

Institution: University of York
Unit of Assessment: 12 – Engineering
1. Unit context and structure, research and impact strategy <u>Context and Overview</u> The Department of Electronic Engineering (EE) has initiated a bold and transformational vision of growth and excellence that will continue into the next assessment period and beyond. Since REF2014, we have delivered significant and targeted investment in staff and associated infrastructure to promote discovery- and challenge-led research in five strategic application areas that cut across the Department's two umbrella research groups (Intelligent Systems and Nano-Science and Communication Technologies) and which align with the broader research strategy of the University (Institutional Environment Statement (IES), 4, 12): • Autonomous & Robotic Systems • Communications for Challenging Environments • Electronics for Healthcare • Immersive and Interactive Technologies • Next Generation Electronic Devices & Materials The scale, ambition and sustainability of our research and environment are highlighted below and described in detail in the following sections: Research environment: Significant investment has been secured to upgrade existing infrastructure and develop new research facilities that align with our application areas and support the ambitions of our staff. For example, through departmental and EPSRC funding we have established dedicated wetware and cadaver laboratories to support our research aligned with Electronics for Healthcare. EE is also a partner in the £35m UK Research Partnership Investment Fund (UKRPIF) project 'Global Initiative for Safe Autonomy' establishing the Institute for Safe Autonomy, including flagship facilities to underpin our research in Communications for Challenging Environments and Autonomous & Robotic Systems (IES 11c). Interdisciplinary and collaborative research: EE is distinctive in the scale and ambition of its interdisciplinary research and promotes partnerships that span academic disciplines (across the physical and life sciences, arts and humanities), industry (e.g. Huawei, Google, TAS-UK, Melexis, BBC R&D and Dstl), and cultural and charitable organisations (e.g. Centre for Digital Heritage, Oxfam and Alzheimer's UK). EE leads the £15m AHRC Creative Industries R&D Partnership XR Stories in collaboration with Screen Yorkshire and the BFI, further supported through the £5m Research England Screen Industries Growth Network (aligned with the application area Immersive and Interactive Technologies) (IES 11a). Attracting and developing researchers: Following investment worth £25m from the University of York (IES, 10), we have targeted the recruitment of internationally leading staff aligned with our application areas, particularly Electronics for Healthcare and Autonomous & Robotic Systems. We continue to support and develop staff to achieve their academic ambitions, as evidenced by the quality of their research outputs and the number of academic promotions, and to achieve their wider leadership and impact-focussed aspirations, e.g. three members of staff hold/ have held senior leadership positions within the University (Robinson, Murphy, Timmis) and four members of staff founded and lead University spin-out companies (Smith, Tyrrell, Pelah and Timmis). Training the next generation: We continue to attract and train the best PhD candidates globally and the number of PhD degrees awarded has increased 50% since REF2014. The quality of our students and training provision is evidenced by the quality of their research outputs and positions they have secured in prestigious companies and universities.

Evaluation with reference to REF2014**Vision for research and impact:**

The broad aims of the Department for research and impact were and continue to be:

1. To undertake world-leading research in areas of existing strength and to grow capability in emerging areas of societal and economic importance.
2. To provide research facilities and a vibrant research culture that will attract research staff, early career researchers and research students and supports all researchers equally to achieve their research and career aspirations.
3. To undertake impact-led and collaborative research and promote translation of our core research to commercial implementation and societal adoption.

Key achievements in research and impact:

Below we highlight notable research achievements across our five strategic application areas that evidence the success of our research excellence and impact strategy.

Communications for Challenging Environments:

We are distinctive in conducting research that cuts across both the physical layer and networking aspects of wireless communications in underwater vehicles and high-altitude platforms (HAPs). This strategic application area has been enhanced during the REF period through recruitment of new staff (**Ko, Ahmadi**). Our research is supported through UKRI and EC funded projects (e.g. SPOTLIGHT Marie Curie ITN, 5G-AURA Marie-Curie ITN, EU FP7 ABSOLUTE, EP/R003297/1, EP/P017975/1) and supported by academic and industrial partners, including BT, Orange, Thales, TE Connectivity, Jozef Stefan Institute, the Woods Hole Oceanographic Institution, MoD and Stratospheric Platforms. EE is a founding partner of the Institute for Safe Autonomy (**Grace** is Research Lead for Communications) that will establish a new flagship facility with dedicated laboratory space for experimental validation of communications for challenging environments and underpin new opportunities for research in quantum communications, in collaboration with the cross-departmental York Centre for Quantum Technologies (YCQT). Specific highlights include:

- We have developed and demonstrated the Helikite USRP Testbed for rapid and routine experimental evaluation of wireless protocols from HAPs. This innovation was a Winner of the 2018 National Instruments EMEA Engineering Impact Awards in Wireless Communications and is being used to provide wireless communications for temporary events as part of the Mobile Access North Yorkshire project (funded by the UK Government 5G Testbeds and Trials initiative). Using this versatile platform, we have also demonstrated a range of physical layer and network innovations, including antenna beamforming and spectrum coexistence coupled with artificial intelligence to perform self-organisation. These innovations have since been validated in partnerships with industry. For example, funded by Stratospheric Platforms Ltd (www.stratosphericplatforms.com), we have evaluated our novel, patented antenna beamforming concepts for 'direct to the handset' mobile wireless from the stratosphere. **Grace** has recently been recognised as an Ericsson UK 5G Trailblazer/ Pioneer, highlighting the significance of our research in the delivery of temporary 5G connectivity using aerial platforms.
- We developed both physical layer transmission and networking techniques designed for the harsh underwater propagation environment. This includes full-duplex underwater communications to significantly increase the capacity of the highly constrained underwater channel and demonstration of intelligent MAC protocols which can reconfigure and self-heal. These innovations have been evaluated in lake and sea trials in Israel (supported by the Royal Society), Scotland and through the MOD Progeny programme, for military underwater applications led by Thales.

Electronics for Healthcare:

Our healthcare research spans three main themes; computational approaches to healthcare, surgical robotics and biomolecular diagnostics. This strategic application area has been enhanced during the REF assessment period, including recruitment of new staff (**Tse, Patil**),

refurbishment of dedicated laboratories and expansion of interdisciplinary collaborations with biomedical academics, clinical practitioners and with patients and their carers. Our research further supported through close alignment with the University research themes Technologies for the Future and Health and Wellbeing and through engagement with the York Biomedical Research Institute of which six members of EE staff are principal investigators. Since REF2014 we have been successful in attracting significant funding from a range of funders to support our healthcare research, including from UKRI [BBSRC: BB/L018160; EPSRC: EP/P027571/1, EP/P030017/1, EP/P02324X/1, EP/M027538/1; and MRC: MC_PC_15073] and charities [Royal Academy of Engineering, Royal Society and Parkinson's UK]. Notable successes include:

- We have developed and applied patented algorithms inspired by evolutionary processes to improve the diagnosis and treatment of Parkinson's disease. This technology has since been clinically validated and commercialised through the spin-out ClearSky Medical Diagnostics (**Smith**, co-founder and director), is currently used in medical centres world-wide, including in the UK, Australia and China (see REF3) and is supporting clinical trials for repurposed drug therapies to slow or even halt the progression of Parkinson's (collaboration with University of Cambridge and King's College, London). In addition to translational research, we also undertake fundamental computational research into the structure and function of the nervous system in health and disease. This includes collaborations with leading neuroscientists at University College London, University of Oxford and the National Hospital for Neurology & Neurosurgery to apply novel neuronal signal processing techniques developed in EE to investigate and quantify altered connectivity in the Parkinsonian brain.
- We demonstrated a range of electronic, photonic and micromechanical diagnostic platforms for parallel detection of disease biomarkers (including proteins and metabolites) using technologies compatible with conventional CMOS processing. Our innovative diagnostic technology has since led to further, funded collaborations with York Teaching Hospital NHS Foundation Trust to translate new biosensor technology for the diagnosis of drug resistant infections [EP/P02324X/1] and with Oxfam Australia to explore water quality monitoring technology co-designed with communities to ensure innovations that are appropriate, equitable and sustainable [EP/P027571/1].
- We developed the first MRI-compatible monitor to provide cardiac blood flow velocity and 12-lead ECG information for patient physiology monitoring during MRI imaging and MRI-guided surgery. The technology received regulatory approval following human clinical trials at Harvard and Johns Hopkins teaching hospitals and is now commercialised by the spin-out MIRTLE Inc. (<http://www.mirtlemed.com/>).

Autonomous & Robotic Systems:

Since REF2014 we have recruited new staff (**Post, Miyashita, Hu**) and invested in new infrastructure enabling us to expand and broaden our research in robotic systems. We now conduct research in both robotic hardware and software, including the development of software tools for assuring the safety of autonomous robotic systems. Since REF2014 we have been successful in attracting significant funding from UKRI [EP/R03561X/1, EP/R025479/1, EP/M025756/1, EP/N007050/1] and the EU. These successes underpinned the award of the UKRPIF 'Institute for Safe Autonomy' (**Tyrrell** is on the Management team) establishing a dedicated new building with additional specialist laboratories for experimental evaluation and validation of robotic systems on land, in water and in the air alongside space for 100 people enabling co-location of researchers from across the University. Notable exemplars of our research include:

- We demonstrated fault-tolerant hardware using self-tuning spiking neural networks inspired by astrocyte-neuron interactions in the brain, that exhibits fault tolerance to injected hardware failures, even in noisy environments [EP/N007050/1]. This resulted in a funded collaboration with Dstl to deliver a fault-tolerant autonomous robotic system, capable of environmental mapping of hazardous chemicals.
- In collaboration with researchers at MIT, we demonstrated metamorphic robots that exploit heat and solubility to trigger self-folding and dissolution of a polymer exoskeleton in order to control morphology and capability, here metamorphosing between a robot that can move on ground, water and air.

- We developed a Common Data Fusion Framework (CDFF) to effectively combine data acquired by sensor networks onboard satellites, rovers and other space vehicles. This open framework has been adopted for all European Space Agency Strategic Research Clusters in robotic sensing, communications and power transfer technologies. This research was supported by Horizon 2020 funding [€3.5m, InFuse project] in a consortium including Space Applications Services NV (Belgium), German Aerospace Centre, German Research Centre For Artificial Intelligence, Magellium Sas, the University of Strathclyde and the Laboratory Of Systems Analysis And Architecture.

Immersive and Interactive Technologies:

Building on our extensive experimental facilities, interdisciplinary expertise and existing strengths in immersive audio, our research has become increasingly impact-led in applications from virtual and augmented reality (**Kearney**, REF3) to health and wellbeing and acoustic modelling of historic sites (**Murphy**, **Daffern**, REF3). Our research has been strengthened by the recruitment of **Kearney** and the promotion of **Murphy** to University Research Champion of the Creativity strategic research theme, and by our extensive and diverse research collaborations with Google, Huawei, BBC R&D, Xperi/DTS, Meridian Audio, Houses of Parliament, Sennheiser, Arup, AECOM, National Trust, and York Museums Trust. EE was a founding partner of the Digital Creativity Labs in York, a multidisciplinary EPSRC/AHRC/InnovateUK Digital Economy Impact Hub between EE, Computer Science and Theatre, Film, Television and Interactive Media [EP/M023265/1] and leads the £15m XR Stories AHRC Creative Industry R&D Partnership Cluster project [AH/S002839/1]. Notable achievements include:

- We have developed new higher order ambisonic and binaural audio algorithms for realistic soundfield creation and reproduction to enhance the audio experience for example in online video gaming [EP/M001210/1, AH/N00356X/1, AH/R009139/1, Google]. Take-up of this technology has been significant (as detailed in REF3), including Omnitone and YouTube platforms, and with Sennheiser we have developed novel content for their new AMBEO augmented reality headset. Our binaural algorithms dedicated to immersive experiences for next generation 5G mobile devices have been further developed in collaboration with Huawei and Google.
- We have developed auralisation tools to support the characterization and design of urban, architectural and environmental soundscapes [NE/N018745/1, EP/P001947/1], demonstrated through collaboration with AECOM (through a Royal Society Industry Fellowship, IF130114, hosted in EE) and Arup in their major environmental acoustics projects, including the auralisation of the new Stonehenge bypass. In partnership with the Houses of Parliament (see REF3), we have further applied auralisation and reconstruction to historic architectural sites, leading to a major national exhibition, 'Voice and Vote' in Westminster Hall in 2018, that was seen by more than 100,000 visitors [AH/P012094/1] and most recently with Sorbonne University, France, and University of Parma, Italy, on 'The Past Has Ears' European Joint Programming Initiative on Cultural Heritage Infrastructure including partners at Notre Dame, Paris [AH/V001094/1].

Next Generation Electronic Devices & Materials:

Our research is targeted in two themes, reconfigurable electronic hardware, an area that has been strengthened by the recruitment of **Bale**, and solid-state spintronic devices and materials. These themes have been supported by significant EPSRC funding [e.g. EP/R032823/1 EP/K040820/1, EP/M02458X/1] and collaborations with leading international academic institutes, including Tohoku University, Nanjing University, MIT and TU Kaiserslautern, and with key industry leaders such as JEOL Ltd, Seagate, Arm and Hitachi. Highlights include:

- We have expanded our research in biologically-inspired software to increasingly encompass hardware systems e.g. Platform Grant EP/K040820/1 and InnovateUK. This has led to demonstration of reconfigurable and self-repairing electronic hardware that can be optimized via an evolutionary algorithm to overcome the atomistic, statistical variations inherent to current nanoscale silicon technologies. These algorithms have been further developed for multi-objective automated circuit optimisation and have since been evaluated and validated through collaboration with e.g. Huawei and Arm and are

being commercialised through the University spin-out, ngenics Global Ltd (**Tyrrell**, founder and CEO).

- We developed and demonstrated the first all-metal, three-terminal lateral spin valve with spin modulation that is around 30% higher than other spin valve architectures. This device has significant potential for application in on-chip memory applications and is protected through international patents held in the UK, US and Japan.
- We also undertake research into novel analytical technologies for device characterisation and demonstrated a new and non-destructive approach to characterise hetero- and homojunctions in nanoelectronic and spintronic devices using a conventional scanning electron microscope. We are supporting the major chip manufacturer Seagate to apply this technique for evaluating memory disk read heads and magnetic random-access memories.

Future Strategic Research Vision

Over the coming REF period we will continue to promote and deliver world-leading, impact-led and collaborative research that defines the research agenda across our five, strategic application areas. This will require continued investment to reinforce the application-area structure that has proven successful over the last four years. The University has agreed a bold and ambitious plan for recruitment of new staff and new infrastructure focused initially on strategic priority areas Electronics for Healthcare and Autonomous & Robotic Systems. The development of our strategic priorities is an ongoing and collaborative process that combines bottom-up intelligence of local expertise, interests and facilities with top-down input from across the University (IES, 9, 10, 12), funder priorities and from our Industry Advisory Group, to reflect local, national and international priorities. We will continue to strengthen the scope of our research by promoting and expanding partnerships that cross traditional disciplinary boundaries and will explore mechanisms for closer engagement with other departments. This collaborative approach aligns with the University vision and priorities (IES 12, 18) and ensures inspirational and innovative research with broad relevance and impact. We will also strengthen partnerships outside of academia to create pathways that enhance the translation and impact of our research in areas of national and societal importance e.g. robotics and autonomous systems. Our specific objectives for the next REF period are:

1. **Recruiting and supporting staff:** Through continued support of existing staff and recruitment of new staff aligned with our strategic application areas, we will increase capacity to support major research initiatives and deliver excellent science. This includes recruitment of academic, teaching, research and support staff necessary to increase the number of large-scale grants, for example in Electronics for Healthcare and Robotics & Autonomous systems. We will achieve this through focused replacement of posts, expansion into identified growth areas and management of our student numbers. We have already secured funding from the University (worth over £25m) for new laboratory space, recruitment of new academic staff aligned to our strategic applications areas (3 Professors and 6 lecturers related to Electronics for Healthcare and Robotics & Autonomous systems, and 4 lecturers in broader areas) and recruitment of new teaching staff (2 in management and 1 in electrical engineering) to manage teaching load for research active staff.
2. **Collaborative, impact-led research:** A key strategic objective is to enhance and expand partnerships within and beyond academia, and to establish an impact pipeline that will allow the Department to maximise the impact of our fundamental and applied research across academia, society, industry and commerce. Evidence of our commitment to collaborative, impact-led research includes the wide range of partnerships that span academic disciplines (across the physical, life and social sciences), industry and commerce (e.g. Huawei, Google, BBC R&D and Dstl), cultural and charitable organisations (e.g. Centre for Digital Heritage and Alzheimer's UK), and our spin-out companies and entrepreneurial activities (e.g. **Smith, Pelah, Timmis**, Royal Academy of Engineering Enterprise Fellowship). We will continue to engage with the University Research and Enterprise Office (REO) to identify and develop new partnerships aligned

with our research interests, and to conduct “commercialisation reviews” of all activity, to allow early identification of intellectual property issues, patent applications and spin-out possibilities. The XR Stories Creative Industry R&D Partnership Cluster (**Murphy**) that aims grow the screen industries in Yorkshire and the Humber, demonstrates our success in delivering collaborative, impact-led research. We will also continue to promote impact through an ethos of open research. For example, within the Electronics for Healthcare strategic application area, we have precedence for co-production of research through partnerships with healthcare workers, charities and with patients and carers (**Smith, Johnson, Daffern**). By continuing to work closely with the Department of Health Sciences, the Involvement@York network, Hull York Medical School and York Teaching Hospitals NHS Foundation Trust, we will establish a network of partnerships for translation of our healthcare research.

3. **Research Facilities:** We will continue to support and enhance facilities that underpin the core research interests of our staff and invest in new, specialised infrastructure aligned with our strategic application areas. Targeted development of current facilities and investment in new infrastructure will be prioritised by the Departmental Research Committee (DRC), informed by our strategic research vision . We will achieve this through two mechanisms: 1) A rolling equipment replacement programme (in place) supported through Departmental funds, for servicing of laboratory instruments and replacement of key instruments. 2) Where appropriate, we will seek funding from the University or from external funders to develop strategically important new facilities. We have already demonstrated success through this route including the Bio-Inspired Technologies laboratory that was established in 2016 through an EPSRC equipment grant (EP/M028127) as a biosafety level 2 facility to support research in diagnostic technologies for healthcare. Going forward, we have already secured funding to establish new facilities that align with our research aspirations in Communications for Challenging Environments and Autonomous & Robotic Systems. This includes University support to establish a new mechanical engineering facility including equipment for precision machining and fabrication of small and large-scale robotic systems (£3m). Similarly, the Institute of Safe Autonomy (£35m UKRPIF) will provide dedicated facilities for validating robots on land, air and water, alongside laboratories to develop and characterise HAPs and underwater communication technologies.
4. **Research student community:** During the next REF period, we will increase the number of postgraduate research students enrolled in the Department, aiming for 3 PGR per FTE (currently 2.2 PhD students/ FTE). Since REF2014, we have already demonstrated success in winning funding for postgraduate studentships from across UKRI, international government scholarships and industry (see section 2) and we will build on these successes to further diversify funding aligned with our strategic application areas. For example, as we have done through the Wellcome DTP Combating Infectious Disease: Computational Approaches in Translational Science (CIDCATS), we will continue to engage with colleagues across the University to establish funding from UKRI, the EU and charities to support interdisciplinary PhD studentships, and to explore opportunities to fund a cohort of interdisciplinary PhD students, particularly aligned with strategic application areas Electronics for Healthcare and Autonomous & Robotic Systems. We have also been successful in attracting funding from industrial partners for PhD students aligned with strategic application area Immersive and Interactive Technologies (e.g. Google, BBC R&D and Meridian Audio) and will work with REO to identify and develop new partnerships and industrial studentship funding across our research portfolio.

Open research and research integrity

The Department expects the highest standards in how staff, students and visitors plan, conduct and disseminate their research, in compliance with University policies (IES, 14). Informed by University policy (IES 15-17) and supported by the Open Research Strategy Group (ORSG), we also enhance the visibility of our research by promoting a culture of open research at all phases

of the research cycle, from co-production of research to sharing of data and resources, and dissemination. Examples of open research include:

- *Co-production*: Through EPSRC grant (EP/P027571/1, **Johnson**) we have developed participatory approaches that embed marginalised communities in R&D to ensure innovations that are appropriate, equitable and sustainable. We also actively engage with patients and carers to promote translation of our healthcare research, for example patients with Parkinson's disease supported testing and validation of an evolutionary algorithm-based approach to home diagnosis of Parkinson's dyskinesia (**Smith**). We are supported in patient and public involvement by the Involvement@York network who provide access to patients and public cohorts, share best practice, and support the management of compliance, including GDPR and safeguarding.
- *Sharing of data and resources*: Subject to IP, confidential or commercially sensitive data, research data is archived and shared openly through The Research Data York service which manages the York Research Database. Data files along with metadata uploaded to the database (via Pure) are assigned a digital object identifier to allow citation of the dataset. Where possible, we also support open sharing of source code e.g. NeuroSpec (<http://www.neurospec.org>, **Halliday**) maintains an archive of MATLAB routines for multivariate Fourier analysis of time series and/or point process data.
- *Open Access publishing*: Subject to funder requirements, all publications (including journal articles and conference papers) are archived and shared through Pure and the White Rose Research Online repositories. Postgraduate research student theses are archived in the open access White Rose eTheses Online (WREO) repository shared by the Universities of York, Leeds and Sheffield. The University Library manages the York Open Access fund for payment of open access publication charges. Compliance with the University policy on the Publication of Research is monitored through the Departmental Research Committee who also promote awareness and understanding of this policy in the Department.

2. People

Staffing strategy and staff development

EE comprises 29 (FTE 28.2) members of academic research staff, 12 research staff and an average of 60 postgraduate research students/year. Academic staff, postdoctoral research associates (PDRAs), and post-graduate research students (PhD, DPhil, MSc by Research), are embedded in one of our two research groups; Intelligent Systems and Nano-Science (ISNS) and Communication Technologies (CT). This research group structure fosters research collaboration and critical mass for long-term sustainability, oversight of infrastructural development, coordination of large grant applications and well-defined leadership to support individual career aspirations. Research groups are led by a senior academic who also support delivery of the Departmental strategic vision in conjunction with the DRC, Deputy Head of Department for Research (**Smith**) and Head of Department (**Tyrrell**).

The Department provides dedicated research and facility support through eight technical support staff (FTE 7). The technical support team are regularly embedded within academic research projects. For example, between 2017 and 2019, the technical support team collaborated closely with academic staff to design, develop and deploy the Helikite USRP Testbed and to evaluate the platform for experimental evaluation of wireless protocols from HAPs. The University is a signatory of the Technician Commitment (IES 40) which supports the visibility and career development of our technical support staff through courses, fora and TechYork conferences.

Recruitment strategy

Our recruitment strategy aims to attract the best talent and maintain excellence in both teaching and research across areas of established excellence and to support growth in our strategic application areas. Reviews of staffing and prioritisation of recruitment are evaluated against Departmental needs (including strategic initiatives, succession planning, teaching requirements), Faculty and University targets (IES, section 3), and external factors including funder priorities and student recruitment.

Staff appointments:

Since REF2014, we have recruited a total of 9 new members of academic staff. Appointments are generally made at junior level (Lecturer/ Senior Lecturer) in order to ensure sustainability and succession; **Kearney** (2015), recruited to strengthen research in Immersive and Interactive Technologies, **Bale** (2019), to reinforce ongoing research in biologically-inspired systems, **Ahmadi** (2020) and **Ko** (2019) to strengthen research in wireless communication technologies, **Patil** (2020) aligned with Electronics for Healthcare and **Miyashita** (2016) and **Post** (2019) recruited to support growth in Autonomous & Robotic Systems. We also attract and recruit established senior research leaders to align with strategic initiatives. For example, **Hu** (2020) was recruited (at Reader level) to provide new expertise in power electronics to support the Autonomous & Robotic Systems strategic application area and **Tse** (2020) recruited to a new chair in medical robotics to enhance, inspire and diversify research in Electronics for Healthcare.

Career Development: Academic Staff

We support academic staff and research fellows at all stages of their career to meet their potential. This is achieved through a combination of Institutional (IES, section 3) and Departmental initiatives that are accessible to all staff. These are detailed below:

1. *Support for new staff:* All new academic staff and independent research fellows undertake a targeted induction programme that introduces them to the Department, the Faculty and the University. Department level support for new academic staff includes pump-priming funds to support start-up costs and collaboration building (value dependent on the nature of research and facility requirements), reduced teaching commitment for 1 year (minimum 50% of the Departmental norm), and prioritisation of research student allocation. At the University level, newly appointed academics without commensurate teaching experience undertake the AdvanceHE accredited, Masters-level PGCAP programme. ECR's (lecturers in their first post and independent research fellows) are additionally assigned a senior mentor to support their transition to academic independence. Evidence of the quality of our support and mentoring of ECR's includes the award of external funding e.g. **Kearney** (EPSRC First Grant in collaboration with the BBC and AHRC), **Daffern** (two AHRC grants in collaboration with National Trust and Age UK) and **Post** (EPSRC Supergen ORE hub grant).
2. *Performance and Development Review (PDR):* All staff undertake an annual PDR to reflect on their achievements and to identify needs and associated development activities commensurate with each stage of their research career. The HoD conducts all academic PDRs and has oversight of all other PDRs enabling recognition of achievement and performance benchmarking at the Departmental level. The University Learning and Development (L&D) team offer a wide range of training courses in topics including supervision of research students & staff, knowledge exchange & impact and developing research proposals. The Department works closely with the L&D team to develop a suite of training that supports individual needs.
3. *Workload management & Sabbatical scheme:* The balance between research, teaching, enterprise and administration is managed by the HoD using a workload model visible to all staff in an anonymised form to ensure transparency. This is reviewed annually (over a three year window allowing for future planning) in one-to-one meetings with the HoD. The Department sabbatical system strengthens research by supporting extended visits to national and international collaborators from within and without academia. The scheme is available to all academic staff through a transparent application process assessed by the DRC. The DRC also identifies individuals who would benefit most from sabbatical leave (IES, 23). This approach to sabbatical allocation has been highly successful e.g. **Johnson** exploited a 6-month targeted sabbatical to develop national and international collaborations to support three EPSRC grants (£1.2m as PI, £6.1m as Col) and **Murphy** secured a position as University Research Theme Champion in Creativity, leading to the award of the AHRC XR Stories project as a consequence.
4. *Promotion:* Applications for merit-based promotion of academic, research and teaching staff are assessed annually by the University Academic Promotion Committee (APC) supported by subject-specific advice from the Faculty Advisory Panel (FAP) that includes

a representative of the Department. Individuals are encouraged to discuss their case with the HoD and candidates are supported in preparing promotion documentation by the FAP representative. Since REF2014, 4 staff were promoted to senior lectureships, 3 to readerships and 2 to professorships.

5. *Personal research fellowships and Research leaders:* Since REF2014, we have supported staff to apply for and be awarded a number of prestigious, external fellowships including **Hirohata** (Royal Society Industry Fellowship, in collaboration with the Hitachi Cambridge Laboratory), **Timmis, Pelah & Smith** (Royal Academy of Engineering Enterprise Fellowship) and **Tse** (Royal Society Wolfson Fellowship). We have also supported three members of staff into senior leadership positions within the University: **Robinson** (Pro-Vice-Chancellor for Teaching, Learning and Students), **Murphy** (University Research Theme Champion for Creativity) and **Timmis** (Pro-Vice-Chancellor for Partnerships and Engagement).

Career Development: Post-doctoral Research Assistants (PDRAs)

The University of York has held the HR Excellence in Research award since 2010; evidence of sustained commitment to the Concordat to Support the Career Development of Researchers (IES, 27, 28). Department mechanisms to support PDRAs are guided by University policy and align with the principles of the Concordat. All PDRAs undertake an annual PDR with their line manager that follows the same principles as those for academic staff. Career development needs are identified in collaboration with the University Research Excellence Training Team (RETT, IES 32) which provides training courses and advice in research skills, engagement and career planning. We also work closely with RETT to support outstanding PDRAs to apply for personal fellowships, e.g. EE hosted a Centre for Future Health Fellow (funded by the University/Wellcome Trust), mentored by Johnson. The Early Career Research Forum (ECRF), led by an elected PDRA and supported by a senior member of academic staff, has representation on the DRC to provide a link between research staff and Departmental and Institutional support teams. Our success in the career development of PDRA staff is evidenced by the permanent positions they have subsequently been awarded, including tenured academic positions in the universities of York (Bale), Edinburgh, Herriot-Watt, Hull, Plymouth, Wolverhampton, Leeds Trinity, and in industry including Seagate Technology, AECOM, Fraunhofer, Sony, Xperi/DTS, Meridian and the BBC.

Training and Supervision of PGR Students

Since REF2014, we have awarded 143 PhD degrees. Oversight of training, supervision and support for PGR students is provided by the York Graduate Research School (YGRS) (IES, 30) and all Departmental initiatives governing PGR students align with YGRS Policy on Research Degrees (IES, 31-34). The quality of our PGR graduates and of our PGR programme is reflected in their subsequent high-profile positions in academia, including at the University of Surrey, Aalto University, the University of Swansea and Imperial College London and in industry including Sony, Fraunhofer, Xperi/DTS, Meridian and Quiagen. We also support outstanding PhD students to apply for independent fellowships e.g. Amelia Gully was awarded a British Academy Fellowship held at the University of York.

Admissions:

PGR recruitment and admissions are led by the Department in collaboration with the YGRS. All candidates are invited to interview and this assessment feeds into the final selection made by a recruitment panel assembled from senior academics. Recruitment is informed primarily by student quality and alignment to areas of research strength ensuring students are embedded in a supportive group with well-defined leadership. We have diversified funding for PhD students and since REF2014 have trained students using funding from UKRI, (EPSRC, AHRC, NC3Rs), the EU, Industry (including Google, Roke Manor, Huawei, SELEX Galileo Ltd, BBC R&D, DTS Licensing Ltd, Meridian Audio), international scholarships (Mexico, China and Nigeria through the Nigerian petroleum industry), charities (Holbeck Charitable Trust) and Department/University funding. We have also supervised interdisciplinary PhD studentships for example by engaging in the Wellcome DTP CIDCATS.

Supervision and progress monitoring:

To ensure quality PhD supervision and support, all new staff receive training in PGR student supervision through courses delivered by the RETT and the PGCAP programme. Staff supervising their first PhD student are supported by an experienced member of academic staff who act as academic co-supervisor. All PhD students within the Department are supported and evaluated by a Thesis Advisory Panel (TAP) consisting of at least two academic staff in addition to the primary supervisor. The TAP meets the student every 6 months to assess progress, identify training needs and provide an opportunity for students to independently assess supervision arrangements. The Department created and pioneered the use of Skillsforge to record and archive supervision meetings, progress reports and training plans. Skillsforge is now in use across 12 universities in the UK. Formal examination by viva voce examination with an independent examiner occurs at months 12 and 24 which includes a review of the thesis plan and exemplar publication.

Professional skills training and career development:

The Department runs an annual two-day PhD conference attended by academic staff, PDRAs, PGR students and representatives from industry. All first year PGR students deliver a 3-minute thesis presentation, second year PGR's present a poster supported by a 3-minute 'flash' presentation while third year students deliver a 15-minute conference paper. Students are guaranteed Departmental funding to attend at least one international conference. Career advice and training in transferrable and specialist skills are provided by the RETT including courses focussed on career planning, research management and public engagement. RETT also delivers the York Learning and Teaching Award (YLTA) which is a bespoke, Masters-level programme to provide professional development and support for graduate teaching assistants.

Equality and Diversity

EE operates transparent approaches to recruitment, promotion, allocation of duties and nomination to senior Departmental and University positions. We ensure that Departmental business, including scheduling of committee and research group meetings and timetabling of teaching commitments are sensitive to staff with children or caring responsibilities and are compatible with flexible working arrangements. The Departmental Equality and Diversity Committee has established a policy, guided by the University strategy (IES, 21, 35-37), to promote best practice in equitable representation and experience across all 9 protected characteristics. The Committee, which includes broad representation (academic staff, PDRAs and PGRs), monitors all departmental activities through a comprehensive set of measures. We recognise the importance of equal participation of women at all levels in a subject that has traditionally been, and remains, male-dominated. The Department has engaged with the Athena SWAN charter since 2008, through its Athena SWAN Working group, and achieved the Bronze award in 2012, renewed in 2017. We established and continue to support the student-run society Supporting Women in Engineering at York (SWEY) and have established a female support officer to offer support and advice to our female PGR students. Equality and diversity is reflected in all Departmental activity. For example, in compliance with the University Code of Practice, our submissions to REF2 and REF3 were informed by excellence and an equality impact assessment considering age, disability, ethnicity and gender. Similarly, in 2019 Kearney and Murphy were co-chairs for the Audio Engineering Society's (AES) International Conference on Immersive and Interactive Audio, that helped to promote best practice in equality, diversity and inclusion, including double blind reviewing, use of preferred gender pronouns, and gender balanced paper, panel, and keynote sessions. Kearney and Murphy received the AES Governors Awards for this event.

3. Income, infrastructure and facilities**Research Income**

Through leadership, investment in staff and research infrastructure, and Departmental development activities, such as investment in our strategic application areas and the targeted sabbatical system, we have increased the number of grant applications submitted and the value of grants awarded, evidenced by a 20% increase in the research funding/ FTE compared to

REF2014 awarded across our strategic application areas to staff at all stages of their careers. The Department has remained successful in winning research funding from the EPSRC and during the assessment period, members of the Department have been PI and Col on prestigious EPSRC Platform and Programme grants. We have also enhanced the scale of our interdisciplinarity research enabling us to diversify sources of funding, notably in the creative arts and in biological and biomedical sciences, reflected in grants awarded by AHRC, BBSRC and MRC. We have also continued to attract funding beyond UKRI, including European funding agencies, charitable, industrial and other external institutions. Noteworthy grants that demonstrate the diversity of funding include:

UKRI:

Halliday, Self-repairing Hardware Paradigms based on Astrocyte-neuron Models, EPSRC, EP/N007050/1, £683,915; **Murphy**, Creative Media Labs: Innovations in Screen Storytelling in the Age of Interactivity and Immersion (now XR Stories), AHRC, AH/S002839/1, £6,374,965, Col on The Digital Creativity Hub, EPSRC, EP/M023265/1, £4,039,831; **Mitchell & Zakharov**, Col on USMART - Smart dust for large scale underwater wireless sensing, EPSRC, EP/P017975/1, £1,284,429; **Johnson**, Sensors for clean water: A participatory approach to technology innovation, EPSRC GCRF, EP/P027571/1, £1,182,012, Col on Biophysics of Infection and Immunity: From Molecules to Cells to Tissues, MRC Discovery award, MC_PC_15073, £679,802; **Tyrrell**, Autonomous Robot Evolution (ARE: Cradle to Grave, EPSRC, EP/R03561X/1, £1,012,141, Bio-inspired Adaptive Architectures and Systems, EPSRC Platform grant, EP/K040820/1, £919,337

EU: Marie-Sklodowska-Curie Innovative Training Networks:

Dawson, Col on Pan-European Training, Research & Education Network On Electromagnetic Risk Management; **Grace**, Col on SPOTLIGHT and Col on Application-aware User-centric Programmable Architectures for 5G Multi-tenant Networks (5G-Aura).

Charities:

Chesmore, Automatic acoustic observatories: non-invasive long term monitoring of acoustic species, Leverhulme Trust, £310,933 (collaboration between EE and the departments of Biology and Environment & Geography); **Murphy** in collaboration with Dr Alex Southern from AECOM, Royal Society Industry Fellowship Scheme, IF130114; **Smith, Pelah, Timmis**, Royal Academy of Engineering Enterprise Fellowships.

Industry:

InnovateUK (7 projects worth £414k); Qinetiq/DSTL/Thales (worth total of £600k); DCMS 5G Testbeds and Trials (£434k), Huawei (three funded projects totalling £435); Google (£180k); HAS Ltd (232k); Orange £79k, Hikstor £199k

Research facilities

The Department houses state of the art infrastructure and associated technical support to underpin the excellence of our research, the aspirations of our research staff and a competitive advantage in the retention and recruitment of staff and students. Annual facility costs are recovered through access charges from grants, external users, industrial collaborators, and Departmental investment. We encourage the use of our facilities by internal and external collaborators and advertise high-value equipment on the N8 Shared Equipment Inventory (<https://www.n8equipment.org.uk>). Sustainability and enhancement of our facilities during the coming period has already been secured, for example through the Department's participation in the Institute for Safe Autonomy and recent investment from the University to establish new infrastructure to support research and research-led teaching in areas beyond electronic engineering. Notable high-value facilities aligned with our strategic application areas include:

1. *Immersive and Interactive Technologies*. The AudioLab supports research between engineering and the creative arts and houses three recording studios and an anechoic chamber. Each studio is equipped with the latest versions of leading Digital Audio Workstations and include HDTV screens for sound-to-picture work. The facility includes a 50-channel spherical speaker array and motion-tracking cameras for VR-related work.

- High-quality measurement microphones and audio-interfaces are also available for field work, along with 360-degree camera arrays for video & audio capture. XR Stories and the University are investing more than £1m to redevelop Kings Manor in the centre of York to support R&D and engagement with the immersive/interactive and screen (film, TV and games) industries.
2. *Autonomous & Robotic Systems.* The York Robotics Laboratory features a purpose-built 90m², double height arena for ground-based and aerial robotic research. The lab is equipped with state-of-the-art tracking systems, a robot experiment arena and a workshop with full-time technical support. Specialised robotic laboratories have also been created, including the Autonomous Robotic Evolution laboratory and the Space Robotics and Autonomous Systems laboratory. Our success in the award of the flagship £35m UK UKRPIF Institute for Safe Autonomy will significantly extend our robotic facilities. Specifically, this will include dedicated laboratory space for the construction and evaluation of ground and aerial robotic platforms and water tanks for trialling of underwater robots.
 3. *Next Generation Electronic Devices & Materials.* The Departmental Cleanroom houses equipment for the fabrication and characterisation of micro- and nanofabricated devices including spintronic devices and microfluidic devices for lab-on-chip applications. The interdisciplinary facility supports researchers from across the Faculty of Sciences and training for postgraduate and undergraduate students (typically 30/annum). Since REF2014, £500k of internal and external funds (e.g. JST-CREST JPMJCR17J5) has been invested to provide new capabilities and update equipment. The facility is supported by an experimental officer and two technicians (one 100% FTE, one 50% FTE). Microfabrication facilities include UHV molecular beam epitaxy for the deposition of novel spintronic materials complemented by equipment for the characterisation of spintronic materials and devices, including atomic force microscopy, magnetometers, cryogenic measurements and X-ray diffractometer.
 4. *Electronics for Healthcare.* The Bio-Inspired Wetware laboratory, established in 2016 following investment of £400k from internal and external funding (EP/M028127), supports research in healthcare technologies. This biosafety level 2 facility houses molecular characterization equipment including Raman and infrared spectroscopy, a quartz crystal microbalance, multiple research-grade potentiostats and bench space for sample preparation. The facility supports the research of ~15 staff across the Faculty of Sciences and training for PGRs. The Department is also developing an animal cadaver laboratory for validation of robot-assisted surgical tools.
 5. *Communications for Challenging Environments.* The Centre for High Altitude Platform Applications includes 21m³ and 34m³ tethered balloon/kite hybrids which are capable of deployments up to 400 m altitude for validation of novel communication protocols. Facilities to support our research in this strategic application area will be strengthened and extended through the Institute for Safe Autonomy which will include 100m² indoor laboratory space for HAP-related communication research, adjacent to an outdoor roof-based test space capable of launching Helikites. The building will also be equipped with a bespoke test pool providing one of the largest academic test facilities in the UK for the evaluation of underwater networks.

We also benefit from access to other major facilities across the University, including the new HPC facilities (IES 41) and the York JEOL Nanocentre which contains a suite of electron microscopy systems, including ultra-high resolution TEM (recently upgraded with £3.2m from EPSRC matched by £1m from UoY and £250k in-kind support from 8 industry partners). The Department is a founding member of the Nanocentre and remains an active user and partner including winning internal funding (£350k) to support new capability, including a direct laser writer dedicated for rapid prototyping of microfluidic systems.

Supporting impact

Our ambition is to maximise impact across all research activities within the Department, which will be monitored and facilitated using alignment with a modified Technology Readiness Level (TRL) scale. It is recognised that impact can occur at all levels of the TRL scale ranging from

academic impact through technology demonstrators, to full working prototype, commercial exploitation and societal benefit.

- The *Departmental Impact Officer* (DIO) has responsibility for monitoring and promoting impact activity within the Department in conjunction with Departmental Research Committee (DRC), the Department's Research Support Team (DRT), the University's Research and Enterprise Office (REO) and the Faculty Impact Manager (FIM) (IES, 49). Individual researchers are encouraged to consider impact at all levels: individual, group and departmental.
- *Research groups* consider impact as part of their regular group meetings, to include a review of impact across the group, and develop an impact-informed and impact-led research ethos. The DIO assists with interactions between the REO, FIM and external bodies. At departmental level, impact is reviewed regularly through DRC which receives reports from group leaders on impact case studies and future impact opportunities e.g., University allocated funding for impact and knowledge exchange (IES 50). The DRC also seeks assistance from the faculty marketing team to promote research, raise external visibility of research and its current and potential impact.
- *Researchers* are encouraged to engage with national and international organisations, panels and professional societies in a range of research-centred activities such as establishing national and international standards, influencing policy and practice, and organising conferences, workshops and symposia (see section 4 for details).

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

Research collaborations:

The Department continues to make significant contributions to our discipline and, through our national and international collaborations, to the wider research base. For example, our research on spintronic materials and devices includes collaboration with academics from across the world, including many leading academic institutes, such as Tohoku University, Nanjing University, University of Cambridge, MIT, TU Kaiserslautern, and the Indian Institute of Science. More broadly, of the archival journal papers selected in support of our REF2021 submission, 70% are published with co-authors external to the University, with 50% including international collaborators.

In addition to academic collaboration, our staff are also engaged in research collaborations that contribute to industry, cultural organisations and charities. For example, over the assessment period, 42% of our collaborative research projects have been performed in partnership with industrial organisations. This collaborative approach ensures a pipeline for translation of our core research leading to commercial implementation and societal impact and helps inform our research priorities, supported by our External Advisory Board (including members from IBM, Arm, BAE Systems and Eurofins).

Our research in immersive and interactive technologies exemplifies how our research contributes to the economy and society. Academic research into Ambisonic based binaural surround sound for realistic soundfield creation and reproduction, developed as part of the EPSRC SADIE project (EP/M001210), were adopted by Google as part of their immersive VR pipeline, known as Google Resonance. This includes YouTube 360 as well as applications developed for Google cardboard and the Google Daydream VR headset (REF3). Millions of users worldwide who utilise Google's VR platform use the York SADIE binaural filters, making them the new standard for spatial audio quality in VR productions. Other examples of strategic end-user collaborations include AECOM, Bang and Olufsen, BBC R&D, Arup, Sennheiser, BT, Orange, Huawei, JEOL, Thales, Dstl and Stratospheric Platforms.

Aligned with our culture of open research, the Department strongly supports public engagement in research and hosts a range of annual outreach events aimed at engaging young people in STEM subjects e.g., UKESF Summer School, IET Faraday Challenge, and EDT INSPIRE summer schools. Other examples of outreach activity include York Talks (**Murphy** 2015, **Johnson** 2018, **Daffern** 2020), Deer Shed Festival 2017, Lakes Alive Festival 2018 (**Daffern**)

YorNight 2020 (**Cumanan**), York Festival of Ideas 2016 (**Kearney**), Voice and Vote, Westminster Hall 2018 (**Murphy**). Parkinson's UK patient groups 2016 (**Smith**).

EE currently hosts 16 visitors/ honorary fellows who have elected to spend sabbatical leave within the Department to undertake collaborative research. These include visitors from national and international academic institutes, e.g., Michihiro Ohta (National Institute of Advanced Industrial Science and Technology, Japan), Prof Gusz Eiben (Vrije Universiteit Amsterdam) and Prof. Rodrigo De Lamare (Pontifical Catholic University of Rio de Janeiro). We also encourage honorary fellowship applications from beyond academia that align with our research strengths e.g., Alex Southern from AECOM, supported by a Royal Society Industry Fellowship (IF130114) and Prof Kevin Steptoe from Palma CEIA Semidesign.

Interdisciplinary research:

The Department is distinctive in the contribution of our research across traditional disciplinary interfaces, particularly in relation to research aligned with Electronics for Healthcare and Immersive and Interactive Technologies. This is exemplified by the collaborations that EE has established across all three Faculties at York (Sciences, Arts and Humanities, and Social Sciences), our membership of the York Biomedical Research Institute (IES 45), and by the 30% of our REF outputs flagged as interdisciplinary. Notable examples of our interdisciplinary research include:

Digital and Creative arts:

EE has a long-standing track record of collaboration with researchers and end-users in the creative arts. For example, XR Stories (**Murphy**) supports research and development for companies working in digital technologies across the Yorkshire and Humber region. This impact-led project funded by EPSRC, AHRC and InnovateUK, is a collaboration between EE and the departments of Computer Science, Archaeology, Theatre, Film Television and Interactive Media, Sociology and Education, alongside non-academic partners including Screen Yorkshire and the British Film Institute. Other examples include collaboration with the Royal College of Music and the departments of Psychology and Environment and Geography at York to investigate the health and wellbeing benefits of group singing in virtual reality (**Daffern**, AH/R009139/1, REF3)) and the Listening to the Commons project (**Murphy**, AH/P012094/1), a collaboration with the Department of History and the UK Parliament to generate 3D visual and acoustic models of the historic Commons.

Biological, Biomedical and Healthcare:

The Department has expanded activity with researchers and end-users in medicine/biology. For example, underpinned by our expertise in medical applications of biologically-inspired algorithms, we are now collaborating with biologists to address fundamental biological questions including understanding the molecular basis of Parkinson's disease through classification of movement disorders in Zebra fish models and tracking and classification of cells within in vitro cell cultures (**Smith**). With colleagues in the departments of Biology, Physics, Chemistry and Health Sciences, and with end-users at the York Teaching Hospital NHS Foundation Trust, we have developed a range of technologies for detection of disease biomarkers in vitro, (**Johnson**, EP/P02324X/1, EP/P030017/1). We have extended these collaborations to include Stockholm Environment Institute at York, Oxfam and the Government of Vanuatu to translate this technology for water quality monitoring in low and middle income countries (EP/P027571/1).

Academic Leadership:

As a research-intensive Department that nurtures current and future academic leaders, engagement with the wider community is central to the activity of our staff. For example, **Hirohata** is currently Secretary/ Treasurer and President-Elect (starting 2021) of the IEEE Magnetics Society, **Grace** has been recognised by Ericsson, as one of 25 '5G Trailblazers', **Everard** was selected to be the IEEE Distinguished Microwave Lecturer 2018–2020 and **Howard** was elected a Fellow of the Royal Academy of Engineering (2016).

- *Journal editorial roles.* Exemplars include **Tyrrell**: Editor in Chief IET Proceedings – Computers and Digital Techniques, Associate Editor for BioSystems (Elsevier), IEEE

Transactions on Evolutionary Computation, IEEE Transactions on Cognitive and Developmental Systems. **Hirohata**: Journal of Physics D: Applied Physics, Frontiers in Condensed Matter Physics, Journal of Magnetism and Magnetic Materials (Elsevier). **Hu**: IEEE Transactions on Industrial Electronics, IET Renewable Power Generation, IET Intelligent Transport Systems. **Mitchell**: IET Wireless Sensor Systems, IET Wireless Sensor Systems. **Tempesti**: Genetic Programming and Evolvable Machines. **Avrutin**: Optical and Quantum Electronics (Springer). All members of staff regularly provide peer review for international journals, including major journals such as Nature, Nature Physics, Nature Communications, and IEEE publications.

- *Conference committee roles*. Staff play a leading role in conference organisation, examples include: **Hirohata** Co-Chair of European Congress and Exhibition on Advanced Materials and Processes (2019), International Conference on Magnetism (2018), 8th Joint European Magnetism Symposia (2016). **Murphy** Chair of Audio Engineering Society International Conferences on Audio for Games (2015 & 2016), Co-Chair Audio Engineering Society International Conference on Immersive and Interactive Audio (2019). **Avrutin** Programme committee of the IEEE International Semiconductor Laser Conference (2016 & 2018). **Kearney** Co-Chair Audio Engineering Society US Convention (2017, 2018, 2019 & 2020). **Tyrrell** Co-General Programme Chairman for the 10th International Workshop on Information Processing in Cells and Tissues (2015), Technical Chair for IEEE CEC (part of IEEE WCCI 2020), Co-Chair for IEEE International Conference on Evolvable Systems: From Biology to Hardware (2015, 2016, 2018 & 2020). **Smith** Chair GECCO Workshop on Medical Applications of Genetic and Evolutionary Computing (2014-2019).
- *Invited talks*. Our academic leadership is exemplified by invites to present at leading international conferences. Examples include **Mitchell**, Plenary speaker, ACM International Conference on Underwater Networks & Systems (2019); **Ko** Keynote speaker, IEEE Int. Conf. on ICT Convergence (2018); **Hu**, Keynote speaker, International Conference on Energy, Resources, Environment and Sustainable Development (2019); **Murphy**, Invited speaker, South by Southwest (2020); **Tempesti**, Plenary speaker, 22nd International Conference on System Theory, Control and Computing (2018); **Burr**, Keynote speaker, International Conference on Emerging Technologies of Information and Communications (2019); **Dawson**, Invited speaker, IEEE EMC Society Meeting (2016); **Hirohata**, Invited speaker, International Magnetism Conference (2015 & 2017); **Tyrrell** Invited speaker, 2nd Resiliency Workshop (2019).
- *Departmental spin outs*. Four companies have been spun-out from the Department; ClearSky Medical Diagnostics (**Smith**, clearskymd.com), ngenics Global UK (**Tyrrell**, ngenics.com), Simomics (**Timmis**, simomics.com) and Asuuta Ltd. (**Pelah**).
- *Research review committee roles*. UKRI (EPSRC, BBSRC, Royal Society, Royal Academy of Engineering, Leverhulme), European Research council, and international governmental and research organisations (e.g. Toshiba Fellowships, German Research Foundation, Foundation Ireland, Agency for Science, Technology and Research Singapore, Foundation for Polish Science, Austrian Science Fund, FONDECYT, Academy of Finland).