

Institution: Heriot-Watt University
Unit of Assessment: Sub-panel 11: Computer Science and Informatics
1. Unit context and structure, research and impact strategy

Research Unit Context & Structure

Vision: To be a leading centre for research and development of transformative intelligent, interactive, and rigorous systems, especially in robotics and foundational AI techniques, while spearheading globally significant applications that exploit the potential of these areas of computer science.

The School of Mathematical and Computer Sciences (MACS), one of five schools making up Heriot-Watt University, has considerable autonomy over its budget, appointments, research strategy and teaching. Our research groups in the Computer Science Department (HWCS) in MACS continue to be the same as those returned in REF14, namely Intelligent Systems, Interaction, and Rigorous Systems. Group staffing structure is shown below, with underline indicating main affiliation when a member is in multiple groups.

Intelligent Systems	
Areas: biomedical informatics, intelligent systems, pervasive and ubiquitous systems, robotics, machine learning and semantic web	Aylett, Baillie, Broz, Burger, Corne, Dondrup, Gray, Hastie, Lemon, Lones, <u>Petrick</u> , Rieser, <u>Taylor</u> , <u>Vargas</u> , <u>Pang</u>
Interaction	
Areas: affective and autonomous agents, natural language processing, conversational artificial intelligence, human-robot interaction, human computer interaction and multimodal interaction	<u>Aylett</u> , <u>Baillie</u> , Bartie, <u>Broz</u> , Chantler, <u>Dondrup</u> , Eshghi, Hastie, <u>Just</u> , Konstas, <u>Lemon</u> , Padilla, Petrick, <u>Rieser</u> , Taylor, Vargas
Rigorous Systems	
Areas: cyber security, dependable systems and useful logic, types and re-writing	Gabbay, Georgieva, Ireland, Just, Kamareddine, Komendantskaya, Lindley, Loidl, Maarek, McKinna, Radomirovic, Stewart, Scholz, Pang, Wells

Table 1: Research Groups in UoA.

Our structure reflects a pattern of sustainable growth, with research active staff up by 10%. We aim to double that growth to 20% in the next 5 years through the University's Bicentennial Research Leaders fund. Major post-2014 developments include the establishment of a 'Human Robot Interaction' lab (14 academics) which runs through and connects our three main groups. This was an organic development resulting from our growing research activity in this area. One example is our Robotics and Autonomous Systems EPSRC CDT awarded in 2014 (£5.74M), which we used to create the Edinburgh Centre for Robotics (ECR). Lane from Engineering was the PI but the Co-I in Computer Science was Taylor (EP/L016834/1). The CDT was awarded jointly with the University of

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Edinburgh and over 30 industrial partners. This CDT was subsequently renewed in 2019 (£7M) moving from having an Engineering lead to a HWCS lead, with Hastie as (PI) & Taylor (Co-I) (EP/S023208/1), and now involves 40 industrial partners. Our grant funding in this area has also grown through an EPSRC Industrial Strategy Challenge Fund for the Robotics Hub for Offshore Robotics for Certification of Assets (ORCA) EP/R026173/1, Hastie, Chantler (HWCS) and colleagues (Lane PI, HWU Engineering) worth £14.6M, which is one of the largest industrial strategy challenge funds awards. The Hub brings together leading experts from 5 universities with **over 30 industry partners including BP, Chevron, Schlumberger, Kawasaki, Lloyds, and Kuka Robotics**. The goal of the hub is to use robotic systems and artificial intelligence to revolutionise asset integrity management for the offshore energy sector. We have been awarded several further large EU and EPSRC grants in this area, see Section 3. Regarding infrastructure investment we won a EPSRC capital award (£7.2Mm to HWU and Edinburgh University) in late 2013 which enabled us to spend £802K creating the Robotarium West at HWU, which was completed in 2016. The most recent of our robotics activities with the University of Edinburgh led to an Edinburgh City Deal funded by Scottish, UK and local governments, in which HWU was awarded £22.4M (HWU added £6.5M to this fund making the investment overall approx. £29M) to establish a UK National Robotarium. The National Roboatrium will act as a catalyst to work with industry translating HWCS research into practice. The infrastructure and awards outlined have helped underpin new collaborative ventures between all our groups as well as turbo-charge new external interactions (see Sections 3 & 4 for information).

Growth in our Research Since 2014

Our research income **has increased by 38%** overall since REF 2014. We have radically increased our funding base in areas that both support our vision and align with global priorities. Sustaining future developments, we have also grown external industry and academic collaboration (evidenced throughout Section 4 and REF3a) and have now an established profile in future global priorities that crosscut our research groups such as energy, AI, robotics and health.

In REF 2014 we indicated the following goals:

1. investment in new opportunities and existing areas of strength;
2. broader industrial activity;
3. wider UK and international collaborations;
4. increasing research student numbers;
5. strong support of researchers at all career points, especially female members of staff.

We have achieved all five of our goals. For example, we achieved: goal 1 by using the HWU Global Platform Appointment process to grow and enhance our research academic staff base and bolster our 3 groups (see Section 2) and grants to increase the number of RA's by 15%; 2. As regards growing our industrial partnerships we have undertaken **107 projects with industrial partners** (see Sections 3 & 4). 3. The national context saw the emergence of the AI and Robotics theme and the reshaping of EPSRC's approach to ICT to increase their emphases on Robotics, AI and Cybersecurity. This resulted in several funding awards in robotics (see research groups and Section 3) and foundations/verification of AI. Exploiting goals 1-3 and our own initiatives we achieved goal 4 and increased PhD student numbers (39 to 103). As regards goal 5 **46% of our Professors are female**, this compares very favourably to the **national average of 16%**. Significant progress has been made on all strategy goals (evidenced here and in the relevant sections cited).

2014-20 Strategy, Achievements and Future Plans (2020-25)***Intelligent systems***

We aim to transform the quality and potential for large scale optimization, robot control, decision-making, and pervasive computing, by drawing on inspiration from nature and via new synergies among machine learning, optimization and complexity science.

Our Strategy 2014-20 was to widen both academic & industry collaborations around these threads, including bringing these ideas “to bear on major societal & environmental challenges”. This strategy was progressed via several new collaborations organized around the United Nations Sustainable Development Goals (SDG), with organizations including the World Business Council for Sustainable Development (WBCSD), the Chinese Society for Environmental Sciences (CSEC), and Scene Ltd (a social enterprise working in India). Our strategy then expanded towards exploiting these alliances to:

- (i) help us understand key research questions around the adoption of intelligent systems in real-world settings, especially regarding SDGs, and then
- (ii) seeking to address these questions in collaboration with stakeholders.

Evidence of impact of this work can be seen in one of our submitted Impact Case Studies. The case study (logistics) builds on existing and new partnerships with WBCSD and companies in the road transport sector to assist with decarbonisation of freight transport. Meanwhile, via support from two EPSRC Quantum Hub grants (£185k, shared with HWU Physics), we grew academic collaboration in this area to lay the groundwork for exciting future developments.

Evidence of our strategy in operation and associated achievements: since 2014 we have won 10 projects with industry collaborators (£1.56M), developing new, robust and deployable ideas for machine learning and large-scale optimization. We engaged with the WBCSD on a freight industry working group 2014-2016; this led to a 2018-20 Innovate UK award to investigate both business models and algorithms for asset sharing in road freight, the outcomes of which have now informed WBCSD global policy documents and have been implemented in leading commercial transport management software. Another focus is health monitoring, with Lones’ EPSRC First Grant (EP/M013677/1) exploring intelligent systems for new diagnostic approaches to Parkinson’s disease. Lones continued this work in a partnership with a diagnostics SME Clear Sky medical (clearskymd), they are now conducting clinical trials of their innovative diagnostics device. Pursuing our strategy in the area of robotics, Petrick’s research in automated planning in the context of robotic systems working safely and reliably with humans has resulted in a collaboration with PSA Peugeot-Citroen on factory automation (EU FP7 STAMINA, 2013-2017). He investigates questions in temporal planning for autonomous robotic inspection tasks (EPSRC ORCA Hub) and epistemic planning in robot/human interaction (EPSRC EP/R031045/1).

Our top-level Objectives 2021—25:

- (i) sustain and grow stakeholder collaborations and impact around SDGs, especially climate mitigation, energy and health;
- (ii) continue to address key research questions in optimisation and planning, especially industry deployment and public acceptance of these technologies;
- (iii) build a new emphasis on understanding and designing intelligent systems that are robust to significant change, and;
- (iv) grow our portfolio of emerging technologies including quantum computing.

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This reflects adaptation of our 2014-20 objectives in the light of increasing urgency of the UN SDGs and the new challenges of mid- and post-pandemic society.

Interaction

We aim to enable future intelligent interactive systems that can collaborate effectively and adaptively with humans, covering human-robot interaction, multimodal interaction, human computer interaction, and natural language processing.

The interaction grouping has focused on multimodal interaction, supported by advanced probabilistic techniques in modelling and planning, thus handling uncertainty in interactions and improving the effectiveness of human/machine interaction. We have developed and applied techniques for scenarios ranging from spoken dialogue systems (such as Alexa), to multimodal interfaces for autism, healthcare, and social robotics. Achievements include novel theory and applications of reinforcement learning to Natural Language Generation and robust spoken dialogue management, data-driven techniques enabling rapid generation of multimodal interfaces for new applications, virtual characters for communication skills learning in autism, and advances in socially intelligent robots. **Strategy 2014-2020** was twofold:

- (i) to further develop and capitalise on this work in important social contexts;
- (ii) to extend the theory, models and platforms from individual towards social interaction, and to focus on multimodal interaction, supported by advanced probabilistic techniques in modelling and planning.

Evidence of our strategy in operation and associated achievements from 2014-2020 include Lemon, Rieser, Konstas leading a group of PhD student finalists twice in the Amazon Alexa Prize 2017 and 2018 (see Section 4). This group has been awarded £6.4M (from ESRC, EPSRC (e.g. Diligent, Madrigal, and Babble), EU-H2020 and Leverhulme) to develop spoken dialogue systems. Regarding modelling usable interaction for rehabilitation and security we have won 5 awards from EPSRC (Baillie, Broz, Vargas, Aylett, (EP/T013737/1, EP/N034546/1, EP/I032037/1, EP/T017511/1, EP/T021063/1)). We are currently working on advances in socially intelligent robots and how to ensure safer user interactions in hazardous environments (Orca Hub, Hastie). The group has collaborated with over 50 companies on real world projects which saw our ideas, concepts and solutions adopted into practice, some of these companies are world-leading e.g., Amazon, Softbank, Kawasaki, Total, Schlumberger, Honda, Lloyds and Ocado.

Our top-level Objectives 2021—25 for Interaction are:

- (i) to further develop our core scientific work in the areas of conversational AI, NLP, machine learning, multimodal interfaces, and Human-Robot Interaction, and
- (ii) to apply and evaluate these methods in ecologically-valid real-world settings in areas such as healthcare, assistive living technology, under-water robotics and smart workplaces.
- (iii) to further develop our industry collaborations (e.g. Softbank, Kawasaki, Total, Honda, Ocado, Amazon, and PAL robotics) in order to perform both foundational and applied research, in particular supported by the new National Robotarium research facility, for which the group members have designed a suite of research labs (see Section 3)
- (iv) A further important objective here is to enhance the impact of our research via spin-out companies such as the conversational AI spin out company Alana AI (Lemon & Rieser).

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Rigorous Systems

Our work focuses on the development of theories, techniques and tools to improve the dependability of systems. Key areas are the design and implementation of portable and parallel programming languages, formal verification and explainability of complex intelligent and autonomous systems, and formal verification and design of security protocols.

Strategy 2014-20, was to expand and apply that research to enable the creation of trustworthy AI applications, and verify the reliability, safety, and security of complex software systems. Working towards this goal, we hired new staff with world-leading expertise in security (Maarek, Just, Radomirovich) and verification of AI (Komendantskaya). This resulted in new work on verifiable AI that investigated novel frameworks for developing and implementing security and regulatory policies for complex deep learning AI. For dependable computing we broadened the use of advanced type systems, develop modelling methods for secure systems and theorem proving technologies to design and validate new programming language foundations in domains such as symbolic computation. Examples of realising this vision are: (i) high-level language concepts and associated compilers (e.g. SaC) that enable solutions (e.g. costed parallel compilation) usable in arbitrary existing contexts (e.g. C, Java), with no need for users to adopt a new language; (ii) scaling scientific and symbolic computations on HPC architectures and computer vision languages (e.g. RIPL) for programmable hardware; (iii) using formal methods to verify AI techniques; (iv) formal modelling and verification of cryptographic protocols e.g. for 5G mobile communication; (v) advances to bidirectional programming in model-driven development, algebraic effects and handlers as well as extensible datatypes in functional programming.

Evidence of our Strategy in Operation and Associated Achievements

The group won £1.7M for type system approaches for verifying System on Chip design (EP/N028201/1 Scholz, Stewart); EPSRC Platform Grant £1.3M to enable the visualisation of reasoning processes (EP/N014758/1 Ireland); EPSRC £1.3M to develop type based novel framework for documenting, implementing and developing policies for complex AI systems (EP/T026952/1 Komendantskaya); EPSRC £283k UK Trustworthy Autonomous Systems (TAS) Node on Governance and Regulation (Ireland). Gabbay's foundational work in nominal logics seeks to revolutionize how computer science handles names and won an Alonzo Church Award for Outstanding Contributions to Logic and Computation (2019). Ireland's EPSRC Platform Grant is creating impact by providing the underpinning infrastructure for a unique blend of theoretical AI research spanning theory formation, evolution, visualisation of systems, learning and proof engineering. Applications are wide ranging and include ontology management, emergency response, healthcare workflows, industrial scale embedded formal methods, disaster recovery planning and privacy analysis. Project partners have applied the visualisations in aerospace (NASA) and improving modelling of healthcare pathways (NHS).

Our top-level Objectives 2021—25 are to further solidify our impact and apply our work in the areas of:

- (i) verification of foundational AI techniques towards trustworthy AI for autonomous systems and computational finance;
- (ii) systems and languages for high-performance machine learning;
- (iii) compiler guaranteed proofs for automatically generated programs;
- (iv) formal methods for cyber-security and their applications to emerging and evolving systems and protocols. The group will capitalise on academic and industry collaboration initiatives (e.g. NASA, NHS, BAE systems, Xilinx, DSTL, Codethink) and will perform

foundational research to realise large-scale software verification and high-performance architectures.

Open Access

We provide free, open online external access to our publications via our Research Portal to ensure that our research results are transparent and have wide reach. We also provide free and open online access to as much as possible of our raw data and experimental results. As regards our further commitment to open access one of our impact case studies (see our submitted REF3) reports on how we assisted publishers to make their Open Access Articles systematically discoverable. The ticTOCs and journalTOCS projects respectively developed the world's first metadata schema for scholarly publications, and then built on that to produce the de facto standard for scholarly journal Table of Contents (TOC) and is being used by over 30,000 journals.

Ethics

We operate within the jurisdiction of the Schools' Ethics Committee reporting to the University Ethics Committee. The School Director of Ethics also sits on the University Ethics committee. The University has recently (2019) adopted a University wide system for ethical approval to ensure consistency of approach. We train our staff to anticipate and understand the wider ethical and societal impacts of their work. Ethics approval is a compulsory aspect of our pre-submission internal grant review procedures and expected to be revisited throughout the lifetime of an award. We follow the principles of the UK Forum for Responsible Research Metrics, including robustness, humility, transparency, diversity and reflexivity. In HWCS we have a strong ethics culture, which permeates all our research project proposals as we believe strongly in the concepts of Explainable AI, user-centred design and privacy by design for all pertinent projects.

COVID Impact Statement

There have been two areas of impact.

Section 2 Staff

- Staff have had to continue with full time work whilst also doing full-time caring and childcare (including home schooling), significantly reducing their productivity. It is anticipated that this will have a medium-term effect on grant income, publications and impact.
- in the area of staff development meetings, training and exchanges are only available online. This has an especially large impact on ECRs as networking at this stage in their careers is paramount.
- The delay of all in person experiments has had a severe effect on our research associates and PhD students' development, especially regarding the Interaction grouping. It is anticipated that this will have an impact on our publications and PhD completion times.

Section 4 Collaboration and Contribution to the Research Base, Economy and Society

We had an impressive collaboration and contribution track record as can be seen by our list of invited industrial talks e.g., Google, Vodafone, Microsoft, Amazon and public exhibits e.g. Royal Society Summer Festival, Subsea Expo, Edinburgh International Science Festival, Chelsea and Westminster NHS Trust etc. We had over fifty events planned for 2020 which all had to be postponed, moved online or cancelled which had an impact on our ability to undertake as much outreach.

2. People

Staffing Strategy and Staff Development***Academic staffing strategy***

Academic staffing strategy: Our broad strategy is to aim for sustainable growth and as a result our research staff number has grown by 10%. We have also created permanent teaching and scholarship posts to support our teaching and release more time for research. We have a healthy balance of senior and early-career staff, and a robust balance of theory-oriented and application-oriented groupings, since each of these directions maximises our agility in the face of shifting priorities, opportunities, and developments in computer science. Our recruitment strategy during 2014-20 aimed to: (i) maintain and strengthen our three groups, (ii) increase the numbers of early and mid-career staff who straddle two or more of our groups, and hence underpin future larger-scale research programmes (e.g. Orca Hub which has as Co-Is, Chantler, Hastie and Petrick).

Group	Joined
Intelligent Systems	Broz, Dondrup, Pang
Interaction	Baillie, Bartie, Eshghi, Just, Padilla
Rigorous Systems	Komendantskaya, Lindley, Maarek, McKinna, Radomirovic, Stewart

Table 2: New academic staff and their primary research group.

Hastie (2010) and Rieser both hired as early career (2012) were promoted to Professors (2017) and Baillie and Komendantskaya (2015 mid-career appointments) were also promoted to Professor (2018/2019); all are female. Hastie and Rieser bring unique approaches at the interfaces of machine learning, probabilistic reasoning, NLP, and dialogue. Hastie is Director of the EPSRC CDT-RAS, Co-I on the EPSRC ORCA HUB, PI for the EPSRC Trustworthy Autonomy Node on Trust, National Robotarium Academic co-lead, and awardee of an RAEng/Leverhulme Senior Research Fellowship. Rieser was PI on the EPSRC Diligent and Madrigal grants, academic lead on our Amazon Alexa Challenge finalists' group in 2017 & 2018 and is an RSE Fellow. Baillie has strengthened our Human Robot Interaction area bringing expertise and concepts from Human Computer Interaction and adapting them for HRI, she has been PI on 5 grants from Digital Health Innovation Centre, Innovate UK, and EPSRC. Komendantskaya established the Research Lab for AI and Verification, that brings together researchers from Rigorous Systems, Intelligent Systems and Interaction. She has held 4 grants from EPSRC, NCSC, DSTL.

We have had some staff turnover with 6 staff leaving either due to promotion (Professor: Lohan, Robertson); Associate Professor (McGookin, Louchart), moving to senior management (de Wilde as Pro-VC of Research at University of Kent), or to research opportunities at distinguished institutions: Edinburgh University (McNeil), Norwegian Defence Research Institute (Grovi). We have also had 3 staff retire (Michaelson, Pooley, Taylor, H).

People Support and Development

We enable and support all staff and students' research ambitions by maximising access to time, training, travel, equipment and facilities. This has especially benefited our early career staff, see Section 4 for some outcomes. We also operate a light-touch annual review process to emphasise personal development. We follow the recruitment principle of recruiting, selecting and retaining the best – in part by ensuring vacancies are advertised globally, and via personal approaches to high calibre staff in our strategic areas. In terms of valuing and supporting, we provide relief from teaching

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for the first two years of a full-time academic post, accompanied by a PhD scholarship(s). We operate a mentoring scheme for new academics to ensure that senior staff connect with and support junior colleagues. We also have a MACS Early Career Academic Forum which meets every two weeks organises activities that can help early career academics to advance their careers, e.g. grant writing workshops. It also nominates an early career academic from HWCS to attend the monthly management meeting.

High-level monitoring and review are achieved by regular staff surveys and data collection (e.g. registration data for career development courses). Regarding equality and diversity, we hold an institutional Athena SWAN Bronze award and the school of MACS holds an Athena SWAN Bronze award. We strongly support women, in terms of development and promotion. Our actions resulted in **46% of our Professors being female, this compares very favourably to the national average of 16%** (according to the latest HESA figures). This aids our efforts in making sure that selection panels, boards and committees are representative.

Studentship Allocation

We use EPSRC CTD and DTP funds to support early career researchers and people who have returned after a leave of absence. For example, Stewart, Konstas, Dondrup, Eshghi, Padilla, Broz who are all in the early stages of their careers were awarded students from our DTP or from our internal James Watt Scholarship scheme. We use James Watt Scholarships to attract international students who are linked to our three key research groupings. In total 73 studentships between 2014-20 have been sponsored by the School via a variety of means.

Visiting / International staff

Our strategy is to widen our engagement with world leaders in areas that overlap our interests, and/or help us better engage with global priorities, we use HWCS, Edinburgh Centre for Robotics (ECR) and Scottish Informatics and Computer Science Alliance (SICSA) funds to support this.

Training

The main mechanisms available since 2014, are through SICSA, ECR, HWCS and the research futures academy. Our academics lead three of the seven research themes of SICSA. Close engagement with SICSA themes enables our academics to create links with international leaders in their field who provide talks and workshops that benefit not just senior academics but also early career researchers and PhD students. This is further enhanced by us being able to bid to host SICSA Distinguished International Visiting Fellowship visits. These visits enable the creation of joint research proposals and knowledge exchange across an in-depth two-week period.

Provided by Scottish Informatics and Computer Science Alliance (SICSA)	
SICSA has the following seven research themes (HWCS lead in brackets): HCI, Cybersecurity, Networking & systems, Data Science (Chantler), Cyber-Physical Systems (Dondrup), AI (Hastie), and Theory, Modelling and Computation.	
Research Theme Workshops and Networking Events	119
Distinguished International Visiting Fellow Programme (DVF) (some visiting professors were: Elise Van De Hoven (U.Melbourne), Kia Hook, Royal Institute of Technology (KTH), Tony Balpeame, U.Ghent. Stuart Shieber, Harvard University, Mostafa Ammar, Georgia Tech, Daniel Sorin, Duke University)	39
Post Doc/Early Career researchers International Exchanges	27
Women in CS research days	6

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Table 3: Academic events and exchanges provided by SICSA.

Provided by HWCS: We have a research seminar programme which is funded by the department and it has welcomed over 130 distinguished international academic and industrial speakers: Georg Von-Wichart (Siemens), Roberto Pieraccini (Google Zurich), Jeremy Gibbons (U.Oxford), Salah Sukkarieh (U.Sydney) etc. We also run a series of talks led by HWCS academics in which they present their research on how they have won funding from a variety of different funders.

Provided by HWU Research Futures Academy: The aim of the academy is to support doctoral students and early career researchers to develop skills and competencies to enhance their personal and professional capabilities and future employability.

- Postgraduate Certificate in Academic Practice (PGCAP - focus on early-career staff)
- Learning Enhancement and Development Skills (LEADS) courses for Approved Tutor and Approved Teacher status (focus on research students)
- Researcher Development: the academy offers an extensive programme of bespoke training courses designed to increase research capability and success. Courses include, Research Ethics, Advanced Research Methods and Statistics, Grant Writing and PhD supervision.

Research Students

During this REF period we have seen an increase in PhD scholarships (103 wholly or part-funded since 2014, of which 57 have now completed an **increase of 46% on our completion rate from 2014**). The increase in scholarships was mainly due to our having industrially led PhDs through our partners in the CDT, Orca and DataLab. The numbers by year and totals can be seen in submission 4a. We currently have 46 full time students, with a further 11 writing up. We had 39 completed students returned in 2014 therefore over this REF period we have **increased our research student completion by 46%**. This demonstrates an active and growing research student activity within HWCS.

In terms of our robotics CDTs (see section one, first awarded in 2014 and renewed in 2019) in Robotics & Autonomous System we have been awarded £12.7M, the EPSRC investment in the most recent CDT is £6.5M, which when matched with the £11M pledged by industry partners will train 88 PhD students. Many of which will have use of our unique world-class collection of robots and ancillary equipment and will soon be housed in the new National Robotarium. The PhD students also benefit from the training provided that spans two Universities (UoE and HWU) and each student has a budget of £5k for the duration of their studies that can be used for training, equipment and travel.

Events, Talks & Training

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Provided by HWU (see also Research Futures Academy)

- Annual Postgraduate Conference (organised and run by HWU postgraduates)

Provided by HWCS (these moved online during lockdown)

- Annual Postgraduate welcome get together in the Autumn,
- Annual school Conference Day
- Research student seminar programme (organized and delivered by our PhD students)

- Weekly teatime get-together with biscuits and coffee/tea provided.

Provided by SICSA	
Regular themed Summer Schools (that can be attended by any SICSA PhD student)	75 (28 run by HWCS)
Annual SICSA PhD conference	7
Annual Demofest (where PhD students get to showcase their work through demos and posters to industry, academia and the third sector)	6
Masterclasses delivered by DVFs	39
Early career industrial knowledge exchanges	9

Table 4: Events, Talks and Training Provided by SICSA.

We use the above mechanisms to build on a backbone of monthly meetings of individual student/supervisor teams, aiming to ensure a stimulating and collaborative programme for all our students. High quality supervision is assured by the regular meetings being logged on a central online system that enables any student who appears to be falling behind, and/or not engaging sufficiently, to be easily identified and appropriate follow-up action taken by the school Director of PGRS. Formal progress monitoring takes the form of annual report and presentation both of which are assessed by an internal HWCS expert in the area. An interview takes place with the internal assessor and the student and a formal report is written by the internal assessor and the student's primary and secondary supervisors regarding the report and progress of the student.

The standard experience for an HWCS research student whose studies were within the 2014-20 period included: 2 training-oriented conferences and workshops, 3 academic conference trips (incl. one overseas), 3 internal presentations, 3 internal progression vivas, 3 demofests (poster/demo sessions with industry and academic audiences), three summer schools (one international), 3 PhD SICSA conferences, 6 Masterclasses, and 4 short training courses.

All PhD students have access to a budget of £750 per annum for research expenses, such as conference attendance or miscellaneous equipment. This budget can be used flexibly across a student's period of study, meaning that unused funds can be carried forward to subsequent years as necessary.

In addition our students have access to funds gifted by Amazon, Google, Adobe, and Microsoft which has funded 10 student conference trips, 5 internships (Amazon (Curry, Papaioannou), Adobe (Agarwal) and Microsoft (Watson, Shalyminov) as well as the purchase of 4 GPU machines (2 Amazon, 1 each from Microsoft and Adobe).

Equality and Diversity

We were among the first in the UK to receive the HR Excellence in Research recognition from the European Commission in 2010 and have held this award for ten years. We hold an Athena Swan Bronze award (awarded 2016 and renewed 2020), however our commitment to equality and diversity goes beyond just achieving this. For example, University wide activities are overseen by the Equality and Diversity Advisory Group (EDAG), this group is made up from representatives from across the university community. A critical path to achieving the equality and diversity targets is to ensure everyone in the University community understands how they contribute to a culture of 'Inclusion for All'. This requires all staff, researchers and PhD students to complete the basic ethics and diversity awareness training, but also provides the option to extend the training with other workshops,

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covering various issues in diversity, equality and bias, offered through the University's Research Futures Academy. An example of the effect this is having on gender balance is indicated by the number and variety of roles undertaken by women in HWCS. For example, our Director of Ethics is female Aylett, and Hastie is joint academic Director of the ECR and the new National Robotarium. It is notable that the Head of School, Pelloni, is female. We have a Women in HWCS social group that has invited talks with guest speakers on topics that are of wide interest (e.g., careers advice, writing research papers, managing large multidisciplinary grants etc) as well as organising a very active outreach events program. A successful MACS Athena SWAN Bronze application was led by the school-wide Self-Assessment Team (SAT) that included several HWCS women. In our Athena Swan Bronze Award, we focused on the following key principles: recruiting, valuing, supporting, and developing researchers. We also ensure that female and under-represented academics are involved in the short-listing and sit on interview panels. This along with our training on unconscious bias, that all interview panellists must attend, has resulted in fair and transparent recruitment.

In terms of valuing and supporting we offer our academics a 6-month sabbatical/study leave that is aimed at supporting people, who have had a period(s) of maternity, familial leave, other unexpected leave or have taken on a substantial admin role. Admin burden is especially recognised as having had an unduly negative impact on female promotion prospects in the past. The study/sabbatical leave support covers all teaching and admin responsibilities leaving the academic to focus 100% on their research. We also support flexible working by having a policy in place regarding suitable timings for important and regular meetings that takes into consideration child and caring needs. We have also supported home working since 2014.

Selection of Outputs

We ensured full equality and diversity in the preparation of UoA REF2021 submission by:

- Creating and maintaining a gender, race and age/experience balance of the internal review team;
- Ensuring all of our outputs were reviewed by external experts chosen by our internal review team;
- Creating a supportive working environment for the team (in person and latterly at distance) that encourages freedom of expression, mutual respect and shared value/understanding of the critical importance of the preparations and the REF process itself;
- Ensuring that all members of the REF Team had completed equality in REF and unconscious bias training;
- Embodying career development and training as a reason for inclusion in the REF Team.

We adhere to the principles of full equality and diversity in all aspects of our operation.

3. Income, infrastructure and facilities

Income Portfolio 2014-20 and Future Plans

Our funding portfolio by area is given below. Complementing data in REF4, we show totals for projects that started or were awarded between 08/2013 and 07/2020. Only the HWCS component is given. We show in parentheses the percentage increase compared to REF2014. Our **overall income shows an increase from £9.36M - £12.93M we have therefore increased our income by 38% from 2014.**

From	Income	Percentage Change from 2014
Research Councils UK BIS	£7.25M	69%
Charities All	£373K	767%
Government all	£778K	813%
Industry all	£838K	84%
other	£312K	890%
all	£12.93M	38%

Table 5: Income percentage change from 2014 REF.

We have increased our funding across 14 of the 16 funding categories specified by REF2021. The charities rise is due to our success with Leverhulme Fellowships (Rieser and Hastie). Our work in robotics (Orca Hub, Alexa Prize etc) has seen our industry funding increase. The largest rise, in terms of amount, is with the Research Councils from £4.2M to £7.25M.

Our future planning involves building on our current profile through developing exciting and substantial interdisciplinary proposals addressing real world issues. Some specific areas for such proposals will be:

- (i) to develop computational intelligence applications to enable intelligent forecasting to improve the environment and our renewable energy future (Intelligent Systems);
- (ii) to develop further multi-modal, creative and robotic systems for a wide range of societal applications in social robotics and health (Interaction);
- (iii) research advances and breakthroughs in artificial intelligence, verified and secure software as it applies to large scale systems and to industry as a whole (Rigorous Systems) and
- (iv) to continue our world leading research in conversational artificial intelligence (All groups).

We plan to achieve some of these aims by broadening our funding sources to include more Innovate UK awards, and by developing more alliances with specific organizations and academic/industry consortia.

Strategy 2021-2026

	Strategically grow research in these areas:	Building on concepts and outcomes of recent grants:
i	computational intelligence applications to enable intelligent forecasting to improve the environment and our renewable energy future	Corne projects (KTP #9839 with Route Monkey Ltd, 10/2014—04/2018. KTP with FreightShare Lab (FSL) & Innovate UK #103890, Baillie & Corne #11228.
ii	multi-modal, creative and robotic systems for a wide range of societal applications in social robotics and health	Hastie, Chantler & Petrick, ORCA EPSRC Grant EP/R026173/1), Hastie (EP/R026173), Aylett (EP/N034546/1), Baillie (EP/T021063/1), Hastie (EP/V026682/1)
iii	research advances and breakthroughs in AI, verified and secure software as it applies to large scale systems and to industry as a whole	Ireland (EP/N014758/1), Baillie, EP/T017511/1, Komendantskaya (EP/T026952/1, EP/K031864/1) and VETSS grant CONVENER, NSCS grant SecCon-NN
iv	our world leading research in conversational artificial intelligence	Rieser (EP/M005429, EP/T023767, EP/N0175361), Lemon (EP/M01553X/1) and EU projects JAMES, MuMMER, and SPRING

Table 6: Notable grants from which we will build the planned areas i-iv**Infrastructure & Facilities**

In the area of robotics the initial investment of £802K from EPSRC in 2013 to create the Robotarium West (completed 2016) was a significant boost to our existing facilities and enabled us to create a dedicated Human Robot Interaction (HRI) Laboratory, Assistive Living Robot apartment, robotics seminar room, and field robotics lab. As a result we have received significant and distinguished visitors e.g. Roberto Pieraccini (Director of Engineering at Google), Dr Michael Gienger (Principal Research Scientist, Honda), Dr Elie Allouis (Senior Robotics Systems Engineer, Airbus). As well as key academic figures in the robotics area e.g., Cynthia Brazeal (MIT), Prof Belpaeme (Univ. Ghent). We anticipate that the **new National Robotarium** will only increase the interest in our world leading robotics and data driven research.

The National Robotarium

The Edinburgh and South East Scotland Science and Innovation Audit (SIA) detailed how the ability to collect, store and analyse data from an array of diverse sources will become increasingly important in driving economic growth, social change and public services and this led to the City deal (agreed and signed July 2017). HWU and UoE will jointly deliver the Data Driven innovation (DDI) strand of the deal. The DDI Programme will be delivered through a network of five DDI Innovation Hubs of which the National Robotarium is one, with the others being the Bayes centre, Edinburgh Futures Institute (EFI), Usher Institute, and Easter Bush.



Figure 1: Artist's Impression of The National Robotarium due for delivery in Spring 2022

The National Robotarium will provide state of the art facilities to co-locate researchers, research and development engineers, entrepreneurs and educators to deliver the UK's leading international centre for the translation of new robotics research into new products and facilities. We plan to widen our impact through our co-design activities and outreach to the wider community outside robotics e.g. health, construction etc. Through our Living Laboratories and engagement mechanisms, we will enable subject matter experts to understand the needs of major companies and end users. The National Robotarium will be located on the Heriot-Watt University campus and has a current spend of **2M for new robotics equipment**. The activities proposed build on the established partnership of Heriot-Watt University and University of Edinburgh through the Edinburgh Centre for Robotics (ECR) and all researchers will have access to the resources and equipment of ECR.

Lab	Size (m ²)
RAS (Robotic Autonomous Systems)	355
HRI (Human Robotics Interaction)	346
ULTRA (Laser/Logic/Types/Rewriting/Automation)	360
PARTNER & Seminar Space	250
Overall	1414

Table 7: Allocation of Space in National Robotarium

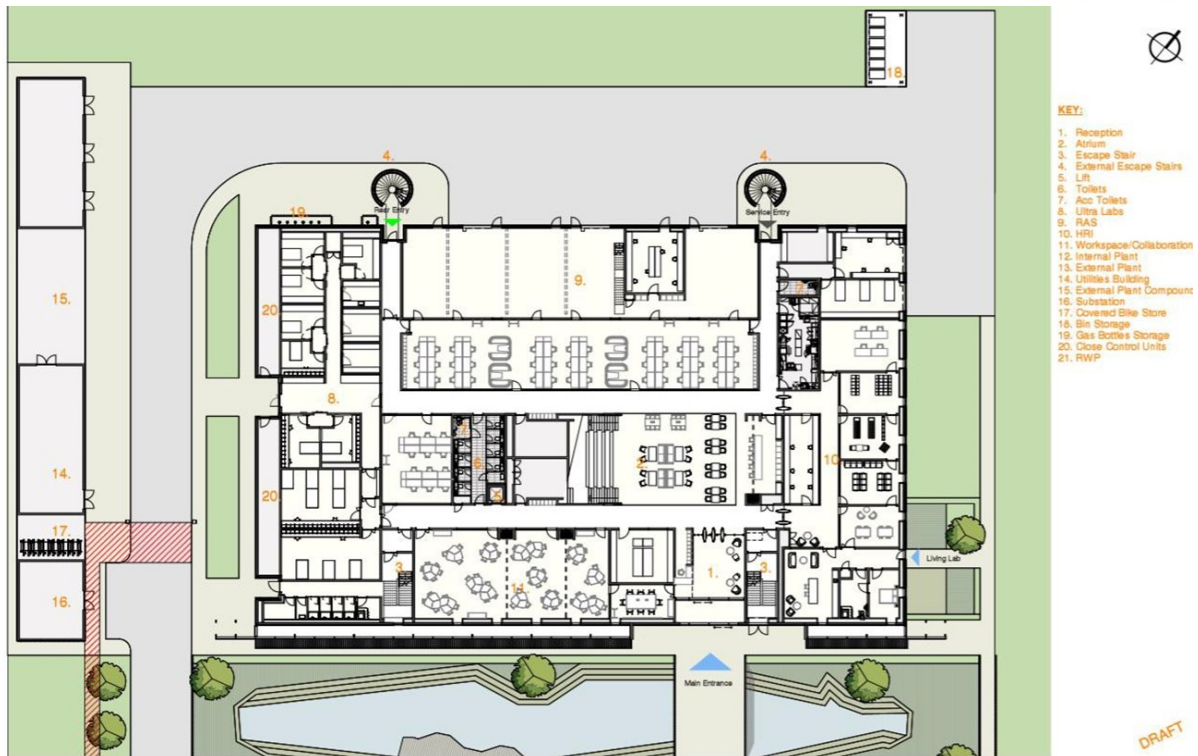


Figure 2: Architect’s Drawing of the ground floor of the National Robotarium in which all of the labs to the right will be used by our research groups and includes an Assistive Living Robotics Lab (front right).

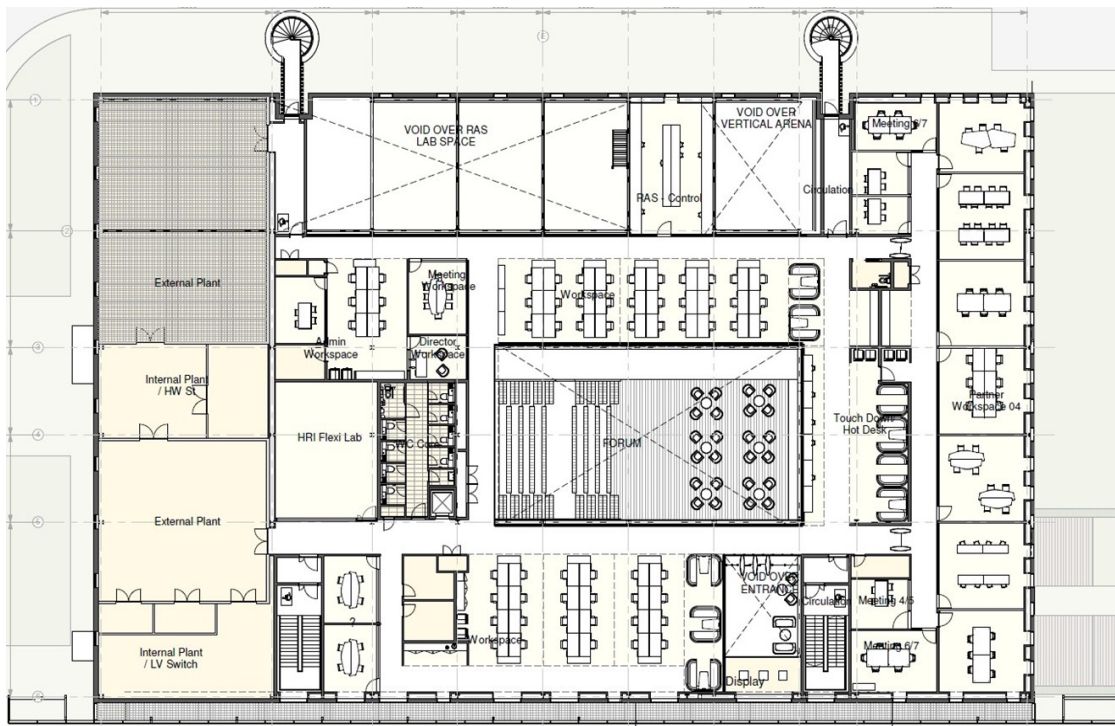


Figure 3: Planned 1st floor of the Robotarium, which contains a hot desking office, a further HRI research lab and a double vaulted space (see centre back) for our field robotics lab

The National Robotarium will house internationally important research areas and labs and will include a field robotics laboratory (Vargas, Petrick), 7 HRI labs (Lemon, Hastie, Taylor, Baillie, Broz, Bartie, Aylett, Rieser, Chantler, Lones, Stewart), a meeting/seminar room, 2 hot desking offices with 15 desk spaces for visiting researchers and PhD students, and a fully equipped kerb-to-kitchen

Unit-level environment template (REF5b)

robotic assistive sensed living apartment, which has its own living room, kitchen, bedroom, bathroom, care giver bedroom, garden area, front door, and its own independent heating and lighting infrastructure (Baillie, Broz, Aylett, Lemon, Hastie). Three major awards will use this new facility: EU Project SPRING (Socially Pertinent Robots in Gerontological Healthcare, £1M, Lemon & Dondrup); COG-MHEAR: Towards cognitively-inspired 5G-IoT enabled multi-modal hearing Aids (EP/T021063/1, Baillie £3.25M) and EPSRC TAS Node on Trust (EP/V026682/1, £3M Hastie). The new National Robotarium will be a truly world leading facility. In addition, we benefit from facilities across Edinburgh Centre of Robotics including full use of the **Bayes Centre** sited at the University of Edinburgh. This is a new building housing a large number of hot desking labs/offices, a large seminar room for workshops and talks, and two robotics labs. The Bayes Centre along with the National Robotarium is one of the five hubs financed as part of the £1.3BN Data-Driven Innovation (DDI) Programme within the Edinburgh and South East Scotland City Region Deal.

The Grid

The National Robotarium is complemented by another significant investment in the GRID building, which is our new flagship facility to advance our global research and entrepreneurship. This open space collaboration facility allows broad cohesion between academic disciplines, industrial partners and our global community.



Figure 4: GRID Building adjacent to Loch at the Edinburgh Campus

The GRID resides at the heart of our Edinburgh campus, and constitutes an investment of £19M by HWU. The facility has many joint networked spaces where staff can discover, tackle challenges and explore their intellectual passions. Of particular use to researchers in HWCS includes spaces to explore originality (Creative Studio), to quickly prototype hardware with the latest 3D and rapid prototyping technologies (Flex and Maker Studios), to develop industry-level algorithms and software (Digital Lab), to visualise and explore prototypes of their ideas (Immersion and Games Studio), and to engage with industrial partners (Enterprise Hub). The GRID also includes flexible and immersive learning and teaching areas complemented with the enterprise area to encourage interaction and design-led education. One of our main motivations for this facility was HWU's interest in empowering its staff and students to develop ideas, from conception to launch in a global market.

University Underpinning Support

In terms of research support for academics the university has a centralised research and business development professional support team (RED) that provides the following:

- Research Development - provides specialist support for academic staff seeking to win research funding.
- Global Challenge Research Fund - supports the implementation of the University's GCRF Strategy.
- Business Development – works with academics to increase research income from industry and business.
- Research Grants Office – assists academics with their post-award management of their externally funded research grants and contracts.
- Public Engagement Team- assists academics in realising the potential of their research results and work through supporting them in undertaking outreach events and disseminating to audiences outside academia.

Computing Resources to Support Research

We have three dedicated computing technicians within HWCS who are there not just to support teaching delivery but also to support the specific needs of our research projects. We also have a graduate apprentice technician who supports the robotics work of our 3 groups.

The University Information Services Research Support (ISRS) team works in partnership with the Research Engagement Directorate (RED) and other IS divisions to help facilitate research-related planning, and to meet the needs of both the individual researcher and the wider institution.

The key objectives of ISRS related to the REF are:

- Research Outputs Support: it is responsible for ensuring that all tangible research produced within the University and subsequently published is recorded in a consistent manner and compliant with open access and REF mandates.
- Support for the use of High-Performance Computing facilities.
- Capability to store, preserve and access increasingly large volumes of electronic research data sets.

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

Approach to Collaboration and Contribution

We coach staff to be collaborative and entrepreneurial in contributing globally to our discipline. In total we have undertaken 491 collaborative projects over the REF period with external partners from academia, charities, government, NHS and other external bodies. As regards working with industry, 107 of our projects were in collaboration with industry. We have organised our collaboration and contributions to the research base, economy and society into three main categories;

1. Collaboration and contribution to the research base;
2. Working with industry and Government to foster knowledge exchange and to have an impact on the economy;

Unit-level environment template (REF5b)

3. Activities to disseminate and create impact from our research work and findings as regards wider society.

Please note that often an activity will embrace more than one of the categories.

Collaboration and Contribution to Research Base**Conference Keynotes & Chairing**

Keynotes Conference & International Workshops	Academic
<ul style="list-style-type: none"> ➤ Artificial intelligence and Simulation of Behaviour Symposia, 2018 ➤ Symposium on Multimodal Agents for Ageing and Multicultural Societies, 2018 	Aylett
<ul style="list-style-type: none"> ➤ IEEE Spoken Language Technology Workshop (SLT 2021) ➤ European Chatbot Summit (2021) ➤ Workshop on Search-Oriented Conversational AI (SCAI at EMNLP 2020) ➤ Re:WORK Conversational AI Summit (2020) ➤ Intelligent Virtual Agents Conference (IVA-2019) ➤ NSF Workshop on User-Oriented Agents, (2019) ➤ 2nd workshop on Vocal Interactivity in-and-between Humans, Animals and Robots VIHAR-2019 (Turing Institute) ➤ ReWORK AI Assistants Summit 2019, Amazon Research Day 2019 ➤ 2nd SwissText Analytics Conference (SwissText-2017) 	Rieser
<ul style="list-style-type: none"> ➤ Data Conference 2020: Delivering better care 	Baillie
<ul style="list-style-type: none"> ➤ SIGDIAL Conference 2017 ➤ Apple Siri conference 2019 	Lemon
<ul style="list-style-type: none"> ➤ Uphill Battles in Language Process. Workshop (EMNLP 2016) 	Konstas
<ul style="list-style-type: none"> ➤ Brazilian Conference on Intelligent Systems 2017 	Corne
<ul style="list-style-type: none"> ➤ Open PHACTS: The Data Today keynote at Open PHACTS Symposium (2016) 	Gray
<ul style="list-style-type: none"> ➤ PPDP'20, International Symposium on Principles and Practice of Declarative Programming. ➤ ICMS Big Proof workshop (Newton Institute (Cambridge), 2019. ➤ Coalgebra, Now! – a FLOC 2018 workshop ➤ Computer-Aided Mathematical Proof workshop, Isaac Newton Institute for Mathematical Sciences, 2017. ➤ Programming Languages and Compilers, 2017. ➤ Algebra and Coalgebra meets Proof Theory (ALCOP), 2017 	Komendantskaya

Chairing Conference / International Workshops Academic	
<ul style="list-style-type: none"> ➤ Chair of the European Robotics Forum (ERF) 2017 ➤ Chair of IEEE Conference on Robot and Human Interactive Communication (RO-MAN) 2014 ➤ Chair of Special Session on Social Robotics RO-MAN 2015 	Vargas
<ul style="list-style-type: none"> ➤ Senior Area chair for EACL'21 ➤ Programme chair for Safety for Conversational AI (2020) ➤ Area chair for ACL 2017 & 2018 ➤ Chair International Conference on Natural Language Generation (INLG'16) 	Rieser
<ul style="list-style-type: none"> ➤ Association for the Advance of Artificial Intelligence (AAAI) Symposium Series 	Petrick
<ul style="list-style-type: none"> ➤ Chair of SIGCHI Mobile HCI, 2018. ➤ Sub-Committee Chair 2020 SIG CHI Conference. ➤ Associate Chair SIG CHI Conference Series 2014-2019 ➤ International Steering Committee SIGCHI ACM from 2020 ➤ International Steering Committee Chair SIGCHI Mobile HCI 	Baillie
<ul style="list-style-type: none"> ➤ Chair of the International Real World Domain Specific Languages Workshop (RWDSL) 2019 ➤ Track Chair of The Semantic Web–ISWC 2016 & 2014: International Semantic Web Conference 	Stewart
<ul style="list-style-type: none"> ➤ Programme Chair for SIGDIAL (2014) ➤ Area Chair for ACL (2018, 2020), ICASSP (2020) and NAACL (2016) 	Hastie
<ul style="list-style-type: none"> ➤ Area Chair for COLING 2018 and EACL 2020 	Eshghi
<ul style="list-style-type: none"> ➤ Co-Chair of AAAI Fall Symposium on Artificial Intelligence for Human-Robot Interaction 2016, 2017 	Broz
<ul style="list-style-type: none"> ➤ Programme Chair IPCAT 2015 ➤ Publicity Chair, IEEE Symposium on Computational Intelligence in Bioinformatics and Computational Biology (CIBCB) 2015 	Lones
<ul style="list-style-type: none"> ➤ Programme Chair for AAAI FSS 2020 	Dondrup
<ul style="list-style-type: none"> ➤ EMNLP 2015 co-chair (Discourse and Dialogue) ➤ Area Chair for ACL 2017 	Lemon
<ul style="list-style-type: none"> ➤ Area Chair for ACL 2018 ➤ EMNLP 2018 	Konstas
<ul style="list-style-type: none"> ➤ Chair SWAT4HCLS – Semantic Web Applications and Tools for the Life Sciences (www.swat4ls.org) 	Burger
<ul style="list-style-type: none"> ➤ Chair 22nd Symposium on Practical Aspects of Declarative Languages (PADL'20) ➤ Chair PPDP'19, 21st International Symposium on Principles and Practice of Declarative Programming, 2019 ➤ Chair TEASE-LP 2020: Trends, Extensions, Applications and Semantics of Logic Programming 	Komendantskaya

Invited Academic Talks

Our academics have been invited to deliver over 100 research talks at Universities nationally and internationally, some key ones are listed in the table below.

University	Academic
➤ Robots and Interactive Storytelling. U.Kyoto, U.Auckland, U.Wellington, U.Lisbon, all 2018, U.Coimbra, Portugal, 2019.	Aylett
➤ Designing Health technologies: UCL, 2018, U.Glasgow, 2016, U.York 2016, U.Bristol 2015 and U.Cardiff, 2019.	Baillie
➤ Assistive Robotics Technologies & AI: U.Edinburgh 2020 & U.Newcastle 2017.	Broz
➤ Dialogue Systems and NLP: U.Bielefeld 2016, Queen Mary University, 2016; U.Gothenburg, 2015; BCS, 2019	Eshghi
➤ NLP & HRI: RAEng Research Forum, 2018	Hastie
➤ Usable Security and Cybersecurity: U.Dalhousie, 2016, Masaryk University 2015, and U.Glasgow, 2014.	Just
➤ Automated Reasoning and Machine Learning: Queen Mary University 2019, U.Birmingham 2019, U.Cambridge 2019), U.Edinburgh 2016, U.Bath 2016, U.Birmingham 2015, Oxford 2015, École Normale Supérieur de Lyon 2016, U.Swansea and U.Bath (by on-line conferencing, 2020),	Komendantskaya
➤ Automation & Planning: RSE-CHINA Robotics and AI Workshop 2018, U.Edinburgh, 2018.	Petrick
➤ User-Oriented Agents, Universities of Carnegie Mellon, U.Edinburgh, U.Glasgow (2019); U.Pennsylvania (2017); U.Hamburg (2015); Karl-Ruprecht University (2014); U.Cambridge 2014; TU-Munich 2013, U.Berkeley (2013).	Rieser
➤ International Workshop on Neurobotics and Neural Disorders, 2019.	Broz
➤ Using PL/Python functions in PostgreSQL. U.Edinburgh, 2015.	Bartie
➤ Bioschemas: Improving Discoverability for Life Sciences Resources, ELIXIR IDP Community (2019). ➤ Supporting Dataset Descriptions in the Life Sciences, European Bioinformatic Institute (2017); ➤ Integration in a Big Data Context, Seminar at the Urban Big Data Centre (2015) ➤ Scientific Lenses over Linked Data. Edinburgh (2015), U.Bozen-Bolzano (2014) U.Brighton (2014)	Gray
➤ Smart Sensor technologies: UFRN (2019), Universities of York (2018), Hull (2017), Stirling (2016) & Newcastle (2015), Royal Society of Chemistry (2016).	Lones
➤ NLP: Invited talk at U.Illinois, U.Sheffield, U.Athens, 2017 ➤ U.Glasgow 2018	Konstas
➤ Cybersecurity: University of Applied Science Lucerne (2018 and 2019); INRIA Rennes (2019), U.York (2019), U.Luxembourg (2017), U.Edinburgh (2016).	Radomirovic

Unit-level environment template (REF5b)

Editorships and Associate Editorships

A significant percentage (40%) of our academics are editors or associate editors of high quality journals e.g. ACM transactions on intelligent interactive systems (ACM TiiS), Dialogue and Discourse 2019-present, Personal and Ubiquitous computing, International Journal of Mobile Human Computer Interaction, Advanced Robotics, Interacting with Computers, Genetic Programming and Evolvable Machines etc.

Expert Reviewing

Over 20 of our academics are sought by EU, UKRI (particularly EPSRC), Charities and Industry as expert reviewers. They review for funders nationally (e.g. EPSRC, BBSCR, Wellcome Trust, Turning Institute, Royal Society, Parkinsons, UK, Carnegie) and internationally (e.g. EU Horizon 2020, FET, ERC, Netherlands Organisation for Scientific Research, NRC Canada, NSF USA, FFG Austria, SNF Switzerland). One of our academics (Taylor) was **recognised for his outstanding contribution to the EPSRC Review College 2017/2018**.

Papers / Academic Prizes	Academic
➤ Honourable Mention ACM DIS 2017 Research Papers for "Image-based Emotion Feedback: How Does the Crowd Feel?"	Chantler
➤ Honourable Mention ACM CHI 2017 Research Papers for "Understanding Concept Maps: A Closer Look at How People Organise Ideas"	Chantler & Padilla
➤ Best paper, ASME 2013 IDETC/CIE Conference 2013, "The Evaluation of a Virtual-Aided Design Engineering Review. System for Automated Knowledge Capture and Reuse"	Chantler
➤ Honourable Mention award (top 5% of papers) at Mobile HCI 2015. For why aren't users using security protection?	Just & Baillie
➤ SIGEVO Impact award ACM (2017). The award specifically indicates that a paper is now considered 'seminal' by this research community	Corne
➤ Best study paper award at Human Robot Interaction Conference 2016	Dondrup
➤ Runner-up for best paper award at SigDial 2017. ➤ Winner of SemEval Shared Task 7: Sentiment Analysis for Arabic Tweets (2016).	Rieser
➤ The Alonzo Church award (jointly with Andrew Pitts) 2019 ➤ LICS test-of-time award 2019	Gabbay
➤ Influential Paper Award by the 2018 International Conference on Automated Planning and Scheduling (ICAPS 2018).	Petrick
➤ Best paper award at ACL 2017 (Robo-NLP workshop)	Lemon & Eshghi
➤ ACM "Humies" Human Competitive Awards 2018, Gold prize	Lones
➤ Winner of LSDSem Shared Task 2017	Konstas

Industry, Government and Wider Economic Collaboration

We are aware that to facilitate adoption of our work in policy areas and in industry, it is imperative to engage with industry and government to raise and maintain awareness of our scientific research. We have undertaken over one hundred projects with Industry, and we have also undertaken extensive activities to connect with government and government agencies.

Industry Talks & Knowledge Exchange	Academic
<ul style="list-style-type: none"> ➤ Invited talk at the Dstl Accelerator collaboration event. London, 2018 ➤ ORCA Open Day, Edinburgh, with industry VIPs, 2018 ➤ ORCA trials at ORE Catapult, Blyth with industry VIPs, 2019, Fort William with industry VIPs, 2018 ➤ Invited talk at the Future of the North Sea Digital Transformation Conference, Edinburgh, 2019 ➤ SPE Offshore Europe Exhibition, Aberdeen, 2019 	Hastie
<ul style="list-style-type: none"> ➤ Invited talk at Amazon Seattle and Microsoft Research Redmond, 2017 ➤ Amazon Research Day Cambridge 2018 ➤ Invited talk at Google London 	Konstas
<ul style="list-style-type: none"> ➤ Invited speaker at Apple NLU workshop, Cambridge UK 2020 ➤ Royal Society of Edinburgh AI lectures series 2020 ➤ Invited keynote at Amazon Research Days, Edinburgh 2019 ➤ Invited talk at Google Workshop on Conversational Search 2019 ➤ Invited talk at Thomson Reuters 2017 ➤ Industry secondment with Nuance Communications, 2018 	Rieser
<ul style="list-style-type: none"> ➤ Microsoft Research designing rehabilitation technologies for the home, 2017 ➤ Vodafone, London 2018, designing better mobile human interaction design models. 	Baillie
<ul style="list-style-type: none"> ➤ Virtual City Guides: how spatial models can help interfaces disappear, Centre for Environment, Heritage and Policy, Stirling, Feb 2017. 	Bartie
<ul style="list-style-type: none"> ➤ Invited speaker Facebook AI summit 2017 ➤ Invited speaker BBC voice + AI summit 2018 ➤ Invited keynote speaker Apple Siri conference, Cambridge 2019 	Lemon
<ul style="list-style-type: none"> ➤ Dataset Descriptions in Open PHACTS and W3C HCLS IG, NDEX Webinar (2014). 	Gray

Industry Prizes	Academic
<ul style="list-style-type: none"> ➤ Guardian Award for Business Collaboration for the ORCA HUB partner consortium, 2018 ➤ Converge Challenge Pitch competition semi-finalist (2019, 2014) 	Hastie
<ul style="list-style-type: none"> ➤ Alexa Prize Challenge (Won 3rd Place in 2017 and 2018) total student prize money \$100,000 USD (+ \$350K academic gift from Amazon) 	Rieser, Lemon and Konstas (supervised the student team)
<ul style="list-style-type: none"> ➤ Edinburgh Apps Challenge, Edinburgh Council, 2014 ➤ Adobe research gifts 2019 & 2020 (\$16,000 USD) ➤ Google Faculty Award (\$40,000 USD) ➤ Apple Faculty Award (\$100,000 USD) with Kontas as Co-I 	Rieser
<ul style="list-style-type: none"> ➤ EPSRC SCORRES project (EP/P031145/1) Smart agriculture, precision irrigation for subsistence farmers in India. Corne led the computer systems work that did the processing and decision-making: <ul style="list-style-type: none"> ○ 2017/18 Rushlight Award for Resource Innovation ○ 2017/18 Rushlight Award for Water Management ○ Official Innovate UK Success Story 	Corne
<ul style="list-style-type: none"> ➤ Medipex NHS Innovation Awards 2015, Winner in Medical Devices and Diagnostics category 	Lones

Government & International Bodies and Professional Organisations



Figure 5: Academics presenting and discussing our Robotics work with the Deputy Secretary of State for Scotland

Many of our academics have been asked to advise government ministers and committees. We have also been asked to be chairs of international bodies and associations e.g. IFIP, IEEE, ACM.

Expert Advisors/Scientific Leads	Academic
<ul style="list-style-type: none"> ➤ UKRI Global Expert Mission to the USA for Robotics for extreme environment in March 24-30th, 2019. ➤ Advisor for the Scottish Government's AI Strategy 2017-present. ➤ Presentation on Robotics at the House of Commons, London, 2019 ➤ Board Member Scottish Research Partnership in Engineering (SRPe) for Robotics and AI. ➤ IEEE subcommittee member for Speech and Language Processing. ➤ Board member for IEEE standard on Transparency for Autonomy (P7001). ➤ Invited expert to the Digital Catapult Pit Stop for Dstl, London. 	Hastie
<ul style="list-style-type: none"> ➤ Founder of the International Federation for Information Processing (IFIP) Working Group 1.9/2.15 – Verified Software. 	Ireland
<ul style="list-style-type: none"> ➤ Chair IFIP WG14.5 2010-2018 ➤ Scottish Parliament Health Committee expert speaker, 2016 work related to building usable technologies for stroke rehabilitation 	Baillie
<ul style="list-style-type: none"> ➤ EPSRC ICT Strategic Advisory team for 5 years, ➤ UKRI Digital Economy Programme Advisory board 5 years. ➤ Innovate UK Panel Member. ➤ Data Lab Innovation Centre, Advisory Board (3 years to date). ➤ Software Sustainability Institute, Steering committee (5 years to date) ➤ ScotlandIS Data Cluster, Industry Advisory Group (appointed 2020) 	Chantler
<ul style="list-style-type: none"> ➤ Advisory board of Dialogue Systems Technology Challenge (DSTC) 2017 ➤ Policy advisor: Member of the RSE Scoping Group on Artificial Intelligence (2019- current), ➤ UKRI Closed Roundtable on Next Generation AI (2019), ➤ Contributor to the GOV.UK Centre for Data Ethics and Innovation's report on Smart Speakers and Voice Assistants (2019), ➤ Steering board of the Dialog System Technology Challenges (since 2017) 	Rieser
<ul style="list-style-type: none"> ➤ Panel member for formation of new research institute (Walton Institute), Ireland 	Taylor
<ul style="list-style-type: none"> ➤ Chair of Bioschemas Steering Council (4 years to date) ➤ Scottish Informatics Linkage Centre Advisory Board (2013-2019) ➤ ELIXIR UK Management Board (2016-2019) ➤ ELIXIR UK Steering Committee (4 years to date) 	Gray

Contribution and Impact of our Research on Wider Society

As many of our talks, demos and exhibits are group efforts involving our post-graduate researchers, PhD students, alongside our academics we have not put this section into tables. We believe taking part in such events support the training of our PGRs and also provides role models to a diverse audience as regards careers in STEM.

Public Talks

- Rieser public lecture on her groups work on the Alexa Challenge at the European Researcher's Night, Edinburgh Zoo. RSE Curious programme (2020), Tea & Talk at the RSE Summer programme (2020), Allen Institute for AI NLP Highlights Podcast #108 (2020)
- Broz Art of Possible: Rise of the Robots. Glasgow, UK 2018.
- Aylett, The Robots are Coming! Cabaret of Dangerous Ideas, Edinburgh Fringe Festival 2017.

Public Engagement Prizes

- Rieser, EPSRC Telling Tales of Engagement Award 2018 (£10,000)

Public Exhibitions & Events

- Rieser "Designing a Feminist Alexa" workshop with the Royal Society of Edinburgh (2020), German School visit with "Native scientist" (2016).
- SoCoRo project exhibited at the Edinburgh International Science Festival in April 2019.



Figure 6: SoCoRo project demo at the Edinburgh International Science Festival

The National Museum of Scotland hosted a major exhibition of robots in 2019 this was the most significant collection of humanoid robots ever assembled. The exhibition included early clockwork machines and a T-800 endo skeleton which featured in Terminator Salvation. Visitors learned about the latest innovations in robotics research at ECR. The exhibition attracted over 60,000 visitors.



Figure 7: Demonstrating our HRI research using the Cosmo Robot at the National Museum of Scotland Robotics Exhibition 2019 (family day shown on left and an exhibition night event on the right)

- Hastie appeared on BBC news (October 2019). Robotic inspectors developed to fix wind farms - <https://www.bbc.co.uk/news/uk-scotland-50030184>
- BBC TV: documentary "The Joy of AI" 2018; Tomorrow's World Live 2018 (Lemon)
- BBC science editor, David Shukman, visited the ECR this resulted in the Centre's robotics research being on BBC News at Ten.
- We undertook the ORCA Hub Exhibit at The Royal Society Summer Science Exhibition in London, 2019.
- The virtual Royal Society Summer Science 2020 Exhibition: What are they up to now? Robots in the danger zone - YouTube <https://www.youtube.com/watch?v=msdPYRUNMIM>



Figure 8: Royal Society Summer Science Exhibition 2019

We also exhibited our assistive living robotics work at the Chelsea and Westminster Hospital Trust, Innovation Exhibition.



Figure 9: Exhibition at the Chelsea and Westminster Health Trust Innovation Event

The ORCA Hub exhibit at the 2019 Babcock Festival of Engineering in Rosyth, running demonstrations for over 300 local school children. They also ran demonstrations for school pupils in Aberdeen as part of the ORCA Hub SubseaExpo 2019.



Figure 10: Orca Event demonstrations to school pupils as part of the ORCA Hub