MOOC in Web Science).
10) Reward and Recognition: Impact will be given greater prominence in staff promotion through encouragement of impact-led promotion cases as well as greater use of impact in support of research-led cases.

d. Relationship to case studies

We look at the role played by the impact approach outlined above in our impact case studies (ICS).
Commercial consultancy: Several of the ICS include elements of industrial consultancy through ECS Partners. The *Applications of Agent Technology* ICS includes industrial training consultancy for companies such as BAE. In the early stages of the *Open Data* ICS, consultancy was provided to the Department for Transport on linked data journey planning. Consultancy for the Department for Energy and Climate Change supported market testing of the MyJoulo system for consumer-based energy monitoring in the *Intelligent Energy Management* ICS.
Commercial research contracts: The *Applications of Agent Technology* ICS includes over £1M in funding from BAE on autonomous systems. The *Intelligent Energy Management* ICS includes a £1.6M commercial contract with Secure Meters. These followed standard University contracts and set-up was supported by RIS.
Start-ups: Our ICS exemplify several cases of incubation of commercial start-up activity. The *Applications of Agent Technology* ICS includes two start-ups (Aerogility and Aroxo); the *Web Science* ICS includes two (Garlik and Seme4); and the *Open Repositories and Digital Archiving* ICS also includes two (Arkivum and EPrints Services). These start-ups were incubated through the University structures already described: ECS Partners, IT Innovations and RIS. The Open Data Initiative in the *Open Data* ICS is supporting the creation of new businesses in open linked data.
Impact on policy: The *Open Data* ICS includes the major role played by Berners-Lee and Shadbolt in shaping UK Government policy on open data. The *Web Science* ICS includes the role played by Berners-Lee, Hall and Shadbolt in creating and shaping Web Science crossing multiple disciplines. It also includes the role played by Moreau in defining WC3 standards for Provenance. Ramchurn worked with Hampshire County Council by on disaster simulation (*Applications of Agent Technology* ICS). In all cases ECS allowed the staff the time to engage in these important activities and provide the necessary administrative support. ECS also supports the impact of the Web Science work by hosting the Web Science Trust.
Public engagement: The ICS include examples of staff being supported to present research agendas and results. These include *Web Science* (Cheltenham and Winchester Science Festivals) and *Applications of Agent Technology* (Big Bang Science Fair and the Farnborough Air Show).