Institution: University of Warwick

Unit of Assessment: UOA 11 – Computer Science and Informatics

a. Context

The main non-academic users of the Department's research are: SMEs, global corporations, public- and private-sector research laboratories, health trusts and government departments. Economic, intellectual, technical and social impact is achieved at regional, national and international level in areas ranging from crime, national security and defence to medicine, culture, education and healthcare. This is made possible through established partnerships with beneficiaries, collaborative research with industry, staff secondments and consultancy, leading to the development and licensing of new products, a strong patent portfolio, the creation of spin-out companies, and impact on government policy.

b. Approach to impact

Annual research income from industry, central and local government, and charities has risen year on year over the assessment period; it has increased by over 600% compared with the previous period, and now represents 22% of the Department's total research funding. The Department hosts numerous industry-funded PhDs, sponsored by companies including GE Healthcare, Google, HMGCC, Jaguar Land Rover, IBM and Intel. The Department creates an average of one new start-up every three years, many of which are now leaders in their field and have a worldwide customer base: Allinea Software Ltd (founded 2009) was recently recognised as one of the world's 100 fastest growing private companies (see Case Study 3). Software products created as a result of the Department's research have had worldwide impact: Microsoft's System Centre Capacity Planner (see Case Study 2) was the most widely used product of its type between 2006 and 2010. Academics have filed 31 patent applications during the assessment period, and have engaged in outreach involving thousands of individuals.

1. Partnerships and strategies for engaging with key users

The Department comprises three research divisions, each engaged in a mix of basic, strategic and applied research with SMEs, large companies and research laboratories in both the public and private sectors. Oversight of the Department's impact and external engagement strategy is provided by its Industry Advisory Board (which includes members from Capgemini, Citrix, Detica, HP, IBM, Microsoft, Morgan Stanley) and by academics assigned to industry liaison (*Sanchez*, *Sviridenko*). The strategies in place for establishing and nurturing these partnerships include:

- **Delivering research focused on long-term stakeholder challenges**, for example through the £3.8M EPSRC Centre for Discrete Mathematics and its Applications (*Czumaj*), whose industry partners include AT&T Labs, Google Research, IBM Research, Microsoft Research.
- **Sustaining long-term research partnerships** with several organisations, e.g. UK Atomic Weapons Establishment, 2008-2016 (*Jarvis*) and Forensic Pathways, 2008-2015 (*Li*).
- **Engaging in multi-partner pan-European collaborative R&D with industry** including DIVeFor (*Li*) and MALog (*Joy*) with companies including ALTEC, CyberWatcher, Mokono.
- **Engaging in R&D to ascertain technology readiness**, e.g. the TSB-funded Digital Millanber project (*Li*), with industry partners including Pearson Education and Intellego Group; the TSB-funded development of OPV-based wireless sensors (*Jarvis*), with Molecular Solar Ltd.
- **Pursuing industry CASE awards**, by pairing DTAs with organisations including AHDB, AWE, GE Healthcare, Google, IBM, Ingres, Intel, HMGCC, JLR.
- **Leveraging competitively won fellowships to industry** for maximum impact, seconding staff e.g. to Rolls-Royce (*Jarvis*, Royal Society Industry Fellowship), Forensic Pathways (*Li*, Marie Curie Fellowship) and EMBL-EBI (*Liakata*, Leverhulme Trust Early Career Fellowship).
- **Hosting visiting research fellows from industry**, including from AWE, HP, IBM, LBNL, TCS.
- **Engaging in consultancy** with organisations including Airparks Ltd, AT&T Labs, Deutsche Bank, GCHQ, NatCen, Police Improvement Agency, IBM, Rolls-Royce, The Guardian.

2. Department and University support for achieving impact

To enable these strategies to bear fruit, the Department has also:

(i) promoted staff training, particularly for ECRs, in areas including research project management, knowledge transfer, intellectual property management and patent writing;
(ii) developed a research funding incentive scheme to allow academics time to nurture and fully exploit research partnerships with key external users;
(iii) enabled academics to take research sabbaticals with industry partners;
(iv) recruited new academic staff from industry, including *Ciucu* (Deutsche Telekom), *Cormode*

(AT&T Research) and *Sviridenko* (IBM Watson), to lead new applied research programmes.

In order to achieve impact from its research, and gain support with the development and licensing of new products and services and the formation of spin-out companies, the Department has actively engaged the following University central support mechanisms:

- the Business Engagement Unit and Corporate Relations;
- Research Support Services (contract research, IP, knowledge transfer) and KTP Office;
- Warwick Ventures Ltd (business and investor access to University IP);
- the University of Warwick Science Park (adjacent to the University, and providing support for start-up businesses, e.g. Warwick Warp Ltd).

2. Evidence of follow-through from these activities

The strategies and support outlined above have enabled the Department to:

Boost economic growth in the region: Thanks to the Department's agile approach to opportunities, and its effective use of institutional support, it has created an average of one new start-up every three years. Many are now world leaders: (i) Allinea Software Ltd (founded 2009) was recently recognised as one of the world's 100 fastest growing private companies; (ii) Warwick Warp Ltd (founded 2005, see Case Study 1) has developed fast, accurate fingerprint recognition systems, which process 50,000 fingerprint transactions per day to UK building sites (2013), and are about to be deployed in UNHCR refugee camps in Syria.

Develop new standards: Examples include (i) defining the Portable Content Framework through consultancy with the BBC (2006-2009), which remains the established international standard for interactive-TV broadcasting (*Beynon*), and (ii) ongoing work with the BSI technical committee IST/37 on coding of picture, audio, multimedia and hypermedia (*Martin*), used by the BBC, BT, QinetiQ, Sony Europe, British Sky Broadcasting, and others.

Generate IP for new products: Examples include (i) the Forensic Image Analyser (developed by *Li* during his industry fellowship and sold by Forensic Pathways Ltd), used by INTERPOL to add image and video retrieval functionality to its international child sexual exploitation image database (2013) and by police forces in the UK, Japan, France and Australia (2012-2013), and (ii) Volocity, a flagship medical imaging product (developed through several CASE awards with Improvision, later acquired by PerkinElmer), which is recognised as the universal solution for 3-D analysis of fluorescence microscopy images and is used by medical laboratories worldwide.

Underpin scientific processes for national security and defence: This includes improving the efficiency of scientific delivery at the UK Atomic Weapons Establishment and the US National Nuclear Security Administration, through a significant impact on high-performance-computing procurement and processes (2007-2013), which underwrite the safety and performance of the UK's nuclear deterrent (*Jarvis*, long-term research partnership with AWE).

Impact on social policy, including education and health: Examples include (i) leading work commissioned by the NHS on the impact of IT on patient care, which has contributed to healthcare policy in the UK, Australia, Belgium, UAE and Saudi Arabia (*Procter*), and (ii) research into learning management systems (*Joy,* the EU-funded MALog project), which has impacted on the delivery of education in sub-Saharan Africa and South America.

The above examples each show significant economic, intellectual, technical and/or social impact, with international reach extending across areas ranging from combating crime to biometric security and defence, and from medicine to culture, education and healthcare.

4. Outreach and public engagement

Computer Science is one of Warwick's flagship Departments for outreach, and leads on many UK computing outreach initiatives. Activities are research-based and often underpinned by specific research outcomes (e.g. *Paterson*'s solution to the long-standing overhang problem, 2009).

Computer Science at Warwick hosted the **National Academy for Gifted and Talented Youth** between 2002 and 2007 (superseded by the **International Gateway for Gifted Youth**, 2008-) and in this capacity has made a valuable contribution to computer science education for high-achieving secondary school students in England. The Department also contributes to national Computing At Schools (CAS) initiatives, including: developing a Google/BCS/CAS-sponsored **Computing for Teachers MOOC** to enhance delivery of the new KS3 and KS4 computing curriculum (with over 100 participating schools); hosting the **2013 International Lego® Engineering Conference**, promoting engagement with science, technology and engineering; delivering an annual

Computing Your Future event, attended by hundreds of Sixth Form students every year. To support this activity the Department recruited a full-time Outreach Fellow (*Rocks*) in 2012.

Many research projects have their own outreach activities: *Wilson*, *Martin* and *Bhalerao*'s fingerprint recognition systems were showcased at the London Science Museum in 2010, demonstrating the use of biometric technology in the battle against fraud; *Procter*'s application of innovative computational methods and tools to the analysis of social media data from the 2012 London riots, featured in The Guardian, The Independent, the BBC and others, was presented to the Shadow and Home Secretaries and won the 2012 Award for Data Journalism. *Liakata*'s pioneering research on automating the cycle of scientific experimentation received worldwide publicity and was identified as one of the top 10 scientific discoveries of 2009 by TIME magazine.

c. Strategy and plans

Developing and maintaining *impactful research* is at the heart of the Department's strategic research objectives: 1. To engage in inter-/multi-disciplinary research to improve quality of life, health, national security, education and social cohesion; 2. To develop new computing science techniques and seek methods of application and commercialisation; 3. To provide leading advice and knowledge transfer to government and industry, and promote jobs and growth through technical innovation. Progress towards these aims is promoted and monitored by the Department's Research Committee and Industry Advisory Board. There are several project-based and policy-based initiatives to support these objectives, examples of which include:

Project-based initiatives

Center for Urban Science and Progress (CUSP): In 2012 Warwick seized the opportunity to pursue one of its ten Global Research Priorities (Sustainable Cities), and address the current worldwide challenge of increasing urbanisation, by becoming part of a five-university consortium to create a new interdisciplinary research centre in New York (with NYU, Carnegie Mellon University, IIT Bombay and University of Toronto). Warwick's contribution to this initiative is led by *Jarvis*, who will also be heading the new EPSRC Centre for Doctoral Training in Urban Science (EP/L016400/1, £4M) from 2014. CUSP is working with industry (including IBM, Cisco, Siemens, National Grid and Arup) and government agencies (including Planning, Transport, Health, Police) to develop technological solutions to help cities become more productive, livable and resilient.

National Automotive Innovation Campus: This 27,000m^2 £94M national research facility (funded by the UK Research Partnership Investment Fund, Jaguar Land Rover and Tata) will open on campus in 2016 and will provide a critical mass of academic, large industry and SME capability. This will enable the Department to grow existing R&D activities, including CASE awards, with companies such as JLR in areas including in-car safety systems and smart dashboards.

Policy-based initiatives

Growth strategy: The Department has made a strategic decision to develop its expertise in Data Science, hiring new staff (inc. two professors) and making provision for a major new extension with the Departments of Mathematics and Statistics. With this expansion, the Department will foster new impactful areas of research, e.g. social media, wireless sensors, streaming algorithms.

Continuing Department support and incentives: Academic staff are encouraged to establish collaborations and thus pathways to impact through sabbaticals; staff are given encouragement and opportunity to pursue industry fellowships; diverse consultancy is encouraged; Warwick has a generous approach to IPR, with 50% of commercialisation proceeds granted to the inventor.

Extending outreach and networking: Forthcoming events include: hosting the IET World Space Week event on Space Robotics (2013); running the Robot Safari at the Science Museum (2013), part of the European Robotics Week; hosting the Cyber Security Schools Challenge (2014).

d. Relationship to case studies

1. "*Impact of image analysis research on fingerprint biometrics and multimedia forensics*" relates to the economic and societal impact of Department spin-out Warwick Warp Ltd and of the patented Forensic Image Analyser (sold by Forensic Pathways Ltd).

2. "*Impact of performance modelling research on IT capacity planning and national nuclear security*" relates to the development of a leading Microsoft product and to knowledge transfer used in underwriting the safety and performance of the UK's nuclear deterrent.

3. "*Impact of high-performance-computing (HPC) research on worldwide HPC capability, and on the UK and international HPC industry*" relates to the economic impact of three Department spin-outs – Streamline Computing Ltd, Allinea Software Ltd, Concurrent Thinking Ltd.