Institution: University of Glasgow

Unit of Assessment: 12

1. Unit context and structure, research and impact strategy

1.1 Unit Context and Structure

The James Watt School of Engineering has operated as a unified unit since 2010 and was renamed for our eponymous engineer on his 200th anniversary in 2019. Engineering comprises one third of the College of Science & Engineering and is one of its eight Schools and Centres. The School has 296 staff on academic tracks: 116 Research & Teaching (R&T); 154 Research (R); and 26 Learning, Teaching & Scholarship (LTS). 119.24 FTE R&T and independent R staff are submitted to REF. Our student community comprises 443 postgraduate research (PGR), 401 postgraduate taught (PGT) and 1836 undergraduate (UG) students in Glasgow, plus 2133 UG transnational education (TNE) students taught in Singapore and China.

1.1.1 Structure

The School is of sufficient size and breadth to deliver research across the major engineering fields. The School is organised into five Research Divisions (**Fig. 1**) such that our management is structured around research. The Divisions are thematic and thus form the foundations that allow us to develop and implement our research strategy and respond flexibly to emerging engineering and societal challenges. The School shaped this management framework in 2010 and it has sustained and developed as an agile and adaptable research structure.

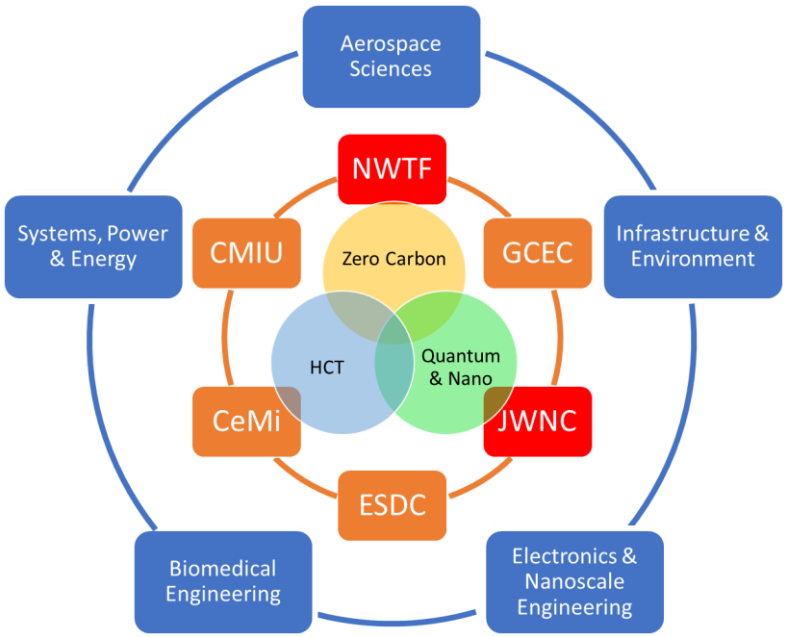

Figure 1. Thematic structure

Our thematic Divisional structure (blue) sustains strong internationally leading Centres (brown) and dynamically mobilises research around global societal challenge-led areas of Zero Carbon, Quantum & Nano, and Healthcare Technologies, where discovery and innovation are enabled by our national facilities (red).

CeMi: Centre for Cellular Microenvironment; **CMIU**: Centre for Medical & Industrial Ultrasonics; **ESDC**: Electronic Systems Design Centre; **GCEC**: Glasgow Computational Engineering Centre; **JWNC**: James Watt Nanofabrication Centre; **NWTF**: National Wind Tunnel Facility

The School is led by the Head of School (**Cumming**), aided by the School Executive Group (SEG) of leaders across research, teaching, administrative and technical support, creating a strong one-School ethos. Heads of Research Divisions (HoRDs) are responsible for the direct management and development of all academic staff in the School. The HoRDs' primary responsibility is research leadership, working together to steer the School's research strategy and shape the School's

research environment, through the SEG, chaired by the Head of School, and Research Committee, led by the Director of Research (**Gadegaard**).

All academic staff find a primary home within a Research Division, providing a research-focused structure that fosters collegiality and productive collaboration. Groups of staff with cognate expertise in a common research field come together in shared labs and workspaces, easily overlapping and connecting across the Divisions. We support an interdisciplinary research culture within the School and through strong interfaces with the physical, medical, life and social sciences, so that major societal challenges can be tackled effectively. Thus, we also develop, support and lead interdisciplinary Research Centres of excellence and enable cross-cutting challenge-led research strengths to emerge and grow.

1.1.2 Research Divisions

Aerospace Sciences (AS – HoRD **Kontis**). AS focuses on greener and safer travel, supported by our world-class experimental wind tunnel and testing facility, including supersonic and trans-sonic capabilities. Extensive simulations expertise covers flight mechanics and fluid dynamics phenomena of fixed and rotary-wing aircraft. We have built capacity in autonomous systems, driving innovations in space (including future air-space transport), aerial, ground and underwater vehicles and exploration.

AS is delivering an Impact Case Study (ICS), with strong links to industry and certification bodies (**Barakos**). We make a central contribution to the UK National Wind Tunnel Facility (NWTF), lead the Next-Generation Rotorcraft programme (MENtoR) and the ESA Plume-Regolith Testing consortium, and contribute to European initiatives (NITROS, TEAMAero, ACARE). We have contributed to the formulation of the Aerospace Defence, Marine and Security Strategy for Scotland 2016 and Europe's Vision for Aviation: Strategic Research and Innovation Agenda.

Biomedical Engineering (BME – HoRD **Salmeron-Sanchez**). BME brings together research in advanced medical diagnostics, rehabilitation engineering and biomaterials, with emphasis on engineering underpinning life sciences and at the clinical interface. Cross-Division collaborative research in biomedical engineering features very strongly in the School and BME is leading our challenge-led Healthcare Technologies research.

BME hosts 3 ERC Investigators (**Gadegaard**, **Cooper**, **Salmeron-Sanchez**), is delivering 3 ICSs and is currently leading an EPSRC Transformative Healthcare Technologies 2050 Programme (**Cooper**), EPSRC Healthcare Technologies Programme, Sir Bobby Charlton Foundation translational grant, EPSRC CDT IifETIME and EU H2020 grant (**Salmeron-Sanchez**).

Electronic & Nanoscale Engineering (ENE – HoRD **Hogg**). ENE research addresses socially and industrially important applications in electronic, photonic, microsystem and nanofabrication technologies. The JWNC (**Fig. 1**) underpins the Division's research in key areas, including in sensors, telecommunications, quantum technologies, THz and millimetre wave technology, and advanced microelectronic devices.

ENE is delivering 4 ICSs and spin-outs (**Asenov**, **Cumming**). Our device modelling research pioneered atomistic TCAD and our leadership in silicon compatible GaN power electronics has galvanised UK activity (**Thayne**, EP/K014471/1). ENE makes a central contribution to the UK National Quantum Technology Programme and contributes to the talent pipeline through partnership in 2 CDTs and leading the H2020 ITN TeraApps. Quantum photonics, sensors and electronics have been strengthened through leadership appointments (**Weides**, **Badolato**, **Vellaisamy**).

Infrastructure & Environment (IE – HoRD **McBride**). IE focuses on innovative solutions to problems in the built and natural environment. Pioneering work includes fundamental contributions to mechanics, the creation and industrial application of advanced computational modelling tools, and low-cost solutions to global challenges in water supply and remediation.

Through a strategic leadership investment (**Steinmann**) and EPSRC Strategic Support Package (**Pearce**), the Glasgow Computational Engineering Centre was founded. Early career stage researcher (ECSR) appointments have led to Fellowships: **Shire** in geotechnics (Royal Society/Scottish Water Industrial Fellow) and **Vignola** in biofiltration (RAEng Research Fellow),

and our senior staff have won RAEng Chairs: **Pearce** (RAEng/EDF Energy Research Chair), **Smith** (RAEng/Scottish Water Research Chair), **Sloan** (RAEng Chair in Emerging Off-Grid Water Biotechnologies).

Systems Power & Energy (SPE – HoRD **Cochran**). SPE research spans the mechanical and electrical sciences, giving it agility to form strong cross-disciplinary clusters. SPE has trebled in size since 2014, realising the School's strategy to create significant strength in Communications, build new capacity in Energy & Sustainability and Ultrasonics, and increase cross-divisional capability in Materials & Manufacturing.

Deployment of the School's established Chairs attracted research leaders: Rankine Chair (**Falcone**, Vice-Chair, United Nations Commission for Europe Expert Group on Resource Management; Board of Directors, International Geothermal Association), and James Watt Chair (**McInnes**, RAEng Chair in Emerging Space Technologies; ERC Advanced Grant). Growth in Ultrasonics (**Cochran**, EPSRC CDT in Future Ultrasonic Engineering) and Communications (**Imran**, UofG lead The Scotland 5G Centre) respectively established a new Centre (CMIU) and a cross-divisional Communications, Sensing and Imaging group now of 30 R&T staff.

1.1.3 Research Centres

Building Centres of research excellence has been an additional cornerstone of the School's research strategy, ensuring our growth is an enabler for sustainable pioneering work and vitality in areas of strength. Four Research Centres are now led from the School (three of them established since 2014). The award of Centre status requires strong evidence of a critical mass of highly collaborative and internationally leading research. The Centres have created an identity in strategic research fields where the University has world-leading capability: **Centre for the Cellular Microenvironment** (CeMi); **Centre for Medical & Industrial Ultrasonics** (C-MIU); **Electronic Systems Design Centre** (ESDC); and **Glasgow Computational Engineering Centre** (GCEC) (details in Section 3.5).

1.1.4 Challenge-Led Research (details in Section 3.4)

We coalesced challenge-led research in technology areas where we are recognised as having significant strength and making internationally leading innovations. The School's thematic structure makes it easy to connect researchers around emerging challenges. Our focus now is in: **Healthcare Technologies**; **Quantum & Nano Technologies**; and **Zero Carbon Technologies**, where we can drive innovation and impact underpinned by our Research Centres and Facilities, particularly the JWNC.

1.2 National Facilities

James Watt Nanofabrication Centre (JWNC) (Director: **Marsh**). The JWNC is a world-leading facility, comprising >£37M of nanofabrication tools and supporting >£53M active research grants in the University as well as the four EPSRC Quantum Technology Hubs. (See Section 3.4.1)

Wind Tunnel & Testing Facilities (Director: **Green**). The School is a hub in the UK's National Wind Tunnel Facility (NWTF). Our wind tunnels are accommodated in a dedicated building, housing multiple co-located national aerospace test facilities supporting our aerospace research. (See Section 3.4.2)

The Scotland 5G Centre (UofG Lead: **Imran**). The Scotland 5G Centre is an innovation and test facility, established as a partnership between the Universities of Glasgow and Strathclyde and the Scottish Futures Trust, securing £5.3M from the Scottish Government, plus additional £4M for nationwide technology hubs. Its purpose is to demonstrate the importance and impact of enhanced digital connectivity enabled by 5G technology. Launched in the School by the First Minister in 2019, along with the Scottish Government's 5G strategy, the Centre provides national leadership in this area.

1.3 Research Strategy and Management

1.3.1 Research Management

The School's Research Committee is responsible for the strategic direction of the School's research and impact, and for shaping and delivering University research policy. The leadership

team (Head of School, Director of Research and Heads of Research Divisions) also form the core of the School Executive Group.

The Research Committee works to influence and align with priorities of major research funders and industry sectors, for example UKRI and government committees, national and international networks, and industry secondments (see Section 4.2). It develops related research initiatives, including in external engagement, research training, and responses to major funding calls. Research strategy emerges in continuous dialogue in and between Research Divisions that is captured by Research Committee. Thus, we create teams to harness the strengths of the School and tackle major challenges, for example the EPSRC Transformative Healthcare Technologies 2050 programme in Quantum Imaging for Monitoring of Wellbeing & Disease in Communities (**Cooper**, **Imran**, **Vuckovic** plus co-investigators from Medicine, Physics, Computing Science). Postgraduate Research Convenor (**Sorel**), Impact Champion (**Kelly**) and ECSR Champion (**Clerici**) are key members of the Research Committee, providing leadership and strategic direction in these three important functions. A Financial Manager and Research Support Manager provide dedicated administrative support.

1.3.2 Research Strategy

Since REF2014 the School's strategy has delivered significant growth. Our plan was based on targeted growth in priority areas, to strengthen our Research Divisions, establish new Research Centres and build our strengths around three challenge-led themes. We focused on attracting, supporting and developing international research leaders and ECRs (including >£4M in support of professorial posts and >£400k for ECSR posts in dedicated start-up funds, not including related estates investments), while also investing in additional teaching support in important engineering skills. Since 2014 R&T staff grew by 43%, grant income per FTE by 25%, PDRA staff by >50%, and PGR student headcount has more than doubled (**Fig. 2**).

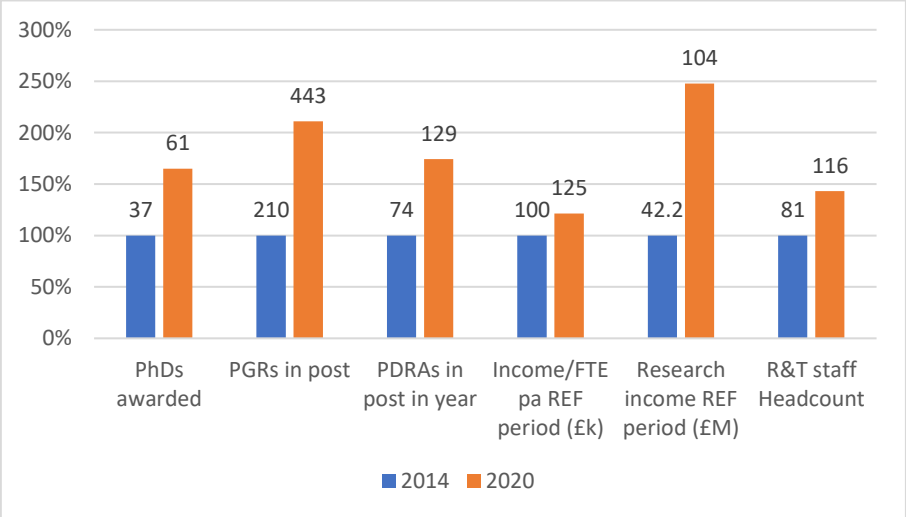

Figure 2. School of Engineering growth in REF period

We have targeted priority areas and invested in clustering important cross-School research. An example of a new targeted area is our substantial Communications, Sensing & Imaging (CSI) group (**Imran**). CSI has led new collaborations with China (primarily through our TNE partnership) and with developing nations through multiple GCRF grants, and has secured funding from the Scottish Government to establish The Scotland 5G Centre. Clustering is exemplified by the School's recent investments in Materials research, as an emerging cross-School theme. We have appointed five new posts and co-located materials labs across biomaterials, additive manufacturing, smart infrastructure materials and composites.

Rapid growth has brought significant challenges for the School's estate. The University has responded by investing in major refurbishments of Engineering buildings, totalling £14.2M since 2014, to accommodate new labs and workspace to ensure a high-quality research environment. Some of our most successful interdisciplinary research groups and labs are being rehoused in a 17,000m^2 state-of-the-art Advanced Research Centre (ARC), opening in 2022 as part of the

University's £1bn campus development. The ARC will bring together 600 researchers from across the University in a highly collaborative environment.

The School's growth strategy is motivated by the ambition and vision of our community of academic staff to deliver research excellence, better positioning ourselves to capture research opportunities by building critical mass in larger, more diverse, more inclusive and more effective teams, and to widen collaboration prospects and leadership development of all, and particularly our ECSRs. Led by our Equality Diversity and Inclusion Group (see Section 2.2), ED&I perspectives have constituted the driving ethos of this vision and are the overarching strands of the School's strategy, influencing our staffing decisions, research directions and investments, and informing our estates developments.

The University of Glasgow identifies its cross-University research strengths as Research Beacons. The School's research contributes significantly to three of these beacons, Nano & Quantum World, Future Life, and Precision Medicine, through our leadership and engagement with EPSRC Quantum Hubs and the JWNC, and through research excellence in our challenge-led technology themes, including close research interfaces with medicine and life sciences. The School also increasingly contributes to a fourth beacon (Addressing Inequalities) through our growing leadership and volume of GCRF projects with partners in developing countries (see Section 3.2).

The School has been the University's vanguard of Trans-National Education (TNE) and collaboration, now with two successful established engineering partnerships, with the University of Electronic Science & Technology of China (UESTC) in Chengdu and Singapore Institute of Technology (SIT). Academic staff supporting TNE at UESTC are domiciled in Glasgow, enabling us to grow the School's research base, particularly driving a new research direction in Communications. Consequently, we launched a new international centre for doctoral training in partnership with UESTC (see Section 4.1). We have partnered with the Economic Development Board (EDB) Singapore to fund PhD research on Industrial Project Placements with companies in Singapore, for example with Sembcorp Marine where the PhD outcome of a hybrid ultrasonic technology is now under development for ballast treatment.

1.3.3 Impact Strategy and Achievements

Recognising a weakness in the breadth of our pipeline from research discovery to industrial impact in REF 2014, our aim has been to develop a culture of building impact into all our research activities. We facilitate impact opportunities by engaging widely with external partners, especially industry and the NHS, and supporting these links with targeted investments. An example is our research in 5G which, through engagement with Vodafone, Cisco and BT and our targeted investments in staff, enabled engagement with the Scottish Government and ultimately the creation of The Scotland 5G Centre. An important enabler has also been to increase and improve public engagement, to ensure our research is widely communicated and connects with society (see Section 4.3.4).

Success is evidenced by our increased industry funding (by 149%); five new spin-outs (Acu-Flow, III-V EPI, Multicorder Dx, Thermoelectric Conversion Systems, Vector Photonics); increased number of projects with industry direct cash funding on grants (by 60 not including CDTs); and the £511k of direct funding to our CDTs so far.

To deliver our impact strategy we use our resource to create an impact-supporting environment:

- A new role of Impact Champion (**Kelly**) was created to support and manage impact across the School and link with College resources, including Business Development Managers (BDMs), Impact Acceleration Awards and Impact Associates.
- An impact pipeline has been established to identify emerging impact from grants and contracts and ensure investment and support are put in place to maximise the timely effectiveness of the impact.
- Challenge Champions have been appointed to lead on creating opportunities for impact from our challenge-led areas in Quantum & Nano (**Weides**), Healthcare (**Reboud**) and Zero Carbon (**Yu**) Technologies.

- An Entrepreneur Club is run by academic staff experienced in entrepreneurship, working alongside the Adam Smith Business School and our College BDMs. Events are designed to build familiarity with business ideas, potential products, fund raising and company formation.
- External Engagement workshops are run regularly to share our experiences of working with industry and coordinate our management of key partners.
- We proactively seek applications for entrepreneurial funding, including Enterprise Fellowships, the Innovation to Commercialisation of University Research programme (iCURE) and venture capital, and we link applicants with all the University's supporting functions. Our successful applicants run workshops to share their experience.

The University and College support the School with dedicated professional staff:

- A BDM (**McCorriston**) is assigned to the School, with recent additional expertise gained through her secondment to EPSRC in 1919/20, working on the impact agenda.
- A Doctoral Training Hub Manager (**Hughes**) supports and coordinates all the CDTs, also sharing best practice.
- The Head of College Research Support (**Harkness**) works with the School to manage strategic partnership accounts (e.g. Leonardo).
- **Toma** was appointed as BDM to support JWNC and develop new strategic partnerships.
- Cross-College roles include **Diegoli** in support of the QT Hub, QuantIC.
- Research and Innovations Services provide support for contracts, IP and spin-out.
- We support training for STEM Ambassadors and outreach through our Public and Community Engagement Advisers.

The Research Support Team provide significant management and support for major funding bids, including EPSRC Centres for Doctoral Training (CDTs). We now lead 2 new CDTs and are partners in 3 others, creating a total of 95 new industry partnerships. The College has also made strategic use of UKRI Impact Acceleration funds to appoint Impact Associates, PhD-qualified and active in key technical areas in ICT Devices, Biotechnology, and 5G. Impact Associates also support large projects, e.g. The Scotland 5G Centre.

1.4 Achievement of Strategic Aims from REF2014

Our REF2014 submission set out 5 strategic aims that have been major drivers of our research strategy. The size of the School has changed significantly in the intervening years. Growth has delivered rapid changes in research directions, reflecting new national and international funding priorities as well as serendipitous opportunities. Our solid foundation of management via thematic research has allowed us to institute a dynamic and responsive approach, that readily adapts to change and new opportunities. Our achievements against our aims are introduced here and described more fully in Sections 2, 3 and 4.

Develop a large cohort of ECSRs into future research leaders. We have appointed 59 new academic staff at ECSR (Lecturer) grades, with current ECR staff making up 24% of the academic pool. 100% of eligible ECSRs have met the promotion criteria of the Early Career Development Programme (ECDP), with 58% fast-tracked, through effective mentoring, support and research leadership development (See Section 2.5).

Capitalise on SFC and University initiatives in the areas of sensors, energy and healthcare. Our aim was to build on the School's pivotal role in the funding in 2013 of CENSIS (Scotland's Innovation Centre for Sensing, Imaging and Internet of Things), which the University leads. As a result, we developed our three challenge-led areas, particularly through targeted professorial appointments in: Healthcare (**Gourdon**, biomaterials, **Steinmann**, computational engineering); Quantum & Nano (**Weides**, quantum circuits, **Badolato**, photonic quantum technologies, **Hogg**, photonics); and Zero Carbon (**Falcone**, energy, **Barakos**, computational fluid dynamics) Technologies. The School's partnership in all 4 EPSRC QT Hubs is underpinned by JWNC and CENSIS.

Develop centres of excellence in our priority areas. This led to the formation of three new Research Centres plus the existing ESDC. The Centres all lead large and diverse grant portfolios (GCEC £3M, C-MIU £14M, CeMi £15M). GCEC was established through an EPSRC strategic support package and Wolfson Merit Award to attract **Steinmann**, and an RAEng EDF Energy

Research Chair (**Pearce**). C-MIU and CeMi are leading EPSRC Programme Grants (**Lucas**, **Salmeron-Sanchez** respectively) and EPSRC CDTs (FUSE **Cochran**, and lifETIME **Salmeron-Sanchez**) (See Section 3.5).

Lead new strategic initiatives around broad technology platforms. This led to the uniting of our research strengths around our three thematic challenge-led areas, driving technology innovations in Healthcare, Quantum & Nano and Zero Carbon Technologies (see Section 3.6).

We also played a leading and strategic role in the UK National Quantum Technologies Programme (NQTP), contributing to the strategic document, and subsequently leading one of the 4 QT Hubs (QuantIC). We are now a partner in all 4 QT Hubs, following funding for phase 2 after the Blackett Review to which we contributed.

The School rapidly established critical mass in communications research through growth of its partnership with UESTC, leading to funding of The Scotland 5G Centre and its rural innovation hubs (see Section 1.2).

Maintain and strengthen our leading position in nanotechnology, including the James Watt Nanofabrication Centre. The University has made significant investments to enhance the world-leading position of the JWNC and its dependent activities, including Quantum Technology. Major Capital Equipment awards of £9.73M from the UKQT programme, £2M EPSRC and £4.4M of estate investment by the University led to expansion of the clean room to allow for future capacity. We made new leadership appointments (**Weides**, **Hogg**, **Badolato**) and strategically co-located QT researchers, including from Physics (**Faccio**), in the School.

1.5 Future Research and Impact Plans

The School is now embarking on its next phase of expansion while moving to fewer, larger research teams (e.g. Centres) collaborating intensively and sharing laboratory facilities. We plan to use our thematic research challenges to link the Centres' and Divisions' cross-disciplinary research, providing an external interface to academic and industrial partners through their occupancy of the ARC. The School's forward strategy to 2025 is to grow our R&T academic staff complement to 165. Our immediate strategic aims are as follows:

JWNC diversification. The JWNC has been hugely successful at realising research in photonics, QT and electronic devices, and now needs to build capability in 3-D heterogeneous integration to enable transformative research in Quantum Systems and Architecture. It will also underpin a new generation of activities aligned with investments in capability to support Healthcare and Zero Carbon Technologies.

Healthcare Technologies. New posts will build on existing strengths to permit greater cross-Division interactions. Committed investments will further strengthen and extend interfaces with the clinical and life sciences, including the planned co-location of key research areas in the University's new ARC and through a strategic partnership with the NHS Medical Devices Unit.

Robotics and Autonomous Systems. By combining emerging strengths in the Schools of Engineering and Computing Science, we will grow complementary capacity and capability, to establish a partnership in robotics and autonomous systems, investing in new staff and facilities to build a new cross-College Centre.

Staffing. We will recruit high quality leaders and ECSR staff to grow our priority areas. We will further improve the effectiveness of our recruitment processes, aiming to continue to enhance the diversity of our talent pool (see also Section 2.3).

Income. In the current REF period, we have significantly increased the number of PIs across the School (see Section 3.1). We are now focusing on supporting more staff to apply for larger collaborative grants to enhance both the research volume and inclusivity.

Impact. Recognising the positive influence strategic partnerships have already had on the impact of our research, we aim to build partnerships with a wider range of companies. We currently have strategic partnerships with companies including, Synopsys, Thales, Leonardo, M Squared Lasers, CST Global, Gas Sensing Solutions, Kelvin Nanotechnology, Cisco, EDF Energy and Stryker in key technology areas, for example, QT with Thales, computational modelling with EDF Energy

and ultrasonic technologies with Stryker. We aim to grow this number to at least 20 in the next REF period.

Enhance existing academic strengths. We will further grow Quantum & Nano, Healthcare and Zero Carbon Technologies, to define new innovative technology platforms. We will support the emergence of new Centres of Excellence, particularly in Communications, Energy & Sustainability, and Robotics & Autonomous Systems.

Spin-out and impact. We will extend the management of our impact pipeline to identify more spin-out opportunities from our research and develop a strategy to make investments that target emerging entrepreneurs (see also Section 1.3.3).

Further grow our international stakeholder engagement through GCRF. We have seen significant success in GRCF funded projects being led by the School. Our plans for sustaining partnerships and impact are described in Section 3.2.2.

2. People

2.1 Overview

The School brings together a globally diverse academic community of 119.24 FTE REF returned staff from 25 countries. 40% are UK nationals with 31% from the EU, 23% from Asia, 3% from Africa and 2% from the Americas, achieving a balanced and effective research capability. Over the REF period our researcher community of post-doctoral staff have hailed from 50 countries and our current PGR student profile is 31% home/EU and 69% international. 24% of our staff and 45% of our PGR students are BAME. In the REF period we have recruited internationally, e.g. senior staff from CNR Genova (**Vassalli**), University of Ottawa (**Gourdon**), Cornell (**Badolato**), Karlsruhe (**Weides**), Masdar Abu Dhabi (**Kumar**) and City University Hong Kong (**Vellaisamy**). An important driver is to increase the number of women at all grades/career stages. Currently women constitute 13% of our academic staff (14% of professors), 22% of post-doctoral researchers and 30% of PGR students.

2.2 Equality, Diversity & Inclusion (EDI)

The School's Equality, Diversity and Inclusion Group (EDIG) (co-chairs **Smith**, **Goldie**) remit is to develop and implement our strategy for EDI, including the Athena SWAN principles, and reports to the School Executive Group. EDIG works to embed EDI within the School under five themes of professional development; culture; outreach; data analysis; and communications.

Rowntree Fellowships – Gauchotte-Lindsay

The School awarded a Rowntree Fellowship to **Gauchotte-Lindsay**. The funding was used to appoint a PDRA for the 8 months of her maternity leave plus an additional 4 months on her return to work. This ensured continuity of her research and a subsequent rapid re-establishment of research projects, outputs and grant applications. She was immediately supported and mentored through the promotion process to a successful application 6 months after returning to work.

Our EDI Action Plan, which formed the basis of our Athena SWAN Bronze award, especially recognises the challenges of under-representation of women in engineering. The plan was formed through wide consultation within the School and drives initiatives beyond a focus on gender, including in recruitment and advertising, flexible working, career development, career breaks and supporting ECSRs. In response to this consultation, the School has run poster and workshop campaigns to highlight issues of bullying, harassment, sexism and racism in the workplace. Here we highlight 3 of the School's EDI initiatives:

Rowntree Fellowships. The School offers an enhanced funding package, additional to the College Academic Returners Scheme provision of up to £10k support. We add a further £10k for staff in the first year of returning from maternity, paternity, adoption or shared parental leave who are resuming independent research activities. Funding is flexible, including for conferences, hiring PDRAs and teaching support. Rowntree Fellowships (named after the School's first female graduate) aim to address the impact of the parental leave and can be accessed before, during or after the career break.

visNET – inclusion through collaborative technology. The School leads the EPSRC funded Inclusion Matters project (visNET, EP/S012079/1), to remodel the implicit rules of networking and collaboration, particularly addressing the barriers to international travel at key career stages by innovative use of collaborative digital technology. visNET supported a leadership programme for 30 female postdoctoral researchers, including 10 from our School. Training, coaching and peer-mentoring, to develop online visibility and networks, culminated in academic-industry engagement events. Three of the School's participating PDRAs secured academic positions during this training (e.g. **Vignola** won an RAEng Fellowship and was appointed to a Lecturer post).

Opening up Photonics (OuP). OuP is an initiative driven by our research strength in this field and was co-created in 2018 by a Knowledge Exchange Associate (**Annand**) and Technology Scotland. OuP is a platform for photonics professionals to discuss the future of photonics in the UK and is supported by IoP and the Knowledge Transfer Network (KTN). As a result of its work celebrating female successes and understanding particular gender equality challenges in the photonics community, OuP has now partnered with Equate Scotland to deliver a series of training workshops exploring gender diversity in all organisations.

The School is supported in its EDI work by the University's Equality Unit that provides training to create an environment free from discrimination and unfair treatment. Staff in the School take mandatory training courses, including: Equality and Diversity Essentials; Understanding Unconscious Bias; and Implementing Reasonable Adjustments.

2.3 Staffing Strategy

The School's staffing strategy stems from its research strategy (as described in Section 1.3.2), which has aimed to grow the size of the School to increase our capacity and research quality and to better respond to societal challenges. Since 2014 we have increased our FTE academic staff by 47%. We have also focused on increasing the research income per FTE. Thus, income growth has been a key mechanism to support sustainable staff growth. Success is evidenced by our increase in income per FTE of 29% (see Section 3). Staff appointments have been focused on recruiting ECSRs while also bringing new leadership into the key areas described. We grew capacity and capability in areas that strengthened our Research Divisions, enabled emergence of our new Research Centres, and built on our strengths in cross-cutting, challenge-led technologies. Our major strategic staffing interventions are outlined below.

Quantum & Nano Technology. Two leadership appointments in QT further enhanced our position in the UK and internationally. Our strength builds on more than three decades of excellence in micro- and nanofabrication, delivered through our JWNC. The School is an integral partner in the UK's QT strategy and with the appointment of **Weides**, in quantum computing, we are now an active partner in all 4 QT Hubs. A further appointment, **Badalato**, is consolidating strength in optical nanostructures and single photon sources. **Thayne** and **Sorel** are delivering impact through CO_2 sensor development (see ICS).

Biomedical Engineering. We have strengthened the BME Research Division through appointments across all grades, **Vassalli** (Reader), **Cantini** and **Jimenez** (ECSR proleptic posts, MRC and RAEng Fellowships respectively), **Gourdon** (Professor), particularly to reinforce research at the life sciences interface where research is delivering 3 ICSs led by **Cooper**, **Reboud**, and **Yin**.

Computational Engineering. The School identified a risk to the UK's historic strength in computational engineering and, following discussions with EPSRC, a strategic package was awarded (EP/R008531/1) to support the appointment of **Steinmann.** This subsequently underpinned the formation of the Glasgow Computational Engineering Centre (GCEC) (see Section 3.5) and led to investment in 3 new ECSR posts (**Aggarwal**, **Lee**, **Saxena**).

Zero Carbon Technologies. **Falcone** was appointed to the Rankine Chair in Energy Engineering, consolidating an existing strength in thermal energy, which has since grown by 2 internal professorial promotions (**Yu** and **Paul**). This area is influencing internationally through **Falcone**

chairing the United Nations Economics Commission for Europe on geothermal energy. Water engineering is another strength, playing an increasing international role through GCRF projects. This trajectory was supported by the appointment of **Smith** as Senior Lecturer, promoted to professor in 2019, working closely with Scottish Water.

Aerospace Sciences. We have continued to build critical mass, including in our infrastructure and equipment co-located at the site of the National Wind Tunnel Facility. Leadership (**Barakos**) and ECSR (**Steijl**) appointments enhanced our strength in computational fluid dynamics, forming the basis for an ICS. Recruitment has also focused on growing cross-Division research in space and exploration technologies through a leadership appointment to the James Watt Chair (**McInnes**), now holding an RAEng Chair in Emerging Space Technologies and ERC Advanced Grant, and ECSR appointments (**Worrall**, **Grustan-Gutierrez**, **Fotouhi)**.

Communications, Sensing & Imaging (CSI) group. Huge growth in communications research in the School has been achieved, and investments in building the CSI group has been enabled by strategic focusing of our UESTC TNE recruitment in this field. The School has long-standing excellence in communication technologies, for example in device technologies for optical communication, which forms the basis of an ICS led by **Kelly**. Our recruitment drive in 5G, initially through a leadership appointment, (**Imran**), resulted in rapid growth of a large team of 30 early and mid-career academics in this field. The academics, spanning next generation communications technology and applications, are now formed as a strong CSI group, a key factor in the emergence of The Scotland 5G Centre and new GCRF funded international partnerships in 5G (see Section 3.2).

Materials & Manufacturing. In 2019 the School saw an opportunity to strengthen research in materials engineering by uniting research across the Divisions, developing critical mass and investing in new capability. The strategy aimed to better align research with manufacturing, identified as a growth area driven by the UK national strategy ISCF (transforming construction, manufacturing, and future materials) as well as the Scottish Government initiative in Advanced Manufacturing. Investment in a new Additive Manufacturing laboratory established a 3D printing facility for new research across construction materials, composites, metals and biomaterials (**Kumar**, **Unluer**, **Li**). This also developed complementary experimental research to align with and strengthen GCEC. As well as investing in co-locating infrastructure, 5 new appointments were made in this area.

The staffing strategy has played an important role in increasing our research capacity and hence research quality and impact in the areas where we address societal challenges in Healthcare, Quantum & Nano and Zero Carbon Technologies. Importantly, we also have a significant increase in more ambitious grant applications (resulting in 32 awards >£2M) and in our research income per FTE (increased by 25%), which have been crucial in our endeavour to create advanced and well equipped laboratories and facilities in support of our new staff (see Section 3.3).

2.4 Recruitment Strategy

The School operates a transparent recruitment process for academic posts at all grades. With a focus on recruiting ECSRs, we have developed our EDI action plan to attract applicants from a diverse talent pool. We proactively identify talented researchers internationally and also potential female applicants. The proportion of female academic staff in the School is 13%, which is just above the UK average of 12.4% for Women in Engineering (www.wes.org.uk/content/wesstatistics). We changed our recruitment processes so that staff in the related research field engage with potential applicants in their international networks and we make targeted invitations to visit the School and give research seminars, especially to female researchers. Where recruitment agencies are used for leadership appointments, there is an agreed expectation of diversity in the candidates brought forward for shortlisting. We fund visits for immediate family members and engage agencies to explore partner career opportunities, places to live and schools if required. In the REF period, the School has recruited 24 female academics; 2 Professors, 4 Senior Lecturers/Readers, 14 Lecturers and 4 Fellows. In 2020, 3 offers for 7 new posts were made to women.

Research staff with competitively funded research fellowships (e.g. EPSRC, RAEng, Leverhulme, plus the University's Lord Kelvin Adam Smith Fellowships) are interviewed for an open-ended

contract during their fellowship. In the REF period we have appointed 5 fellowship holders through this process.

International recruitment. The School has created a supportive environment for our international staff, leading the Russell Group (RG) in best recruitment practice (**Table 1**). For example, we pay the full costs of visa applications (50% of the RG does not) and the Immigration Health Surcharge (90% of RG does not) for all newly appointed staff and for dependent family members through the relocation allowance (80% of the RG does not).

Table 1. Supporting our international staff

From: "Challenges and costs of the UK immigration system for Russell Group universities", 2019					
	Russell Group Universities				JW School of Engineering
Fees paid for or reimbursed	**Paid**	**Not paid**	**Sometimes**	**Partially reimbursed**	
Visa application fees (Tier 2)	50%	30%	10%	10%	Paid
Immigration Health Surcharge (IHS) (Tier 2)	10%	70%	10%	10%	Paid
Dependent family members	0%	80%	5%	15%	Paid through relocation fund
Indefinite Leave to Remain	20%	65%	10%	5%	Interest-free loan arranged
Other visa applications	35%	55%	5%	5%	Paid for Tier 1

2.5 Staff Development

The School provides a structured programme of training opportunities for staff at all levels. These are predominantly provided through HR Employee and Organisational Development and take the form of instructor-led sessions as well as on-line tools. There is a range of mandatory courses which cover; Health, Safety & Wellbeing, General Data Protection Regulation, Equality & Diversity, Recruitment & Selection. Further courses provide training in managing people, difficult situations, communication skills and networking, plus a range of IT courses. The outcomes are discussed during the annual Performance & Development Review (P&DR), where staff are supported to consider their Continuous Professional Development.

2.5.1 Early Career Development Programme (ECDP)

Supporting ECRs – Accelerated Promotion

Lavery (Professor of Structured Photonics) joined the School in 2014 immediately following his PhD, as holder of an EPSRC Doctoral Prize and RAEng Research Fellowship. Fast-tracked through ECDP, he was promoted to Senior Lecturer in 2018 and Professor in 2020. In 6 years he has won >£5M in funding as PI, is coordinator of the H2020 FET-Open, Super Pixels, and leads an EPSRC GCRF project road-mapping deployment of high speed networks in developing countries. In 2018 he became the Mobile World Scholar Gold Medal winner and was awarded the Royal Society of Edinburgh Makdougall Brisbane Medal in 2019.

All ECSR academic staff join the University's dedicated ECDP, a framework to support and develop academics to deliver research excellence, responsibly and with integrity, and a learning environment covering all aspects of the academic role. Importantly, the research component of the programme includes grant writing workshops supported by highly experienced staff in the School and College. The programme enables ECSR staff to meet the criteria for promotion to Senior Lecturer within a defined timescale (intermediate Lecturer grade within 3 years, Senior Lecturer grade within 5 or 7 years, depending on the starting grade). It also provides a fast-track career advancement route for rising stars.

- To date, 100% of eligible ECSR staff have achieved promotion and 58% have achieved accelerated promotions.

- We provide mentorship, where ECSRs are paired with senior staff, typically outside their immediate research field, providing a broader integration and diverse perspectives.
- We have leveraged four additional ECSR appointments through the University's Lord Kelvin Adam Smith (LKAS) Fellowship programme (a fully funded tenure-track three-year post, focussed on an ambitious research programme in one of our priority areas).
- We have a College-wide programme of targeted support to develop ECSR skills, including grant application writing, partner engagement and interview training. 71% of our current ECSRs hold a grant, including 8 Fellowships, with 56% holding UKRI grants.

2.5.2 Additional Support for ECRs

Supporting and developing our ECRs to become successful researchers and future research leaders was a primary objective of our REF2014 future strategy. Since then, we have appointed 59 new academic staff at Lecturer grades. ECR staff currently make up 24% of academic staff.

The School provides every ECR with a minimum start-up package of a PhD studentship and £10k. The College provides additional funding, including through strategic equipment funding (supported by EPSRC), where ECRs can bid for equipment from £25 to £50k. Examples include a Surface Profilometer (**Mulvihill**) and a Differential Scanning Calorimeter (**Cantini**), in both cases enhancing successful bids for external funding.

We have encouraged diversification in funding, particularly focused on supporting applications from ECRs, via charities, e.g. Leverhulme (**Clark**) and institutions, including The RS (**Connelly**), RSE (**Nazarzadeh**) and RAEng (**Jiminez**, **Tassieri**, **Middlemiss**, **Millar**). Our ECRs have also achieved significant success in GCRF, with 9 grants (£490k) as PI, evidencing the School's support of ECRs in building international partnerships in developing countries (see Section 3.2.2). We have also provided targeted BDM support for industry partnering to secure InnovateUK funding (e.g. **Nazarzadeh**, **Casaburi**, **Childs**, **Li**).

2.5.3 Developing Leaders

The School invests in long-term leadership development of staff with the strongest career trajectories, including through the University's Academic Leadership Programme (e.g. **Lucas, Salmeron-Sanchez**, **Pearce**, **Cumming**) and Aspiring Leaders Development Programme (e.g. **Smith**, **Reboud**) with formal training by external consultants and dedicated coaching. In the REF period our academic staff have been University Vice-Principals (**Cooper**, **Pearce**) and College Deans (**Cumming**, **Cooper**, **Pearce**, **Davies**). ECRs on a strong trajectory are put forward for the RSE Scottish Crucible (**Childs**, **Neale**, **Moran**, **Tassieri**, **Clark**, **Gauchotte-Lindsay**, **Valyrakis**, **Jiminez**, **Couto**) and Aurora (**Escorcia-Carranza**, **Keating**) leadership programmes.

We also work with external consultant Dr David Fraser (drdavidfraser.com), who provides support for strategic management and individual staff coaching (of 22 academic staff to-date). He also helps us to deliver effective School leadership, and identify and accelerate leadership potential of academic staff. He also delivers a range of external engagement workshops in the School, helping us to build impact into the development of research leaders.

2.5.4 Post-Doctoral Staff Development

In 2020, 2 of the University's 4 Research Culture awards were won by staff in the School for their outstanding work to support PDRAs, particularly supporting their career development (**Gauchotte-Lindsay**) and for motivating researchers, sharing networks and encouraging diversity (**Imran**), where more than 60% of the CSI group he leads are BAME.

Recognising the critical transition from post-doctoral level to independent researcher, the School initiated a scheme to work directly with candidates to develop bids for externally funded fellowships. Since 2015, 35 PDRAs have taken part in the scheme. This has led to 10 successful fellowships (6 male and 4 female) and 6 lectureships (3 male and 3 female). We have supported PDRAs via visNET, to understand and mitigate against the barriers for women's networking (see Section 2.2).

Additionally, the School supports PDRAs with a process of local mentorship outwith their formal supervisory line-management, whereby experienced senior staff provide independent career advice. PDRAs who are applying for academic or entrepreneurial fellowships are supported with

specialist training offered by the School on developing their proposals (see Section 2.5.6). The School encourages mobility opportunities, especially for overseas laboratory/research experiences, through the Scottish Research Partnership in Engineering (SRPe) Postdoctoral and Early Career Researcher Exchange (PECRE) awards (**Timoney**, **Yang**, **Cui**, **Ali Nasri**).

The University also has a dedicated Researcher Development team and structure, focused on PDRA development. Programmes include monthly Careers Lunches, an annual Research Conference, leadership development through the Glasgow Crucible and a wide range of courses including personal development, research governance, impact, networks and CPD.

2.5.5 Promotion

The School supports its staff to achieve their academic career goals. Annual Performance & Development Review (P&DR) allows staff to set individual targets and discuss career planning. The annual promotion application process starts with promotion workshops, delivered by HR and the Head of School. Heads of Research Division then have individual discussions with staff regarding their readiness for promotion and encourage staff to identify where they have met or nearly meet promotion criteria. This process has been very successful with an overall promotion success rate of 84% across all grades. In particular, this proactive approach has resulted in more applications from women. It is notable in **Table 2**, that at grade 7/8 the success rate for female staff is higher than for male staff and that they make up 17% of promotions, which is above the gender ratio in the School. At professorial level 2 out of 9 applications and successful promotions were from women, who now make up 14% of the School's professoriate.

Table 2. Academic staff promoted in REF period

Grade		Female		Male		Overall
		No.	**%**	**No.**	**%**	**No**
Grade 7 Lecturer	Apps	5	14%	31	86%	36
	Promoted	**100%**		**97%**		**97%**
Grade 8 Lecturer	Apps	7	18%	31	82%	38
	Promoted	**100%**		**87%**		**88%**
Grade 9 Senior Lecturer	Apps	4	13%	26	87%	30
	Promoted	**100%**		**85%**		**81%**
Grade 9 Reader	Apps	2	18%	9	82%	11
	Promoted	**0%**		**63%**		**50%**
Grade 10 Professor	Apps	2	17%	10	83%	12
	Promoted	**100%**		**70%**		**75%**
Overall	Apps	20	16%	107	84%	127
	Promoted	**90%**		**86%**		**84%**

2.5.6 Entrepreneurial Support and Development

The School aims to increase entrepreneurial activity from research and support PGRs and PDRAs to pursue an entrepreneurial career path. For example, **Nazarzadeh** was awarded an RSE Unlocking Ambition Fellowship to take nebuliser technology to market, and in 2019 won the Higgs EDGE Award for entrepreneurship. Our staff have been directly involved in entrepreneurial activities, including spin-out companies, some of which are ICSs (see also Sections 1.3.3 and 4.3.2). They also deliver workshops for staff and PGRs to highlight how they turned showcase research innovation into commercial success. We have seen success through, for example, the Innovation to Commercialisation of University Research programme (iCURE) (**Taylor**), RAEng Enterprise Fellowship (**Siviter**), UKRI Innovation Fellowships (**Clerici, Georgiev**), KTPs (**Yin**, **Kelly**, **Sorel**, **Thayne**, **Salmeron-Sanchez**, **Hogg**) and industry secondments (**Kelly**, **Yu**, **Anderson**, **Giorgiev**, **Ceriotti**) (more details in Section 4). The University organises 2 annual

external engagement focused workshops: Building External Relationships, which supports industry and external partner engagement; and KE, IP & Commercialisation with input from industries, entrepreneurs and academics who have been involved in spin-outs. This has been particularly instructive for academic staff recruited (at all grades) from overseas.

2.6 Post-Graduate Research Students

PGRs are integral to the research environment in the School. They are the emerging ECRs of the future, capable and able to advance their own distinctive research contributions, intellectually and with impact. PGRs are key drivers of the overall research culture of the School, creating the character of research teams. Their training and research results are crucial to the advancement and standing of the School and their skills development is key to ensuring their post-graduation employment in diverse engineering sectors. The structure and training embedded within our 5 EPSRC funded CDTs are made available to the whole cohort of our PGRs.

In the REF period we have awarded 345 doctoral degrees, increasing from 37 at the start of the REF period (2013/14) to 61 in 2019/20. We strongly support diversity and work proactively to increase the gender balance across our PGR cohort, including PGR membership of EDIG. We have found that offering cross-disciplinary challenge-led projects focused around healthcare technologies and the environment, has enabled us to increase the proportion of female applicants. Currently 30% of our PGR students are women.

2.6.1 PGR Growth

In 2014, the School set a target to increase the PGR/staff ratio to 3.0 over a 10-year period, which has seen an increase from 2.4 to 3.7. Exceeding our target relied on our growth strategy delivering an enhanced research talent base, focusing our research leadership and strength in Centres and challenge-led themes, and hence increasing our research income per FTE. The resulting increase in EPSRC awards converted into an increase in UKRI studentships (140 since 2014 with 35 of those in 2020). We have led and been partners in 5 EPSRC CDTs during the REF period (LifeTime, FUSE, Intelligent Sensing and Measurement, Applied Photonics, PIADS) plus 3 Horizon2020 Innovative Training Networks (ITNs). Two new doctoral training centres have been established in 2020 with our partners in China (see Section 4.1).

We have increased our PGR headcount from 210 (65% international) to 443 (69% international). As a result of our strategy to increase our industry funding and engagement, part of this success has been through industry funded PhDs which have increased from 6 to 20. Notably (**Table 3**), there has been a substantial increase in recruitment, particularly as a result of success of our new research leaders and ECRs attracting more PhD candidates and our enhanced international reputation, especially attracting self-funded international students, plus our new CDT cohorts.

Table 3. PGR growth

HESA year	PGR No.
2013/14	210
2014/15	256
2015/16	286
2016/17	310
2017/18	348
2018/19	421
2019/20	443

2.6.2 Supervision, Progress and Support Mechanisms

In the REF period we have implemented a PGR strategy (led by **Sorel**). Two areas of focus have been submission rates and researcher mobility experiences. We increased the 4-year submission rate by developing a culture and expectation towards meeting submission deadlines, more careful annual monitoring of student progress and remedial actions with timely interventions and

mentoring, and a tighter selection process. We have achieved a significant improvement in student satisfaction and a steady increase in our 4-year completion rates from ~46% (students who started in 2010) to ~70% (students who started in 2014) and this continues to rise.

We support incoming and outgoing mobility scholarships, including through the Scottish Research Partnership in Engineering (SRPe) scheme, participation in international programmes (e.g. The Royal Society, British Council, JSPS) and through the College Mobility Fund (funded >50), as well as providing placements at partners though our international funded research collaborations. PGRs are visiting researchers in external HEIs each year, often at top universities across the globe (including Yale, UCLA, Caltech, Cornell, University of Rome, McGill, UESTC, Tokyo Institute of Technology, University of Hong Kong) and we welcome on average 37 PGR visiting researchers each year. This adds to our international reach, fosters and strengthens supervisor collaborations and gives students a valuable independent research experience.

Appreciating that unforeseen factors can influence PhDs, such as illness or unexpected departure of a supervisor, we have established a hardship fund of 5% of the total PGR costs (student stipend and fees). We support non-UKRI funded students to take extended maternity leave (6 months) from this fund. Non-UKRI PGR students have also benefited from PhD funding extensions during the Covid-19 pandemic via a Scottish Government support package.

Research groups and Centres provide leadership roles for PGRs, for example in organising seminar programmes, equipment training for more junior PGRs, and leading on initiatives such as maintaining laboratory booking systems and equipment loans. The School has a strong culture of groups and Centres working in shared laboratory spaces and shared office spaces to develop cohort identity. The JWNC additionally offers extensive training for all PGRs whose research can benefit from developing nanofabrication skills. The School trains all PGRs as Graduate Teaching Assistants, developing their skills in supporting the academic development of our undergraduate students. We also support students' growth and ambition beyond their PhD. For example, substantial mentoring from the School supported **Millar**, **Jiminez** and **Middlemiss** in being awarded RAEng Research Fellowships.

Our PGR students are members of the College of Science & Engineering Graduate School, providing a strong environment for co-learning and training across disciplines. Good supervisor practice is fundamental to the success of PGR training and the Graduate School delivers PGR Supervisor Development courses, with a particular focus on first-time supervisors. The Graduate School PGR training programme includes mandatory components in responsible research and innovation, integrity, ethics, data management and good practice. Elective components include career preparation courses, entrepreneurial training and communication skills, plus training and opportunities in public engagement (see Section 4.3.4).

3. Income, Infrastructure and Facilities

3.1 Research Income and Awards

The School's growth strategy has enhanced the intellectual vitality of our research environment. As a result of building capacity in our Divisions, creating new Centres and uniting our research strengths in challenge-led technology areas, we have both increased and diversified our research income. We have increased the number and percentage of larger collaborative grants and the number of staff holding grants. In 2014 70% of grant income was held by 11% of our staff and 72% of R&T staff held grants, whereas in 2020, as a direct outcome of our strategy and thematic structure, the respective values are 70% held by 19% and 74% holding a grant.

During the assessment period, we have won 660 awards. These represent an increase in our income (**Fig. 3**) over the assessment period from £42.2M reported to REF2014 to £104M and an increase in average income per FTE per annum from £100k to £125k (see also **Fig. 2**). 2019/20 has been an outstanding year for research awards in the School, totalling over £25M, with our current operating research portfolio now over £100M.

Diversification of research income has also been achieved (**Fig. 4**). By embedding mentoring for grant writing and reviewing in the Research Divisions (supporting the training of the ECDP), ECRs

have been very successful at winning grants (e.g. EPSRC NIA, **Gonzalez-Garcia**, **Zhang**) and Fellowships (e.g. RAEng Research Fellowships, see Section 4.1).

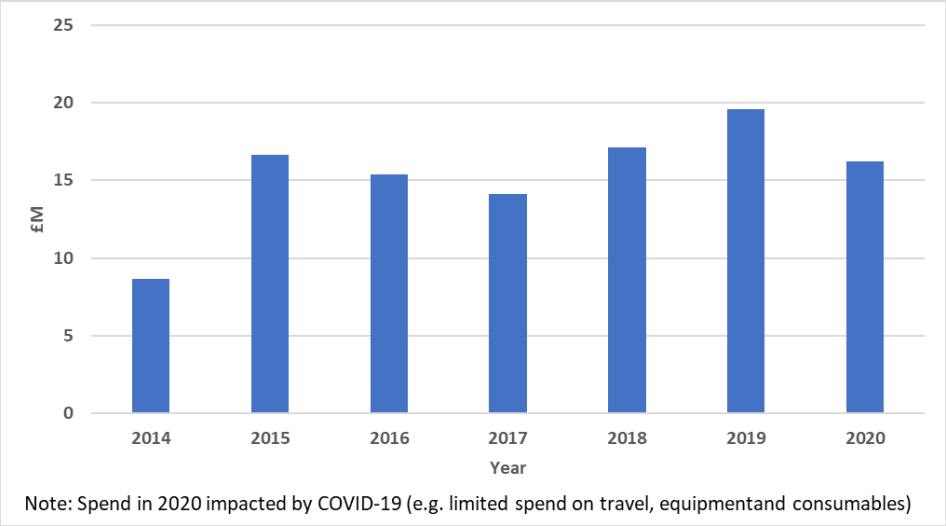

Figure 3. School of Engineering income in REF period

Our senior staff are leading more large grants (e.g. EPSRC Programmes, see Section 3.2.1). The rise in EU funding has resulted from our investment in supporting staff to build and join consortia, as well as targeting and supporting staff to pursue ERC awards, with the University EU Office providing additional training and expertise. Thus, we have been successful in ERC, H2020, H2020 FET Open and ITNs. We have increased charity funding and industry funding, assisted by our external engagement initiatives, including support to enhance, manage and leverage external relationships provided by our external consultant (Dr David Fraser) (more in Sections 1.3 and 2.5).

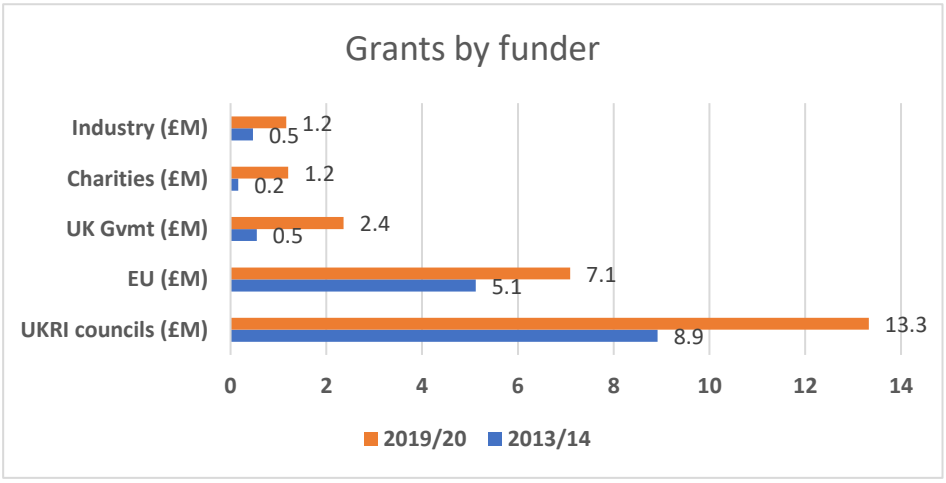

Figure 4. Grants awarded by funder (in year)

3.2 Research Grant Portfolio

3.2.1 Large and Significant Awards

The School is playing a major role in the UK's Quantum Technology programme, primarily through our research excellence and innovation in QT devices delivered through the JWNC (the sole major cleanroom in the UKQT programme). We are a key player in all 4 QT hubs (**Cumming, Paul, Hadfield, Sorel**, **Weides**). In supporting and sustaining the JWNC's world-class facilities, the School successfully bid for an EPSRC equipment award for an electron beam lithography tool (£2M).

The School has led 7 EPSRC programme grants; Frontier Engineering in Synthetic Biology and Industrial Biotech (**Sloan**), GaN Power Electronics (**Thayne**), Sonopill (**Cochran**), Multicorder (**Cumming**), Engineering Growth Factor Microenvironments (**Salmeron-Sanchez**), Ultrasurge

(**Lucas**), and Transformative Healthcare Technologies 2050 in Quantum Imaging (**Cooper**). Five are/were hosted in Centres (ESDC, CeMi and C-MIU) and all seven are based in our challenge-led areas, demonstrating our success in investing in our strengths. We are Co-Is on a further 6 EPSRC programme grants, with participation from **Yin** and **McGinty** (SofTMech), **Dahiya** (Hetero-print), **Paul** (Engineering Photonic QT), **Paul** (SPEXS), **Imran** (COG-MHEAR) and **Gollee** (Closed-Loop Data Science). **Salmeron-Sanchez** is also leading a major (£2.8M) Sir Bobby Charlton Foundation programme to develop bone regeneration for landmine victims.

Pearce received £2.4M as an EPSRC strategic support package to appoint **Steinmann** and establish the Glasgow Computational Engineering Centre, with a further EPSRC award (£1.2M) supporting predictive modelling of manufacturing processes.

Awarded individual fellowships demonstrate the high international reputation of the School. We have hosted 4 ERC Consolidator awards (**Hadfield**, **Gadegaard**, **Weides**, **Salmeron-Sanchez**). **Salmeron-Sanchez** has been awarded 2 ERC-PoCs to commercialise his bone technology following from his ERC Fellowship. Fellowships awarded during the REF period from EPSRC have been held by **Dahiya** (2 successive: Engineering Fellowships for Growth in Robotics, and an Innovation Fellowship) and **Paul** (QT Fellowship). Finally, **McInnes, Paul** and **Sloan** currently hold RAEng Chairs in Emerging Technologies and **Pearce** and **Smith** hold RAEng Research Chairs (others are reported in Sections 2.5.6 and 4.1).

Our target for growth of our PGR per FTE ratio (as described in Section 2.6) focused on supporting funding bids for cohort training. We are now leading 2 new CDTs (**Salmeron-Sanchez**, **Cochran**), are Co-Is in another 3, and lead 4 ITNs (**Franke, Wasige, Dahiya, Lavery**).

3.2.2 Global Challenges Research Fund (GCRF)

Strategic use of Block Grants – supporting GCRF

We engaged College BDMs to organise workshops with the College of Social Sciences around global sustainability themes. As an outcome, the School joined the Sustainable Futures in Africa (SFA) network, an interdisciplinary collective of academics, NGOs and practitioners across Uganda, Nigeria, Malawi and Botswana. Two further workshops (in 2017 and 2018) were organised in Lagos, Nigeria, hosted by Prof Ajayi, Deputy Vice Chancellor at the Technical University, and the School subsequently hosted Dr Pullanikkatil, Co-Director of SFA, for two months in 2018, enabling our academics, including ECRs, to establish strong links with African partners.

The School has been successful in winning 27 GCRF grants, totalling >£1.1M. Our focus on societal challenge-led areas, to unify our research around important technologies (as described in Section 3.4), has been a particularly strong platform for GCRF, with significant awards in Zero Carbon Technologies (>£2.5M) and Healthcare Technologies (>£2.2M). The School's success in attracting GCRF funding is already translating to impact and informing REF ICSs (e.g. Novel Low Cost Diagnostic Tools and their Impact in Africa, **Cooper**).

Our success in GCRF funding was facilitated by our EPSRC and Scottish Funding Council (SFC) block grants, as a catalyst to build collaborations. We awarded small grants to support new collaborative projects with ODA partners. Our strategy is to build future leaders in our challenge-led areas. We therefore proactively supported ECRs with applications to these funds, and through project initiation and network building in ODA countries. We have awarded seed funding to 8 ECRs, thereby extending our reach into Africa, Asia and South America.

3.2.3 Industry Funding

Industry funding has increased by 149% in the REF period, assisted by our support of developing InnovateUK applications. For example, the JWNC has enabled partnerships in 23 InnovateUK industrial projects of total value £37.5M (£4.3M income to the School). The School works with hundreds of companies, many directly funding and supporting UKRI and EU research projects, CDTs and/or research students. For example, activities in the communications sector remain strong with optoelectronics manufacturer CST Global (**Kelly**) and, more recently, our 5G communications research with Huawei and Vodafone (**Imran**). In 2019 we formed a new strategic partnership with Leonardo (**Cumming**). We have increased industry funding of PhDs (see Section 2.6.1) including with Teledyne Bowtech, Stryker, CST Global, Thales, Facebook Reality Labs,

BAE Systems, and Scottish Power Energy Networks. Gold Standard Simulations (**Asenov**), a School spin-out, has been acquired by Synopsys, the largest electronic design automation company in the semiconductor sector (see related ICS).

3.3 Infrastructure

Estate – Campus Development. The School plays a central role in the University's campus development plan, and staff drawn from 3 of our research strengths (QT, BME, and environmental engineering) will relocate to the new Advanced Research Centre which will open in 2022. Representing a £113M investment with capacity to house 600 academics, postdoctoral researchers and PGRs, it will create and support a highly collaborative environment to attract, stimulate and enable interdisciplinary research.

Estate – Laboratories and Workspace. The School has benefited from significant investment in its infrastructure during the assessment period with refurbishment of approximately 20% of its space, including labs and workspace. The School has invested £14.2M expanding and refurbishing its estate to accommodate the growth experienced in the past six years. BME labs and C-MIU labs have been refurbished to accommodate the growth in researchers and equipment. We have developed new Quantum Technology labs (**Weides**, **Hadfield**) and an Additive Manufacturing laboratory (**Unluer**, **Kumar**). In 2020 we have committed a further £3.35M to refurbish 1200 m^2 of new office space to create a modern and engaging environment for approximately 100 staff and researchers.

High Performance Computing. We have invested £550k in high performance computing (HPC) equipment in support of the School's strength in the Glasgow Computational Engineering Centre (GCEC), including for Computational Mechanics (**Pearce**, **Steinmann**) Device Modelling (**Asenov**) and Computational Fluid Dynamics (**Barakos**). The HPC facility consists of 5000 CPU cores and over 87600 CUDA cores in a mix of dedicated and shared resources available to all staff, supported by an HPC manager.

3.4 Major Facilities (also see Section 1.2)

3.4.1 James Watt Nanofabrication Centre (JWNC)

The JWNC houses £37M of nanofabrication tools in an 1800 m^2 clean room expanded by 1000 m^2 since REF2014. The JWNC delivers micro- and nano-fabrication to develop solutions for many of our research groups, including nanotechnology, optoelectronics, medical diagnostics and energy. The JWNC facility is at the interface of research discovery and manufacturing, providing a globally unique capability and environment. A significant investment (£16.13M) has been made for equipment to deliver Quantum Technologies. The facility houses 3 high-end electron-beam lithography tools, multiple photolithography systems, metal and dielectric depositions systems, a comprehensive plasma processing suite capable of processing silicon, III-Vs, diamond and superconductors, and an extensive complementary suite of metrology tools, all supported by 22 dedicated technical staff and 3 post-doctoral researches. This sets the JWNC apart as leading nanofabrication in the UK and widely recognised globally. The JWNC is operated as a major TRAC facility and, through an agreed CAPEX programme, follows a planned investment schedule, with approximately £1M per annum to replace and upgrade equipment. The JWNC also provides space for Kelvin Nanotechnology Ltd (KNT), the commercial arm of the facility. KNT is a School spin-out delivering commercial access to the JWNC and its expertise, providing advanced photonics and quantum components to more than 300 global companies and 100 academic institution customers, from micro-SME spin-out to global blue-chip corporations.

3.4.2 National Wind Tunnel and Aerospace Testing Facility

Experimental aerodynamics research is located in a bespoke building housing the deHavilland low-speed wind tunnel, a major facility for UK rotorcraft research and a component of the UK National Wind Tunnel Facility, funded by EPSRC and UK Aerodynamics (www.nwtf.ac.uk/) and accessible to the UK research community. An ATI funded rotor rig was created for the wind tunnel through the UK Vertical Lift Network and the facility supports grants including EPSRC Mentor, Innovate UK wind turbine and Jaguar Land Rover projects, and EU H2020 TailSurf with Airbus. Co-located experimental facilities include the AWE Multi-Phase Turbulence Shock Tube and the ESA/ESTEC funded Plume-Regolith Testing Facility (PRTF), one the seven ESA designated

strategic facilities, aligned with ESA's Robotic Exploration Programmes for missions including Mars Sample Return.

3.5 Research Centres (also see Section 1.1.3)

Centre for the Cellular Microenvironment (Directors: **Salmeron-Sanchez** (Engineering) and Dalby (Institute of Molecular Cell & Systems Biology)). CeMi spans engineering and life sciences to target research within the remit of lifelong health and wellbeing. CeMi is pioneering research in stem cell engineering, advanced functional biomaterials, bone tissue engineering and *in vitro* tissue models, and leads a number of flagship grants including EPSRC Programmes (Engineering growth factor microenvironments, and Quantum imaging for monitoring of wellbeing & disease in communities), Sir Bobby Charlton Foundation grant (Regenerative medicine technologies for the treatment of civilian blast injuries), ERC (Synergistic growth factor microenvironments for bone regeneration) and EPSRC CDT (lifETIME – Engineered tissues for discovery, industry and medicine).

Centre for Medical & Industrial Ultrasonics (Director: **Lucas**). C-MIU brings together research across the whole range of applications in ultrasonics, currently pioneering advances in ultrasound capsule endoscopy, interventional surgical devices, targeted drug delivery, and planetary, sub-sea and sub-glacial exploration tools. C-MIU has strong industry partnerships across sectors, reflecting ultrasonics' pervasive presence in technology, and collaborates closely with NHS clinicians. The centre leads an EPSRC Programme (Ultrasurge – Surgery enabled by ultrasonics) and CDT (FUSE – Future ultrasonic engineering). The CDT has consolidated a partnership with Strathclyde University's Centre for Ultrasonic Engineering, now forming the largest global centre for ultrasonics, based in Glasgow, the birthplace of medical ultrasound.

Electronic Systems Design Centre (Director: **Dahiya**). ESDC supports a broad spectrum of heterogeneous electronics systems technology. Focussing on the synergistic design and development of high-speed electronic components, the centre develops breakthrough electronic systems with cutting-edge performances. In 2016 and 2017, ESDC was a finalist for the NMI awards in the Best University Research Centre category. ESDC provides high-end electronic system solutions for emerging cross-disciplinary applications across all 3 of our challenge-led research areas.

Glasgow Computational Engineering Centre (Directors: **Steinmann**, **McBride**). GCEC was established following the award of an EPSRC strategic support grant, supporting the appointment of **Steinmann** from Germany to a Chair of Computational Engineering Science and recognising the School's strength and leadership, but lack of critical mass, in computational engineering. GCEC has established an international network of centres (CIMNE, UPC Barcelona; CERECAM, Cape Town; CICDE, Michigan; Zienkiewicz Centre, Swansea) and has close industry partnerships with EDF Energy and Rolls Royce. GCEC promotes development of high-quality scientific software as community endeavours, exemplified by MoFEM (mofem.eng.gla.ac.uk), adopted by the nuclear industry for structural integrity assessment of the reactor cores of the UK's fleet of nuclear power stations.

3.6 Challenge-Led Research Strengths

Healthcare Technologies (Champion**: Reboud).**

Healthcare Technologies is the School's strongest challenge-led theme in terms of breadth and size. It is a theme that has demonstrably attracted a diverse researcher community, including near 50/50 gender balance, is strongly engaged with outreach, and has deep international links with low-income countries, for example developing origami diagnostics for blood-borne diseases. Healthcare Technologies derives from our internationally leading research in biomaterials, cell and tissue engineering, medical diagnostics, ultrasonics and digital health. Impact is created by spanning research and innovation from bench to bedside, from fundamental research through diagnostics to clinical trials (providing 2 ICSs, see Section 4.3.2). We bring together advances in science and engineering in new ways, e.g. combining nanotechnology, 3D printing, modelling, and machine learning, in the development of tissue repair technologies. This research links physical, clinical and life sciences in cell engineering and, for example, in health technology informatics which is experiencing a revolution in areas where we have strong collaborative research in

predictive analytics, home monitoring and smart intervention. Partnerships with MedTech industries and the NHS have been key and spin-out companies include Modedx, SAWdx and Clyde Biosciences.

Impact – Veterinary Case Study

A first outcome of the Sir Bobby Charlton Foundation Programme (**Salmeron-Sanchez**) was the treatment of Eva the dog, a 2 year old Münsterlander with a complicated 2 cm non-union bone defect and infection, after being hit by a car. In collaboration with the Small Animal Hospital, our new bone regeneration bioactive materials were trialled in Eva in surgery, preventing amputation. Two months later, bone had regrown, the fracture had consolidated and Eva has since enjoyed a normal life. The case attracted significant attention, including from the BBC, major national newspapers and other vets. The team secured an ERC Proof of Concept grant to perform a veterinary clinical trial and have now successfully treated 13 previously untreatable bone fractures in dogs and cats.

Quantum & Nano Technologies (Champion: **Weides**). The School is an integral partner in the UK's Quantum Technology strategy. Our strength in this area builds on more than 3 decades of excellence in micro- and nano-fabrication and is delivered through our JWNC. The School has made strategic investments to enhance our QT position in the UK and we are now an active partner in all 4 of the UK Quantum Technology Hubs. Impact is through the many industrial partners on the £53M research grants and contracts underpinned by the JWNC, evidential in the 4 Impact Case Studies supported by this facility. Impact is also created directly by Kelvin Nanotechnology Ltd (KNT), which provides fabrication services for diverse market sectors and is a qualified supply chain partner for multiple global product lines. 170 companies in 23 countries have worked with KNT in the past 3 years.

Zero Carbon Technologies (Champion: **Yu**). The climate crisis and resource depletion has brought the need to deliver zero carbon engineering solutions into sharp focus. In recognition of this, and building on existing strengths in renewable energy, carbon capture and storage, heat recovery and environmental engineering, the School coalesced these around a theme of zero carbon technologies. Our research in renewable energy reaches from South America to sub-Saharan Africa (e.g. through GCRF projects). Water and environment research is delivering low-carbon water technologies, from remote Scottish Islands to Thailand, India and Mexico. We recognise that increased renewable energy production has to be accompanied by lowering energy demand, so we have invested in new staff in low-energy manufacturing (**Ying)** and sustainable infrastructure materials (**Unluer**).

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

4.1 Collaboration and Reach National Collaboration.

Royal Academy of Engineering (RAEng)

Elected Fellows, FREng: **Cooper**, **Marsh**, **Cumming**

In REF period:
Chair in Emerging Technology: **McInnes**, **Sloan**, **Paul**
Research Chair: **Pearce** (EDF), **Smith** (Scottish Water)
Visiting Professorships: **White**, **Yu** (see Section 4.1.2)
Research Fellowship: **Tassieri**, **Middlemiss**, **Jiminez**, **Millar**
Senior Research Fellowship: **Paul**
Development Fellowship: **Vignola**
Industrial Fellowship (Alba Orbital): **Ceriotti**
Enterprise Hub: **Reboud**
Enterprise Fellowship: **Siviter**
Scientific Adviser: **Tassieri**
Endorsement as UK Exceptional talent: **Abbasi**

The vitality of the School's research is founded in the interdisciplinarity empowered by our thematic structure. This is evidenced by the broad portfolio of research income where we collaborate widely, including the many large multi-institution EPSRC programmes, CDTs and other flagship grants (see Section 3.2). Our interdisciplinary research is increasingly supported by BBSRC, NERC and MRC, national academies including the Royal Academy of Engineering and Royal Society of Edinburgh, and charities (e.g. **Busse**, Leverhulme Fellowship) including Wellcome, Sir Bobby Charlton Foundation and Cancer Research UK. We

are also members of the UK Regenerative Medicine Platform (ukrmp.org.uk/hubs/acellular-smart-materials-3d-architecture).

Industrial Partnerships. Reflecting the centrality of industry challenges to our research, the School reinvigorated the Industrial Advisory Board (IAB), with 20 new members representative of our major research areas and supporting our Research Divisions. The IAB have engaged with our ECR community to facilitate direct networking with industries and in the development of independence and leadership. The IAB also provides mentorship and support in careers advice for PhD students and we have established new research partnerships, for example with Leonardo.

Our industrial reach is exemplified by our central role in the UK strategy for Quantum Technology and the corresponding importance of the JWNC, in providing access for UK researchers to world-class nanofabrication, and in facilitating industrial innovation through KNT. Our Centres for Doctoral Training are partnered with 95 industries, based in 19 countries, from spin-outs to major global corporations. We have strategic partnerships in key areas of expertise, including Thales in QT, Stryker in Ultrasonics, and EDF Energy in Computational Engineering, providing sustained funding of Research Chairs, PGR studentships and research contracts.

The College has strategically used EPSRC IAA funding to appoint Impact Associates with expertise of business partnership development in our three challenge-led technology areas. We have also leveraged Visiting Professorships to enhance our industrial reach in these areas, with three examples given here. **White** is RAEng Visiting Professor in Technological Entrepreneurship. He was CEO of two life science AIM-quoted companies and is now CEO of Novel Technologies Holdings and Chairman of Mikota. His extensive experience in manufacture of medical devices, advanced biologics and API's has brought valuable links to wide international industrial expertise and partnerships in Healthcare Technologies. **Ma** played a visionary role in the development of the Synopsys TCAD tools and was instrumental in the acquisition of Gold Standard Simulations in 2016. As a result, Synopsys now has a 25 strong R&D division in Glasgow, representing a substantial career pipeline for our PGRs and PDRAs. **Yu** is the RAEng Visiting Professor in Integrated Energy Systems. He is Head of Future Networks at Scottish Power Energy Networks and is supporting our Zero Carbon Technologies research, cementing a strong partnership with Scottish Power through research grants and funded PhD studentships.

International Partnerships. The School's strategy for developing international partnerships comprises three distinct mechanisms: Firstly, working in collaboration with TNE partners with UESTC in Chengdu we have established a new PhD programme. The Ministry of Education in China has approved the dual PhD programme in the field of electronics and communications, for 5 years of cohorts, totalling 45 studentships, benefiting from shared supervision and funding for extended research visits. Our PGR cohort is based in the School of Information & Communications, where we have our strongest existing links in the areas of communications and healthcare technologies.

Secondly, the School has successfully created ODA country partnerships to win significant GCRF awards (see Section 3.2). We have also been proactive and successful in engaging with the RAEng GCRF initiatives, with a focus on developing the international reach of our early and mid-career academics to tackle global socioeconomic and healthcare challenges. Again, this initiative has been supported by the College Impact Associates, providing seed funding from the College to facilitate ODA partnerships and grant applications in Zero Carbon Technologies in Kenya, Nigeria, Cameroon and Bangladesh. The School has been lead or partner on 27 GCRF awards, and an RAEng Engineering for Development Fellowship (**Vignola**).

Thirdly, the School has grown its academic and industrial collaborative research through the H2020 European funding initiatives, including strong engagement with the European Research Council (6 awards). The School has also targeted the funding of ITNs in order to grow and diversify the number of partnerships.

Finally, the Scottish Research Partnership in Engineering (SRPe) has provided a mechanism for international engagement through the Pools Engagement in European Research (PEER awards) and Postdoctoral ECR Exchanges (PECRE awards) (see Section 2.5.4).

4.2 Research Leadership and Recognition

Engaging with Government

Paul is a Dstl Visiting Fellow, a member of the MOD Defence Science Expert Committee, chaired the MOD Position, Navigation and Timing Deep Dive (2019), was UK technical senior for TTCP negotiations for Five Eyes Quantum Enabled Navigation programme (2018), chaired the EC ICT Energy Strategic Research Agenda (2016), provided scientific support on QT to the Minister for Defence Procurement in 2020 and is on the Government Office of Science Scientific Advisory Group for Emergencies (SAGE) register since 2014.

Our contribution to the research base is widely recognised through leadership on strategic positions of funding bodies. During the census period our staff have been on EPSRC's Strategic Advisory Teams: **Paul** (Capital Equipment), **Cooper** (Healthcare Technologies), **McGinty** (Mathematics), **Thayne** (Physical Sciences) and **Pearce** (Engineering). **Cooper** is a member of the ERC starter grants panel (LS7) Diagnostic Tools, Therapies and Public Health, **Thayne** was an Evaluator for the EU Critical Space Technologies Programme, **Salmeron-Sanchez** is a member of the Welcome Trust panels, **Busse** sits on the EPSRC Strategic Advisory Committee for e-Infrastructure and **Lucas** is on the UKRI FLF College. We have 35 members of EPSRC College. **Weides** was co-author of Opportunities for Superconducting Quantum Technology in the UK, NPL Report 2018 and lead author of The UK Superconducting Quantum Circuit Centre (SQCC): A Vision for the National Foundry for Quantum Computing Circuits, report to government 2019 and Member of the BEIS Quantum Computing Deep Dive: Roadmapping Workshop 2020. **McInnes** Chairs the UK Space Agency Space Technology Advisory Committee and **Kontis** is a member of the Advisory Committee for Aerospace Research in Europe Working-Group 3: Protecting the Environment and the Energy Supply. **Falcone** is United Nations Economic Commission for Europe (UNECE) Vice-President of the Expert Group on Resource Management and leads the Geothermal Sub-group for the development of geothermal specifications and guidelines for the UNFC. **Cumming** was a Member of the Scottish Science Advisory Council (2012-16).

Fellows of Engineering and Science Professional bodies include:

- Royal Academy of Engineering: FREng (**Cooper, Cumming, McInnes, Marsh**).
- Royal Society of Edinburgh; FRSE (**Asenov, Cooper, Cumming, Lucas, Marsh, McInnes, Paul, Sloan, Hadfield and Salmeron-Sanchez**)
- Royal Society Wolfson Merit Awards: **Cooper, Cumming, Cochran, Steinmann, McInnes, Sloan**
- Fellows of Engineering and Science Professional Bodies including: FICE (**Pearce**); FIEEE (**Asenov, Cumming, Marsh**, **Dahiya** plus 14 Senior Members); FAIAA (**Kontis**); FIET (**Cooper**, **Cumming**, **Marsh**, **Imran**); FIMechE (**Kontis, Lucas**, **Harkness**); FRAeS (**Kontis**, **Barakos**); FIoP (**Cooper, Hadfield, Marsh, Paul**, **Cochran**, **Hutchings**, **McInnes**, **Weides**); FOSA (**Hadfield**, **Marsh**).

Significant Prizes and Awards include: **McInnes**, MBE 2014; **Paul**, IoP President's Medal 2014; **Hadfield**, IoP Joule Prize 2019, **Lavery**, Mobile World Scholar Gold Medal 2018, RSE Sir Thomas Makdougall Brisbane Medal 2019; **Barakos**, RAeS Written Paper Silver Award 2018; **Clerici**, Italian Physical Society Sergio Panizza Optoelectronics prize 2014; **Cochran**, National Instruments Engineering Impact Humanitarian Award 2019; **Heidari**, IEEE Sensors Council Young Professional Award 2019; **Imran**, IEEE Communications Society Fred W. Ellersick Prize 2014; **Vellaisamy**, 47th International Exhibition of Inventions Gold Medal 2019; and **Lucas**, IET Achievement Medal 2020.

4.3 Impact and Contribution to the Wider Research Base

4.3.1 International Technical Societies and Conferences

Dahiya is President-Elect (2020-2021) and Distinguished Lecturer (2016-2021) and was Chair of UK and Ireland Chapter of IEEE Sensors Council (2016-2018); **Cochran** and **Lucas** were General Co-Chairs IEEE International Ultrasonics Symposium 2019 and **Cochran** is Vice-President for Ultrasonics IEEE UFFC Society; **Salmeron-Sanchez** was Chair of the FEBS conference, Biological Surfaces and Interfaces 2017; **Heidari** was General Chair of 27th IEEE International

Conference on Electronics Circuits and Systems; **Hadfield** was Co-Chair, European Conference on Applied Superconductivity 2019.

Keynote and plenary lectures were given at international conferences by **Asenov** (9), **Imran** (6), **Salmeron-Sanchez** (6), **Cooper** (4), **Cumming** (2), **Lucas** (2), **McInnes** (2)**, Sloan** (2), **Grassl** (2), **Hadfield** (2), **Paul** (2), **You** (2), **Falcone**, **Ijaz**, **Kontis**, and we have 2 Editors-in-Chief and 19 Associate Editors of high quality International Journals.

Our staff successfully brought major international conferences to Glasgow, including: IEEE Sensors (**Dahiya**); IEEE International Conference on Electronics Circuits and Systems (**Heidari**); UK China Emerging Technologies Conference (UCET) (**Imran**, **Zhang**); European Conference on Computational Mechanics (**Pearce**); Computational Modelling of Complex Materials across the Scales (**Steinmann**, **McBride**); European Conference on Applied Superconductivity (**Hadfield**); IEEE International Ultrasonics Symposium (**Cochran**, **Lucas**).

4.3.2 Impact Mechanisms

As detailed in Section 2.5, we have an established programme of training and coaching at all levels to support and encourage entrepreneurship. This has led to a number of spinout companies during the REF period, including Acu-Flow and Multicorder DX. The School is proactive in generating impact from our research as provided in the Impact Case Studies (ICS). Where the majority of the ICSs rely on IP and know-how for commercialisation, the School also recognises the importance of mechanisms for impact. The University has pioneered the route of Easy Access IP which aims to maximise knowledge transfer through simple transactions and agreements before focusing on monetary aims. The School goes beyond this by implementing an open impact environment to provide the wide academic and industrial community access to tools and research developed in the School. In a similar spirit to Open Access for research outputs, we openly share research innovations with the wider research base, especially where there is no clear route to market. Examples include:

- **Cooper** and **Reboud**, development of origami-based diagnostics. This is currently being trialled in Tanzania and also forms the basis of an ICS.
- **Pearce** and **Kaczmarczyk**, development of open source finite element modelling software, MoFEM (mofem.eng.gla.ac.uk/mofem/html/). MoFEM (Mesh Orientated Finite Element Method) is an open source finite element analysis code that has been widely adopted, with applications in nuclear graphite developed in partnership with EDF Energy and forming an ICS.
- **Asenov** and **Georgiev**, building on the success of simulation software for semiconductor devices developed by **Asenov** and acquired by Synopsys (see ICS), the team has continued to develop open source software for transistor designs.
- **Porr** has developed and commercialised data acquisition hardware and software using open source code (www.linux-usb-daq.co.uk/).
- **Imran** has 3 projects with Huawei on latency and reliability control for open loop multi-hop V2X communication.

4.3.3 Response to Covid-19

The School's structure facilitated many rapid responses to covid-19 and a few examples of the research contributions are:

Scottish Funding Council GCRF Covid Emergency Response Fund – Characterising Covid-19 occupational exposure among healthcare workers through the validation of point-of-care diagnostics (**Cooper**).

Mobile Health Clinic VAN – CODIS: Jointly with Telefonica O2 our researchers developed a mobile connected health clinic to provide medical care and delivery of essential supplies to people in remote locations and care homes (**Imran**).

EPSRC funded Risk EvaLuatIon FAst INtelligent Tool (RELIANT) for Covid-19. This is a new interactive tool that evaluates the risk of infection from droplets and aerosols in the indoor environment generated when breathing, talking, coughing and sneezing (**Cammarano**).

4.3.4 Communicating with the Public

Disseminating our research to the public and championing engineering to communities, from school children to government, are at the heart of our School ethos. We support all of our staff and researchers to train as STEM Ambassadors and provide media and outreach training. Working closely with the University's Dean for Public Engagement, we have developed a strategy to showcase the breadth and diversity of our research, presented here.

Researchers have presented their research at the Parliamentary and Scientific Committee STEM for Britain in Westminster (e.g. **Aggarwal** 2019). In 2018, PhD student **Mason** won the STEM for Britain Gold Medal in Engineering in a presentation to MPs at Westminster. In the same year **Salmeron-Sanchez** presented to The Royal Society Summer Science Exhibition, Material matters: biomaterials for bone repair.

We also work closely with our (more than 20) engineering student societies. **Cooper** and **Reboud** supported Handprints to work with the STEM Academy Scotland to take research on prosthetics into schools, and worked with FemEng (female engineering society) to run workshops on low-cost disease diagnostics during their annual FemEng in Rwanda project.

To celebrate the RAF Centenary, a state-of-art flight simulator created by researchers in the School (**Barakos**) allowed school pupils to pilot a virtual WW1 Bristol Fighter, in the project Wings to War – Glasgow and the birth of the RAF.

We organise many events at the annual Glasgow Science Festival including two UK Space Agency funded events; Get Me into Orbit, and Roving with Rosalind (**Worrall**). The Amazing World of Quantum Physics (**Pusino**, **Escorzia**) developed Quantum Technology-based ideas to help resolve a zombie apocalypse, also presented at TEDx Glasgow. Floodopoly, an interactive exploration of flood risks in the UK, led to PhD student **Koursari** winning the Womens Engineering Society Top 50 Women in Engineering Sustainability and the Women Leaders Association Rising Star in STEM awards in 2020.

4.3.5 Influencing Policy and Advocacy through Public Engagement

Quantum & Nano Technologies are a significant arena of influence through government engagement. For example two lectures on QT and Quantum Communications were given to the Ministry of Defence and to all global UK embassies (**Paul**), and IndiPix™ (Mid-infrared sensing and imaging technology) was presented to the House of Commons Science and Technology Committee (**Cumming**).

Researchers have also worked with engineering professional societies, such as IEEE CommSoc on Busting the Myths About 5G – Facts Versus Fiction (**Imran**).

Staff have been awarded funding from the RAEng Ingenious scheme, including **Dahiya** to demonstrate ubiquitous tactile surfaces and the science of landslides through the Electronic Touch project, and **Jiminez**, who worked with secondary school teachers to co-create new tools to integrate biomedical engineering into the Physics curriculum, >10% of Scottish secondary schools now use the tools.

Supporting training in Outreach

Middlemiss won the Scottish Famelab, explaining a complex scientific topic in 3 minutes to a lay audience. He then won the UK final of Three-Minute Thesis, explaining his entire PhD in 180 seconds, and the University of Glasgow Science Slam, a speed lecturing event in a Glasgow pub. In 2018 he won the Isambard Kingdom Brunel Award Lecture from the British Science Association in recognition of his research and outreach activities. He has been interviewed for BBC Radio 4's flagship science show, Inside Science, and the BBC World Service's Science in Action programme, where he has also presented and produced several short documentary films.