

Institution: University of Bradford
Unit of Assessment: B12 Engineering
<p>1. Unit context and structure, research and impact strategy</p> <p>Unit context and structure:</p> <p>Research in this UoA is based in the Faculty of Engineering and Informatics. The Faculty operates a horizontal structure across its six departments, promoting a strong interdisciplinary approach to both teaching and research that combines engineering disciplines (biomedical, civil, chemical, electronics, and mechanical), computer science, and media, design and technology.</p> <p>Research in the UoA is rooted in the engineering tradition that has shaped the City of Bradford's industrial history from the formation of the Mechanics Institute (1832) in response to the local need for workers with cutting-edge skills relevant to the workplace. This remains valid today with research in the UoA focussing on innovative engineering research that shapes future societies, while embracing the values of diversity, social inclusion and cross-disciplinary collaboration. Our research aligns with national industrial strategic priorities for innovation and enhancement of productivity, working collaboratively with extensive international networks, while also striving to bring the benefit of advanced knowledge and skills to our City and region.</p> <p>Most of the research in the UoA is channelled through well-established Research and Knowledge Transfer (R&KT) Centres that act as hubs for interdisciplinary research collaboration and impact. The UoA hosts four of the University's eight interdisciplinary R&KT Centres, namely:</p> <ul style="list-style-type: none"> • Advanced Materials Engineering Centre (AME) • Polymer Micro and Nano Technology Centre (PMNT) • Bradford Centre for Sustainable Environments (BCSE) • Automotive Research Centre (ARC) <p>A fifth, the Centre for Pharmaceutical Engineering Science (CPES), is shared with the Faculty of Life Sciences. The R&KT Centres serve as focal points for University investment and are key drivers for external funding. Each supports a critical mass of researchers and facilities to sustain progress, and collectively they sit across three strategic research themes that have evolved from the strategies presented in RAE2008 and REF2014.</p> <p>Theme 1: Advanced Materials, led by Professor Coates, FEng, incorporating the work of the AME, PMNT and CPES R&KT Centres.</p> <p>Theme 2: Sustainable Environments, led by Professor Lam, incorporating the work of the BCSE R&KT Centre.</p> <p>Theme 3: Automotive and Energy Efficient Systems, led by Professor Campean, incorporating the work of the ARC R&KT Centre.</p> <p>These research themes stimulate multidisciplinary engagement across the R&KT Centres, the six Departments in the Faculty, other faculties in the University, and links with external groups, other universities and industrial partners. This ensures a critical mass of researchers from diverse groups and teams to develop larger more adventurous research projects with greater impact. The research themes and R&KT Centres have permeable boundaries, with mobility of individual researchers for specific research initiatives, to maximise multi-disciplinarity and synergies between core disciplines in addressing major global issues such as health and healthcare, sustainability, and energy. The R&KT Centres each have a critical mass comprising a core group of lead researchers, with a Director to provide stability in strategic direction and</p>

operational responsibility. To promote strategic focus and cohesion within and across the UoA, strategy, budgeting and investment decisions are made by the Faculty RKT Committee, chaired by the Associate Dean RKT (ADRKT). Committee membership is drawn from active researchers and research leaders (including Directors of R&KT Centres), with representation for early career researchers and technical staff.

Research strategy:

Our research strategy was refreshed in 2017 to align with the evolving landscape of global challenges, and industrial and research priorities. This reaffirmed the aim of conducting fundamental and translational engineering research having impact on the local, national and international communities, and defining strategic policies and actions to achieve this within the framework of our research themes and priorities.

Building Research Leadership:

We recognise that the catalysts for achieving and sustaining excellence in research are the inspirational engineers who initiate and lead innovative research and engage and develop the future generation of research leaders. To this end we have invested strategically during this REF period with the appointment of three 50th Anniversary Chairs with high quality international research profiles (Priest from Leeds, Guo from Aberdeen, T Khan from Calgary). Professor Bridgeman joined us from Birmingham (now University DVC Research, Innovation & Engagement) and contributes to the research base of the UoA. Looking to our future research leaders, we have also invested substantially in early career researchers, as detailed in Section 3.

Strategic research themes and objectives during the assessment period

The three strategic research themes identified above support six research objectives (ROs) that have guided activity and progress over this REF period.

T1: Advanced Materials Engineering

RO-1: To carry out fundamental research to develop advanced polymeric and biomedical materials via processing, with associated modelling and simulation, aimed primarily at health and wellbeing, and precision product development.

RO-2: To develop resource efficient materials, enhancing the value of feedstock and circular economy routes.

T2: Sustainable Environments

RO-3: To address challenges associated with the development of low energy construction techniques and materials, aiming to achieve a cost reduction in built assets, lower emissions from the built environment, and improve resource efficiency and utilisation of raw materials.

RO-4: To address the vital issues of water security and resource efficiency, combining rigorous experimental analyses to gain insight into water and wastewater engineering processes and coastal systems, with the development and integration of modelling methodologies to provide innovative approaches to the simulation of these systems.

T3: Automotive and Energy Efficient Systems

RO-5: To advance modelling and analysis methodologies for complex multidisciplinary systems to support productivity enhancement for technology and product development and manufacture of future automotive systems on the journey to Net Zero.

RO-6: To address the need to limit energy consumption of battery-powered devices, the biggest challenge for future wireless systems, aiming to prolong their operational time and avoid the need for active cooling.

Progress with the achievement of the objectives

RO-1: Significant progress has been made in medical/biomedical materials research, including: bioresorbable and non-resorbable materials, often with tailored properties or property gradients, for orthopaedic components in joint repair or replacement; tissue fixation devices, including shape memory bioresorbable polymers (Smith & Nephew Ltd, Innovate Orthopaedics, Fortius Clinic); oriented polymer stents for vascular repair (Arterius: Impact Case Study, ICS, B12-4: “High value manufacturing of enhanced property precision tubular products for biomedical and water applications”); orthodontic products (DRFP, DB Orthodontics); spinal braces (Invivio) and structured films for wound dressing. Other successes include drug delivery technologies including micro-needles (Renefra, Sabic, Gates Foundation) and a range of medical devices for minimally invasive surgery (Surgical Innovations).

RO-2: Research on resource efficiency includes enhancing polymer product properties and quality and enhancing materials re-use, or ‘green’ processing. Staff in the UoA were awarded one of only four UK-China EPSRC-NSFC grants for low carbon manufacturing (with Sichuan University) addressing hard-to-recycle materials. Routes to manufacture of enhanced acoustic and thermal insulation materials from difficult-to-recycle elastomeric polymers have been developed for a lower carbon footprint. Our academics also made substantial contributions to the EPSRC Resilient Materials 4 Life programme (with Cardiff, Cambridge and Bath Universities and industrial partners Costain, Cemex, Highways England) include shape memory tendons embedded in concrete to provide a system that triaxially confines and post-stresses the cementitious matrix. This has greatly enhanced ductility and imparted a high resistance to cracking.

RO-3: We have undertaken extensive research on the behaviour of shear connectors in composite beams, including the use of demountable shear connectors, aiming to substantially reduce carbon emissions. Research includes the development of geopolymer binders and concrete (Horizon 2020-EU, UKRI) and demountable reinforced concrete structures (UKRI), promoting the notion of reusing structural elements after their service life. Current EPSRC-funded research on circular economy is uniquely focused on other construction materials, for example, bricks.

RO-4: The focus is cost-effective and sustainable production of potable water and the treatment of wastewater. We are working with several international institutions (e.g., in Libya, Iraq, Italy, Bangladesh, Australia, Kuwait, Jordan, China) on thermal and membrane desalination processes for economic and sustainable production of drinking water. Other treatment-related work (UKRI - EPSRC, MRC, Research England) has addressed multiphase modelling of non-Newtonian fluids in anaerobic digesters to optimize biogas recovery and renewable energy generation; analysis of air blower performance in multiphase activated sludge plant modelling at wastewater treatment works to reduce the operational carbon footprint; and the prediction of leakage from buried pipes to reduce wastage.

RO-5: We have advanced our approaches to multi-physics systems modelling and multi-disciplinary design optimisation, focussed on minimising environmental emissions of engines (Innovate UK, EPSRC-CASE, JLR, Ford) and acoustic emissions of vehicle braking systems (JLR, Bentley, Airbus). Our work has informed decisions on modelling methodologies and adoption of design strategies and solutions at our industrial collaborators (JLR, Bentley). Tribology research focussed on optimised powertrain lubrication and the use of polymers in place of metals under extreme operating conditions (Rocol, Nylacast). Our novel model-based methods for function and function failure analysis, integrated in a “Failure Mode Avoidance” for automotive systems engineering, were adopted at scale by our industry collaborators (Ford, JLR) with demonstrated impact for productivity improvement in Product Development (See ICS

B12-1: Enhanced Automotive Product Development). Our systems reliability research has shifted significantly towards the use of real-world big data analytics for intelligent personalised healthcare of propulsion systems, and we have set up an Advanced Automotive Analytics (AAA) research laboratory with our industrial collaborators (JLR).

RO-6: Our staff developed Energy Efficient and Reconfigurable Transceivers (EERT) through collaborative research (H2020-MSCA-ITN-2016-SECRET-722424) and achieving impact through KTP collaborations with Datong PLC (now 7Technologies Ltd). Research on radiofrequency devices to reduce the potential health hazard of electromagnetic (EM) radiation in addition to low energy operation, led to a collaborative patent application (GB/23.05.17/GBA201708242) with SARgard; a novel mobile-device antenna with EBG structures suitable for the deflection of radiation from mobile wireless devices. Research includes novel methodologies for the planning and operation of smart energy distribution networks to determine the optimal mix of renewable energy sources and energy storage systems and to improve the economic and technical efficiency of renewable sources integrated into the distribution network.

Research objectives over the next five years

1. To achieve a strong, balanced portfolio of research funding by building upon our strengths, supported by writing retreats, thematic symposia, research sandpits focusing on interdisciplinary research and exploration of ideas among our three research themes; see Section 3 for strategy to increase funding income. A multidisciplinary approach to both fundamental and impact focused work, building upon long-term strategic relationships with industry (JLR, Ford, Sinopec and Sabic), will strengthen our bidding efforts to a wide range of funders: research councils, overseas aid, industry and charities.
2. To recruit academic staff in line with the strategic priorities of our research themes and R&KT Centres, to fill gaps in emerging and innovative areas and to strengthen existing expertise. Our staffing strategy is detailed in Section 2.
3. To develop and maintain research partnerships with the best international institutions. We enjoy strong collaborative relationships in Europe and China and one of our objectives is to develop these links further and create greater impact outside the UK; for example, based on our Horizon 2020 funded projects or highly successful RCUK Bradford Science Bridges China and EPSRC Global Engagements programmes (see Sections 3, 4).
4. To strengthen our collaboration with other R&KT Centres, research institutes and groups in the University, including the Digital Health Enterprise Zone (DHEZ) and the Wolfson Centre for Applied Health Research (CAHR), to support the interdisciplinary approach to advanced healthcare and sustainable societies themes (see Institutional Level Environment Statement (ILES)).
5. To consolidate the future sustainability of our research teams through the recruitment of outstanding doctoral and post-doctoral researchers, and highly qualified technical staff.

Research impact strategy

The focus on the impact of our engineering research is embedded in our research strategy and implemented through the activity of our R&KT Centres. Our impact strategy is structured in five levels:

1. Focus on engineering innovation with direct application to global sustainable development goals, e.g., our work in water engineering has made significant contributions to potable water supply (Bridgeman, Mujtaba); in sustainable built environments through reusable/demountable structural elements (Ashour, Lam); and sustainable smart grids in developing countries (Mokryani).

2. Engage with public institutions and bodies to support the development of policies and standards for the benefit of society and all communities, e.g. research in the BCSE underpinning international standards and guidelines (Lam, Oltean-Dumbrava).
3. Engage with industry stakeholders and networks at national and international levels, to proactively support the translation of our research into industry practice. Such research and knowledge transfer collaborations, with funding for research and translation of research to practice, underpins our Impact Cases.
4. Engage with local manufacturing industry in the City of Bradford and region, to support innovation and technology development. Proactive engagement with regional ERDF funding schemes such as “Access Innovation” and “Connecting Innovation” supports our work with local companies. We participate in bids led by Bradford Council and Leeds City Region authorities for the broader benefit of local industry. We have engaged directly with a large number of companies offering access to our research facilities and specialist equipment and expertise.
5. Transfer of knowledge and skills to the engineering workforce, to accelerate the transition from research to workplace through the development of people as well as technologies. A large-scale example is our research-led CPD short courses delivered by the Automotive R&KT Centre, which has engaged over 3,000 engineers during the REF period, through our collaborations with JLR (TAS programme), Ford, SAFI Consortium (Airbus, Renault, PSA and Valeo), and via our Braking of Road Vehicles Course.

In pursuing our impact strategy, we consult with our disciplinary Industrial Advisory Boards (Mechanical, Civil, Chemical, Medical and Electronics), which have broad industrial representation from local to national and international interests, augmented by the appointment in the REF period of senior and experienced industrialists as Visiting Professors and Research Fellows (e.g., Delaux, Global Director of Reliability at Valeo and President of the Confederation of European Environmental Engineering Societies) and three Royal Academy of Engineering Visiting Professors (Fox from Nylcast, Debney from Arup, Akhtar from Jacobs).

With input and support from our industrial advisors, we have hosted industry-focussed events, such as the “PC70” event organised by the Polymer IRC and the European Reliability Research Road-mapping Workshop in June 2019, to guide with scoping future research based on industry needs.

The Faculty recently appointed an RKT Business Development Manager (BDM) who now works with UoA staff to support effective bid development, identify research opportunities, and facilitate interaction with government funding bodies and industry.

Interdisciplinary research

We regard the interdisciplinarity conferred by our internal structure as a strategic asset for future development, and proactively promote interdisciplinary collaboration both within and outside the UoA. Individual staff are encouraged to engage freely in discussion and collaborations with researchers from across the Faculty and the University. For example, our researchers are deeply engaged with the Advanced Healthcare research theme of the University, through participation in research initiatives and projects associated with the DHEZ and the Wolfson CAHR. Research in the AME and PMNT R&KT Centres is closely integrated with the Centre for Pharmaceutical Engineering Science and the Schools of Pharmacy and Medical Sciences, and Chemistry and Biosciences in the Faculty of Life Sciences, evidenced by significant joint research outputs, research projects and Impact Case Study B12-3.

Within our UoA, interdisciplinary collaborations are driven by the smart digitalisation global agenda. This is illustrated by the creation in the ARC R&KT Centre of the Advanced Automotive Analytics Institute (AAA), collaborating with researchers from UoA B11 (Computer Science). The AAA was launched in 2016 in partnership with JLR and secured significant seed funding to carry

out interdisciplinary research on engineering data science for data- and knowledge-driven systems engineering design and lifecycle management, with a focus on systems reliability and health management. This is a major opportunity for growth, with subsequent engagement with major international partners (the SAFI consortium) and a strong pipeline of collaborative research. Other examples of interdisciplinary collaborations on smart digitalisation between researchers in engineering and computer science include energy efficient smart sensors for security and healthcare applications, smart grids and communication networks.

Sandpits and workshops to nurture interdisciplinary bid development are organised regularly, on themes such as sustainable energy, digital health, transformative healthcare, and resilience. For example, a sandpit focusing on our response to Covid-19 resulted in seven interdisciplinary projects and bids.

Open research environment

The University recognises the key role that an open access (OA) approach to research has for all stakeholders. To that end, the University has implemented a series of initiatives that encourage and incentivise staff to go beyond the basic open access requirements for REF (see ILES). Within the UoA and wider Faculty we actively promote OA and open research. We operate a system of mandatory peer review of all grant applications where OA considerations must be addressed, and we ensure that we implement stringent data management plans for all data arising from projects including simulation results, experimental data and computing code. The peer review process requires reviewers to consider the extent to which applications have OA activities and funds embedded within them (where permitted by the funding agency).

Research integrity culture

A pillar of our research culture is to carry out research with a high level of integrity, maintaining values of honesty, rigour, transparency and open communication. We promote an environment of care and respect for all individuals, and accountability for a positive research environment, with the aim of making our research results trusted by other researchers, by users of our research, and by society in general. New academic staff are inducted into the University's ethics policy which commits to maintaining high ethical standards in research. Ethical compliance and research involving human participants, tissues or databases of personal information requires advance approval by the University Research Ethics Committee.

Research staff in the UoA are encouraged to consider the wider consequences of their research, and engage with practical, ethical and intellectual challenges inherent in high quality research, embedding a culture of research integrity as outlined in the following ways:

- Provision of training on research ethics and mentoring opportunities to support the development of researchers' skills throughout their careers;
- Provision of systems within the research environment that identify potential concerns at an early stage, for example, the PhD progress monitoring system and grant peer review process;
- Provision of mechanisms for providing support to researchers in need of assistance; for example, mentoring systems for Early Career Researchers (ECR) and joint supervision of PhD students.

2. People

Staffing strategy and staff development

Our aim is to sustain vibrant teams with clear leadership and commitment, working in a supportive but stretching environment, where researchers are empowered to share and work across discipline boundaries and so deliver our vision. Each research group comprises a

dynamic blend of senior staff, providing research leadership, and high-calibre early career researchers (ECR) working together in a collaborative environment. Academic staff workload is managed by allocating time for research activities. In addition to the 15% allocation of University funded research time to all staff with significant responsibility for research, time allowance is provided for research bid development, supervision of doctoral researchers, external consultancy, research networking and scholarly engagements, conference organisation and other research-related management and citizenship roles.

Staff changes since REF2014

During the REF period, our research capacity and capability in engineering have been strengthened by the addition of four Chairs (Bridgeman, Guo, T Khan, Priest), providing internationally excellent research leadership and expertise. The newly-appointed professors received University and Faculty support for laboratory refurbishment and equipment according to their needs, for example the newly established tribology laboratory. Since 2014, 10 new academics (Cooke, Dao, John, Kabir, A Khan, Mokryani, Sefat, Pimenidou, Pu, Scrimieri) have been recruited, providing a good mix of senior and early career researchers across the three core research themes. In addition, there have been six promotions to Professor (Ashour, Kelly, Gough, Oltean-Dumbrava, Patel, Whiteside), five to Reader (Brown, Buckley, Caton-Rose, Twigg, Youseffi) and four to Senior Lecturer (Bryant, Dai, Pu, Rahmanian). Five academics who were submitted in REF2014 (UoA 12 and 14) have since retired or left to take up leadership positions elsewhere.

Staff Development & Training:

The University is a signatory to the UUK Researcher Development Concordat and is fully committed to implementing an action plan to support career development of research staff.

Career development is a priority and is facilitated by the annual performance development review (PDR). PDRs allow each academic staff member to review research progress with their line manager against agreed objectives and identify future research targets, including grant applications, paper writing, PGR supervision, networking and workloads. Support, professional and career development needs are identified, aiming to enable all members of staff (including postdoctoral) to achieve their full potential whilst working at the University. PDRs are aligned to the University's strategy and reflect the vision, plans and objectives of the UoA and Faculty, and identify staff eligible to apply to the Performance Recognition Scheme (PRS) or for promotion. We support staff in preparing high quality research applications, via rigorous internal peer review by two senior colleagues as well as our dedicated BDM and the central Research and Innovation Services (RaIS) team.

ECRs are assigned an experienced research mentor, who is not their line manager, to support their career development (including support for professional development and professional qualifications). ECRs are provided with career development opportunities to enhance their research profiles when they discuss and agree their research development plan with their research mentor; for example, they are encouraged to join senior colleagues as co-investigators to learn and develop their research bidding skills. ECRs have a reduced teaching load and no administrative duties for their first three years, providing them with more freedom to focus on their research activities. Our ECRs are encouraged to apply for University ECR Pump Priming grants that aim to provide seed corn funding for research activities, including undertaking fieldwork and data collection, supporting a future funding proposal, or hosting visiting academics, practitioners, policymakers and industrial partners to develop collaborative projects. In addition, ECRs are supported to undertake principal PhD supervision roles following initial involvement as Associate Supervisors.

An ECR Forum (ECRF) was established in 2019 across the Faculty, so facilitating interdisciplinary dialogue with staff in Computer Science and Media, Design & technology, with regular monthly meetings, to provide a constructive interdisciplinary environment for nurturing research leadership skills and the development of innovative research ideas. The ADRKT and

BDM take the lead in defining and developing workshops and activities tailored to the ECRs' needs. These workshops give ECRs the opportunity to present their core research areas, their expertise, priorities for collaborations, and to receive feedback and support from peers and mentors. In 2019-20, our ECRF meetings increased the group awareness on IP, how to write and apply for their successful first grant, and how to engage and collaborate with industry. A Microsoft Teams group supports conversations between meetings, enabling researchers to share information about possible research proposals collaborations, papers and conferences.

Skills and competences for all staff are developed via best practice workshops and training courses delivered by the University RaIS team, Personal and Organisational Development team (POD), IT Services and the Library. For example, POD offers a range of internal courses and access to external opportunities that include personal, managerial, research and teaching development. To enable staff to fulfil statutory and other training requirements, they have access to a suite of flexible e-learning modules available via the POD online portal. Mandatory courses for all staff are provided in: (i) Health and Safety; (ii) Diversity in the Workplace; (iii) Data Protection, Freedom of Information and Information Security. Additional courses on Recruitment and Selection and Unconscious Bias are provided for all staff who are involved in interview panels. An optional module in Personal Resilience is provided through the e-learning platform. Data show that take-up of e-learning modules is high. To support our existing and developing leaders, the University developed the 'Bradford:Leader' programme, a leadership training course offered to academics and professional support staff, that is specifically designed to prepare managers for strategic roles and transformational change. Three academics from this UoA (1 female, 2 male) have successfully completed 'Bradford:Leader'. Time is allocated in the staff WLM to undertake specified training and staff development activities.

Career progression

We provide a highly supportive environment in which success is valued and we offer fast-tracked career progression for our outstanding ECRs. Promotions follow strict guidelines that are readily accessible on the University website for all staff, along with grade descriptors. Consideration as to whether an individual is ready for promotion is made in conversation with the line manager during the PDR, and staff are supported through the process by their line manager and, where appropriate, senior members of staff. For academic and support staff regrades, the person applying for promotion must follow a transparent University process, with details provided annually by the Faculty Dean.

Post-Doctoral Research Assistants (PDRAs) & Visiting Research Fellows

In addition to attracting research active academic staff, the nature of our research has facilitated a high number of externally funded PDRAs and visiting research fellows working alongside our staff. In the REF period, 40 externally funded PDRAs and 50 visiting research fellows (mainly from overseas research institutions) have contributed significantly to our research environment, providing a comprehensive global view and additional maturity of thought and practice to support our research culture, in particular our PhD researcher progression.

Support to Doctoral Researchers

During the REF period, our research groups have supervised to graduation 106 postgraduate researchers (PGRs), with a significant number holding prestigious Research Council awards and international government funding. Our postgraduate admission strategy relies on recruiting high quality students, with the goal of developing highly skilled PGRs to contribute to the research base and workforce. Research in the UoA provides a highly supportive environment for PGRs and facilitates exchange of ideas, expertise and skills. Our PGRs benefit from studying in an interdisciplinary academic environment with access to an excellent range of well-equipped research and office facilities. All PGRs are provided with a desktop computer, access to our laboratory facilities, technician support where needed and a budget for external personal development activities – including conference attendance.

All PGRs have a supervisory team, comprising a Principal and an Associate Supervisor. All are required to agree a Personal Development Plan with their supervisors at the beginning of their study to identify a schedule of training throughout their research programme, and there is a rigorously enforced system for recording both student progress and regular formal meetings between students and their supervisors. By the end of their first year, PGRs submit a report, which is assessed by two independent academics. Progression to the rest of the PhD journey is subject to successful oral defence of the report. An annual monitoring report is formally completed by the PGR and Principal Supervisor, allowing any progress issues or skills development needs to be identified. We emphasize PGR training and support, integrating students into the research community, aiding them towards successful completion and providing high quality personal, professional and career development opportunities.

In addition to the technical skills training provided by the UoA and across the Faculty, the University library and staff development teams provide a comprehensive programme of research and transferable skills training (including employability skills). The University also offers a unique, flexible and responsive PGR Framework that takes a collaborative whole-institution approach to training and development for doctoral researchers. This covers all of the 12 sub-domains of The Researcher Development Framework (RDF) from Vitae (see ILES).

Our PGRs organise, and participate in, bi-monthly seminars. An Annual Innovative Engineering PGR Conference, organised by students with support from the Director of PGR, provides PGRs with the opportunity to present their work in oral presentation or poster formats. Best paper, poster, and presentation awards are made. Our researchers (PhD, PDRA, visiting research fellows) are encouraged to work together to share ideas and to generate lively discussion through seminars and workshops.

Equality and Diversity

The University is committed to promoting equality, diversity and an inclusive and supportive environment for students, staff and others closely associated with the University, in conformity with the provisions of its charter, and its strategic objectives (see ILES). All staff are required to undergo online diversity and equality training. All staff involved in the recruitment and selection process are fully trained on equality, diversity and unconscious bias by completing an e-learning module, followed by one day of directed training.

For both staff and students, there is explicit information in our recruitment literature to encourage applications from minority backgrounds and from female engineers, in order to widen access into engineering. The University is a signatory of DORA, promoting the assessment of research on its own merits rather than the use of metrics.

The University was named the Times and Sunday Times University of the Year for Social Inclusion 2020, recognising its outstanding impact on social inclusion that ensures all students, irrespective of their background, are supported to achieve their potential and go on to achieve success.

The Faculty has an Equality and Inclusivity champion who works within the UoA to advertise and promote activities such as Women's International Day and Rosa Parks Symposium to staff. Individual successes and contributions are recognised and celebrated in the Dean's staff emails and a monthly Newsletter.

The University has a strong ethos of diversity in gender, ethnicity and all other aspects. Our academic staff also come from a range of countries and continents. However, we do not operate any form of positive discrimination: our policy is to attract the "best of the best".

GENOVATE is a 7th Framework Programme funded project coordinated by the University of Bradford, aiming to transform organisational culture for the advancement of equality and opportunity for men and women in research and innovation. It is headed by Professor Archibong who has been selected nationally as one of 10 Inspiring Leaders by Aurora, a women-only

development programme bringing together experts from HE to address the under-representation of women in positions of leadership in the sector. Professor Oltean-Dumbrava was a co-grant holder, organising all the project events in the Faculty in which our UoA sits, attending all cafes at the University level, all events, and most of the international meetings. She received the VC's outstanding research prize for her contribution to this research. Our Faculty is also part of the Women in Science and Engineering (WISE) network, enabling staff to attend courses and workshops organised by other Universities, such as courses on 'Personal Effectiveness' and 'Personal Development for Women'. The University's academic representative of the WISE network (Brown) is based in the UoA and she organises WISE events on and off Campus. The UoA supports all female staff to participate in the Advance-HE Aurora Leadership training programme by funding places for staff at relevant grades.

Construction of our REF submission

In the construction of this REF submission, we have followed the University's REF code of practice, demonstrating a fair approach and equal opportunities across all academic staff in the Faculty. In particular, we implemented an inclusive process for our REF submission that is free from discrimination, harassment, or victimization on the grounds of age, disability, gender reassignment, marriage and civil partnership, race, religion or belief, sex, sexual orientation or because of pregnancy, maternity, paternity, or any other inappropriate distinction.

The selection of outputs for inclusion in this submission is based primarily on the quality of outputs as determined by peer review, and the fit with this Statement. Output metrics such as journal rankings and citation data have not been used to determine the inclusion or exclusion of an output.

After the output review process was completed, individual staff were able to access the internal ratings of the outputs they nominated. They were offered face-to-face feedback for any further clarification or complaints. After selecting the best paper for each academic submitted, the rest of the papers were arranged in score order. A line was drawn at the point to make the total number of papers required for submission. If there was a tie, the output with better alignment to the environment statement was adopted. Although the number of the female staff employed in this UoA is relatively low, all female colleagues have significant responsibility for research and are represented in our submission.

3. Income, infrastructure and facilities

Over the REF period, the UoA has shown a steady trend in gaining external funding from a variety of sources to support our strategic research activities, attracting an average of approximately GBP2,700,000 per annum. The UoA's strategic plans strongly encourage staff with significant responsibility for research to obtain external funding from a range of funders to provide stability for our research finances and a healthy balance in our research project portfolio. Main sources of funding include UKRI, charities, EU (particularly Horizon 2020) and industry. The proportion of funding from each source varies depending on the research group. The Faculty provides various support mechanisms to all its researchers (i.e. those within and outside this UoA) to generate research income to carry out high-quality, high-impact research as outlined below as part of our future strategy to increase our research income.

Examples of major and prestigious grants during the REF period include:

- EPSRC Capital grant of GBP3,400,00, with GBP3,100,000 University and industry additional support for novel processing and characterisation of materials.
- Shape memory bone and soft tissue fixations, EPSRC, GBP904,000, 2017.
- High Efficiency Recycling of Polymers, EPSRC, USD791,000, 2017.

- HIMALAIA - High-Impact Injection Moulding Platform for mass-production of 3D and/or large micro-structured polymer surfaces with antimicrobial, self-cleaning, anti-scratch, anti-squeak and aesthetic functionalities, EU H2020, GBP434,000, with another 10 partners, 2017.
- Structural and Fire Resistance of a Reusable Steel/Concrete Composite Floor System, EPSRC, GBP376,000, 2015.
- Grow MedTech Initiative, HEFCE/Research England/UoL, GBP369,000, 2018.
- SINOPEC - China Petroleum & Chemical Company, EPSRC- Phase 2, GBP357,000, 2017.
- CoMAnDO - Computational Methods for Anaerobic Digestion Optimization, EPSRC, GBP336,000, 2017.
- Flow Induced Crystallisation, EPSRC, GBP328,000, 2015.
- Construction and Demolition Waste-based “Green” Lego-like Structural Components, MSCA Individual Fellowships (IF), Horizon 2020, GBP199,000, 2019.
- Newton Prize 2020, Reducing CO2 emissions with new green concrete, UK-TURKEY country prize, awarded for pioneering research and innovations to solve global development challenges, UKNC for UNESCO, GBP189,000.

During the REF period, the UoA participated in major a European Training Network (MSCA-ITN), providing world leading research training to Early-Stage Researchers (ESR); for example:

- MICROMAN - Process Fingerprint for Zero-defect Net-shape, GBP195,000, with another 20 partners from academia and industry, 2015, <https://cordis.europa.eu/project/id/674801>.
- SECRET - Secure network coding for reduced energy next generation mobile small cells, GBP378,000, with another 8 partners from academia and Industry, 2015, <https://cordis.europa.eu/project/id/722424>.

The UoA maintained strong industrial links during the REF period, undertaking collaborative research funded by industry. The long-standing collaboration with JLR is an excellent example, and a stream of research projects funded in the period included Intelligent Personalised Powertrain Healthcare project (2016-2020, GBP500,000), Systems Engineering Design Excellence through Failure Mode Avoidance (2014-17, GBP220,000) and two fully funded PhD studentships (GBP95,000 each). Other significant examples include Dyson contract research on extrusion of thin films (GBP732,000) and SABIC plastics BV research on solid phase orientation (GBP210,000).

Strategy to increase funding income in 2021-2025:

We are strategically seeking to increase funding to ensure we maintain vitality and sustainability of our research. Our action plan to achieve this includes the following:

- We aim to achieve a balanced portfolio of income between fundamental research funded by Research Councils, Horizon Europe and major industrial collaborations, and funding for translational research and knowledge transfer from a variety of sources, with an emphasis on collaborations with industry, in particular companies local to Bradford and the region.
- All staff are encouraged to continuously review their bidding plans through the annual Personal Research and Innovation Plan process (see ILES).
- The strategy and bidding plans for the R&KT Centres are reviewed through the Research Grant Action Plan (RGAP) meetings which take place twice a year (see ILES). The R&KT

Centres are expected to review their performance and plans against KPIs and targets assigned by the Faculty RKT Committee.

- By concentrating on our strategic research themes, we aim to achieve strength and depth behind our bidding initiatives, which enables us to leverage strength for larger bids.
- We will continue to run workshops and sandpits to stimulate interdisciplinary creativity for generating novel research ideas and initiatives.
- We will continue to run fortnightly writing workshops (“shut-up and write!”) and writing retreats to facilitate writing up of bids for individual researchers and groups.
- We will seek to build on our strong academic and industrial collaborations to develop consortia with greater bidding power.
- We will continue our system of peer review to enhance the quality of bids to sustain and further improve our bidding success rate (currently around 25%).
- We prioritise support for research leadership development of our ECRs by encouraging applications for fellowships and first grants and support them through effective mentoring to achieve their planned research objectives, the impact and follow-on bidding plans.
- The recently-appointed BDM, together with the central RaIS team, provide effective support for all researchers in the UoA over the whole project lifecycle, from horizon scanning, idea generation, bid development, submission and contractual negotiation, to supporting dissemination, impact monitoring, project legacy management and commercialisation.
- We will continue to celebrate our success with research through our monthly Faculty research newsletter, and through our annual research showcase for Innovative Engineering.

Infrastructure and facilities:

We have invested heavily in our infrastructure and facilities during this REF period. Our facilities are complemented by a wider University infrastructure, comprising financial and business development resources, conference and workshop facilities, the RaIS team, several University advanced research facilities e.g., Analytical Centre (see ILES). The RaIS team supports IP protection, business development, grant development and submission, industrial partnerships, and local business engagement, amongst other activities.

Research facilities in this UoA are recognised worldwide, in particular the Heavy Structures Lab and the Polymer IRC with extensive capabilities for materials characterisation, manufacturing, synthesis, simulation, monitoring and testing, and the interdisciplinary Advanced Automotive Analytics laboratory launched in 2016 in partnership with JLR. During the REF period we invested in our facilities enhancement as detailed below.

Technical support is currently provided by 14 Technicians and two apprentices, with two new apprentices recruited each year. We are signatories to the Technician Commitment which provides development opportunities via the National Technicians Development Centre (<https://nationaltechnicianscentre.ac.uk>). Our technician team designs and manufactures major test rigs, and members actively participate in research projects to the extent that their contributions have been acknowledged in the authorship of research outputs (for example, Thompson has jointly published ten papers and a patent in the REF period for his active contribution to various projects).

Research laboratories within the UoA dedicated to the three research themes are presented below.

Research in the **The Advanced Materials Engineering (AME) (T1)** occurs in our world-class Polymer IRC laboratories, hosting the Advanced Materials Engineering (AME) and Polymer Micro and Nano Technology (PMNT) R&KT Centres, and co-hosting the Pharmaceutical Engineering Sciences and the Visual Computing R&KT Centres, both across the engineering-life sciences boundary. These laboratories occupy ~4500m² with some 40 processing lines from nanoscale to macro (small industrial) scale. These include unique solid phase orientation processing (die drawing) in batch and continuous forms, from micro to macro scale (precursor of the manufacturing line in Eovations LLC), and an extensive range of high precision injection moulding facilities (collaborations with Wittman Battenfeld, Austria and Fanuc, Japan), and single and twin-screw extrusion (collaborations with Thermo Scientific) for polymers, polymer nanocomposites and pharmaceuticals. All processing lines have detailed computer monitoring of machine parameters and process variables including temperature, pressure, rheo-optical and spectroscopic, using in-process sensors, many of which we have pioneered - particularly thermal meshes, ultrasound and in-process IR, UV and Raman spectroscopic probes. Additive layer manufacturing facilities (five 3D printers) complete our processing capabilities. The AME laboratory includes facilities for small scale solid phase orientation processing (e.g. approximately 100µm wall thickness bi-axially oriented novel stents), mini-mixing for polymer nanocomposite evaluations, and micro-moulding technologies and control strategies in collaboration with a leading technology supplier (Wittman Battenfeld). Our materials characterisation facilities include 3D Atomic Force Microscopy for polymers, nanomaterials and tissue, for property mapping and surface feature characterisation, complemented by White Light Interferometry and Confocal Laser Microscopy and larger scale laser scanning. Bose micro testing and Hitachi bench top SEM allow rapid evaluation of microscale products, complemented by full-scale mechanical, thermal (DSC, TGA, DTMA), rheological (shear and capillary), structural (SAXS/WAXD, Raman, FT-IR, UV-vis spectroscopies, TEM) and chemical testing (in addition to the facilities provided by the Analytical Centre).

The Sustainable Environments (T2) theme hosts the Heavy Structures Laboratory, Hydraulics Laboratory, Acoustics Laboratory and Soil Mechanics Laboratory. The Heavy Structures Laboratory has one of the largest strong floors in the UK, equipped with a main ring hydraulic system with twin pumps capable of delivering 300l/min of hydraulic power that supports full-scale testing of structures in static, dynamic, and impact loading situations. Several servo-controlled actuators and control systems are installed and loading frames have a capacity of 5,000kN. Experiments on the longest single span composite beams and continuous concrete beams and slabs have taken place in the facility with funding from the UK and Europe. The Hydraulics Laboratory is one of the largest in the UK, housing a number of flumes and hydraulic rigs for the study of environmental fluid mechanics and urban water drainage. Flow measurement devices available include Particle Imaging Velocimetry and Acoustic Doppler Velocimetry (equipped with side- and down-looking probes) that are capable of measuring both sediment-laden and clear water flows. The Acoustics Laboratory hosts an extensive range of acoustic equipment to support materials characterisation (e.g., transmission loss, impedance tubes, flow resistivity, porosity and tortuosity, anechoic chamber), materials production (granulator, cyclone separator, mixers, moulds, cold extrusion), and numerical modelling. The Soil Mechanics Laboratory has recently been modernised to house advanced testing equipment including a fully automated, unsaturated triaxial testing system, fully automated cyclic loading machines for soils testing, a geothermal testing rig and a large-scale shear box.

Facilities for the **Automotive and Energy Efficient Systems (T3)** theme include seven laboratories. The Propulsion Systems Research Laboratory has experimental facilities including state-of-the-art regenerative dynamometers, hardware-in-loop with powertrain modelling, an axle mounted chassis dynamometer, brake squeal and friction test rigs, mechanical power transmission (belts) test rigs, and in-vehicle instrumentation and data logging equipment with GPS for on-road vehicle and driver evaluation. The Braking Research Laboratory houses experimental equipment and bespoke dynamometers and test rigs for the analysis of braking systems, with a particular focus on noise, vibration, and harshness thermal effects and wear. The Tribology Laboratory houses accelerated life testing machines to investigate friction, wear and lubrication of a wide range of mechanisms. The Materials and Surface Engineering

Laboratory facilities include electrochemical cells and electrochemistry equipment for coating development and accelerated corrosion testing. Equipment for accelerated materials life testing for wear and friction of the surface, advanced joining of dissimilar materials and material property, and microstructure characterisation is available. The Bradford Engineering Quality Improvement Centre (BEQIC, established in 1995 in partnership with Ford) provides a collaboration environment for researchers and industry stakeholders (Ford, JLR, Airbus, Renault, PSA, Valeo) engaged with systems engineering and Product Development research. The Advanced Automotive Analytics Laboratory includes state of the art computing facilities and big data storage within an interactive and creative team working space for interdisciplinary engagement and visualisation.

The Energy and Smart Grids Laboratory has a modelling facility for research in the area of planning, operation and optimisation of smart energy systems using GAMS, MATLAB, AIMMS, OpenDSS and Python software programmes. The Radio Frequency Research Laboratory facilities include a 100 m³ microwave anechoic chamber, automated measurements up to 20 GHz, Near-Field and Far-Field antenna range, wide range of RF/Microwave equipment and 5G MIMO including FPGA testbed. Software facilities include CST, HFSS and Wireless-insite, and Hybrid Electromagnetic solver including optimiser process. A fully computerised sound-protected radio frequency anechoic chamber hosts extensive facilities in supporting mobile and wireless activities, including ultra-sound measurements for many funded H2020 and innovated UK projects. The measurement facility in the chamber covers a wide spectrum frequency ranged up to 22 GHz and also supports the near and far fields radiation measurements.

Computing facilities:

The UoA has access to extensive general and dedicated computing facilities within the Faculty and across the University. Each researcher is provided with hi-spec desktop PC's suitable for the level of their computational investigation, installed with generic and specialised software as required (e.g., MATLAB, AutoDesk, ABAQUS, ANSYS, Autodesk Moldflow, Fluent, gPROMS, ASPEN, CFX). The Faculty annually renews the licenses for its specialised research software to the benefit of UoA staff.

Research Information System (RIS):

Our RIS has been introduced to improve the experience of applying for and managing grants and outputs. It acts as a single repository for all research activities of researchers within the university. It has been extensively used by academics in this UoA for managing outputs including OA and REF2021 preparation (See ILES).

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

Collaborative research is fundamental to our activity and output. Our research teams have a strong record of collaboration with researchers from UK, China, Europe, North America, India, Japan, and Turkey, evidenced by joint national and international research projects, EU projects, Royal Academy of Engineering (RAEng) and Royal Society international exchange visits, joint journal publications, and funded visits by post-doctoral researchers.

Research Collaborations:

Our international agenda has been strongly supported by staff collaborating with researchers in a range of countries, both EU and non-EU; the emphasis is on working with the best partners and those most appropriate for specific research being undertaken. Our research collaborations have enabled academics in the UoA to increase their productivity and impact as well as to produce outstanding research addressing global challenges. During the REF period, our staff published 660 papers with international partners (Data from Scopus).

A major feature since REF2014 has been the significant expansion of research associated with advanced materials with enhanced properties for healthcare technologies, progressed with

leading Chinese partners, via the highly successful and visible RCUK Bradford Science Bridges China and EPSRC Global Engagements programmes, led by our Advanced Materials team. These, and other core partners, have now had over 70 ECR exchanges and extensive journal publications, joint research grants, and international cooperation awards. Although affected by the Covid-19 pandemic, which has restricted exchanges, collaborative links remain strong with ongoing research programmes (EPSRC-NSFC), industry (Sinopec), follow on projects from the Royal Society Fellowship (Changchun) and a new collaborative research studentship scheme with Beijing University of Chemical Technology (to start in 2021). Our UK-China Advanced Materials Research Institute is due to continue its Research Workshops on-line in early 2021.

We formed three joint international research laboratories with leading Chinese groups: Joint International Laboratories for: Polymer Micro-processing (with Sichuan University, recognised by Ministry of Science & Technology China in 2014), Polymer Process Physics (with Changchun Institute of Applied Chemistry, Chinese Academy of Sciences in 2015) and Soft Matter Technologies (with Beijing University of Chemical Technology in 2016). Collaboration with these leading Chinese groups and two others, ICCAS Beijing and SIMMCAS Shanghai, has given us substantial access to major beam line characterisation (Shanghai and Beijing in particular) in addition to the facilities time we have won competitively through EPSRC at Grenoble and Diamond (UK), allowing a significant expansion of this activity accompanied by high level joint publications.

Our staff have collaborated with large European consortia in many projects. For example, the Horizon 2020 project, MICROMAN, with 23 industrial and academic partners provided training to 13 Early-Stage Researchers (ESR) on innovative process fingerprint framework for zero-defect net-shape micro manufacturing and validation of technologies in industry for the production of micro components for the bio-medical, healthcare, machine tool, pharmaceutical and quality control sectors. Our staff have collaborated with European partners in SECRET, a collaborative European Training Network (ETN) providing an excellent educational training platform for 17 ESRs in the field of wireless communications and networking.

Furthermore, staff are encouraged to apply for appropriate funding to achieve meaningful and sustainable international collaborations. Our staff have secured grants from various research councils to facilitate overseas research visits and interaction with the best scientists around the world, aiming to develop science and innovation partnerships, build capacity and promote collaborations, for example the RAEng Distinguished Visiting Fellowship (Turkey and China), as well as exchanges with China and India and international exchange schemes offered by the Royal Society and RAEng.

In a recent review of our international relations and collaboration, it was identified that more could be done to facilitate international research collaboration. A new Associate Dean role for External Relations and Marketing was created to help reduce the barriers to research collaborations with international partners. One objective is to create more Faculty-level bilateral agreements built around flexibility and with funding attached, for example Erasmus/Turing agreements and awards, from which this UoA will benefit.

Engagement with research users:

Our research groups enjoy productive relationships with key engineering and manufacturing partners, spanning large scale engineering organisations, SMEs, national and international partners. We have a strong track record of successful collaborations in medical technology and healthcare, both nationally and internationally. Highlighted research areas include medical device development (NHS-Bradford Teaching Hospitals, St James University Hospital, South Manchester Hospital), orthopaedics and prosthetics research (Northern Sheffield General Hospital, Fortius Clinic), manufacturing microneedle delivery systems for drugs and vaccines (Sabic, Microsystems UK Ltd, Renephra Ltd, Maddison Ltd, Innocore), manufacturing antimicrobial and antifouling surfaces (Dyson Ltd, CRP-Fiat, Eurothodontica, Albea), and pharmaceutical manufacturing process development (Nemauro Pharma Ltd, Pfizer, AstraZeneca

Novartis Pharma, Huaxi Hospital China). A detailed description of this type of work is captured in ICS B12-3 (“A new thermoplastic granulation process for nutraceutical manufacture reduces production costs, improves quality and increases business resilience”) that presents an entirely new manufacturing approach for 38 different products (Kelly with Health Innovations Ltd.). The “High value manufacturing of enhanced property precision tubular products for biomedical and water applications” ICS (B12-4, Coates with Arterius Ltd.) highlights our work to develop new resorbable shape memory stents which has resulted in industry leading component performance and a new manufacturing facility.

We have worked with SMEs to create new manufacturing processes that are now in full production (Elcometer Ltd, BNL Ltd, Agemaspark Ltd, Polymer Medics Ltd) and an excellent example of this type of relationship with industry can be seen in ICS B12-2 (Whiteside with PPE Ltd.) which saw the creation of a new manufacturing business unit for production of high value sealing components.

In the Sustainable Environments theme, we have established research collaborations with leading industrial partners. The work resulted in the development of innovative materials, for example fire resistive and acoustic materials for engine enclosures and buildings (Kimpton Energy Solutions Ltd, CorkSol), novel materials for acoustic applications made from plastic bottles (Texfelt) and cost-effective new generation super-plasticisers for concrete/mortar manufacturing (Eye-Dale Limited). We developed computational models for simulation of various systems for industrial application; for example integrated models for stability of offshore wind energy systems (Wood Group), computational modelling of non-Newtonian flow with specific focus on anaerobic digestion (The Fluid Group, North Midland Construction, Severn Trent Water), rapid water quality analysis for enhanced community prosperity and disaster relief (Fishermans’ Rest, Malawi), and Bespoke Decision Support Tools and Techniques for Sustainable, Affordable Social Houses (UK Incommunities). We are considered one of the few UK centres with sustained research in liquid thin film coating technology and science in collaboration with international companies (Tata Steel, Toyobo).

We also have extensive engagement with the automotive industry, focussed on productivity improvement in product development and manufacturing. The work on reliability and model-based methods for Failure Mode Avoidance had led to significant improvements in Product Development effectiveness at Ford and JLR – as captured in ICS B12-1 (Campean). Collaboration on systems resilience and reliability modelling based on real world big data analytics (JLR, Arrival, Valeo, Airbus), and systems dynamics-based modelling and optimisation of turbochargers manufacturing (Borg Warner) are further examples. In 2019 we organised a European Reliability Research Roadmapping Workshop attended by representatives of 13 Companies (including Airbus, Renault, PSA, Valeo, JLR, Arrival) and organisation (including the UK Ministry of Defence) from four European countries, shaping up a roadmap for future research priorities.

Wider contributions to the economy and society:

We have contributed to changes in engineering and medical practice, e.g. wound dressing with diagnostic functionality, shape memory tissue fixations, bioresorbable stents (Coates, ICS B12-4), precision medical devices for surgery, commercial ostomy product with improved biocompatibility (truly interdisciplinary work with UoA B8 supporting a case study); and precision modelling of manufacturing processes (Whiteside, ICS B12-2: “Micro-Form – new process for manufacturing ultra-precision components with high value rubber materials”).

Our academics have organised workshops for key research users and beneficiaries that also enhance our research impact, including healthcare themes, advanced manufacturing, timeline of 5G developments and its growth towards 2020. Lam contributed to the drafting of the latest European, Australian and New Zealand Standards on composite structures.

Our research contribution to transforming the nation's built environment through the provision of a sustainable and resilient infrastructure using low carbon, adaptable and sustainable

construction materials in the EPSRC RM4L will have an impact on all aspects of our infrastructure but also on engagement with industry, facilitating scale-up, marketing, and commercialisation of these resilient materials for the construction industry.

Our water and wastewater team developed technology that is able to measure water quality rapidly for enhanced community prosperity. The technology is mainly applicable as an initial screening tool for indicative microbial water quality, and one that is ideally suited to simple pollution scenarios such as assessing the impact of faecal contamination in river or groundwater at specific sites, especially in disaster relief situations. The technology has been successfully used in South Africa and a new project will examine water quality in Malawi.

We are also leading a feasibility study, Pi-CREST project, into solar and wave power in Nigeria; the project is a collaboration with the Nortech Management Ltd, Bayero University, Kano, and Renewable Energy Agency in Nigeria, funded by Innovate UK. Pi-CREST is developing modelling tools to overcome uncertainties in planning and operation of local energy systems, particularly as the country is increasingly reliant on fossil fuels, and benefiting the 40% of Nigerians who are unable to access secure, clean electricity

Engagement with diverse communities and the public:

In all our funding bids we build budget provision to engage with diverse communities and public, aiming to maximise the dissemination reach and impact of our research. For example, the INNERS project, exploring cost-effective solutions for better use of resources and producing heat and energy from the Urban Water Cycle, delivered a series of European roadshows events across the six European countries of the consortium.

Contribution to the sustainability of the discipline, including exemplars of interdisciplinary research

Many of our research projects require collaboration with mathematicians, chemists, biologists, computer scientists, health care professionals and engineers from other branches, reflecting our long-term strategy of building up interdisciplinary collaborations. In addition to the interdisciplinary projects mentioned in Section 1, two examples of our interdisciplinary collaborative work include:

- Acting as lead for the Translate HEFCE Catalyst Fund in medical technology, creating a network of academic, clinical and commercial partners in the Leeds City Region (GrowMedTech Research England Connecting Capability Fund), addressing national and international priorities in healthcare and sustaining independence in older age.
- Contributing to national/international priorities in addressing healthcare for aging populations (musculo-skeletal medical technologies), and sustainability/circular economy for plastics materials (novel Chinese technology for difficult-to-recycle materials and low carbon manufacturing technology) achieved via research teams from mechanical, bio-medical, chemical, electrical engineering, materials, biomedical science, physics, chemistry, pharmaceutical engineering science.

During the REF period, our staff made wider contributions to, and received recognition from, the engineering research community as described below.

Journal editorships: Our academics serve on the editorial boards of major journals; we hold 27 editorial board positions for international research journals. Of these, three are Editors-in-Chief and many have been Guest Editors or are Associate Editors. For example, Ashour was the Editor-in-Chief of the Structures and Buildings Journal, ICE (2014-2017), Coates is Editor-in-Chief of Plastics Rubber & Composites: Macromolecular Engineering, and Lam is currently Editor-in-Chief of Steel and Composite Structures, Techno-press. Our mid-career and ECR academics are developing their editorial skills by joining journal editorship, for example ECR Kabir joined the editorial board of Applied Sciences (MDPI) and Mokryani is Associate Editor of

Renewable Power Generation, Generation Transmission and Distribution and Journal of Engineering (IET), and an editorial member of International Transactions on Electrical Energy Systems (Wiley) and The Smart Grid Newsletter (IEEE).

Our staff served as Guest Editors for eleven Special Issues published in various leading journals, for example, Priest was a Guest Editor for the 41st Leeds-Lyon Symposium on Tribology – Integrated Tribology, Tribology International, Elsevier, 2016 and “The tribological behaviour of carbon fibre reinforced polyaryletherketones (PAEKs) through their glass transitions”, Proc. Instn. Mech. Engrs., Part J: J. Engineering Tribology, 2015.

Fellowships: Many of our academics are recognised through Fellowship election for various learned and professional institutions, including those of RAEng (Coates), IMechE (Coates, Priest), IET (Abd-Alhameed), ICE (Bridgeman, Oltean-Dumbrava), IChemE (Benkreira), IStructE (Ashour; Lam), IMMM (Coates; T Khan, Priest); IEEE (Abd-Alhameed), CIWEM (Bridgeman), International Water Association (Bridgeman), Institute for Mathematics and its Applications (Bridgeman), Royal Society of Arts & Commerce (Bridgeman), Society of Tribologists and Lubrication Engineers (Priest).

Prizes & awards: The quality of our research leadership is demonstrated by successes, awards and honours received by our staff. Highlights include:

- Coates was awarded the China International Science & Technology Cooperation Award 2017, China's highest award for a foreign scientist, one of only six British winners of the award since 1984, in recognition of the substantial role that Coates played in promoting scientific collaborations with leading Chinese polymer groups and industry in China, particularly in advanced materials for healthcare through the RCUK Science Bridges China and Global Engagements programme and founding the UK-China Advanced Materials Research Institute. Coates also received the China 70th Anniversary Medal 2019 for his excellent contributions in promoting the science and technology cooperation between China and the UK. Coates received the Society of Plastics Engineers (SPE) International Award 2018, the top annual international award of the SPE, presented to honour a person's lifetime achievement, mainly for his research contribution to controlled structuring of polymers. The international Polymer Processing Society James White Innovation Award 2017 was awarded to Coates for his innovative developments in polymer processing technologies with high commercial impact.
- Bridgeman won the 2017 ICE West Midlands Civil Engineering Award in recognition of his work in developing a low-cost water testing device, making the device ideally suited for use in disaster-relief situations and for monitoring water quality in low resource countries and helping to improve access to safe, potable water around the world.
- Priest received the 2015 Tribology Trust Silver Medal from IMechE, the highest UK award in recognition of an exceptionally meritorious contribution to the science and technology of tribology (IMechE on behalf of the Tribology Trust).
- Lam was awarded the Frederick Palmer Prize by the Institution of Civil Engineers for the best research paper published in the ICE proceedings - Building and Structures in 2017. The results obtained from this work informed the latest revision of the Eurocode 4 for the serviceability requirements for composite beams with low degree of shear connection.
- Sweeney won the 2019 Innovation Award from the Food and Drink Federation and the Innovative Packaging Machinery Award at the PPMA 2019, in recognition of developing a novel stretch wrapping process that is greener and safer than shrink wrapping.
- Ashour received the Newton Prize 2020 (Turkey), awarded for the best research and innovation, tackling global challenges and promotes the economic development and social welfare of Newton partner countries.

Membership of Research Council or similar national and international committees: Our academics have contributed to national and international research councils and scientific committees; for example EPSRC Peer Review & Prioritisation Panels (Benkreira; Bridgeman, Coates); EPSRC Engineering Strategic Advisory Team (Bridgeman), IWA Specialist Group on Sludge Management Committee (Bridgeman), IAHR UK Chapter (Bridgeman, Chair, 2017-18), IMechE Automobile Division for Yorkshire (Priest, Immediate past Chair), UK Tribology (Priest, Vice Chair), UKRI Future Leaders Fellowships (Bridgeman, Panel college member), Royal Society's International Exchanges Panel & Newton Mobility Grants and Kan Tong Po Fellowships (Ashour), Hong Kong Research Grants Council (Lam, member). The Polymer IRC group at Bradford has recently established an international network of leading polymer engineering researchers (Polymer Engineering International), aiming to promote polymer-related research. Coates has chaired and co-chaired many EPSRC panels, most recently Transformative Healthcare Technologies, 25-26 November 2020, and many of our academics are members of the EPSRC Peer review college (Ashour, Benkreira, Bridgeman, Coates, Guo, Lam, Sweeney, Twigg). We have refereed many research proposals for European and overseas research councils, including Horizon 2020, Canada Foundation for Innovation, Netherlands Organisation for Scientific Research, BBSRC, Wellcome Trust, British Council, IET, ICE, Swiss Research Council, National Science Foundation (USA).

Invited keynotes, lectures and/or performances, or conference chair roles: During the REF period we delivered 30 plenary, keynote, and invited talks in various national and international conferences and workshops as well as chairing many conference scientific/organising committees. For example, Coates gave a plenary talk on "Process Structuring of Polymers science" at the Society of Plastics Engineers Annual Technical Conference (Orlando, USA, 2018) and a plenary talk at the 33rd international conference of the international Polymer Processing Society (Cancun, Mexico, 2017). Priest gave a plenary talk on "Automotive Engine Tribology: 50 Years of Travel Since the Jost Report", 43rd Leeds-Lyon Symposium on Tribology (Leeds, 2016). Campean gave a keynote on "Automotive IVHM: Towards Intelligent Personalised Powertrain Healthcare" to the Annual Meeting of the Confederation of European Environmental Engineering Societies" (Bruxelles, 2019).

Major conferences hosted by our research groups include the 9th International Conference on Steel and Aluminium Structures-2019 (attended by over 150 delegates from 25 countries), the 2020 International Multi-Disciplinary Conference Theme: Sustainable Development and Smart Planning, led by the University of Bradford. Priest Chaired the integrated 41st Leeds-Lyon Symposium on Tribology, 2014.

Co-operation and collaborative arrangements for PGR and ECR training: The ongoing Science Bridges China programme (EPSRC, RAEng, 5 Chinese Scholarships Council 1-year programmes) has trained more than 30 ECRs and PGRs for at least one month, up to one year since 2014. We held 11 international research workshops in the UK and China, including a British Council Newton Early Career Researcher Workshop in Chengdu (2016) with 11 UK universities participating. These, and other core partners, have now had over 70 ECR exchanges and extensive journal publication, joint research grants, and international cooperation awards. Whiteside provided training to ECRs on Microinjection Moulding Workshop at DTU (Denmark) as part of an ITN.