

Institution: University of Kent

Unit of Assessment: 11: Computer Science and Informatics

1. Unit context and structure, research and impact strategy

1.1 Context and Structure

UoA11 at Kent is the School of Computing. We conduct research of the highest quality in our four priority areas, for each of which we have established a well-resourced research group. These four groups are:

- *Programming Languages and Systems (PLAS)*. Research in PLAS focuses on foundational aspects of Computer Science by addressing the formalism, implementation, and verification of programming languages, encompassing functional programming, type systems, concurrent systems, and automated verification. PLAS members are widely recognised for the quality of their research, publishing solutions to longstanding problems and holding programme committee memberships for conferences such as POPL, ICFP, ICLP, with regular publication in such conferences (see Section 4.3). csrankings.org places Kent second in the UK (2014-20) for Programming Languages.
- *Computational Intelligence (Complnt)*. This group researches novel AI techniques, including machine learning (ML) and bio-inspired AI methods, as well as applying AI to real-life areas. It explores the important theme of developing and using transparent, interpretable AI. The group is internationally acclaimed, as evidenced by programme committee memberships for conferences such as AAAI and IJCAI, and by high citation rates in the REF2021 period: 13 out of 17 outputs submitted by this group are in the top quartile in field-weighted citations. The group contains members with h-indices (Google Scholar) of 64 (Freitas) and 37 (Bowman).
- *Cyber Security (CyberSec)*. This group researches a broad range of topics in cyber security, including authentication and authorisation, communication and network security, security testing and verification, socio-technical security and privacy, AI and security, digital forensics and online harm, information hiding and quantum cyber security. It hosts the Kent Interdisciplinary Research Centre in Cyber Security (KirCCS), one of the UK's 19 Academic Centres of Excellence in Cyber Security Research (ACE-CSR), as recognised by the National Centre for Cyber Security (NCSC, part of GCHQ) and EPSRC.
- *Data Science (DataSci)*. This group researches the application of AI to various types of data, with a strong emphasis on health-related issues. The work includes streaming data, biomedical signal analysis and categorical ML. This group places a strong emphasis on real-world impact, including support from Dstl, KTPs, and various charities, as well as significant public engagement contributions (see Section 4.4).

Typically, researchers in the School of Computing belong to one of these main research groups. Collaboration is strongly encouraged, and researchers may be secondary members of other research groups. This arrangement has fostered cross-fertilisation of ideas and provided a thriving culture for research discussion. (Section 4 reports multiple cross-group grants and collaborations.)

1.2 Research Strategy 2013-20

To achieve the research strategy outlined in our submission to REF2014, our **strategic priorities** during the REF2021 period were to: attract future research leaders; focus our research on crucial areas of Computer Science; develop an excellent research environment; and foster outstanding interdisciplinary research and impact.

- *Attracting future research leaders.* We have been successful in recruiting new lecturers identified as having outstanding potential, thanks to our considerable efforts to provide wide-ranging support within a nurturing environment (see Section 2.1). In return, we set research activity expectations of the highest international standards. All 18 ECR appointments in our submission embraced these expectations. Section 4.3 highlights prestigious awards, fellowships, and grants held by our ECRs. These staff have taken on leading roles in their research communities (e.g. Jordanous, Kell, Orchard), as well as School-level research and innovation responsibilities (e.g. Arief, Batty, Kafali), and contribute significantly in public engagement with research (e.g. Chennu, Jordanous, Nurse).
- *Focusing research on crucial areas of Computer Science.* In the REF2021 period, we consolidated our research in high-priority areas (programming languages, cyber security, AI, data science) as defined by UK Government strategy (see Section 4.2) and EPSRC's ICT portfolio. We aim not simply to gain critical mass, but to build groups in targeted areas that are large enough to achieve worldwide leadership: by providing a strong support base for our researchers and establishing breadth and depth of expertise in that research area. Each group has 10+ staff. Towards the end of the REF2021 period, we discontinued our Computing Education Research Group. Whilst this group made valuable research contributions, there were a number of staff departures, and we made a strategic decision to concentrate replacements in the other research groups.
- *Developing an excellent research environment.* The School's large research groups enable a thriving research culture across a spectrum from theoretical research to real-world impact. We emphasise quality, synergy, and knowledge exchange, and this has led to significantly increased research and enterprise income (see Section 3.1). Research integrity is intrinsic to all our research activities, as discussed below.
- *Fostering outstanding interdisciplinary research and impact.* We take pride in our collaborative and interdisciplinary research, detailed in Section 4.1. The School sits at the centre of many interdisciplinary initiatives at the University. We have a wide range of partners in both the public and private sectors, and from other disciplines. Our research and innovation strategy is informed by consultation with our School's industrial panel, hosted twice a year. Our School Director of Innovation leads on impact activities, helps maximise impact opportunities, and leads our School-wide impact and engagement strategy. Consequentially, as Section 4.4 reports, **we have achieved significant impact during the REF2021 period in addition to our three impact case studies.** The School also hosts the Enabling Innovation: Research to Application (EIRA) AI Knowledge Exchange lead (see REF5a), which has led to the development of new industrial partnerships, resulting in eight research and innovation-focused grants. We have also benefitted from sustained engagement with University support, currently located in Research and Innovation Services (RIS) (see REF5a).

Thanks to our sustained increase in high-quality research and impact activity over the REF2021 period, we have largely met the targets set in our research plans reported in REF2014, whilst remaining responsive to the ever-evolving research landscape. Our achievements with respect to our REF2014 plans are as follows:

- *Awards of £1.3 million per annum by the end of 2016.* This target was exceeded. The financial year 2015-16 shows research awards were £2.6 million to the School.
- *Formation of a second research group at Medway.* This target evolved to better fit our growing body of staff at Medway and our strategy for larger research groups in high-priority areas. A new Data Science research group was established, focusing on applied data science and AI, in place of the previous Future Computing group. This strategy has proven highly successful; for example, £795k in innovation awards secured by Medway-based

researchers in 2018-19. Owing to COVID-19, financial pressures, and lower student recruitment to our Medway UG programmes, we are restructuring the School so that it is based solely at the Canterbury campus. This will enable further interaction and collaboration between Data Science and other research groups at Canterbury.

- *50 PGRs.* We achieved this, with exactly 50 PGRs registered as of 31 July 2020. The School averages 7-8 PhD completions a year.
- *Extend our collaboration with other Schools through the University's interdisciplinary research centres.* We achieved this. We continue to lead KirCCS and now also lead the new Institute of Cyber Security for Society (iCSS) (see Section 3.2). We actively participate in the Centre for Reasoning (located in UoA 30). The Deputy Director of the University's recently established Institute of Cultural and Creative Industries (iCCi, see REF5a) is based in the School of Computing. We also co-lead three new cross-disciplinary research networks supported by the University (see REF5a): AI in the Public Interest (Rodgers); Conflict, Security, Rights, and Violence (Nurse); and Digital Culture (Jordanous).
- *Continue inter-group collaboration within the School.* This remains strong (see Section 4.1). It is evidenced, for example, by high incidence of secondary membership: 40% of our Category A staff (14 out of 37) belong to more than one research group.

We have been similarly successful in meeting our REF2014 impact goals. Our aims were:

- *Open-source (OS) release of research results and contribution to international OS projects.* We have long championed OS code, with OS software as the default for our research. This has paid dividends for our research impact. Of particular note are our contributions to OpenStack and Greenfoot, as detailed in two of our case studies.
- *Building and maintaining strategic, long-term collaborations.* We continued collaborations with partners such as Oracle and Erlang Solutions (see our REF2014 submission and our REF2021 Greenfoot impact case study), and have established multiple strong new partnerships since 2014, such as with NVIDIA and through KTPs. We supported the EIRA consortium (see REF5a) for building industry collaborations. This influenced our significant increase in innovation funding since 2018 (see Section 3.1).
- *Targeting follow-through activities and funding designed to maximise industrial impact.* As well as our considerable increase in annual innovation income since 2018, we have considerable success in attracting innovation funding; for example, our Industrial Strategy Challenge Fund grant and three KTPs (see Section 4.2).
- *Interdisciplinary activity: computing having an impact in a variety of application domains.* Section 4.1 details our work with many collaborators across the social sciences, humanities and sciences. Of particular note is our work with clinicians, leading to the Brain Injury Rehabilitation impact case study.
- *The widest possible dissemination and public engagement with our work.* Many of our staff appear regularly in the press, radio, and TV (see Section 4.4), including those involved in our three impact case studies. We have research-led modules freely available online, active online promotion of our research and impact, and a dedicated outreach officer.

Our three impact case studies illustrate the range and significance of our research, and its benefit to industry, government, healthcare, and communities. These case studies were supported by our Director of Innovation, by RIS (see REF5a), and by continued engagement with existing and new partners. The above bullet points detail how our case studies relate to our impact strategy. Examples of research impact and engagement beyond these case studies are provided in Section 4.4.

1.3 Research Integrity

Research integrity is embedded in **all stages of the research process**, and we comply fully with University research ethics procedures. Our Research Ethics Officer (REO) sits on the School Research and Innovation Committee, with a standing item for ethics ensuring its discussion at each meeting of the committee. The REO is responsive to ethics-related queries raised by any researcher, and our PhD student training includes research ethics.

Early discussion of grant ideas is encouraged through sharing one-page descriptions with the heads of research groups, so that feedback can be integrated early on. We request 2+ reviews of all significant bids, **in a process of continuous shepherding**. Additionally, the Head of School reviews all First Grant/New Investigator awards before submission. We also benefit from excellent University support (see REF5a).

Several of our staff hold leadership positions in professional bodies, including BCS, IEEE, and CPHC, thereby making important contributions to the development and promotion of professional frameworks. We also make a strong contribution to standards; e.g. ISO, W3C, QAA, and MPEG.

Our culture of research integrity is also present in our encouraging of an **open and transparent research environment**, prioritising making our research as accessible as possible. Our strong commitment to open-source code has enabled our achievement of an impact goal (see Section 1.4). In addition to benefiting from University APC funding, the School covered open access costs for five publications in the REF2021 cycle.

1.4 Research and Impact Strategy 2021-26

We will build on the successful strategy of the REF2021 period, continuing with **large research groups** aligned to crucial areas of Computer Science research. The **collaborative and interdisciplinary work** described in Section 4.1 remains central to our approach, further enabled by our move to the Division of Computing, Engineering and Mathematical Sciences (see REF5a) and our ongoing leadership of cross-disciplinary networks (see Sections 1.2 and 3.2). We will maintain an agile approach, whilst focusing on world-leading outputs. We will **maintain sustained growth**, whilst supporting the research base in Computer Science. Over the next five years, we plan to:

- Concentrate on developing areas of existing strength (PLAS, where we are a world leader; Cyber Security, where we are ACE-CSR) and areas where we are increasing strength and impact (Computational Intelligence; Data Science).
- Continue the policy of large (10+ members) active research groups with a collaborative culture to meet regularly, target national priority areas, and promote engagement across research groups and from other relevant research areas.
- Increase our annual research and innovation income by 30% to exceed £2.1 million by 2025 (to be achieved through actions such as increasing incentives and setting targets for research groups).
- Maintain our policy of recruiting largely to lecturer posts, building careers, and promoting from within. As described below, our strategy is to carefully nurture staff, helping them to raise their profile internationally and gain promotion internally. We plan to increase our academic staff on Education and Research (E&R) contracts by 15%, to 40 FTE by 2025.
- Encouraging research visits (both incoming and outgoing) to expose our staff (especially PhD students, RAs, and ECRs) to further world-class research.

The School's research has strong impact on the products, services, and practice of the software industry, as well as on the use of computing systems in a range of industrial and social sectors. We will continue enthusiastically to engage with external partners, including industry, charities, the NHS, and government bodies. Our **five-year plan for impact** includes:

- Actively targeting funding that supports impact-raising activity, particularly concentrating on schemes where the School has a record of success, including industrial fellowships, Defence Funding, and Innovate UK streams.
- Supporting contacts with industry through a yearly engagement event.
- Engaging with the new Kent and Medway Medical School (KMMS) to further our e-health research.
- Engaging further with local businesses through the University's Eastern Academic Research Consortium (Eastern ARC) and existing EIRA partners (see REF5a).
- Increase engagement with standards bodies.
- Taking advantage of increased opportunities for interdisciplinary impact and engagement with staff from other Schools in our new academic Division.

2. People

2.1 Staffing Strategy and Staff Development

People are at the heart of our research, and this is reflected in our staffing strategy. In our recruitment strategy, we prioritise early career researchers, with a view to nurturing the next generation of research leaders. World-class research requires world-class researchers. Research potential is thus a major consideration in our recruitment. We have a substantial staff development programme, which helps early career researchers achieve their potential, as well as supporting established staff. We embed equality, diversity, and inclusivity throughout our activities, and fully support the Concordat for Career Development of Researchers. As detailed below, our significant investment in our researchers during the REF2021 period has included:

- Grant top-up support, including match funding to extend postdoctoral researcher time by six months, and dedicated research studentships attached to grants;
- Generous internal budget of £90k per annum for conference attendance for staff and PhD students;
- Internally funded PhD studentships, including stipend (on average, 4 per year);
- Investment in partial continuation funding for a fourth year for any PhD student close to completion (on average, 3-4 per year);
- Investment (£10k) to facilitate cross-campus communications;
- Teaching relief and extra research time allocation for new appointees.

Our strategy is to build world-class research capability. We do this by focusing on areas where we have critical mass (Programming Languages and Systems; Cyber Security; Artificial Intelligence; and Data Science), recruiting ECRs with outstanding potential, and committing to first-class staff development support, offering a structured path to realise that potential at all career stages. Of our submitted staff appointed during the REF2021 period, all have long-term/permanent contracts, and 86% (18 out of 21) were recruited at lecturer level.

Research activity is overseen by our School's Director of Research and Heads of Research Groups. In terms of current and future management of research activity and succession planning, our Directors of Research during the REF2021 period (Rodgers, 2014-19; King, 2020) and six of our nine professors are long-established staff who were internally supported to professorships. Various more recently appointed staff hold research-related responsibilities (see Sections 1.2 and 2.3). This includes our Director of Innovation (Arief), whose activities support staff to achieve impact from their research (see Section 1.2), alongside institutional support.

Internal funding. Our **institutional support** for First Grant/New Investigator awards has been commended by reviewers. The package includes a commitment to six months' additional postdoctoral researcher time and a fully-funded PhD studentship connected to the grant, under the supervision of the applicant, as well as mentoring for the PI. We also offer PhD studentships

for Fellowship applications and target studentships for investment areas. All eligible post-probationers have submitted EPSRC First Grants/New Investigator applications. 53% of these applications in the REF2021 period were successful.

We have a **generous research budget** of £90k per annum (£45k for staff, £45k for students), with actual spend averaging £72.3k per annum, from £53k (2014-15) to £105k (2018-19). This fund provides support for initial experiments and equipment, grant writing, impact activities, visiting potential project partners nationally or internationally, open access publishing, consortium building, and hosting workshops to raise visibility. Importantly, it supports **conference attendance**, with **all reasonable requests for funds granted** where the researcher is presenting a paper or in other relevant circumstances (for example, following substantial periods of leave – see below).

Our research group organisation is designed to provide support for all researchers. The groups' size (each with 10+ staff) is large enough to provide a range of peer support and informal mentoring opportunities, while being sufficiently focused to build a strong community. During the REF2021 period, we increased funding for research seminar expenses, spending over £5k per annum in 2018-20.

Workload allocation. The School has a fair, transparent and extremely comprehensive Workload Allocation Model (WAM) for academic staff that has evolved over many years. The WAM, based on 1650 hours per annum, recognises the wide variety of work undertaken by our staff and encourages high quality research – with, for example, a higher allocation for outputs recognised (by an internal, gender-mixed panel) to be of the highest quality, and WAM-based incentivisation for the **submission of grant proposals** (see Section 3.2).

Early career staff are given **reduced teaching loads** (a 50% reduction in year one; 25% reduction in year two) to enable them to study for a Postgraduate Certificate of Education (PGCHE) and to develop their research. We emphasise commitment to research-led teaching in PGCHE training, contributing the module 'Developing as a Researcher in Higher Education'. The School also encourages ECRs to engage with the University's ECR Network, established to provide mutual support and training (see REF5a).

To further assist research development, ECRs on E&R contracts are allocated **250 extra hours per annum for research** in year one, decreasing by 50 hours each subsequent year. This is in addition to the baseline allocation every academic receives for research (400 hours per annum). The School absorbs the indirect costs of this allocation.

Staff development. For post-probation staff, **study leave** supports research development, advertised annually for full-time and part-time permanent staff. A gender-mixed panel reviews and helps refine applications before submission to the University. We typically support four terms of study leave each year. Section 4 reports how other institutions often offer to host our staff during their study leave, including industry hosts. We also support exchanges between academia and industry formally through recruitment of industry-based research staff (Dimitrakos).

We fully implement the University's **probation scheme**, and also provide a mentor for new staff. The Probation Supervisor, typically senior and from the same research group and campus as the probationer, guides probation plans and writes probation reports. The mentor, assigned through consultation with the new academic, offers informal guidance tailored to the new appointee's needs.

All staff participate in an annual 'Reflect, Plan, Develop' (RPD) **appraisal** process (see REF5a). This includes discussion of all aspects of work, career aspirations, work/life balance, and support needed to help staff achieve their and the School's goals. This helps foster an all-inclusive, non-discriminatory culture in the School. The Head of School receives a summary of each RPD. Additionally, the School monitors and supports staff through its research groups (which provide

discussion of work in progress), and annual Individual Research Planning (IRP) meetings with their Head of Group and the Director of Research.

The School organises various **training events**, including 'Valuing Everyone', grant development, teaching and research away days, and strongly encourages uptake of additional training provided at University level, across all levels of staff seniority. We nominate staff for leadership programmes, for example, the women-only Aurora programme and the University's Leadership for Areas of Specific Responsibility (LASR) programme. Rodgers (LASR) is now Head of School and Ramaswamy (LASR) is now Head of the Data Science research group. Following Aurora training, Bocchi and Jordanous both achieved promotion to Senior Lecturer. Bocchi is now PhD Admissions Officer and Jordanous REF Coordinator.

Our staff are supported in **promotion** applications by the Head of School and the School Promotions Panel. Promotion success is decided at University level, based on clearly defined criteria (see REF5a). Fourteen of our submitted staff achieved promotion during the REF2021 period, including five lecturers hired in the REF period (with one further promoted in autumn 2020). The School Promotions Panel proactively reviews and works with all staff not promoted over a five-year period, encouraging applications as appropriate or suggesting activities towards an application; for example, grant applications or additional publications.

2.2 Research Students

Recruitment. The School's approach to recruitment of doctoral research students mirrors our approach to recruitment of staff: we seek to attract candidates of the highest quality and potential, and support them comprehensively. As of 31 July 2020, we had 50 registered PhD students. During the REF2021 period, the School averaged 7-8 completions a year.

Funding. The majority of our PGRs (87%) receive full studentships from the School and University, externally: usually 11-12 PhD studentships per year, with 20 in 2019-20. We provide 3-5 School scholarships a year. During the REF2021 period, our students were also funded by **funding bodies** (eight EPSRC studentships, five GCHQ/NCSC studentships), and by the University (17 studentships). In line with School strategy, priority for School-allocated funds is given to students supervised by new ECRs, then for staff without PhD students.

Support. The School requires all PhD students to attend a conference in their first two years of registration, paid for by the School. This encourages students to **engage with their research community** as early as possible and to network with their peer group outside of Kent. Typically, they have a paper or poster to present, but, even if not, attendance is still supported by School funds. Students are encouraged to submit papers to conferences over and beyond this requirement, and the School supports their attendance with funding. No reasonable request by a research student to attend a conference or workshop has been refused in the REF2021 period, with approximately £1,000 spent per student per annum (a budget of £45k per annum).

PhD students can request funds to attend external training. During the REF2021 period, no such request has been refused. Students have attended a variety of tutorials and summer schools relevant to their research, such as experimental skills and neuroimaging. Technical training for PGRs is also provided by their supervisors. PhD students have full access to the School's various technical resources (see Section 3.3).

We also encourage our students to participate in **industrial internships and international exchanges**. The School has active research links with various external partners (see Section 4), to the benefit of research students. Over the REF2021 period, Computing PhD students have benefitted from internships with Google, Microsoft Research, Alan Turing Institute, NVIDIA, RIM/Blackberry, BT, European Space Agency, and in the US and Japan (for example, through an agreement between Japan's National Informatics Institute and Kent).

To maximise PhD completion rates (in addition to comprehensive targeted training and careful

student progression monitoring), in 2016 we introduced financial support for PhDs close to completion. Such students could apply for partial continuation funding in their fourth year (three months' full funding or 12 months' 50% funding, with teaching requirements of two hours per week for the 12 months' funding). We supported all applicants, 3-4 students per annum.

PGR equality, diversity, and inclusivity. EDI in recruitment for students and staff is a key priority to us. We have sought to increase the proportion of women registered on our PhD programme, currently at 20% (10 out of 50), just above the HESA sectoral average of 17-18%. Our ongoing Athena Swan work to increase the number of external female applicants includes advertising our PhD scholarships on female-targeted social media and mailing lists. Initial PhD interviews are conducted by the potential supervisors; for consistency as well as for gender balance, successful candidates at this stage have a follow-up interview with the Director of Graduate Studies (Fincher, female) and Director of Research (Rodgers, 2014-19; King, 2020, both male).

We draw many PhD students internally from our BSc/MSc programmes. We support staff to introduce modules informed by their research; our lecturers become role models for a career in research. Several of our research-informed modules are convened by female lecturers. Bocchi (female), as PGR Admission Officer, speaks to final-year BSc/MSc students about PhD opportunities.

Academic support. All PhD students in Computing have a supervisory team. Any supervisor who has not yet supervised a student to successful completion is paired with a second supervisor (as supervisory chair) for guidance and mentoring. Students meet with their supervisor(s) weekly and provide monthly summaries (certified by the supervisor) to a reporting system monitored by the Director of Graduate Studies. A supervisory panel ensures that all students are provided with suitable support, and evaluates the student's research at progression points. The Director of Graduate Studies sits on all supervisory panels, for consistency.

In their first term, students attend regular training workshops on Computer Science research skills, led by a Professor from the School. We also run targeted training sessions at sensitive points; for example, a session for final year students on thesis submission and viva preparation. We also encourage our students to take advantage of the extensive University training provided by the Graduate and Researcher College (see REF5a).

Students have various opportunities to discuss and develop research ideas outside the formal supervisory and training arrangements. All PGRs belong to at least one School research group. They are expected to attend their primary group's weekly seminars, which provide opportunities to network with other researchers, present their work, and enhance their presentational skills. PGRs are also encouraged to join research visitors for lunch, expenses paid. Research students present their research at an annual student-organised mini-conference, and at Research Fairs organised by the University. Social activities also help build cohort identity, such as a popular annual PhD away weekend (Bath, 2017; York, 2018; Cambridge, 2019; with £300 per student committed by the School towards expenses).

2.3 Equality and Diversity

The School is committed to incorporating principles of equality and diversity into every aspect of our work, including recruitment and promotion. University and School input, alongside the Concordat to Support the Career Development of Researchers, has shaped the School's way of working, improving our recognition of work/life balance, flexible working, support for new parents, and other staff with caring responsibilities:

- We have a core-hours policy of 10.00 a.m.-4.00 p.m. for meetings and most social events.
- Researchers generally work flexibly and/or remotely informally.
- Flexible-working requests from staff are received sympathetically and facilitated whenever possible to enable them to research productively. Over the REF2021 period, requests for

flexible working to assist staff wellbeing have all been approved.

- The School supports mobility between full-time and part-time to accommodate staff, with all such requests granted during the REF2021 period.
- Part-time and fixed-term staff are offered the same career pathways and support as full-time staff, with the WAM scaled to their hours worked.
- Researchers with disabilities are provided with additional technology as needed.

At University level, Soria has been actively involved in initiatives such as adding the 'rainbow flag' to the University's logo online and on social media platforms during Pride Month (June 2020). Soria was also instrumental in securing the first order of rainbow-coloured University of Kent lanyards, to be financed by the University.

The School has held an Athena Swan Bronze Award since 2014 (renewed in 2018). The WAM gives credit for the Athena Swan team and EDI representative roles, and our action plans are embedded in School culture, including staff at different levels of seniority throughout the School.

- We have revised the wording and imagery used in our online presence and recruitment literature:
 - Research by Kent's Information Services on job application strategies found higher numbers of essential criteria correlated with fewer female applicants. Consequently, our job adverts have reduced essential criteria and include a statement encouraging female/minority applicants.
 - Our website shows people of a diverse range of backgrounds (genders, ethnicities, etc.).
 - Our adverts for academic posts highlight family-friendly policies (for example, core hours for School activities, flexible working, parental leave support).
- Interview panel members are trained on recruitment best practice, including avoiding unconscious bias. Following University practice, academic recruitment panels are always mixed gender.
- New staff complete modules on unconscious bias at induction. In 2014-15, all School staff completed 'Valuing Everyone' training, tackling unconscious bias, and exploring inclusivity and team dynamics (shortlisted for a 2015 Times Higher Education Award).
- All School committees include representatives of both genders.
- We prominently publicise equality and diversity events to our staff and students; for example, displaying on our display screens LGBT History month schedules and events celebrating diversity.
- The School strongly encourages and supports female staff to apply for leadership training programmes (e.g. Aurora) and for promotion, and to take on roles of responsibility for research within the School and University.
- We formalised the additional support provided directly by the School for maternity/paternity/adoption leave (see below).

We can already see the positive impact of these changes. In the most recent staff survey, 91% stated they were treated the same regardless of protected characteristics such as gender, race, or religion (up from 85%). This is still too low and we target achieving 100% as soon as possible.

As mentioned above, two female lecturers took Aurora leadership training in this REF cycle; both were since promoted. The staff members to have achieved promotion in the REF2021 period includes two staff who took substantial maternity leave periods. Several research and innovation-related positions of responsibility within the School are currently held by female staff:

- Director of PhD Admissions (Bocchi);
- Director of Graduate Studies (Research) (Fincher);
- Deputy Director of the Institute of Cyber Security for Society (Franqueira);
- REF Coordinator (Jordanous);
- Director of Internationalisation and Deputy Director of iCCi (Li(L)).

Three of our five submitted female academics were recruited during the REF2021 period. Three of the five [REDACTED] achieved promotion in the last three years. Fincher is already a Professor. Only one is at Lecturer level [REDACTED], and she was appointed in 2019. We also supported a **Daphne Jackson Fellowship** for women returning to academia from career breaks (2014-16). Our Fellow obtained a Readership in her next academic appointment.

In this REF period, three staff on E&R contracts have taken maternity or adoption leave. As well as following institutional procedures, the School offered additional support that was, at first, not formally documented. Following two experiences of maternity/shared parental/adoption leave [REDACTED] the School reflected on the support provided, and formally designed guidelines and procedures to support academics to re-engage with research after extended leave. This enabled us to offer more formalised support for maternity/shared parental/adoption leave, such as [REDACTED] maternity leave two years later, and for others taking extended periods of leave. Our offer is:

- Staff retain use of all services while on leave.
- Selected named colleagues handle contact with the staff member during leave and the role of Keeping-in-Touch (KIT) days was clarified.
- A fixed-term lecturer appointed to cover leave helps the member of staff to retain previous teaching on return.
- The School implements a teaching workload reduction of 25% in the year following return.
- We avoid giving new teaching on return wherever possible (following feedback).
- The School also offers options on return to work of transitioning to part-time [REDACTED] and/or with generous flexible working arrangements [REDACTED] for at least two years after the return date.
- On return, academics have enhanced access to research budget, to help support them re-engage with research.

We are proactive in supporting our researchers with caring responsibilities, and, as standard, approve research budget requests for extra funding (for example, to enable partners to accompany staff/students during research travel, for support and wellbeing).

Lastly, our REF Working Group, which oversaw all aspects of our REF2021 submission, has adhered fully to the University's REF Code of Practice. The group includes staff from South America, continental Europe, and Asia, with male and female members across a spread of ages. All Working Group members took REF-specific EDI and unconscious bias training. Our REF Coordinator (Jordanous) was until recently the School's EDI representative. A member of the University REF team attended all Working Group meetings to ensure Code of Practice compliance.

3. Income, infrastructure and facilities

3.1 Income

In the REF2021 period, the School's **total research income has increased significantly**, from £936k average per annum in the first three years of the REF period to an average of £1.44 million in the last three years. As part of our strategic approach to generating income, we devote considerable attention to nurturing and developing high-quality grant proposals, particularly targeting UKRI/R1 funding (which increased from 29% to 49% of our total funding during the REF2021 period).

As described in Section 4, we seek to build and maintain long-term collaborations and strategic partnerships (e.g. Oracle, Erlang Solutions, NVIDIA). We have increased our success rates with KTPs, with three partnerships in the last two years, and we secured eight EIRA grants (see

REF5a) to help build relationships with new partners. The School's innovation funding has also increased considerably, from an average of £38k total awards achieved per annum in the first three years of the REF2021 period to an average of £525k total awards per annum in the last three years.

We achieved **income from several significant grants** during the REF period, including:

- European Commission:
 - H2020: Collaborative and Confidential Information Sharing (£450k), NeCS, (£389k), RAMSES (£306k), BehAPI (£44k),
 - FP7: NeCS (£389k), Fed4FIRE (£113k);
- EPSRC, including Trustworthy Refactoring (£730k), STARDUST (£555k), Quantum Communications Hub (£445k), PRiVELT (£400k);
- RAEng, including Batty's Fellowship (£421k);
- GCHQ / National Cyber Security Centre (NCSC), including a studentship (£112k) and six VeTSS projects (average £75k each);
- Innovate UK, including three KTPs, average £205k);
- Public/private sector, including Oracle (£314k, £298k), Huawei (£227k, £54k), Road Safety Trust (£195k), and BT (£90k, £45k, £35k).

Other funders included: Google, Leverhulme Trust, Royal Society, ACM, BCS, HEFCE, MoD, and Dstl.

The award figures above, and throughout this statement, refer specifically to the money awarded to Computing at Kent. However, given the School's strong track record in securing joint grants through collaborative and interdisciplinary work (see Section 4), many of the above are larger awards overall. For example, we co-lead STARDUST, which has eight partners and a total award value of £1.82 million. Similarly, the Kent-led PRiVELT project has 11 partners and a total award value of £1.14 million. Our grants also often include international or interdisciplinary collaboration (see Section 4.1).

3.2 Operational and scholarly support for research and impact

Our strategic approach to generating income includes **encouraging and rewarding high-quality grant writing**. We run annual Grant-Writing Workshops that are open to all research staff and research students. These workshops guide researchers to take an initial research idea through to full draft. We have also run annual research-focused away days on research quality and grant writing. We **reward the submission of grant proposals** with WAM hours allocation (20 hours for small grants (under £100k), 60 hours for medium grants (£100k-£1 million), and 120 hours for large grants (£1 million and above). Our research budget covers requests for expenses incurred in building research consortia. The enhanced access to research budgets and extra time provided to those returning from leave (see Section 2.3) supports researchers; for example, to write research proposals. Further examples of the extensive ways in which we support, promote, and reward research are provided in Section 2.1.

The School is responsive to national and international research priorities, as described in Section 4.2. For example, through our alignment with the Government's national cyber security strategy, we have attracted over £6 million in cyber security funding during the REF2021 period. The School is at the forefront of a **major strategic investment** by the University into the new Institute of Cyber Security for Society (iCSS), which concentrates on research with many other disciplines, including Engineering, Sociology, Law, Business, Politics, and Psychology. (University investments include two Computing lectureships, several PhD studentships annually and £196k worth dedicated space allocation.)

Our joining the new Division of Computing, Engineering and Mathematical Sciences will also be beneficial for future income, increased research support and the opportunity to scale up our

research. It will reduce administrative loads within the School, freeing up more time for research. We will also have access to additional specialist facilities, including a VR suite and an anechoic chamber, as well as technical support in new areas (for example, robotics), provided by an 18-person team.

3.3 Research Facilities and Infrastructure

We invest generously in facilities and infrastructure for research. The School budgets £90k per annum for research spend, plus £130k per annum for equipment spend. Our research budget funds suitable specialised kit, and other research expenses (Section 2.1). The equipment budget covers the purchase and replacement of individual machines for staff, as well as maintenance of specialised computing machinery. This investment is supported by a dedicated five-person technical team within the School, who provide day-to-day support and expertise, system management, and general technical advice across hardware, software and systems.

The School provides shared filestore for projects, web services for researchers' web presence, crowdsourced experiments, and hosting services for web domains (for example, greenfoot.org, which we hosted until 2018). It also provides a well-used GitLab server (2k+ projects, 596 current users) and a Subversion repository supporting external collaboration for Kent-based research projects. There are also more specialised resources, such as clusters supporting research projects including our high-performance computing cluster (17 CPU/4 GPU multi-core servers) and an in-house poster printer. We provide OpenStack Cloud virtual machines and storage, managed by a dedicated team. We also have access to three University HPC clusters and filestore.

Our staff have also successfully **secured equipment via external grants**; for example, GPU servers (Batty, GCHQ), Internet of Things (IoT) sensors, VR equipment, and software (Arief, GCHQ; Li(S), EPSRC), mobile phones (Batty, GCHQ), non-invasive nerve stimulation equipment (Ramaswamy, EIRA), road safety equipment (Ramaswamy, Road Safety Trust), quantum beacons (Hernandez-Castro, NCSC) Many of these grants have been with project partners, allowing the equipment to contribute to knowledge exchange and impact. For example, Batty's work with the GPU servers mentioned above and NVIDIA-donated equipment led to ISO standardisation contributions (Section 4.1), while Ramaswamy's two projects above are being applied by Mindspire Ltd and Road Safety Trust, respectively.

The School hosts a **MakerSpace**, known as the Shed, which has space for building and making digital artefacts. In addition to providing a 3D-printing and laser-cutting hub, it specialises in the rapid development of small electronic devices. It directly supports work on developing numerous IoT devices by providing access to an extensive range of wireless development boards, sensors, and actuators. It also provides access to a number of simulated physical environments. Budgeted spending on the MakerSpace facilities and support is £8k per annum, with a support team of two specialist technicians.

We provide **significant support for lab-based experiments and other empirical work**. We have a dedicated experimental room with an attached observation room. Our Cyber Security lab allows different types of experiments, including behavioural studies and experimental hacking of IoT devices. It contains screen-based eye-trackers, one pair of eye-tracking glasses, two VR kits with eye-tracking features, one eye-tracker capable of working with EEG equipment, a range of IoT devices, mobile devices and other ICT equipment, purchased through University investment (over £75k in 2017-18) and external funding. Additional eye-tracking equipment valued at £8k provides empirical support for usability studies. We have various EEG equipment, supporting work by those modelling brain function.

For several years, we have benefitted from **state-of-the-art videoconferencing** hardware. This was prioritised, with the School split across two sites 30 miles apart, to enable our staff to remain connected while avoiding heavy travel burdens. We invested over £10k on equipment (cameras, ceiling and hand microphones) and software licences (Gotomeeting). Much has been invested in making **both campuses appropriately equipped** for researchers based locally. (Note that staff

can access all School equipment at both campuses.) Here, the School has also benefitted from institutional investment; for example, £72k for additional EEG equipment at the Medway campus, and an additional £3k and space investment to set up Medway's Intellectual Hub, a dedicated well-equipped space for research experiments, research discussions, and videoconferencing.

Library spend during the REF2021 period increased every year from £133k (2013-14) to £228k (2019-20), averaging £169,320 per annum; this has supported book purchases and periodical bundles, including ACM Digital Library, IEEE/IET, Science Direct, Springer, and Wiley Blackwell.

The cost of several **software licenses** is covered for Computing researchers by the University: relevant examples include Matlab, NVivo, SPSS, Jisc Online Surveys (previously BOS), EPrime, Rhino, Microsoft Office, Zoom, and Vscene.

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

Our environment statement describes how we appoint staff with strong potential and support them at all levels of their career. As evidence: **all submitted staff receive mentions in this section.**

4.1 Collaboration and Interdisciplinarity

There is a **strong interdisciplinary element** to the research of many of our staff. Cross-disciplinary funded projects that we have led in the REF period include:

- EPSRC:
 - PriVELT (Li(S) and Freitas, IT/Psychology/Sports, £429k);
 - ACCEPT (Li(S), Criminology/HCI/Social Anthropology, £167k);
 - PProCEED (Nurse, AI/HCI/Healthcare/Financial Services, £164k);
 - Computational Tools for ECG Connectomics (Chennu, Medical imaging/Healthcare, £101k);
 - Two Discipline Hopping awards (Freitas, AI/Healthcare/Biosciences, £104k; Chu, Computing/Physics, £49k).
- Other funders:
 - Brain endurance training (Li(L), Army/RAF, £300k);
 - Social planning (Otero, KTP, £212k);
 - Cognitive approaches to road safety (Ramaswamy, Road Safety Trust, £195k);
 - Ageing and genetics (Freitas, Leverhulme, £139k);
 - Forensic facial recognition (Bowman, Innovate UK, £92k).

We have numerous collaborations around biosciences, e-health, psychology and neuroscience (Barnes, Bowman, Chennu, Chu, Freitas, Hernandez-Castro, Li(L), Ramaswamy, Soria). Our Cyber Security group collaborations include engineering, psychology, law, business and management, criminology and policing, anthropology, sociology, economy, politics and international relations, tourism, and journalism (Arief, Bhattacharjee, Franqueira, Kafali, Li(S), Nurse, Hernandez-Castro, Pérez-Delgado). Other cross-disciplinary research makes contributions to library and information sciences (Jordanous, Li(S), Nurse), physics and mathematics (Bhattacharjee, Chu, Hernandez-Castro, Pérez-Delgado, Petricek, Wang), and humanities (Jordanous, Petricek).

Figs 1 and 2 below show the spread of cross-disciplinary classifications across our 2013-20 publications. We have several publications in venues in other disciplines (e.g. Biology, Neuroscience, Digital Humanities), demonstrating our broader academic impact. In total, 69% of our 2020 publications appear in interdisciplinary venues, according to Scopus. Our research fund has covered expenses for activities building research collaborations.

In total, 40% of submitted staff (14 out of 37) belong to more than one research group. Our cross-group collaboration within the School includes numerous joint grants, including:

- Li(S) (CyberSec) and Freitas (CompInt), £429k, EPSRC;
- King (PLAS) and Dimitrakos (CyberSec), £389k, H2020;
- Otero (CompInt) and Migliavacca (DataSci), £217k, Innovate UK;
- Ramaswamy (DataSci) and Bowman (CompInt), £198k, Road Safety Trust.

Percentage of Kent Computing authors' publications during the REF period published in publication venues that are tagged as interdisciplinary (Scopus ASJC)

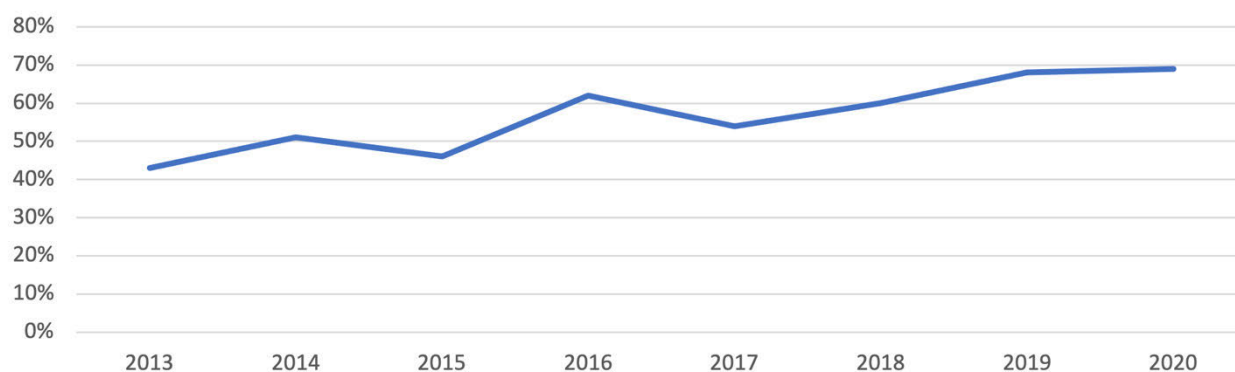


Fig. 1: Percentage of publications in interdisciplinary venues, rising from 43% (2013) to 69% (2020).

Cross-disciplinary outputs: count of Library of Congress Top Level classifications for the 1019 UoA11 publications in Kent Academic Repository.

Excluding: QA Mathematics (inc Computing science) (812); Q 335 Artificial intelligence (167); T Technology (233)

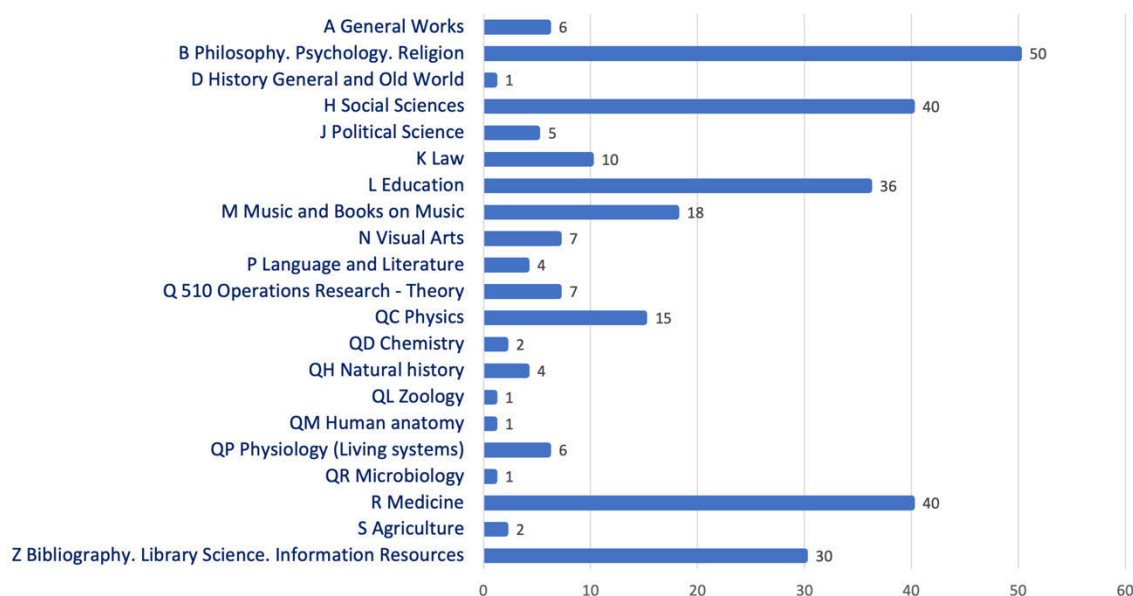


Fig. 2: Cross-disciplinary classifications of our outputs during the REF2021 period.

Section 3.1 gives examples of our **funded international research collaborations**. Our funded projects span several countries, including Argentina (e.g. Bocchi), Belgium (e.g. Chennu), Brazil (e.g. Freitas), Denmark (e.g. Bocchi), Germany (e.g. King), Italy (e.g. Dimitrakos), Portugal (e.g. de Lemos), Spain (e.g. Hernandez-Castro), and the US (e.g. Orchard).

Overall, 51% of our publications in the REF2021 period have **international co-authors** (Scopus data). Our **publication collaborations stretch across 51 countries worldwide**, including co-authors from the Americas (seven countries), Asia (18), Africa (two), Australia (two), and Europe (22).

Research activity with partners in both **the public and private sectors** has increased notably over this REF period, particularly in the last two years. We have increased success rates with Innovate UK, securing three KTPs in the past two years. Eight successful EIRA grants helped us **build relationships with new partners**. Project partners in the REF2021 period include Google, Huawei, Jane Street Capital, NVIDIA, Facebook, ISO, National Research Foundation Singapore, Erlang, Hong Kong IO, BT, National Crime Agency, McAfee Labs, Expedia, Oracle, and local partners Portafina and HR GO. Scopus data shows 13 patents citing our publications during the REF period.

Our vibrant research culture attracts leading researchers who want to work with us. We have a **regular stream of research visitors** from all over the world, who see Kent as a productive environment in which to invest months (even years) of their research time. For example, Otero and Freitas have hosted several visitors from Brazil, from Readers to PhD students. Wang hosted an EC Marie Curie Fellow, Professor Chua. Arief hosts a long-term honorary researcher from Turkey, while Hernandez-Castro has hosted visitors from the UK and Spain, and Li(S) from Turkey, China, and France. Professor Eliot Moss (Massachusetts) visited our PLAS group for several weeks each year. Other honorary research appointments from institutions in the US, Japan, and India, as well as independent researchers, illustrate the welcoming and productive environment that appeals to visitors. We have also hosted many short-term visitors, particularly to give research talks (an enriching way of making our research seminars diverse and wide-ranging).

As well as hosting visitors, we also retain good links with other institutions through **formal external visiting statuses** at Cambridge (Batty, Chennu, Kell), Cranfield (Nurse), Oxford (Nurse), Newcastle (Arief), Surrey (Li(S)), UCL (Bowman), Westminster (Soria), and internationally (China: Li(L), Wang; Malaysia: Ramaswamy; Belgium: Marr), and the Alan Turing Institute (Chennu, Petricek). Bowman holds a 50% appointment in Psychology at the University of Birmingham. During **sabbaticals** supported by Kent, our research has been hosted at institutions in Australia and Germany (Chu), China (Wang), Italy, Spain, and Greece (Hernandez-Castro), Portugal and Italy (De Lemos), and the UK (Bowman, UCL), as well as industry partners (Owens and Grigore, Facebook).

4.2 Responsiveness to National and International Research Priorities

Our research groups align to crucial areas of computer science attracting heavy investment and/or targeted growth.

Our School's responsiveness to the Government's national cyber security strategy and related international priorities (for instance, in Singapore, Israel, and the US) is demonstrated by our leading role in securing **recognition for the University by NCSC/GCHQ and EPSRC as an ACE-CSR** (2015-17 and 2018-22). This is also demonstrated by our success in attracting over £6 million in cyber security funding in the REF2021 period.

Our PLAS and Cyber Security groups have significant involvement with four national cyber security research institutes funded by NCSC/EPSC:

- Research Institute for Sociotechnical Cyber Security (RISCS): Nurse is one of nine RISCS Principal Investigators; Li(S) serves on RISCS' Scientific Board.
- Research Institute in Verified Trustworthy Software Systems (VeTSS) has funded six Kent Computing projects in the REF2021 period, for Batty, Kell, King, former staff Owens (two; both while employed at Kent), and Batty/Grigore, totalling £441k.
- Evidencing our sustained servicing of these priorities: VeTSS succeeds Research Institute in Automated Program Analysis and Verification (RIAPAV, 2014-17), also funded through UK's national cyber security programme. Kent was one of six RIAPAV partners (King as PI) and collaborator for two of the six RIAPAV-funded projects (King, £33k, £30k).
- Research Institute in Trustworthy Interconnected Cyber-physical Systems (RITICS): Kent is one of thirteen partner institutions, led by Li(S).
- Research Institute in Secure Hardware and Embedded Systems (RISE) granted Hernandez-Castro £36k in equipment funding.

The **Industrial Strategy Challenge Fund's (ISCF) Digital Security by Design EPSRC** theme funds Batty/Kell's £481k project building on the team's C/C++ ISO contributions. Further funding from Innovate UK saw us secure seven awards in the past two years (totalling £812k).

Looking to future contributions to national/international priorities, ISCF continues to invest in several relevant areas of AI and data economy in areas relevant to our research, particularly AI/data science in security, quantum science, and the creative sector. The Industrial Strategy also poses four **Grand Challenges**, two of which we address:

- **Ageing Society**: our cross-disciplinary work, particularly by Freitas, has directly impacted on research of the genetics of ageing.
- **Artificial Intelligence and Data**: we have invested in our Complnt and DataSci research groups and have recruited Chennu, Grzes, Jordanous, and Soria in the REF2021 period.

An international priority is tackling COVID-19. In June 2020 Li(L) secured £58k charity funding (a 5% share of £1.3 million including London NHS partners and Chinese academic/medical partners) to use AI to study rheumatoid arthritis medication for improving COVID-19 outcomes. Our MakerSpace has also been heavily involved in manufacturing PPE for local keyworkers.

4.3 Contributions to, and Recognition by, the Research Base

Citations. The School's research is well-cited: almost 50% of our submitted outputs (38 out of 80) are in the top 15% in terms of field-weighted citations, with two-thirds (52) in the top quartile according to Clarivate Analytics data. Some of our submitted outputs solve long-standing problems in their field (e.g. Grigore, Kahrs, Lange, Marr, Orchard).

Awards. The research achievements of our staff have been recognised in awards and prizes. PhD thesis awards were received during the REF2021 period by Batty (the prestigious ACM SIGPLAN John C. Reynolds Doctoral Dissertation Award and the CPHC/BCS Distinguished Dissertation Award, both 2015), and by Freitas's external PhD student Coelho Barros. Nurse holds an EPSRC Rising Star in Research award. In 2018, Fincher received a Suffrage Science Award, celebrating the scientific achievements and influence of women in science. In 2019, while still a member of staff in the School, Thompson was awarded Doctor and Professor honoris causa by Eötvös Loránd University.

Twelve of our staff and their students hold best paper awards, including Petricek (ACM PLDI Distinguished Paper, 2018, ACM SIGPLAN Research Highlight, 2018), Otero (GECCO 2016), De Lemos (ACM QoSA 2014) and Li(S) (International Conference on Human Aspects of Information Security, Privacy and Trust, 2017). Migliavacca was awarded an ACM Test of Time award at ACM DEBS 2019; and Jordanous received a Most Influential Paper award at ICCS 2018. Li(L) holds a Showcase Your Innovation British Council award (2018).

Fellowships. Further recognition of our staff has come through fellowships. Our current staff base includes two BCS Fellows (Li(S), Wang) and two Alan Turing Institute research fellows (Chennu, Petricek). Freitas is an elected Senior Member of AAI. Batty holds an RAEng Research Fellowship. Petricek held an ACM History Fellowship. Dimitrakos held an NICT Distinguished Visiting Researcher fellowship in industry. Jones (retired in 2020) is a BCS Fellow and Royal Society of Arts Fellow.

Leadership roles. Several staff have chair/coordinator status on national or international bodies. Wang is Chair of the IEEE UK and Ireland Computer Society Chapter (12,000 members), and Li(L) is Secretary for this IEEE Chapter. Fincher is Vice-Chair for the UK Chapter of ACM SIGCSE, as well as current Chair and previous Vice-Chair of CPHC. King is Director and Treasurer of the Association for Logic Programming. We have also contributed to the foundation of new bodies. Dimitrakos is a founding member of the IFIP Trust Management WG11.11. Li(S) is Vice-President and Founding Co-Director of the Association of British Chinese Professors.

Conference organisation. During the REF2021 period, our staff have contributed to the organisation of almost **100 research events** including conferences, workshops, and symposia. These include: ICLP (King, 2016); IEEE CEC (Otero, 2019); IEEE VL/HCC (Rodgers, 2016-17); and ACM SIGCSE (Utting, 2018-20). We have **hosted various research events at Kent**, including: PPDP 2014 (King, Chitil); IEEE Young Profession Congress, 2015 (Li(L)); AISB 2015 Convention (Jordanous); ECSA 2017 (De Lemos); ARES 2019 (Arief, Hernandez-Castro); ICER 2019 (Fincher); and Pint of Science, 2020 (Nurse). Our staff have also served on conference or community steering committees (Batty, Chitil, De Lemos, Dimitrakos, Grigore, Jordanous, Kell, King, Li(S), Marr, Petricek, Rodgers).

Editorial boards. Staff on editorial boards include: Dimitrakos, Editor-in-Chief of the *Journal of Trust Management*; and Fincher, Editor of *Computer Science Education* for 16 years until 2017. In the REF2021 period, our staff also contributed as special issue editors (Bocchi, Chu, De Lemos, Franqueira, Kafali, King, Li(L), Li(S), Marr, Orchard, Otero, Petricek, Rodgers). Additionally, Bowman, De Lemos, Dimitrakos, Franqueira, Freitas, Jordanous, King, Li(L), Li(S), Marr, Nurse, Otero, Ramaswamy, and Wang all serve on journal editorial boards or undertake regular associate editorial duties.

Grant-awarding panels. Staff have served on grant-awarding panels both nationally (EPSRC: Jordanous; British Council: Ramaswamy) and internationally (NSERC (Canada): Hernandez-Castro; NRC (Norway): Chu; Chinese government studentships: Li(S)). Eight submitted staff are members of the **EPSRC Peer Review College**: De Lemos, Freitas, Li(S), Ramaswamy, Rodgers, and Wang (plus four emeritus professors) as full members, and Hernandez-Castro and Jordanous (and one honorary staff member) as associate members.

Many of our staff also **review grant proposals** for national funders (EPSRC, MRC, STFC, BBSRC, Leverhulme, RAEng, Newton Fund, Nuffield, Alan Turing Institute) and international funders (H2020, FP7, and research councils in Canada, USA, Israel, Austria, Belgium, Czech Republic, France, Germany, The Netherlands, Switzerland).

Advisory roles. Our staff hold advisor statuses across a variety of bodies including:

- Standards
 - ISO: C/C++ language (Batty, Kell);
 - ISO/IEC MPEG RVC (Reconfigurable Video Coding) standard (Li(S));
 - QAA: Co-Chair Computing Subject Benchmark Statement (Fincher);
 - W3C Verifiable Credentials (Chadwick, retired 2020);
 - NFV SEC (Dimitrakos);
- EPSRC and TSB scoping workshops (Bowman);
- UKRI-funded research networks (Jordanous, Li(S), Nurse);

- Working groups or expert advisory groups for ENISA (Castro, Dimitrakos), IFIP (Dimitrakos), Huawei (Cloud) (Dimitrakos), and West Midlands Police (Bowman).

Staff on advisory boards for large grants or research institutions worldwide include Dimitrakos, Hernandez-Castro, Li(L), Li(S), Nurse, and Wang.

Keynote lectures. Many of our staff have delivered keynotes across the world during the REF2021 period, at academic, industry and public sector events, including:

- IEEE European Modelling Symposium (EMS), Pisa, 2016 (Wang, keynote);
- 6th International Workshop on Confluence, Oxford, 2017 (Kahrs, keynote);
- Credit Suisse's AI & Robotic Expo, London, 2018 (Jordanous, keynote);
- 16th Annual Conference on Privacy, Security and Trust, Belfast, 2018 (Li(S), keynote);
- London Grace Hopper Colloquium, May 2020 (Fincher, invited talk).

PhD supervision of external students. Formally-recognised **supervision of external doctoral students** is another way in which we shape research nationally and internationally. Examples include: Batty, Bowman, Dimitrakos, Freitas, Hernandez-Castro, Jordanous, Li(S), Rodgers, Marr, Orchard, Otero, and Soria, in the UK, Europe (Austria, Belgium, France, Germany, Italy, Netherlands, Spain), and worldwide (Brazil, China, Israel). Dimitrakos has acted as an Industrial Supervisor to eight students in the UK and Europe. Li(S) hosts a UK–Lille research studentship and Batty hosts interns from the École Polytechnique, France.

4.4 Wider Contributions to the Economy and Society

The School has a robust **public and media engagement agenda** that extends beyond traditional academic publication routes to support wider public dissemination of our research (in line with Section 1.2). In the REF2021 period, such activities have included invited talks to public and governmental organisations: Singapore Ministry of Defence (King); UK Cabinet Office, NATO CyCON, Singapore MoD (Nurse); and the Indian Government (Ramaswamy). Chennu and Nurse presented at New Scientist Live. Chennu, Jordanous, and Nurse delivered Pint of Science talks. Other activities have seen our staff featured in national and international newspapers: *Telegraph* (Ramaswamy), *Independent* (Chennu, Ramaswamy), *Daily Mirror* (Chennu), *Newsweek*, Japan (Nurse), *La Repubblica*, Italy (Jordanous), *Wall Street Journal* (Nurse), as well as *Wired* (Chennu, Nurse, Ramaswamy), *New Scientist* (Chennu), BBC TV and Radio (Chennu, Migliavacca, Ramaswamy), and Sky Arts (Jordanous).

Our impact case studies demonstrate the **wide-ranging impact of our work** on the software industry and on the use of computing systems in a range of industrial, healthcare, and social sectors. Other notable examples of how our research contributes to the economy and society include:

- The Cyber Security group identified vulnerabilities in hardware and software (which have been responsibly disclosed and suitably patched), and contributed to the standardisation effort in random number generators, working closely with partners such as GCHQ. Arief's research changed the international standard for handling electronic transactions. During the COVID-19 lockdown, the group disseminated information prominently on home IT security.
- The PLAS group improved the treatment of concurrent systems in graphics cards, verified the safety of code used in nuclear power plants, and worked closely with external partners such as Facebook, NVIDIA, and GCHQ. The MET office deployed Orchard's CAMFORT project for meteorological software error detection. Members sit on two ISO standards groups for C and C++.

- The Computational Intelligence group developed novel ML techniques that uncovered new biomarkers for ageing (Freitas), leading to two consultancies to East Kent Hospital University NHS Foundation Trust. Bowman harnessed brainwave responses for facial recognition, with Visionmetric Ltd. Jordanous's creativity model is used to structure coaching on professional creativity, in brand design (Folletto) and litigation (Ken Broda-Bahm, Holland & Hart LLC).
- The Data Science group engaged with external partners to improve vehicle brake light design (Ramaswamy, Road Safety Trust) and healthcare outcomes (Soria, Nottingham City University hospitals, which could lead to accelerated prognosis of breast cancer). It also received funding from Dstl, Google, and Huawei, and demonstrated significant public engagement activities (Chennu, Ramaswamy, see above).
- In our former Computing Education group, Utting's BlackBox project facilitated large-scale data gathering/analysis on learner patterns in programming.

The range and significance of our research impact has been underpinned by our strong record of interdisciplinarity and industrial collaboration, and our responsiveness to national and international priorities. It reflects the high standing of our staff, our ongoing investment in resources and infrastructure, and our commitment to nurturing all our researchers as leaders in their research fields.