

Institution: Lancaster University

Unit of Assessment: 11 Computer Science and Informatics

1. Unit context and structure, research and impact strategy

Key Highlights

- Established and co-led 3 Institutes building interdisciplinary research communities and increasing research income by 33%
- Increased research impact and engagement related income to £8.6M, including 50% growth in collaborative research from £2M to £3M since 2014
- Increase in the number and importance of publications in top-10% most cited, up by 20% to 447.

1.1 UNIT CONTEXT AND STRUCTURE

Over 50 years, Lancaster's School of Computing and Communications (SCC) has established a strong international research reputation. We offer a unique environment that facilitates a broad range of impacts by bringing research, business and societal stakeholders together. This stems from our long-standing strategy centred around research excellence with real-world application: "*we build what we study and we study what we build*". This mantra values meaningful engagement with stakeholders at the heart of what we do, including testbeds in daily use by stakeholder groups, as much as excellence in terms of publications. We believe that addressing many of the major societal challenges requires an inherently diverse and interdisciplinary perspective. SCC is *actively driving this interdisciplinary agenda* across the University in areas including data science, cyber-security and social futures. This collaborative approach has led to *a step change in the quality of the research environment* for our staff and students, and given rise to major new research directions, such as environmental data science.

Every RAE/REF period to date has seen *growth* in breadth *and* depth of our research outputs and impact (Table 1). In the last period we have increased our research income, publications in SciVal, and top-10% field weighted citations index

Table 1: Key indicators for the REF2021 period as an evidence of sustainability (research income is according to HESA as spent for the period; the value of awards for the REF2021 period is £39.4M with £9.3M in 2020)

Indicators	RAE2001	RAE2008	REF2014	REF2021
Research income (£M)	6.7	15.0	18.8	28.5
PhDs awarded (FTE)	61	62.5	114	141
Total number of publications	471	1555	1848	2427
Peer reviewed publications indexed in SciVal	147	646	1136	1645
Publications in Top-10% most cited field weighted	24	182	356	447
Engagement / KE Income (£M)	-	4.1	7.8	8.6
Overall research quality profile (1-5* or % 4* /3*)	5	80%	91%	

Our achievements since 2014 include:

- our highest ever research income generation;
- the largest number of peer reviewed publications, with

- iii) above discipline norm field weighted citation index¹;
- iv) most significant engagement and knowledge exchange (KE) income;
- v) largest number of PhDs graduated; and,
- vi) most significant period for progression and diversity of staff.

Our performance is in line with Russell Group research intensive institutions and our number of citations per paper is *above* the Group median (10.3).

SCC Structure

We attribute this success to our strong commitment to provide **an open and collaborative environment that fosters interdisciplinary working**. Staff are members of research groups that synergise collaboration, provide informal mentorship and peer support. Staff also associate with University Research Centres and Institutes to increase critical mass in priority areas by working with other disciplines.

SCC's academic staff (49.45FTE up from 43.25FTE in 2014) currently comprise nine groups listed with the core areas where we make a significant intellectual contribution:

- *Software Engineering* - code analysis, defect prediction, software testing, program repair, developer human factors;
- *Networking* - Software Defined Networking, Network Functions Virtualisation, resilience and network security;
- *Distributed Systems* - Middleware, Cloud Computing, Green Computing, IoT, Self-adaptive Systems, Complex Systems;
- *Interactive Systems* - New forms of sensing interaction, input, actuation and display; novel interaction modalities and toolkits; design-led prototyping;
- *Pervasive Systems* - Development, deployment and evaluation of mobile and pervasive computing systems; 'in-the-wild' deployments; display networks;
- *Communication Systems* - Development, design, and performance evaluation of new concepts and techniques for wireless communication;
- *Security* - Critical Infrastructure Protection, Systemic Cyber Security Risk Management, Threat Intelligence and Data, Systems Security;
- *Data Science* - NLP, explainable AI, ML, computer vision, deep learning;
- *Digital Health* - Digital technology to transform healthcare delivery and empower individuals' active and healthy lifestyle.

Centres and Institutes build cross-institutional collaboration and drive research.

A key outcome of SCC's collaborative approach was the creation and co-leadership of *three of the four* flagship university-wide Institutes: *Data Science* (DSI, Davies), *Social Futures* (ISF, Harper) and *Security Lancaster* (SL, Suri). The Institutes recognise that computing is at the centre of understanding and shaping modern society, requiring a multi-disciplinary perspective. They create critical mass and community, and leverage expertise from across the University in areas of high strategic importance. The Institutes are a tremendous resource for SCC staff in terms of mentorship and engagement. Dedicated activities and resources stimulate collaboration, e.g. research retreats, grant preparation workshops, invited talks, visits and visitors. We also lead several established cross-department centres e.g. in corpus linguistics (UCREL), and encourage new grass roots centres to emerge, e.g. intelligent systems (LIRA).

Engagement of **research** within teaching and knowledge exchange **is a key part of our culture and environment**. *Onsite* business engagement staff provide bespoke support for translational impact by building relationships and working with stakeholders. Co-located businesses are selected to maximise potential for engagement and knowledge transfer.

It is notable that all our *academics* have eligible outputs and we have **the lowest ratio (7%) of staff on teaching-only contracts nationally**². This is three **times lower** than that of other UK

¹ Twice the UK mean for Computer Science, and comparable with the Russell Group of leading research intensive Universities.

² As evidenced by HESA data.

Universities and demonstrates an approach to research-led teaching that is firmly aligned to the school's ethos of research excellence.

Our collaborative spirit is evidenced by the composition of our outputs: more than half (55.44%) of publications are co-authored by international authors, half of our grants (49%) within the REF period involve partners from other Universities including 19% international. A further 29% involve SMEs, 15% large corporations (half of which are international), and an additional 7% of our grants involve other stakeholder groups such as healthcare, charity, local government and social enterprise.

1.2 RESEARCH AND IMPACT STRATEGY DURING THE ASSESSMENT PERIOD

Our research takes a real-world, systems-oriented and interdisciplinary focus. This involves external stakeholders in the creation of experimental testbeds and deployments. The academic, business and societal impact of this strategy is best illustrated by our wide ranging impact case studies: micro:bit (over 4M devices worldwide promoting computer science education); B4RN (an innovative co-operative offering the fastest rural fibre broadband in UK, providing gigabit access to digital services to over 5,000 homes in 79 parishes, with global influence); Smart Water (transforming the efficiency of urban surface water management by 20% using pervasive computing, in over 100 locations); and, marketing insights from comparative linguistics tools (spun out as Relative Insight, now with offices in New York and London, and major platform clients including Samsung).

These impacts result directly from our 2014 – 2020 strategy to:

- **Maximise real world relevance through interdisciplinary collaboration** and target more ambitious collaborative research bids – *evidenced through the creation and leadership of 3 interdisciplinary research Institutes;*
- **Structure for research excellence** by bringing academics in previously separate departments together to tackle problems from multiple perspectives – *evidenced through the creation of 3 new research groups and 2 new University Centres, the maturation of groups to centres, and centres to institutes;*

Maximise impacts by working with partners & stakeholders, via embedding on-site and dedicated knowledge exchange support – *evidenced through increase in the number of full-time KE staff; refresh of on-site businesses based on collaboration potential; and work with worldwide partners including Microsoft, BBC, BT, Google, SITA Aero, QinetiQ, Philips, Airbus, Huawei, and over 1,000 SMEs. e.g. flagship projects such as the £5M NG-CDI prosperity partnership with BT; and three industrial accelerators: £6M GM Cyber Foundry, £1.36M SPRITE+, and £1.5M Secured University Enterprise Zone.*

1.2.1 Progress against Strategic Aims for Research & Impact identified in the REF2014

The strategy of the School to undertake *interdisciplinary research; structure for research excellence; and maximise impact* creates an environment in which researchers are stimulated to address new challenges, explore new ideas and solve open real-world problems by working collaboratively. Our sub-goals under this strategy included: setting ourselves ambitious EDI targets (>10FTE female staff by 2026), increased our research leadership by targeting major fellowships; and targeting more significant and ambitious scale research bids - a minimum of one £1M+ bid per group. We have made substantial progress:

Objective 1 – Interdisciplinary Research Growth. 1) *Nurture our key strengths-in-depth; 2) Grow new strengths on the foundation of our core research groups; and, 3) Maximise real-world relevance through cross-disciplinarity.* We also sought to resource key growth areas with a view to increasing our leadership more strategically.

Demonstrably achieved by:

- a) Co-establishing three University interdisciplinary research Institutes (section 3.1) that cut across our research portfolio in strategically important ways - all under SCC academic

staff leadership from their inception. The Institutes provide a sustainable vehicle for our research; facilitate the cross-fertilisation of ideas; as well as offering training, community, and critical mass to focus toward large strategic grants. As exemplars of this success, over a 5 year period, DSI has secured £23M to Lancaster and established new cross-disciplinary partnerships such as Centre for Environmental Data Science (CEEDS) with UKCEH. Security Lancaster (SL) has become a twice-accredited NCSC cyber-security centre of excellence, home to the £11.8M UK national hub for social science research on security threats (CREST), and £8.8M of regional cyber industrial accelerators.

b) Creating and Leading two inter-disciplinary research centres:

1) *LIRA Centre for Robotics and Autonomous Systems*, founded in 2018 (Director: Angelov) comprising 50 academics including a mix of experienced research leaders (Fellows of IEEE, ACM, IET, ASAS) as well as developing early career researchers from SCC, Engineering, Lancaster Environment Centre, Faculty of Health and Medicine, and Management School. LIRA has 8 themes: fundamentals and challenge driven areas such as Biomedical, Environment and Agriculture, Intelligent Transport, Advanced Manufacturing, Nuclear Decommissioning, Security and Defence and Society and Human Behaviour.

2) *Centre of Digital Health and Quality of Life Technologies*, founded in 2019 (Director: Helal). Created in partnership with the Department of Health Research, CDH-QLT focuses on using digital technologies to take a proactive approach to health, with the aim of preventing illness and improving quality of life. The centre is developing innovative digital health platforms, future degree programmes, and increasing community engagement.

c) We cemented bridges between University departments with two new senior joint appointments including *Helal* (SCC and Division of Health Research), and *Harper* (SCC and Social Futures).

Due, in part, to this strategy, the amount of funded research to SCC has grown from £18.8M to £28.5M according to HESA.

Objective 2 – Structured for Research Excellence. 1) *Maximise academic impact*; 2) *Maximise academic synergies*; 3) *Boost the strategic role of the research groups*.

Demonstrably achieved by strengthening our core research groups and founding three others. This is exemplified by the journey of the security group, which rapidly evolved during the REF period: moving from an SCC group to a leading research institute by combining our strengths, targeting appointments, and crossing disciplines to meet the evolving needs of our partners (for example the Home Office and GCHQ).

- a) Successfully sustained our core research groups (*Networking, Distributed Systems, Interactive Systems, Pervasive Systems, Communications and Software Engineering*) each with a long track record of excellence. Significant grant awards (>£1M value) have followed (*Hutchison 2014; Race 2017 – converged network infrastructures*); Distributed Systems (*Blair 2016 – Environmental Data Science*); Pervasive Systems (*Sas 2017 – Affective Computing; Harper 2018 – Material Social Futures*); Interactive Systems (*Alexander 2020 – Deformable Screens*).
- b) Establishing three new groups (*Data Science, Security and Digital Health*) in response to emerging societal challenges such as the data deluge, the need for secure and resilient infrastructures, and the aging population. Major activity includes supporting the newly opened £41M Health Innovation Campus; 1M+ grants (*Prince 2019*); and the hire of Distinguished Prof. *Suri*, bringing leadership of a major EU Cybersecurity Competence Network (CONCORDIA) to Lancaster.

The academic impact of our work has grown. We have seen a 44.8% growth (1136 to 1645) of peer reviewed publications indexed in SciVal. Our publications in the top-10% most cited (field weighted for computer science) have increased by 26% from 356 to 447 and now represent more than a quarter (27.2%) of the SciVal indexed peer reviewed publications. Our work has

garnered peer recognition, for example, in HCI we've received over a dozen best paper awards from ACM CHI (including Karnik, 2014, Friday 2015, Gellersen, 2019, Sas, 2019 and 2020).

Objective 3 – Impact. 1) *Maximize impact through KE;* 2) *Exploit the new role of Head of Business Partnerships and Enterprise.*

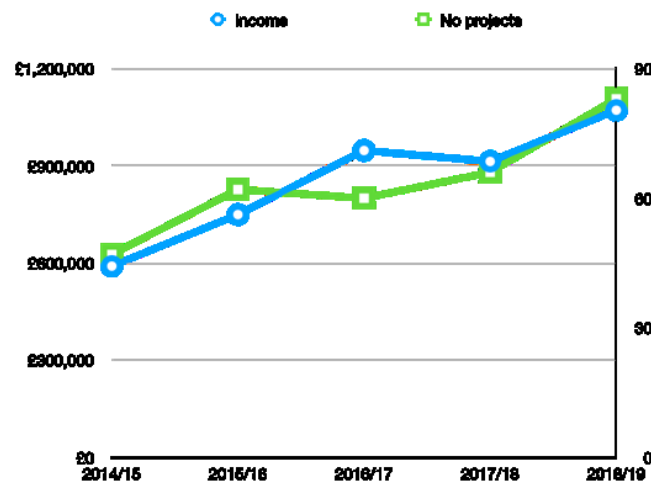


Figure 1 - Contract and Consultancy Research Income and Project growth 2014-2019

Under the oversight of Head of Business Partnerships and Enterprise, who is integrated into SCC's management team, to ensure regular and effective communication; our strategy to maximise impact from our research through two principal approaches: 1) investing in 3.8 FTE of KE staff embedded directly within all School activities, and 2) careful choice of co-located resident companies and business partners to maximise the potential for knowledge exchange and impact. The structured resident support scheme and targeted company recruitment mean companies entering the facility have a research collaboration plan in place. This investment creates a unique environment making engagement and industry collaboration integral to our operation. Income from collaborative research has grown from £2M to £3M since 2014; consultancy income more than doubled year on year from around £40K in 2014 to over £100K in 2019; and contract research follows the same profile, topping £1M for the first time in 2019 (Figure 1).

SCC's impact strategy has directly led to the School's three recent KTPs (Upside Energy; JBA; Mitigate Cyber) and enabled two of its four Impact Case Studies. Beyond co-located SMEs, the school engages with 150 SMEs through the £6M Greater Manchester Cyber Foundry, 90 SMEs through the £1.36M Lancashire Cyber Foundry and 250 SMEs through the Cumbria Innovation Platform (directly linked to our growth in contract research income above). SCC's industry linkages have been instrumental to successes including Department of Health funded Connected Health Cities (CHC), £5M NG-CDI Prosperity Partnership and PETRAS. Since its inception, SCC and Infolab21's co-location model, has provided the template for impact and engagement across the University, leading to similar instantiations in Chemistry (CTAP) and Environmental Science (Gordon Manley Centre), the backbone of the recent £1.5M Secured University Enterprise Zone, and template for the £41M Health Innovation Campus, featuring the same embedded model of colocated business, KE and academic departments. This has led to a broad range of non-academic impact types including educational (22.7%), cultural (18.2%), policy (13.6%), productivity and public engagement (9.1% each). Current KE return data suggests as an institution we are highly effective at KE, with £28 returned for each £1 of public money spent.

1.3 FUTURE STRATEGY AND PLANNING

Lancaster University's main strategic goal is to be a global leader in HE, widely respected and transforming lives, communities, practices and thinking. In SCC, we anticipate continuing our principal ethos of embedding real-world focus, deploying systems, responsible innovation with stakeholders, and interdisciplinarity at the heart of what we do. We see this as being both true to

our long-standing approach to research, but also has resulted in growth in the quality, depth and number of outcomes as highlighted in section 1.1.

Over the coming REF period we will be seeing the retirement of a small number of longstanding valued colleagues who helped establish the current collaborative culture. We will be considering how to consolidate and share this culture going forward as we plan to make a number of hires to maintain established strengths (e.g. networking, software engineering, HCI) and capitalise on areas where we have made major investments in staff and research infrastructure including cyber-security, data science and digital health.

- **Investing in people.** We have made a major investment in staff and now have a substantial cohort of 23 ECR staff, who we wish to mature into research leaders. We are proactive in promoting staff, and have been highly successful at making strong cases: leading to 11 new SL/readers and 7 new professors (9 promoted) in the last period. We need to continue to invest in training, progression and mentorship, with a particular focus on ensuring that we maintain our balanced approach to engagement and teaching, as well as aspiring to maximise research quality and impact.
- **Growing the scale pipeline.** We see centres and institutes continuing: the Institutes have just undergone an external 5-yearly review, and we anticipate the existing Centres and Institutes continuing well into the next REF period. We anticipate a period of consolidation and restructuring of groups within SCC to maximise staff desires to engage with multiple interest areas and on cross-disciplinary themes. We plan to improve the external communication of our research to best reflect this innovative structure.
- **Enabling interdisciplinarity and engagement.** Collaboration and engagement with stakeholders in our research are consistent with our goal to *maximise real-world relevance through cross-disciplinarity*. We see this continuing, especially within areas including resilient infrastructures, security, pervasive systems, digital health and associated testbeds (5GRIT lead: Race; AffecTech lead: Sas). The Health Innovation Campus (lead: Helal), and potential development of Eden Project North (digital environment, lead: Blair) and Whyndyke Garden Village (an NHS Healthy New Town, lead: Helal) will provide ideal environments for this style of user engaged research.
- **Educational and recruitment pipeline.** Continuing recent practice, the school will continue to sponsor research internships to encourage the brightest and most enthusiastic students to engage with research from undergraduate level, leading to further postgraduate study and ultimately in some cases, successful research careers. We created two honorary early career fellowships named after two influential former colleagues (Shepherd, Parkes) who exemplified the best aspects of the Lancaster culture, in order to hire staff in their mould to continue to recruit and build the Lancaster ethos; we will likely do this again in the coming period. Investing in people who are balanced and enthusiastic academics, and open to our style of collaborative and stakeholder engaged style of research remains at the heart of our future plans.

The Covid-19 pandemic has given us a glimpse of flexible ways of working especially in terms of how we engage with our research peers nationally and internationally. Our community has remained active and resilient during this challenging time, which gives us confidence that our long-term future strategic plans are achievable. We will be looking to take the best features from new ways of working to ensure the vitality and sustainability of our research into the future.

2. People

Key highlights

- Growing the school staff by 14% in support of strategic priority areas, of which, 74% are ECR as part of our commitment to new vitality
- Complementing ECR with 4 senior hires in strategic areas, 2 supporting increased interdisciplinary activity
- Improved support for PGR and PhD students – helping on-time completion rise from 64% to 78%
- Increased staff diversity including growth in female PDRAs, lecturers and senior staff including recruiting Hall (now Deputy Head of School) and advancing Sas (Faculty Assistant Dean of Research Enhancement).

2.1 STAFF

Strategy. Our staff have always been, and remain SCC's overriding priority and strength. We foster a supportive and openly collegiate environment, which provides excellent opportunities for both intellectual and personal growth. The school currently has 49.45FTE Category A staff comprising 14 Professors, 15 readers/senior lecturers and 22 lecturers. Our research achievements are only possible with the support with our excellent project related research staff, we employed 84 research associates during the period.

We see this vibrant and growing community of staff and alumni as *a key outcome* of our people strategy set out in 2014; to '*foster critical mass*', '*grow key new areas*', and '*maintain balance between leadership and new talent*'. In terms of *critical mass*, the school has grown, in absolute terms by 14% (from 43.25 FTE in 2014, to 49.45 FTE). The modest increase in absolute headcount hides an underlying refresh of staff (33.7 FTE new staff since 2014), driven partly by our strategic aims, but also by natural career progression especially of some of our more senior staff. This has allowed us to *rebalance* our staff mix with 74% of our hires being early career and *support the growth of key new areas* into new research groups/areas.

To maintain balance, we have also made 4 Professorial appointments, two of which demonstrate an intentional deepening of interdisciplinarity (*Helal* – joint with Division of Health, *Harper* – joint with Sociology, via ISF) and support our aim of *growing key new areas*, and *strengthening existing groups* (Hall/ Software Engineering, Suri/Cybersecurity).

We focused on *growing our talent* by putting in place school-wide improvements to staff and researcher development with a focus on helping staff develop and progress at *all stages* of their careers. This is evidenced by: having advanced 9 staff to full Professor and 5 to Reader in the period; and school staff taking institutional level leadership roles, e.g., SCC staff co-direct 3 of the 4 flagship interdisciplinary Research Institutes and 3 cross-faculty research centres. We also made *a substantial contribution to the field as a whole* by helping 8 staff to progress into major leadership positions nationally and internationally: e.g. *Rashid* now leads the Cyber Security Group at Bristol; *Yan* is now Professor of Cyber Security at Linköping, Sweden; and *Whittle* first as Executive-Dean of Science at Monash and now Data Institute Director at Australia's prestigious CSIRO.

Early career researchers (ECR). A key part of our people strategy focuses on attracting and developing world-class ECRs. We value collegiality, a passion for research and for research-led teaching. Early career staff are allocated to a research group, with separate research mentors from the school's senior staff. Group leads provide frequent oversight, from establishing objectives, identifying aspirational publication targets, and providing ongoing career support and coaching including identifying development and support needs. Objectives are regularly reviewed and adapted, e.g., minimally at PDR. ECRs are actively encouraged to affiliate with one or more institutes or centres to provide access to wider rolling seminar programmes, research retreats, and collaboration networks.

Bootstrapping success. All ECR receive a start-up fund from the school to stimulate initial activity. All newly appointed academics are allocated lower teaching and administrative loads

(50% in the first year, 75% in the second) in order to facilitate the development of their research portfolio. Beyond this, the School also benefited from the University's 50th *Anniversary Lectureship (AL)* scheme, which sought to identify academic leaders of the future with the potential to become Readers or Chairs within 5 years. The ALs are relieved from their teaching load *entirely* for the first two years excepting optional tutoring, project supervision and guest lectures.

Supporting research bids and fellowships. The School offers tailored support for grant bid development to all staff. Grant applications go through rigorous internal review, which involves feedback from at least two members of academic staff (three for EPSRC new investigator awards). A PhD studentship is matched to a first successful UKRI or Fellowship award. Because of these strategies, all academic staff actively apply for research grants, with success evident in that 73% of academic staff are PI of a project. We have actively encouraged fellowship applications in the period, and have recognised research intensity in the workload model. This strategy has been effective: *G. Blair, Alexander, Garraghan, Jiang, Angelov, Giotsas* have been awarded EPSRC, ERC, Leverhulme, ELLIS and RIPE, fellowships respectively, totalling over £5M. Fellow status has been accorded to *Angelov* (IEEE, 2016), *Helal* (IEEE, 2015) and *Harper* (ACM, 2014), as well as AAAS (*Helal*, 2019), CHI Academy Status (*Harper*, 2014) and Academia Europea (*Helal*, 2020).

Encouraging leadership. We actively encourage leadership and focus on the recruitment of outstanding researchers with leadership abilities. Leadership opportunities are discussed with staff as part of career planning, and are encouraged and supported, through, for example, workload adjustments. Leadership is demonstrated through the active engagement of academics from the School in faculty and University level roles including the Pro-Vice Chancellor for Academic Development (*Davies*) and supporting faculty Associate Dean roles (*Rashid* - AD PGR; *Race* – AD Research; *Sas* - AD Research Enhancement), which directly influence the ethos, vision and strategy at Faculty and University levels, including the strategy for overall PhD training at Lancaster (*Edwards*, *Director of the Doctoral Academy*).

Developing careers. Staff development for academics starts with a three-year probation for new Lecturers, which includes rigorous annual reviews. New academic staff in the School receive lighter teaching loads during their probation period. The School research budget, devolved to Groups, is used strategically to support speculative activity (e.g., research visits, pump priming activity). All new academic staff participate in induction sessions, which provide initial information about the resources available including mentorship, KE and pre- and post award professional services support. They also undertake the PG Certificate in Academic Practice (CAP), and a series of associated development and mentoring activities.

Through a mix of informal support from mentors and group leads, plus the annual appraisal round, we identify and encourage continual professional development (CPD), including participation in programmes to build leadership and develop careers. These include University courses in coaching, management and leadership, job shadowing and so on. All our research active staff can participate in programmes such as The Balanced Academic and the Resilient Researcher. Diversity, unconscious bias and 'recruiting the best' training (for those on recruitment panels) is mandatory to sensitise to possible EDI biases. Staff are encouraged to develop their career even exceptionally by taking additional qualifications, e.g. Executive MBA (*Sas*, 2018).

Our active sabbatical programme enables the School to refresh its research outlook and staff expertise. All staff accrue academic research leave time and may apply to take 1 term in 7 or 1 academic year in 7. Cases are considered based on timeliness and strategic importance and a well-developed sabbatical proposal. 19 academics benefitted from sabbaticals this REF period; an investment in staff estimated at around £750K. 13% of sabbaticals prioritised early career staff (unusual as sabbatical entitlement needs to be accrued), with 2 cases last year accelerating cases for female staff who had not previously thought themselves eligible.

2.2 RESEARCHERS AND RESEARCH STUDENTS

Researchers. A fundamental part of the school is our postdoctoral researchers (PDRAs) and PhD students, and these are an essential part of the staff pipeline. Both are encouraged to

engage with the wide range of available training opportunities, and informal activities including mentoring, dedicated workshops, our annual PhD conference as well as weekly “brew time”, “brown bag” presentation sessions, and grass roots writing group and maths club activities. PIs and supervisors discuss long term career planning with researchers: this often results in researchers taking on limited teaching or student supervision duties to bolster their CVs. The School’s Graduate Academy provides training on consultancy projects with industry, and helps researchers build networks in the private sector. We also support postdoctoral researchers in developing their own proposals for independent research.

Career support for researchers is formalized through an action plan, which is aligned with the Concordat for Early career researchers and includes commitments to the Concordat in Public Engagement in research and the Concordat in research integrity. We aim to provide bridge funding between contracts where possible to avoid unnecessary redundancies and associated contractual uncertainty.

Research students. The School has long-standing PhD programmes in Computer Science and in Communication Systems, and leads a CDT (LDSP-MSF, Harper). 33% of our PhD students are from the UK, 16.5% from EU countries and the rest from overseas. During the REF period, we have graduated 141 FTE PhDs, including a cohort of *HighWire* CDT students joint with Lancaster University’s Institute of Contemporary Arts (LICA) and triple accredited Management School. Our PhD graduate destinations include roles with major multinational companies including *Google, Microsoft, Amazon and Facebook*, academic posts overseas, a wide range of posts in UK academia and industry, and others have created their own start-up businesses (e.g. Hardy & Ellis inventions, developing mixed reality interactive products, finalist in the UK Business Tech Awards 2018, winner of the 2019 European Digital Press Association (EDP) Award; or Vidal working for Focal Smart Glasses for North, in Canada, acquired by Google, June 2020).

We recruit internationally, leveraging our world-wide reputation in each of our research areas. We have several formal international partnerships (e.g. Erasmus exchanges with ETH Zürich and LMU Munich) and many other long-standing collaborations through which we attract and exchange students. We have further increased the international impact of our doctoral training through leading and participating in the *H2020 Marie Curie Initial Training Network (AffecTech, Sas, €3.8M)*.

We have invested significantly in improving processes and activities for PhD students under the oversight of a new Director of Postgraduate Studies role. This role ensures effective progress monitoring, training and supervision arrangements, assisted by the Research Committee. Our strategy is to create distinctive opportunities based around research groups with opportunities to work across the PhD cohort including seminars, reading and writing groups, informal talks and informal activities. Our goal is to provide a flexible framework that recognises all students are different and encourages and supports where needed without overly restricting those students that need flexibility.

Submission deadlines are set at 4 years for full-time students and 7 years for part-time, with rare exceptions for individual circumstances. We treat these deadlines as a shared responsibility and have created a robust support system for students and supervisors including improved progress monitoring and enhanced access to research training. Student monitoring comprises a set of defined checkpoints, commencing with an initial assessment of the student’s skills and knowledge from which training needs can be identified, followed by a series of progress panels until the student is ready to submit. Each PhD student is appraised every 6 months, with clear guidance on what should be included at each point. This offers:

- Early thesis planning and completion timelines, along with progress checks during the writing-up period.
- An appraisal panel of two academic staff, independent from the supervision, and consistent throughout the PhD, to provide extra support. The first panel member is a “subject specialist”, assigned to advise on the specific research topic. The second a member of the PGR Committee, to provide more general feedback, ensure consistency and fairness across appraisals in the School, and also feedback issues and concerns via the PGR committee.

- Initiatives aimed at improving the research culture for students included an annual School PhD conference, new seminar series, better representation, and facilitating student-led community activities.

A wide range of research training courses are provided including in-house 'masterclasses', 'brown bag' skills talks and Q&A sessions, short courses, and a wide range of further courses coordinated by the Faculty's Graduate School (now Doctoral Academy led by Edwards). *HighWire* introduced, and we retained, a taught component on research methods, ethics, interdisciplinary perspectives and critical analysis, which is now compulsory for all students. Our Graduate Academy in SCC offers vocational experience through short-term consultancy projects with industry supported by KE staff.

Research students are actively encouraged to attend conferences, summer schools and doctoral colloquia internationally, and we dedicate research training and travel funds to support this. We organise informal opportunities to meet and exchange ideas, including an annual PhD conference which allows all PhD students to showcase their work and get feedback from school colleagues.

All of these changes have helped to improve the research environment for PhD students and also to improve on-time completion rates. Since the new support system in 2016/17 we have since seen an improvement in on-time submission of 14% with 14 of 18 submissions on-time in 2019/20. The success of our strategy and the quality of our students is also evident in the successful completion of 141 FTE PhDs in the REF period (our greatest number to date), and awards such as the 2020 Doctoral Dissertation Award by INNS (*Gu*), 5 EPSRC Doctoral Prizes and highly competitive internships (at *Microsoft, Nokia, Google, Amazon, Philips, Alibaba, ARM*) and other destinations.

2.3 EQUALITY AND DIVERSITY

The School is committed to the advancement of equality throughout all aspects of career development and has procedures for raising and investigating any issues relating to discrimination. We were awarded Athena SWAN Bronze in 2014, which helped us shape our action plan for taking steps to improve gender balance and diversity. This included reviewing the composition of school committees, hiring procedures, and raising awareness and exploring how we can remove barriers experienced by BAME colleagues. Resulting from this in 2015/16, we defined a new 10-Year People Strategy, and Equality, Diversity and Inclusion is core to this. The people strategy realised the need for a new Athena SWAN Director administrative role linked into key internal committees and directed towards an Athena SWAN Silver application in 2021.

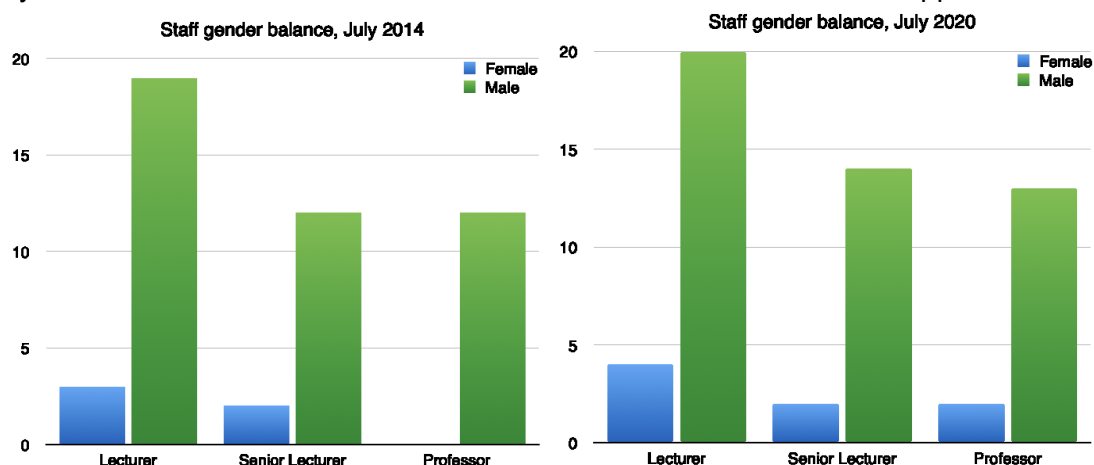


Figure 2: Gender profile by career stage (REF2014 left, REF2021 right)

As a result of these initiatives, we advertise widely, and our adverts welcome applications from 'all diversity groups', reinforcing our commitment to equal opportunity. Our recruitment materials include a diversity statement and diverse images. Panel chairs undertake 'unconscious bias' and 'recruiting the best training'. This is bearing fruit (Figure 2): we are pleased to see female PDRAs rise from 15% to 21%, female lecturer numbers rise from 13.6% to 17.4%, and we now have 2 female professors (13.3%). Professor (*Hall*) was recruited to strengthen Software Engineering

and is also Deputy Head of School. Sas was promoted in the period, and notably was also the recipient of a Digital Female Leader Award in the Science category in 2019. There is still a long way to go, but we are pleased with this progress.

Our EDI champion created the now vibrant *Women@Infolab* group to provide community building, mentorship and support for female staff and students in the school. This ensures more effective communication of particular gender related issues and experiences. For instance, resulting from a grass roots initiative, we will be hosting the BCS Lovelace colloquium next year.

We have a significant body of early career staff (23 at grades 7/8, 20 under age 40) and have been pleased to support requests for maternity and paternity leave, and adjustments to working hours on childcare related grounds (12 paternity and 5 shared paternity leaves were approved during the REF period). We encourage use of MARS (maternity/adoption research support) funding which provides small grants to sustain research and career progression during periods of parental leave (2 cases so far).

Our school comprises staff from a range of ethnic backgrounds (29% BAME). We have been pleased to be able to progress many of our staff in the period, leading to an increase in BAME staff at more senior levels: Senior Lecturer (38.5% from 17.6%) and Professor (26.7% from 23%), Figure 3. We have maintained our proportion of staff with a declared disability (4% of staff, 5% in 2014).

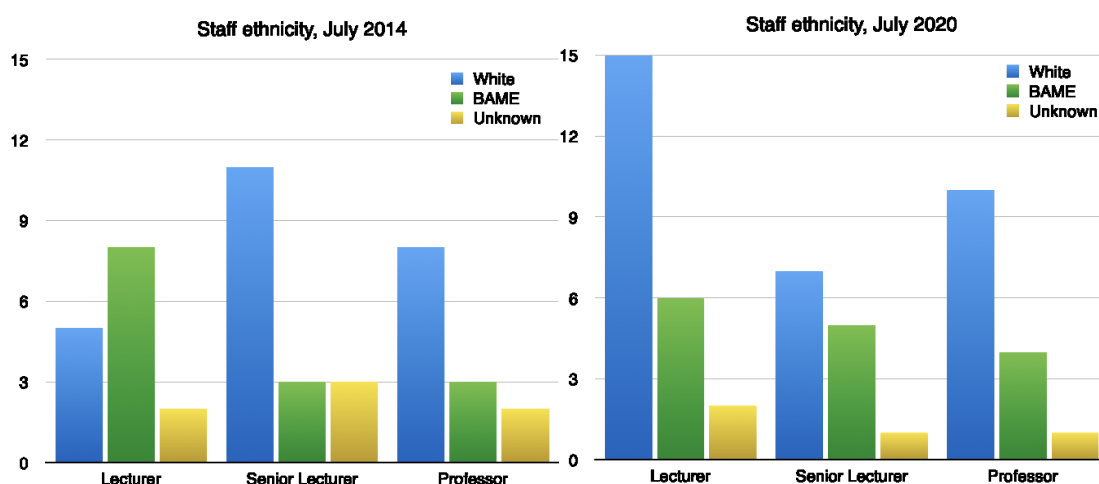


Figure 3: Ethnicity profile by career stage (REF2014 left, REF2021 right)

Our diversity is further strengthened by our active Visitors Programme. 116 researchers from 26 different countries have held visiting positions with the school since 2014, enabling new collaborations and sharing of knowledge worldwide.

2.4 WELLBEING & MENTAL HEALTH

Supporting our staff and students' wellbeing is a growing focus and in 2017 the school created wellbeing officer roles for both students and staff, who now undertake specific training and responsibility as clear point of contact and gateway to professional support where needed.

As part of our commitment to the Concordat to Support the Career Development of Researchers we provide all staff with access to confidential professional support through the Employee Assistance Programme and implement the Five Ways to Wellbeing framework, used by the Government, the NHS and charities like Mind.

To continue to progress this important area, the school has recently formed a Staff Wellbeing Engagement group, which has been linked through the Institution's Safety, Health & Wellbeing (SHaW) committee structure, to ensure that as this provision grows, the Institute wide support options and wellbeing resources are made increasingly available.

3. Income, infrastructure and facilities

Key highlights

- Sustained growth of research income from £18.8M to £28.5M (51%) over three times the rate of growth of staff FTE (14.3%)
- Strategic investment in infrastructure via institutes and centres to strengthen interdisciplinarity research
- Increase in number of academic staff winning at least one project as a PI (73%)
- Supported >£5M of major fellowships at both senior and junior levels

3.1 RESEARCH PORTFOLIO

One of our strategic priorities has been to grow research income and income per head, with a particular emphasis on increasing the number of active PIs, targeting of larger awards and diversifying our range of funding sources. This has been successful: research income has gone from £18.8M to £28.5M, a 51% growth – more than twice the growth rate of staff FTE. The total amount of grant funding awarded during the REF2021 period is £39.4M. This growth included diversification of our research portfolio and has followed the targeting of new strategic areas such as Data Science and Digital Health. Evidencing this, we highlight:

- **Large Awards**, e.g. EPSRC funded Senior Fellowship (G. Blair, £2.5M) acting as a springboard for further awards in a new area of environmental data science; EC funded AffectTech (Sas, €3.8M) resulting in multiple award winning publications; the Next Generation Converged Digital Infrastructure project (Race, £2M, £0.9M from EPSRC and £1.1M from BT), instrumental for B4RN impact case study; Towards Ultimate Convergence of All Networks, TOUCAN (Hutchison, £1.2M); Leverhulme Trust funded Doctoral Scholarship programme in Material Social Futures (Harper, £1.4M); and, H-unique ERC (co-I, Angelov, £1.6M) focusing on tackling image based online crime, and widely publicised in the media.
- **Increasing PIs**: As a result of our mentoring, support and management programmes all academic staff actively apply for research grants, with ~73% of academic staff winning at least one project as a PI.
- **Sustainability of funding**: In REF2014 SCC were the top UK UoA recipient of EU funding. We have successfully diversified our research funding, increasing the share of UKRI awards (from 38% in REF2014 to over 54%). We also draw upon UK Government and charity funding increased from 6.7% to over 22.5% (Figure 4). Direct industry funding has increased 47% since 2014 to 9.5%.

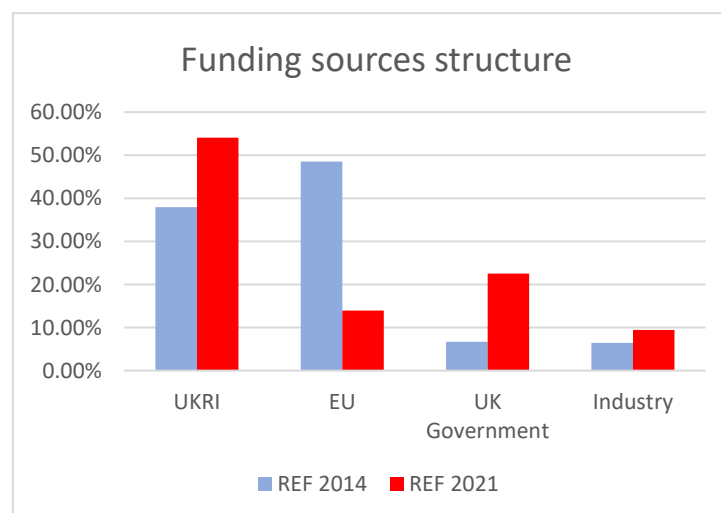


Figure 4: Funding by source (REF2021 vs REF2014)

Our growth in research income has provided a solid basis for strengthening our core strategic pillars:

Interdisciplinary research. Our portfolio mix reflects our strengths in interdisciplinary research including in data science, security and health. Some examples: *Gellersen* attracted £0.9M of interdisciplinary funding for EPSRC funded *Monitoring Dementia with eye movements*; *Sas* has secured £0.8M for work on *personal technologies for affective health*; *Angelov* is leading the school's £1.6M part of the *H-unique* ERC project which brings together deep learning, image processing, biometrics and forensics to revolutionise identification of criminals from hands in online images; *Helal* is leading NHS funding of £0.8M for the Connected Health Cities.

Our pro-active role in the interdisciplinary Institutes and Centres has been central to increased research funding success:

- *The Data Science Institute - DSI* (co-Director: *Davies*) was founded in 2014 building on Lancaster's historic strengths in Computer Science, Statistics and Operational Research. It has grown to become one of Europe's strongest and most diverse single-institution data science communities of over 118 staff and 193 researchers. DSI embraces data-driven challenges across disciplines including the environmental sciences, health and medicine, epidemiology and population health, humanities, sociology and creative arts. Over 5 years, DSI has applied for £128M in grants, securing £23M to Lancaster (£46M to partners); launched our most successful MSc programme; and secured over 200 industry placements yielding over £500K additional funding from companies, e.g. Amazon, eBay, PwC, EY, Santander.
- *Security Lancaster – SL* (*Suri* – co-Director; *Race* and *Prince*, Associate Directors) draws together 47 academic staff from all faculties and includes Psychology, Physics, Management, Health & Medicine and Politics, Philosophy & Religion. It creatively challenges the way that individuals, organisations and societies secure and protect themselves with a holistic understanding of security risks from a socio-technical perspective. SL has been instrumental in broadening SCC's research base, allowing access to both EPSRC and ESRC funds as well as sources that SCC has not historically accessed such as the Home Office, MoD and US DoD. We were approved to host one of 8 (now 19) GCHQ Accredited Centres of Excellence in Cyber-Security. SL is home to national/EU research centres and industry accelerators, collectively worth over £20M. SL secured £2.8M in grants, as well as the Greater Manchester and Lancashire Cyber Foundries promoting cyber-security in regional businesses, and latterly the Secure University Enterprise Zone (UEZ). More recently, SL led a successful £3M Security Node on Trustworthy Autonomous Systems (TAS-S) funding (PI: *Suri*, co-Is: *Angelov*, *Hutchison*, *Giotsas*).
- *The Institute for Social Futures - ISF* (co-Director: *Harper*) brings leading social science and humanities research together with computer, engineering and medical science to develop thinking, visioning, analysis and data relating to the futures we want and need. Harper was a strategic appointment from Microsoft research and is a social scientist by background. ISF has brought in £6.8M; co-leads the £1.5M Leverhulme Doctoral Scholarships programme in Material Social Futures with the Materials Institute (Chemistry, Physics and Engineering) delivering 21 new PhDs over 5 years with specific training to better engage with boards, government, regulators and policymakers around socially contextualised material innovations.

Structured for research excellence. By leveraging research groups, institutes and centres, we have created more opportunities to build collaborative and cross-department teams to prepare for research bids resulting in research income growth. The informal mentorship and intellectual life of the Centres and Institutes has been particularly beneficial for early career staff in terms of effective career development. This has led to the securing of major grants and fellowships, e.g. ERC Starting Fellowship (£1.5M, *Alexander*), EPSRC Early Career Fellowship (£1M, *Garraghan*), and the Leverhulme Fellowship (£253K, *Porter*), to date instrumental in promotion cases for *Alexander* - Professor; *Porter* - Senior Lecturer.

Maximising Impact. Our impact strategy of embedding KE staff within the School, choosing co-located companies based on their synergy with our research, and embedding and supporting impact plans into research projects has resulted in broadened collaboration with UK and global

industry. Examples include projects with major partners such as *BT* (Race), *ARM* (Wang) and *Raytheon* (Nagaraja), but also a wide variety of SMEs such as *In Touch Ltd*, *DemoPad Software Ltd*, and *Quantum Base Ltd*. Many of these connections were brokered initially by KE staff.

We have maintained strong connections with international companies securing funding from *Ford* (Angelov), *Airbus* (Hutchinson), *Sony* (Gellersen), *Microsoft* (Finney) and *Huawei* (Jiang) among others. These projects are instrumental for wider impact, allowing us to leverage research council funding by using industry funding to take research outcomes closer to market. An example of this is the Microsoft-funded project led by Finney which was critically important for the *micro:bit* initiative (one of our impact case studies). *Micro:bit* exemplifies the broader, social and educational impact of our research that reached millions of young children in over 50 countries³.

Another of our impact case studies, *B4RN*, also highlights our testbed and stakeholder engaged approach to research, in terms of social as well as technical implications. For example, this culminated in April 2020 in a partnership between *B4RN* and *Zykel Communications* that bought ultra-fast broadband to 21 primary schools in the North of England enabling them to make use of the latest education technology and software, whilst teachers and students complete work online, attend virtual events, seminars and workshops, and make use of cloud-based resources for the first time. This was invaluable during the COVID-19 pandemic. Commenting on the *B4RN* connection, a clinical lead for intensive care stated. '*It has allowed us to work at home when appropriate but still maintain good quality work and information from patient records and particularly scans (which are data heavy) as well as [...] ensuring the best clinical advice [...] It has been so important to us that we had access to the most up to date publications and research [...] online and with fast, reliable access.*'

3.2 INFRASTRUCTURE AND FACILITIES

Strategic investment. The foundation of the Institutes has triggered major strategic investments in staff, estate and infrastructure:

- The University has funded the DSI administrative staff and appointment of 17 new academic staff including four 50th Anniversary Lecturers and underwriting 0.5FTE of an SCC co-director (*Davies*). Including administrative and co-working space for DSI within the SCC building, InfoLab21, co-located with our KE team and our resident companies.
- Investment in the Digital Health Group (*Helal*) and two lecturers to complement £41M Health Innovation Campus, co-locating innovative health businesses.
- *The Institute of Coding* is a £20M Government investment that has brought together academia, industry and education to boost future digital skills in UK. Our involvement led by *Finney* (Director at Lancaster), *Prince* and *Friday* attracted £581K funding to the School, allowing us to offer new studio led teaching facilities enabling a new more diverse and inclusive minor curriculum for non-Computing majors (*L. Blair, curriculum lead at Lancaster*).
- The *Wolfson Secure Data Science Infrastructure (SDSI)* is co-funded by the Wolfson Foundation and Lancaster University (£1.5M) and scheduled to open in 2021. The SDSI will offer the ability to handle data at a range of government classification levels, enabling research including highly sensitive health, IP sensitive or classified information with appropriate levels of assurance. This will be a unique HEI-based facility in the North West.
- Lancaster is part of the recently announced Research England Secure Digitalisation Enterprise Zone (Secured UEZ), which will drive economic growth, create jobs and help businesses develop innovative new products and services. Funding (£1.5M) from UKRI. Secured UEZ is one of the 20 UEZs nationally.

Infrastructure. Our purpose-built building (InfoLab21) offers creative space co-locating academic, research, KE staff and research students in teams. The physical environment supports our collegiate strategy for doctoral and postdoctoral training by providing shared

³ [Microbit impact case studies](#)

'research studio' space that is office, experimental lab and meeting space all in one. Larger experimental spaces and more specialist research facilities are managed by a dedicated 3 person systems team, on site, who support researchers and systems infrastructure throughout project lifecycles. This team are instrumental in helping cost, procure, install and run bespoke research infrastructures, maximising value for money to the institution and our funders.

Examples of these facilities include:

- Virtual server cluster to support bespoke research project and staff VM needs, plus related student projects at undergraduate, masters and PhD levels.
- A cyber security Industrial Control Testbed for attack detection and mitigation; the Fujitsu Threat lab which includes highly configurable attack surfaces for creating honeypots to monitor network borne and VM staged cyber-attacks.
- A GPU cluster comprising 110 systems for accelerating deep learning model training and related research into distributed AI performance and energy efficient machine learning strategies.
- The PCB Fab Lab and two hardware/maker spaces with fabrication and prototyping facilities such as laser cutting and 3D printing.
- Large research laboratory for hosting for experiments such as Centre of Digital Health' 'smart house' prototyping area and LIRA workshop where a range of mobile robots and unmanned autonomous vehicles (drones) are assembled. Used in projects such as the InnovateUK funded £1.3M CTHULHE project (£400K for SCC) that recently demonstrated an autonomous robot for cleaning hazardous industrial waste such as the Sellafield nuclear waste ponds.
- HCI Evaluation Lab for developing interactive device and AR/VR experiments and conducting controlled studies involving user interaction.
- A specialist research networking lab for network protocol experimentation, e.g. introduction of programmable and software defined network elements, alternative protocol stacks, or bridging to specialist LoRA and 5G wireless testbeds.

Business impact infrastructure. The intentional co-location of businesses and our KE team within the School fosters formal and informal networking and adds significant value to the companies and researchers working together in InfoLab21. Collaboration is fostered via a mix of targeted recruitment and a structured resident company support scheme, where companies entering the facility are required to have a research collaboration plan in place with a named SCC academic sponsor. This structured process has ensured three recent KTPs and directly enabled one of our four Impact Case Studies. During the REF period, co-located companies have hosted over 30 SCC student internships and extra-curricular projects and over 25 projects via other departments at the institution. KE Staff are involved throughout the school's grant development processes: identifying partners; collaboration opportunities and co-creation of impact pathways. KE staff provide guidance on commercialisation, intellectual property rights and contract negotiation, which is particularly valuable for ECRs when starting out.

The School's Graduate Academy team of 15 staff run a £7.6M portfolio of engagement projects employing analyst developers and utilising paid SCC student placements to support over 200 small businesses in Cumbria, Lancashire and Greater Manchester in generating new products and services to evolve and differentiate their businesses. Project staff both re-skill and gain vocational experience whilst also helping regional businesses prosper. At the start of the REF period, the InfoLab21 Strategic Innovation and Support Programme closed having assisted 365 companies. The project was the Government's national pilot in 'Transformational ICT' for business and its success went on to embed the Graduate Academy model in a number of projects, including in Lancaster and in Greater Manchester (GM) as part of the GM Cyber Foundry Project.

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

- Expanded collaboration and partnership with leading Universities and Industry via projects, institutes and centres (over 50% of outputs co-authored internationally)
- Leadership and contributions to the research base, including major leadership roles such as IEEE (president-elect); chairing major conferences, and over 20 editorial boards
- Economic impact via direct industry funded research projects (up from 36 to 74), creating two new cyber-security impact accelerators (Greater Manchester, Lancashire)
- Social impact via Computing at Schools engaging with over 1,000 teachers, changing computing at school via micro:bit, and enabling rural access with B4RN

4.1 RESEARCH BASE: ACADEMIC PARTNERSHIPS AND COLLABORATION

One of our research strategy pillars is to build on our long history of national and international collaborations, within and across the discipline, with industry, community, governmental organisations and charities. Partners of our projects include world-leading Universities such as MIT (micro:bit, *Finney*), Stanford, KTH and University of California (AffectTech, *Sas*), CMU (Cloudlets, *Davies*), Cornell and University of Massachusetts (TAS-S, *Suri*), University of Florida (Royal Society, *Angelov*), Austrian Institute of Technology (TOUCAN + others, *Hutchison*), Ford Research and Innovation, Palo Alto (autonomous driving, *Angelov*).

We contribute platforms and datasets to the global academic community. This is exemplified by the release of Wmatrix4⁴ corpus analysis and comparison tool (*Rayson*), version 4 released in December 2018, and a number of public corpus linguistics datasets⁵. Wmatrix4 has 6,828 academic users around the globe and was licenced by successful spin-out Relative Insight to underpin their advertising platform (see impact case study).

Contributing to an open and exciting environment for our researchers, we regularly host research visitors including extended stays from senior academics worldwide on sabbatical leave (e.g. from the USA, Australia, Brazil, EU), researchers seconded from collaborating institutions as well as visiting PhD students for a “sandwich” year, e.g. from Spain, Brazil, Slovenia and others. As an evidence of our strong international collaboration and the value of these international collaborations more than half (53.35%) of our submitted outputs are co-authored internationally.

4.2 ACADEMIC LEADERSHIP AND CONTRIBUTIONS TO THE RESEARCH BASE

We contribute substantially to research community activities and leadership and our academics hold a variety of notable positions. Exemplars include: *Helal* was member of the Board of Governors of the IEEE Computer Society - the largest IEEE Society. *Angelov* was Vice President of the International Neural Networks Society (INNS) elected for two consecutive terms (2017-2020) and is a member of the Board of Governors (BoG) of INNS (2014-2023) and was member of the IEEE Systems, Man and Cybernetics Society (201-2017) as well as IEEE Distinguished Lecturer (2017-2020). *Suri* is Chair of the CIP group of the US Army Research Office, Chair Advisor of the Microsoft Research Advanced Technology Labs; *Suri* has held the IEEE Distinguished Visitor position since 2019; *Cheverst* has held the position of ACM Distinguished speaker since 2015. *Knowles* is a member of the ACM Europe Technology Policy Committee.

Editorial positions in journals and chairing major conferences. Our staff make a number of contributions to the leadership of major scientific journals. This includes editor-in-chief of 5 journals: IEEE Transactions on Dependable & Secure Computing (*Suri*), IEEE Pervasive Computing (*Davies*), IEEE Computer (*Helal*), Evolving Systems (*Angelov*), Internet Services and

⁴ [Wmatrix corpus analysis and comparison tool](#)

⁵ [Professor Paul Rayson Datasets](#)

Applications (*Blair*). They also serve on the editorial boards of over 20 further leading journals, including:

- IEEE Transactions on Cybernetics (*Angelov*); *Big Data* (*Suri*); *Cloud Computing* (*Suri*); *Wireless Communications* (*Navaie*)
- ACM Transactions in Human Computer Interaction (*Sas*); Taylor and Frances *Human Computer Interaction Journal* (*Sas*)
- IEEE Communications and Surveys (*Navaie*); ACM Computing Surveys (*Suri*)
- Personal and Ubiquitous Computing (*Gellersen*)

They serve as editors of three book series on computer science, neural networks and computational linguistics, e.g. Hutchison: *Lecture Notes on Computer Science* (Springer); Angelov: *Proceedings of the International Neural Networks Society* (Springer), Rayson: *Rutledge Frequency Dictionaries* (Taylor and Francis).

Significant Conference organisation and chairing roles: General (co-)Chair. School academics were actively involved in organising and co-chairing a number of major international conferences, a representative sample includes:

- *NeurIPS Workshop on Human-Centred Machine Learning*, Vancouver, 2019; *IEEE Symposia on Deep Learning, SSCI-DL*, 2017-2020; *INNS Conferences on Big Data*, 2015-2016 (*Angelov*)
- *ACM Conference on Ubiquitous Computing, UbiComp* 2014 (*Friday*)
- *International Conference on Smart Homes and Health Telematics*, 2014; *Digital Health as a Service Symposium (DHAASS)*, 2019 (*Helal*)
- *IEEE International Conference on Cloud Engineering (IC2E)*, 2018 (*Suri*);
- *ACM SIGCOMM* 2018 (*Giotsas*)

Significant Conference organisation and IPC/TPC chairing roles. School academics were actively involved in International Programme and/or Technical Committees Chairing roles. We encourage junior staff to participate in these activities as part of their career development. Some representative examples include:

- International Joint Conference on Neural Networks, IJCNN, 2016, 2019; IEEE International Conference on Fuzzy Systems, FUZZ-IEEE, 2014, 2018; IEEE International Conference on Intelligent Systems, 2014, 2016, 2020 (*Angelov*)
- IEEE/ACM International Conference on Distributed Computing Systems, 2015 (*Suri*)
- ACM SIGHI Conference on Designing Interactive Systems, DIS, 2014, 2016, 2019; 2020 ACM CHI Conference on Human Factors in Computing Systems, 2014, 2016, 2018, 2019, 2020 (*Sas*; 2019-2020, *Knowles*)
- 10th IEEE Conference on Cyber, Physical and Social Computing, 2017 (*Ni*)
- ACM Conference on Ubiquitous Computing, UbiComp, 2015; ACM Mobile HCI, 2015 (*Gellersen*)
- IEEE Wireless Communications and Networking Conference, 2014 (*Navaie*)
- IEEE XP Conference on Agile Software Development, 2016 (*Hall*)

Other exemplars of specific esteem and leadership include: Queen's Anniversary Prize (*Rayson*, 2015); IEEE Golden Code recognition (*Helal*, 2018); IEEE Outstanding Contributions award (*Angelov*, 2017), Santander *Chair of Excellence*, University Carlos III, Madrid (*Angelov*, 2016), Steering group member Royal Society Digital Technology and the Planet (*Friday*).

4.3 ECONOMY: COLLABORATION WITH INDUSTRY AND USER COMMUNITIES

Collaboration with industry continues to be a key part of our research and impact strategy. The majority of our grants are from research councils with *in-kind* contribution from industry or from industry direct funding or InnovateUK. The number of research projects directly funded by industrial partners has grown from 36 to 74 during this REF period, with a diverse set of national and international companies such as *BT*, *ARM*, *Google*, *Raytheon UK*, *Ford*, *Airbus*, *Sony*, *Microsoft* and *Huawei* working with us. The close engagement with our research users is pivotal for understanding and impact on vital real-life issues. We often involve user groups from the very

beginning of our research development, even before a specific project proposal is conceived, to identify problems, requirements, reservations and aspirations to inform the research approach.

Engaging stakeholders in our work is critical. Our approach is to integrate the academic and business communities *enabling socially, environmentally and economically impactful* research. Our KE staff led to generation of £10.5M of the schools' £28.5M grant income from partners; an average contribution of £1.75Mpa; supported over 60 guest lectures; put 82 MSc students into industrial experience placements; created 50 other industry internships and engaged with over 200 SMEs. Over the same period our co-location facility housed 21 companies, where all resident companies collaborate with academic researchers. This co-location and support directly lead to KTPs focusing on novel security frameworks with Upside Energy (Marneredes); managing flood risk with JBA (Blair); and threat intelligence with Mitigate Cyber (Prince) – plus the foundation of the Greater Manchester and Lancashire cyber-foundry projects, spearheading the translation of cyber-security research into regional companies and beyond.

4.4 SOCIETY: IMPACT, COMMUNICATION AND OUTREACH

Much of our research is done in partnership with community stakeholders or with wider societal impact in mind. This is illustrated by the following subset of our activities:

Our long running engagement with the *BBC*, led to our pivotal engagement with *micro:bit*, as described in one of our impact case studies. *Micro:bit* is a pocket-sized computer with a very low barrier to entry that has been given to every 11/12 year old child in year 7 or equivalent across the UK, for free. Lancaster, as the only academic partner in the industrial consortium, led the device software component (*Finney*) and engaging through the programme with 29 partners including *Amazon, ARM, Microsoft, Samsung, Barclays, and IET*. While the *micro:bit* programme is important in terms of industrial collaboration and commercialisation, the most important impacts of this project are societal and educational. By engaging early with school age children, we are bringing the next generation of software experts 'into the fold' and hopefully helping stimulate a software boom similar to that seeded by the original BBC micro in the 1980s. Our involvement in the development of the *BBC micro:bit* was covered in 146 media publications/digital articles including major domestic titles such as the *BBC, Yahoo, International Business Times, Electronic Weekly, Computer Weekly, Tech Radar, IT Pro*, and *Reuters* reaching an audience of more than 14M. It also received international media attention, including outlets in Germany and India.

The H-unique hand-identification project is pioneering deep learning in identification of criminals by the image of their hand. If successful, this project will open the door to prosecuting dangerous sexual predators from the materials they post online, something that is extremely challenging to do using current methods. This work has been covered by 180 media publications/digital articles including the *BBC, Daily Mail, Independent, Daily Telegraph, Daily Mirror* and many local/regional newspapers across the UK, reaching around 8.5M readers. This research was also the subject of a special *BBC Radio 4* documentary called '*The Hand Detectives*' and was discussed on *BBC Radio 4 Today* programme, the *BBC World Service, BBC News Channel (TV), BBC2, BBC 5Live, BBC 6 Music*, and *BBC Scotland*. The research was highlighted on *CBC* – the Canadian national radio broadcaster as well as on 22 different *BBC* regional radio stations. The total broadcast reach was in excess of 10.9M.

Computing at School Regional Centre. Leading the regional Computing at School Northwest Regional Centres (*L. Blair, Director*), worked to train regional teachers to promote good Computer Science teaching practice. During this period, we worked with over 1,000 teachers and delivered 4,200 CPD learning hours of training. In addition, we ran annual 'Girls in Computing' workshops for 50-60 primary age children; ran a creative A-level workshop for 3 schools on a *micro:bit*-based Smart City exploring IoT and privacy; an Isaac Computing Discovery Day for 90 15 to 18 year olds in conjunction with the National Centre for Computing Education; and annually run Taster Days, STEM challenge days, Summer Schools and Visit Day activities. This quote represents the significant impact this work has had on teaching professionals at a more personal level:

"The coordinators were invaluable to me at a time when I did not see a future for myself in a profession that I had been in for over 10 years. Following that meeting and the courses that they provide I have gone on to find a passion for the subject, which I never thought I would be able to do [...] which has now led to me being a master teacher and hub leader."

We identified a need to better communicate with non-technical stakeholders in our previous REF period and have been working to better promote and explain our research, and its value, to the community at large. A number of our staff are now regularly consulted by members of the press, leading to radio and TV appearances. We are proactive in identifying and communicating the stories of our research with support from the University's Press Office. We communicate frequently to audiences across the globe via a range of TV, radio, and print media including national newspapers such as the Sunday Times, the BBC News website as well as its flagship technology programme Click, Reuters, Wired, and The Economist.

Examples include:

- *Institute of Coding* was covered in 16 media publications/digital articles including SC Magazine, Insider Media, Times Higher Education, Prolific North, and Gov.uk reaching an audience of more than 1.6M. Our academics often give interviews on national radio such as BBC Radio 5 Live (audience 2M), BBC Radio 4 (audience 3.3M), BBC Radio 2 (audience 4.5M).
- Further exemplars of SCC staff in the media, include comments on the HSBC biometric security (Prince, 2016); Digital memories (Sas, 2016), Dark Web (Prince, 2016), Streaming and energy usage (Hazas, 2018), (Hazas, Giotsas and Widdicks, 2019), Smart wearable technology that detects emotions (Sas, 2019), (Gellersen and Clarke, 2017), Data centres' energy use (Garraghan, 2020). We gave interviews on different TV channels or on hot topics, including BBC (Prince, 2015; Rashid, 2017; Clarke, 2017; Suri, 2019, 2020), Sky (Markarian, 2016 and Rashid, 2017, Prince, 2018 twice, 2020), ITV (Rashid, 2017), TRT (Rashid, 2017), Reuters (Karnik, 2016) and CNN (Suri, 2020).

Our work has had a wide range of research, economic and societal benefits. We were pleased to have supported a promotion case to Professor with significant societal impact (*Finney*). We are now helping define University promotions criteria for engagement and teaching promotions pathways in addition to the more traditional research and balanced criteria. We are confident that this potential for recognition will enable research with impact to continue across the school and the institution more broadly.