

<b>Institution: University of Glasgow</b>
<b>Unit of Assessment: 11, Computing Science</b>
<b>1. Unit context and structure, research and impact strategy</b>

### 1.1. Context

The Unit has 44.6 FTE R&T academic staff, 33 research staff (including 2.0 independent R-only FTEs) and we supervise 133 PhD students. We taught 678 undergraduate and 308 PGT FTEs in 2019-2020. We have a strong, vibrant research and teaching culture, increasing our total research income by 47% since REF2014. Our research is making pioneering, world-leading contributions and delivering global impact across the breadth of the discipline. The Unit is structured around four core Research Sections (complemented by the Centre for Computing Science Education, devoted to learning, teaching and scholarship).

<b>Formal Analysis, Theory and Algorithms (FATA)</b>	<b>Glasgow Interactive Systems (GIST)</b>	<b>GLAsgow SyStems (GLASS)</b>	<b>Information, Data and Analysis (IDA)</b>
Head: Manlove, 10.6 Cat A staff	Head: Vinciarelli, 8 Cat A staff	Head: Pezaros, 10.8 Cat A staff	Head: Murray-Smith, 17.2 Cat A staff
Algorithms and complexity, programming language foundations, formal modelling, model checking and verification	Multimodal Human-Computer Interaction (HCI), social robotics and social signal processing, data analytics and ethics	Computer systems, parallel systems, networked systems, safety critical systems engineering	Information Retrieval (IR), data systems, machine learning, computer vision and autonomous systems

We have an international reputation for generating world-leading theory, and for informing cutting-edge practice, with particular strengths in the areas of Information Retrieval (IDA) and Human-Computer Interaction (GIST). Examples include:

- **IDA** – our research is ranked first in the world by number of papers in the specialism’s premier publication venue (ACM SIGIR<sup>1</sup>) while **Ounis and MacDonald** are both in the top ten of all SIGIR authors in the world. The Section develops and maintains Terrier.org, a popular open-source IR platform which has been downloaded over 100k times and has been cited over 3900 times (Google Scholar). One of our Impact Case Studies (**Macdonald and Ounis**) comes from this Section’s work with [text removed for publication];
- **GIST** – **Brewster** has the largest number of publications of any author at the specialism’s premier publication venue (ACM CHI<sup>2</sup>), and we have the second highest publication volume of any university at the ACM MobileHCI<sup>3</sup> conference. **Brewster** was a General Chair of the ACM CHI2019 conference, the first time it had ever been in the UK and it was hosted in Glasgow because of the Section’s world-class reputation. **JR Williamson** was chosen as one of the founding members of the ACM Future of Computing Academy;
- **FATA** – algorithms developed by our researchers have helped NHS Blood and Transplant increase the number of kidney transplants in the UK from paired donation by 44% during the REF2021 period. **Manlove** won the RSE Lord Kelvin Medal for this work. **Norman** has been one of the principal developers for PRISM, a world-leading, award-winning (Haifa Verification Award) open-source probabilistic verification tool that has had over 75,000 downloads while related papers have received over 4,000 citations;
- **GLASS** – the Section has a prominent position in parallelism research, e.g., leading the EPSRC MaRIONet Network of Excellence and leading 3 of the 5 SADEA Manycore projects. Key activities are around open-source and standards, leading to two ICS (**Trinder, Perkins**).

<sup>1</sup> <https://dl.acm.org/conference/ir/affiliations> (as at 31/7/20)

<sup>2</sup> <https://dl.acm.org/conference/chi/authors> (as at 31/7/20)

<sup>3</sup> <https://dl.acm.org/conference/mobilehci/affiliations> (as at 31/7/20)

## Unit-level environment template (REF5b)

**Johnson's** research has had significant influence on the development of European and Global policies in cyber security associated with Critical National Infrastructure security and the aviation industry, in collaboration with, among others, GCHQ and the Cabinet Office.

### 1.2. Structure of the Unit

After REF2014, the Unit underwent a strategic reorganisation to combine expertise from our then seven groups into our current four research Sections, starting 2017. The Unit is run by the Head of School (HoS) and the School Executive (comprised of Professors, the Heads of the core committees and Section heads).

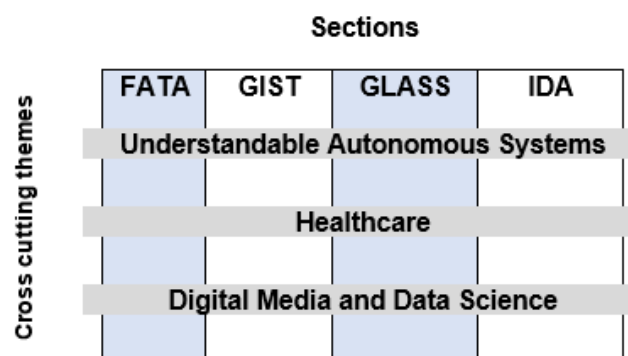
Our restructuring strategy was to consolidate our expertise into a coherent and flexible structure, giving us bigger communities to tackle larger-scale, global research challenges, and be prepared for the increase in government investment in R&D to 2.4% GDP over the next decade. Capitalising on our increased student numbers, we have grown the Unit's total academic FTE by 60% with 38.5% of that growth in R&T staff to build critical mass and bring expertise that allowed better synergies across our areas of research. Our recruitment strategy was to invest in long-term development through recruiting diverse young talent and provide leadership through competitive internal promotion. Early career colleagues now make up 29% of our staff. We have built strong connections with major industries with local presence (e.g., BBC, IBM and JP Morgan Chase) to develop capabilities in areas of national investment (e.g., healthcare, digital media).

#### 1.2.1. Early Successes of the New Structure

Our restructuring strategy has enabled the new Sections to undertake novel, world-leading work by combining skills of multiple section members, bringing in significant funding to tackle new research problems. For example, the £3million EPSRC Closed-Loop Data Science project (led by **Murray-Smith**) demonstrated how the critical mass formed around the IDA Section was brought together for a unique approach to data science, also bringing in companies such as Amazon, JP Morgan and Skyscanner. Within FATA, **Calder's** Science of Sensor Systems Software (S4) EPSRC Programme Grant also involves **Miller** and **Sevegnani**, with collaborators in St Andrews, Liverpool and Imperial College. **Singer** (parallel systems) in GLASS run the £900k EPSRC FRuIT project that also brought together **Pezaros** and **Perkins** (networked systems), to explore scale models for Cloud Computing leveraging clusters of hundreds of Raspberry Pi's across the UK. Within GIST, the €3million H2020 FETOpen LEVITATE project, coordinated by **Brewster**, includes **JR Williamson** and **Freeman** to work on highly novel forms of ultrasound-based interaction. There are also large cross-Section activities: the UKRI SOCIAL CDT (led by **Vinciarelli**, with **Foster** and **Ounis** as Co-Is) brings together academics from GIST, FATA and IDA, and is joint with the School of Psychology to train students to build the future of socially intelligent artificial agents.

### 1.3. Strategy over the REF period

- *Create a flexible and adaptive research structure to solve the most significant research problems and ensure our work has the highest relevance and impact:* Our strategy was to restructure, building on our core strengths and expertise but be agile and adaptive to new problems by using dynamic cross-cutting themes (initially identified by the Executive and put before the Unit for discussion).



Three of these are currently running. Evidence of success of the new structure includes our academics receiving >20 best paper awards from top international conferences and journals, 4 EPSRC Programme Grants (S4, ABCD, Populations, and the recently announced QUEST Healthcare 2050), one ERC Advanced Grant Fellowship (**Brewster**), and over 40

## Unit-level environment template (REF5b)

academic prizes, showing our research is of the highest international quality. Our projects also have strong industrial involvement with >135 companies across the Unit, giving our research relevance and impact, and feeding into our ICS (companies involved in our ICS: **Trinder**: Ericsson, EDF, Erlang Solutions; **MacDonald** and **Ounis**: [text removed for publication]; **Perkins**: Ericsson, CallStats; **Manlove**: NHS).

- Increase the number and diversity of academic staff to achieve economies of scale and critical mass comparable to the upper half of the Russell Group:* Our strategy was to increase the size of the Unit to allow us to tackle larger problems, and bring in new blood to revitalise the Unit after many retirements at the end of REF2014. At the REF2021 census date, the Unit had 44.6 R&T FTE (with an additional 2 fellows), having grown from 32.2 R&T FTE in 2014 and putting us in the upper quartile in the Russell Group (HESA 2017-18 data). Our strategy has been to employ excellent ECR's to complement the established staff in each Section. Alongside this, we have recruited new staff in cross-cutting strategic themes such as autonomous systems (**Hesham, Michala**), healthcare (**Deligianni**), and media and data science (**McDonald, Pugeault**) as these are areas with high societal need for research.

Year	R&T Staff FTE
2013 – 14	32.2
2014 – 15	33.2
2015 – 16	34.2
2016 – 17	36.6
2017 – 18	36.4
2018 – 19	40.4
2019 – 20	44.6

We have recruited excellent new ECRs energetically over recent years to build our strength for the future and to maintain our teaching and research quality; 46% of our staff are new since REF2014, 32% of our new recruits are female and we recruited from 12 different countries. Our strategy is paying off with our ECR staff showing excellent trajectories, for example: of staff appointed since August 2018, 7 already have grant funding as PI or Co-I; **Foster** has achieved promotion to SL within 3 years; **Khamis**, within one year of his first academic appointment, has produced 5 excellent full papers in ACM CHI, the top publication venue in HCI.

- Increase research funding commensurate with our larger size and position in research rankings:* Our strategy was to bring in more bigger grants, focusing on EPSRC and H2020, and recruit LTS staff to reduce teaching load to give time for world class research. Our external research funding has increased by 35%, to a total research income over the REF period of £21.9M, with 14 grants of over £500k distributed across the Sections and academics. We have recruited 7 LTS staff since 2018, giving a total of 9, to support teaching and scholarship. To support staff in their research, the University recently provided £390k investment for new research infrastructure.
- Increase PGR numbers and recruit and nurture the best students:* Our strategy was to extend our PhD cohort and broaden our pool of excellent students to build research strength from the ground up. Headcount of PGRs supervised by Unit staff has risen by 80% since 2014. 37% are female and our PhD students come from 36 different countries. We competitively recruit the best students from across the world, with funding from EPSRC DTA, Horizon 2020, industry partnerships and EPSRC iCASE. We specifically aimed at gaining an EPSRC CDT to strengthen our PGR numbers and the £5m SOCIAL CDT (socialcdt.org) will add a further 50 students in collaboration with the School of Psychology, along with 16 companies and organisations (including, Dyson, Flash Robotics, Microsoft, and Telefonica).

### 1.4. Impact strategy

To build on our REF2014 3.68 Impact GPA (ranked 12<sup>th</sup>), we further refined our strategy, concentrating on a small set of objectives to bring impact to the fore, which led to a cascade of favourable outcomes. Two main objectives were:

- Develop long-term national and international partnerships to enhance our research, teaching, and impact:* We have developed strong relationships with world-leading companies: e.g. Google, Facebook, [text removed for publication], Amazon (e.g. collaboration with [text removed for publication] led to **MacDonald** and **Ounis**' ICS). We have led international

## Unit-level environment template (REF5b)

- (COST Action CA15210) collaboration networks on kidney exchange programmes, delivering impact on kidney transplantation across Europe (**Manlove** ICS). We used the University's Industrial PhD studentship programme taking advantage of College 50% matched funding; the Social CDT; partnership with JP Morgan; the EPSRC Closed-Loop Data Science grant; Google AI Faculty & Bloomberg Awards; and a partnership with Naver Labs in Grenoble;
2. *Instil a culture of knowledge exchange, entrepreneurship and impact among staff and students:* We appointed a Unit Business Development Manager (BDM) in 2014 to ensure entrepreneurship and impact were embedded in the Unit's culture. She explores mechanisms to support greater impact through research and entrepreneurship, and to widen the current pool of organisations that collaborate with the Unit. Successes include the integration of engineers from local consultancies (e.g., OBASHI) alongside staff and PGRs, and industrially funded PGR studentships (Craneware, JP Morgan). Our BDM also supports engagement in entrepreneurship initiatives such as hosting of the StartupGrind initiative events during the academic year, a multidisciplinary recent collaboration with Glasgow's Adam Smith Business School on a Startup Factory weekend, and the negotiation of space at the local Skyscanner offices for the Unit's spinouts. We have an Industrial Advisory Board (IAB) comprising 13 companies (including IBM, Tata, JP Morgan Chase, Skills Development Scotland, and BBC) to support our impact, teaching and research activities.

The strategy has led to one successful spinout (Scoop Analytics), 18 startups, and four RSE Enterprise Fellowships which provide business development, training and funding for academics. Two of these led to continuing, growing businesses (Opinew and Prodsight). Our staff have won 26 EPSRC Impact Acceleration Account (IAA) awards for taking research to impact. To support our impact strategy, we have:

- Encouraged staff to embed impact from the start of grant preparation. All new projects include time from our BDM to support impact and exploitation, while we share best practices in impact in grant applications through a grant proposal repository. We regularly run workshops and events dedicated to KE and Impact within the Unit (e.g., on KTP, InnovateUK schemes) and, over the REF period, we have had 7 InnovateUK and 2 KTP awards;
- Hosted one of the hubs of the SFC Data Lab Innovation Centre (2014-2019): This led to 6 collaborative industry projects worth over £220k. The Data Lab also provided £348k to fund masters students on our data science and data analytics MSc's. 36 of the students were matched to industry partners for their placements, including: Merkle Aquila, Simul8, NHS NSS, Scottish Government, ScottishPower and Clydesdale Bank;
- Led Knowledge Exchange (KE) in the Scottish Informatics and Computing Science Alliance (SICSA) research pool (sicsa.ac.uk), with activities including Demofest and industrial participation (**Ounis** was former SICSA KE Director, **Storer** is the current SICSA Deputy Director and Director of KE & Impact). SICSA is supported by the Scottish Funding Council and Scottish HEIs to foster collaboration within the remit of UoA 11 across the sector, and engage with industry and increase KE;
- Actively supported the development of REF Impact Case Studies (ICS). Academics leading these are given incentivisation funding to support their time in developing their cases;
- Recruited academic staff in the media and data science theme (**McDonald, Pugeault**), to enable a new MSc and build a strong relationship with BBC Scotland and other local media companies.

Our ICSs come directly from our impact strategy: **Trinder's** ICS is linked to encouraging open source initiatives; **Manlove's** ICS is a result of encouraging staff to embed impact in projects from the start; **Ounis and Macdonald**, and **Perkins'** ICSs are the result of prioritising research that addresses the pressing challenges facing local and global society (i.e. energy consumption; network standardisation).

### 1.5. Multi-disciplinary Research

The Unit strongly supports multidisciplinary research and it is a key part of our strategy to 'solve the most significant research problems'. The Unit fosters larger scale activities across and between the

## Unit-level environment template (REF5b)

Sections through our cross-cutting theme lectureships while the Unit's Research Committee provides seed funding for building collaborations bottom-up. We have had a wide range of multidisciplinary research over the REF period. The Unit (**Ounis**, **Triantafillou** and **Ntarmos**) was a founding partner of the Urban Big Data Centre (in collaboration with social science). **Murray-Smith** is part of QuantIC, the UK quantum technology hub ([quantic.ac.uk](http://quantic.ac.uk)). Our UKRI Social CDT (**Vinciarelli**) supports significant multidisciplinary work involving 50 PhD students. Each has two supervisors from different disciplines, drawn from psychology, neuroscience, engineering, and management. **Chalmers'** £1m Human-Data Interaction EPSRC Network+ project has a strongly multidisciplinary core, with Co-I's from ethics, medical informatics, art and engineering. The most recently funded HDI projects combine sociology, digital media and community health. We have taken advantage of the University's LKAS Fellowships scheme to promote multidisciplinary work, e.g. we currently have one fellow (**Turpin**) working in IDA, coming to us from Physics. There has been a significant increase in the demand for CS supervisors to co-supervise PGR students in other disciplines, increasing to 28 students in 2019-20 from just 6 in 2013-14.

### 1.6. Open Access

The Unit strongly supports open access<sup>4</sup>, with the Research Committee in charge of the topic. Over the reporting period, the Unit's Open Access outputs have almost doubled. All publications (and data from completed projects) are deposited on the Enlighten institutional repository. Projects within the Unit also meet funder open access requirements, for example depositing data on services such as Zenodo and OpenAire.

Year	% OA Outputs
2014	48.1
2015	64.5
2016	75.3
2017	85
2018	88.6
2019	89.2

### 1.7. Research Integrity

We follow the approach laid out by the University<sup>5</sup>, promoting a culture of research integrity through the roles of Integrity Champions and Advisers, and the model is currently being used as a case study for both the UK Research Integrity Office and the Royal Society (see our Institutional template). Within the Unit, all staff undertake research integrity training. Integrity issues are handled initially by Section Heads giving information and advice. The Unit has an Ethics Champion (**Gay**) as does the College (**Pearce**) who staff can consult. We have yearly research away days for staff and integrity is a topic that is discussed. Research integrity training is mandatory for 1<sup>st</sup> year PGRs.

### 1.8. The Future

The Unit has grown strongly based on the strategy established after REF2014 and is now in an excellent position to undertake ground-breaking research and scholarship. Recruiting new ECRs means we are able to continuously revitalise the Unit, generating new research areas and collaborations, and has set us on the path for a robust future. A key element of our future planning is to align with the massive paradigm shifts in research culture and associated funding structures, e.g. as outlined in the UK R&D Roadmap, and in this we will be actively supported by the College and University. Given our success over the REF period, the University is continuing to invest strongly, with a further 11 new R&T posts guaranteed over the next 18 months.

Following the outbreak of COVID-19, the Unit developed agile approaches for essential access to restart research and work on campus. Staff and PGR students have been encouraged to attend online conferences to keep engaged and disseminate work. The Unit has taken a lead in this area, setting up an instance of Mozilla hubs as a platform for the community to run virtual conferences (the first was ACM IMX2020 in June 2020) while staff have been involved in COVID-19-related research and awarded grant proposals (e.g., **Enright**, **Yuan**).

Our strategy for the future builds on our strengths:

<sup>4</sup> [www.gla.ac.uk/myglasgow/openaccess](http://www.gla.ac.uk/myglasgow/openaccess)

<sup>5</sup> [www.gla.ac.uk/myglasgow/ris/researchpolicies/researchintegrity/](http://www.gla.ac.uk/myglasgow/ris/researchpolicies/researchintegrity/)

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- *Adapt and grow our research structures to address emerging research challenges and ensure our work is relevant and achieves high impact.* Eight of the new academics to be appointed will reinforce and renew the existing Sections, the other three will be used to support a new cross-cutting theme, with potential topics around programming languages and cybersecurity under discussion. We plan to add one new research Section over the next REF period to grow our portfolio. We will do this dynamically: developing a prominent theme, splitting a large section, or a nucleus may be recruited to address a specific research need;
- *Inspire and enable our research staff to achieve their ambitions.* A key focus is to enable our talented early career academics to become established, demonstrate strong leadership and achieve eminence;
- *Continue to increase research funding, impact, and research ranking commensurate with our growing size.* We will increase the proportion of large grants, with a focus on both EPSRC and industrial funding like Innovate UK. We will enhance research impact through our impact strategy leading to a cultural change supported by our BDM.
- *Continue to increase PGR numbers and quality commensurate with our growing size.* We seek to broaden our pool of excellent students beyond the EU. We will pursue large scale doctoral funding, like CDTs and doctoral programmes with strategic industrial partners.

## 2. People

### 2.1. Overview

The Unit is a diverse community with 44% of Cat A and 42% of remaining research staff from the EU and overseas, bringing together 20 unique nationalities. 18.75% of REF eligible staff identified as belonging to ethnically diverse communities. We have begun to address the sector-wide challenge of gender balance, and have improved gender diversity of R&T staff by 7.8%, achieved proportionate representation in all our activities and processes, set diverse role models, and targeted outreach activities. We have modernised policies to improve inclusivity and Equality and Diversity (E&D) to support flexible working, parental leave and return, mentoring and career development support for all staff, while our paid study leave programme offers significant professional development opportunities. Research staff (PDRs) are an integral part of the Unit with established representation in the Unit's Research Committee and Executive, and in quarterly postdoctoral forums with the HoS. The team of representatives organize a range of social and professional PDR-focused events to encourage networking and collaboration, and to promote a positive culture in alignment with the Concordat for the career development of researchers and the University's action plan around collegiality, career development, recognition, open research, and integrity<sup>6,7</sup>.

Following the outbreak of COVID-19, a suite of much more regular online interactions between academic staff, PDRs, and PGR students was organised with key staff including the HoS. This removed barriers resulting from the imposed lockdown and accommodated the needs for staff and PGR students to work effectively and safely from home, while enabling the monitoring the wellbeing of staff and students.

### 2.2. Staffing Strategy and Staff Development

#### 2.2.1. Recruitment and Promotion Strategy

Within the reporting period, the Unit has seen a growth of 39% in R&T FTEs to build our strength for the future and to maintain our teaching and research quality. 22 new Cat A staff have been recruited at Lecturer or equivalent level, with 11 achieving internal promotion from a variety of routes including fixed-term research contracts (**Anagnostopoulos, Aragon Camarasa, Dardha, Freeman, McCreddie, McDonald, Sevegnani, JR Williamson**) as well as the University's Lord Kelvin and Adam Smith (LKAS) scheme (**MacDonald, Ntarmos, JH Williamson**) for emerging leaders, after following competitive and transparent appointment processes. This followed our strategy for

<sup>6</sup> <https://www.vitae.ac.uk/policy/concordat>

<sup>7</sup> <https://www.gla.ac.uk/myglasgow/ris/researchculture/researchcultureactionplan/>

## Unit-level environment template (REF5b)

employing excellent ECRs to enhance the sustainability of the Unit, and demonstrates the successful exploitation of all available support and career development mechanisms (discussed later in this section) to provide career pathways for part-time and fixed-term staff. A new scheme introduced in 2018-19, aims at supporting ECR R&T staff further through the allocation of one PhD studentship within two years of appointment. Nine of these studentships at home/EU fees and full stipend have been awarded in the current REF period (recipients **Yuan, Steuwer, Dardha, Cano Reyes, Dalton, McCreadie, Aragon Camarasa, McDonald, Sevegnani**). R&T staff recruitment was complemented by the appointment of a further 7 Learning Teaching and Scholarship (LTS) FTEs for an overall 60% growth in the Unit's staff over the REF period.

Leadership throughout the REF period has mainly been through internal promotion (e.g. seven internal promotions to professor), demonstrating clear career pathways for ECR staff in alignment with the Concordat. This complemented previous external leadership appointments (**Triantafillou, Trinder**), and has been facilitated through identification of appropriate candidates by line managers at annual appraisals and via self-nomination. To strengthen applications, yearly promotion workshops are run in the Unit, and promotion is commonly discussed during mentoring sessions. Applications from females comprised 24% of overall applications, which is on par with the 21.5% female staff during the review period. In the current assessment period, 62% of all eligible Cat A staff have been promoted at least once.

Alongside the Section-based restructuring of the line management of the Unit and the established roles of the deputy HoS (**Norman**) and the Executive, pathways to internal promotion constitute part of the long-term succession planning of the Unit which transitioned to a new HoS in June 2020 (**Gay**).

### 2.2.2. Career Development

Through cost subsidy, the Unit encourages staff to attend training opportunities offered by the University through Continuous Professional Development (CPD) courses, ranging from recruitment and personnel management, to E&D, to research integrity and General Data Protection Regulation (GDPR). Academic and Research staff in the Unit have attended 205 instances of training over the assessment period with 27% female engagement. In addition to centrally-provided courses, the Unit supports women to attend Advance HE's female-only Leadership Foundation for Higher Education (LFHE) Aurora. Since the first year of Aurora participation in 2014-15, 80% of attendees have achieved promotion following completion of the programme.

New Lecturers participate in the University's Early Career Development Programme (ECDP) through which they create a long-term personal development plan and set annual objectives to develop the skills for promotion from Grade 7 to Grade 8 within 3 years, and then to Grade 9 (Senior Lecturer/Reader) within a further 5 years. The Unit has had 23 staff on ECDP during the assessment period (14 of whom under 3 years at the census date). From the 9 staff who have been on ECDP for 3 years or more, 75% have already achieved promotion to the next grade within the target period. An additional staff member has been promoted within 2 years.

### 2.2.3. Mentoring and Development Support

As part of a strategic approach to inclusiveness and our commitment to the Concordat for the career development of researchers, the Unit extends the University-wide ECDP scheme through an internal mentoring scheme to provide personalised and subject-specific career development support to all members of staff at all levels upon request. PDR staff receive mentoring from their PIs, including advice on career progression, work-life balance, and technical feedback on job / fellowship / funding applications. In addition, the Job-Seekers Register gives guaranteed interviews for new jobs to internal candidates who are approaching the end of their funding.

For academic staff, the Unit has moved from a flat line management model to Section-based line management in response to staff feedback to provide better support considering the Unit's growth. The Head of each Section has formally taken over line management for all academic non-professorial staff in their Section. Full line management transitioning was preceded by the Head of each Section conducting the annual appraisal of staff since 2016. This move has enabled staff to have a closer relationship with their line manager, and to be able to receive timely and more focused

## Unit-level environment template (REF5b)

feedback and development support. Since these staged changes, average success rates for promotion applications for the Unit have increased to 89% (2017–2020) from 66% in the previous period (2014–2016).

### 2.2.4. Appraisal/Development Review

The Unit undertakes an annual Performance & Development Review (P&DR) which provides the opportunity for all staff to reflect upon performance and development over the past year and agree objectives and plans for the forthcoming year. The P&DR cycle includes regular review meetings scheduled throughout the year to capture progress on the objectives and to offer constructive feedback and recognition, and a final face-to-face review meeting which is a two-way discussion between staff and their line manager to reflect on achievements, objectives, challenges, and to set out future plans that will enable staff to fulfil their longer-term career aspirations.

### 2.2.5. Networking and Grant Funding Support (Workshops and Training)

The Unit contributed financially to the establishment of the University-wide Women in Research Network (WIRN) in 2016, which offers research staff across STEM subjects the opportunity to hear prominent women discuss their challenges and pathways to success.

The Unit actively supports staff, especially ECRs, to identify independent and fellowship funding opportunities (e.g. **Khamis, Omoronyia**), and offers annual support and training workshops for staff to apply for such funding schemes. For example, there was a dedicated workshop organised in 2016/17 to highlight opportunities and support applications for prestigious female-only fellowships. During the assessment period, 10 PDRs from the Unit have participated in ECR Fellowship Workshops, with 60% securing lectureship positions within 3 years of completion. The Scottish Crucible is an annual leadership and career development ECR event focused on creating future research leaders across Scotland. The Unit has had good representation at the Crucible over the reporting period (Females: Andrei, **Foster, JR Williamson, Dardha, Meeks**; males: **Sevegnani, Nabi**). A notable leadership success from Crucible attendees has been **JR Williamson's** selection to the ACM Future of Computing Academy.

### 2.2.6. Study Leave Programme

The Unit has a paid study leave sabbatical programme in place (one semester every four years) to enable members of academic staff to further their research or to gain significant new professional experience. Over the reporting period, 12 members of staff were granted study leave, 10 for an entire academic year and 2 for a single semester. 33% of the paid study leaves were granted to female academics, a higher proportion than the current academic staff female representation, demonstrating strong engagement and desire for professional development. Examples of recent successes resulting from activities undertaken while staff were on paid study leave include the €3m EU FETOpen LEVITATE project (**Brewster**, includes **JR Williamson** and **Freeman**) and the £670K EPSRC project on Modelling and Optimisation with Graphs (**Prosser**).

### 2.2.7. Engagement Facilitation with Industry/Public/Third Sector

Engagement is a key part of our Impact Strategy. Long-term partnerships and a culture of KE are instilled through the Unit's active IAB<sup>8</sup>. Academic staff are given opportunities to present current research projects and topics for feedback and engagement. Board membership is diverse and has traditionally comprised the local technology industry (JP Morgan, Morgan Stanley, SAS, Craneware), the Public Sector (Scottish Government, Skills Development Scotland), and international technology organisations (Tata, Google, IBM, Arm, Skyscanner). Examples of concrete collaborations from the IAB include: the partnership with Skyscanner and JP Morgan in the EPSRC-funded *Closed Loop Data Science* project (**Murray-Smith**); jointly funded PhD studentships with JP Morgan Chase (**Storer**); an MoD tender led by Thales to implement machine learning techniques for novel image analysis challenges (**Johnson**); the commercialisation of Privacy by Design technology (**Omoronyia**) in partnership with Morgan Stanley; and the appointment (0.1 FTE) of Mark Logan, former Skyscanner CEO and Board Member, to a visiting professorship funded by the Royal

<sup>8</sup> [www.gla.ac.uk/schools/computing/industry](http://www.gla.ac.uk/schools/computing/industry)



## Unit-level environment template (REF5b)

Academy of Engineering to work on the development of courses in Growth Science and Entrepreneurship for staff and students.

### 2.3. Equality and Diversity

#### 2.3.1. Overview

The Unit is committed to Equality and Diversity (E&D) in its core policies and procedures, including a supportive and flexible working environment, with commitment from all levels of the organisation in promoting equality. We achieved Athena SWAN Bronze in 2015, currently pending renewal. The most recent staff survey in 2018 showed an increase by 7% in staff that find “the environment inclusive of all genders”, while the percentage of staff who think that “meetings in the School are scheduled flexibly to enable those with caring responsibilities to attend” more than doubled since 2015 with the introduction of a 10:00-16:00 core hours policy to lower the barriers for those with diverse caring or other responsibilities.

The Unit adheres to the University E&D policy which includes commitment to disability equality, ensuring that all staff, students, and visitors have a positive experience of the work, learning, teaching, and research environment. The Unit adds to the relevant University-wide policies through proactively attending to staff with protected characteristics on a case-by-case basis and considering additional measures, such as access to additional entrance lift and priority access to local space for teaching if centrally managed teaching rooms are not available in close proximity for staff with disabilities.

#### 2.3.2. Academic and Research Staff Gender Representation

The Unit entered the reporting period with 12.5% female REF-eligible staff. After following our strategy to increase the number and diversity of academic staff, and taking decisive positive action to improve gender diversity, it ends the reporting period with 21.5% female Cat A staff (female academic R&T staff at 20%). From the 22 new Cat A staff appointed in the reporting period, 7 have been female – 31.8%. Among academic staff Grades, the majority of female Cat A staff are at Grade 8, while two female Professors (**Calder, Miller**) represent 15.4% of academic staff at the highest Grade (Grade 10).

Among research staff the percentage of female staff at Grade 7 – the main Grade for post-doctoral researchers – is higher than at Grade 6, showing a clear pathway to progression for women.

#### 2.3.3. E&D in Recruitment Processes

Candidates for interview are selected using pre-determined essential and desirable criteria. Appointment panel members must undergo Recruitment and Selection training (a prerequisite of which is E&D and Unconscious Bias training). Panels have at least one member of each gender and, for posts at Grades 7 and above, at least 40% female members. Not to overburden female staff with this, appointing committees often have female staff from other cognate Schools such as Psychology. The Unit is committed to accommodating childcare arrangements of potential interviewees when scheduling interviews, while interviewees can claim carer expenses associated with them attending the interview.

#### 2.3.4. Visibility and Diverse Role Models (for students)

The Unit is committed to providing role models especially for female students, early in their exposure to the discipline<sup>9</sup>. Funding and support is provided for the establishment of the Glasgow University Society for Women in Tech (GU SWITCH), a network founded in July 2017 to tackle the lack of female role models and social networks for those students. The network helped hosting CyberFirst, a female-only, 5-day Summer School programme run by GCHQ for secondary school pupils. We host Ladies of Code, a monthly open meetup with technical talks from leaders in the field and expert workshops. Since January 2018, the Unit has hosted a weekly session of the codefirst:girls free coding course for students who are not enrolled in computing science.

<sup>9</sup> [www.gla.ac.uk/schools/computing/diversity/activities](http://www.gla.ac.uk/schools/computing/diversity/activities)

We ensure that there is appropriate female staff representation at Open Days; that half of Level 1 and Level 2 undergraduate courses are delivered by female colleagues. This has resulted in an increase of female students enrolled in undergraduate CS plans from 14.7% in 2014 to 19.4% in 2019.

### 2.3.5. Widening Participation

The Unit participates in the University's Widening Participation Pre-University Summer School<sup>10</sup>, targeted at 16-17-years-old school pupils from deprived backgrounds (measured on the Scottish Index of Multiple Deprivation). This is the largest summer school of its kind in Scotland and around half of the participants subsequently enrol as UG computing students at Glasgow, with 24% of these admissions from females (5-year, 2014-2018 average).

### 2.3.6. Committee Representation

Female representation on committees is either higher or on par with the overall gender balance of the Unit. We endeavour to ensure appropriate committee representation that balances gender and ethnically diverse communities. Responsibilities rotate naturally due to changing circumstances and personal development plans to ensure staff receive exposure to a range of admin roles and responsibilities in support of their career development ambitions.

Committee	Female representation
School Executive	22%
Research Committee	33%
Learning & Teaching Committee	30%
Research Student Committee (staff)	25%
Research Student Committee (students reps)	50%

### 2.3.7. REF2021 Submission

The Unit's REF-eligible staff male-female ratio is 79%-21%. All staff involved as Champions or reviewers in the Unit for REF2021 have completed E&D and Unconscious Bias training. Staff were made aware that they could voluntarily and confidentially declare any personal circumstances that may have affected research productivity without being individually identified or approached.

Selection of outputs authored by current staff was made according to the institution's Code of Practice (CoP) to maximise the GPA of the Unit's outputs sub-profile even if outputs were unevenly allocated across staff, different career stages, or not allocating all outputs to their senior author. In addition, also according to the CoP and with the endorsement of UCU Glasgow, there has been clear separation between REF and performance assessment and hence output selection decisions have no bearing on the career progression of any individual colleague.

### 2.3.8. Flexible Working

The Unit supports a culture of informal flexible working and working from home. Such requests are made to the line manager, and managers are encouraged to be sensitive to individual needs. The Unit also observes the University policy on formal flexible working. Any member of staff can make a flexible working request, and all requests were approved in the reporting period. These rules changed significantly due to COVID-19, and now all staff are currently working from home by default. The University has procedures in place for managers to support their staff to return to working on campus as and when Units reopen.

### 2.3.9. Parental Leave

Staff are offered early support through their line manager in the case of pregnancy. Cover for research, teaching, and administrative duties is arranged with the HoS or the Head of School Administration, and may involve hiring additional staff. There have been five occurrences of paternity leave and 2 of maternity leave over the reporting period, taken by academic and research staff.

<sup>10</sup> <https://www.gla.ac.uk/study/wp/summerschool/>

## Unit-level environment template (REF5b)

### 2.4. Research Students

#### 2.4.1. Overview

The number of PGRs supervised by the Unit's staff has risen to 133 (from 74 in 2013-14). Female PGR student ratio has risen from 19% (2013-14) to 37% (2019-20), improving significantly the Unit's PGR gender gap, and in alignment with addressing one of the identified challenges of the sector. The Unit's PGR population is increasingly international, with 73% coming from the EU and overseas in 2019-20 (from 60% in 2013-14), from 31 different countries (36% from ethnically diverse communities in 2019-20). 7% of the PGR students have declared a disability (2019-20).

There has been increasing demand for academic co-supervision of PGRs on programme plans in a range of other scientific and medical disciplines (from 2.4 FTEs / 6 students in 2013 -14 to 7.8 FTEs / 28 students in 2019-20). PGRs are an integral part of the Unit's research culture and community, and our strategy over the REF period was to recruit and nurture the best talent. This is evidenced through the significant contributions PGRs have made to over 49% of the Unit's total outputs over the REF period. PGRs are also involved in significant outreach and research culture activities facilitated by the Unit, such as the PGR-led (Olaosebikan) Programming Workshop for Scientists in Africa (PWSAfrica), the PGR-led contribution to the CoderDojo movement (Ryan) running community-based programming clubs for young people, and the Glasgow Women in Computing Science (GWICS) group (Cooper).

#### 2.4.2. Approach to PGR Recruitment

We competitively recruit the best students from a wide range of sources from across the world, with students funded by EPSRC DTA, Horizon 2020, LKAS, industry partnerships, EPSRC iCASE, and foreign governments (e.g., China, Saudi Arabia, Malaysia, Oman, Nigeria, Turkey, and Thailand). When applying for admission, applicants are asked to write a proposal which is a core part of their PhD application and is subsequently evaluated in terms of research potential, originality, and rigour, alongside the candidate's track record. The Unit has developed an in-house, online supervisor search tool<sup>11</sup> for potential PGRs to identify relevant members of staff based both on their (online) profile but also the topics they publish. Each application is reviewed by a minimum of two academic staff before a decision about admission is made.

The Unit has also introduced international and home/EU excellence bursaries to attract talented PGRs who would not otherwise have considered Glasgow as a destination through fee discount. The scheme started in 2018–19 and shows significant promise through a 38% increase in international student headcount on CS plans, over the last year.

#### 2.4.3. Progress Monitoring and Support Mechanisms

During the latest Postgraduate Research Experience Survey (PRES) 2019, PGRs reported very high satisfaction with their supervisor's skills (93%) and availability (90%), and an 86% overall satisfaction (up 4% from 2016/17), showing positive evidence to the Unit's strategy of nurturing our excellent PhD students. PGRs get close support through hour-long, in-person weekly meetings with their primary supervisor. Each is also assigned a second supervisor with complementary expertise who also has a pastoral role. The Unit operates a mentoring scheme where PDRs mentor PGRs and can share their knowledge, skills and reflection regarding postgraduate studies and beyond.

The Unit has an established annual progress monitoring procedure where PGRs write a yearly progress report and are orally examined by two members of academic staff independent from their supervisory team who subsequently provide detailed feedback. This allows for impartial advice on ongoing thesis plans and further career progression.

#### 2.4.4. Skills Development and Training

Students are also supported through an extensive PGR training programme offering mandatory E&D courses, research data management, GDPR, and research integrity. There are also numerous

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<sup>11</sup> <https://www.gla.ac.uk/schools/computing/postgraduateresearch/supervisorsearch/>

## Unit-level environment template (REF5b)

elective activities and courses on transferable skills, ranging from technical to presentation and effective (scientific) writing.

Support for participation in conferences and workshops for PGRs whose sponsorship does not cover travel is provided through a dedicated budget. On average, 20 students per year benefit from this. PGRs are encouraged to publish in the best conferences, with travel support prioritised for higher ranked venues. The Unit encourages and supports PGRs engaging with the organisation of social and research related activities. For example, PGRs organise and run a mental health student support group.

### 3. Income, infrastructure and facilities

#### 3.1. Income

The strategic consolidation of the Unit's core strengths has resulted in an increased and diversified funding portfolio. During the assessment period, the Unit has attracted an average of £3.7M p.a. proportioned ownership of external award income, with £25.8M in new HESA-eligible awards through 146 separate projects.

Figure 1 depicts the distribution of awards among Cat A staff, demonstrating increase in the spread of award income as staff develop their careers. Figure 2 shows significant (>20%) improvement in the gender distribution of award income over the assessment period, reinforcing the Unit's approach to E&D. The Unit has maintained diverse sources of research income, strengthening the vitality of our research portfolio, and has achieved an overall growth of 47% in competitively awarded research income (spend) over the assessment period.

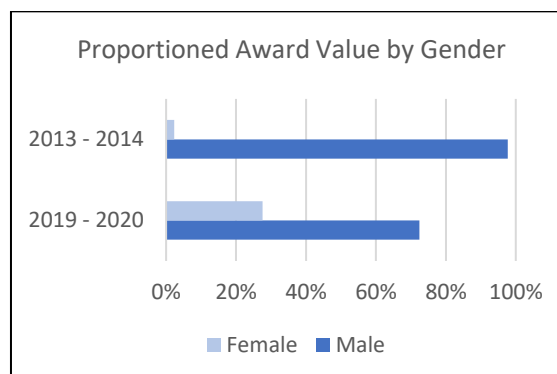
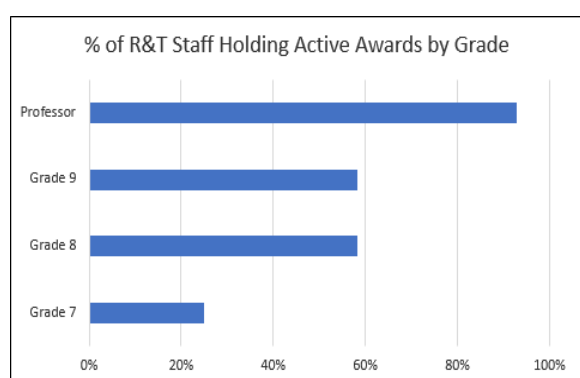


Figure 1: Percentage award-holders by Grade

Figure 2: Percentage award value by Gender

#### 3.1.1. Research Portfolio

Our strategy for increasing research income was to target bigger grants from EPSRC and H2020, focusing on the most significant research problems. Major prestigious grant awards made by external bodies during the assessment period include the £3M Closed-loop data science UKRI EPSRC grant led by **Murray-Smith** (IDA), the £1.9 M ViAJeRo ERC Advanced Grant Fellowship awarded to **Brewster** (GIST), the £4.2M UKRI/EPSC Science of Sensor Systems Software (S4) Programme Grant led by **Calder** (FATA), the £1.8M EPSRC Border Patrol grant led by **Vanderbauwhede** (GLASS), and the £300k Royal Society of Edinburgh (RSE) Personal Research Fellowship awarded to **Meeks** (FATA). **Murray-Smith** leads the Unit's participation in QuantIC, the £6.4M UKRI/EPSC University of Glasgow led quantum imaging hub. **Ounis** was Co-PI of the UKRI/ESRC £6.9M Urban Big Data Centre with **Triantafillou** as Assistant Director, and **Vinciarelli** leads the £5m UKRI *Social* CDT. This research forms a significant part of the outputs returned for this assessment period. For example, **Brewster** (ca. 20k citations) and **Murray-Smith's** (ca. 8.3k citations) published works are extremely well cited, with many best paper awards, and appear consistently in the flagship venues in HCI, (e.g., ACM CHI and ACM TOCHI); **Ounis's** work includes outputs and best paper awards in top venues in Information Retrieval (e.g., ACM SIGIR, where the Glasgow group is the highest cited of any University in Europe).

Similarly, research funding played a crucial role in supporting the generation of the Unit's Impact Case Studies for this assessment period. The authors of the submitted ICS were jointly awarded a funding portfolio of over £4M over the assessment period, averaging in £200K p.a. per investigator in award generation.

### 3.1.2. Consultancies & Professional Services

The Unit encourages staff to engage with industry and government, allowing up to 30 days a year within contract. Since 2014, staff have participated in 21 consultancies with 14 different companies/agencies, typically focused on giving specific advice, evaluating or improving products, with companies including: EDF Energy, US Air Force, Jabra, Mainetti, First Agenda A/S, Blue Bear Systems Group, Bridgeall Libraries, CCRS Borkers, Neurodata Lab LLC, Singapore Technologies Kinetics, and Qinetiq. Such activities contribute significantly to strengthening the impact of the Unit's research. For example, **Perkins'** partnerships with Ericsson and Huawei have contributed to the development of international standards for real-time multimedia communication which have subsequently been incorporated in all major web browsers. **Murray-Smith's** collaboration with B&O led to their flagship product, the BeoSound Moment, in 2015.

### 3.1.3. Industrial PhD Funding

The Unit consistently capitalises on the College policy for 50% match funding on industrial PhD sponsorships to increase external income and ensure long-term engagement with industry. The Unit has attracted external funds for 23 such studentships from companies such as Evi, Google, B&O, Microsoft, Nokia, Obashi, Satalia, Toshiba and Widex, and studentships under the UKRI/EPSC iCASE scheme (e.g., with ARUP, BT, DSTL, JLR, Schlumberger). This funding has contributed to highly impactful research such as the development of forensic tools to minimise the risk of safety-critical system malfunctions, now used by the UK civil nuclear industry to protect it from possible cyberattacks (**Johnson**).

## 3.2. Infrastructure and Facilities

### 3.2.1. Overview

The Unit is based in the terraced Lilybank Gardens complex and the adjacent Sir Alwyn Williams Building. The University and the College have continued to invest in the Unit's £6M building during the reporting period. A total of ca £2.5M has been invested in laboratory, office, meeting and social space, and other strategic research infrastructure. These investments included the conversion and extension of meeting room and office space (£997K), the refurbishment of student laboratories (£985K), and the investment in research infrastructure through strategic funding bids for, for example, file servers, multicore process servers and compute clusters, GPU and networking testbed equipment (£500K). This level of investment has resulted in a dramatic improvement of the research environment and reflects the regard that the Unit holds institutionally.

### 3.2.2. Organisational Infrastructure

The University has made significant investment in the Unit with the funding of 22 permanent academic (Cat A) staff in the reporting period (as discussed in Section 2), in response to the strategic objective of expanding the Unit's size to be in line with the upper half of the Russell Group. New appointments have been strategically targeted on strengthening the Unit's research expertise to be in a strong position to respond to global research challenges. For example, recent recruits in the areas of healthcare (**Deligianni**), machine learning (**Jensen**), and data science (**Yuan**) helped to create critical mass for the Unit's role in the successful proposal of the recently awarded £5.5M UKRI/EPSC Transformative Healthcare Technologies 2050 Programme Grant QUEST on Quantum Imaging for Monitoring of Wellbeing & Disease in Communities (**Murray-Smith**). Similarly, investment in growing the Robotics area with two appointments (**Foster**, **Aragon Camarasa**) resulted in ca £1m of research income across several projects funded by UKRI/EPSC, EC, and industry.

### 3.2.3. Operational and Scholarly Infrastructure

The Unit's Research Committee monitors the research environment, developing strategy, supporting grant application processes, publicising research results and opportunities, and pump-priming research (approx. £38K p.a. for the research committee and £8K p.a. for supporting research-related costs such as conference travel and hosting of external speakers). Together with 26 projects from the College's Impact Acceleration Account, such small-scale yet strategic investment has resulted in highly impactful research such as the development of scalable programming language constructs, the focus of one of the Unit's ICS (**Trinder**). The computing infrastructure within the Unit is supported by 2 Systems managers, 2 systems programmers and 2 senior technicians. The Unit has been represented (Macdonald) on the University's Steering Group ensuring effective engagement with *The Technician Commitment* and, in particular, how it relates to IT technicians. More recently, departure of a senior technician has allowed us to look at the demographics in the team and support replacement with a lower grade appointment to support succession planning and development.

Following the outbreak of COVID-19, the Unit has conducted surveys among staff and PGR students to identify operational infrastructure needs and, as a result, ergonomic chairs and desks were delivered to the homes of PDR and academic staff. All requests for such equipment have been met from the Unit's operational budget, while further equipping approaches for PGR students are being considered.

### 3.2.4 Advanced Equipment and IT Resources

The Unit has invested significantly in its everyday IT needs and also state-of-the-art research infrastructure. The overall related consumables spend throughout the reporting period totalled ca £1.6m to 31<sup>st</sup> July 2020, with an average spend of £226k p.a. In addition, the Sections have received significant investment in specialist research IT infrastructure:

A 10-node, high-performance cluster is shared between FATA and GLASS. It is used to conduct large-scale experiments involving algorithms for NP-hard graph problems, algorithms for matching problems, reproducible parallel combinatorial search applied to computer algebra, and new decision diagram-based constraint solving systems. This is a unique resource designed for reproducible parallel symbolic computation (configured for consistency rather than throughput) that goes beyond what is provided through regional and nationally managed high-performance research infrastructures. It facilitated research at the intersection of GLASS and FATA, resulting in a recent £500k UKRI/EPSC grant award on Session Types for Reliable Distributed Systems (**Gay, Trinder**).

The IDA Section maintains dedicated compute and GPU clusters to support cutting-edge experimentation on Big Data search and recommender systems as well as leading research into artificial intelligence and deep learning systems, including conversational agents and smart robotics. Such infrastructure has facilitated research on search engine query efficiency prediction that resulted in increasing the efficiency of [text removed for publication] and underpins one of the Unit's ICS (**Macdonald, Ounis**).

GIST owns a prototype version of a Pepper robot used within the H2020 MuMMER Project (**Foster**) including new sensors and design modifications which are to be commercialised as a result of the project, as well as a PufferSphere and a dedicated VR workshop (**JR Williamson**). The Section also owns one NAO Robot for experiments on social human-robot interaction, and has three unique ultrasound haptics arrays used in **Brewster's** FETOpen LEVITATE project, a six-camera Optitrak motion capture system for highly accurate hand and object tracking, and a Dexmo haptic glove for VR and haptics work.

GLASS facilities include a distributed compute cluster for experimentation with cutting-edge software stacks and a large-scale Single-Board Computer cluster, emulating scale models for Cloud computing which was used as the basis for the £900k UKRI/EPSC Federated RaspberryPi Micro-Infrastructure Testbed grant (**Singer**); a "processor zoo" that comprises a rich set of accelerators, including a range of GPGPUs and FPGAs for emulating heterogeneous compute environments which provided a platform for foundational work in the £1.5m UKRI/EPSC Exploiting Parallelism

## Unit-level environment template (REF5b)

through Type Transformations for Hybrid Manycore Systems grant (**Vanderbauwhede, Gay**); an extensive networked systems laboratory for large-scale network simulation, emulation, and Internet traffic storage and analysis which has supported research that resulted in the award of the £750k EPSRC Situation-Aware Information Infrastructure grant (**Pezaros**). The Cyber Defence Lab (**Johnson**) is a unique facility that provides exclusive access to a set of safety-critical network infrastructures including both conventional technologies but also avionics and vetronics testbeds, hosting data from digital twins of several UK critical infrastructures and defence applications based on specialist equipment donated by partner organisations. The labs have facilitated highly impactful research in securing Industrial Control Systems which has shaped Scottish, UK-wide, European, and UN cyber security policies for the civil nuclear and aviation industries.

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

#### 4.1. Leadership Examples

The Unit has had a prominent role in leading UK Computing Science over many years, as well providing strong international leadership and strategic direction to the field. **Sventek** was Chair to the UK Computing Research Committee (UKCRC) at the start of the assessment period, **Johnson** is currently on its Executive Committee with another four academics (**Brewster, Calder, Murray-Smith, Trinder**) as members. **Calder** was Chief Scientific Adviser to the Scottish Government 2012–2015, and has been included in the Top 50 Women in Engineering in the UK (2016). She chairs the Science Advisory Committee for Dept of DCMS, sits on the Prime Minister's Council for Science and Technology, and is a member of the Technical Advisory Panel to the Investigatory Powers Commissioner's Office (IPCO). **Johnson** co-chairs the GCHQ/NCSC steering committee on industrial cyber security, while he frequently consults and sits on committees of government departments (e.g., in 2018–2019, DCMS, DfT/BEIS, HMRC) and the Houses of Parliament (e.g., in 2018–2019, House of Commons Science and Technology Committee, House of Lords Select Committee on Communications). **Perkins** is the chair of the Internet Research Task Force (IRTF) which focuses on research issues related to the long-term evolution of the Internet and, in close collaboration with the Internet Engineering Task Force (IETF), contribute to the development of international standards. His work in the IETF has led to his ICS on WebRTC protocol standards.

The Unit has provided strong leadership and direction for SICSA as part of our Impact Strategy, chairing more of the research themes and directorships than any other University (e.g., Deputy and KE & Impact Director: **Storer**, 2019–; Graduate Academy Director: **Singer**, 2016–2018; **Foster** and **Pezaros** recent research theme leads). The Unit has had significant influence on the direction of SICSA, for example **Murray-Smith** initiated the Data Lab Innovation Centre ([www.thedatalab.com](http://www.thedatalab.com)) to create an interface between academia and industry in Scotland during his time as Director, which led to 104 collaborative projects and £590m of economic impact.

Collaboration is at the core of the Unit's ethos and is a key part of our strategy to 'solve the most significant research problems'. Staff across the Sections lead sizeable multi-partner projects, such as the £4.2m S4 EPSRC Programme Grant with Imperial, Liverpool, and St. Andrews (**Calder**), the £1.2m AnyScale Applications EPSRC project with Edinburgh and Manchester (**Singer**) and the £5.3m MultiModal Mall Entertainment Robot (MuMMER) EC project with Heriot-Watt, Softbank Robotics, VTT, and Ideapack (**Foster, Vinciarelli**).

**Manlove** chaired the European Network for Collaboration on Kidney Exchange Programmes COST Action CA15210, to develop a common framework for data and optimisation for kidney exchange. The cross-Scandinavian ScandiaTransplant kidney Exchange Programme was based on the results from the project, with its first successful matching run in 2019. **Gay** chaired COST Action IC1201 on Behavioural Types for Reliable Large-Scale Software Systems that developed new foundations, programming languages, and software development methods for communication-intensive distributed systems.

## Unit-level environment template (REF5b)

The Unit developed and hosts Terrier (developed by **Macdonald** and **Ounis**), an open source state-of-the-art search engine that provides a unique platform for development and evaluation of large-scale information retrieval applications. The platform is widely used, e.g. by Amazon Alexa Search, USA; Yahoo! Research, Argentina; Chinese Academy of Sciences; Italian National Research Council; University of Southampton; Almoviva SpA, Italy; FX Palo Alto Laboratory.

### 4.2. Leadership in Academic Knowledge Exchange

Members of the Unit have had more than 250 international conference roles, chairing, serving on technical, executive, and organisational committees, and reviewing during the assessment period, including: chairing 27 world-class conferences and workshops, including premier events such as ACM ICMI 2017, while 50 keynote, plenary and invited talks were given in international conferences, other academic institutions, and industrial summits.

The Unit hosted ACM CHI 2019, the flagship human-computer Interaction conference with **Brewster** as a General co-chair (with **JR Williamson** and **Freeman** taking significant roles). The event attracted almost 4000 of the world's top researchers to present the future of interactive technology. This was the first time the conference had ever been held in the UK and was brought to Glasgow due to the reputation of the Section. **Brewster** was also a founding member of the ACM CHI Steering Committee, which sets the strategy and direction for the entire conference series.

#### 4.2.1. International Degree Examination Panel Memberships

Unit staff acted as external examiners outside the UK for PhD and habilitation degrees in >35 defences, including: Australia, Austria, Czech Republic, Cyprus, Estonia, Finland, France, Germany, Greece, India, Italy, Netherlands, New Zealand, Norway, Portugal, Slovenia, Spain, Switzerland.

#### 4.2.2. National and International Board Membership and Advisory Roles

Our staff play a significant role in advisory boards across the world. **Anagnostopoulos** is on the advisory board of Repado Ltd. **Calder** was the Chair of the EU Future and Emerging Technologies Scientific Advisory Group, setting the direction of fundamental research across Europe. She was a member of The Nurse Review (2015) which led directly to the formation of UKRI. **Johnson** is advisor to the board of Frequentis, a technical advisor on UK aviation cyber security strategy for the Department for Transport (DfT), advisor to the minister on cyber security of critical infrastructure for the Department for BEIS, and advisor to US Air Force on safety and cyber security. **Pezaros** is on the International Scientific Advisory Board for the National Centre for Scientific Research Demokritos, Greece. **Rogers** is on the board of the Machine Learning in Computational and Systems Biology (MLCSB) Community of Special Interest (COSI) of the International Society for Computational Biology (ISCB). **Vinciarelli** is on the scientific advisory board of the NeuroData Lab international AI Hub, and on the robotics advisory board of the French Agence Nationale de la Recherche (ANR).

#### 4.2.3. Research Collaborations with Research Users, including Industry Users

The Unit has collaborated with >135 companies over the REF period. The Unit currently hosts a number of iCASE PhD studentships, collaborating with companies such as Jaguar Land Rover, Arup Group, BT, DSTL, and Schlumberger Cambridge Research Limited. We actively support the research community, e.g. **Vinciarelli** has a Feature Selection library on MATLAB File Exchange which has been downloaded ~18000 times since 2016.

Through the Unit's participation in QuantlC (**Murray-Smith** and **Turpin**), state-of-the-art machine learning techniques have transformed the capabilities of the Physics partners' optical imaging systems, enabling applications at unprecedented levels of performance, including pushing the limits of fibre optic systems, single-pixel cameras and seeing around corners, as well as applications in the area of inverse problem solving, enabling imaging systems to see through highly dissipative materials.



## Unit-level environment template (REF5b)

**Omoronyia's** expertise in cybersecurity led him to gain funding from Innovate UK & the KTN *Cybersecurity Startup Accelerator Programme* to commercialise a research-based decision support tool for the verification of privacy/security in software design, working with 21 companies. He will strive to commercialise tools to help technology-based companies achieve provable regulatory compliance through security, privacy and transparency by design.

**Interdisciplinary collaboration** is widespread. The overwhelming majority of papers are multi-author, with 42.7% of outputs involving international and a further 17.6% national collaborations. Over 40% of grants have been with other Units or Institutions. **Ounis** (with **Macdonald** and **McDonald**) is the only academic partner in the Cicero project with Archives and Security/Defence contractors, funded by the Foreign and Commonwealth Office, to develop tools to review sensitive documents. The Unit's research work in identifying sensitive documents before archival was highlighted in Sir Alex Allen's reports to the Prime Minister on Digital Records (20141 & 20152). A KTP spin off in Glasgow is currently deploying solutions for the FCO.

**Pezaros'** £758k Situation-Aware Information Infrastructure project brought together computer networking and information retrieval at Glasgow and Lancaster to detect and mitigate the effects of adversarial events on critical networked infrastructures. The €5.9m EuroFIT project (**Chalmers**) combined scientists, community health and football clubs (including Arsenal, Manchester City, PSV, FC Porto) to target overweight men and support them to become more physically active. Long term trials showed significant improvements in physical activity, diet, wellbeing, and biomarkers of health.

### 4.3. Prizes and Awards

Over the REF period, the Unit's staff have won ~40 prizes, awards, and distinctions demonstrating the high quality of our staff and research, including: **Calder**, OBE: DBE awarded in 2020; Royal Society Wolfson Research Merit Award (2011-2016); Suffrage Science Maths and Computing Award (2016). **Brewster**: elected Fellow of the Royal Society of Edinburgh (FRSE) in 2017, elected member of the ACM SIGCHI Academy in 2014 and an ACM Distinguished Speaker in 2015. **Johnson**: elected FRSE in 2019. **Manlove**: SICSA PhD supervisor of the year 2019, and distinguished paper award at CP 2016. **Dalton**: Google Faculty and Bloomberg Data Science Research Awards 2019. **Aragon-Camarasa**: EPSRC ECR Capital award 2019. **Meeks**: IPEC 2016 best paper award, **Norman**: Haifa Verification Conference (HVC) award. **Pezaros**: best paper awards from IEEE Cloudnet 2014 and IEEE HPSR 2015. **Singer**: best paper award ITICSE 2019. **Steuwer**: best paper award ACM CGO 2018, and HiPEAC Paper Award for ASPLOS 2018 paper. **Khamis**: honourable mention award ACM MobileHCI 2018, MUM 2017. GIST Section members won 8 best paper and honourable mention awards at the ACM CHI conference over the REF period.

### 4.4. Other Indicators of Wider Influence

As well as senior colleagues, our ECRs have a strong influence across the wider community. For example, **McCreadie** works closely with Police Scotland and developed a new incident management system to link first responders to the command centre and is currently under deployment. **JR Williamson** is Vice President for publications on the ACM SIGCHI Executive Committee and is currently elected on ACM's Europe Council. Through her work, new publication templates have been established to support accessibility for all ACM conferences; **Dardha** is a member of the Computer Science Committee of the London Mathematical Society (LMS). **Meeks** is member of the Royal Society of Edinburgh's Young Academy of Scotland. It is highly competitive and members must show "outstanding professional achievement" to be nominated.

Members of staff have taken editorial board and guest editorship roles for 36 international journals (including, e.g., ACM Transactions on CHI, Elsevier Information Processing and Management, Elsevier Theoretical Computer Science, IEEE Transactions on Network and Service Management) during the assessment period. The Unit hosts twelve full and one associate member of the EPSRC College of Peer Review.

#### 4.5. Further Contributions to Society

The Unit has had a major influence in leading the transformation of the teaching of Computing Science in schools. **Calder** chairs the BCS School Curriculum and Assessment committee. Recent activities include recommendations to OfQual on the exceptional arrangements for Computer Science examinations due to COVID-19, and to DfE on the content of the GCSE. Cutts, MBE, launched the Centre for Computing Science Education (CCSE) in 2017, with a focus on curriculum and pedagogical research, and influencing policy and practice. Cutts worked with Education Scotland to design the new Scottish CS curriculum, launched in 2017 and adopted nationally for all 3-15-year-olds. It is now delivered in all state primary and secondary schools by Scotland's 650 CS-specialist and >23,000 non-CS-specialist teachers. Within the University, CCSE has pioneered the development of Graduate Apprenticeships, a new degree programme in partnership with 25 employers. The programme will generate >£1m p.a. for the Unit when fully operational in 2020.

The Unit supports several PGR-led services, e.g., HackyHour that provides free computing expertise to users across the University. The student-led Glasgow University Software Service (GUSS – managed by **Storer**) allows University colleagues to leverage student computing skills. Students benefit from gaining real-world experience while customers benefit from custom-designed solutions. One recent success is the development of AppITree with the Institute of Mental Health and Wellbeing for supporting people with brain injury, now undergoing clinical trials.

The Unit has actively championed the development of the Programming Workshop for Scientists in Africa ([www.pwsafrica.org](http://www.pwsafrica.org)), a PGR-led initiative to empower young scientists in Africa to push the frontiers of knowledge in science and technology. Funded by the Unit, SICSA, and the University's Global Challenges Research Fund, annual programming workshops have been delivered to over 100 students in Nigeria and Rwanda.