

Unit-level environment template (REF5b)

Institution: Durham University
Unit of assessment: 11. Computer Science and Informatics
Section 1. Unit context and structure, research and impact strategy
Context <p>Durham University's Department of Computer Science (DurCS) is a small but rapidly growing department whose importance, growth and well-being is strongly supported by the University (see Institutional Environment Statement IES§1.1, IES§1.2), so much so that Computer Science became an independent department in 2017, choosing to split from the School of Engineering and Computing Sciences. The cohort of staff is in the process of an exciting managed growth from 16 permanent teaching-and-research academic staff at the time of REF2014 to a target of 43 staff by 2022 and 59 by 2027, with 27 staff submitted to REF2021*. In December 2020, DurCS will move to a new purpose-built £42M building housing DurCS and the Department of Mathematical Sciences (IES§4.2). The formation of DurCS and the subsequent massive expansion and relocation has dominated the assessment period**.</p> <p><i>* An additional 9 new teaching-and-research members of staff, 3 female, have been appointed since July 2020. Whilst these appointments conform to the strategies detailed below, they are outside the REF census period and so receive no further mention. Henceforth, all data and discussion relate only to the REF assessment period.</i></p> <p><i>** COVID-19 has caused significant disruption to DurCS and the University. The plans outlined in this document are accurate at the time of writing and are expected to be realised unless the duration or effects of the pandemic exceed current assumptions. Further details are available in the "Institutional-level statement on COVID-19".</i></p>
Research structure <p>Computer Science research is currently partitioned into "theory" and "applied", reflected in the two research groups <i>ACiD</i> and <i>ICG</i> (with all persons appointed prior to REF2014 unless otherwise stated).</p> <ul style="list-style-type: none">• <i>Algorithms and Complexity in Durham</i> (ACiD; 11 members) works, broadly, on algorithms, computational complexity and discrete mathematics at the interface between pure mathematics and theoretical computer science. Members are Bordewich, Dantchev, Friedetzky, Gadouleau, Ivrisimtzis, Johnson, Krokhin, Martin*, Mertzios, Paulusma (Head of Group, HoG), Stewart. (Appointed in * 2016.)• <i>Innovative Computing Group</i> (ICG; 17 members) works on methods for data understanding, Artificial Intelligence (AI), visualisation and efficient large-scale computation spanning a range of data modalities, and the role of human interaction within such methods and across a broad range of computing systems. Members are Al Moubayed*, Black**, Breckon, Budgen, Cristea** (HoG), Hadžidedić†, Ivrisimtzis, Koulieris**, Li, Long†, Love†† (HoD), Mitchell**, Obara, Shi†, Sturgeon†, Weinzierl, Willcocks**. (Appointed in * 2017, ** 2018, † 2019; †† joined from Physics 2017.)
Achievement of strategic research and impact aims over the assessment period <p>Since 2014, the research strategy from REF2014 has been strongly enacted (and has evolved since the split; see below). This strategy, taken from the REF2014 environment template and interspersed with enacted exemplars, was as follows:</p> <p>a) <i>"to focus on and establish critical mass in our core areas of research so that there is an encompassing relationship between these topics, the research and the researchers involved, and so that our research in these core areas is internationally leading"</i></p>

- ACiD had critical mass at REF2014; moreover, there is strong research coherence and mixed co-authorship on a large number of research outputs and grant proposals within ACiD, e.g., ACiD has published 77 papers in the following universally-acknowledged world-leading journals and conferences:
 - Algorithmica, FOCS, ICALP, IEEETransInfTh, IEEETransParDistSys, JourACM, JourCompSysSci, JourCombThSerB, JourParDistComp, LICS, PODC, SIAMJourDiscMath, SIAMJourComp, SODA and STOC.
 - ICG has been significantly strengthened with 10 new appointments since 2017 (4 female) and broader in scope but now approaching critical mass in:
 - imaging and vision (encompassing bioimage informatics, computer graphics, computer vision, image processing and vision science via Breckon, Ivrisimtzis, Koulieris, Li, Long, Love, Obara, Willcocks).
 - artificial intelligence (encompassing machine learning, deep learning, natural language processing, pattern recognition, human-AI interaction and applications via Al Moubayed, Breckon, Cristea, Hadžidedić, Long, Obara, Shi, Sturgeon, Willcocks).
- b) *“to strengthen and further develop relationships between theoretical and practical research”*
- There are new research partnerships between ACiD and ICG such as: Bordewich/Breckon on anomaly detection in video; Mertzios/Weinzierl on graph-theoretic data movement formalisations in computer simulations; Gadouleau/Mitchell on post-quantum cryptography; Gadouleau/Weinzierl on maximum surface-to-volume ratio of space-filling curve partitions; and Stewart/Al Moubayed on applying evolutionary algorithms within deep learning.
- c) *“to increasingly develop research collaborations both within the wider spectrum of Computer Science and also of a multi-disciplinary and industrial nature so that not only does the research undertaken impact significantly on other disciplines and on real-world problems but also involves high-quality Computer Science research”*
- There is a wide range of ongoing research with academic partners in Durham, e.g., Anthropology, Biosciences, Business School, Earth Sciences, Education, Engineering, Geography, Mathematical Sciences, Psychology and Physics.
 - There are numerous inter-disciplinary research outputs involving authors from Breckon, Cristea, Gadouleau, Hadžidedić, Ivrisimtzis, Johnson, Koulieris, Krokhin, Long, Love, Mertzios, Obara, Paulusma, Sturgeon, Weinzierl and Willcocks with researchers from departments of
 - Agriculture and Food, Business, Earth Sciences, Economics, Electrical Engineering, Engineering, Genetic Medicine, Linguistics, Mathematics, Medical Sciences, Optics, Optometry, Pharmacology, Physics, Psychology, Sports Science and Vision Science, and the NHS
 and in topics including
 - algebra and combinatorics, astrophysics, atmospheric modelling, BAME equality, coastal ocean modelling, computational mechanics, display engineering, economic games, education, epidemiology, healthcare, marketing, modern languages, numerical analysis, robotics, partial differential equations, protein biochemistry, seismology, sensing, sports science, vision science and visual perception.
 - Industrial concerns involved in active research collaborations include
 - Apt-Core, Astro Zeneca, Autonomous Devices, Blue Bear Systems Research, Boeing, Boots, Bruker, Centre for the Protection of National Infrastructure, Cosmonio, Createc, Cryptalabs, Cubica Technologies, Department of Transport, Dyson, Geospacial Research, Gilardoni, Google, Home Office Scientific Development Branch, IBEX Innovations, IBM, Intogral, Jaguar Landrover, Kromek, Leica, Leonardo, Machines with Vision, Micro-X, Microsoft, Metropolitan Police Service, MOD, MODUS, NHS, Nikon, NM Group, Nvidia, Orsted, Petards, Pearson Engineering, Procter & Gamble, QinetiQ, Rapiscan Systems, Renault, Schlumberger,

Selex Galileo, Smiths Detection, SQR Systems, Syngenta, UK's Defence Science Technology Laboratory (DSTL), Unilever, US Department of Homeland Security, VisonMetric and ZF Race Technologies

- d) *"to provide the core scientific capability of iARC"*
- As part of our restructuring, iARC (Institute for Advanced Research Computing, a university research institute) was redeveloped in 2017 as ARC (Advanced Research Computing), a dedicated computing support unit within the Research Division of the University whose aim is to leverage computational, data-intensive and research computing practice across all disciplines (IES§4.3). Both iARC and ARC have supported various Computer Science research projects.
- e) *"to build a vibrant and dynamic research environment: within which there are both focussed and more general research activities; that engages with research and researchers on both a national and an international level; and that is conducive to collaborative activities"*
- The massive departmental expansion, in terms of staff numbers, wider and more collaborative activities, impact creation and the new building, has strongly contributed to this strategy.

At REF2014, Computer Science's impact strategy was practically constrained, given its research portfolio at that time. The REF2014 impact strategy sought to amend this and has been enacted but the departmental expansion since 2017 has changed the situation dramatically and rendered this strategy somewhat obsolete. Nevertheless, the REF2014 strategy (taken from the REF2014 impact template) was as follows:

- a) *"to use our expertise in systems and computer methodologies to enable impact via collaborations with key industry players such as IBM"*
- b) *"for iARC to be at the fulcrum of all computationally-relevant impact activities across Durham University and for Computer Science to lie at the heart of all iARC activities"*
- c) *"for ACiD to influence the impact of Durham Computer Science research through collaborative activities with IC [now ICG] and other departments"*
- d) *"to increase the engagement of Computer Science researchers with committees and organisations having impact upon public policy"*.

Obara and Breckon were appointed as part of our intention to strengthen the area of computer methodologies and its engagement with key industrial collaborators (and which has evolved into the current imaging and vision research cluster). This strategy has borne fruit, e.g., Breckon's wide-ranging industrial research portfolio and engagement with governmental security policies (cf. our case studies) and Obara's involvement in the University's strategic partnership with Procter & Gamble (IES§1.1, IES§2.5.3) and development of the start-up Integral (now Gliff.ai; Obara/Willcocks).

Our impact strategy for post-2021 is detailed below but has been operational since 2017 and we highlight here a notable early success of this strategy. Our appointments since 2017 together with our sustained focus on impact have resulted in an initial portfolio of over 30 potential case studies for a post-2021 REF, with involvement from Al Moubayed, Black, Bordewich, Breckon, Cristea, Gadouleau, Hadžidedić, Ivrišimtzis, Koulieris, Li, Long, Obara, Paulusma, Weinzierl and Willcocks in areas including

- anomaly detection, athletic performance, automotive sensing, autonomous devices, drug design, fire detection, fraud detection, hardware security, healthcare data anonymization, kidney exchange, medical informatics, mental health, natural language processing, seismic data evaluation, technology training, tectonic plate movement, underwater robotics and X-ray imaging.

In short: the vitality of our impact landscape and our approach to sustain impact generation from DurCS research have been transformed.

Research and impact strategies post-REF2021

The post-2017 expansion has necessitated a re-evaluation of our research and impact strategies and these have already taken effect. A primary intention is to ensure that our research feeds into impact in an unencumbered fashion and that our impact is supported and strengthened by and feeds back into our research.

Our strategic vision for Durham research is

- *"to have well-formed and sustainable groups of researchers working together and producing excellent research so that these groups cover areas of research across the Computer Science research spectrum, interact with researchers and/or application domains within DurCS, the University and beyond, and produce research that helps to shape the discipline of Computer Science and/or benefit wider society at both a national and global level."*

By securing critical mass in chosen areas and performing beyond the sum of our parts, we aim to engage (selectively) across the research spectrum. In order to facilitate our research vision, we have the following strategies, interspersed with brief exemplars of their enactment:

- a) *"retain critical mass in core areas of research, establish critical mass in emergent areas of research, and build new areas of research so that researchers within a group can work together to produce excellent research and also so that researchers within different groups can collaborate on intra-group research"*
 - With recent recruitment, we have developed cognate groups of researchers in imaging and vision and in artificial intelligence; we intend to do likewise as regards scientific computing and distributed/network computing, and we are looking to establish a new research bridge to Mathematical Sciences (with whom we will share a building).
 - ICG is in the process of strategically realigning into smaller research groups. In order to facilitate this fragmentation, we are in the process of establishing four sub-groups within ICG, namely VIVID (Vision, Imaging and Visualization in Durham), AIHS (Artificial Intelligence and Human Systems), NESTiD (Network Engineering, Science and Theory in Durham) and Scientific Computing that will become new research groups post-REF2021.
- b) *"develop more research collaborations both within Computer Science and also of a cross-disciplinary and industrial nature so that the research produces academic impact within Computer Science and/or impact on societal and environmental challenges"*
 - ACiD currently leads the EPSRC Network Grant "AlgoUK: A Network for Algorithms and Complexity in the UK" (PI Stewart, with support from research groups at KCL, Leicester, Liverpool, RHUL and Warwick) which caters for and interacts with *all* of the UK algorithms and complexity community.
 - Within the assessment period, research funding has been awarded of over £530K from Procter & Gamble (Obara); over £700K from Defence Science and Technology Laboratory (Breckon, Obara); over £590K from the Department of Transport (Breckon); over £350K from Renault (Breckon); and over £300K on HPC involving a range of other universities and companies (Weinzierl).
- c) *"build a vibrant, dynamic, diverse and inclusive research community within which there is a varied range of research activities, that engages with research and researchers on both a national and an international level, and that is conducive to cross-discipline collaborative activities, with research excellence pervasive throughout"*
 - The new building and our expansion contribute significantly to this strategy.
 - ACiD hosted over 50 international visitors from 13 different countries within the assessment period, almost all of whom gave research seminars, and also organised and hosted the workshops and conferences: "Geometry and Computation on Groups and Complexes" (jointly with Newcastle); "Algebraic, Topological and Complexity Aspects of Graph Covers"; "British Colloquium for Theoretical Computer Science BCTCS"; "Computability in Europe CiE"; and "Mathematics of Constraint Satisfaction" (postponed due to COVID-19).

Our impact strategy has been significantly enhanced and our strategic vision is now

- *to have impact creation embedded within all aspects of our research, the promotion of a strong impact culture, a diverse portfolio of impact activities, and the involvement of many staff in impact creation.*

We recognise that involvement in impact creation can occur at all points on the pathway from (prior to) the inception of the original research through to the point of impact and beyond, and come in many shapes and forms so that all staff have the potential to be stakeholders (this contributes to our stated intention for a "seamless" connection between research and impact). In order to facilitate our impact vision, we have the following strategies, interspersed with brief exemplars of their enactment:

- a) *"promote a strong impact culture and develop and enable impact appreciation and awareness across the Department"*
 - Impact features strongly in the University's new promotion and progression benchmarks (IES§2.5, IES§3.2).
 - Strong attention has been paid to the potential for impact creation in recent recruitment rounds, resulting in a significant increase in the vitality and sustainability of our potential impact generation portfolio (see above).
 - DurCS has fully supported members of staff as regards impact arising from research, e.g., Obara and Procter & Gamble, Breckon with his impact cases spanning the automotive, defence sensing and aviation security sectors (cf. DurCS impact cases).
- b) *"provide leadership and co-ordination for the Department's external engagement and impact activities and strategically manage the development, dissemination, support and sustainability of departmental impact"*
 - We have a departmental Impact Officer (IO, Ivrisimtzis; IES§2.5) whose role is to support and assist staff in potential impact creation and to develop opportunities for DurCS impact across the University.
 - We have a departmental Research Committee on which sit: the Director of Research (DoR, Stewart); the IO; the HoGs; the Director of Postgraduate Studies (DPG, Friedetzky); and PGR and PDRA representatives. The DoR and the HoGs also sit on the Senior Management Group (SMG) within which all strategy is developed, as do the Director of Education (Johnson) and the Director of Equality, Diversity and Inclusion (EDI, Black).
 - Credit has been built into the departmental Workload Allocation Model to support staff who have substantial loads concerning impact activities.
- c) *"encourage and enhance the development of cross-disciplinary links with other academic disciplines, knowledge transfer and public engagement so as to build pathways to impact"*
 - There is active staff engagement with a range of Durham's multi-disciplinary research institutes including Institute for Data Science (Breckon, Cristea, Shi, Sturgeon, Weinzierl), Biophysical Sciences Institute (Love, Obara), Durham Energy Institute (Breckon), Institute for Computational Cosmology (Weinzierl), Institute of Medieval and Early Modern Studies (Cristea) and Wolfson Research Institute for Health and Wellbeing (Breckon, Budgen, Love, Obara) (IES§2.2). Cristea leads the cross-departmental Digital Humanities Steering Group.
 - We currently have active or recent involvement in a number of Knowledge Transfer Partnerships (KTPs) including ones with Cievart (improve identification and treatment of radiotherapy side effects using AI; AI Moubayed, Long), The Footy Club (generate human-readable, search engine optimised product descriptions to automatically match product data; AI Moubayed, Long), Modus Seabed Intervention (develop enhanced Hybrid AUV capabilities using advanced AI; Breckon, Ivrisimtzis), NM Group (automated LiDAR classification and power line modelling; Breckon, Obara) and Distinctive Publishing (generate a publishing ecosystem that facilitates collaboration/co-creation of content by applying AI; Cristea, Obara).

- Support from the University's Grant Seedcorn Fund (IES§4.1) for transitioning from academic research outputs to impact has been given on 10 occasions in the assessment period and on 4 occasions matched with departmental funding, e.g., Breckon received £6K to support industrial liaison, and Weinzierl received £5K to fund software development.

Research integrity and open research

Durham University leads the way in open access to published research, ranking 4th in the world for percentage of publications that are available through open access (IES§2.4). The University Library provides a central open access publication repository, Durham Research Online, and supports research data management and open data (IES§2.4). DurCS adheres to the University's research integrity and open research and data policies (IES§2.2). These policies are repeatedly emphasised by the DoR and IO, staff having benefitted from training by HR professionals in new data protection laws (GDPR), in Unconscious Bias and in effective collegiate research practices. DurCS also adheres to the University's policy that all research grant proposals should be internally peer-reviewed prior to submission. Each grant proposal is checked by the DoR in this regard and also in relation to protocols on ethics and financial management before being signed off.

The following are exemplars of research integrity and open research. Cristea et al. built and made publicly available a gold Arabic corpus for Twitter-based Telecom data; all software developed by Mitchell is released under open licences with versions archived in perpetuity on Zenodo; and Breckon makes a notable amount of his software and datasets publicly available via Durham Collections.

Section 2. People

Staffing strategy

Our staffing strategy has had two primary drivers since the formation of the new department, namely growth and diversity, and this will continue to be the case. Our intention is to reach 59 permanent academic staff by 2027 and we are in the fortunate position of being able to appoint at all grades (our 27 REF2021 teaching-and-research staff comprise 11 Full Professors, 6 Associate Professors and 10 Assistant Professors); though we will ensure sustainability, support and career progression (cf. critical mass within research groups). As regards staff recruitment, we follow an improved EDI-supporting University recruitment process (IES§3.1) and set up search committees and actively headhunt likely individuals (we have seen strong sets of applicants for all positions advertised).

Staff development

All but 2 of the 10 appointments we have made since 2017 are at the Assistant Professor level (the other 2 are Full Professors) and we view the staff development of these early-career researchers (ECRs) as being of the highest importance. In line with University policy, every member of staff (and not just ECRs) is assigned an experienced mentor (not their line manager) to support career and research development and provide individual assistance with all aspects of university life, e.g., grant proposal preparation, MSc/PhD supervision, teaching and administration (one-to-one meetings occur regularly). Preferential treatment is given to new ECRs as regards teaching/administration via 50% load in their first year and 75% in their second (DurCS has a transparent workload allocation model). The allocation of department-funded and university-funded PhD studentships is purposefully heavily biased towards ECRs, e.g., Koulieris, Willcocks and Al Moubayed have recently received university- and department-funded PhD studentships. Moreover, every staff member applying for an EPSRC New Investigator Award is promised matched funding for a PhD studentship. The Durham Centre for Academic Development (DCAD; IES§3.3) supports all researchers at all stages of their

careers but in particular ECRs, e.g., through "Newton's Apple" and the Leading Research Programme.

PDRAs within DurCS have the opportunity to undertake undergraduate teaching, if they so wish, with appropriate training and support. Since REF2014, 25 PDRAs have been funded through research grants, with the majority who have left going on to academic positions or industrial research labs in the UK and abroad, e.g., to universities in Bergen, Birmingham, Cambridge, Darmstadt, Derby, Glasgow, Hertfordshire, Middlesex, Novosibirsk and Amsterdam, as well as to Beijing Aerospace UAV System Engineering Research Institute. PDRAs are supported with guidance and mock-panel events when they submit fellowship proposals and through the Careers and Enterprise Centre and DCAD as regards career planning and progression.

The University has completely redeveloped its promotions and progressions process (IES§3.2). In short, all staff mandatorily submit CVs each year to ensure that everyone is considered fairly as regards promotions, with all staff receiving feedback from the promotions and progressions process via a confidential meeting with the HoD (the Department Promotions and Progression Committee is diverse and all those on it have undergone EDI training). Staff can apply for research leave on the basis of one-term-in-seven (IES§3.3). Research leave can also be allocated strategically in order to support impact development and be applied for by new parents returning from maternity, adoption or shared parental leave. Research leave also enables staff to undertake significant research visits to other institutions, e.g., Ivrisimtzis to Yale, Bordewich to Canterbury, New Zealand (twice), and Friedetzky to Hamburg.

Every member of staff automatically receives £1,000 per annum (cumulatively) to support research activities such as conference travel, academic visits and small equipment purchases. Additional research support funds are awarded to the PIs of successful grant proposals (equivalent to 10% of the funded overheads), and the University also matches this 10% by contributing into a departmental research fund that is used strategically for all (IES§3.3).

Research Students

DurCS has two mechanisms to allocate internal funding to PhD studentships. The first is to invite all applications with no restriction on topic or field, which are judged on the academic strength of the candidate and project, equality and diversity, the fit to our research strategy, and the potential to support ECRs. The best candidates are put forward for Durham Doctoral Scholarships, but guaranteed funding from DurCS (if eligible) even if their applications are unsuccessful, or to the Chinese Scholarships Council (if eligible). This offers security to the candidate in accepting the position at Durham early and avoids losing strong PhD candidates to other institutions. The second mechanism for funding allocation is to call internally for staff to propose PhD projects that will support the research and impact strategies of DurCS. The best project proposals are then guaranteed funding, enabling staff to advertise fully-funded PhD positions widely (which can often draw a larger and stronger pool of candidates). DurCS is also heavily involved in MISCADA, an MSc in scientific computing and data analysis, which provides a feed for PhD student recruitment.

All PhD students within DurCS receive 3.5 years of funding and have both a primary and secondary supervisor. In addition, DurCS funds conference attendance, research support activities and equipment for each student up to a total amount of £2,500 per annum. Each research student undertakes our Graduate Programme (monitored by the DPG) which includes a written report after nine months of study and an associated viva, and thereafter annual progress reports. It is obligatory within our Graduate Programme that research students give seminars on their research; we encourage and support students to reach as broad an audience as possible, e.g., a number of PhD students have given seminars within the University's Institute for Data Science. We operate a portfolio model of training whereby research students create a tailor-made training package by selecting from a menu of courses from within DCAD. There is also departmental involvement in CDTs with Breckon/Obara

involved in the Leverhulme Centre for Visual Arts and Culture CDT and Breckon in the Aura CDT.

DurCS holds an annual Research Day, organised by our PhD students, which allows students to present their research through talks and posters to the rest of DurCS and to industry visitors. PhD students and PDRAs also organise a regular Junior Seminar Series (at which they gain experience in presenting and receive feedback from their peers) and ad hoc research events, e.g., reading groups, and can nominate external speakers for research group seminar series. PhD students are also encouraged to play a role in the supervision of UG projects when appropriate.

Since REF2014, we have had 46 PhD and 3 MRes students graduate and there are currently 47 PhD and 2 MRes students who are enrolled and yet to graduate. Our current research student cohort comes from over 10 different countries with funding from a variety of sources including EPSRC, Durham University Scholarships, CONACyT, EU IIP, various industrial concerns, and overseas governmental and institutional funders (there are also self-funded students). The quality of our students is testified by the fact that during their studies at Durham, our students have had joint publications with researchers from Alagoas, Athens, Beirut, Bergen, Bordeaux, Brussels, Canterbury, Glasgow, Grenoble, Helsinki, Leeds, Lyon, Mainz, Metz, Montpellier, Munich, Newcastle, Singapore, Oxford, Prague, QUB, RHUL, Rome, Roraima, Sao Paulo, Shenzhen, Shinshu, Toulouse, Trento, Utrecht, Vancouver, Warsaw, Warwick and Wellington.

Equality and Diversity

DurCS is fully committed to the University's EDI principles and values (IES§3.6). DurCS has always been diverse in terms of staff nationality with current staff from Bosnia and Herzegovina, Bulgaria, China, France, Germany, Greece, Netherlands, Poland, Romania, Russia, Syria and the UK. However, we have not had a good gender balance and serious consideration of this weakness has been undertaken in recent years. At the time of REF2014, none of the 15 staff we returned were female. It has been a particular focus of the recent growth strategy to both make the application process fair and accessible and to make the department welcoming and attractive for all genders. This starts with reviewing the wording of advertised job descriptions to highlight inclusivity and to ensure they fully reflect the opportunities available in DurCS, regardless of gender, and persists throughout the process to final interviews, where female academic membership on interview panels is mandatory. In consequence, since 2017 we have appointed 4 female permanent academic staff, as well as a further female Assistant Professor (Teaching), including 2 female Full Professors, one of whom, Black, leads on improving equality and diversity within Durham.

We have instigated additional management practices in order to facilitate inclusivity, e.g.: our departmental promotions and progression committee has two female senior staff members, Black and Cristea; equality and diversity are taken into consideration at all stages of departmental planning, such as in the development of the new building; and the Director of EDI has been constituted as a senior departmental role.

As a department we are endeavouring to make female role models significantly more visible throughout our research environment and also to enable connectivity to other networks and activities aimed at providing a better gender balance.

- a) We have recently formed the Durham University Women in Tech group, which forms part of our department Computer Society; there are already over 30 members.
- b) In 2018 we launched a prestigious scholarship for aspiring female computer scientists to support them throughout their undergraduate studies: the Anne-Marie Imafidon Women in Technology Scholarships.
- c) In 2019 we took 5 of our female undergraduates to the Grace Hopper Conference in the US where they had the opportunity to connect with many global tech employers and

other women in tech from around the world, as well as learn about research opportunities from female experts in, e.g., AI, data science and cybersecurity.

- d) A good gender balance is a strong focus when drawing up speakers for seminar series and other research events, e.g., before her appointment at Durham, Black provided an inspirational talk to DurCS on how she helped save Bletchley Park.
- e) The female members of our External Advisory Board (see below) take a hands-on approach in promoting Computer Science and its research interface with industry, and specifically in recruiting women into the discipline.
- f) We inaugurated the Durham Lovelace Lecture, a prestigious lecture held each year during International Women's week to celebrate the achievements of women, which is now led by Engineering at Durham. Recent speakers have included Professors Danielle George (Manchester), Carron Shankland (Stirling) and Joanna Haigh (Imperial).
- g) We are developing an annual Steve Shirley Lecture, building on a lecture (in partnership with Google) by Dame Stephanie Shirley in DurCS in November 2019.

DurCS was awarded funding of £500K from the Institute of Coding for "TechUPWomen", a programme to provide women from BAME and underrepresented communities in the Midlands and the North of England with an intensive six month course on topics including coding, data science, cyber security, machine learning and agile project management to transform or kick-start careers (the full grant is with researchers from the Universities of Edge Hill, Nottingham and York). Additional funding is being sought and the TechUPWomen grant could form an impact case of any post-2021 REF. DurCS has an Athena Swan Bronze Award and a Silver Award is in preparation. DurCS also has a Disabilities Support Officer.

Section 3. Income, infrastructure and facilities

Research income

ACiD has a strong research funding record for a theoretical research group with the following EPSRC- and Leverhulme-funded research grants, totally over £3M (in FEC value), being active within the assessment period:

- "Efficient Graph Colouring Algorithms via Input Restrictions" (Paulusma, Johnson, £607K, 2016-19); "The Complexity of Promise Constraint Satisfaction" (Krokhin, Paulusma, £555K, 2018-21); "Detecting Induced Graph Patterns" (Paulusma, Stewart, £493K, 2013-16) "Interconnection Networks: Practice Unites with Theory (INPUT)" (Stewart, £438K, 2013-16); "Algorithmic Aspects of Temporal Graphs" (Mertzios, £407K, 2017-20); "Topology, Geometry and Laplacians of Simplicial Complexes" (Dantchev, Ivriissimtzis, £395K, 2013-16); "AlgoUK - A Network for Algorithms and Complexity in the UK" (Stewart, Paulusma, £134K, 2017-20); "Memoryless Computation and Network Coding" (Gadouleau, £130K, 2013-15); "Algorithmic Aspects of Intersection Graph Models" (Mertzios, £128K, 2013-15); "Robustly Tractable Constraint Satisfaction Problems" (Krokhin, £102K, 2012-15).

Prior to the merger in 2016 of the EPSRC's research themes of Maths of Computing and Theory of Computation within its ICT portfolio, ACiD was acknowledged by EPSRC as being one of four major EPSRC research investments in Maths of Computing. Some research highlights from the above grants (in collaboration with the PDRAs) follow.

- Research outputs co-authored by Mertzios and the PDRA Zamaraev on "Algorithmic Aspects of Temporal Graphs" were published in ICALP, AAI and JourCompSysSci.
- Research outputs co-authored by Krokhin and the PDRA Oprsal on "The Complexity of Promise Constraint Satisfaction" were published in STOC and FOCS.
- Research outputs co-authored by Paulusma and the PDRA Dabrowski on "Detecting Induced Graph Patterns" and "Efficient Graph Colouring Algorithms via Input Restrictions" were published in JourCompSysSci (x4), Algorithmica (x3) and SIAMJourDiscMath.

- Research outputs co-authored by Stewart and the PDRA Erickson on "Interconnection Networks: Practice Unites with Theory (INPUT)" were published in IEEETransParDisSys, JourParDistComp and JourCompSysSci.
- As part of the "Interconnection Networks: Practice Unites with Theory (INPUT)" grant, an open-source software tool INRFlow providing a flow-level simulation framework for modelling large-scale networks and computing systems was developed, authored by Stewart, the PDRA Erickson and also researchers from Manchester (JourParDistComp).

Since the start of the departmental expansion in 2017, ICG have secured research funding of over £3.9M whereas other ICG grants active within the assessment period amount to over £1.7M (in FEC value). Funding has come from a variety of non-industrial sources including:

- EU, UK government (Centre for Defence Enterprise, Centre for the Protection of National Infrastructure, DA-CMT Shrivenham, Department of Transport, DSTL, Home Office, Innovate UK, Metropolitan Police Service, MoD, NHS), US government (Department of Homeland Security), EPSRC, Royal Society, ESRC, AHRC, the Nuffield Foundation and KTP and KTA schemes.

Funding from industry includes funding from:

- Cievert, Daykin and Storey, Clickso and Foster Findlay Associates (Al Moubayed)
- Autonomous Devices, Cosmonio, Jaguar Land Rover, Leonardo, MODUS, NM Group, Petards Joyce-Loebl, QineteQ, Rapiscan Systems Limited, Renault and ZF Race Technologies - Conekt (Breckon)
- IBEX Innovations Limited and Geospatial Research Limited (Ivrissimtzis)
- Boots, Dyson, Intogral, Procter & Gamble and Unilever (Obara).

Some research highlights from the above funded research follow.

- Funding by the UK Home Office, Department for Transport, UK Centre for the Protection of National Infrastructure and the Metropolitan Police Service resulted in research outputs in IEEETransInfForensSec and JourXRaysciTech which underpin the current case study "Advanced Algorithm Development for use in X-ray and Computed Tomography Security Scanners used for Transport and Border Security" (Breckon).
- Funding from Jaguar Landrover, ZF Race Technologies – Conekt and Renault resulted in research outputs in ICIP, ECCV and ICMLA, which underpin the current case study "Real-time Scene Understanding for On-Vehicle Automotive Sensing" (Breckon).
- Funding from DSTL, Innovate UK, MOD and UK Technology Strategy Board resulted in research outputs in SPIEOptPhotonics (x3) and SPIEGroundAirMultisensInterop which underpin the current case study "Object Detection, Classification, Localization and Tracking for Automated Wide-Area Surveillance" (Breckon).
- Research outputs co-authored by Obara and the (then) PDRA Willcocks, who was funded by Dyson and Procter & Gamble, were published in IEEETransPatAnalMachineInt, IEEETransMedImaging and IEEETransInfForensSec.

Our strategic vision as regards research income generation is that every member of staff's research should be supported by external funding, with collaborative proposals featuring strongly, and that our overall research income portfolio should be diverse and make use of all potential funding opportunities. There is a strong expectation signalled to staff that research funding should be secured. Receiving 10% of the overheads of a funded proposal provides another strong incentive.

Our intention to build critical mass in specific research areas feeds into our strategic vision for research income generation as critical mass encourages and supports collaboration in securing research funding (cf. ACiD's research grant collaborations above). Having a high-quality research group of critical mass also means that the group attracts high-quality potential collaborators. Again, ACiD is a case in point: "Interconnection Networks: Practice Unites with Theory (INPUT)" was part of a joint proposal with Manchester whose PI was Professor Steve Furber FRS FRSE; and "Algorithmic Aspects of Temporal Graphs" is part of a joint proposal with Liverpool whose PI is Professor Paul Spirakis. Having a thriving seminar series (which

both ACiD and ICG have) facilitates the development of collaborative grant proposals, e.g., "Algorithmic Aspects of Temporal Graphs" (Paul Spirakis, Liverpool; seminar 2015) and "Efficient graph colouring algorithms via input restrictions" (Stéphane Vialette, Université Paris-Est Marne-la-Vallée; seminar 2014), and there are currently ongoing grant proposals involving: Al Moubayed and data scientists from Caspian (a Newcastle-based company); Gadouleau and researchers from Manchester; Li and researchers from Swansea; Paulusma and researchers from Glasgow; and Weinzierl and researchers from Columbia, all of which have arisen following seminar visits.

Departmental infrastructure and facilities

As regards departmental facilities and laboratories, extensive consultations with academic staff were held during the development of our new building (IES§1.1). As well as the usual office space, the building includes the following research facilities:

- 6 research breakout spaces, featuring informal furniture and whiteboards; dedicated research space for PDRAs and PhD students; a high-specification meeting room for video conferencing; and a 100-seat Scott Logic Lecture Theatre
- a Visualisation Laboratory housing research equipment relating to computer vision and visualisation so as to support on-site trials with industrial partners, including a range of specialist surveillance cameras and permanently installed live thermal image feeds (this replaces our current Visualisation Lab which underpinned much of the work for our impact case studies)
- a Heavy Duty Laboratory to support our research in autonomous vehicles and aviation security and: to operate two fully electric vehicles with on-board sensor suite comprising stereo vision, radar and LIDAR sensing for on-road/off-road vehicle autonomy research; and to contain two airport security scanners (dual-energy multi-view X-ray) coupled with extensive aviation-focussed test material
- a Robotics Laboratory to support research in autonomous robotic guidance, human robot interaction and robot sensor design, where there is space for indoor drone experiments on a number of robotics platforms including six Nano humanoid robots, a robotic human-interactive head, two open-rover all-terrain wheeled devices and a wide range of both commercial and in-house drones
- a SCENE Laboratory equipped with AR equipment (from mobile phone applications to Microsoft HoloLens), 3D printers, 3D scanners and VR headsets, to enable the creation of various human interaction "scenes" in relation to research in applied and interdisciplinary fields
- a Displays Laboratory equipped with specialist optics equipment to enable the design and construction of experimental display prototypes, the development of innovative imaging algorithms and performance evaluation through psychophysical experiments
- a Learning Laboratory equipped with tablets, sensors, small robots, head-mounted display devices and projectors to support research on human-AI interaction and human-centred design
- a research server room, hosting a Network Compute Cluster (NCC); a network of cutting-edge NVIDIA CUDA GPUs for machine learning which was enhanced in 2019 with University funding of £150K that partially funded 96TB of high-speed data storage and servers hosting 49 cutting edge NVIDIA GPUs) and a 16 node BlueField cluster (from Mellanox)
- a Hazan Venture Lab forming a dedicated workspace for young entrepreneurs (individuals and teams), designed to facilitate formal and informal interactions with other innovators and industry partners
- additional laboratory space for future expansion.

To aid our expansion, an External Advisory Board (EAB) was set up in 2016 consisting of 16 distinguished individuals from the forefront of industry, academia and the public sector who are recognised as leading figures in their respective fields, with its remit being to provide advice

and support to DurCS as regards industry-related aspects of teaching, research and impact.

Members include:

- Anne-Marie Imafidon MBE: cofounder and CEO of Stemettes, an award-winning social enterprise inspiring females into STEM subjects (over 13,000 participants in its first 4 years)
- Rashmi Misra: Head of Business Development of AI at Microsoft; she was formerly Head of Artificial Intelligence Solutions at Hewlett Packard Enterprise and has held senior positions at Motorola
- Giselle Stewart OBE: Director of UK Corporate Affairs for Ubisoft; Director of TIGA, the games developers' trade association; and Vice-Chair of Dynamo NE, a not-for-profit group set up to grow the North East IT Economy
- Lincoln Wallen: CTO of Improbable Worlds Limited, which develops distributed simulation software, and former CTO of DreamWorks, a US animation company
- Simon Meacham: Head of Information and Intelligence at Lyft; former CEO of the cyber security firm Trust Networks Inc.; and who has recently worked in support of the White House Office of Science and Technology Policy in the Executive Office of the President
- Neil Hunt: Chief Strategy Officer for Curai who was previously Chief Product Officer at Netflix where he led the product team on the Netflix experience.

The EAB helps DurCS to better understand the complex interface between academic research and the real world, and its members actively support and assist in this regard. In addition, the EAB has enabled DurCS to secure £3M in philanthropic donations and the Anne-Marie Imafidon Scholarships to support Women in Technology and internships and industry placements for our students, in particular those from disadvantaged backgrounds.

University facilities

Durham University already has a significant computational infrastructure: it hosts one of the UK's largest academic high-performance computing resources through its Hamilton and COSMA supercomputers (IES\$4.3). Weinzierl and his collaborators use Hamilton mainly as a prototyping and performance analysis system to develop software that is later rolled out to large-scale production HPC machinery. Durham's HPC infrastructure enabled Weinzierl to secure the EU H2020 project ExaHYPE (2015-19, with collaborators in Italy, Germany and Russia and with a budget of almost €2.9M, over £666K of which came to Durham) and to subsequently develop the open-source engine (also called) ExaHYPE to solve hyperbolic partial differential equations in first order formulation on dynamically adaptive space-tree grids. Weinzierl has had collaborations with Durham's Institute of Computational Cosmology in Physics, involving a joint grant with Intel, two jointly supervised PhD students and EPSRC-funded grants, within which they used the COSMA supercomputer. In addition, two grant successes in this area have recently been announced: with colleagues from Physics, Weinzierl (CI) has been awarded an EPSRC grant "Massively Parallel SPH for Engineering and Astrophysics at the Exa-Scale" (£368K); and Weinzierl (PI) has been awarded an EPSRC grant "ExaClaw: Clawpack-enabled ExaHyPE for heterogeneous hardware" (£167K; the ExaClaw software forms an ExCALIBUR use case). Weinzierl is also a PI behind the DINE (Durham Intelligent NIC Environment) supercomputer which is installed in collaboration with DIRAC/COSMA (DIRAC provides HPC facilities for the national STFC theory community and is hosted at Cambridge, Leicester, Durham and Edinburgh). Furthermore, it was announced in February 2020 that Durham will host a new £3.1M Northern Intensive Computing Environment (NICE) supercomputer, Bede, to be used to address challenges in subjects ranging from artificial intelligence to advanced X-ray imaging by the N8 Research Partnership (IES\$2.5.3) of leading universities in the North of England (this will be installed by ARC; IES\$4.3). There is also some usage of national HPC facilities through the ARCHER national supercomputing service (Mitchell).

NETPark (North East Technology Park; IES\$2.5.3) is a specialist business park that provides a dynamic and supportive environment to accelerate the growth of ambitious, innovative, high tech companies into global markets, supported by Business Durham, the economic

development organisation for County Durham. We have recently used facilities there to host large equipment items and experiments, e.g., full-scale airport security baggage scanners (Breckon) and our start-up company Intogral (Obara/Willcocks).

University research support

Research and Innovation Services (RIS) provide specialist support for all staff as regards research funding (IES§4.4). Within RIS, there is a Research Operations team member responsible for DurCS who meets with staff individually to advise on funding opportunities, assists staff with costing and preparing grant applications, and arranges award set-up and post-award support. DurCS is also supported by the Research Development Team and the Partnerships and Engagement Team who assist staff to engage in commercial research, e.g., Obara's ongoing research in collaboration with Procter & Gamble is part of a wider university relationship with Procter & Gamble managed by the Partnerships and Engagement Team (IES§1.1, IES§2.5.3). The University provides research support funds through mechanisms in addition to the Grant Seedcorn Funds mentioned above, including Strategic Research Equipment bids, e.g., DurCS received £150K for a GPU compute cluster for machine learning as well as seedcorn funding.

DurCS is also supported in engaging in bids by ARC who provided support for: the successful TechUp bid (Black, Cristea); successful proposals with Renault, UK Home Office and the MOD (Breckon); Weinzierl's recently awarded EPSRC proposals (see above) where ARC injected 0.3 FTE over 15 months as matched funding; securing 4 ERDF PhD studentships (Al Moubayed, Breckon, Ivrisimtzis); and an ongoing research proposal involving the North East Regional Special Operations Unit (NERSOU) on serious crime (Willcocks).

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

Research collaborations

Engagement in the University's research institutes is strong (see above) and research collaborations thrive in DurCS, e.g., there are DurCS research outputs co-authored with researchers from over 35 UK universities and 40 non-UK universities. There are numerous funded collaborations with other researchers, many of which are inter-disciplinary, seek to address national priorities and sustain the discipline of Computer Science. Some examples follow:

- Krokhin is PI on "The Complexity of Promise Constraint Satisfaction" (EPSRC, £441K) with researchers from the Faculty of Mathematics and Physics at Charles University.
- Stewart was PI on "Interconnection Networks: Practice unites with Theory (INPUT)" (EPSRC, £353K, "Working Together" initiative) which was joint with Professor Steve Furber FRS FRSE, Computer Science, Manchester
- Mertzios is PI on "Algorithmic Aspects of Temporal Graphs" (EPSRC, £319K) which is joint with Professor Paul Spirakis, Computer Science, Liverpool.
- Obara is PI on "At Home Diagnostic Technologies to Enable Self-Care" (GlaxoSmithKline, £245K) with researchers from Psychology and Biosciences at Durham.
- Long has a Fellowship "Intelligent Healthcare Systems for Large-scale Populations" (MRC, £238K) with computer scientists and neuroscientists from the Chinese Academy of Sciences, Nanjing University of Science and Technology and Newcastle University.
- Weinzierl is PI on "ExaClaw - Clawpack-enabled ExaHyPE for heterogeneous hardware" (EPSRC, £167K) with applied mathematicians, earth scientists and computer scientists from Munich and Columbia Universities and Barcelona Supercomputing Centre.
- Breckon is CI on "A New Partnership in Offshore Wind" (EPSRC, £3.9M) with engineers from Durham, Sheffield and Hull Universities.

- Obara is CI on "Preparedness and planning for the mountain hazard and risk chain in Nepal" (NERC, £3.8M) with researchers from Geography at Durham, Newcastle, Northumbria and Oxford.
- Weinzierl is CI of the consortium behind "ExaHyPE - an Exascale Hyperbolic PDE Engine" (EU, €3.5M) with computer scientists, engineers, physicists and earth scientists at Durham, Frankfurt, Munich and Trento Universities.
- Obara is CI on "LINC-NET: A Bio-image Data Driven Informatics Approach Quantifying Nuclear Biomechanics That Predicts Metastasis" (Rosetrees Trust, £796K) with researchers from Biosciences, Mathematics and Physics at Durham.
- Obara is CI on "Church, State, and Nation: The Journals of Herbert Hensley Henson, 1900-1939" (AHRC, £705K) with researchers from the Government and International Affairs at Durham and History at Durham and Leeds.
- Love is CI on "How the eye focuses: Basic mechanisms and opportunities for advanced displays" (NSF, US\$537,554) with vision scientists from UC Berkeley.
- Dantchev and Ivriissimtzis were CIs on "Topology, Geometry and Laplacians of Simplicial Complexes" (EPSRC, £395,679) with mathematicians from Durham and Newcastle Universities.
- Bordewich is CI on "The Combinatorics of Reticulate Evolution" (New Zealand Marsden Fund, NZ\$655K) with mathematicians from the University of Canterbury and Sorbonne Université.
- Weinzierl is CI on "Massively Parallel Particle Hydrodynamics for Engineering and Astrophysics" (EPSRC, £294K) with engineers, physicists and computer scientists at Durham, Hertfordshire, Liverpool John Moores and Manchester Universities.
- Obara is CI on "Automated 3D Measurement of Macular Holes" (Northern Accelerator Research England, £100K) with researchers from Genetic Medicine at Newcastle University.
- Gadouleau was PI on "Cellular Automata and Boolean Networks" (Royal Society, £11K) with mathematicians from Institut de Mathématiques de Marseille, CNRS and Aix-Marseille University.

Partnerships and networks

The University has a strategic partnership with Procter & Gamble (IES\$1.1, IES\$2.5.3) and within this, Obara has developed a strong ongoing relationship. He has secured 6 grants from the company worth over £535K in total, he provides advice to the executive team in relation to data science and AI research and he has given invited specialised talks to P&G R&D teams globally. Obara is also AstraZeneca Visiting Professor in Image Processing and Artificial Intelligence at AstraZeneca, Cambridge. Breckon currently has: an agreement for IP exploitation in return for bespoke technical support for algorithm integration with Gilardoni (who also integrated and tested his algorithms in one of their products); and a rolling supply contract with Rapiscan (who have adopted one of his algorithms to support their global product-line). Breckon has had research consultancies with Autonomous Devices, Blue Bear Systems Research, Cosmonio, Kromek Group PLC, Micro-X, Pearson Engineering and VisionMetric, resulting in funding and an enhanced research relationship. Weinzierl has a close relationship with RSC group, a Russian supercomputer company: they are partners on two of Weinzierl's grants and there are RSC co-authors on some of his research outputs. RSC allow Weinzierl access to experimental machines. Willcocks has a partnership with NHS University Hospital of North Durham whereby large X-ray/CT datasets from the hospital are exclusive to Durham.

Contributions to and engagement with industry and society

DurCS has other occasions of impact that are not reflected within the case studies and some of which are initial steps towards additional impact development.

Obara has contributed to the development and implementation of BisQue, a free web-based, cross-platform and open-source system for the exchange and exploration of 5D biological

images which has been developed mainly at the University of California, Santa Barbara and which is used by many research and commercial institutions such as iPlant and Pfizer. He has also given talks at the following companies: GE Oil & Gas (Newcastle); Unilever (Port Sunlight); GlaxoSmithKline (London); and AstraZeneca (Cambridge). He contributed to a UNESCO meeting on data protection and security to fight against the illicit traffic of antiquities attended by agencies such as Interpol, International Council of Museums, and Office Central de Lutte contre le Trafic des Biens Culturels (Paris).

Weinzierl's collaborations with IBEX Innovations have led to PhD co-funding under the ERDF umbrella and they have granted him access to novel hardware worth around £1M per year that is not yet on the market. He has also co-authored papers with researchers from Intel (USA) and this has led to in-kind grant proposal support. His links with Mellanox have resulted in free access to novel networking solutions, in-kind grant proposal support and the preferential purchase of a SmartNIC/Mellanox-enabled cluster. Weinzierl is the driving force behind two major open-source codes: Peano and ExaHyPE. These codes are used by an ERC Starting Grant and also the EU's Centre of Excellence in Solid Earth (ChEESE). ChEESE actively supported Weinzierl's grant proposals in 2019 and committed to run his future codes on European supercomputers.

Breckon is a permanent member of the Cabinet Office Cyber Security Expert Group as an academic expert advisor with responsibilities to advise on specific cyber-security risks to the UK under the National Risk Assessment. Breckon was appointed as an expert adviser to a UK government Blackett review (details classified). Breckon is currently a member of the scientific advisory board of Machines with Vision.

As well as the start-up Intogral (Obara/Willcocks), Durham research has contributed to 3 other start-ups: Fjelltopp (integration, management and comprehension of public health data; 2 DurCS PhDs); Cosmonio (AI systems that automate the process of extracting visual information from images; DurCS PhD); and Udara (specialist aerial computer vision consultancy; DurCS PhD).

Breckon, Friedetzky and Weinzierl have all given Saturday Morning Science public lectures.

Contributions to the research base

A number of staff hold or have held editorial positions with journals.

- Editor-in-Chief: Computer Journal (Section A) (Stewart).
- Editorial Board: Computer Journal (Paulusma), Frontiers of Artificial Intelligence (Cristea), Graphs and Combinatorics (Paulusma), IEEE Transactions on Learning (Cristea), IET Computer Vision (Breckon), International Journal of Cyber Ethics in Education (Li); International Journal of Distance Education Technologies JDET (Li); International Transactions in Operational Research (Paulusma), Journal of Discrete Algorithms (Stewart), Journal of Graph Theory (Paulusma), Networks (Paulusma), Pattern Recognition (Breckon), Philosophical Transactions of the Royal Society A (Stewart), SIAM Journal on Computing (Krokhin), Visual Computer (Koulieris).
- Guest Editorships: Discrete Applied Mathematics (Paulusma).

9 staff have attended events at invitation-only international research institutes within the assessment period such as Dagstuhl, Oberwolfach, Lorenz Center, Indian Institute of Mathematical Sciences and Centre International de Rencontres Mathématiques. Furthermore, Bordewich, Krokhin and Paulusma have organised 3 Dagstuhl seminars and Stewart was a Member of the Schloss Dagstuhl Review Board.

There is a strong engagement with UKRI agencies (beyond the usual proposal reviewing).

- EPSRC Panel Chair: Stewart (programme grants).

- EPSRC Panel Membership: Breckon (x4), Budgen (x4), Krokhin, Paulusma, Stewart (x4).
- UKRI Panel Membership: FLFs (Krokhin, x2), STFC (Breckon), MRC (Stewart).

As well as the usual proposal reviewing for over 20 international funders, DurCS staff have sat on various panels of funding agencies.

- Panel Chairs: Academy of Finland Mathematics Review Panel (Stewart).
- Panel Memberships: EUROGIGA Review Panel for EUROCORES (Stewart), FCT Portuguese Funding Body (Cristea, x2), French National Research Agency (Breckon), National Centre for Research and Development Poland (Obara), Norwegian Funding Agency IKTPlus (Cristea, x3), Research Council of Norway Mathematics Expert Panel FRINATEK (Stewart), Research Foundation of Flanders (Breckon, x4).

Staff have received various keynote invitations to speak at national and international research events.

- International: 100 Years of Matching Theory in Hungary (Paulusma), International Workshop on Boolean Networks IWBN (Chile; Gadouleau), 33rd Computational Complexity Conference CCC (USA; Krokhin), 29th Workshop on Cycles and Colourings C&C (Slovakia; Paulusma), 41st International Workshop on Graph-Theoretic Concepts in Computer Science WG (Germany; Paulusma), 14th Int. Symp. on Mathematical Morphology ISMM (Germany; Obara), 13th Int. Conf. on Parallel Processing and Applied Mathematics PPAM (Poland; Weinzierl), 10th Int. Joint Conf. on Software Technologies ICSoft (France; Budgen), SIAM Conference on Computational Science and Engineering (USA; Mitchell).
- National: Workshop on Algorithms in Networks, Graphs, Distributed Computing (Stewart), Bristol Algorithms Day (Stewart), 27th British Combinatorial Conference BCC (Paulusma), Combinatorics Colloquium (Johnson), 19th Annual UK Workshop on Computational Intelligence UKCI (Cristea), 9th International Conference on Educational and Information Technology ICEIT (Cristea), 4th International Conference on Information and Education Innovations ICIEI (Cristea), London Algorithmic Workshop (Stewart), Workshop on Network Sciences and Technologies (Mertzios, Stewart).

As well as the usual reviewing for journals and conferences, DurCS staff have sat on program committees on over 90 occasions, chaired program committees and organised workshops and conferences:

- PC Chair: CiE (Paulusma), ICIEI (Cristea), ICWL (Li), ITS (Cristea)
- Conference and Workshop Organisation: 8ECM Minisymposium (Paulusma, COVID-postponed), ACCV RGB-D Workshop (Breckon), ATCAGC (Johnson, Paulusma), BCTCS/AlgoUK (Johnson, Martin, Mertzios, Paulusma), ICALP Satellite Workshop (Mertzios, x3), Int. Conf. on Cyberinfrastructure for Historical China Studies (Sturgeon), ISC (Weinzierl, x2), PASC (Weinzierl), SIAM CSE (Weinzierl, x2).

Staff have received awards and been invited to contribute research papers and edit volumes for journals and other publishers, e.g., Krokhin co-edited a volume of surveys on constraint satisfaction published by Schloss Dagstuhl; Li received the best paper award at Conference on Innovation and Technology in Computer Science Education ITiCSE; Paulusma was invited to contribute a survey on graph colouring to Journal of Graph Theory; and Paulusma was invited to contribute to a special issue of Networks on past winners of the Glover-Klingman Prize.

Staff have contributed to various learned societies and research organisations across Computer Science: ACMUKWomen (AI Moubayed); British Machine Vision Association (Breckon); LMS (Martin, Stewart); UKCRC (Paulusma, Stewart). ACiD is a partner in the Center for Discrete Mathematics, Theoretical Computer Science and Applications DIMATIA (a joint project of Charles University, the Czech Academy of Sciences and Institute of Chemical Technology, Prague; Stewart is a member of the Advisory Board of DIMATIA).