

Institution: University of Surrey
Unit of Assessment: 11 Computer Science and Informatics
1. Unit context and structure, research and impact strategy 1.1. Organisation and Structure of the Unit The Department of Computer Science (the “Unit”) has a world-class reputation for research in Cyber Security, and in Computational Intelligence, as evidenced in this submission. After a strong result in REF2014, the Department embarked on a strategic programme of growth, with the objective of consolidating and strengthening these areas. The Department is now well-placed to address vital challenges from both a formal and an empirical perspective, while making globally important, impactful contributions to areas such as the theory and application of evolutionary computing and optimisation techniques, and foundations and applications in cybersecurity and privacy. The research growth has also been strengthened by the Department’s placement within the newly formed School of Computer Science and Electronic Engineering. This is enabling the Department to exploit synergies with Electronic Engineering to further strengthen its research power. Key external recognitions include its Centre for Cyber Security being recognised as one of 19 Academic Centres of Excellence for Cyber Security Research (ACE-CSR), and Professor Jin, Head of the second research area, being recognised as a Clarivate Highly Cited Researcher in 2019 and 2020. The Department is home to 23.5 FTE research active academic staff, supported by 10 RAs and 42 PhD students. The University is committed to the continuing growth of Computer Science at Surrey. As part of our strategic growth plans two new Professors (Chockler and Sastry) established a new Distributed and Networked Systems (DANS) Research Group. In addition, the critical mass of our two other research groups, Nature Inspired Computing and Engineering (NICE) and Secure Systems, was further consolidated with the recruitment of two Senior Lecturers and four Lecturers in the first part of 2020. Further appointments will follow. The NICE Group, led by Jin, has 9.5 FTE academic staff. The remaining academics (14) are structured under the umbrella of the Surrey Centre for Cyber Security (SCCS) led by Schneider and Manulis (Deputy). SCCS combines the Secure Systems Group, led by Schneider, with 12 academic staff, and the newly established DANS Group, with two professors and 5 affiliate members from the other two groups. The DANS Group will be a focus for strategic appointments over the next two years. There is a welcome overlap of membership and exchange of ideas among the three research groups, and with other research groups and centres across the University, assisting the Department’s mission to serve as a collegiate home for all researchers. PhD students are an integral part of our research activities. All research-active staff teach in the Department with research-led teaching the norm. Researchers may arrange to perform all teaching duties in one term only, allowing for dedicated research projects to be pursued during the remainder of the academic year. Staff are supported by Jin, the Department’s Director of Research, whose role is a supervisory one; encouraging an inclusive research culture, promoting Departmental synergies, and facilitating the integration of research within the School, Faculty, University and beyond. The Faculty of Engineering and Physical Sciences (FEPS) assists the Department’s research initiatives and oversees REF processes. FEPS also provides dedicated funding for impactful research, bidding activities, and PhD scholarships, supplementing Departmental contributions. 1.2. Research Objectives and Strategy The Department’s research objectives and strategy have remained consistent since 2014: 1. Sustainable growth via a supportive, balanced and coherent research environment. 2. Aim to be world leading in strategically identified core areas that build on existing strengths, provide a balanced portfolio, and promote contributions to the discipline and wider societal

questions.

3. Attain the critical mass necessary to develop new PhD and early career researcher (ECR) training in line with discipline best practices.
4. Significant engagement with multidisciplinary initiatives across our Faculty and the University.

In pursuit of objective 1, the Department made an investment in 3 additional academic posts (a 15% growth) during this REF cycle alongside natural refreshing to re-energise and expand its research capability. It has also recruited a cohort of Teaching Fellows on Teaching and Scholarship contracts. These Teaching Fellows and Senior Teaching Fellows, new since 2014, play a crucial role in freeing research time for other colleagues and ensuring the research active staff are able to focus on more advanced courses with top-quality research-led teaching.

Progression is a key indicator of a productive research environment. Over this REF period 17 colleagues, including teaching staff, have achieved promotion.

To achieve objective 2, the Department's continued expansion has focused exclusively on excellent hires in our core areas (see Section 2 below) to achieve the goal of rebalancing our research groups. This has ensured that the Department has the means to regularly attract sizeable research grants and produce research with impact. The EPSRC £3.8M Next Stage Digital Economy Centre in the Decentralised Digital Economy is one recent example; also illustrating collaboration within the newly formed School of Computer Science and Electronic Engineering.

Objective 2 is further supported through our long-term strategy of hiring colleagues with research agendas that deliver impact through networks outside academia. Impact is also supported by a team of Visiting Researchers and Professors who have a strong commitment to mentoring our research out into Government, Industry and the Third Sector. The heads of our Research Groups all have strong and active programmes for delivering impact. For example, the work of Jin (Head of NICE) on evolutionary optimisation is generating broad interest across a range of industries, with a particularly strong engagement through Honda Research Institute Europe into their products (see Impact Case Study). Jin was also appointed "Finland Distinguished Professor" by the Finnish Funding Agency for Innovation for three years, working with companies on various industrial optimisation problems. Schneider (Director of SCCS and Head of Secure Systems) has been at the forefront of applying secure and verifiable e-voting in government and commerce since 2004 (see Impact Case Study). Of the joint heads of the newly established DANS Group, Sastry spent a significant part of his career working in industry and industrial research labs (Cisco Systems and IBM TJ Watson Research Centre). Chockler also has a background in industry (IBM Research), and his research continues to be focused on solving real-world problems seeking to uncover deep trade-offs and their implications for system engineering practices.

With regard to objective 3, our research capability was also greatly reinforced by our expanding PhD programme that brought in 30 excellent doctoral students who have transformed the Department's research environment. Our engagement with industry and EIT Digital has led to the establishment of an externally funded Centre for Doctoral Training (CDT) in **Future Connected Technologies** during 2020, which will further strengthen our PhD training programme.

To achieve objective 4, the two main research groups have lead roles in virtual research networks that engage with researchers throughout the University:

1. NICE plays a leading role in the **Surrey Centre for Mathematical and Computational Biology**, which is a community of researchers across all three Faculties in the University that has established a large number of productive cross-disciplinary funded research projects on bioinformatics and computational biology.
2. SCCS is one of 19 Academic Centres of Excellence in Cyber Security Research recognised by the UK Government's National Cyber Security Centre in partnership with the EPSRC. SCCS has members from seven research groups/centres across two of the three Faculties in the University. Members of the Centre also play an integral part in **Surrey Blockchain**, an interdisciplinary research hub across the University of Surrey backed by £3M UKRI/EPSC investment, which focuses on fusing blockchain with artificial intelligence technologies.

Central to the Department's continued development is the growth of activity around three research

groups and collaborations across the group boundaries. All our research includes a **foundational** element developing understanding and theory, and an **application** element to specific problem domains and to building practical solutions. The practical application of theory is an important driver for the foundational research, providing a testing ground and a source of more fundamental challenges.

We proceed with a brief overview of our research activities:

NICE Group, led by Jin, includes Bauer, Feng, Guerin, Krause, Li, Moschogiannis, Tamaddoni Nezhad, Tang, and Thorne.

The core research under this theme focuses on developing efficient algorithms for solving data-driven and multi-objective optimisation problems in applications such as aerodynamic design optimisation of turbine engines, optimisation of vehicle dynamics, hybrid electric car control, and vaccine selection. Machine learning techniques such as semi-supervised learning, transfer learning and Bayesian optimisation are used to assist evolutionary optimisation of complex problems, and in turn the evolutionary optimisation theory is itself being used to develop innovative machine learning algorithms, such as automated machine learning and multi-objective machine learning.

As the group has expanded and evolved, the core competencies have developed to include evolutionary computation, computational neuroscience (spiking neural networks and neural plasticity), complex networks, autonomous/self-organising systems, reinforcement learning, explainable & privacy-preserving AI, knowledge extraction, computer vision & image processing, natural language processing, and computational biology. The aforementioned engagement with the Surrey Centre for Mathematical and Computational Biology helps to retain focus on the NICE theme, but also to build capacity through collaborations across the University. NICE has been strengthened by the recent recruitment of Bauer (UKRI Research Fellow), with expertise on computational modelling and the analysis of biological dynamics, and Thorne, with expertise in statistical models in systems biology and bioinformatics.

Surrey Centre for Cyber Security (SCCS), led by Schneider and Manulis (Deputy) is formed of two groups, with partly overlapping memberships and related topics:

- **Secure Systems Group**, led by Schneider, includes Boureau, L. Chen, T. Chen, Dash, Dongol, Dragan, Gerault, Gillam, Granger, Manulis, and Treharne.

The group has strong expertise in trusted computing and trusted systems, privacy and authentication, secure communications, blockchain & distributed ledger technologies, security verification, and applied cryptography.

The group focuses on advanced techniques and applications such as high-function encryption schemes & digital signatures, authentication & key exchange protocols, cryptographic solutions for privacy-preserving identity management, secure data sharing, and information exchange. The group is technical lead for H2020 FUTURE TPM (Future Proofing the Connected World: A Quantum-Resistant Trusted Platform Module) a consortium of 15 academic and industry partners from across Europe who are researching a Quantum-Resistant TPM - a hardware chip which is used as a 'root of trust' for a computing system.

Group members have also been involved in setting several world records in discrete logarithm computations. For example, providing a rigorous algorithmic breakthrough which provably solves the discrete logarithm problem (DLP) for finite fields of fixed characteristic in quasi-polynomial time for infinitely many cases. Such proofs are exceptionally rare in mathematical cryptology. The algorithm was used to solve a DLP in a field of bitlength 30750, smashing the previous record of 9234 bits. Work on next-generation authentication mechanisms, including passwordless authentication, is in cooperation with FIDO Alliance members (an open industry alliance which promotes the development, use of, and compliance with, standards for authentication and device attestation). Research on security of electronic payment protocols is joint with leading payment providers, including CreditCall and Streeva.

Group members have also been building protection mechanisms into emerging technology in the rail and automotive transport sectors. Group members also work on foundational and

applied aspects of formal verification for security and privacy involving a range of techniques from model-checking to theorem proving. A variety of automated tools and domain languages are used but with a focus on the use of non-classical logics and state-based symbolic verification.

- **DANS Group**, jointly led by Chockler and Sastry, includes Bauer, Dongol, Li, Moschogiannis, and Treharne.

The group's research spans both technical and socio-technical challenges in the context of established and emerging technologies such as the Internet, World Wide Web, blockchains and distributed ledgers, cloud computing, and social networks.

In particular, group members have been working on distributed coordination, development of control policies, concurrency control, fault-tolerance, distributed trust, resource management, complex network analysis, including controllability & criticality, and on formal verification techniques and tools.

The group maintains a strong inter-disciplinary focus on socio-economic questions arising in the context of user interaction with these systems and emergent behaviours that stem from such interactions. The research covers both theoretical underpinnings of such systems as well as large-scale data-driven empirical analyses.

1.3. *Future Strategy - plans for 2021 to 2026*

Our aim is to further establish the NICE Group and the SCCS as two internationally recognised research centres. To do this, we will need to grow both the numbers and profile of our internationally leading research staff. Strong teaching with support of a team of teaching fellows will ensure the financial stability of the Department as it continues to grow its research base.

In order to be able to prepare more competitive research bids at the multi-million pound level, we will need to grow our links with global players to add power and impact to the research of the NICE group. The achievement of this will be facilitated by the University wide investment of £400k into developing AI@Surrey, together with the recent formation of the School of Computer Science and Electronic Engineering. Together, these will help establish NICE within a coherent AI and Data Science presence at Surrey.

As further support towards achieving this objective, the launch of our very successful Data Science MSc in October 2019 is also playing a significant role for the NICE group; continued staff recruitment is supported by the need to service and continue to stimulate the demand for this course. The appointments in the first part of 2020 of Bauer, Guerin, Feng and Thorne are illustrative of the level of investment in the Department by the University. These new appointments will help us achieve our ambitions of strengthening both academic excellence and industrial impact.

The SCCS is further along the path to its establishment as a globally leading research centre. To drive a broader research agenda including multidisciplinary cyber security research across the University and promote the research and education activities of the University in relation to cyber security, we are establishing a cross-disciplinary research and education network, **Surrey Security Network (SSN)**.

In the immediate term, recruitment will have a focus on building critical mass for the newly formed DANS Group. This group is already providing an extra dimension to the research performed within SCCS and will further enhance the reputation of the Department as a globally leading research centre for cyber security.

We also have an objective of growing SCCS as a nexus of innovation with SMEs. In order to achieve this objective, we will continue expanding our externally funded CDT in Future Connected Technologies, established in 2020, with cross-disciplinary projects on the intersection of cyber security, artificial intelligence and communications by working closely with EIT (the European Institute of Innovation and Technology) Digital and industry sponsors.

1.4. Impact**1.4.1. Facilitation of impact**

Approaches to realising impact include delivery of commissioned research (e.g., with the Corporation of London on carbon sequestration assessment and HP Labs on quantum-resistant cryptography) or collaborating with a start-up (e.g., a long-established work on security with Consult Hyperion). Relationships with industry are often established for collaborative research.

We enjoy a strong and active engagement with the University's Technology Transfer team. Innovate UK SMART projects, and KTPs feature strongly in our portfolio; a recent KTP with AT Medics on medical informatics received the highest grade of 'Outstanding' together with a 'Certificate of Excellence'.

To build collaborations that have a direct pathway to impact, we build long term strategic partnerships. These are exemplified by the work of Schneider leading to the Impact Case Study (ICS) on e-voting, and the work of Jin leading to the ICS with Honda. Regular seminars and presentations are provided by the University's Research and Innovation Support Team for new and existing staff. The recent (September 2020) appointment of a Professor in Practice (Ryman-Tubb), with 35 years' experience of industrial innovation in Data Science and AI, will also provide a significant enhancement to our future impact culture.

We also contribute to security reviews of existing as well as upcoming technical specifications as part of our work with the LoRa Alliance Security Working Group and their Technical Committee. The LoRa Alliance is one of the largest alliances in the technology sector, committed to enabling large scale deployment of Low Power Wide Area Networks for the Internet of Things (IoT). We are working with Surrey County Council on their IoT devices roll-out programme, which uses our cyber security expertise.

Krause maintains an advisory role with the IoT infrastructure provider Balena, on his earlier work on Digital Ecosystems (Impact Case Study). His more recent work has led to an engagement through 2020 with the City of London on the assessment and optimisation of carbon sequestration in their extensive land holding around the perimeter of Greater London. Tang shares her time between the University and a major USA based healthcare provider. Chen maintains an active research relationship with Hewlett Packard Laboratories.

1.4.2. Future vitality / sustainability of impact

Researchers across the Department have achieved impact that is responsive to vital emerging challenges. All of the ICSs that have been submitted have the potential to grow. The strategy to support these ongoing projects includes the continued growth of e-voting as a central theme in the Surrey Centre for Cyber Security, and the part-time appointment of Tang with a leading company in the healthcare sector.

1.4.3. Relationship of Selected Case Studies to Impact Strategy

The impact case study led by Jin with Honda is a key exemplar of the core research outputs of the NICE group in many-criteria optimisation. Most of the underlying work is in the public domain and demonstrates how the work of the NICE group can be applied to solving engineering problems that may otherwise be intractable.

The impact case study led by Schneider on e-voting acts as a key demonstration of the work of SCCS in secure and trusted voting. These two ICSs were deliberately selected as "flagships" for their respective research groups.

The impact case study led by Krause on IoT infrastructure is illustrative of the domain of applicability of the DANS group within SCCS.

All three ICSs are based on long-standing engagements with key stakeholders in their respective domains, all three are founded in internationally leading foundational research, and all three involve active long-term engagement of their associated researchers with the commercial or governmental organisations facilitating the impact.

1.5. *Interdisciplinary Research Enhancing the Vitality and Sustainability of the Environment*

The Department has had a tradition of engaging with and co-leading large-scale interdisciplinary projects since 2003. This started with FP6 Digital Business Ecosystems (Grant agreement ID: 507953), immediately followed by FP6 OPAALS (Grant agreement ID: 034824). OPAALS finished in 2010, but we were then co-investigators in EPSRC ERIE (for Evolution and Resilience in Industrial Ecosystems; EP/H021779/1) involving the Departments of Sociology, Mathematics, and the Centre for Environment and Sustainability. An even broader level of interdisciplinarity was achieved through the concurrently running MILES (Models and Mathematics in Life and Social Sciences), funded under the EPSRC Bridging the Gaps call (EP/I000992/1).

Since then, inter-disciplinary research has remained central to the strategy of the Department. Major foci for this are provided by Surrey Security Network, and the Surrey Centre for Computational Biology, University wide networks co-led by the Secure Systems and NICE groups respectively. Other particular exemplars of interdisciplinary research are found in on-going collaborations across Faculties within the University. The recently established collaboration between Krause and Giglio (School of Law), a leading expert on Roman Law, on formally modelling the evolution of legal argument structures is a good example of one of the more unexpected collaborations that has emerged from the open research culture within the University.

1.6. *Open research culture and ethics*

The Department is committed to transparency, open communication and making research findings widely available to other researchers and the public. Researchers in the Department aim for the highest standards of research ethics and openness. This is a requirement for publishing in the top journals where refereeing is rigorous, and code must be deposited as a matter of course, as well as data whenever permissions allow. The Surrey Research Insight (SRI) team supports and advises on open access and enhancing research visibility. Data and publications are shared through the SRI open access repository. Researchers deposit all outputs at the point of acceptance, and this is a formal objective in the appraisal process. Upon completion, all PGRs deposit an electronic copy of their thesis in the SRI repository. The Department works in close collaboration with the Library, and experts from the Library have presented to the Department on issues related to open access.

Formal processes ensure research is of the highest ethical standards. The University Research Integrity and Governance Office (RIGO) provides guidance on proposals and ethical review submissions. The Department works closely with the University's legal department with aspects including contractors, consultants and sub-contracts for research partners. Data is stored securely, maintaining subject confidentiality where relevant, and preventing unauthorised access or loss. The University Ethics Committee (UEC) has a diverse, interdisciplinary membership including lay representation. It works closely with the Faculties and the Department has been represented throughout the REF period.

2. People

2.1. *Staff Strategy*

The key aims of our staffing strategy are: (1) to strengthen and grow the core research areas through targeted appointments of talented staff; (2) to become more representative of diversity; (3) to use opportunities for appointments to strengthen interdisciplinary collaborations; (4) to achieve a balanced mixture of ECRs, mid-career and senior staff, to ensure vitality and sustainability, as well as leadership; and, (5) to manage increasing student numbers through the recruitment of career path Teaching and Senior Teaching Fellows.

The recruitment of new staff is led by the Department's Senior Management Group which includes the Head of Department, Director of Research and the leaders of the three research centres. Following a major strategic review of the Department in 2016, we have appointed 16 new staff including two at professorial level. The majority of appointments have been at lecturer and senior lecturer level to strengthen the strategic direction of the existing research groups. The two professorial appointments were made to establish a new research area, as mentioned in the research strategy. Building equality and diversity has been a key objective of our recruitment strategy with more than half of our staff (13 out of 23.5) of non-white-European ethnicity.

Industrial engagement has been further strengthened with visiting appointments, Professorial appointments and with fractional appointments. Jin has, for example, continued to build on the relationship with his former employer Honda Research with the support of Markus Olhofer (Chief Scientist, Honda Research Institute Europe GmbH) as a Visiting Professor. Tang was externally funded for a 12-month sabbatical and then moved to a 50% appointment with the remainder of her time working as a research team leader at the international company that funded her sabbatical.

2.2. *Staff Development and Support*

We pair up new lecturers and ECRs with a Senior Colleague to offer advice on the development of a research career. Lecturers and ECRs benefit from a well-developed probation process. They attend training in teaching methods during this period. Teaching loads are gradually ramped up over the probation period, typically starting with a shared module in the first year and increasing to two modules by their third year.

Start-up funds are available to new staff to attend conferences while they establish their own research funding.

Every staff member has a formal annual appraisal with their line manager in the Staff Development Review process. Mentors are assigned to new members of staff, and any member of staff can request mentor support for specific developmental activities.

Grant applications are supported by peer review and guidance provided by the University research support office and senior academics within the Department. New Investigator Award (NIA) applications, especially, are peer reviewed by at least two senior academics from the Faculty "Peer Review College". We have an Intention to Bid process to ensure that University support is provided during bid development as needed.

During the last five years, the Department has taken a more proactive approach to supporting the career development of ECRs. They actively engage in our teaching programme through tutorial support, project supervision and occasional lecturing, and undergo training on proposal writing. As an example of the success of this approach, a former PDRA Dragan was recently recruited onto our Academic staff from a highly competitive international pool of applicants.

Further details of the University wide strategy for researcher development can be found in the Institution Environment Statement.

2.3. Research students

2.3.1 Summary

The Department has seen a steady rise in successful PhD completions since the last REF, averaging 9 per year compared with 6.8 per year in the REF2014 cycle.

This increase has been accompanied by both an increase in the levels of training and support provided, and the quality of the students recruited, as measured by GPA.

2.3.2 Training, Supervision and Monitoring

The University's Doctoral College provides a large number of courses, some compulsory, for PGRs and ECRs. In addition, as an ACE-CSE our students supervised within SCCS are provided with funds to attend events such as the 2019 Winter PhD Cyber School in Newcastle. Students in the other two groups are supported by Department funds for conference attendance.

CDT in Future Connected Technologies: The Department is coordinating the CDT in Future Connected Technologies, established in 2020, which offers opportunities for cross-disciplinary industry-sponsored doctoral projects in the areas of Cyber Security, AI and Communications. This CDT receives 50% funding from EIT Digital and 50% from Industry Sponsors and has the capacity of up to 15 PhD studentships per year, with generous stipends of £20k per year. Recruitment is already underway with the first PhD project sponsored by Saab started in October 2020. Five further companies have committed to fund PhD projects so far, and their start is planned for 2021.

All students in the Department have a primary supervisor plus a second supervisor. At least one of the supervisors must have previously supervised a PhD student through to successful completion. After one year, PGRs must submit a formal Confirmation Report to summarise achievements and to outline thesis plans. Two internal examiners interview the student. Problem areas are identified, and an action plan is developed to ensure timely completion.

Since 2014 the examiners present at that formal assessment are also required to comment on progress at the 24-month review.

PGR progress and training are overseen by the Faculty Research Degree Committee, which meets monthly and is attended by our Director of Postgraduate Studies (Gillam).

2.3.3 Support for Part-time/Distance Doctoral Researchers

Over the current assessment period the Department has graduated 4 part-time PhD students. All part-time students are provided the same office, equipment facilities and training opportunities as full-time students, and attend the University on a regular basis for supervisions and review meetings.

There is also a long-standing Joint Supervision Programme (JSP) with King Abdulaziz University, Saudi Arabia, to provide joint supervision of married female faculty staff who are unable to study in the UK due to family commitments. In total, 5 PhD students graduated from this programme during the assessment period, with a further 2 joint PhD students currently registered. Each student on the programme has a Surrey principal supervisor and a second supervisor. The students are supported by regular video conference calls and by at least three on-site visits per year either with the Surrey supervisor visiting Jeddah or the student travelling to Surrey.

2.3.4 Skills Development

PhD students contribute to, and benefit from, both the Department research culture and membership of the Department and the wider University Doctoral College. Within the Department, students participate in PGR workshops organised by the Department's PGR Director. These include a range of workshops on topics such as literature reviewing, referencing and networking, conferences and social media.

Each research group runs a weekly reading group where students are expected to present on a regular basis, which gives them an opportunity to practice presenting in a supportive environment.

PhD students are expected to attend at least one leading conference and present a paper during

their PhD. The Department provides each student with an allocated fund, as well as providing a general fund for students requiring funding for further conferences and training.

We have also been able to offer some students fully funded short-term (1-2 week) exchange visits to leading research institutes around the world. Examples include visits to: Federal University of São Carlos, Brazil (2019; 2 students); Nanjing University of Posts and Telecommunications (2019); University of Wollongong (2019); University of Jyväskylä (2015). All students funded by Honda have regularly visited the Honda Research Institute in Germany.

As well as benefitting from exchange visits, our own PhD students also benefit from an environment in which over 20 visiting PhD students have been hosted from China, Singapore, Brazil and Australia. These two-way exchange visits help us to offer a vibrant international research experience to all our students.

Destinations: Our graduating PhDs go into a variety of careers. Most have progressed quickly to senior management positions, but they also include PDRA positions in the UK and internationally, often progressing to academic positions. International PhD students have returned to academic positions in their home country, especially those from the Saudi Arabian JSP Programme where former students have seen accelerated promotion to senior positions in their respective institutions, providing a significant contribution to the career development of their female members of staff.

2.4. Equality, Diversity and Inclusion (EDI)

The gender balance of the academic staff in the Department is reflective of the general situation in academic computer science (12% female, 88% male). However, of the female staff, two are Professors, one (0.5FTE) is a Reader and one is a Senior Lecturer. See also our support for married female staff in Saudi Arabian Universities (Sub-section 2.3.3). Ethnicity is more representative, with 36% white and 57% BAME.

We have 23% of research active staff being Research Fellows, 51% Senior/Lecturers, 2% Readers and 24% Professors. Our recruitment at Senior/Lecturer level has seen the appointment of high attainment researchers and we expect to see a series of promotions to Reader level as we continue to feed into this pipeline.

Online Unconscious Bias training is mandatory for all staff, and face-to-face training on this topic is mandatory for all staff involved in recruitment, disciplinary and promotion procedures. As a consequence, EDI is always actively considered in all job-market decisions at the Department level.

The good practices at the University level are fed back to the Department from the Faculty EDI committees, but the Department also takes many initiatives to promote EDI through its Athena Swan action plan. For example, all group meetings and seminars are held between the core hours of 10am to 4pm. Policies also allow for a phased return to work following parental leave or periods of illness, and the Department has been very flexible in these cases. Caring responsibilities and health needs are also taken into account when organising conference attendance, participation in the job-market activities, or other necessary travel to support research, with colleagues being authorised to use more expensive modes of travel when that is more convenient and justified.

All staff have the opportunity to apply for flexible working arrangements with regards to the timetabling of their teaching, and many do. Flexibility and work-life balance is greatly assisted by the balanced teaching loads in the Department which allows colleagues to organise their research and other commitments in a way that, for example, suits their caring responsibilities or health needs. For these reasons, and others, the Department was Awarded Athena Swan Bronze status in 2017.

These flexible practices allowing a good work-life balance gained a new impetus with the Covid-19 pandemic, with all members of staff being supported to work remotely while caring for their families.

3. Income, infrastructure and facilities

3.1. Research Funding Strategy

Since the last REF period our focus on enhancing research quality within the Department, has seen a steady increase in our research income, and in the diversity of funding sources. The total research income in the REF2021 period was £6.5M, more than double that of the REF2014 period (£2.5M).

As shown in REF4b, the Department has focused on steadily increasing the funding contribution from UKRI Research Councils during the assessment period, increasing almost four-fold from £130k in 2013/14 to £500k in 2019/20. For industry funding the Department prefers to work with partners at a strategic level through KTPs, collaborative research, PhD projects and long-term strategic consultancies. For example, L. Chen has a consultancy relationship with HP Labs, Krause with the City of London and Tang with a major international healthcare provider.

Funding for PhD students is available through an allocation to the Department.

The University Doctoral College also provides funding for PhD students through scholarships. Applications for these are assessed on a competitive basis; given the limited availability they are only available to students of the highest quality. We have been awarded at least one of these for each year that this scheme has been running.

Over the past 6 years, Honda has funded five full PhD students (covering overseas tuition fee and stipend, as well as travel to international conferences) for three years. Other industry funded PhD studentships include:

- one full PhD studentship funded by Ulucu, a company from China;
- one home PhD student jointly funded by NPL (iCASE),
- one jointly funded by the Pirbright Institute.
- two EngDs, respectively with Bosch UK and HR Wallingford.

Our CDT in Future Connected Technologies, 50% funded by EIT Digital and 50% funded by industrial sources, is providing us with funding for up to 15 PhD studentships per year.

3.2. Facilities

Most offices for staff and PhD students are located on one floor, together with a dedicated seminar room and video conference room. All permanent members of staff have individual offices with appropriate IT equipment and software, and each full-time PhD student has a dedicated desk in one of the shared spaces.

The Department has access to the AI@Surrey Compute Cluster to support the data intensive evolutionary optimisation and machine learning of the NICE group. This is a cluster of 16 multi-GPU servers with over 120 high-performance GPUs for data intensive computation. The cluster is connected to the University's storage system via fibre channels for processing of large datasets. Compute resources are managed by an HTCondor scheduling system for GPU based machine learning using large dataset. The system uses HTCondor with Docker containers so that researchers can specify the libraries and versions required, allowing both a customisable experience and encouraging open and reproducible research. The facility provides a local resource to support our research and provides a platform to develop capabilities for using national GPU facilities such as JADE if even greater compute capacity is required.

In 2019, the University of Surrey invested £1.7M in a new dedicated 200 seat computer science laboratory which is also available for research. All these Linux machines are equipped with high-end Nvidia Quadro P4000 Graphics Cards. These are set up as a pool of machines that can be accessed remotely, if required. Queued jobs are run on the first available machine, or a user could queue multiple machine learning jobs to be run in parallel on different machines. Researchers in NICE can thus progressively scale their work from the computer science laboratory cluster to the AI@Surrey cluster to a national facility as their work

advances.

The Department has a number of resources for supporting the research of SCCS on networking, distributed systems and security.

An **OpenNebula server** provides an isolated cloud environment for supporting research on edge and cloud computing, and on security.

Distributed Computing Testbed: To support our strategy of expanding the internationally leading research profile in technical foundations of secure and trustworthy distributed computing, the Department has recently invested in a state-of-the-art distributed computing testbed. This comprises five Dell PowerEdge R340 servers equipped with SGX-capable CPUs and RDMA-enabled Mellanox ConnectX-5 network interface cards connected via the Dell EMC S5232F-ON Switch with 32 100 Gigabit Ethernet ports. The cluster will serve as a first-of-a-kind distributed testbed supporting Remote Direct Memory Access (RDMA) capabilities alongside Software Guard Extensions (SGX) technology to enable trusted execution of critical code. To the best of our knowledge, this combination of capabilities is unique and is not available from the existing academic hardware testbeds anywhere else in the UK.

LoRa testbed: This is formed primarily of one LoRaWAN gateway, 4 LoRaWAN sensors and 15 LoRaWAN Pycom IoT devices. These sit alongside other LoRaWAN gateways present in the University campus, forming a LoRa ecosystem to facilitate research in IoT security. The availability of this test bed, together with the SCCS expertise on security and privacy, led to the University being invited by the LoRa Alliance to become an institutional member, joining the LoRa Alliance Security Working Group and their Technical Committee.

Surrey Blockchain: This is a university-wide testbed for distributed ledger technologies (<https://blockchain.surrey.ac.uk/>) and is a shared resource to support collaboration on research on the fusion of AI and Blockchain between the SCCS, the Centre for Vision, Speech and Signal Processing (CVSSP), and the Centre of Digital Economy at Surrey (CoDE). Each project may demand specific DLT attributes: a shared permissioned chain maintained across multiple archives; a permissioned public ledger; and/or a fully unpermissioned public chain. We have implementations running on the Multichain (open source), Guardtime (proprietary) and Ethereum test networks. We participate in the public Rinkeby network and administer our own private campus test network for development.

Testbed for Satellite Constellations: In collaboration with the Surrey Space Centre, we have created a testbed to simulate communications in a constellation of small satellites using ODROID XU4 Single Board Computers and LimeSDRs. This puts us in a unique position to conduct research on networking and cyber security aspects of space systems and satellite communications. At present the testbed can simulate 10 satellites and their communications with the ground control station. This testbed is now being extended to address distributed, networked clusters of satellites. Physically, the footprint will increase by 50%, adding heterogeneity and more scalable processing (using Jetson Nano TX2/Xavier NX) along with reprogrammable capability (using NetFPGAs) to enable experimentation with network and security protocols.

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

4.1. Collaborations, Networks and Partnerships

The Department maintains a close involvement with Industry to ensure specific research activities are directed in a way that addresses long-term societal needs as well as being academically sound. This collaboration is a two-way process, with research outputs transferred to industry and then with research questions being fed back. We find this is a powerful way of stimulating research programmes and directing them to maximise both societal and academic impact.

The most significant examples of research relationships are:

Jin with Honda Research Institute on evolutionary design (leading to an ICS);

Jin with the Multi-objective Optimization Group, Faculty of Information Technology, University of Jyväskylä, Finland;

Jin with State Key Laboratory of Synthetical Automation of Process Industry, Northeastern University, China;

Tang with Moorfields Eye Hospital and Queen's University, Belfast on diabetic retinopathy diagnosis, and with a major multinational in the healthcare domain; work which has enabled us to demonstrate the global generalizability of her research outputs;

Schneider with the Universities of Luxembourg and Melbourne, King's College, London, Monax industries and the Electoral Reform Services on electronic voting (leading to an ICS);

Manulis with the National Cyber Security Centre;

Chockler with IMDEA Software Institute, Technion, Tel-Aviv University, Emory University, Cornell, KTH, and IBM Research;

Sastry with the Alan Turing Institute as Visiting Researcher and one of the co-leads of the Turing Social Data Science Special Interest Group;

Sastry with BBC R&D, Vodafone R&D, Cisco Systems, the UK Parliament, Wikimedia Foundation and the Samaritans.

The Department actively supports academic interaction with industry through its Industrial Advisory Board and by funding opportunities for developing new collaborative links. Strategic relationships are also developed with the companies mentioned above and others, building up links through the placement of professional training year students, graduate recruitment, research-related undergraduate and MSc projects, and scholarships for PhD projects. These relationships are also firmed up through strategic visiting chairs, for example Markus Olhofer (Honda), Gloria Benson (Consult Hyperion), George Saleh (Moorfields Eye Hospital), Spencer Thomas (NPL), Adrian Waller (Thales Research and Technology).

Alan Woodward, a Visiting Professor in the Department, raises public awareness about our cyber security research and helps to promote our Department in public media through frequent commentaries in established media outlets such as BBC, The Times, Telegraph, and Daily Mail. Many of his interviews have also been picked up by foreign media.

4.2. *Wider contributions to economy and society and engagement with communities*

A core part of the Department's research strategy is to facilitate a full stack of technological readiness from its foundational research through to direct engagement with product developers and community stakeholders. Our contributions are very broad, from the globally significant ones to local engagement with the third sector (long term relationships on IT innovation with the Surrey Wildlife Trust and Royal Horticultural Society, for example) and local community (in areas with high indices of social deprivation in North West Guildford, and other less privileged areas of Surrey).

Beneficiaries of our research include, but are not limited to:

- The general public, whether that be through simpler parental controls for electronic devices, or improving the traveller experience for mobility impaired rail passengers, or in detecting eye diseases;
- Commercial organisations through developing IoT solutions, blocking predatory behaviours for Network Providers or creating jobs associated with electronic voting;
- The environment, through savings in CO₂ emissions through optimisation models of energy use in hybrid vehicles, systems level modelling of ecological networks and services, or the application of AI to remote monitoring of carbon sequestration.

4.3. *Contribution to sustainability of discipline*

In order to maintain the vitality of its research and the discipline itself, the Department actively participates in collaborative projects with partners outside the University, and in different disciplines, in order to benefit from the resulting dialectic. The EPSRC funded VOLT (Voting over

Ledger Technology) project is a strong example. Schneider's trusted voting work benefitted from partnership with King's College London's Department of Political Economy with its expertise in game theory, rational choice theory and behavioural economics. In a different domain Krause is building a community of interest on innovative applications of machine learning and IoT to agroecology with a forthcoming book jointly edited with Prof. Xhafa of the Universitat Politècnica de Catalunya and a webinar to over 600 students in India.

4.4. *Responsiveness to national, international priorities*

The Department actively responds to national and international priorities. For example, its role as an ACE-CSR provides direct engagement with GCHQ on targeting its research to global challenges in security and privacy. Opportunities for usage of IoT and Blockchain, respectively, continues to expand and draw on the Department's work on digital identity and trust. The work of the NICE Group on evolutionary optimisation is having important application in energy reduction problems, such as optimisation of the management of hybrid vehicle drivetrains (ICS), that feed into the UKRI Sustainable Digital Society priority area.

4.5. *Influence, contributions to and recognition by research base*

Learned Societies/professional bodies: Membership of, and active engagement with, professional bodies is actively encouraged within the Department. Support for progression to Fellowship status of their respective societies is a component of career progression within the Department with senior members expected to achieve this level. **Jin** is a Fellow of the IEEE. **Schneider, Gillam and Treharne** are Fellows of the BCS. **Schneider** is also a Fellow of IET. **Krause** is a Fellow of the Institute of Mathematics and its Application, and a Chartered Mathematician.

Distinctions/prizes: **Jin** has been recognised by the University of Surrey as a Distinguished Chair. He was named a Highly Cited Researcher in 2019 and 2020 by Clarivate, recognising him as one of the most influential researchers across the globe. He was a "Finland Distinguished Professor" at University of Jyväskylä, Finland, "Changjiang Distinguished Professor" at Northeastern University, China, and Visiting Professor at Donghua University, China.

In the newly formed DANS Group, **Chockler** received an ACM DEBS Most Influential Paper Award, 2019, and a Best Paper AWARD at the 32nd International Symposium on Distributed Computing (DISC'18). **Sastry** was nominated a Supervisory Excellence Award (175 nominations; shortlisted to final 2 from Faculty), received the 2019-20 PLuS Alliance Fellowship, his PhD students won awards for "Best Impact" and "Scientific Excellence" across the Faculty in 2019, he received a Best Paper Honorable Mention in 2018 at The Web Conference (WWW), the PhD project of a student was a finalist (top 4 in the creative computing for the digital economy category) at the EPSRC Connected Nations Pioneers Competition, and obtained 2018 Best Paper Award at ACM SIGCOMM Mobile Edge Communications Workshop.

Other Best Paper Awards for members of the Department include an IEEE Transactions on Cognitive and Developmental Systems Outstanding Paper Award for **Guerin** in 2019. **Tamaddoni Nezhad** is a Co-Investigator, Technical Director and Programme Committee member of the EPSRC Human-Like Computing Network Plus (2018-2023).

Editorships: **Jin** is Editor in Chief of *IEEE Transactions on Cognitive and Developmental Systems*, and of *Complex & Intelligent Systems*. **Schneider** is an Editorial Board Member of the *Journal of Cybersecurity and Privacy*. **Sastry** is a member of the Inaugural Editorial Board of the *Journal of Social Computing* and an Editor of *Elsevier Online Social Networks and Media*. **Treharne** is an Associate Editor of ACM Computing Surveys. **Gillam** is Founding, and ongoing, Editor-in-Chief of *SpringerOpen Journal of Cloud Computing*, **Krause** has been Editor (Computing and Software) for the *IET Journal of Engineering* since its inception in 2013, and is Deputy Editor for *BMJ Healthcare Informatics*. **Manulis** is an Editorial Board Member of the *IEEE Transactions on Information Security and Forensics* and *Springer's International Journal of Information Security*.

Eleven other members of the Department are also Editorial Board members or Guest Editors of major journals in their respective areas of research.

Advisory/Reviewing:

Schneider and Krause have served on EPSRC funding panels and Treharne has been an EPSRC TIPS network plus panel member.

Schneider, Jin, Gillam, Krause, Manulis and **Treharne** are members of the EPSRC Peer Review College, and Sastry is a member of the Flanders Innovation & Entrepreneurship (VLAIO) grants committee; **Chockler** acted as panel member for: the French National Research Agency (ANR) in 2017 and 2019; the Economic and Social Research Council (ESRC), New and Emerging Forms of Data - Policy Demonstrator Projects, Commissioning Panel Member, January 2017; the Israel Science Foundation (ISF), 2015; the Flemish Agency for Innovation by Science and Technology (IWT), ICON Call 2014; Computing in the Cloud action line of European Institute of Innovation & Technology ICT Labs (EIT ICT Labs) Call 2014. **Tamaddoni Nezhad, Tang** and **Krause** are also active as international grant proposal reviewers.

All members of the Department are regular PC members for conferences within their research areas and reviewers for relevant Journals.

Conference/programme chairs:

Jin has been: General Chair, IEEE Congress on Evolutionary Computation, 2020; General Co-Chair, 2016 IEEE Symposium Series on Computational Intelligence, 2016; Chair, 2015 IEEE Symposium on Computational Intelligence in Multi-Criteria Decision-Making; Founding Co-Chair, 2014 IEEE Symposium on Computational Intelligence in Big Data.

Schneider was General Chair of ESORICS (the 25th European Symposium on Research in Computer Security, Surrey 2020). Prior to that he had been Programme Chair of ESORICS 2019, and General Chair of the 21st International Information Security Conference (Surrey, 2018).

Manulis was Programme Chair of an Interdisciplinary Workshop on Trust, Identity, Privacy and Security in the Digital Economy (DETIPS) 2020; Programme Chair of Information Security Conference (ISC) 2018; Programme Chair of Applied Cryptography and Network Security (ACNS) 2016. These last two were hosted at Surrey, demonstrating further the depth of engagement between the Department and the security research community. **Dongol** was Conference Chair of Integrated Formal Methods 2020. **Sastry** was a Technical Programme Committee member for ACM Hypertext and Social Media 2018, and for IEEE COMSNETS 2017.

Keynote/plenary/invited talks:

Members of the Department have given at least 38 keynote, plenary and invited talks during the assessment period. Highlights include invited keynotes: Plenary speech on “Evolutionary multi-objective federated learning”, International Symposium on Neural Networks, 2019 (**Jin**); 11th International Conference on Web Information Systems and Technology, 2015 (**Sastry**); 8th International Conference on Cloud Computing and Services Science, 2018 (**Gillam**).