

Unit-level environment template (REF5b)

Institution: University of Southampton																												
Unit of Assessment: 11 Computer Science and Informatics																												
1. Unit context and structure, research and impact strategy 1.1 Overview The School of Electronics and Computer Science (ECS) has 95 academic (CAT A) staff (including 39 professors) split across UoAs 11 and 12, of which 51 staff (20%F) are being returned in UoA11. Situated in the Faculty of Engineering and Physical Sciences, ECS, established in 1947, is the oldest school of its kind in the UK and has an annual economy of £46M (£25M for UoA11). The interdisciplinary nature of ECS reflects its highly interconnected and collaborative philosophy. UoA11 draws especially upon, and benefits from, numerous other disciplines as evidenced below. This is a key element to our strong environment, both for the generation of new insights and for the translation of fundamental research into meaningful economic, societal and human impact. Our environment has resulted in key achievements over the past REF period, including: • An influential government artificial intelligence (AI) review entitled “Growing the AI Industry in the UK”, which has shaped the government’s AI agenda (§4.2.1). • The only computer science (CS) Regius professor chair in the UK. • Renewal of the GCHQ Cyber Security Academy Centre of Excellence. • 3 new interdisciplinary centres around AI, digital health and the internet of things (IoT). • A £1.5M Shell-funded centre with engineering focusing on digital maritime. • Over £40M funding awarded to UoA11 including a CDT, 2 EPSRC platform grants and leading the £12M (total value) UKRI Trustworthy Autonomous Systems (TAS) Hub. • Over the REF period, we increased the percentage of female academic staff in CS from 11% to 20%, and of female PGR students from 26% to 32%. The Unit is wholly situated in ECS with academic staff split across five research groups for line management purposes. As shown in Table 1, AIC brings together pioneering research in AI, human-computer systems, complexity science and health/wellbeing. CPS undertakes research covering electronics and computer science that enables advances in engineering of cyber-physical systems. CSY brings together interdisciplinary expertise in whole-systems security bridging software, hardware and human factors. VLC produces internationally leading research in machine learning and computer vision. WAIS studies socio-technical systems at scale, using a combination of data, computational and social science methods to understand interactions among information systems that compose the Web and the Internet. Two groups, VLC and CPS, are split with UoA12. Table 1: Research Groups <table border="1"> <thead> <tr> <th>Group</th> <th>Head</th> <th>UoA11 Count</th> <th>UoA11 FTE</th> </tr> </thead> <tbody> <tr> <td><i>Agents, Interaction and Complexity (AIC)</i></td> <td>Norman</td> <td>15 (4F/11M)</td> <td>14.96</td> </tr> <tr> <td><i>Cyber-Physical Systems (CPS)</i></td> <td>Gunn</td> <td>5 (0F/5M)</td> <td>5.00</td> </tr> <tr> <td><i>Cybersecurity (CSY)</i></td> <td>Sassone</td> <td>7 (1F/6M)</td> <td>6.40</td> </tr> <tr> <td><i>Vision, Learning and Control (VLC)</i></td> <td>Prugel-Bennett</td> <td>10 (1F/9M)</td> <td>8.80</td> </tr> <tr> <td><i>Web and Internet Science (WAIS)</i></td> <td>Carr</td> <td>14 (4F/10M)</td> <td>12.10</td> </tr> <tr> <td>Total</td> <td></td> <td>51 (10F/41M)</td> <td>47.26</td> </tr> </tbody> </table>	Group	Head	UoA11 Count	UoA11 FTE	<i>Agents, Interaction and Complexity (AIC)</i>	Norman	15 (4F/11M)	14.96	<i>Cyber-Physical Systems (CPS)</i>	Gunn	5 (0F/5M)	5.00	<i>Cybersecurity (CSY)</i>	Sassone	7 (1F/6M)	6.40	<i>Vision, Learning and Control (VLC)</i>	Prugel-Bennett	10 (1F/9M)	8.80	<i>Web and Internet Science (WAIS)</i>	Carr	14 (4F/10M)	12.10	Total		51 (10F/41M)	47.26
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In addition, there are three cross-cutting interdisciplinary research centres with UoA11 staff members: Centre for Machine Intelligence (CMI, **Ramchurn**), the Centre for Internet of Things and Pervasive Systems (CIoT, Merrett), and the Centre for Health Technology (CHT, **Chapman & White**).

UoA11 is also leading the recently established interdisciplinary UKRI Trustworthy Autonomous Systems (TAS) Hub, in collaboration with King's College London and University of Nottingham (<https://www.tas.ac.uk/>, **Ramchurn** (PI), **Butler**, **Chapman**, **Evers**, **Hall** (Co-Is)).

Also, several long-standing University-wide centres are led by UoA11 staff. The *Web Science Institute* (WSI, Directors: **Carr & Hall** (WAIS) and *Leonard* (Sociology)) is jointly led by UoA11 and social sciences. ECS is also home to both the UKRI-funded *Software Sustainability Institute* (SSI, PI: **Carr**) the world-leading hub for research software best practice, and the *Southampton Research Software Group* (RSG) which has a similar role but at the local level. Southampton is also home to one of 19 National *Academic Centres of Excellence in Cyber Security Research* (ACE-CSR), led by **Sassone**, recognising Southampton as an internationally leading institute for research on cybersecurity. ECS is furthermore home to the *IT Innovation Centre* which focuses on enterprise and applied research, and its staff are on enterprise contracts (rather than balanced pathways, REF5a§3.1). Finally, since 2018, Southampton is a member of the *Alan Turing Institute* (ATI) which has strong engagement from UoA11. Figure 1 provides an overview.

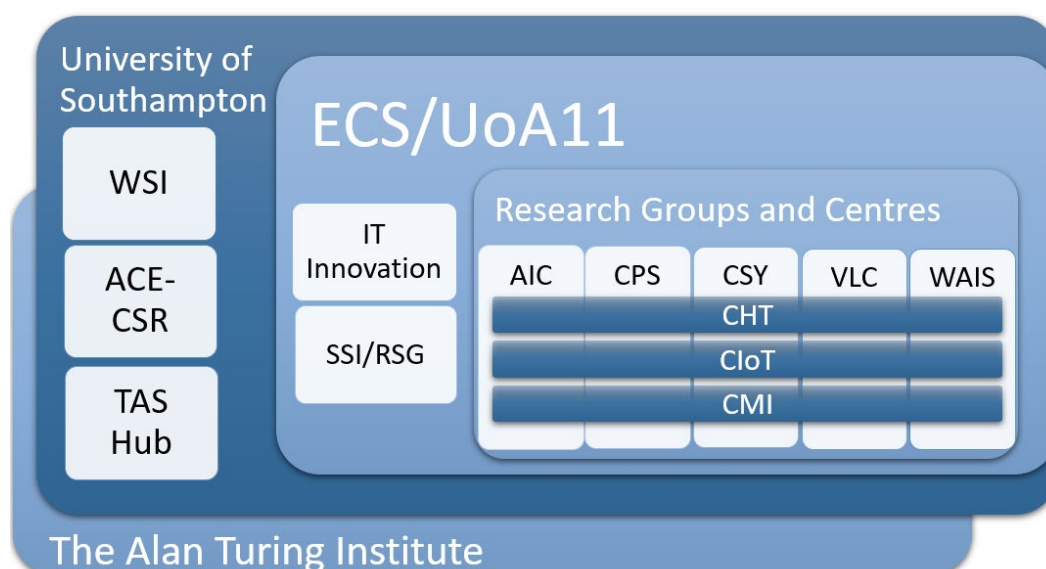


Figure 1: Overview of Unit Structure

1.2 Achievement of strategic aims 2014-2020

Our 2014-20 research strategy aimed to deliver world-class research and impact in a diverse range of interdisciplinary areas including formal methods, cyber security, AI and healthcare. During the 2016/17 academic year we conducted a thorough review of our overall strategy and structure. We identified the need to establish a new interdisciplinary group in Cyber Security and a refocusing of the CPS group (formerly Electronic and Software Systems). A clear need to develop additional cross-cutting research centres was also identified. This led to CMI, CIoT (which evolved from the existing Pervasive Systems Centre) and CHT, along with continuing centres delivering research excellence, impact, industry collaborations and funding.

Another important development has been the retirement of senior academics (e.g. **Poppleton** and **Wald**) and some of our top academics taking up prestigious positions elsewhere (e.g. **Shadbolt** became Principal of Jesus College, Oxford in 2015 and **Jennings** became Vice-Provost at Imperial in 2016). Our strategy has been to replace these positions by predominantly early career researchers (ECRs). Indeed, 22 (6F/16M) of the 51 UoA11 returned staff were hired over the REF period, of which 18 (6F/12M) were ECRs. Despite fewer senior staff, we were able to achieve and, in some cases, exceed our targets. Our aims following REF2014 were:

Aim 1: Deliver excellent science.

Over the REF period we have published almost 2000 research papers (conferences and journals). One indication of quality is the assessment of those indexed by Scopus, where 47% were in the top 25% (by CiteScore Percentile), and 83% in the top 50%, with papers in these categories increasing over the past 2-3 years. Our overall field-weighted citation impact was 1.67 in 2018, and 1.99 in 2019, compared to 1.48 average over 2014-2019, with around 19% in the top 10% for citations. Despite fewer staff we attracted more than £47M of new grant awards (§3.2).

Aim 2: Address major societal challenges.

We have restructured our groups and created the cross-cutting centres focusing on major challenges, including AI, cyber security, IoT and healthcare. These centres have led to some significant success such as the £12M TAS Hub and £1.5M Shell-funded *Centre for Maritime Futures* (CMF) (§3.1), the development of which have been enabled by collaborative activities organised by CMI. The TAS Hub will address the societal issues around AI, and responsible innovation. The focus of the CMF is to use digital technologies including AI to reduce carbon emissions from shipping.

Aim 3: Maximise research impact.

We have extensively engaged with University-level services including *Public Policy Southampton* (PP|S), *Public Engagement with Research unit* (PERu), *Future Worlds*, *SetSquared* (REF5a§2.3), increased our consultancy income (39 organisations; £2.1M income), and initiated new partnerships with industry and government (§4). In addition, we attracted more than £12M of impact-oriented funding including industry funding (§3.2).

Aim 4: Develop research leaders.

Following the research strategy set out in REF2014, we have continued investment in CS and appointed 131 research staff (26%F:74%M), of which 25 were senior research fellows, lecturers and above (32%F:68%M). There were 18 promotions over the REF period.

During the last REF period ECS proposed to grow the size of our Graduate School. In addition to core EPSRC DTP and additional school funding (§2.2), an important part of the training strategy included the establishment of Centres for Doctoral Training (CDTs). These include the UKRI-funded centres: Web Science (EP/L016117/1) and Next-Generation Computational Modelling (EP/L015382/1, led by Engineering) which both started in 2014, as well as the recent Machine Intelligence for Nano-electronic Devices and Systems (MINDS) CDT (EP/S024298/1, started April 2019) and AI for the Future of Society (AIFS, jointly funded by ECS and industry). This strategy has led to an increase in the number of students being awarded PhDs, from an average 28/year in REF2014 to 34/year in REF2021.

1.3 Future research strategy

Our ambition for UoA11 centres around four key pillars:

1. Enterprise

Establishing and sustaining long-term partnerships with industry and government organisations remains a key strategy. Partnership links are established and fostered in many ways, including through consultancy, Industry Days, KTPs, and engagement with ECS and University interdisciplinary institutes (REF5a§2.6) as well as other organisations within the University such as *Research and Innovation Services* (RIS). We will continue supporting our interdisciplinary centres, regularly revisiting them to see if refocusing is needed. We will further build collaborations between the *IT Innovation centre* and the research groups on application-focused grants. Furthermore, we maintain our 50% PhD funding pledge (§2.2.1), whereby the costs of studentships are shared between ECS and external partners, to foster long-term collaborations with industry.

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2. Grow research base in key areas

We will continue to build on our research strengths including formal methods, cybersecurity (e.g. through CSY group and ACE-CSR) the internet of things (e.g. through the CPS group and CloT), and expand in the following areas:

AI and autonomous systems. Central to this will be the TAS Hub with a strong focus on human-centred AI. The research from this newly established hub will build on extensive expertise in this area, including the award-winning ORCHID programme (§4). The hub is led by Southampton establishing a UK-wide collaborative platform to deliver world-leading best practice for the design, regulation and operation of ‘socially beneficial’ autonomous systems which are both trustworthy in principle, and trusted in practice by individuals, society and government. This strand of research will be further supported through **Stein’s** recent prestigious £1.4M Turing Fellowship award on Citizen-Centric AI Systems (EP/V022067/1), as well as our connection to the ATI. The CMI will continue to play a key role in developing and shaping the AI agenda in ECS and across the University, and we aim to appoint a new chair in human-centred AI.

Healthcare and wellbeing. This research will build on our extensive existing work and established links, such as **schraefel’s** prestigious EPSRC Fellowship on building a healthy nation (§3.2). The CHT will play an important role to form new collaborations and expand research funding in this area. There will be an increased emphasis on data-driven approaches for healthcare, driven by our recent NHS Digital Security Toolkit accreditation which enables the processing of pseudonymised NHS data (§4.1). Applications include improved health systems operations management, drug discovery, and precision and personalised medicine.

3. Training the next generation

Training PhD students remains core to maintaining a vibrant research community. Our aim is to continue training high-quality PhD students through the two CDTs led by ECS (MINDS and Future Society), as well as DTP funding. We will use the DTP funding to support strategic Faculty initiatives, including studentships for new cross-disciplinary research centres, improve the proportion of DTP funding allocated to ECR supervisors, and improve the use of the 50% rule (where costs are shared with industry investment). We will also take steps to improve the rates of thesis submission within the funding period and implement measures to further improve on equality, diversity and inclusion (EDI).

4. Increase the number and quality of UKRI submitted proposals and fellowships

Although we have met our targets for overall funding over the past REF period, we see opportunities to continue to improve our success rates. To this end, we will improve our mentoring and workshop initiatives, and deliver an improved internal review process, where each proposal is reviewed by two independent academics. In addition, we are discussing ways to reduce teaching loads for staff preparing proposals.

1.4 Impact strategy

ECS has developed a comprehensive strategy to cultivate, coordinate and establish a broad range of activities that delivers economic, institutional, and societal benefits to both University and non-academic partners. The strategy aims to increase industry funded partnerships of all types, fostering a culture that supports translation of theory to practice. We actively support staff to pursue significant impact activities through reductions in other duties. Staff can also take short term secondments to industry, or part-time buy-out from the University (§2.1).

The ECS strategy for enabling impact is facilitated through a wide range of activities and engagement in interdisciplinary research: long-term partnerships with industry fostered by, for example, the Cyber Security Academy and the ATI; the aforementioned ECS Centres (CMI, CloT, CHT); dedicated impact champion, enterprise director and committees to advise on strategy including incentivisation for enterprise activity by staff and students; an Industrial Advisory Board (IAB), which includes senior representatives from technology-focused companies and provides guidance on education, research and enterprise strategy; a consultancy unit, *ECS partners*, and many University-level partnerships and initiatives (REF5a§2), including *Future Worlds*, *SETsquared*, *Z21*, *RIS* and *PP|S*, some of which are led by

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and/or originated from ECS and all of which have contributed to the impact agenda. Z21 is a partnership between the University of Southampton (UoS) and the Solent Local Enterprise Partnership (LEP) supporting the development of Minimum Viable Products (MVP) and providing pre-seed funding.

Our impact case studies (ICSs) benefited from the ECS approach to impact. For example, w.r.t ICS11-04, our approach to interdisciplinary research (§1.5) led to a collaboration between UoA11 and UoA4, where behaviour interventions through the Royal College of Nursing resulted in reduced occurrence of hand dermatitis, and a reduction of antibiotic prescriptions in the UK and internationally. The promotion of open research and research integrity (§1.6) and the industrial links with the Ordnance Survey and others enabled wide impact with open image capturing and analysis libraries in ICS11-06. Collaboration with the Open Data Institute, the interdisciplinary Web Science Institute, and the leading role that ECS academics have in the Web Science Trust network of laboratories (§1.6), enabled the development of two data-driven innovation incubators, ODINE and DataPitch in ICS11-07; those have been independently assessed to have contributed to the creation of 896 jobs and unlocked €132.4M in revenues in the UK and Europe. The promotion of open research and research integrity (§1.6), and industrial engagement via *ECS Partners* enabled £0.6M commercial income for consulting and training to businesses on software verification and achieved widespread use of open-source software modelling and verification tools as detailed in ICS11-09.

Going forwards, we will maintain our existing strong culture for generating impact through established structures and organisations. We will reflect tangible and significant impact activities in the workload model and provide incentivisation and resources for these activities. We will continue to use *Future Worlds* as the preferred vehicle for marketing ECS research with impact potential, encouraging the costing of *Future Worlds* support in grant applications. We aim to provide a comprehensive overview of schemes and support to generate impact, including different options for commercialisation and blueprints for spinouts. In addition, we plan to develop further mentoring and training especially for PhD students and postdoctoral researchers around responsible research and innovation (RRI) and non-academic impact, using the MINDS CDT as a model. The MINDS iPhD programme integrates RRI and impact training and practice throughout, embedding a culture of impact early on. Students learn to think about impact on policy, society and the economy and how to communicate effectively with a wide variety of stakeholders. This training, along with the CDT Outreach Ambassadors programme, will be rolled out across ECS with a view to influencing PhD and research staff development across the institution.

1.5 Interdisciplinarity

Collaborative research across disciplines is at the heart of our research philosophy and is evident within our group structures, where two of our groups (VLC and CPS) and our centres (especially CloT and CHT) have academic members from both UoA11 and UoA12. These collaborative links are not isolated to groups, however, as illustrated by the EPSRC platform grant “Wearable and Autonomous Computing for Future Smart Cities” (EP/P010164/1), which recognises sustained interdisciplinary research excellence across AIC, CPS and the Smart Electronic Materials and Systems (SEMS, UoA12) groups, and the MINDS CDT which involves CS and nanotechnology and combines forces between AIC and the Zepler Institute for Photonics and Nanoelectronics. We also have close collaborations with the rest of engineering, as evidenced by the Shell-funded Centre for Maritime Futures, a collaboration between CMI and SMMI.

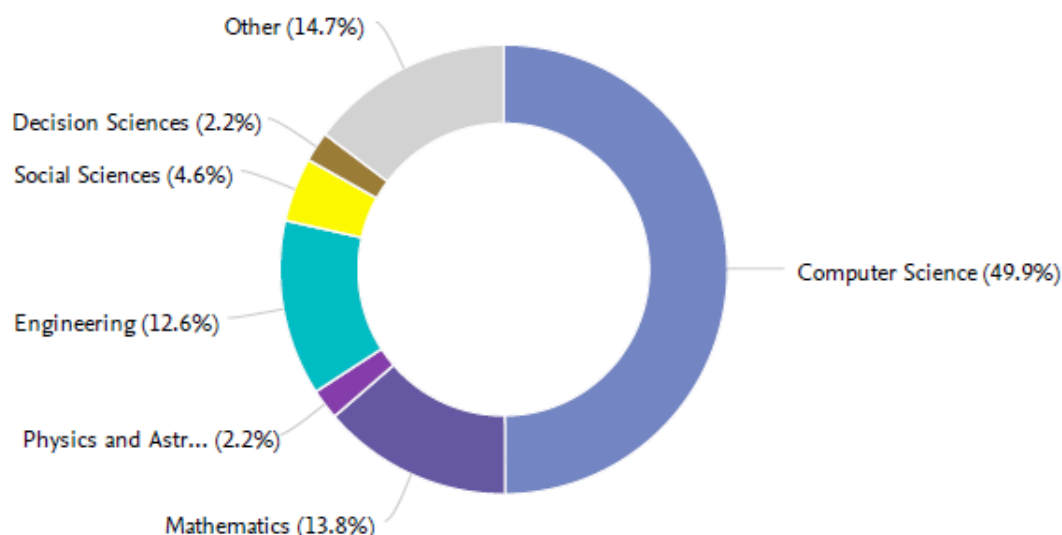


Figure 2: Southampton Publications by Subject Area for UoA11
Source: Scopus, December 2020.

Interdisciplinarity extends beyond engineering. Figure 2 shows that over 50% of papers are cross-disciplinary. Over 25% of the new awards over the past REF period are shared with other UoAs within the University (§3.2), and 39% of our PhD students are co-supervised with other UoAs.

1.6 Open research and research integrity

ECS, specifically UoA11, is at the forefront of open science, data ethics and governance. The first of 18 recommendations from **Hall's** AI review addresses the need to facilitate safe data-sharing by the creation of data trusts, which led to activities on standards for data trusts within the Royal Society and the Law Society of London. Also, **Hall** has been named Chair of the *Ada Lovelace Institute* for data ethics. Others, including **O'Hara**, **Tiropanis**, **Simperl** and **schraefel** have influenced policy around data governance (§4.2.1).

ECS has championed many open data initiatives. **Shadbolt** launched the Open Data Institute in 2011 and *EPrints*, developed by ECS 20 years ago, is the world's leading open-source digital repository platform, having been adopted by 675+ institutional and subject repositories world-wide (REF5a§2.3). The *Web Observatory* (<https://www.webscience.org/web-observatory/>) was developed by academics from the WAIS group towards a global catalogue of datasets, applications and projects related to research on the Web, in collaboration with laboratories in the Web Science Trust network and the Worldwide Universities Network. **Simperl** led *ODINE* (2015-2017), an EU-funded incubator for open data businesses, followed by the EU-funded *Data Pitch* open innovation programme to encourage corporate and public-sector organisations to share data with start-ups and SMEs that work with data (see ICS11-07). In addition, three other ICSs have achieved impact through the development of open-source software: ICS11-04 (tools for behavioural interventions), ICS11-6 (image processing and analysis tools) and ICS11-09 (formal modelling and verification tools). Furthermore, ECS has contributed to creating free and open training materials about digital accessibility with wide reach (§4.2.2). Finally, both SSI and RSG champion the use of open software within the University and the UK, for example, collaborating with the *Wellcome Trust* on openness of software and producing parts of the Trust's funding policy on this subject.

Regarding research integrity, all research involving human subjects and data, including projects using social media and secondary data sources, is reviewed by the Faculty Research Ethics Committee (FREC), applying University Ethics procedures (REF5a§2.8). All staff and PhD students undertake mandatory Faculty-wide training in ethics and research integrity. Reproducible research practices are strongly encouraged with researcher staff, academics and research students alike publishing code and datasets via *EPrints* with library assigned DOIs. The

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University is a signatory to the Concordat for Research Integrity, and there is a dedicated concordat group in ECS with representation from each research group.

2. People

2.1 Staffing strategy and staff development

2.1.1 Recruitment policy

The staffing strategy is implemented through a regular review process and outcomes are incorporated into the Faculty Strategic Plan. A central tenet of our procedures revolves around seeking the best talent worldwide, and subsequently developing tomorrow's research leaders. CS has seen a growth in areas of AI and cyber-security, and we have made strategic appointments in these areas including **Hu** (M) who is a leader in cyber physical hardware security, **Norman** (M) who is a leader in multi-agent systems, and **Staab** (M) who is a leader in semantic web. In addition, our focus has been on nurturing and attracting talented ECRs including those from leading universities and companies in the world: Oxford: **Konstantinidis** (M), **Marchioni** (M), **Zhang** (M), **Atamli** (M); Bristol: **Rastegari** (F), York: **Tarapore** (M); Imperial: **Evers** (F), **Karafili** (F); UCL: **Cai** (M); Surrey: **Kim** (M); CMU: **Sogokon** (M); Rome: **Aniello** (M); Goldsmiths: **Farrahi** (F); MITRE Corp.: **Chapman** (F, recently promoted to full professor). By having an environment that recognises the potential of outstanding, home-grown researchers, appointments have also been made from the best of our own: **Hoang** (M), **Hare** (M), **Packer** (F), **Ibanez Gonzalez** (M) and **Middleton** (M, originally on an enterprise pathway in the IT Innovation group).

Ensuring diversity is a key part of our recruitment strategy has led to significant changes to our policies. Marketing and advertising are written in gender-neutral language to equally represent male and female traits, and we have family-friendly policies supporting flexible/part-time working (§2.1.4). Candidates from under-represented groups are proactively approached and encouraged to apply. All shortlisting and interview panels are mixed gender. Membership of the interview panel is proscribed by role within the University and recent panels have included at least two women (chair and group representative). As a result, since 2014, female academic staff in UoA11 has grown from 11% in 2013/14 to 20% in 2019/20, which is well above the Russell Group benchmark (14%). Over the same period, the proportion of BAME academic staff has grown from 9% to 25%.

2.1.2 Supporting early career researchers

The standard balanced pathway for academics has a 40/40/20 teaching/research/admin workload. However, newly appointed academic staff have a reduced teaching load for the first 3 years with a gradual increase from 40% to 100% of their normal teaching load. They are all appointed mentors, allocated a PhD DTP studentship and £5k start-up. ECRs are given priority in the allocation of studentships. New staff work with their Head of Group/line manager during probation on a comprehensive personal research plan and, regardless of level, are supported by a senior academic colleague from within their research group who provides dedicated support and guidance. In addition, ECRs are encouraged to engage with the ECS Mentoring Programme, through which we match those seeking more focussed support in areas of interest, such as seeking funding or outreach. The mentoring initiative is led by the Senior Mentor, who reports to the ECS Equality, Diversity and Inclusion (EDI) Committee. Mentoring is a confidential process, intended to be a separate activity from regular managerial support and induction.

New staff are also supported through regular workshops covering topics such as finance, non-academic impact and other key aspects of an effective proposal. Successful applicants, more experienced researchers, and senior academic and professional services colleagues facilitate these events, with follow-up typically supported through ECS Mentoring. ECS also has an internal Grant Review Scheme in which all applications receive detailed feedback from two academics. In 2018 we introduced an ECS Fellowship Champion, who runs workshops to promote fellowships (including talks by female fellowship holders), and mentors applicants. ECS

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also runs mock interview panels for those reaching the interview stage of grants/fellowships (uptake 100%).

The University is a signatory to the *Concordat to Support the Career Development of Researchers*. Research Associates (RAs) are encouraged, and enabled, to explore career development opportunities, including workshops on developing a fellowship application, public policy impact, and outreach and public engagement in research. Initiatives such as short-term competitive seed-funding managed through our centres (CMI, CIoT, CHT & WSI) provide a means for research staff to develop research ideas and initiatives that are expected to lead to more significant activities. Additionally, two platform grants (Future Smart Cities and AutoTrust) have Flexible Innovation Funds. Researchers from across ECS can write short, EPSRC-like proposals capturing their own ideas, pitching them to senior academic colleagues, with successful proposals giving RAs the opportunity to plan, work independently on, and lead research projects.

2.1.3 Appraisal, recognition and promotion

ECS operates an open workload model that includes all teaching, administration and research duties. Enterprise and impact are explicitly reflected in promotion and seen as an essential part of the strong unit. All academic and research staff are appraised annually by their line manager through a confidential system designed to review their career progression and explicitly consider plans for progression and promotion. The University actively supports the recognition of success through schemes such as the annual Vice Chancellor's Awards (e.g. **Hare**), and Early Career Awards (**Tran-Thanh**).

ECS holds an internal review panel that evaluates all submitted applications and provides feedback to applicants. This allows applicants to improve their case prior to formal submission to the Faculty. Unsuccessful candidates are offered continued mentoring support to strengthen their case. Between 2013/14 and 2019/20, eight UoA11 staff were promoted to Associate Professor (8M/0F) and six to Professor (5M/1F). Promotions for women are below what is expected, and we have taken extensive measures to improve the success rate including encouraging more women to apply. Specifically, in 2016 ECS introduced promotion workshops with the aim to better inform staff of both the application process and criteria that need to be satisfied for successful promotion. Since 2019 we have held both mixed and female-only versions of these workshops. See also §2.3. Furthermore, as part of our Athena Swan action plan, we actively identify and nominate female staff for prizes and influential external committees. Participation in committees is strongly supported through appraisal and promotion criteria.

2.1.4 Flexible working and maternity leave

The University maternity provision provides up to 52 weeks' statutory maternity leave (regardless of length of service or contract type). Teaching and supervision are covered by paying postdoctoral fellows who want career experience, employing teaching fellows, or by transferring duties to academic staff who are underloaded. In the most recent instance, the University funded a full-time teaching fellow to cover two staff on maternity, both during their leave and after returning to work. In ECS five periods of maternity leave were taken by UoA11 staff between 2013 and 2020. The Faculty has a policy that all ERE staff on fixed-term contracts are eligible to receive fully-funded occupational maternity pay. In 2013 ECS introduced the additional policy that (where the funding body allows) staff can choose to extend their contract rather than hiring in cover, since this is often to their benefit. Up to ten 'Keeping-in-touch'/ twenty 'Shared parental leave in touch' (KIT/SPLIT) days are offered, whereby staff can undertake a limited amount of work without affecting statutory pay (e.g. to ease a return to work).

Arrangements for return to work are made according to an individual's level, roles, responsibilities and needs (e.g. a phased return to work can smooth the transition). Teaching and administration are reduced by 70% for the first year following leave to ease the transition and provide extra time to resume research activities. In April 2019 ECS also invested in a permanent 'quiet room' for mums to express/breastfeed with facilities to store milk safely.

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The University has a formal Flexible Working Policy which includes a process for considering requests for staff to change working pattern, or to change from/to part-time contracts. Requests to change hours are discussed initially with line-managers. Under research-funded contracts they can be approved by the grant-holder; for Faculty-funded posts Head of School and Faculty approval are required. During the REF period, 23 requests to decrease hours and 26 to increase hours were made and all were approved. The gender break-down of requests (20%F) is in-line with our overall staff profile (19%F).

2.1.5 Merit-based sabbatical programme and secondments

Southampton offers the opportunity for sabbatical leave every four years (REF5a§3.2). In ECS, the guidelines for applying include: scope (research plans and measurable objectives); relevance and fit to strategic direction of research (group and individual); funding (staff are encouraged to apply for external funding to support study leave); return from sabbatical and return to normal duties. We also operate an extended sabbatical scheme for secondment or buy-out into companies; e.g. **Ramchurn** was seconded 50% to *North Star Solar* from 6/2018 - 6/2019, and 50% to *Empati Ltd* until 6/2020.

2.2 Research Students

2.2.1 Funding and recruitment

Funding of CS students comes from CDTs (Web Science, AI for Future of Society and MINDS CDTs led by CS, and NGCM led by engineering), DTP funds, CASE studentships, industry and other schemes such as the China Scholarship Council (CSC) partnership scheme (whereby the University waves the fees), Southcoast DTP, Spitfire, and EU ITN. Over the REF period, ECS has also allocated additional funding of £220k/year for PGRs over and above the DTP funds (e.g. to cover international fees in order to utilise UKRI flexibility). Industry funding is through CASE studentships and ECS' matched funding guarantee (50:50 with external funds).

When recruiting, we actively approach female applicants especially from our local students. Our Careers Hub Director (F) runs the ECS Careers Hub and, since 2017, we have a "PhD Opportunities in ECS" stand promoting projects and funding. ECS also runs an annual UG Summer Internship Scheme to encourage the pipeline to PhD, funding ~25 students to undertake research in ECS over 12 weeks. Since 2017, we individually contact all female UGs with marks >70% to promote the scheme and prominently feature women in promotional materials. The proportion of awards to female UGs (24% in 2018) exceeds the proportion of females UGs (CS 16%, EEE 13% 2018/19). Over the entire REF period, we recruited more than 300 new PGR students (33%F) and the percentages of female PGR students studying CS have increased from 25% in 2013/14 to 32% in 2019/20.

2.2.2 Monitoring mechanisms and progression

The *PGR Tracker* tool, developed within the ECS Graduate School in the previous REF period, has now been adopted across the University and is seen as an exemplar of best practice for progression monitoring. This enables formal recording of all the training activities undertaken by each student (including compulsory modules on data management, research ethics and EDI, as well as optional modules on everything from Teaching and Demonstrating to Presentation Skills to ECS-specific technical and research-skills modules). The Doctoral Programme Director (DPD) for CS (**Hare**) together with the Graduate School team use reports from *PGR Tracker* data to identify potential problems with progression before they become an issue and provide support to students and supervisors. The DPD also provides a monthly progression report, broken down by research group and supervisors, which is discussed at monthly heads of research group meetings.

2.2.3 Skills development and preparation for future career

The University Doctoral College, the Faculty Graduate School and ECS provide a broad range of courses to enhance research-centred learning and transferable skills training to optimise the development of postgraduate students. Through Academic Needs Analysis (ANA), each student is provided with a structured and supportive process enabling them to reflect on their own learning and achievements, and to plan for their personal, educational and career development.

Unit-level environment template (REF5b)

Subject-specific training is delivered at Faculty, School and research group levels, which includes formal lecture courses, seminar programmes, reading groups, through to taking formal UG or PGT modules, etc. Eight Faculty-led PGR modules include research methodologies (with interdisciplinary and experimental methods), responsible research, ethics and outreach. This complements central provision including presentation and writing skills. Our students can also join training programmes, such as the Software carpentry sessions run by SSI. Some CDTs have career-oriented modules and training events such as the MINDS CDT on Impact and Communication Strategies which teaches students about pathways to impact and responsible research and innovation. Students are also encouraged to attend summer schools and doctoral mentoring programs, both local and external.

Each ECS PGR student has a personal Research Training Support Grant (RTSG) of £1,200/annum, to present papers at conferences, attend summer schools and buy necessary consumables for research that is not otherwise available. Our students are also encouraged to be actively involved in conferences as volunteers, session organisers and as reviewers.

Students often undertake industrial internships or visit different institutions during their research programme with the support of their supervisory team, and have also won funding to transfer knowledge and build impact from their work. For example, Andrew Hill was awarded an EPSRC National Productivity Investment Fund placement grant (2019) to work with the *Zoological Society of London* for 6 months. Within the MINDS CDT, each student is paired with an industrial partner, and as part of their PhD programme, undertakes an internship with the partner.

The *Future Worlds* start-up accelerator takes a leading role in developing the entrepreneurial skills of our students, providing expert coaching for those developing commercialisation ideas; for example, Daniel Martinho-Corbishley and Jaime Lomeli launched *AuraVision* and Iris Kramer has launched *ArchEO* based upon her PhD research. The culture of developing impact from research within ECS is further illustrated by the work of Tim Matthews and Ryal Beal working with **Ramchurn** to launch the analytics company *Sentient Sports* (§4.2.3).

2.3 Equality, diversity and inclusion

ECS received an Athena SWAN (AS) Bronze award in 2012. While the AS action plan helped deliver changes, initially, the activity was insufficiently embedded in the ECS operational structure. Consequently, we lost our AS Bronze status and created the ECS EDI Committee in 2016/17 to address this. Membership comprises representatives from every major area in ECS, all research groups and job families (REF5a§3.1). The ECS Athena SWAN Self-Assessment Team (SAT) is a subcommittee which focuses on identifying and addressing gender inequality. The Head of School is both a co-chair of the ECS EDI Committee and a member of the SAT. The restructure delivered key initiatives, some of which (e.g. the ECS Mentoring Scheme, promotion workshops, and quiet room) have already been mentioned. Others include International Day Against Homophobia, Transphobia and Biphobia (IDAHTB), Female Staff Forum, Wellbeing Champions, and a new Code of Conduct. The restructuring of the EDI Committee now makes it an integral part of how ECS operates, and the mechanisms in place have proved effective in delivering actions. This is evidenced by our successful 2019 Bronze AS Award. The action plan developed in this submission has been formally adopted by the EDI Committee and approved by ECS Board, with actions distributed to individuals and groups throughout ECS as indicated. We will submit our Silver AS application in 2021.

In line with this plan and the University's *REF2021 Code of Practice*, REF champions participated in unconscious-bias training sessions. For selecting REF outputs, individual academics proposed up to five papers which were assessed by a minimum of two independent reviewers from other research groups to prevent bias. The reviewers were selected based on group and gender representation and were given a similar number of papers to review. The final selection was done through the University's outputs optimisation algorithm, with a custom feature to prefer a balance of papers per person and by gender in case of similar scores.

3. Income, infrastructure and facilities

3.1 Strategy for generating Income

A key element of our funding strategy from REF2014 was to diversify income, drawing upon a wider range of funding sources. This includes supporting new collaborations, particularly across disciplines, by allocating core funding for CloT, CHT and CMI. The School invests £85K annually on seed funding for research activities, and part of this fund has been used to kick-start these centres. The plans for each of these centres focus on them becoming financially self-sustaining in a similar way to WSI. The centres run regular events, bringing together academics from across the University, industry, government and third sector partners. The CMI Showcase brought together over 200 participants including 60 companies in 2019. Similarly, the CHT has held regular “Clinicians meet Engineers” events. These interdisciplinary events have enabled substantial current and future funding through the MINDS CDT, TAS Hub (commenced 01/09/2020, EP/V00784X/1), the Shell CMF, and HD-Sec (commenced 01/08/2020, EP/V000489/1). We have been successful in extending our funding sources, including *Leverhulme Trust*, *John Templeton Foundation*, the *DASA*, *AXA*, *Shell* and *NIHR*. During the assessment period, we have also played a leading role in the University by establishing a number of strategic partnerships with industry and government partners including *Roke Manor*, *DSTL*, *Thales* and *GCHQ*.

Support for developing proposals is provided at many levels. We strongly engage with the University’s *Research and Innovation Services* (RIS, REF5a§1.5), who provide training as well as support for EU and UKRI grants, including business engagement officers to support InnovateUK grants and other industry collaborations. The University’s *Research Finance Hub* provides support for financial planning. We provide additional dedicated training and support within ECS and across the Faculty, including an annual Research Week event with tutorials and Q&A sessions on diverse funding mechanisms. ECS support is particularly focussed on ECRs and colleagues joining us from outside the UK, as well as underrepresented groups. All ECRs, for example, are supported through the process of developing a New Investigator Award (NIA) proposal with one-to-one mentoring, and access to a writing consultant. ECRs have also benefitted from the CPHC “Chair in 10 Years” workshops. Colleagues who have been successful with specific funders or schemes (e.g. *Leverhulme*, or programme grants) are paired with those planning proposals. Subject-specific mentoring and review is supported through research groups, and ECS has an internal grant reviewing process. This process simulates the real review process, including the allocation of referees and mock interviews. The ECS support is targeted at women by having female role models and speakers, highlighting grant successes by woman, and running events specifically for women. For example, CMI organised a “Women in AI” event in 2019 with high-profile female speakers.

3.2 Major grants

Over the REF period, our income expenditure totalled £43M (£5.7M P/A) and we were awarded 166 new grants worth over £47M for UoA11. Our research has been supported by three programme grants: ORCHID (PI *Jennings*, now Imperial, £5.5M, 2011-2016); SOCIAM (PI **Shadbolt**, now Oxford, £6.2M, 2012-2015) with continued funding led by Oxford (PI **Shadbolt**, CI **Hall**, £2.7M, 2015-2018), PRiME (PI *Al-Hashimi*, CI **Butler**, £5.6M, 2013-2018). In 2016, ORCHID won the Collaborate to Innovate award. We have also secured an EPSRC Fellowship for **schraefel** (£1.6M, 2020-2025) and two platform grants: “Wearable and Autonomous Computing for Future Smart Cities” (PI Beeby (UOA12), CI **Ramchurn**, £1.4M, 2017-2021), and AutoTrust (PI **schraefel**, £1.6M, 2018-2023, £886K to Southampton).

Research training has been supported by two competitively won CDTs: Web Science Innovation (PI **Hall**, £3.7M, 2014-2023) and MINDS (PI **Norman**, £5.8M, 2019-2027).

Major interdisciplinary projects include the NERC-funded “*Does developmental plasticity influence speciation?*” (PI Ezard (UOA7), CI **Watson**, £1.6M, 2017-2022), EPSRC-funded “*Early detection of contact distress for Enhanced performance monitoring and predictive inspection of machines*” (PI Wood (UOA12), CI **Niranjan**, £1.1M, 2019-2022), EPSRC-funded GCRF-funded

Unit-level environment template (REF5b)

“*BRECcIA*” project (PI Sheffield (UOA14), CI **Ramchurn**, £5.5M, 2017-2021, £3.6M to Southampton), the EPSRC Network of Excellence “Artificial and Augmented Intelligence for Automated Scientific Discovery” (PI Frey (UoA8), CI **Niranjan**, £1.2M, 2018-2022), EPSRC-funded “*Joining the dots: from data to insight*” (PI Brodzki (UoA10, CI **Niranjan** and includes CIs from UoA10 and UoA5, £1.2M, 2015-2019) and the Shell-funded “Centre for Maritime Futures” (PI Hudson (UOA12), CI **Ramchurn/Gerding**, £1.5M, 2019-2024).

International collaboration is a further characteristic of our research portfolio with more than £22M worth of H2020 EU funding, as well as the US/UK DAIS ITA (PI **Stein**, £728K, 2016-2021) and the “Centre for Spatial Computational Learning” led by Imperial (CI **Hare**, £1.2M, 2019-2022) among others.

Substantial impact-oriented funding includes the EPSRC-funded “Software Sustainability Institute” (PI **Carr**, £3M, 2015-2023), and the H2020 projects “Open Data Incubator Europe” (PI **Simperl**, now KCL, £4.9M, 2015-2017). New UK industry and central government funding totalled £4.2M including £1.25M Innovate UK funding and £1.3M from industry.

3.3 Facilities and infrastructure

We have invested in research laboratories to support both existing research strengths and to directly support the research of ECRs. In 2019, for example, we invested £110K in a new Robotics research lab, including the cost of a TIAGo robotics platform, which supports a range of projects including resilient robotics (**Tarapore**) and human-robot collaboration (**Evers**, **Ramchurn**). The UKRI AI MINDS CDT lab was established in 2019 with £82K of investment from ECS, providing the centre with an environment to support collaborative research and cohort building. We invested in an £70k IoT testbed facility including a £50k contribution from GCHQ. This interdisciplinary multi-purpose environment serves a variety of research activities in the area of cybersecurity and IoT more generally.

Compute-intensive research is supported through the IRIDIS cluster. The University invested £50M into this resource over the REF period (REF5a§4.2). Further investment totalling £192K (24 NVidia RTX8000 GPUs across six cluster nodes) has been made jointly by Faculty, ECS and the MINDS CDT for the exclusive use of ECS staff and research students, particularly in support of AI research.

3.4 Impact

An important route to impact for our research is through consultancy, supported through a dedicated Business Development Manager (Darlington) and *ECS Partners Ltd*. UoA11 staff have provided consultancy to over 39 different organisations totalling £2.1M. *ECS Partners* assists with licencing academic IP and the translation of research via, e.g., the creation of spin-out companies, thus maximising research impact in diverse areas, and supports early routes to market for potential impact cases, including over £0.6M to commercialise a formal verification toolbox developed by **Butler** and others (§1.4).

Economic impact is further facilitated through *Future Worlds* (REF5a§2.3). This accelerator started life in ECS and is now a world-leading start-up incubator which nurtures aspiring entrepreneurs and cutting-edge technologies through one-to-one support and a network of seasoned founders, investors and millionaire entrepreneurs. *Future Worlds* has led to over 30 start-ups launching or raising investment totalling over £5.8m, including five involving CS staff and/or PGR students (§4.2.3).

In addition, *SETsquared’s* Innovation to Commercialisation of University Research (ICURe) programme, provides support for potential University start-ups and spinouts, and has helped establish several successful routes to commercialisation, including *Blupoint* (§4.2.3). Furthermore, the WSI has an initiative *Zero-to-one* (Z21), a £500K collaboration with the Solent Local Enterprise Partnership. Z21 has provided £200K of minimum viable product and pre-seed funding for seven start-ups (involving 12 ECS staff and students) since its inception in 2017. These initiatives have led to £1.2M worth of Innovate UK projects over the REF period including three Knowledge Transfer Partnerships (KTPs, §4.2).

Unit-level environment template (REF5b)

Enterprise activities are at the heart of the *IT Innovation Centre* (§1.1). A centre of excellence in applied research and knowledge exchange, it takes fundamental research through higher technology readiness levels towards the development of ideas for commercial exploitation. IT Innovation also leads the ECS industrial strategy working with other ECS groups and centres to establish industry and public sector propositions, and a culture of collaboration for effecting partnerships. IT Innovation leads the regional initiative *Coalition for Innovation and Digital Health Research* (CIDHR) across Hampshire and the Isle of Wight to build research and innovation pipelines into health and care systems, working with University Hospitals Southampton NHS Foundation Trust Public Health and the NHS Scientist Training Programme.

Impact is further facilitated through the three centres, which provide a primary point of contact for industry and government collaborations, and the organisation of the aforementioned events.

Policy impact is facilitated through the University's public policy unit (REF5a§2.9), which connects researchers to policymakers and provides a range of services around impact including training, secondments, and policy consultations (§4.2.1). §4.2 provides impact highlights achieved over the REF period.

4. Collaboration and contribution to the research base, economy and society

4.1 Research collaborations

CS has a strong track record in building collaborations with other institutions and with industry. Arrangements in place to support this at University level include RIS (REF5a§1.5). In addition, as member of the ATI, we have dedicated staff in ECS to encourage participation. At the census date we had five ATI pilot projects led by CS staff, seven CS ATI fellows (§4.4.1), and another seven where CS staff are co-investigators. Almost all grants have an interdisciplinary component or are joined with other institutions including industry. In particular, the recently awarded TAS Hub facilitates engagement with over 60 partners in areas ranging from computing and robotics to social sciences and the humanities. ECS supports industrial partnership within the WSI-fostered *Centre on AI for the Future Society* within the Web Science Institute (WSI) and, previously, within the Web Science CDT.

ECS also has extensive collaborations, strategic partnerships, secondments and knowledge exchange activities with industry, NGOs, and government organisations. Examples include:

- Collaboration with researchers in Turkey, the UN (ILO) and industry on the use of sensor fusion and stream reasoning algorithms for real-time health and safety regulation monitoring in workplaces (incl. mining operations). British Council/Tubitak, €268K, 2017-19.
- Cyber security: “Chief Scientific Officer” at the Italian Ministry of Economy and Finance (**Sassone**); secondment of researchers as “Technical Fellows” to The UK Cabinet Office (**Ferdous, Margheri**); pilot of blockchain-based systems for “exporter bonds” at the Department of International Trade (**Margheri**); managing mobile phone numbers at Ofcom (**Margheri, Sassone**); peer-to-peer trading of energy at Ministry of Science & Technology, India (**Lombardi, Margheri, Sassone**); large-scale secure payroll at the Italian Ministry of Economy and Finance (**Aniello, Margheri, Sassone**); and taxation in Malta (**Margheri, Sassone**).
- Academic appointments: Endersby (formerly Head of Division DSTL, now CEO of the MET Office), visiting Professor in the CSY group, she sits on the CSA Strategy Board and contributes to our strategy for enabling impact through her role as mentor with *Future Worlds*. **Jennings**, Pro-VC research at Imperial, as Visiting Professor in AIC, contributed to PhD supervision and collaborated on several projects including DAIS-ITA. Stanford-Clark, CTO IBM UK is a Visiting Professor in AIC. Meers, Fellow at DSTL and Head of AI Labs at DSTL, is an Adjunct Professor in ECS, RAEng Visiting Professor and sits on the industrial advisory board, contributing to the TAS Hub. Wilby from Thales is Adjunct Professor in ECS and advises on several ongoing research projects.

Unit-level environment template (REF5b)

- The Arm-ECS partnership celebrated its 10th anniversary in 2018. This Industry-University collaborative initiative focuses on advanced hardware and software co-design, has been cited as an exemplar for such partnerships by the EPSRC, and was invited to contribute to the Dowling Review of Business-University Research Collaborations. It was awarded 'University Research Group of the Year' in 2015 by the UK technology industry body, TechWorks.
- **NHS:** IT Innovation is one of six University groups to secure the NHS Digital Security Toolkit accreditation allowing research teams to process NHS data within a secure and ethical environment. The activity has led to significant local, regional, national and international collaborations. Partnerships with NHS organisations (e.g. University Hospital Southampton (UHS) and Wessex NHS Trusts) and local authorities (Southampton City Council (SCC)) have been established in response to COVID and wider challenges of digital health. ECS is now digital lead within the recently established Wessex Academic Health Sciences Centre and has formed the Social Data Foundation (www.socialdatafoundation.org) as a partnership between University, UHS and SCC tackling challenges of health and social care transformation.
- Shell is funding the Centre for Maritime Futures (CMF) through a £1.5M gift donation.
- Roke Manor sponsored **Sassone's** Royal Academy of Engineering (RAEng) Chair and is a key partner in MINDS CDT.
- GCHQ sponsors the Cyber Security Academy, a GCHQ centre of excellence hosted by ECS and funds several projects.

4.2 Contributions to economy and society

4.2.1 Policy impact

ECS has extensive impact on policy through high profile academics such as **Hall**, **Sassone** and **Jennings**. In addition, policy impact is facilitated through the University's public policy unit, which connects researchers to policymakers and provides a range of services around impact including training, secondments, and policy consultations.

Notable examples include:

- **Hall** is member of the UK Government AI Council and is their AI Skills Champion. She co-authored the influential AI review entitled "Growing the AI Industry in the UK", commissioned by DCMS and BEIS, and has shaped the government's AI agenda. <https://bit.ly/2qExHdU>. This led to the establishment of the Office for AI. **Hall** is a member of the World Economic Forum's Global Futures Council on the Digital Economy, and participated in several UK government roles: UK Government AI Sector deal (2018); Final report of the Global Commission on Internet Governance: One Internet (2016); RUSI report "A Democratic Licence to Operate: Report of the Independent Surveillance Review" (2015).
- **Jennings** was HM Government Chief Scientific Advisor for National Security to the UK government (2010-2015).
- **Simperl** was invited to co-author a White Paper on engagement models for data trusts, presented to the Office for AI, the Government Office for Science and the Department for the Environment and Rural Affairs.
- **Sassone** is member of the Strategic Cyber Governance Group of the South East Regional Organised Crime Unit of the Police; Chief Scientific Officer for project Noi-PA of Ministry of Economy and Finance (Italy).
- **O'Hara's** work has impacted policies around data governance. His anonymisation work led to the Anonymisation Decision-making Framework, published in 2016 by the UK Anonymisation Network (UKAN) and adapted for Australian law in 2017 with CSIRO and

Unit-level environment template (REF5b)

for GDPR in 2020. Since 2019, **Hall** and **O'Hara** have worked with the Royal Society and the Law Society of London to produce standards for data trusts.

- **Snow** (PDRA, AIC group, 2015-2019) was seconded to DEFRA (July-October 2018), and authored a report on behaviour change interventions focussed on indoor air quality.
- **Tiropanis** contributed to the EIT Digital report on "European Digital Infrastructure and Data Sovereignty - A Policy Perspective" (June 2020).
- **Middleton** was AI expert to UK Cabinet Office on "use of AI in policing" (2019).
- **schraefel** was a member of the of the World Economic Forum (WEF)'s data policy working group in 2019-2020 and was invited to work with Facebook on their privacy-by-design approach which contributed to the WEF's report on "Redesigning Data Privacy: Reimagining Notice & Consent for human technology interaction" (July 2020).

Policy impact was also achieved by our enterprise-focused institutes (§1.1), e.g.:

- SSI has significant influence on policy with regards to recognising software as an important part of research, leading to 28 Research Software Engineer groups across the UK, and the development of the e-infrastructure section of the 10-year UKRI roadmap.
- **Pickering** (IT Innovation) co-chaired the Global Research Data Alliance Legal and Ethics working group producing guidance for researchers and policy makers during COVID-19.
- **Boniface** (IT Innovation) led an interdisciplinary team to forecast the impact of COVID-19 on hospitals providing insight to UHS and regional decision-makers.

4.2.2 Broader contributions to the economy and society

In addition to the impact described in §1.4 and §3.4, highlights include:

Health and wellbeing: In 2016 **schraefel** set up the *wellthlab* (<https://www.wellthlab.ac.uk/>) with the vision to "make normal better for all at scale". The lab's mission is to develop, research, innovate, and question how interactive technologies and services can improve health and well-being. This has led to a series of international workshops on the "inbodied interaction" approach to computational interactive technology which **schraefel** has developed and has been featured in a special issue of IX magazine, the leading forum of the ACM for human computer interaction. This work has also been shared in an international summer school sponsored by the ACM and hosted at the UoS with participants from ten countries. This methodology is being adopted in the human-computer interaction undergraduate and post graduate curriculum in the UK and abroad, as **schraefel** has been helping groups including Cardiff, Edinburgh, Bath, Lancaster, Sheffield, Swansea, Brigham Young, UCSD, LSM and others to incorporate the approach into their regular HCI teaching. **schraefel** is also the University's Health and Wellbeing Champion and co-founder of the LivingLab for leading wellbeing as lived research on the University campus.

Accessible technology: Research by **Wald** et al on technologies to address gaps in media accessibility is reflected on the LexDis website (<https://www.lexdis.org.uk>) that provides strategies and support to approximately 10,000 users annually. Because of its recognised impact, LexDis was chosen in 2019 to host the national guidance information for the new UK accessibility regulations. This work also led to the creation of free and open training materials on digital accessibility and inclusive teaching and learning environments that have been used within a series of Massive Open Online Courses (2016-2018) with over 20,000 registrants. Furthermore, through an Innovate UK Knowledge Transfer Partnership (KTP) project (investigators: **Wills**, **Wald**) with *Microlink PLC*, technologies for automated accessibility assessments were produced leading to a turnover and profit increase for the partnering company; this had a further impact in the companies employing disabled people, and to the UK economy by reducing the cost of benefits and increasing tax revenue.

Disaster response: In the aftermath of the deadly earthquake in Nepal in 2015, algorithms developed by **Ramchurn** et al as part of the ORCHID project enabled the processing of large volumes of satellite and aerial imagery, and identified likely impacted locations not yet visited by

Unit-level environment template (REF5b)

emergency response workers. This benefitted rescue work by Rescue Global who were partners on the project.

Smart environmental monitoring: In 2018, a team from ECS included **Rogers** and two CS PhD students (Hill and Prince) who designed and developed *AudioMoth* (<https://www.openacousticdevices.info>), acoustic technology for identifying species and gunshots based on machine learning techniques. This technology has been deployed for the purpose of conservation in 687 projects across six continents and enabled the identification of three new orthoptera species in Brazil, and conservation projects by the Bat Conservation Trust in the UK, as well as the Belize Forest Department in its 25km² Tapir Mountain Nature Reserve. Hill later applied similar technology at the London Zoo where he completed a secondment.

Apart from the KTP on accessible technologies (see above) impact is achieved through two additional KTPs: With *The ai Corporation* (investigator: **Niranjan**) fundamental research on outlier detection in the area of bioinformatics is applied to a credit card fraud detection system of the partnering company. *ExecView* (investigator: **Wills**) is embedding the latest research in business psychology and gamification in its software for project and programme management support.

4.2.3 Spin-outs

The ECS enterprise strategy has resulted in several novel spin-outs during the REF period:

ArchAI (<https://www.archai.io/>) was founded by CS PhD student Iris Kramer. Using deep-learning AI for archaeological surveys to reduce the need for manual field assessment, *ArchAI* received £70K investment from *Future Worlds* dragons (<https://futureworlds.com/ai-archaeologist-tops-triple-investment-success-in-future-worlds-dragons-den/>) and was valued at £770k in November 2020. This led to further funding and an RAEng Enterprise Fellowship (outside of the REF period) for its CEO, Iris.

AuraVision (<https://futureworlds.com/discover-aura-vision-labs/>) was founded in 2017 by former CS PhD students with the help of *Future Worlds* and Z21 funding and resulted from the student's PhD work.

Blu.Network (formerly *BluPoint*; Co-founder: **Wills**) delivers educational materials and health information to people in remote areas using solar-powered content servers. The spin-out was formed in 2015 winning an ICUR programme award and received £500K funding from Innovate UK. The company attracted new investors and, as *Blu.Network*, is deploying pilots in many diverse locations including Dixons Carphone in South Africa.

Empati Ltd. (Director: **Ramchurn**), incorporated in July 2019, is building on research for energy-saving, agent-based algorithms. By the end of the census period, *Empati* had received external investment of £2M and been granted 'notices to proceed' by UK Export Finance for solar energy projects in Colombia and South Asia totalling £500M.

ResearchProof (**Lombardi**, <https://www.researchproof.com/>) has recently been awarded an EU H2020 "SME Instrument Phase1" grant, and Phase1 and Phase2 "Seal of Excellence". Microsoft has shown an interest in the project and in May 2018 offered to support the development of a prototype R&D lab in Zurich.

Sentient Sport (Director: **Ramchurn**, www.sentientsports.com) was launched in April 2020 with help of *Future Worlds* and uses AI to optimise decision making in sports. It builds on the AI research by Ramchurn and his former PhD student Ryan Beal. <https://futureworlds.com/sentient-sports-ai-powered-player-recruitment/>

SPYDERISK (<https://spyderisk.com/>) was founded in 2019 by members of the IT Innovation group and provides tools to automate cyber risk assessment for compliance and certification (e.g. ISO 27001).

WEBDROP Ltd (Co-director: **Tiropanis**), incorporated in July 2019, provides an online secure data sharing service. Z21 provided MVP and pre-seed funding, while *Future Worlds* provided mentoring.

4.3 Public engagement and outreach

Research focused outreach in ECS is led by the Director of Outreach and Recruitment (**Merrett**, UOA12) together with a dedicated Outreach Manager. As a result of her work, **Pau** (F) has won WiSET and UoS Dean's Awards for championing women in STEM. In addition, about 75% of staff at all levels participate in outreach activities. During the REF period we have engaged with over **39,000** young people aged 11-17, and participated in **280** talks and events including: an annual summer taster course, annual Science and Engineering Day, taster days, school assemblies, school lessons, after-school club sessions, teacher breakfast sessions and careers fairs. We also engage with local events such as Pint of Science and the British Science Festival, and major events including the Farnborough Airshow and the BBC Countryfile Show through the University's *PERu*. In her role as the MINDS CDT Outreach and EDI Champion, **Pau** has established an Outreach Ambassadors programme, providing enhanced training for research students in outreach leadership. As this develops, we plan to use this as the basis for a programme across ECS, extending it to research staff.

An important part of our outreach strategy is to tackle gender imbalance and increase female participation in STEM. Since 2017, we have created four 'A-level Physics Kits' demonstrating CS principles. These were piloted with female students and each year we send 250 sets to local schools and train teachers to use them. Also, since 2014, ECS has hosted the annual Smallpeice residential summer school on topics including CS and robotics, with 50 students from 40 schools around the UK (averaging 38%F) and led by a female ECS academic. ECS also annually hosts a range of school visits within its teaching laboratories, and our policy is to ask schools to bring a 50:50 gender group. We also have 'Women in Tech' days with 10-50 female students.

schraefel initiated and leads the national seminar series with international experts on how to improve engagement of women as undergrads in CS (<https://cphc.ac.uk/cphc-seminar-series-the-women-into-computer-science-experience/>), which has over 800 members. This has also led to the Heads of CS ENGAGE group that continue to explore this space.

4.4 Esteem

4.4.1 Prestigious memberships and titles

UoA11 has a total of **38** prestigious memberships and titles from **17** current and former staff (former staff are **Jennings**, **Shadbolt**, **Moreau**, **Simperl**; they were at Southampton during the REF period with titles before they left; **Wald** retired). Specifically:

10 FBCS (**Butler**, **Hall**: *DistFBCS*, **Jennings**, **Moreau**, **Niranjan**, **Sassone**, **Simperl**, **Shadbolt**, **schraefel**, **Hu**); 5 FIET (**Nixon**, **Ramchurn**, **Hall**, **Hu**, **Wills**); 3 FREng (**Hall**, **Jennings**, **Shadbolt**); 3 EurAI Fellows (**Staab**, **Jennings**, **Shadbolt**); 2 RAEng Chairs (**Sassone**: Roke, **schraefel**: Microsoft); 7 Turing Fellows (**Brede**, **Chapman**, **Konstantinidis**, **Ramchurn**, **Simperl**, **Stein**, **Wald**); 3 Orders of Chivalry: **Hall** (DBE), **Jennings** (CB), **Shadbolt** (KBE).

Others: FRS (**Hall**); BMVA Distinguished Fellow (**Nixon**, 2015), IAPR Fellow (**Nixon**); AAAI fellow (**Jennings**); Regius Professor (**Jennings** 2014-2016, **Hall** 2018-).

Other significant memberships include:

Butler: Chair of IFIP Working Group 2.3 Programming Methodology (2013-2019).

Hall: Chair of the Ada Lovelace Institute, (2017); member of AI Council UK Government; member of the World Economic Forum's Global Futures Council on the Digital Economy; BT Technical Advisory Board

Sassone: Academia Europaea, elected member; Member and founding president of ETAPSeV, the European Association for Theory and Practice of Software; Member of the Board and of the Council of the EATCS, the European Association of Theoretical Computer Science; Member and former chair of the EATCS Awards Panel; Member of the IFIP Technical Committee TC1, Foundations of Computer Science; Member of the UKCRC.

Unit-level environment template (REF5b)

Staab: Advisory board member of L3S Research Center, Hannover (2012-2018); Board member of Semantic Web Science Association (2015-2018); Chair of Web Science Trust Network of Research Labs (since 2015).

Funded Fellowships include:

Cai: Issac Newton Trust (2015), Wellcome Trust (2014- 2015).

Marchioni: Marie-Curie (2012-2014).

schraefel: EPSRC Established Career Fellowship (2020).

Tarapore: Marie-Curie (2015-2017).

4.4.2 Major roles at conferences

During the REF period, **20** of our current (at census date) UoA11 staff had a total of **48** chair roles at international conferences, e.g. as general or programme (co-)chair, including ACM Hypertext 2019 (**Millard**, Programme Chair), Ubicomp 2019 (**Farrahi**, General Chair), ACM SigCHI 2017 (Program Chair) and 2017 International Joint Conference on Biometrics (Nixon, General Chair). In addition, most staff at all levels are engaged as regular members or senior members of program committees at top conferences (e.g. AAAI, IJCAI, AAMAS)

4.4.3 Conference plenaries and keynotes

During the REF period, **15** current UoA11 staff gave over **70** plenary and keynote talks at conferences and other major events: **Chapman** (1), **Hare** (1), **Hall** (34), **Hu** (5), **Rastegari** (1), **Mahmoodi** (1), **Middleton** (3), **Martinez** (1), **Millard** (1), **Nixon** (7), **Ramchurn** (1), **schraefel** (1), **Staab** (11), **Tiropanis** (2). These include a plenary at ACM CHI 2017 (**schraefel**) and the World Summit AI (**Hall**).

4.4.4 Journal editorial boards

Over the REF period, **12** UoA11 staff were members of editorial boards or editors of **29** scientific journals: **Butler** (3), **Cirstea** (1), **Farrahi** (1), **Hare** (1), **Hu** (6), **Gerding** (2), **Mahmoodi** (2), **Millard** (1), **Sassone** (4), **schraefel** (2), **Staab** (5), **Wills** (2). This includes Editor in Chief of IET Cyber-Physical Systems (**Hu**) and Advanced Research in Computing and Software Science (**Sassone**). In addition, **13** staff were guest editors for **28** special issues: **Butler** (4), **Chapman** (1), **Cirstea** (2), **Hoang** (1), **Hu** (5), **Mahmoodi** (2), **Marchioni** (1), **Middleton** (1), **Norman** (1), **Ramchurn** (2), **schraefel** (1), **Stein** (1), **Wills** (6).

4.4.5 Honours and awards

13 staff received 17 best paper awards: **Evers** (HSCMA 2017); **Gerding** (IEEE/WIC/ACM WI-IAT 2015); **Stein** (AAMAS 2016 Best Innovative Applications Paper); **Millard** (ACM Hypertext 2016 Engelbart Best Paper Award, E-Learn 2014 Outstanding Paper Award); **Hare** (CrowdBias Workshop); **Hu** (IEEE Systems Journal 2018); **Karafilis** (Best Poster MCAA General Assembly 2019); **O'Hara** (WebSci'16); **Nixon** (CAIP 2015); **Ramchurn** (AAMAS 2015); **schraefel** (IADIS WWW/Internet 2015; UbiComp '13); **Staab** (Outstanding Contribution Design 2018, Best Video ETRA '18, Best Student Paper IEEE CBMS 2017); **Tarapore** (International Society of Artificial Life Award for Outstanding Paper 2016).

Other prestigious awards include:

- **Ramchurn:** IJCAI-JAIR awards honourable mention, 2016 (<https://www.jair.org/index.php/jair/IJCAIJAIR>) .
- **Jennings and Ramchurn:** The Engineer's "Collaborate to Innovate" Award for ORCHID Programme Grant (2016) (**Ramchurn** was Co-I with **Jennings** PI).
- **Butler:** Microsoft Software Engineering Innovation Award, 2014.
- **Cai:** Best Thesis Award, Hong Kong Mathematical Society, June 2014.
- **Hall:** Recipient of MRC Sufferage Science Award, London Institute of Medical Sciences (MRC, 2016); Recognised as 1 of 50 most Inspiring Women in Technology, Inspiring Fifty

Unit-level environment template (REF5b)

(2016); Outstanding Contribution to ACM Award (2014); Recognition of being 1 of 100 Leading Practising Scientists, Science Council (2014); Lifetime Achievement Award, FDM Everywoman in Technology (2014); Honorary degrees: DSc Hong Kong Baptist University (2020); DSc The Open University (2015); DSc University of Bradford (2015), DSc University College London (2014).

- **Martinez:** American Geophysical Union, Leptoukh prize 2017
- **Tarapore:** Awarded Popular Science “Best of What’s New” in the Engineering category (2015).

4.4.6 Funding body and other memberships

A total of **22** current staff have contributed to UKRI panels and equivalent international bodies. Specifically, **10** staff are full EPSRC College Members (**Butler, Hall, Martinez, Nixon, Norman, Niranjana, Ramchurn, Sassone, schraefel, Watson**). A further **4** have sat on UKRI panels and/or acted as reviewer (**Cirstea, Gerding, Marchioni, Martinez**). Finally, many have contributed to other panels, e.g. **Brede** (NWO), **Cirstea** (NWO, ERC), **Butler** (ERC, AXA, ANR, etc) **Gerding** (NSERC), **Niranjana** (ERC, Hong Kong), **Millard** (QNRF), **O’Hara** (COJR, NSERC, SSHRC), **Prugel-Bennett** (Catalonia, Sweden), **Ramchurn** (Mauritius, Norwegian etc), **schraefel** (NSERC, SSHRC, CHIR), **Tiropanis** (NSERC, Leverhume, ERC), **Kim** (Hong Kong), **Staab** (ERC), **Weal** (ESF).