

Institution:

Sheffield Hallam University

Unit of Assessment:

UOA12 - Engineering

1. Unit context and structure, research and impact strategy**Context and Structure:**

This assessment period has been an exciting time for Engineering research at Sheffield Hallam University, with sustained investments in academic appointments, staff development and research infrastructure driving advances in output quality, disciplinary diversification and research facilities. Growth has exceeded our REF2014 aspirations in terms of staff returned and research student numbers, resulting in a burgeoning portfolio of research, consultancy and knowledge transfer. 49 staff (48.6 FTE) are returned in this submission, compared with 31.2 FTE in REF2014. Additionally, colleagues from the Department of Engineering and Mathematics are also being returned under Computing (UoA11), Architecture, Built Environment and Planning (UoA13), and Education (UoA23). Our work on Robotics, which was part of our Engineering submission to REF2014, has been incorporated *en-masse* into the University's new submission to UoA11.

In terms of the research support structures set out in the Institutional Statement, Engineering represents the largest component of the Industry and Innovation Research Institute (I²Ri). Led by **Alderson**, it also comprises research and innovation activities in Biomolecular Science, Computing, and Security and Terrorism. I²Ri is one of four Research Institutes established across the University in 2020, making a significant shift towards removing the boundaries and borders between research groupings, and enabling the building of large-scale interdisciplinary responses to national and global challenges. I²Ri provides Engineering research staff and PGR students with infrastructure, technical and administrative support, and expert guidance in innovation and collaborative thinking.

Our research is aligned to the University strategy of *Transforming Lives*, delivering research that generates innovative, practical solutions to real world problems; and focuses on three main themes: **Functional Materials and Surfaces**; **Smart Technologies and Emerging Materials**; and **Food Engineering and Transformative Manufacturing**. Much of our work is conducted in the purpose-built £5.5M, 2000m² laboratories and office space of our Materials and Engineering Research Institute (MERI). We moved into this significantly expanded research facility in 2014, and have since benefitted from its cutting-edge equipment and modern design. Having academic staff, support teams and research students co-located in this space has resulted in a vibrant and high-quality research environment. As described in our Institutional Statement, Engineering research has also benefitted from a £10M investment in STEM facilities (in 2017), enabling co-location of engineering, physics and chemistry, to facilitate collaboration and interdisciplinarity.

A further substantial institutional investment is our National Centre of Excellence for Food Engineering (NCEFE). Developed in partnership with the National Food and Drink Federation (FDF), and companies including Nestlé, Premier Foods and SMEs, NCEFE delivers engineering led research and innovation to address food sector challenges. Launched in 2014, with a dedicated facility opening in 2019, NCEFE has established itself as an industry-facing catalyst for innovation, skills and training. Its £10.5M, 1815m² industry-facing facility represents an important component of the Sheffield City Region LEP's ambition to grow its Advanced Manufacturing Innovation District and help to physically regenerate the Darnall and Tinsley ward of Sheffield. NCEFE's laboratories incorporate pilot-scale production facilities and workshops, which are specifically designed to enable direct collaboration with global and national businesses.

Realisation of REF2014 Plans:

Our REF2014 research strategy focused on five aspects. We briefly summarise progress against each of these, before setting out our research achievements in more detail against our three focus themes, including references to our submitted outputs and funded projects.

a) Achieve financial stability through a portfolio of research grants & contracts, research students, and consultancy, KT and licensing

We have achieved sustainability by progressing activities across a balance of income streams, totalling **£22M** in this REF period. Thus, in addition to the **£11.22M** of research grant funding submitted under our REF4b/c, and **£2.91M** of QR, we have: gained research consultancy income of **£1.60M**, KT income of **£1.41M**, licensing income of **£358k** and PGR income of **£4.81M**; delivered multiple paid interventions through coordinated KT programmes such as Innovation Futures 2, Sheffield Innovation Programmes 1 & 2, and Grow Med Tech; and conducted 22 full and four short Knowledge Transfer Partnerships (KTPs), and five Enhanced Mentored Internships.

b) Complete planned refurbishments and so deliver positive research environments

The refurbished MERI laboratories and office space and the new NCEFE building are high-functioning research spaces, offering modern well-equipped facilities with excellent infrastructure and technical expertise.

c) Nurture and develop new academic appointments, particularly ECRs

The number, quality and diversity of new academic appointments significantly exceeds that envisaged in 2014. 21 of the 48.6 staff submitted (43%) joined the University within this REF window, with this being a first permanent academic post for 16 of those 21. 29% of our new appointments are female and 48% have ethnicity other than white.

d) Expand PGR provision through internal and industrial bursaries

Research student numbers have grown very strongly through an increase in supervisory capacity, establishment of a central University Doctoral School with bursary scholarship schemes, and realisation of a strategy to grow industry-funded doctorates. Thus, against a REF2014 target of 40, our numbers peaked at over 80; before dropping to 70 due to a deliberate reduction in recruitment during the Covid pandemic, which enabled us to support funded extensions for current students. External PGR sponsorship has been achieved from multinationals (Michelin, Unilever, Siemens, Merck), SMEs (PIL Membranes, MIRA Ltd), government/third sector (HSE, NNL, US DoE, Culham Laboratory, Rutherford Appleton Lab, Sheffield Hospitals) and the EC H2020 CoFund Doctoral Training Alliance programme (801604- DTA3-H2020-MSCA-COFUND-2017).

e) Diversify research areas

This submission is significantly broader in scope than our REF2014 submission, which was made to Electronic Engineering, Materials Engineering and Metallurgy, rather than General Engineering. Our main diversification has been into the **Food Engineering and Transformative Manufacturing** theme, but we have also grown physics/maths research. The portfolio of industrial networks forged by NCEFE has enabled this theme to grow very strongly, particularly since the completion of its bespoke research facility. Growth in other areas has been achieved through concerted recruitment, staff development and nurturing of research-active new appointees. This has run across our vibrant programme of taught awards in engineering and maths, including our provision in physics, which re-opened in 2016.

Research Themes and Pathways to Impact:

Each of our research themes is coordinated by a research Professor, to provide leadership and representation across governance structures. Impact is intrinsically embedded into the mission of each theme, and realised by multiple threads (see Impact section).

Functional Materials and Surfaces

This theme, led by **Hovsepian**, comprises our work on: wear-resistant and functional coatings; nano-structured materials with photonic, photovoltaic and sensor applications; metallurgy; and structural materials. Much of this research has strong economic impact, particularly through a series of long-term partnerships with industrial collaborators and license-holders.

High-Power Impulse Magnetron Sputtering (HIPIMS) surface coating technology, the upscaling of which was pioneered in our production-grade laboratories, is now embedded in industries worldwide. As set out in **ICS2**, the enhanced protection offered by HIPIMS in environments with

high oxidation, wear and corrosion conditions underpins several extended license agreements with major coatings system manufacturers (Hauzer, CemeCon) and our Joint Research Centre with Fraunhofer IST. As well as pioneering novel thin film coatings for photovoltaics and high-wear components (EP/J011398/1, EU 310436, **Ehiasarian** [10.1016/j.jallcom.2019.02.238](#), **Hovsepian** [10.1016/j.apsusc.2016.01.007](#), IUK 71257-487353, patent application EP3527688A1 with Rolls Royce), our HIPIMS group has developed nanostructured coatings for orthopaedic implants with enhanced fatigue resistance (**Ehiasarian** [10.1016/j.surfcoat.2014.02.029](#), PhDs with Zimmer Biomet). Further, our HIPIMS research has been exploited by Trumpf Hüttinger in the production and technological advancement of the Apple iPhone 12 Pro.

Innovative nanostructures are also prevalent in other work under this theme, such as graded bandgap materials for photovoltaic devices (**Dharmadasa** [10.1038/s41598-020-78066-y](#), PhD with CARA), writeable plasmonic structures for anti-counterfeiting solutions (**Cranton** [10.1016/j.optlaseng.2015.12.010](#)), high-sensitivity, portable biosensors for agricultural and food industry applications (**Nabok** [10.1039/c8nr02144a](#)), and in theoretical work on quantum dots (**Harrison** [10.1021/acs.jpcclett.5b02408](#)) and terahertz lasers (**Pereira** [10.1364/OE.22.003439](#), **Harrison** [10.1063/1.4918993](#), MPNS COST Action MP1204).

On metallurgical systems, we have developed approaches to increase the lifetimes of cutting blades (**Luo** [10.1016/j.msea.2018.04.012](#), KTP with Tyzack Machine Knives). We have also worked with a steel manufacturer (PhDs with Tinsley Bridge) to develop heat treatment technologies for ultrahigh strength and wear-resistant steels. Further, we have advanced novel technologies and hybrid materials for helicopter repair (**Kordatos** [10.1016/j.compstruct.2015.03.014](#), FP7 IAPETUS project), approaches to prevent erosion-corrosion loss of neutron source targets (PhD with RAL), and the manufacture of insulating jackets for petroleum pipelines (KTP with BS Stainless).

Our research on novel building materials and methodologies includes the development of low-carbon alternatives to Portland cement (**Mangat** [10.1016/j.conbuildmat.2018.07.180](#), **Starinieri** [10.1016/j.conbuildmat.2018.06.055](#), ISCF 79439-506253) and electrically heated flooring (KTP with Marlborough Brickwork), and prototype microwave curing techniques for in-situ concrete repair (**Mangat** [10.1016/j.conbuildmat.2016.03.007](#), FP7 605664) (ICS1).

Smart Technologies and Emerging Materials

Under this theme, led by **Sammon**, we group our work on soft materials (polymers, gels, auxetics, and fluid flows) with that on glasses and ceramics. Much of this activity is underpinned by fundamentals of physical sciences, which has provided support for new researchers in physics and made for strong multi-disciplinary links with collaborators in biomedical science.

We have achieved major success in developing thermally-triggered gels attuned to biomedical applications, particularly the repair of intervertebral discs (**Sammon** [10.1016/j.actbio.2017.03.010](#), Patent EP2747797) and bone, supported by over £2M in funding with biomedical collaborators (EU246351, EU825925, MR/P026796/1). Multi-disciplinarity has been crucial to this success, generating co-authored outputs with colleagues from the University's Biomolecular Sciences Research Centre (BMRC; UoA5). Further, collaborations have been achieved on polymer nanocomposites, with applications in sustainable packaging and fire-retardancy, and as binders (**Breen** [10.1016/j.clay.2014.10.010](#), **Clegg** [10.1021/acs.macromol.7b02030](#), IUK 132319), automotive components (KTP with Cook Defence Systems), electrolyte gels (**Mader** [10.1016/j.jpowsour.2018.10.049](#)), particulate detection (**Mader** [10.1002/jrs.5113](#), PhD with the HSE), and drug release systems (**Sammon** [10.1021/acs.molpharmaceut.9b01063](#), EP/I501665/1).

Experimental and theoretical work on auxetic behaviours has identified novel mechanisms for sport, consumer products and healthcare applications (**Alderson** [10.1002/adma.201603959](#)); PhDs with Michelin and Pioneer Healthcare; consultancies with Nike, BASF, Babolat, HEAD SPORT GmbH, BSN Medical Inc); and includes collaborations with BMRC and Sports Engineering (UoA24). In addition, self-assembly has been utilised in both conducting threads for wearable tech

(**Aminorroaya-Yamini** [10.1021/nn406026z](https://doi.org/10.1021/nn406026z)) and simulations of nano-structures (PhDs with Unilever and Merck, **Cleaver** [10.1080/00268976.2018.1492744](https://doi.org/10.1080/00268976.2018.1492744), consultancy with DSTL). This sub-theme is an exemplar of the global reach of our research activity, embracing collaborations with the US (Cal Tech, Georgia Tech, University of Pennsylvania), Japan (University of Tsukuba), China (Harbin Institute), Australia (University of Sydney, Murdoch University) and mainland Europe. Across the whole of this submission, 57 of our 116 submitted outputs (over **49%**) have international co-authors.

Our expert use of modelling and simulation to probe fluid flow has been strategically developed to cover a vast range of time and length scales, from foundations of the Lattice Boltzmann methodology for multiphase flows (EP/M006948/1, **Halliday** [10.1080/10255842.2013.799146](https://doi.org/10.1080/10255842.2013.799146), **Xu** [10.1103/PhysRevE.96.053308](https://doi.org/10.1103/PhysRevE.96.053308)), to biomedical and haemodynamic flows (**Halliday** [10.1080/10255842.2013.799146](https://doi.org/10.1080/10255842.2013.799146), **Schenkel** [10.1160/TH16-03-0214](https://doi.org/10.1160/TH16-03-0214), **Spencer** [10.1093/cvr/cvw210](https://doi.org/10.1093/cvr/cvw210)), droplets (**Cheng** [10.1016/j.exptthermflusci.2018.01.027](https://doi.org/10.1016/j.exptthermflusci.2018.01.027)), CFD for aero and automotive systems (**Viswanathan** [10.1016/j.ijmultiphaseflow.2018.09.016](https://doi.org/10.1016/j.ijmultiphaseflow.2018.09.016), PhD with HORIBA MIRA, **Li** [10.1016/j.ijhydene.2018.05.114](https://doi.org/10.1016/j.ijhydene.2018.05.114)), high speed aerodynamics (KTP with EPA Manufacturing), supersonic shocks (**Li** [10.1016/j.ijhydene.2018.05.114](https://doi.org/10.1016/j.ijhydene.2018.05.114), **Cui** <http://doi.org/10.1063/1.4975983>), and ocean-based energy converters (Royal Academy of Engineering UK-CIAPP73, **Kara** [10.1016/j.renene.2016.01.088](https://doi.org/10.1016/j.renene.2016.01.088)).

The growth of our research in glasses and ceramics has far exceeded that predicted in REF2014. As well as performing cutting-edge work on the fundamentals of glass science (**Bingham** [10.1038/s41598-019-51306-6](https://doi.org/10.1038/s41598-019-51306-6), **Forder** [10.1021/ic5028702](https://doi.org/10.1021/ic5028702), Diamond synchrotron time, **Jones** [10.1088/1361-648X/aaab7d](https://doi.org/10.1088/1361-648X/aaab7d), ESRF beam-time) we have made considerable achievements in reducing the environmental impact of glass and ceramics manufacture (IUK 104382, 132334 and 132360, BEIS TRN: 2021/08/2019, PhD with Wienerberger), and advancing technologies for high level nuclear waste glasses (**Bingham** [10.1111/jace.15936](https://doi.org/10.1111/jace.15936), PhDs with NNL and the US DoE). This academic expertise has also been applied to industrial problems, including the development of an innovative high-temperature fibre insulation material, as set out in **ICS4** (KTP009345, SKTP1000819, PhDs with Morgan Advanced Materials).

Our corresponding work on ceramic materials ranges from knowledge transfer activities on ceramic composites (Royal Society IF120126, KTP with Wienerberger), to international collaborations developing a family of environmentally friendly ceramic piezoelectric materials for actuator and energy-storage applications (**Feteira** [10.1039/C7TA09857J](https://doi.org/10.1039/C7TA09857J), Diamond Light Source, **Sterianou** [10.1039/C6TC05515J](https://doi.org/10.1039/C6TC05515J)), highly innovative thermoelectrics (**Aminorroaya-Yamini** [10.1002/aenm.201501047](https://doi.org/10.1002/aenm.201501047)), and novel magnetic ceramics (**Eccleston** [10.1039/C9DT00418A](https://doi.org/10.1039/C9DT00418A)). Modelling and simulation of fast-switching ferrimagnetics and magnetic alloys for future data storage technologies (**Ostler** [10.1038/s41467-019-09577-0](https://doi.org/10.1038/s41467-019-09577-0), NIA awarded 2020 EP/T027916/1) extends this area further into the realm of the underlying physics. Further physics and mathematics research includes experimental nuclear structure physics (**Smith** [10.1103/PhysRevLett.119.132502](https://doi.org/10.1103/PhysRevLett.119.132502), PhD with Culham), theoretical astrophysics (**Baxter** [10.1088/1361-6382/ab310e](https://doi.org/10.1088/1361-6382/ab310e)) and population modelling (**Abernethy** [10.1016/j.ecolmodel.2018.12.003](https://doi.org/10.1016/j.ecolmodel.2018.12.003)).

Food Engineering and Transformative Manufacturing

Food Engineering is founded on the pull of end-application, rather than the push of methodology or academic discipline. Consequently, while NCEFE has its own core research and innovation team, it also draws on the full range of our Engineering research expertise on a project-by-project basis. Transformative Manufacturing, meanwhile, is a rapidly evolving sub-theme of our research portfolio and extends well beyond our traditional Materials Engineering core, to embrace automotive, control, power engineering and engineering management.

Led by **Howarth**, NCEFE has, through the period, undertaken 12 collaborative R&D projects with industry, funded through IUK, Newton Fund, EPSRC and EU H2020 Eranet; with a total project value of £8,232,720, of which funding to Sheffield Hallam was £1,827,636. This includes IUK funding of: heat recovery research with Dext (IUK 102322, **Asthana**

[10.1016/j.egypro.2019.02.100](#), **ICS3**), manufacturing process optimisation with World Feeds, process control research with Nestlé and Greencore (IUK 102327 and 102700, **Howarth** [10.1016/j.jfoodeng.2020.110229](#), **Dubey** [10.1063/1.5123182](#)), and rice milling with overseas partners and Koolmill (EP/P026206/1). A number of studies aimed at maximising the full value chain of food systems include: pyrolysis-based valorisation of underutilised crops (**Kabir** [10.1016/j.jclepro.2016.08.090](#)), upgrading of agro-food waste materials (**Sammon** [10.1016/j.indcrop.2017.10.062](#)), investigation of anaerobic digestion systems (ISCFPoC17_11), and okra-derived biopolymers for pharmaceutical sustained-release applications (**Fleming** [10.1016/j.foodhyd.2017.02.010](#)).

We have also established a substantive research activity in energy management systems. Our three new appointments in this field give us a strong core in power networks (**Liao** [10.1109/TSG.2018.2868461](#)), and microgrids for community energy systems, unified control and autonomous electric vehicle charging (**Issa** [10.1109/TPEL.2014.2359792](#), **Ikpehai** [10.1109/ACCESS.2017.2709254](#)); alongside ongoing activity on fuel cell configurations (**Zhang** [10.1007/s40565-016-0196-5](#)), ohmic heating (**Breikin** [10.4236/ojmsi.2021.91002](#)) and our Energy-focused Horizon 2020-funded Doctoral Training Alliance activity.

The CFD modelling activity for aero and automotive systems, listed under the previous theme, is complemented by work on automotive drive control strategies and diagnostics (**Lenzo** [10.1109/TIE.2016.2540584](#), consultancy with TEXA, PhD with Siemens). Our Control Engineering work ranges from satellite network optimisation (**Battistini** [10.1016/j.actaastro.2017.12.050](#)), to research with Sheffield Children's Hospital to investigate treatments to improve bone strength (**Razaghi** [60/01Harrison](#), POM000156 ICURe). Finally, under this sub-theme, we have a strong track record in engineering management and supply chain networks (**Saad** [10.1504/IJSCOM.2018.091620](#)), with PhD theses applying these methods to petroleum and steel industries, achieving several thousand downloads from our open access repository (e.g. Dr M Khamkham 4959 downloads).

Impact:

As illustrated in the theme summaries above, impact is intrinsic to our research activity. Our approach to impact is based on three priorities: partnerships, knowledge transfer and dissemination. For the first two of these, impact largely is economic - the development of materials, systems, knowledge and skills, in partnership with end-users. The third relates to external engagement via outreach and training of professionals.

Partnerships

Our most direct route for engaging with industrial beneficiaries is through collaborative research projects with partner organisations. This has been achieved through: full cost research projects (e.g. Hauzer, BioMet), EU-funded collaborations (e.g. the FP7 project MCure), TSB and IUK sponsored collaborative research and development partnerships (e.g. six NCFE IUK projects totalling £897k), industrial funding for over 20 PhD projects, and licensing of patents or specific expertise.

Through our expertise in key applications areas and strong internal networking, we have also enhanced our impact via thematic clustering in the areas of Energy, Biomedical and Food Engineering. Our work on Energy includes: new materials for energy generation, transfer and storage; low carbon approaches to materials production and processing; control systems for power networks and microgrids; industrial heat-recovery systems; and mechanisms to enable low-energy data-storage. Our research with Biomedical applications includes: gels for disc and bone repair, joint replacements, bio-medical and haemodynamic flows, novel stent designs, and healthcare technologies. In Food Engineering, our development of NCFE represents a long-term strategic and targeted realisation of a major research and innovation goal, with real-world impact at its core. This is exemplified by the words of Ian Wright, CEO of the Food and Drink Federation: *"The National Centre of Excellence for Food Engineering at Sheffield Hallam is a fantastic example of how manufacturers, government and academics can collaborate to bridge the food industry's research gap. The shared vision and priorities that we have developed will make this world-class*

facility a focal point for research and innovation excellence for the UK's largest manufacturing sector."

Knowledge Exchange

Impact activities through knowledge exchange are supported via strategic project investment in: specialist facilities (e.g. £0.86M HIPIMS system, £150k biomechanical tissue loading suite), 13 HEIF Impact Fellowships supporting partnerships with industry, and direct funding of SME engagement projects. The Sheffield Innovation Programme (SIP), an ESIF supported partnership with the Sheffield City Region Growth Hub and University of Sheffield, and its predecessor Innovation Futures 2, are examples of our programmes to support SMEs through access to expertise and facilities. We have engaged with 77 regional SMEs through these schemes, generating seven new products (six new to market) and extending many interventions into follow-on research and KE activities, such as KTPs and IUK projects.

Dissemination

We have engaged proactively in public-facing outreach, particularly in the Sheffield City Region. In addition to talks to local schools, and in PubhD and Skeptics in the Pub settings, this has included hosting of and contributing multiple sessions to the annual Sheffield Festival of Science and Engineering, e.g. stands by **Breen, Alderson, Clegg** and their PGR students at hands-on events, and public talks by **Cleaver, Cranton** and **Sammon**. **Alderson** has also contributed to the BBC2 [Learning Zone Biomimetics](#) programme (2015).

Jones has led a range of outreach activities on sustainability and e-waste www.whatsinmystuff.org, including appearances in the documentary film "E-Life" (2016), BBC World News (TV) Talking Business with Aaron Heslehurst (2018), and talks at schools across the country. **Alderson, Bingham** and **Sammon** have also had several BBC Radio Sheffield appearances discussing their work during the REF period.

We have an established track record in disseminating our expertise to key professionals by developing and delivering CPD courses, targeted at two specific groups - road traffic accident investigators and bridge inspectors. Across multiple sessions these have, respectively, been used to train 145 accident investigators from 24 police constabularies, and 251 bridge inspectors from UK and international jurisdictions.

Future Research Strategy:

Our future strategy builds on the strong growth and diversification we have achieved during the REF2021 period and reflects our commitment to the wider University objectives outlined in the Institutional Statement. Our Unit strategy is designed to ensure a strong research and innovation culture that delivers excellent performance and sustainable income growth, and focuses on economic and social impact. The formation in 2020 of I²Ri, to which the Unit and the Department of Engineering and Mathematics are aligned, provides the opportunity to shape our future interdisciplinary research and innovation strategy.

Our strategic objectives for the next five years are to:

a) Promote Financial Sustainability by expanding the primary sources of income generation. The Unit will participate in the plans of I²Ri to develop a framework for large-scale funding schemes and create an annual cycle of income generation and horizon scanning, to ensure research is supported through a balance of grant funding, "full cost consultancy" and direct industry-funded work. The Unit will target year-on-year increases of 10% growth in income and achieved through the development of existing staff and appropriately targeted recruitment.

b) Enhance Facilities, Equipment and Infrastructure by building on the consolidation of research facilities through the £16M combined investment in MERI and NCEFE during this REF period, securing new investment and capital funding to enhance this base, and promoting interdisciplinary and collaborative research. Initial investments to be made during the next period include a new £2.74M Testing, Imaging and Characterisation Centre for Innovation, a move to

cloud-based high-performance-computing facilities, and provision of equipment to support emerging research.

c) Consolidate and Expand Research and Innovation Culture and Capacity by growing the Unit, through recruitment and staff development, from the current Significant Responsibility for Research (SRfR) intensity of 40.8%, towards a target of 50%, with a particular emphasis on ECRs. Initiatives delivered through I²Ri will promote interdisciplinary activities and support consortia and bid development to achieve impact. Enhancement of links between the research and innovation activity of the Unit and the taught curriculum will ensure sustainability of capacity and research opportunities, with particular emphasis on PGR development through experience of academic delivery.

d) Develop ECRs through targeted investment of a new University-funded ECR Fellowship Scheme, a coordinated mentoring programme, and direct support for the development of external funding bids, such as New Investigator Awards and Fellowships. All ECRs will be encouraged and supported to participate in the University ECR Network and, through the annual Research Planning cycle for academic staff, the Unit will provide facilities and expertise required to realise individual research plan objectives. Support for researcher development from competitive internal Creating Knowledge and Research Institute funding schemes will be focused on ECRs.

Interdisciplinary Research:

Engineering research at the University has its origins in our interdisciplinary Materials and Engineering Research Institute (MERI), and now ranges across engineering, chemistry, materials, physics and manufacturing. These links and their wider external networks and collaborations now continue through the University's Research Institute-based structure, one of the objectives of which is to promote interdisciplinarity. This engenders an environment that provides a scholarly home, firmly rooted into the academic portfolio of its departments, from which contributions and collaborations are built that drive borderless research. Examples from across the Unit, detailed above, include projects with Biomolecular Science, Sports Engineering, Economic and Social Research, Business, and Food and Nutrition.

Open Research:

The University's Open Access (OA) policy is committed to the principle of making the outputs of publicly-funded research available through unrestricted online access. All staff and research students are introduced to the fundamentals of OA and data management. Our publications and theses are made available through our institutional Green OA facility, the Sheffield Hallam University Research Archive ([SHURA](#)). Since 2017, this has included full digitisation and posting of new and historical theses, 249 of which are from Engineering. For this Unit, download counts in this assessment period are 124,000 papers and 58,000 theses. Staff and research students are also encouraged to utilise ResearchGate, Academia.edu and other academic networking sites to disseminate pre-print publications, and all Category A staff possess an ORCID identifier.

University systems automatically trigger Gold OA where it is a requirement of a funder. We also fund Gold OA for other outputs, priority being given to high impact work and authors who are returning from parental leave or are ECRs. The Library Research Support Team oversees this process, provide a training and advice service, and work with academics to archive research data sets and make these publicly available via the University's research data archive ([SHURDA](#)).

Research Integrity:

We are fully aligned with the University's Research Integrity policy and action plan for the Concordat to Support Research Integrity, as detailed in the Institutional Statement. These include a requirement that research be conducted in accordance with published standards and behaviours, underpinned by Research Misconduct policies. Research ethics and integrity are key topics in our training programmes for research students, supervisors, and early career, developing and experienced researchers. Research ethics processes are systematically embedded and are a specific progress-requirement for doctoral projects. All research proposals are submitted to our University-wide research ethics management system and are scrutinised by research-active staff,

including at least one senior researcher. Our Laboratory Management Group oversees health and safety procedures and risk assessments at a local level, and supplements these with regular walk-around checks. All risk assessments were re-appraised during the Covid lockdown, with subsequent phased re-opening of specialist facilities implemented under strict protocols.

2. People

Staffing Strategy and Staff Development:

Our long-standing aim in staffing has been to sustainably grow our research and knowledge transfer capacity through a concerted combination of recruitment, development and reward. Our strategy for achieving this has principally focused on appointing talented new academic staff and enabling their development into independent research leaders. This is underpinned by a culture of excellence which values high-quality impactful research, enables diversification and interdisciplinary working, and provides specialist facilities, training, mentorship and time.

These approaches are well aligned with wider University objectives for researcher development and its action plan in relation to the [Concordat to Support the Career Development of Researchers](#); **Cleaver** chairs the University's Researcher Concordat Operations Group.

Recruitment and Career Development:

We have a joined-up recruitment policy through which senior staff responsible for research and teaching work together to appoint new faculty with strong potential to deliver on both fronts. As a result of this, 21 of the 48.6 academic staff in this submission joined the institution within this assessment period, this being a first permanent academic post for 16 of the 21.

Below Reader level, individual Research and Innovation Plans are used to ensure a consistent approach to allocation of research time. These plans annually set out a 3-5 year view of how funding, research, outputs and impact activities will work together with approaches to developing personal networks, collaborations and any support required to scale-up achievements. They are then reviewed by the Departmental Research Lead (**Bingham**) and feed into academic work planning. This standardised approach for allocating research time against future plans is the basis for identifying SRfR status, guaranteeing an allocation of at least 20.8%.

A further institutional mechanism for ensuring consistency across different career stages and roles is the University's Academic Careers Framework (ACF). The ACF sets out indicators of achievement in academic citizenship and leadership, research and innovation, teaching and learning, and external engagement. This provides a structured framework for talent identification and career conversations within the annual Performance and Development Review (PDR) process, which gives all researchers the opportunity to review and set new research objectives, in line with the Unit's strategy and their own career development plans.

Early-Career Researchers:

Along with targeted recruitment of new staff aligned to our research expertise, the support and development of ECR colleagues is central to our approach for growing research capacity and community. ECRs are directly supported through mentoring, to foster our culture of research excellence that values quality research with impact, and by being pairing up with experienced supervisors to form PGR supervisory teams. In line with the Researcher Concordat action plan, internal investment schemes prioritise direct support for and/or engagement of ECRs in strategic projects and funded PhD scholarships. This provides both encouragement and opportunity to develop as independent researchers and secure internal fellowships/external funding as a pathway to future leader status. Examples of colleagues who have been supported by such approaches during the period are **Bingham**, **Ostler**, **Starinieri** and **Xu**. Both **Bingham** and **Xu** were (consecutively) ECR representatives on the University's Researcher Concordat Operations Group and have since progressed to Reader (**Xu**) and Professor (**Bingham**).

This consistent implementation of supportive ECR development policies over many years is reflected in the histories of several of the staff submitted here: five gained their own PhDs at Sheffield Hallam (**Clegg, Ehasarian, Razaghi, Sammon, Spencer**) and two are now at Professorial level. Our ECRs also participate actively in governance structures and our ECR Network (see Institutional Statement) promotes community, culture and interdisciplinarity by enabling ECRs of all disciplines to come together through a series of events and workshops, run by and for themselves.

Research Leave/External Exchanges:

Throughout the period, the Unit has supported staff with institutional initiatives to promote the growth of research capability through investment to engage in strategic projects. Mechanisms such as the *Chancellor's Fellowship Scheme*, the *Platform Challenge Fund* and *HEIF Strategic* funding have been used to allocate ring-fenced sabbatical/research time and project funding to support **Bingham, Ehasarian, Jones, Nabok, Ostler** and **Sammon**. In each case, the funding has been used to promote external engagement and build capability.

In addition, HEIF funded *Impact Fellowships* have been awarded to 13 staff through the period, with the objective of enabling them to work with industry, public, and voluntary and community organisations, to develop new collaborations and deepen existing relationships.

Recognition and Reward:

Exceptionally, four staff in this Unit have been promoted to senior university roles in research and innovation leadership in this REF period: **Eccleston** (PVC Research and Innovation, and subsequently Deputy VC Academic), **Cranton** (Dean of Research), **Alderson** (Director of I²Ri), and **Cleaver** (Director of the Doctoral School). Additionally, **Fleming** and **Zhang** both achieved departmental leadership roles as Deputy Heads of Department (NFA grade 10).

In recognition of their excellent research achievements, **Bingham** and **Feteira**, who were ECRs in our previous REF submission, have progressed through Reader to gain personal Chairs. Additionally, **Aminorroaya-Yamini, Asthana, Breikin, Clegg** and **Xu** have all achieved Reader or equivalent (grade 9). Of these, **Aminorroaya-Yamini** and **Xu**, two female new appointees, are exemplars of talented researchers who have achieved accelerated career progression. Twelve other colleagues in this submission have progressed from grade 7 to 8. All individual promotions are assessed against the ACF, to ensure consistency across the institution and apply the principles of the San Francisco Declaration on Research Assessment (DORA).

Relatively few of our established research staff have left the institution for alternative employment in this REF period. Two who did (**Harrison** and **Pereira**) went to Professorial positions at other HEIs. We would though like to note in this submission the enduring contributions of two of our valued colleagues, **Professor Chris Breen** and **Dr Sue Forder**, who very sadly passed away through ill-health whilst still in post.

Research Students:

Postgraduate research (PGR) students are integral to our research community and the growth of our PGR provision has been a key focus in this REF period. **29%** of the outputs submitted by the Unit have PGR student co-authors. We have achieved 77 completions, compared to 58 in REF2014; though a like-for-like comparison with that previous total would be 91, due to several established supervisors now being aligned with the new submission to UoA11.

The University operates a 'hub and spoke' model for the administration and management of research degrees, the hub being the central Doctoral School, led by **Cleaver**, with I²Ri one of four spokes. PGR operations in I²Ri are coordinated by a Head of Research Degrees, who leads a team of academic PGR Tutors (PGRTs), working in partnership with professional services staff. UoA12 has two PGRTs (**Clegg, Xu**) who oversee recruitment, progression and supervisor allocation. Our dedicated Research Student Administration team maintain PGR records and co-ordinate the allocation and maintenance of resources. Our Research Student Administrators also

have a student support remit, signposting to a range of university services, including our growing provision on mental health and wellbeing.

PGR policies and procedures are set by the institutional Research Degrees Committee, to ensure that our research degree provision meets quality thresholds, as stipulated by the QAA UK Quality Code for HE. Institute and University action plans are devised annually, guided by external regulatory change and student feedback, particularly through the national Postgraduate Research Experience Surveys, in which we consistently achieve strong results. We are well networked with PGR operations at other HEIs through **Cleaver** being co-chair of the UKCGE Deans and Directors of Doctoral Schools Network.

Recruitment, Training and Supervision:

PGR admissions are implemented via a pre-offer proforma, developed to ensure adherence with all internal and external (i.e. QAA, UKVI, F&CO ATAS) requirements. All applicants are interviewed by their prospective supervisor(s) and an independent experienced academic (usually a PGRT), who has responsibility for ensuring that admissions decisions are fair, consistent and reliable. As well as growing our PGR population, we have achieved a high degree of diversity - approximately 60% are international and 25% are female. By headcount, ~25% of the Unit's home PGR students have BAME ethnicities, compared with an institutional average of ~11%. This diversity is regularly celebrated through student-led "bring-a-dish" lunches, which range from Wurst to Wensleydale and from Pavlova to Baklava. A range of social events are organised to celebrate festivals from different cultures and to accommodate differing attitudes to alcohol.

All new PGR students attend University and Research Institute induction events. Extensive digital resources are provided via a Blackboard VLE, and the Doctoral School's training and development site, which is based around the Vitae Researcher Development Framework. Training in research practice (data management, analysis and statistics; information retrieval; integrity and ethics; and health and safety) is provided through compulsory training sessions delivered at University and Research Institute levels, supplemented by online training such as Epigeum modules. Project-specific instruction on research methods and instrumentation is then provided by academic or technical staff with appropriate expert knowledge. Sessions on transferable skills are regularly provided by the Doctoral School. A Teaching Skills for Doctoral Students module, obligatory for those engaging in undergraduate tuition, also introduces PGR students to an optional development programme leading to Associate FHEA accreditation.

We attach particular importance to the development of communication skills. Central to this, each May we run a two-day Research Symposium in which all second year PGRs give an oral presentation and all first years present a poster in a conference-like environment. This involves the whole Unit, plus external invitees, and provides a focus for our training cycle and engenders a strong cohort focus across our PGR community. Many of our students have gone on to give external outreach talks (PubhD, Skeptics), and win prizes at professional body meetings. Additionally, one of our students won the [UK 3MT Final](#) (Vitae Conference, 2019) and gained a significant SciComm contract during her PhD.

Supervision is team-based, both to broaden each student's support network and to enable ECRs to contribute/develop their skills. Each supervisory team receives 90 hours allocation and is required to meet University criteria relating to supervisory experience, research expertise, engagement with update sessions and supervisory loading. Where appropriate, external supervisors from collaborating HEIs or industry are included. Supervisor training includes an institutional Research Supervisor Development Programme, plus workshops for research degree examiners and independent chairs. In addition, I²Ri runs "supervisor fora" to update on regulatory changes, promote exchange of good practice and disseminate feedback from PGR surveys.

Funding:

The growth we have achieved in PGR numbers has been underpinned by considerable success in developing a diversity of funding streams, leading to total PGR income of **£4.81M** across the REF period. This has been significantly founded on effective use of institutional PGR bursary

schemes, to both raise the profile of our programmes and leverage commercial funding to provide industry-linked PhD opportunities. Specifically, our effective advertisement of funded places has led, indirectly, to increased interest from government- and self-funded international applicants. Whilst maintaining strict quality standards, this resulted in recruitment of students from over 25 territories, including India, Iraq, Libya and Nigeria. Additionally, by proactively engaging in a collaborative funding scheme with external partners, we gained support for over 20 full- or match-funded PhDs. These included applied projects with industry (Merck, Michelin, MIRA, Siemens, Weinerberger) and other agencies (Culham, NHS, RAL, US DoE), in line with our broader KE objectives. Finally, we played a lead role in establishing the [University Alliance DTA programme](#), firstly developing it as a structured PhD training collaboration, and subsequently being a partner in its successful application for a €6.5 million Horizon 2020 grant.

Progression and Support:

PhD registration is formally completed at the Application for Approval of Research Programme stage at 3 months FT/6 months PT. For this a researcher who is independent of the project and the supervisory team reviews the project quality and viability, the support and infrastructure requirements, the candidate's development needs, and considerations of research ethics and project safety planning. Academic progress is formally assessed at Application for Confirmation of PhD stage at 15 months FT/27 months PT. For this candidates submit a 6000-word report outlining their research aims, a literature review and description of methodologies/techniques, indicative results, and a detailed plan identifying their potential contribution to knowledge. In Engineering, candidates then undertake a viva based on this report, with one or more independent assessors. Overall outcomes based on this, combined written and oral assessment, are then moderated by a PGRT. Imposing a strict 15-month deadline for Confirmation has improved submission rates. Further, where Confirmation assessment identifies issues, it enables our PGRTs to determine where alternative arrangements may be needed to ensure successful completion.

Students with disabilities can access support from the central Disabled Student Support service, including assistance with Disabled Support Allowance applications, and assessments and negotiation of a PGR-specific Learning Contract, which sets out reasonable adjustments for research, supervision and assessment. Our institutional development of a bespoke Learning Contract proforma and process for PGR students has led to a clear increase in the proportion identifying as disabled, and represents sector-leading practice.

Equality and Diversity:

Equality, diversity and inclusion are embedded in all staffing policies and actions, evidenced by the fact that 29% of our new appointments in this REF period are female (exceeding our research student F:M ratios), and 48% have ethnicity other than white. By comparison, female staff made up less than 10% of our REF2014 submission. These increased levels of diversity are further underpinned by our Department of Engineering & Mathematics and MERI gaining a bronze Athena SWAN award in this REF period.

Access to community and training activities via video-conferencing accelerated rapidly during 2020. Increases in attendance and feedback received suggest this has been instrumental in increasing participation, especially amongst part-time students and staff and those with caring responsibilities. We intend to retain and enhance this blended learning approach.

All researchers have ready access to infrastructures which support diverse communities of staff and students. These include locally-available support networks and initiatives relating to BAME, disability, gender and LGBTQ+, e.g. the Allies programme. Through our management structures the Unit ensures that all policies and processes are deployed effectively, including mandatory completion of unconscious bias training.

Recruitment is undertaken in accordance with University policies for equality, diversity and inclusion. Shortlisting involves independent, criterion-based assessment by panel members. All candidates with a disability who meet the essential criteria are automatically shortlisted and are

asked if reasonable adjustments may help at interview. All interview panels include female and male members, and staff involved in recruitment, promotion and selection processes are required to have undertaken recruitment and selection training offered by the university, which includes sections on equal opportunities legislation, gender and diversity.

3. Income, infrastructure and facilities

Research Funding and Strategies for Generating Research Income:

Our funding strategy is to develop staff via a range of funded programmes - encompassing a balance of grant, KT and collaborative funding - towards larger-scale bids. The Unit delivers research through programmes that are heavily co-created with industry and undertaken through regional, national and international collaborations. Our income portfolio is consequently distributed across a range of funding sources, with total income of **£22M**, comprising: **£10.45M** research grant funding and **£765k** in-kind support, submitted under our REF4b/c; with additional research consultancy income of **£1.60M**, licensing income of **£358k**, PGR income of **£4.81M**, knowledge transfer income (HEIF and ERDF) of **£1.41M**, and OfS (REF QR/RDP) income of **£2.91M**.

Impact is central to our research and funding strategy and has been delivered through multiple coordinated KT programmes, such as Innovation Futures 2 (IF2 - **23** companies supported), Sheffield Innovation Programmes (SIP1 - **57** business assists, delivering **7** new products to companies and **6** new products to market; SIP2 - on-going), Grow Med Tech (**5** projects), and through **22** Knowledge Transfer Partnerships (KTPs), **4** short KTPs (sKTPs) and **5** Enhanced Mentored Internships (EMIs - total KTP/sKTP/EMI income of **£2.79M** (REF4b)).

These initiatives create a pipeline of industry-focused projects of increasing significance and value, typically developing from IF/SIP activity, to KTP and other larger-scale funded research delivering real-world impact. Examples of companies where IF/SIP activity has developed into KTP projects include: ACS Stainless Steel Fixings Ltd, Evenort Ltd, PMS Diecasting Ltd and EMSc (UK) Ltd.

Exemplar impact includes EMI/KTP funding with C-Probe Ltd (**ICS1**) on concrete infrastructure led by **Mangat. Luo**'s initial IF1 (previous REF period) and IF2 activity with Tinsley Bridge Group (TBG) has led onto follow-on KTPs with TBG and Tyzack Machine Knives to develop ultrahigh-strength and wear-resistant steel technologies to support the UK's defence and heavy-duty machineries. The work undertaken by **Bingham** into glass and ceramics research includes an sKTP and a KTP with Morgan Advanced Materials, underpinning **ICS4**. **Bingham** has also undertaken a SIP project with Glass Technology Services as part of a partnership which has secured IUK funding (104382) and formed part of Glass Futures Ltd consortia, recently awarded a £7.1M Industrial Fuel Switching Procurement Contract (BEIS) and a £15M Transforming Foundation Industries Challenge investment (UKRI).

Some of the key projects secured in the current REF period are identified by research theme below:

Functional Materials and Surfaces

Mangat - EU_FP7-SME £343k (605664) with six academic and commercial partners around Europe, to develop and demonstrate energy efficient system for accelerated curing during repair and refurbishment of concrete structures.

Hovsepiyan - EU_FP7 £206k (consortium grant of €3.4M) (310436) with 13 academic and commercial partners around Europe, to develop new coatings for supercritical steam power plants for efficient and clean coal utilisation.

Ehiasarian - EPSRC £160k (£329k total award straddling REFs 2014 and 2021) (EP/J011398/1) with six academic and commercial partners, to use HIPIMS to produce solar cell coatings and improve our understanding of the layers.

Smart Technologies and Emerging Materials

Breen - EU_FP7 £1.2M (290098) straddling REFs 2014 and 2021 (total value of €3.1M): Marie Curie ITN, coordinated by Breen, a 12-partner interdisciplinary team of academic and industrial groups with a focus on sustainable packaging solutions.

Sammon - EU_FP7 £133k (246351) straddling REFs 2014 and 2021 (consortium grant of €4.0M) with 10 academic and commercial partners around Europe, to develop biomimetic nano-polymer based gel for minimally invasive treatment for disc regeneration.

Bingham - IUK £173k and BEIS £173k (consortium grants of 2 x £494k) (104382) with five commercial partners, to develop raw materials for the manufacture of more economical, more efficient, lower-emission glasses and ceramics.

Bingham - EPSRC £172k (consortium grant of £2M) (EP/R020957/1) with 17 academic and commercial partners, to develop innovative manufacturing methods to enable production of evolvable bio-hybrid systems with the inherent ability to sense and repair damage.

Food Engineering and Transformative Manufacturing

Howarth - EPSRC £301k (EP/P026206/1) with 12 UK/India academic and commercial partners, to develop bran processing and investigation and evaluation of rice husk ash production and application, testing and exploitation in India.

Dubey - IUK £236k (consortium grant of £575k) (102700) with three academic and commercial partners, to develop a novel micro-formulation technology to manufacture a healthy cheese product.

Howarth - IUK £183k (consortium grant of £497k) (102327) with three commercial partners, to deliver a step change to the capability of milk processing technology at Nestlé.

Asthana - IUK £182k (consortium grant of £451k) (102322) with three commercial partners, to extend heat recovery systems for application in the food manufacturing industry. Underpinning research for **ICS3**.

Organisational and Scholarly Infrastructure Supporting Research and Impact:

UoA12 has a core role in I²Ri, which facilitates enhanced interdisciplinary collaboration, support for horizon scanning, pump-priming, collaboration and developing funding. The UoA12 theme leads serve on the I²Ri Leadership Team, alongside those from UoAs 5 and 11, and the Institute Head of Research Degrees. The Institute coordinates scholarly activities such that researchers have access to regular interdisciplinary events and dialogues with panels, inclusive of gender, race and research career stage. Our Unit-focused scholarly activities include fortnightly research seminars, an annual Symposium showcasing doctoral and new staff appointee research activity (Section 2), and an annual I²Ri Winter Poster event. Researchers from the unit also participate in the annual Creating Knowledge Conference (Institutional Statement).

Alderson convenes fortnightly planning and oversight meetings comprising **Hovsepian**, **Sammon**, **Howarth**, **Bingham**, the Research Institute Manager and Technical Manager. Representatives from Digital Technology Services attend every six weeks to ensure IT and software infrastructure requirements are fit for purpose, and the group co-opts attendance as required (e.g. AD Research, HoD). This ensures strong alignment of research strategy and operational leadership across facilities, IT and professional services.

As with PGR, our research activity is supported by the University's Research and Innovation Services (RIS) via a 'hub and spoke' model. The central team provides governance, policy, funding KE and commercialisation support. The team within I²Ri then drive research income and operations (Institute Manager), and knowledge exchange and innovation (Innovation Manager). A dedicated professional services team (4 FTE and a placement student), managed by the Institute Manager, support PGRs (Section 2), pre and post award grant submissions, and communications.

The Library integrates high quality academic information resources with excellent IT facilities and specialist research-focused staff and training, enabling our researchers to access a vast range of journals and other scholarly materials.

A Technical Manager leads the team of technical staff in support of our specialist laboratory facilities and is responsible, together with the heads of research and PGR supervisors, for health and safety in the laboratories.

Supporting Funding Applications:

All external funding bids go through a rigorous preparation and authorisation process, including a triage and feedback stage, overseen by **Alderson**. Staff are supported by research group leads early in the conceptualisation and writing processes, and by the I²Ri peer review college in later stages of proposal development. RIS support the submission and approvals process, including costings and compliance with funder rules. RIS has specialist advisors for EU and grant funding, along with innovation funding advisors. External grant development support is also facilitated, particularly for large consortia (e.g. Glass Futures Industrial Fuel Switching Procurement Contract (BEIS) and Transforming Foundation Industries Challenge (UKRI)). Successful proposals are supported by the Institute team through initial start-up and project monitoring meetings to establish administrative, financial and management protocols, and ensure PIs are supported with project delivery.

A significant aspect of our support for growing funding and research capacity is through strategic investment in staff, partnerships and projects - to underpin consortia and bid development. For example, **Cleaver** provided close mentoring and peer support to develop two successful early career research proposals: a First Grant application for **Spencer** (EP/M006948/1, £71,769); and a New Investigator Award for **Ostler** (EP/T027916/1, £228,352). Ostler's NIA proposal was itself an outcome from his internal Chancellor's Fellowship funding.

Estate and Facilities, Including Specialist Research Infrastructure and Facilities:

The Unit has benefitted from major investments in the estate and infrastructure. This includes the expanded Materials and Engineering Research Institute (MERI) facilities, the recently launched NCEFE facility, large scale equipment in National Centre for HIPIMS Technology, and refurbishment and co-location of engineering and chemistry provision through a £10M STEM project.

The primary focus of our research - the excellent experimental research facilities, consolidated via the £5.5M refurbishment of the 2000m² MERI Hub in 2014, brings together a suite of laboratories, staff and PGR student workspaces, meeting rooms and social area.

Equipment available in the MERI Hub includes:

- Analytical Transmission Electron Microscope
- Corrosion analysis (SVET, SKP, Environment-Assisted Failure)
- Electrochemistry Suite
- Scanning Electron Microscopes (Quanta 650, Nova NanoSEM200, Quanta 3D FIB/FEG)
- FEI Empyrean Powder X-ray Diffractometer
- FTIR Spectrophotometers (x3), FTIR Microscope and Imaging FTIR Microscope
- Full Metallography Suite
- Hauzer 1000 PVD Coating Rig
- Von Ardenne Cluster Magnetron HIPIMS System
- High Performance Computing (Beowolf Cluster)
- Instron Impact Testing Machine and Dartec-Controlled Fatigue Testing Rigs
- Lesker UHV Sputtering Rig
- Piezoelectric/Ferroelectric Evaluator System
- Raman Microscopes (x3)
- Spectroscopic Ellipsometer
- Thermo-Analytical Instrumentation (DSC, DMA, TG-FTIR, TGMS, TGA)
- Tribological Characterisation Equipment
- TA ElectroForce 3200
- Wavelength Dispersive X-ray Fluorescence Spectrometer
- Wissel Constant Acceleration Mossbauer Spectrometer

A long-term 'renew and replace strategy' is achieved through an annual institutional call for Capital Investment bids. This enables experimental and infrastructure facilities to be updated in a phased manner. Institutional support through this route has enabled £2.1m of expenditure in this period. Equipment acquired includes the new £0.86M Von Arden Cluster System HIPIMS coating facility, and expansion of the Beowolf Cluster from 260 cores to 592 upgraded cores. Secured investment into the next period includes a new TEM as part of a £2.74M Testing, Imaging and Characterisation Centre for Innovation, in partnership with colleagues in Biosciences.

Additionally, researchers in the Unit utilise large test rigs in the Infrastructure Management labs, and research facilities in the Departments of Engineering and Mathematics, and Chemistry/Bioscience. Our £10.5M NCEFE facility provides analytical laboratories, and two large process halls designed to simulate actual food production lines. This industry-facing research and pilot production facility represents another crucial institutional investment in the Unit. Large external facilities (notably STFC RAL and CERN) are used through beam time allocations and via collaborations.

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

Collaborations, Networks and Partnerships:

Research across our themes is geared towards internal and external collaborative partnerships. Building on the mechanisms of engagement and staff support described in Sections 1 and 2, specific examples from across each theme are described below:

Functional Materials and Surfaces

(1) The variety and importance of nanostructured surfaces is highlighted by work of the HIPIMS team (**Ehiasarian, Hovsepien**) including: (i) coatings for aviation jet turbine blades with University of Southampton and Rolls Royce; (ii) antibacterial coatings for *in vivo* applications with EPF de Lausanne and Fraunhofer-Institute for Surface Engineering and Thin Films; (iii) high wear-resistant coatings for joint replacements with Zimmer Biomet UK Ltd; and (iv) doped graphite solid lubricants with University of Strathclyde, Hungarian Academy of Sciences and Hauzer. **Dharmadasa**, in collaboration with Federal University of Technology Akure, Nigeria, has used electrodeposition to create highly efficient photovoltaic materials.

(2) **Nabok and Cranton's** work on sensors includes: (i) bacteriological sensors with: (a) University of Sheffield, University of Pennsylvania, North Carolina State University and Aalto University, and (b) reusable biosensors with University of Sheffield and Novosibirsk State University, Russia; and (ii) the physics of plasmonic behaviour with Nottingham Trent University, University of Nottingham and CNRS Poitiers. Work by **Pereira** on terahertz lasers secured MPNS COST Action MP1204 funding, the epitome of collaborative working.

(3) Collaborative work on steels, led by **Luo**, includes: (i) environmentally friendly electrochemical treatments for steel components with Chemetall, (ii) enhanced cutting blade lifetimes with Tyzack Machine Knives, and (iii) heat treatment technologies for ultrahigh strength and wear resistant steels with Tinsley Bridge.

(4) Research on novel building materials and methodologies includes **Mangat's** work on: (i) development of low-carbon alternatives to Portland cement using rice-straw reinforced cementitious composites with University of Danang-University, Vietnam; (ii) low energy microwave-cured concrete repair mortars with Queen's University Belfast; and (iii) use of carbon fibre rods for strengthening and affording cathodic protection for reinforced concrete structures in collaboration with C-Probe Systems Ltd (**ICS1**). **Starinieri** has also engaged with restoration projects developing nanolime treatments for conservation of historic structures with: (i) Smithsonian Institute, Washington DC; (ii) Getty Conservation Institute, LA; and (iii) University of L'Aquila, Italy.

Smart Technologies and Emerging Materials

(1) Structure property relationships are exemplified in **Alderson's** auxetic biomedical devices research: laparoscopic space creation device (EP/J501839/1, Central Manchester University Hospitals NHS Foundation Trust); compression fabrics (BSN Medical); catheter for mapping atrial fibrillation (Nottingham Trent University); and tissue engineering scaffolds (Sheffield Teaching Hospitals, Pioneer Healthcare). **Aminorroaya-Yamini's** international partnerships include: (i) development of conducting threads for wearable tech funded by Australian Research Council (DP1093952, DE130100310) with Universities of Wollongong, Sydney and Dublin City, and (ii) 2D materials for energy storage applications funded by Japan Science and Technology CREST (JPMJCR15Q6, JP17H02749, JP16F16706, JP16H06441), and the Australian Research Council (DE130100310). Simulations of nanostructures (**Cleaver**) have been leveraged via collaborations including: (i) Tufts University, University of Pennsylvania and Georgia Tech in the USA, (ii) Merck and Unilever funded PhDs, and (iii) DSTL-funded consultancy with QinetiQ and Cranfield University. One of our ECRs, **Ostler**, has been mentored to develop strong collaborations with experimentalists at University of Liège, European XFEL and the Diamond Light Source, to inform simulations of fast-switching ferrimagnetics and magnetic alloys.

(2) **Breen** and **Clegg's** work on polymer clay composites benefits from extensive end-user collaborations: (i) PF-Clay with NetComposites (IUK); (ii) Graphire with Composites Evolution and Aim Altitude (IUK); (iii) external staff visits through the Marie Curie ITN 'NEWGENPAK' from Technical University of Denmark and Instituto Tecnológico del Embalaje (Valencia); and (iv) Erasmus students from Slovak Academy of Sciences, Universidad Autonoma de Madrid and Universite de Haute-Alsace. **Kordatos** has used polymer composite patches to repair helicopter rotor blades with Universities of Manchester, Bath, Sheffield and Ioannina, Greece; and thermography to investigate the repair efficiency in collaboration with Norwegian University of Science and Technology and University of Ioannina, as part of FP7 project ACP8-GA-2009-234333.

(3) **Sammon** and **Mader's** work on regenerative medicine comprising: (i) NPMIMETIC (FP7 246351) was undertaken with 10 partners including AO Foundation (Switzerland) and VUMC (Amsterdam) hosting six exchange visits; (ii) SNIPER (Versus Arthritis); (iii) SNIPER-X (GrowMedTech); (iv) MRC (MR/P026796/1); and (v) hosting visiting VUMC researchers funded by the Dutch Spine Society, COST Action MP1302 Nanospectroscopy, Eurospine and Erasmus.

(4) Our flow modelling group of **Schenkel**, **Halliday**, **Xu** and **Spencer** probe fluid flow covering a wide range of time and length scales, using the Lattice Boltzmann methodology for multiphase flows, especially for haemodynamic systems with: (i) CNR (Rome) and Brunel University; and (ii) University of Sheffield, Queen Mary University, MRC Clinical Sciences Centre, Imperial College, University of Leeds and Erasmus Medical Centre in Rotterdam.

(5) The glasses and ceramics team of **Bingham**, **Feteira** and **Jones** work on the fundamentals of glass science and ceramics for actuator and energy-storage applications and protective armour. The work of **Bingham** is featured in **ICS4**, while **Feteira** has fostered strong international collaborations developing environmentally friendly ceramic piezoelectric materials including: (i) ferroelectrics for solar energy harvesting with University of Sheffield; (ii) lead free ceramics with high recoverable energy density with University of Sheffield, Iowa State University, Xi'an Jiaotong University, Abdul Wali Khan University and North China University of Technology; and (iii) lead-free antiferroelectrics in conjunction with University of Sheffield, Shanghai Institute of Ceramics, Xi'an Jiaotong University, Tangshan Normal University, Xi'an Technological University and Diamond Light Source Ltd in Harwell. **Jones** has engaged heavily with XeraCarb Ltd, developing lightweight ceramic armour plates in collaboration with Cranfield University and Imperial College, leading to follow-on grants including: (i) two MOD CDE projects (DSTLX10000888480, DSTLX1000104116), (ii) TSB funded Proof of Concept 710272, and (iii) an MOD DSTL project.

Food Engineering and Transformative Manufacturing

(1) **Howarth and Asthana** are driving efficiency improvements in the food industry through national and international partnerships, examples include: (i) working with Nestlé Product Technology Centre, Spirax-Sarco and Brunel University to optimise product quality and overall oven performance; (ii) **Dubey** studying the generation of biohydrogen from citrus wastewater with Shahjalal University of Science and Technology, Bangladesh and Universiti Malaysia Pahang; and (iii) **Zhang** with University College Dublin, University di Salerno, Technical University of Valencia, Lund University, TU Berlin and University of Amsterdam, on smart processing of foods.

(2) Further aspects of efficiency and sustainability include: (i) **Fleming** in collaboration with Universities of Huddersfield, Bradford and Bristol Laboratories Limited, looking at okra-derived biopolymers for pharmaceutical sustained release applications; (ii) **Kabir** with University of Nottingham Malaysia Campus, Aston University and Universiti Teknologi Petronas, Malaysia on process optimisation; and (iii) **Sammon** with the CSIC in Valencia, Universitat Jaume I, Castellón and Universitat Politècnica de València, incorporating waste almond shell flour into PLA for food packaging applications.

(3) Research into energy management systems including: **Liao** with: (i) University of Manchester on mitigation strategies in power networks, and (ii) the National Grid to evaluate power quality; (iii) **Issa and Ikpehai** research on microgrids for community energy systems and autonomous electric vehicle charging with Universities of Exeter, Manchester Metropolitan, Bolton and Oslo; and **Asthana** who works with several companies including (iv) Wavin, (v) Orion data centre cooling systems, (vi) BS Stainless and (vii) food manufacturer Rakusens, to achieve energy saving.

Contributions to the Economy and Society:

As exemplified by the range of end-user driven research projects and examples of impact presented in Section 1, our strategy is built on the support of excellent research delivering benefit to the economy and society. The key impacts detailed in our ICSs are:

Work by **Mangat** and O'Flaherty (UoA13) on concrete materials and structures influencing professional practice and providing certified competence training to over 250 bridge inspectors, with commercialisation of research on bridge management expert systems adopted by 45 local authorities, six national and eight international bodies (**ICS1**).

HIPIMS research by **Hovsepian** and **Ehiasarian** leading to the generation of revenue of more than £116M for coatings systems/equipment manufacturers and cutting tool businesses, with applications of HIPIMS improving the performance and longevity of medical implants, enhancing lives (**ICS2**).

NCEFE delivering step-change environmental improvements in global manufacture through food processing heat recovery reducing in CO₂ emissions, leading to £1.35M in additional revenue (**ICS3**).

Bingham's work in collaboration with Morgan Advanced Materials having a direct policy and investment impact on decarbonising UK glass, ceramics and other foundation industries, by resolving thermal combustion flaws in a high temperature thermal insulation material for industrial furnace applications (**ICS4**).

Contributions to the Discipline:**Professional Body Committee Memberships**

Alderson (Executive Board of the Engineering Professors Council [EPC]; *Chair*, Research, Innovation and Knowledge Transfer Committee of the EPC); **Asthana** (UK Energy Research Centre Research Committee; *Registration and Standards Recruitment Panel Member*, Institution of Engineering and Technology); **Cleaver** (British Liquid Crystal Society; *IoP Physics in Food Manufacturing Group*; UK Council for Graduate Education); **Clegg** (*Treasurer*, Clay Minerals Group of Mineralogical Society of Great Britain); **Eccleston** (*Founding Chair*, Institute IoP Physics in Food Manufacturing Group); **Ehiasarian** (Joint European Committee on Plasma Surface

Engineering, *Secretary*, British Vacuum Council); **Hovsepian** (Joint European Committee on Plasma Surface Engineering; *Vice Chair* Thin Films Division of International Union of Vacuum Science Technique and Application); **Lenzo** (IEEE Tellers Committee; IFToMM Transportation Machinery Technical Committee; IEEE Vehicular Technology Society Technical Committee; IEEE Transportation Electrification Community Steering Committee); **Ostler** (*Secretary*, IoP Magnetism Group); **Sammon** (*Chair*, RSC Molecular Spectroscopy Special Interest Group; *Secretary*, RSC Biomaterials Special Interest Group; RSC Materials Chemistry Division, Infrared and Raman Discussion Group Committee); **Spencer** (*Communications Officer*, British Liquid Crystal Society); **Starinieri** (RILEM Technical Committee).

Conference and Workshop Organisation

Alderson, International Conference on Auxetics and Related Systems (Sheffield, 2018 and Committee for 2014-19). **Asthana**, International Conference on Energy and Sustainable Futures, (Nottingham, 2019); International Conference on Renewable and Non-Renewable Energy, (USA, 2019); Power Energy Summit, (Dubai, 2019). **Cleaver**, British Liquid Crystal Conference (Sheffield, 2015); Symposium within APS March Meeting (L.A, 2019). **Clegg**, Clay Minerals Group, Research in Progress meeting (Sheffield, 2018). **Eccleston**, Inaugural IoP Physics in Food Manufacturing (Sheffield, 2017). **Ehiasarian**, International Conference on the Fundamentals and Applications of HIPIMS (Sheffield and Braunschweig, 2014-19); HIPIMS session at Annual Technical Conference of the Society of Vacuum Coaters (USA, 2014-19); Symposium at International Conference on Metallurgical Coatings and Thin Films (USA, 2014-15). **Feteira**, Symposium of Electronic Materials and Application (USA, 2019-20). **Ikpehal**, Committee of IEEE International Symposium on Powerline Communications and its Applications (Manchester, 2018). **Howarth**, Dairy Technology (Sheffield, 2018). **Kordatos**, Committee of International Joint Conference on Materials Science and Mechanical Engineering (Athens, 2020); Committee of International Conference and Expo on Ceramics and Composite Materials (Rome, 2018). **Lenzo**, Special Session at International Conference on Robotics (France, 2020); Special Session at AIMETA (Italy, 2019); Special Session at International Symposium on Advanced Vehicle Control, (China, 2018). **Luo**, International Symposium on Thermal-Fluid Dynamics (China 2019). **Nabok**, Committee of European Conference on Organised Films (2015, 2017, 2019). **Sammon**, Committee of Polymar2018 (Greece, 2018); Infrared and Raman Discussion Group (Sheffield, 2017); Session co-organiser TERMIS (Genoa, 2014); Polymar2013 (Barcelona, 2013); RSC Biomaterials Chemistry Special Interest Group (Sheffield, 2013).

Selected International Keynote and Invited Conference Presentations

Alderson, 'International Conference and Workshop on Auxetics' (Poland, 2014; Malta, 2015; Poland, 2016; Crete, 2017; Poland, 2019), Techtextil North America (Atlanta, 2016), Materials for Tomorrow Conference (Sweden, 2014); **Asthana**, Green Energy Conference (Rome, 2019), International Conference on Renewable and Non-Renewable Energy (Miami, 2019); **Cheng**, International Symposium on Thermal-Fluid Dynamics (China, 2019), International Conference on Combustion Science and Processes (Rome, 2019); **Cleaver**, International Liquid Crystal Conference (Ohio, 2016); **Clegg**, International Conference on Advanced Materials Science and Technology (Indonesia, 2015); **Cranton**, Nanotextnology 2017, (Greece, 2017); **Ehiasarian**, EPS Conference on Plasma Physics (Prague, 2018), European Vacuum Congress (Portugal, 2014), International Symposium on Sputtering and Plasma Processes (Japan, 2017); **Feteira**, CICC-11 (China, 2019); **Hovsepian**, International Conference on Plasma Surface Engineering (Germany, 2014); **Jones**, ChemSpec Europe, (Budapest, 2014); **Luo**, Workshop on PVD Coatings for Cutting Tools (China, 2014), International Symposium on the Hybrid Materials and Processing (South Korea, 2017), SurfCoat (South Korea, 2018); **Sammon** TERMIS (Rhodes, 2019); **Zhang**, British Council Lecture Tour (India, 2016).

Journal Editor and Editorial Board Positions

Alderson, Editor-in-Chief, International Journal of Mechanical and Materials Engineering; Editorial Board, Applied Sciences; Computational Methods in Science and Technology; Guest Editor Physica Status Solidi B; Smart Materials and Structures; **Asthana**, Associate Editor Journal of Design Engineering (Special issue); Journal of Energy and Built Environment (Special issue); **Breikin**, International Journal of Systems Science; **Clegg**, Associate Editor of Applied Clay

Minerals; **Cheng**, Editorial Board, Physics of Gases; **Cui**, Editorial Board, International Journal of Aerospace Engineering; **Dharmadasa**, Editor, Journal of Materials - Materials in Electronics; **Feteira**, Editor, International Journal of Applied Ceramic Technology; Associate Editor, Journal of the American Ceramic Society; Materials; Frontiers in Materials; **Fleming**, Editorial Board, Wounds; **Lenzo**, Editor, Paladyn - Journal of Behavioural Robotics; International Journal of Transportation Engineering and Technology; **Luo**, Editor, Surface Technology, International Journal of Nanomedicine and Nanosurgery, Journal of Material Science and Technology Research, Coatings (Guest), Journal Advanced Materials Science and Engineering (Guest), Imaging and Radiation Research; **Kordatis**, Editor, Special Issue Applied Sciences International Journal; **Nabok**, Editor, BioNanoScience, Chemosensors; **Saad**, Editor, International Journal of Intelligent Computing and Cybernetics; **Zhang**, Editorial Board, International Journal of Engineering Systems Modelling and Simulation.

Service on National Funding Panels

Alderson (chair), **Cleaver** and **Sammon** (all EPSRC); **Asthana** (UKERC, BEIS); **Dharmadasa** (Commonwealth Scholarship Commission); **Kabir** (EPC); **Luo** (Exchange Programme of Royal Society and National Science Natural Foundation of China).

EPSRC College

Alderson, Cleaver, Dharmadasa, Ehasarian, Feteira, Kabir, Jones, Sammon, Xu

Reviewing

Staff review for funders, including: BBSRC, EPSRC, MRC, IUK, Alexander von Humboldt Foundation, Leverhulme Trust, Royal Society, National Science Natural Foundation of China, Polish Science Foundation, Swiss National Science Foundation; and many Q1 journals including: Acta Materialia, ACS Nano, Advanced Functional Materials, Advanced Materials, Biomacromolecules, JACS, Journal of Materials Chemistry A, Nature Communications, PLOS One, PNAS, Physical Review Letters and Polymer.

Prizes

Ehasarian, Plasma Innovation Award of the Plasma Physics Division of the European Physical Society 2018, Industrial Accolade from Oike & Co, Japan 2018; Industrial Accolade from Ionbond UK, 2014; **Dharmadasa**, BriSLA Award 2016 for achievements in Science and Technology; **Hovsepian**, Society of Vacuum Coaters, (SVC) Mentor Award 2017.