Institution: University of Southampton

Unit of Assessment: 11 Computer Science and Informatics

a. Overview

Research Structure within UoA11: The University of Southampton comprises eight Faculties, which are further subdivided into Academic Units (Departments). This return is from the **Electronics and Computer Science** (**ECS**) Department within the **Faculty of Physical Science and Engineering** (**FPSE**). ECS acts as an autonomous entity under the FPSE umbrella, in which certain processes are common across the Faculty, while others differ in order to best meet local or discipline-specific needs. The activities of ECS cover teaching (undergraduate and postgraduate), research and enterprise. ECS has 127 academic staff (38 Professors) 124 research and enterprise staff and 456 postgraduate research students. It equates to an annual economy of ~£37 million. ECS is research-led, but also strives for excellence in teaching and enterprise. It is the largest Department of its kind in the UK with internationally-leading research across Computer Science, Electronics and Electrical Engineering. ECS is recognised for pursuing research that has strong practical applications while being underpinned by relevant theory. The interdisciplinary culture is a major strength of ECS and its REF return is split between UoA11 and UoA13 (Electrical and Electronic Engineering, Metallurgy and Materials). ECS possesses a strong research group culture, in which all academics and researchers belong to a dedicated research group; the Head of ECS (**Prof Neil White**) manages through the Heads of Group.

Research Groups: ECS has six major research groups: ***Agents, Interaction and Complexity*** **(*AIC*)**; ***Communications, Signal Processing and Control*** **(*CSPC*)**; ***Electronic and Software Systems*** **(*ESS*)**; ***Electronics and Electrical Engineering*** **(*EEE*)**; ***Nano*****,** and ***Web and Internet Science*** **(*WAIS*)**. Of these, AIC and WAIS are returned wholly in UoA11, CSPC and ESS are split between UoA11 and UoA13; EEE and Nano are returned in UoA13. The group structures, especially CSPC and ESS, encourage research across Computer Science and Electronic Engineering and highlight the benefit of being a Department that combines these disciplines. Thus, for example, the ESS group includes Computer Scientists and Electronic Engineers working collaboratively on energy-efficient many-core systems spanning the software and hardware layers; the CSPC group includes Computer Scientists and Electronic Engineers working collaboratively on intelligent control systems combining artificial intelligence and control engineering.

Cross-cutting Centres: A system of cross-cutting centres is used to address specific thematic areas by bringing together staff with complementary skills. The ***Web Science Institute*** is a multi-disciplinary team drawn from across the University, to investigate how the web is changing the world and the world is changing the web; led by ECS it also includes researchers from Humanities, Social Science, Business and Law. The GCHQ-recognised ***Centre of Excellence in Cybersecurity,*** is a cross-cutting centre led by ECS, drawing together expertise from Mathematics, Law, Management, and Psychology, to address the security of cyber space from digital and human threats. The ***Pervasive Systems Centre*** brings together hardware and software expertise, delivering innovation in energy-efficient systems and wireless sensor networks. The ***ARM-ECS Research Centre*** is an Industry-University Centre that focuses on advanced hardware and software design methods for energy-efficient, dependable many-core systems. Finally, the ***IT Innovation Centre*** is an applied research Centre that provides innovation in information technology to industry and the public sector, working with over 100 companies as partners and clients; while part of ECS, IT Innovation is based at the Southampton Science Park.

b. Research strategy

b.1 Research Vision

Research vitality is central to all our activities, including teaching and enterprise. Our vision is of a vibrant, integrated research-led community with a reputation for the international significance of its scholarship and research, its technological impact and for the excellence and relevance of its educational programmes. Consequently, there is a strong emphasis on promoting research and sustaining an active research culture with the following aims:

Aim 1: Deliver Excellent Science, which is world leading, advances fundamental understanding and drives technological innovation. This is demonstrated by the quality of our research outputs which are openly accessible on our ePrints repository (containing over 15,000 publications at November 2013). For the Queen's Diamond Jubilee, ECS was awarded the first ever Regius Professorship in Computer Science as a mark of the international standing of its research.

Aim 2: Address Major Societal Challenges, including cybersecurity, digital economy, environment, energy, defence, healthcare and transportation. Examples are provided in Sections b.2 and b.3 and REF3.

Aim 3: Maximise Research Impact, through interacting with industrial organisations (e.g. AWE, BAE, Secure Meters, IBM, Microsoft, BT, Sharp, Thales), by founding successful spin-out companies (e.g. Arkivum, Garlik and Aerogility), by influencing Government and professional standards (e.g., UK Government Advisors), international standards bodies (e.g. W3C) and learned societies (BCS, Royal Society, RAEng). See Section e and REF3 for evidence of this.

Aim 4: Develop Research Leaders: Researchers trained in ECS have important leadership roles in academia and industry. See Section c.2 for evidence of this.

b.2 Achievements since RAE 2008

Comparison of key metrics for Computer Science research in ECS with comparable data submitted to RAE2008 reveals clear evidence of the success of the overall strategy that we have adopted. Research outputs, PhD awards and research income have grown significantly in the period:

- Journal papers: >820 (up 49%)
- Conference papers: >1,500 (up 37%)
- PhD degrees awarded: 140.4 (up 22%)
- Total research funding: £39.5m (up 64%)
- RCUK funding: £14.3m (no change)
- EU research funding: £13.8m (up 158%)
- Industry research funding: £4.6m (up 113%)

The percentage increase with respect to the RAE2008 levels is normalised to take account of FTE of returned staff and length of assessment periods. Of the £13.8m in EU funding, £8.5m was for the IT Innovation Centre. Achievement of these successes during the REF period has been supported by a number of significant strategic initiatives within ECS:

- ***Strategic Re-structuring of Research Groups:*** The ECS research groups were re-organised in 2010 in order to consolidate world-leading areas (e.g. Web Science, Agent-based Computing) and to strengthen interdisciplinary research by building groups that span Computer Science and Electronics (ESS and CSPC). This is directly in line with the strategy set out in our RAE2008 submission, which identified the intention to strengthen and promote broad areas of *Web Science*, to bring together foundational and engineering issues of *complex systems* and to develop design paradigms that cross *hardware and software*.
- ***Investment in New Staff:*** During the REF period, ECS appointed 12 new academic staff working in Computer Science. This enabled us to strengthen existing areas of research excellence and to broaden our research into areas we identified as of strategic importance such as computational biology and computational economics.

The re-structuring and staff investment have resulted in the following groups:

- **The AIC group** (**Head**: Jennings, 15 staff returned in UoA11) undertakes ground-breaking research into the science and engineering of complex socio-technical, socio-economic and socio-ecological systems that underpin the most pressing challenges currently facing society. Research covered by AIC includes **agent-based computing, complex networks, HCI, decentralised systems, computational economics and informed matter.** Six new academic appointments have been made to bolster AIC activity (**Ramchurn**, **Polukarov**, **Costanza**, **Dyke**, **Brede, Stein**).
- **The WAIS Group** (**Head**: Shadbolt, 18 staff returned in UoA11) is an interdisciplinary team dedicated to understanding better the origin, evolution and growth of the World Wide Web and the Internet. Research covered by WAIS includes **web science, semantic web, open data, provenance, cybersecurity, e-learning and accessibility**. Three new academic appointments have been made to bolster web science (**Simperl**, **Tiropanis**, **Weal**).
- **The CSPC group** (**Head**: Hanzo, 5 staff returned in UoA11) crosses Computer Science and Electronic Engineering, developing and applying theory to the capture, generation, processing, intelligent interpretation and transmission of information. **Areas covered by CSPC include biometrics, communications, computer vision, artificial intelligence, control and signal processing.** A new appointment has been made to bolster CSPC artificial intelligence activity (**Niranjan**, with a particular focus on computational biology) as well as three other new appointments returned in UoA13.

- **The ESS Group** (**Head**: Butler, 10 staff returned in UoA11) brings together Computer Scientists and Electronic Engineers in a move to enable research activity on novel architectures and design methods that span hardware and software. Research covered by ESS includes **formal design methods and verification, programming models, software engineering, low-energy design, embedded, many-core and pervasive architectures.** Two new staff appointments have been made to bolster ESS verification and embedded systems activity (**Parlato, Tribastone**) as well as another new staff member returned in UoA13 (**Merrett**).

The effectiveness of our research strategy is demonstrated by several major initiatives during this REF period, including 3 EPSRC Doctoral Training Centres, 3 major EPSRC Programme Grants, multiple EU Projects and the creation of 3 new multidisciplinary centres:

EPSRC Doctoral Training Centres:

- Complex Systems Simulation, £6.5m, 2009-2018, **Directors**: Bullock, Essex (Chemistry).
- Web Science, £6m, 2009-2018, **Directors**: Hall, Shadbolt, Carr.
- Next Generation Computational Modelling, £3.8m, 2014-2023, **Directors**: Bullock, Fanghor (Engineering).

EPSRC Programme Grants:

- **ORCHID**, £5.5m Programme Grant on Human-Agent Collectives led by the AIC Group (**Investigators**: Jennings, Rogers, Moreau).
- **PRiME**, a £5.6m Programme Grant on Power-efficient, Reliable Many-core Embedded Systems led by the ESS Group (**Investigators**: Al-Hashimi, Butler, Merrett).
- **SOCIAM**, a £6.2m Programme Grant on the Theory and Practice of Social Machines led by the WAIS Group (**Investigators**: Shadbolt, Berners-Lee, Hall, schraefel, Moreau).

EU Projects:

- **Major EU Projects coordinated by ECS** include **Pascal 2** (€6.8m, 2008-12, ESS Group) on principled methods of pattern analysis, statistical modeling, and computational learning; **EXPERIMEDIA** (€6.7m, 2011-14, IT Innovation Centre) developing new forms of social and networked media experiences; **ADVANCE** (€3.7m, 2011-14, ESS Group) delivering formal design tools for cyberphysical systems; **WeGov** (€2.7m, 2010-12, IT Innovation Centre + Southampton Institute for Law and Web) addressing engagement between government and citizens via social networking; **OFERTIE** (€1.9m, 2012-14, IT Innovation Centre + WAIS Group) developing software-defined networking for real-time online interactive applications.
- **Major EU Projects in which** ECS plays significant roles include **DEPLOY** (€18m, 2008-12, ESS Group) on industrial deployment of formal engineering methods; **PrestoPRIME** (€12m, 2009-12, IT Innovation Centre) on preservation of digital media; **BonFIRE** (€8.5m, 2010-14, IT Innovation Centre) delivering a large scale experimentally-driven cloud research facility; **SmartSociety** (€6.8m, 2013-16, WAIS Group) on collective adaptive systems where people and machines work closely together to build a smarter society; **TrendMiner** (€3.2m, 2011-14, CSPC+WAIS Groups) on real-time methods for cross-lingual mining and summarisation of large-scale stream media.

New Centres:

- Centre of Excellence in Cybersecurity, **Director:** Sassone (WAIS Group).
- ECS-ARM Centre for Energy-efficient Dependable Multicore Systems. **Directors:** Al-Hashimi, Butler (ESS Group), David Flynn (ARM).
- Web Science Institute, **Directors:** Hall, Shadbolt, Carr (WAIS Group).

b.3 ECS Future Strategic Directions

Our research strategy is developed at *Group* level and at *Department* level based on research trends and findings, societal needs, industrial trends and funding priorities.

Group Strategies: Each research group has developed priority areas for future research:

(i) The AIC Group will further strengthen the synergies from the coming together of researchers in the agents, interaction and complexity space. There are many exciting opportunities to tackle problems as diverse as engineering resilient and sustainable smart infrastructure, or refactoring healthcare systems to cope with demographic change, or anticipating and mitigating the impacts of climate change. These all involve building and analysing complex systems comprising many interacting agents, including people and other organisms, hardware robots and autonomous software agents. AIC will use the ORCHID Programme Grant as a catalyst for new activities in this area and will continue to pursue the fundamental science necessary to understand, model

and implement such systems, as well as tackling key societal applications.

(ii) The ESS Group will continue to nurture its multidisciplinary research environment covering Computer Science and Electronics, developing practical engineering methods underpinned by theory. There are significant funding and impact opportunities in novel engineering methods for future technology including many-core systems, cloud computing, energy, healthcare and transportation. ESS will use the PRiME Programme Grant as a platform to identify new opportunities in cross-layer engineering of many-core systems covering adaptable application design, programming language innovations and decentralised operating system design as well as tackling key societal applications underpinned by high performance embedded computing.

(iii) The WAIS Group will consolidate world leadership in Web Science, setting the research agenda for this new Science globally. The SOCIAM Programme Grant will serve as a catalyst for developing new activities related to Web Science to enable novel and creative solutions to complex social and computational problems in a decentralised fashion, at large scale. Working closely with the Open Data Institute (see REF3a) WAIS will continue to set the research and implementation agenda in an area in which the UK is world leading. By leading multidisciplinary efforts, WAIS will develop new forms of economic, social, political, technological and cultural resources based on a deep understanding of the Web's technologies and social construction.

(iv) The CSPC Group will continue to deliver world-leading research across communications, control, computer vision and artificial intelligence. New challenges in autonomous control, big data, systems biology, energy-efficient adaptive multimedia communications and intelligent security require a holistic approach that covers combined expertise in Computer Science and Electronic Engineering which CSPC is ideally placed to capitalise on. Links to biology and medicine will continue to be a major focus of CSPC.

Common ECS-level Strategies: As well as supporting individuals and groups to drive our research agenda, we also look for opportunities at Department and University levels that require coordinated approaches to research. National and international drivers that inform our strategy include UK Government, RCUK and EU Horizon 2020 agendas. Much of the ICT that we research is a key enabler for the BIS-identified 8 Great Technologies, in particular big data, robotics, autonomous systems, satellites and energy storage. Our cross-cutting strategy can be considered under the following 4 headings:

(i) Major Research Programmes. While continuing to encourage standard grant and fellowship applications, we aim to extend the range of large Programme Grants that consolidate our excellence and facilitate multi-disciplinary research. RCUK and Horizon2020 are being targeted and we are actively involved in agenda setting for these programmes. In particular we will target funding opportunities in the areas of digital economy, cybersecurity, energy, healthcare technologies and aerospace. We will consolidate experience of successful Programme Grant bids with the aspiration to have multiple large grants in every research group.

(ii) Agility in Research. The areas of Web-based socio-technical systems, software engineering, large-scale decentralised systems, data analytics and cybersecurity are fast-moving, and it is imperative that we can avail of the opportunities these provide. A key strategic objective is therefore to broaden our funding base and, in particular, to grow the funding we receive from industry, either directly or through collaborative routes. In the REF period the value of direct funding we obtained from UK industry was £4.6m; in view of the industrial relevance of our research areas, we believe there is considerable scope for further growth. The concept of the cross-cutting centre has been shown to be a successful means of driving new initiatives in multidisciplinary areas, and of involving non-ECS members in our research. This concept will be continued and strengthened to accommodate multidisciplinary research opportunities in *social processes on the web*, *open data*, *energy management*, *big data, cybersecurity*, *autonomous systems* and *healthcare*. ECS will lead on the development of a new **Aerospace Institute** that will provide new multidisciplinary opportunities and challenges for our research (e.g., multi-agent systems, intelligent control and software engineering to enable new generations of dependable autonomous systems).

(iii) Growing Research Partnerships. Partnership management is key to our current success and long-term strategy. Evidence of our commitment to this is provided by the number of mechanisms we employ to form and sustain links with research end users (e.g. alumni events, ECS Industrial Liaison Committee, Industry Days, etc.), our spin-out companies and our commercial consultancy company, ***ECS Partners Ltd***, to provide consultancy to clients ranging

from SMEs to multinationals (details are in REF3a). A key element of the ECS Partners concept, is the exploitation of a broad range of skills and capabilities available across UoA11, to provide an agile structure by which short-to-medium term projects can be used to build relationships with future research partners, thereby opening up additional research opportunities.

(iv) Training the Next Generation. PhD students are the research engine of ECS and we intend to grow the size of our Graduate School (GS). FPSE already allocates more than £500k per year in research scholarships from our MSc and research income, in addition to our Doctoral Training Grant and Doctoral Training Centres. To grow the GS further, we will need to access new funding routes, including EPSRC CASE awards and industry-relevant co-sponsored PhDs. We will also increase our overseas marketing campaign, to attract more self-funded postgraduate students.

c. People, including:

i. Staffing strategy and staff development

c.1 STAFFING STRATEGY

Our staffing strategy is driven by the requirement to maintain a vibrant community that is able to sustain and grow all elements of our research, enterprise and education. ***Academic and Research Staff*** undertake education, research and impact generation. Our staffing strategy covers reinforcement and complementarity:

(a) ***Reinforcement:*** this is driven through junior appointments ***within existing areas of research strength*** to ensure sustainability of these topics, reflect resource availability and facilitate the delivery of our portfolio of taught programmes. The recent appointments of **Ramchurn** (2009) and **Stein** (2013) are examples of this approach to sustainability. Their research reinforces existing work in AIC on applications of multi-agent technology, and capitalises on the ORCHID Programme Grant.

(b) ***Complementarity:*** this involves making appointments in key areas that will generate new multidisciplinary activities and ***bridge existing areas of research strength***, thereby opening up new areas of strategic importance. Examples of this approach within the REF period include **Polukarov** (2010) who is working across Computer Science and Economics, **Simperl** (2012) who is working across Computer Science and Social Science, and **Tribastone** (2013) who is working across software and hardware for embedded systems.

Staffing Procedures and Appointments: The staffing strategy is implemented through a regular review process by Heads of Groups and the incorporation of the outcomes into the FPSE Strategic Plan. Future staffing needs are evaluated against faculty targets and decisions made based upon internal needs and external factors, notably, the overall ***funding landscape*** and our existing and potential ability to ***address societal challenges***. Nevertheless, a central tenet of our procedures revolves around seeking the best talent, worldwide, and developing tomorrow's research leaders.

International Staff Appointments and Visitors. ECS recruits the best talents worldwide. Over the REF period, we have recruited 7 new Computer Science academics internationally: Brede (Australia), Costanza (Switzerland), Parlato (France), Polukarov (Israel), Simperl (Germany), Tiropanis (Greece), Tribastone (Germany). Because of our strong international research presence and networking, we regularly have scholars visiting us, spending typically up to 1 to 6 months. Over the REF period, more than 30 researchers have visited ECS. Examples include Weitzner (MIT), McIver (Macquarie), Morgan (New South Wales), Hoang (ETH Zurich), Leuschel (Dusseldorf), De Nardi (UCL), Penta (Turin), Chakrabarty (Duke). An inevitable consequence of our high profile is that staff are sought for appointments abroad; examples within the REF period include Marques de Silva (to Dublin) and Fischer (to South Africa).

c.2 STAFF DEVELOPMENT

Institutional Framework: The University of Southampton engages strongly with initiatives that support and enable progression of researchers' careers. In 2005 the University was a founder signatory to the Athena SWAN charter, receiving a University level Bronze award first in 2006, and successfully renewing the award in 2009 and 2013, indicating continued engagement. The University ***Diversity Office*** supported **ECS** in achieving an **Athena SWAN Bronze Departmental Award** in 2013 (details later). In 2010, The University of Southampton signed up to the Concordat to support the Career Development of Researchers, while 2011 saw the European Commission present the University of Southampton with the HR (Human Resources) Excellence in Research Award, in recognition of its commitment to supporting the personal, professional and career development of its researchers. Southampton was among just 12 institutions to achieve the award.

Career Development: A key element of our on-going research strategy is to ***develop research***

leaders through mentoring by senior colleagues and training, in line with the ***Vitae*** initiative. Examples of ECS-trained ***academic leaders*** include Prof Dame Wendy Hall (Dean of Faculty), Prof Neil White (Head of ECS), Prof Les Carr (ECS Web Science DTC Director), Prof Dave De Roure (Director of the Oxford e-Research Centre). Southampton-trained researchers who have gone on to ***leading roles in industry*** include Dr Alistair Dunlop (Executive Director, Quantitative Research, JP Morgan Chase), Dr Simon Kampa (Managing Director, Critical Software Technologies), Dr Mischa Tuffield (Chief Technology Officer, PeerIndex) and Dr Maria Karam (Founder, CEO, Tactile Audio Displays Inc).

Local Provision. Integration of Early Career Researchers (ECR) into the research community is a key objective, which is accomplished through local mechanisms guided by university policy.

(i) Induction. On arrival ECRs are provided with a mentor and a personalised, targeted induction programme to introduce them to the University, the Faculty and the Department.

(ii) The Personal Performance and Development Review (PPDR). Staff development is an important element of the mandatory annual PPDR process, which reviews each individual's prior performance, sets future objectives and agrees personal career development needs.

(iii) The Concordat. FPSE has appointed a senior academic (**Prof Hewak**) as the ***Faculty Concordat Champion.*** An initiative in 2013 was the establishment of the ***Dean's Awards for ECRs***, to recognise exceptional contributions in scientific publication, knowledge transfer, enterprise and public engagement. In 2013, 3 ECS ECRs achieved Dean's Awards including **Dr Talal Rahwan** for scientific research and **Dr Reuben Wilcock** for enterprise.

(iv) FPSE Academic and Research Future Leaders Mentoring Network. This is chaired by the FPSE Associate Dean (Research) with membership including HoGs and Deputy Heads of Dept. The Network meets 4 times each year to identify and support outstanding ECRs to secure **prestigious fellowships**, e.g. RCUK and European Research Council (ERC). It reviews applications, helps secure academic and industrial partners, allocates significant Faculty support (typically 1 PhD student plus £50k per application), organises mock panels. During the REF period, 4 UoA11 staff members have held prestigious fellowships: **Noble:** RCUK Roberts Fellowship (2008-2011), **Ramchurn:** RCUK Roberts Fellowship (2009-2012), **schraefel**: Royal Academy of Engineering and Microsoft Research Senior Research Fellowship (2008-2013), **Sobocinksi** EPSRC Postdotoral Fellowship (2007-2009). In addition, **Ivan Markovsky**, now at Vrije Universiteit Brussel, was awarded an ERC Starting Grant (2010-2014) while in ECS.

(v) Initiating Research. Newly appointed academic staff receive pump-priming funding to enable new them to initiate their research. Other seed-corn funding flows through the research group and faculty funds. The **FPSE ECR Fund** supports newly appointed junior members of academic staff to develop research leadership skills, for example, through the organisation of international workshops to set research agendas and develop network of contacts in their own fields. As an example, the fund allowed **Dr Maria Polukarov**, appointed Lecturer in 2010, to organise a workshop on algorithmic mechanism design, bringing together Computer Science and Economics.

Institutional Provision. The following structures demonstrate the institutional commitment to the development of all staff:

(i) The Professional Development Unit (PDU). This University resource provides a dedicated workshop programme with events themed within the four domains of the ***Researcher Development Framework*** (RDF): knowledge and intellectual abilities; personal effectiveness; research governance and organisation; engagement, influence and impact. The support provided ranges from leadership programmes, which help staff develop skills in managing teams to writing funding applications. As part of every PPDR in ECS, PDU courses relevant to the staff member are identified and a timeframe for participation is agreed.

(ii) Postgraduate Certificate in Academic Practice (PCAP). All ECS academic appointees with teaching commitments complete the PCAP training course if they do not hold a comparable qualification. Many ECRs aspire to an academic career and consequently, all ECRs have the opportunity to undertake PCAP training to acquire HEA accreditation.

Equality and Diversity: ECS commitment to Equality and Diversity (E&D) is demonstrated by our achievement of an Athena SWAN Bronze Departmental Award in 2013 in recognition of our ambition to tackle the unequal representation of women at all levels in ECS.

(i) Athena SWAN Action Plan. A consequence of our engagement with Athena SWAN has been

a complete review of the recruitment, retention, recognition and reward systems to ensure that they are fair transparent and well-understood by all staff. Delivery of our action plan is coordinated by a diverse team of 10 staff and students, chaired by **Prof Butler,** who meet every 2 months. We provide diversity training (over 60 ECS staff trained to date), to increase the cultural awareness, knowledge, and skills of staff and commissioned a ***Culture Analysis*** for ECS by the UK Resource Centre for Women in Science to enable staff to understand the impact of culture on diversity in 2011. We have an outreach programme aimed at increasing the number of female undergraduates and have appointed **Dr Reena Pau** to the post of Diversity Outreach Officer to coordinate this. We are providing improved support for career development and promotion, including supporting Postgraduate and Research Fellow forums, career coaching and action learning sets. We are ensuring that the University's flexible and family-friendly working policies are properly understood and valued by all staff in ECS to facilitate greater uptake. We aim to be in a position to apply successfully for an Athena SWAN Silver Award for ECS in 2015.

(ii) Maternity/paternity Entitlements. FPSE has mechanisms to ensure that research staff on fixed-term contracts have similar maternity/paternity entitlements as those on permanent contracts and provides systematic assistance with return to work through reduced teaching loads and flexible working. Where a grant does not cover maternity pay, the Faculty covers the cost; 6 cases of maternity leave and 28 cases of (2 week) paternity leave have been supported in ECS in the current REF period.

(iii) E&D Commitment. The FPSE Faculty Diversity Committee, chaired by **Prof Butler,** develops and oversees E&D policy and monitors diversity statistics. This is enabling the Athena SWAN lead taken by ECS to be shared with other Departments in FPSE. The Committee also addresses other E&D issues such as ethnic and social background. Our support networks for women include ***ECSWomen***, founded in 2005, a student-run organisation supporting women in ECS; ***WiSET***, founded in 2002, a group that helps shape the policies and culture of our University for women in science, engineering and technology. ***Theano***, founded in the 1990's, a networking group bringing together women that is open to all female students and staff across the University.

ii. Research students

c.3 RESEARCH STUDENTS

FPSE Graduate School: The Faculty-wide Graduate School (GS) has overarching responsibility to ensure that University quality frameworks and regulations are applied rigorously. These include monitoring progression, training, supervision, registration status, and receiving and acting upon student feedback. The GS holds 3 Board Meetings annually, reporting to the Faculty Education and Research Committees. Board membership includes the Graduate School Director (**Prof Shepherd**), senior academics and administrators from across FPSE and postgraduate research (PGR) student representatives from each research group.

Admissions and funding. Funding for students is provided through multiple routes including the EPSRC doctoral training account (DTA) DTC funding, industrial funding, direct University funding and self-funding (e.g. Government sponsorship of international students). The GS strategy is to attract the best students through funded scholarships for international and EU students while, for UK students (for whom DTA funding can be used) enhanced stipends are offered. University-funded scholarships are allocated on a competitive basis by a panel that judges applicants on academic quality, the strategic importance of the research, and any matched funding.

Induction. Induction occurs at a number of levels. The University provides students with a high level perspective, while the Faculty induction explains the progression stages to ensure successful completion of their PhD and the compulsory and optional training that exists. Local induction provides more in-depth guidance, in particular, concerning subject-specific training.

Supervision. Each PhD student has a supervisory team of at least 2 academic staff with a clear primary supervisor. At least one member of the team must have prior experience of PhD supervision to successful completion, enabling new academics to be mentored in supervision. Mentoring is also available to the students should they wish to raise issues on a confidential basis.

Progress Monitoring. The GS has pioneered a web-based system, ***PGR Tracker*****,** which supports progression monitoring and enables formal recording of all the training activities undertaken by each student. This system prompts students, supervisors, and examiners when tasks are due for completion – students submit reports through the tracker and supervisors/ examiners give feedback on the reports and any subsequent viva. The Tracker also records training activities undertaken by students.

Professional Skills, Training and Support. The University ***Researcher Development & Graduate Centre*** provides a broad range of courses to enhance research-centred learning and transferable skills training for postgraduate students. Each student is provided with a structured and supported process enabling them to reflect on their own learning and achievements, and to plan for their personal, educational and career development. Subject-specific training is delivered at Faculty, Department and research group levels, which includes: formal lecture courses; seminar programmes; attending high-level UG or PGT modules; etc. Each ECS PGR student has a personal Research Training Support Grant of £1,200 per annum, conditional on progression, to present papers at national and international conferences, and attend relevant summer schools.

Career Development. Engagement with employers is an essential part of PGR career development. Many students within the Faculty are working on topics that are highly relevant to industry and their research often involves collaboration with these industrial partners. Students frequently attend conferences which often incorporate large industrial shows while industry-based researchers are regularly invited to give seminars to the PGRs. PGR students participate in ***widening participation*** activities where they both lead activities and mentor young students to consider university study; for example, in ECS, there are successful programming and robotics schools' outreach programme. PGRs are also trained to take part in teaching activities, such as laboratory demonstrating to undergraduates. Other PDR development initiatives include:

(i) Mayflower Scholarships. PGR students in this programme spend 25% of their time delivering teaching, which particularly appropriate for students intending to pursue an academic career. Typically 4 Mayflower scholars per year join ECS.

(ii) PGR Internships provide a learning environment through which research students contribute towards a project delivery within a host organisation. Typically 10 PGR students per year from ECS undertake internships with industrial partners.

(iii) The Research Mobility Programme (RMP). The RMP offers PGRs and ECRs the opportunity to visit one of the international Worldwide Universities Network (WUN) partners. In 2013, 3 ECS PGRs visited partner institutions for reseach collaboration.

(iv) The Career Destinations Service is available to all University staff and alumni, and includes dedicated PGR and international student support. It holds careers fairs and events, provides training on CVs, applications and interviews and helps with work placements.

(v) The ECS Careers Hub. The ECS Careers Hub was established in 2008 to promote the employability of UG and PG students. Over 100 companies (e.g., Accenture, ARM, BAE, BT, IBM, Imagination, Thales) are affiliated to the Careers Hub and Annual ECS Careers Fair.

ECS provides a supportive environment that is effective in ***delivering excellent science*** and in ***developing researchers***. This is highlighted by prestigious awards to our PGR students including:

- **Rahwan**: 2008 CPHC/BCS Distinguished Dissertation Award (for the best British Doctoral dissertations in Computer Science).
- **Tran-Thanh**: Honorable Mention Prize in the ECCAI 2012 Distinguished PhD Dissertation Award (for the best European PhD thesis in AI) and runner-up in the 2013 CPHC/BCS Distinguished Dissertation Award.

d. Income, infrastructure and facilities

Research Funding: ECS has a highly successful track record of winning research funding from the Research Councils, notably EPSRC, EU and Industry. Of a total of £39.5m research income for Computer Science during the REF period, the major components are:

RCUK: £14.3m, EU: £13.8m Industry: £4.6m

As of November 2013 we had an EPSRC portfolio exceeding £28m in value for Computer Science research. Compared with other UK Computer Science Departments, based on data from the EPSRC web site in November 2013, this put us in third place behind UCL and Edinburgh.

Future Funding Strategy: The key element in our future funding strategy is diversification in order to draw upon a wider range of funding sources, including DSTL, TSB, EU Horizon2020, ERC and through interaction with pertinent industries. Our experience with EPSRC Programme Grants is being shared to enable even greater success. With support from the University ***EU Office*** and from IT Innovation, we are organising workshops to encourage a broader range of ECS academics to engage with EU funding. The world-leading nature of our research activities will continue to make us attractive to a range of established partners (e.g. ARM, BAE, AWE, DSTL) as outlined in REF3a and the success of our consultancy services is providing a means of building new relationships.

Consultancies and Professional Services: Southampton has a strong commitment to leadership in enterprise and innovation. The approach is to encourage staff to carry out consultancy that will enhance the skill set and experience of the staff. The governance framework of the University requires all consultancy activity to comply with University Financial Regulations, the Consultancy Policy and additional policies on Conflict of Interest. ECS Partners constitutes an important element in our strategy to establish links with industry and evidence of its success includes: revenue growth from £462k in 2008 to ~£2m in 2013; the establishment of a long-standing relationship with BAE Systems; the formation of the ***ARM-ECS Centre***, which attracted nearly £1m of industrial research funding over the REF period.

Research Support: To facilitate local initiatives, all research groups are allocated a ***Recurrent Grant***, determined by the research funding that the group generates. This is used to pump prime new research initiatives, build partnerships, support research visits, conference attendance, etc. This supports ECRs who do not have existing grants to fund such activities. In addition, a percentage of overheads brought in as part of research grants is returned to the Principal Investigator to spend at their discretion. Our ***Partnership Manager*** (Joyce Lewis) coordinates ECS business relationships for research collaboration and student careers. Our ***Senior Enterprise Fellow*** (Dr Reuben Wilcock) works with ECS researchers to maximise the commercial impact of their innovations by taking research demonstrators through to commercial products (see REF3a). The University ***Research and Innovation Services*** play a critical part in facilitating collaboration with industry, by providing the specialist expertise needed to support relationships with research users, deal with legal issues, manage IP, etc. A ***Collaboration Manager*** (Woolley) and two ***Research Support Officers*** (McCourt and Di Chio) provide dedicated support to ECS staff.

e. Collaboration or contribution to the discipline or research base

We outline the range of important roles played by ECS staff that contribute to sustaining the discipline of Computer Science and help to broaden its reach and impact. This contribution is recognised by the many honours achieved by ECS staff with particular highlights since 2008 being:

Dame British Empire (Hall, 2009)
Knight British Empire (Shadbolt, 2013)
Queen Elizabeth Prize for Engineering (Berners-Lee, 2012)
President of the ACM (Hall, 2008-2010)
Fellow Royal Society (Hall, 2009)
Fellow of IEEE (Jennings, 2009)

• **Advisory positions for government:** ECS Computer Scientists hold Government advisory roles helping to increase the appreciation of our discipline by policy-makers. Significant examples during the REF period are **Jennings:** a Chief Scientific Advisor to UK Government (since 2010). **Hall:** Member of Prime Minister's Council for Science and Technology (2004-2010). **Berners-Lee & Shadbolt**: UK Government Information Advisors (2009-2010), Members UK Public Sector Transparency Board. **O'Hara:** Chair Transparency Sector Panel for Crime and Criminal Justice (Home Office / Ministry of Justice expert panel on open data).

• **Leadership roles in industry and research councils:** During the REF period over 20 members of ECS UoA11 have performed these leadership roles. Of particular note: **Berners-Lee:** President and Co-Founder Open Data Institute**. Bullock**: EPSRC/Scottish Executive Panel on Research Pooling in Computer Science, EPSRC Working Group on Systems Engineering. **Hall**: Member of DSTL Board (2012-) Non Executive Director Idox. **Jennings:** Scientific Advisor for Lost Wax and Aerogility (2000-) Scientific Advisor for Aroxo (2009-2012). **Martinez:** Technology Strategy Board Technical Advisory Group on Environment (2008). **Moreau**: Chair W3C PROV Working Group on standards for information provenance. **Shadbolt**: Member of REF2014 Panel for UoA11, Chairman and Co-Founder Open Data Institute, Chief Scientific Officer for Garlik (2006-2011)**.** 15 academics from UoA11 are members of the EPSRC College and we regularly review proposals for other funding bodies (e.g., BBSRC, NERC, ERC, EU).

• **National and international advisory board membership:** During the REF period ECS UoA11 members served over 25 key organisations supporting the research base. Of particular note: **Berners-Lee:** United States National Academy of Sciences, Director of Web Science Trust. **Bullock:** Board of International Society for Artificial Life**. Butler:** Vice-Chair IFIP WG2.3 Programming Methodology (2008-, Chair 2014-). **Hall**: President of the ACM (2008-2010) Chair of Web Science Trust, Scientific Council of the ERC (2005-2010) British Library Board (2007-).

Jennings: Chair Royal Academy of Engineering Industrial Secondment Scheme, Royal Society Research Appointment Panel (2009-2013) Royal Academy of Engineering Membership Panel (2008-11). **Martinez**: American Geophysical Union Earth and Space Science Informatics Exec Comm. **Niranjan**: ERC Starter Grants Panel (2010-2012). **Noble:** Board International Society for Artificial Life, Secretary of the Society (2010-2012). **Harnad**: Hungarian Academy of Sciences. **Sassone**: Council of European Assoc of Theoretical Comp Sci. **Shadbolt**: Director of Web Science Trust**,** Chair BCS Nominations Committee (2008-2010)**. Wald:** UK representative Liberated Learning Consortium on Speech Recognition for Learning.

• **Journal editorships, editorial board membership:** ECS members returned in UoA11 are on the Editorial Boards of 53 international journals. Of particular note **Brede**: ICST Trans on Complex Systems. **Harnad:** J Experimental & Theoretical AI, PSYCOLOQUY (co-editor), Philosophy and AI. **Bullock**: Adaptive Behaviour. **Butler:** Formal Aspects of Computing. **Moreau:** Editor in Chief Concurrency and Computation: Practice and Experience (2008-2012). **Costanza**: Intl J of Mobile Human Comp Interaction. **Dasmahapatra**, J Automated Experimentation. **Jennings**: ACM Trans Internet Technology. J Autonomous Agents and Multi-Agent Systems. J Logic and Computation. **Lewis**: J Multimedia Information Retrieval. **Martinez**: Sensor Networks. **Polukarov**: J Electronic Commerce Research and Appls. **Rogers**: J AI Research. **Shadbolt**: IEEE Intelligent Sys, AI Review. **Sassone**: Assoc Editor Computer Journal, Editor in Chief of ACM Selected Readings, Managing editor Advanced Research in Computing and Software Science, Theoretical Comp Sci, Logical Methods in Computer Science. **Zauner**: J Unconventional Computing.

• **Conference programme chairs:** During the REF period, ECS members returned in UoA11 have Chaired over 20 conferences. Of note **Bullock:** Intl Conf on Artificial Life, 2008. **Noble:** Intl Conf on Artificial Life, 2008. **Cirstea:** Organiser of Intl Conf on Algebra & Coalgebra in Comp Sci, 2011. **Butler**: Formal Methods 2011, Theoretical Aspects of Soft Eng 2013. **Sassone**: BCS Visions of Comp Sci Conf 2008. **Millard**: Theme Chair Hypertext 2013. **Niranjan**: Pattern Recognition in Bioinformatics 2009. **Fischer**: Automated Software Eng Steering Comm, Generative Prog and Component Eng 2009.

• **Keynote addresses:** During the REF period there have been over 80 invited talks at scientific events by ECS UoA11 members. **Bullock**: Knowing and Understanding through Computer Simulation 2011. **Butler**: Integrated Formal Methods 2009. Marktoberdorf Summer Sch on Dependable Sys 2008 & 2012. **Harnad**: Open Access and Research Conf 2008, European Conf on Scientific Publishing, 2010. **Niranjan**: Research Capacity Building in a Post-war Context (Sri Lanka, 2012). **Rogers**: Autonomous Agents & Multiagent Sys 2012, Intl Conf on Computational Sustainability 2012. **Sassone**: Symp Trustworthy Global Computing 2010, Intl Conf on Concurrency Theory 2010. **schraefel**: Intl Semantic Web Conf 2010, Digital Humanties Conf 2008. **Shadbolt**: White House Smart Disclosure Summit 2012, EU Ministerial Conf Posnan 2012, Royal Society Public Lecture 2010, Web Science Conf 2009. **Sobocinski**: Coalgebraic Methods in Comp Sci 2012. **Watson**: European Conf on Artificial Life 2009. **Zauner**: Summer Sch on Biological and Chemical Inf Tech 2012, Invited Scientist at the Meta.Morf 2012 Biennale for art and technology.

• **Awards:** In the current REF period we have had over 40 awards in UoA11. Of particular note **Fischer**: Automated Software Eng 2012 Most Influential Paper Award. **Jennings:** Engineer's Award for Best Aerospace and Defence Project for ALADDIN (2009) BAE Chairman's Award for ALADDIN's Technology Transfer activities (2009) Winner US State Department's TAG challenge on social mobilization and rapid information gathering (2012) Best Paper Knowledge Engineering Review (2008). **Rogers and Ramchurn:** Intl Conf. on Autonomous Agents & Multiagent Sys (AAMAS) Best Industrial Demonstrator (2008) Best Paper AAMAS (2010). **Rogers and Wilcock**: Winner British Gas Connecting Homes competition for MyJoulo (2013). **Wilcock**: Royal Academy of Eng ERA Foundation Entrepreneurs Award (2013). **Wills**: Best Paper Comp & Inf in Eng 2009.

• **Leadership of consortia:** In the REF Period we have led over 10 major academic/industry consortia. Of particular note **Jennings:** EPSRC ORCHID Programme Grant (4 Universities, 2 Companies). **Rogers**: Intelligent Agents for Home Energy Management (5 Industrial partners). **Bullock:** EPSRC/ESRC Resilient Futures (8 Universities). **Butler:** FP7 ADVANCE Project (5 partners). **Gunn: Pascal 2** Principled methods of pattern analysis, statistical modeling, and computational learning (23 Partners). **Shadbolt**: EPSRC SOCIAM Programme Grant (3 Universities, 15 Industry/Government partners). **O'Hara**: UKAN Anonymisation Network (Funded by Information Commissioner's Office, 5 partners, 15 network members).