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| <b>Institution: Staffordshire University</b>                       |
| <b>Unit of Assessment: 12 - Engineering</b>                        |
| <b>1. Unit context and structure, research and impact strategy</b> |

**a. Overview**

Engineering research at Staffordshire is highly interdisciplinary and collaborative. Our vision is to undertake world-leading research to address complex real-world challenges to improve peoples' lives, environments, productivity, and sustainability. We focus on building synergies between research interests within engineering and across disciplines within the University. This focus fosters collaborative opportunities and enhances our routes to impact.

We undertake research within three themes:

- Biomechanics (*Branthwaite, Chatzistergos, Chockalingam, Healy, Naemi, Needham, Pierscionek*): Applications to biomedical, healthcare, and assistive technology, clinical solutions, addressing issues related to diseases and conditions that are a public health concern.
- Renewable and Sustainable Engineering (*Ardekani, Gohari Darabkhani, Komilian, Sadat-Shafai*): Addresses the design of small and medium scale sustainable energy conversion mechanisms, storage, and systems driven by optimising energy solutions to ensure maximum productivity and minimum total life cost.
- Digital Systems (*Amjad, Asaduzzaman, Benkhelifa, Dodd, Shiry Ghidary, Griffiths, Sedky, Soliman*): Addresses algorithm development and interdisciplinary applications of digital approaches to a range of systems. Our research investigates how to apply digital approaches to ensure systems are safe, secure, productive, and more intelligent.

In line with the University strategy (REF5a, Section 2), this Unit of Assessment (UoA) is a consolidation of areas submitted to REF2014 in UoAs 11, 15, and 26. Our submission presents the focus on thematic engineering research in each area.

Research is organised around interdisciplinary research centres bringing together staff from the School of Digital, Technology and Arts and the School of Life Sciences and Education to address the three themes:

- Biomechanics: Centre for Biomechanics and Rehabilitation Technologies (CBRT, led by Chockalingam)
- Renewable and Sustainable Engineering: Centre for Renewable and Sustainable Engineering (CRSE, led by Sadat-Shafai)
- Digital Systems: Centre for Smart Systems, AI, and Cybersecurity (CSSAIC, led by Benkhelifa)

We prioritise collaborations with academic, industry, and policy-making partners at home and abroad. These relationships ensure strong, impactful engagement with our research communities and end-users (Sections 4a, b). We have used them to power a programme of sustainable growth supported by significant partner- and university-level investment in our research cohort and infrastructure (Section 1c). In line with the University's vision of a civic university (REF5a, Section 1), we generated funding of £4,075,904 (matched funding £2,819,868) for five knowledge exchange projects within the assessment period. These projects include establishing the Staffordshire University Innovation Enterprise Zone (IEZ) to support regional industry engagement (Section 4b). We actively support the wider research community, including as co-producers with national and international partners (Section 4a), as members of industry and government working groups (Section 4b), and as editors and organisers of international journals, conferences, and public engagement opportunities (Section 4c).

**Research Governance.** The unit follows the University policies (REF5a, Section 2) on research governance, including upholding the Concordat to Support Research Integrity and we are working towards full compliance with the Concordat on Open Research Data. We assist our researchers to ensure all outputs are available open access.

### **b. Vision, strategy, and plans**

Our vision is to positively impact on how and where people live and work by carrying out world-leading fundamental and applied research in biomechanics, small to medium scale renewable energy systems, and digital approaches to a range of application areas. We achieve this vision through interdisciplinary collaborations with national and international partners from academia, industry, government agencies, and NGOs.

The research and impact strategy is informed by, and responds to, specific external drivers linked to the three themes above, including:

- United Nations Sustainable Development Goals: Good Health and Well-Being; Clean Water and Sanitation; Affordable and Clean Energy; Decent Work and Economic Growth; Industry, Innovation, and Infrastructure; Sustainable Cities and Communities; Responsible Consumption and Production; Climate Action; and Partnerships for the Goals
- UKRI Strategic Priorities: Environment; Biology and Biomedicine; Artificial Intelligence; Productivity; Health, Wellbeing, and Human Rights; Digital; and Productivity and Technical
- Horizon Europe Strategic Clusters: Health; Digital, Industry, and Space; and Climate, Energy, and Mobility

Exploiting interdisciplinary collaborations with national and international academic and industrial partners (Section 4a), and facilitated by our cross-cutting research centres, we address key challenges in:

**Biomechanics:** We specialise in the foot, spine, and the eye, bringing together engineering, biology, and healthcare technology to improve health and wellbeing in a clinical setting. We research tissue mechanics, biomechanics of the diabetic foot, evidence-based musculoskeletal clinical practice, footwear biomechanics, orthotic intervention, insoles and prescription footwear, spinal biomechanics and etiopathology of scoliosis, opto-mechanical modelling of the eye, and the effects of aging. We apply a multilevel approach that includes modelling biological structures and orthotic interventions, undertaking clinical evaluations, and assessing healthcare impacts.

**Renewable and sustainable energy:** We research small to medium scale energy generation and storage including solar, thermal, biogas, combined heat and power, liquid air, and smart grids. We apply a multiscale approach to design optimisation from materials research in organic solar cells, computational fluid dynamics for component design in biogas and micro combined heat and power (microCHP) plants, to robust optimal operation of smart grids.

**Digital systems:** The research addresses service and cloud computing, robotics, manufacturing, infrastructure, the environment, agriculture, biology, and healthcare. We work in all aspects of systems from sensors, data analysis, and machine learning to communications, cloud computing, cybersecurity, Internet of things (IoT), intelligent decision making, and autonomous systems.

We focus on three underpinning methodologies throughout the UoA. Most staff work across all three:

**Computational modelling:** to develop algorithms and fundamental models to achieve better engineering design. Examples: finite element modelling of the ulcerated diabetic foot; opto-mechanical modelling of the aging eye lens; computational fluid dynamics (CFD) modelling of microturbine combustors; CFD modelling of thermal characteristics of solar collectors; modelling of sensor networks; and machine learning for electroencephalogram (EEG) signal representation.

**Design optimisation:** to develop and apply novel techniques to optimise engineering design.

Examples: design of diabetic patient-specific insoles; biologically-inspired implant lenses; organic solar cells; novel microturbine combustor for biofuels; phase change material thermal energy storage; sensor networks; and hybrid waveguides for on-chip ultrafast photonic networks.

**Experimental validation and evaluation:** to ensure our research outcomes meet the challenges of real-world implementation. Examples: shear wave elastography measurement of the mechanical behaviour of the heel pad; Brillouin scattering and x-ray interferometric measurement of the eye; validation of novel biofuel combustor performance in microturbines; and validation of spectrum assignment in large-scale hardware-constrained IoT sensor networks.

Our future strategy over the next five years is:

**Research Capacity and Capability.** Increase from 18.4FTE to > 32FTE through development and mentoring of existing teaching-focused staff and new appointments at both early-career and senior levels.

- Use our research centres to continue developing our active and vibrant research culture by encouraging innovation and risk taking in a supportive environment (Section 2b).
- Provide equipment, facilities, and infrastructure to ensure our researchers continue to deliver world-leading research that is sustainable and facilitates maximum impact (Sections 3c, d).
- Biomechanics – diversify from foot biomechanics to broader musculo-skeletal conditions and rehabilitation engineering. Extend into assistive technology, systems biology, and engineered biological systems by focusing on materials and additive manufacturing.
- Sustainable and renewable energy – continue to strengthen in small to medium scale renewable energy, e.g., inorganic solar cells, power systems control, electrical and thermal energy storage, energy harvesting, and smart grid systems.
- Digital systems – consolidate the expertise in communications and networks; build capacity in robotics and autonomous systems, AI and machine learning, and cybersecurity.
- Expand career development support by using RIIS (Research, Innovation, and Impact Services), our research centres, and the Professoriate to supply mentoring, training, and development, including dedicated support for early-career researchers.
- Increase sustainable Postgraduate Research (PGR) recruitment with a target of 10% growth p.a. by focusing on international collaboration and distance learning PhDs, EngDs, and researcher engagement with current undergraduate and Postgraduate Taught students.

**Enhancing Leadership and Collaborations.** Build on our existing national and international collaborations and leadership in key bodies.

- Senior staff will use their experience of working with national and international bodies (e.g., EPSRC, NIHR, EU, WHO) to support early career researchers to develop leadership.
- Broaden and enhance our strong interdisciplinary collaborations with diverse national and international partners (Section 4a). We will extend our national and international networks and recruit prominent visiting fellows and professors (Section 2b).
- Through the research centres, develop greater interdisciplinary collaborations with colleagues across the University, e.g., biology and engineering/computing, sustainability, and healthcare.
- Raise the profile of our research by ensuring all academics actively engage with national and international industry and professional bodies, editorial activities, and conference organisation. Ensure funding is available and accessible to support such activities.

**Enabling and Facilitating Impact.** Continue building partnerships that increase our research's academic and social impact.

- Improve the visibility and reach of our research centres, exciting the public to the benefits of research, and motivating new collaborations to co-develop and exploit our research (Sections 2a, 4a, and 4b).

**Unit-level environment template (REF5b)**

- Use IEZ support and knowledge exchange projects to build partnerships with industry, focusing on the Stoke and Staffordshire LEP region (Section 4b).
- Build on our existing strengths and leadership in engaging with end user groups, NGOs, and influencing policy, as demonstrated in our healthcare research, to expand impact successes within all of our research themes.
- Acquire an open research platform to host all research outputs, data, and software. Collect access information to drive engagement and increase potential for new partnerships.
- Embed impact awareness training for all academics (with the University Research Impact Manager). Use specialist Vertigo Ventures Impact Tracker software to collect impact evidence as a matter of course.

**Income.** Double our per FTE research income and ensure a robust, diverse, range of funding bodies (Section 3b).

- Provide all academics with training to access funding opportunities, write successful funding proposals, and to lead and manage grant projects.
- Support grant proposal development through our research centres, ADREs (Associate Deans for Research and Enterprise), RIIS, coaching, and internal peer review college. Expand use of cohorts to drive grant writing and peer-to-peer support.
- Support internal and external collaborative proposals through networking events and funding to engage with potential partners.

**c. Research achievements since 2014**

Our research themes, biomechanics (UoA26), sustainable and renewable engineering (UoA15), and digital systems (UoA11) have remained since REF2014. We have organised them into one unit to prioritise and support their strong underpinning engineering research as a basis for our ongoing, sustainable growth.

We have achieved a stable, regulated expansion of our research capacity. Compared to UoA15 REF 2014, our research income has increased from £586,680 to £3,184,731 (£69,843 to £173,083 per FTE), the number of peer reviewed publications from 156 to 494 (18.6 to 26.8 per FTE). A significant percentage of our publications are collaborative (67.4%) and co-authored with international partners (51.8%). The number of PhD awards has increased from 9.5 (UoA15 REF2014) to 56.

We have invested in 8 staff appointments, state-of-the-art facilities in advanced manufacturing and prototyping, advanced materials, digital facilities (Section 3c), and dedicated space for PhD students (Section 2c). The investment has significantly impacted on our research capacity with 24 out of 46 REF2021 outputs submitted attributed to new staff. The University has invested in a new SmartZone (2019) collaboration facility, enhancing our knowledge transfer capacity and the research capability of our partner local companies.

We are one of twenty universities awarded funding to establish a University Innovation Enterprise Zone (launched November 2020) to enhance the translation of our research, support industrial collaboration, and nurture spin-out companies (Section 4b). We formed new strategic partnerships with many international universities and NGOs (Section 4a), established two new research centres (CRSE; CSSAIC) and developed interdisciplinary research initiatives internally with the School of Health & Social Care and the School of Law Policing & Forensics.

We made significant impact in supporting industry (e.g., design of renewable micro turbine power generators, deployment of LPG leak detection system, automated process for customised insoles) (Section 4b). Our work in healthcare made national and international impact in policy (e.g., UK Parliamentary enquiry on footwear choice; WHO Standard for Prosthetics and Orthotics), change to clinical practice (e.g., treatment of diabetic foot conditions in India, Tanzania, and extended to Peru and Turkey; standard operating procedures at Central and Northwest London NHS Foundation Trust) and professional guidelines (updated British Association of Prosthetists and



Orthotists guidelines that are issued to all NHS agencies). These healthcare impacts form the basis of our impact case studies.

**Biomechanics.** Since REF2014 the area has shifted focus from sports science (previously UoA26) to biomechanics and clinical applications in healthcare. It is now internationally renowned for its work on foot, spine, and eye biomechanics. The number of peer reviewed publications in the period was 192. The research is underpinned by significant collaboration (75.5% of outputs collaborative, 56.2% international).

*Key achievements:* We have made significant advances in the modelling and clinical management of diabetic foot complications. In collaboration with AR Hospital, India, we developed a unique approach utilising ultrasound elastography to establish that softer heel pads are associated with foot ulceration in diabetic patients [output identifier 2424]. This work, resulting from the EU FP7 funded DiaBSmart project (2011-15), led to the development of a novel low-cost approach to assess foot ulceration in developing countries. A patient-specific insole prescription that optimises the insole stiffness to best redistribute pressure underneath the foot was proposed [2400,3066]. This work resulted in a patent (Deformable Support Structure, PCT/ 5170/4243PGB), which we harnessed to win £1.1M of funding (NHS England) in collaboration with Cadscan Ltd to develop ultra-customised insoles. This work continued in an investigation of the viscoelastic behaviour of the heel pad under dynamic load and weight-bearing activities using novel simulation and shear wave elastography [2434,3895,4812]. Chockalingam demonstrated, for the first time, the application of Non-Instrumented Movement Inhibition (NIMI) to quantify embodied intellectual and emotional engagement as elicited by visual engagement [2845]. NIMI was shown to be elicited by adding visual accompaniment to audio-only stimulus or making a stimulus cognitively engaging [3531]. We supported the WHO Standard for Prosthetics and Orthotics which were unanimously approved in the Resolution on Improving Access to Assistive Technology at the 71st World Health Assembly, May 2018. Research validating a simple clinical test (paper grip test) for assessing strength of the hallux in people with diabetes has received significant interest among clinicians and researchers [5427]. Advances in dynamic finite element modelling of age-related opto-mechanical relationships in the eye based on Brillouin scattering and X-ray interferometric measurements of the longitudinal modulus [6283] led to collaborations resulting in the EU Horizon 2020-funded MSCA Innovative Training Network 'Opto-Biomechanical Eye Research Network' (OBERON), total funding €3.88M (awarded 2020). Our novel and highly accurate physiologically realistic gradient refractive index model of the lens [6376] has been selected for inclusion in Optics and Photonics News's 'Optics in 2020' Best in Optics selection.

**Renewable and sustainable engineering.** Our research has made significant contributions in the development of small and medium scale renewable energy generation and storage. 46 outputs were published in the period, underpinned by significant collaboration (56.5% of outputs collaborative, 47.8% international).

*Key achievements:* We advanced knowledge of how organic solar cells work at a molecular level. Our findings allow significant performance improvements during the design stage and provide the foundations for large scale organic photovoltaic devices [3007,4498]. This work led to Newton Institutional Link funding (£143,686, awarded 2020) in collaboration with Alexandria University, Egypt, to develop large-scale organic photovoltaic devices. For the first time, a solution to simultaneous flame stabilisation and NO<sub>x</sub> emission control in thermo-photovoltaic micro-combustors was developed [5844]. Working with Bladon Jets (UK) Ltd, funded by Innovate UK (total funding £935,600, 2017-2019), Gohari Darabkhani designed and evaluated a combustor that permits the burning of biogas in a commercial microturbine [6225]. The design was developed commercially and led to the first deployment of a product of this size (12kWe), in South Sahara Africa. Novel CFD optimisation has been applied to the shape, thermal and optical characteristics of concentrating solar collectors [6744,6067] and phase change material thermal energy storage [6062,6161]. Working in collaboration with partners in China, Australia, UK, and South Africa this work was recognised by the German Ministry of Research and Education and was adopted by industry (SOLASTOR, Australia)

**Digital systems.** Bringing together researchers from the Departments of Engineering and Computing, the research focuses on algorithm development and digital approaches to applications including energy, communications, autonomous systems, and healthcare. 63.3% of the total of 256 published outputs are collaborative (49.2% with international co-authors).

*Key achievements:* In the area of networks, Griffiths (funded by GE Grid Solutions) proved in simulation a novel fast non-unit protection algorithm for HVDC grids that requires minimal hardware, has no communication delay, and offers reduced cost [5012]. We developed novel approaches for network optimisation including self-reconfiguration of visual sensor networks [5102] and dynamic spectrum allocation [3951]. The latter work was the first to apply post-optimisation analysis to assess sensitivities and accuracy and now forms the basis for many 5G testbeds to increase spectrum usage efficiency. Benkhelifa developed a solution for guard-band-aware spectrum assignment in large-scale hardware-constrained IoT sensor networks [5436]. This research led to a QR-GCRF collaboration with Yarmouk University, Jordan, to develop and deploy an LPG-leakage detection IoT solution, since piloted in food outlets in Jordan. Soliman designed a new strip-slot hybrid waveguide with extremely large and flat dispersion over broad wavelength range that can be applied to on-chip ultrafast photonic networks [5694]. Sedky developed an open-source 3D smart home simulator to support researchers in IoT and machine learning that led to a Knowledge Transfer Partnership (£103,516, started September 2020) with VR Simulation Systems Ltd [3622]. In the area of robotics, Dodd proved, for the first time, the benefits of using informative priors in Bayesian map building for indoor simultaneous localisation and mapping [6796]. He demonstrated the application of supervisory control theory as a formal method to reduce ad hoc development in swarm robotics [6242]. Shiry Ghidary has pioneered the use of deep belief networks for 3D motion reconstruction [6787] and made contributions to nonlinear dimensionality reduction with application to EEG signal representation [6793,6794].

## 2. People

### a. Staffing strategy

We recruit early-career and established researchers, providing tailored support to ensure they have the capability to produce world-leading research and impact. Our strategy is to recruit people who fit within one of our core themes (Section 1a) and research across at least two of the methodologies (Section 1b), whilst ensuring diversity, sustainability, and agility within the themes. We therefore strengthen our research team, exploit synergies, and respond to the changing research landscape to meet future national and international priorities, e.g., in renewable energy we have built from our strength in organic solar cells to broaden into wider small to medium scale technologies with a strong focus on CFD modelling.

To provide strategic leadership in research and enterprise, the University recruited four ADREs (REF5a, Section 2) with experience of interdisciplinary research and enterprise. Two are within this UoA: Dodd (previously University of Sheffield) and Pierscionek (Nottingham Trent University). Seker (UoA3) provides interdisciplinary leadership bridging biology and healthcare with engineering and Zhao (UoA17) leads interdisciplinary research on business transformation through technology. All academic recruitment panels include an ADRE to ensure research potential is fully considered.

Our strategy to bring together our engineering research into one UoA (Section 1c) has allowed us to use targeted recruitment to build on our strengths in focused areas.

**Biomechanics:** Maintained its critical mass with significant retention of staff from REF2014 UoA26. Branthwaite, Chatzistergos, Chockalingam, Healy, Naemi, and Needham all remained in post, shifting their research emphasis from sport and exercise sciences to biomechanics (Section 1b). Pierscionek was recruited in January 2020 to broaden the research to vision and optics and strengthen interdisciplinary collaboration with biological sciences. Dr Nicola Eddison (Clinical lead for the Orthotics Service, The Royal Wolverhampton NHS Trust, not returned) has been seconded

to CBRT since February 2019 (0.2FTE) as Senior Research Fellow supporting collaboration with local NHS trusts and the wider prosthetics and orthotics community.

**Sustainable and renewable energy:** Recruitment has focused on building capacity in small to medium scale energy generation and storage technologies. Gohari Darabkhani (Cranfield University) was recruited (August 2016) to provide leadership and enhance our knowledge transfer capabilities. Gohari Darabkhani's research focuses on design and optimisation of biogas/hydrogen microCHP systems, carbon capture, and liquid air energy storage using CFD. We appointed Ardekani (University of Pretoria, August 2019) for his expertise in simulation-based optimisation and computational thermofluids with applications to solar energy and energy storage systems. We recruited Komilian (ex-PhD student, July 2020) to provide long term sustainability in organic solar cells (supporting Sadat-Shafai).

**Digital systems:** We strengthened expertise in signal processing, artificial intelligence and wireless networks and focused on greater interdisciplinarity between computer science and engineering. We recruited Dodd (September 2019) to support growth in autonomous systems. Asaduzzaman joined (February 2014) from the University of Dhaka based on his research on statistical modelling in communications, healthcare, and the environment. Shiry Ghidary (Amirkabir University of Technology, Tehran, February 2020) strengthens our research in machine learning, computer vision, and brain-computer interfaces. Amjad joined the full-time staff (September 2017) having previously completed a PhD in the University. Underlining our commitment to staff development, we moved Griffiths from teaching focused to research active. Amjad and Griffiths provide expertise in communications and signal processing to support Soliman.

#### **b. Staff development and support**

We ensure a supportive research culture that encourages staff to be ambitious and take risks to achieve their potential. We support staff to pursue research goals and seek opportunities that develop them personally and professionally. Research staff receive at least 20% of their contractual time to undertake core research activities including conducting personal research, developing new research ideas, funding applications, and contributing to the internal and external research culture (including editorial duties, conference organisation, and contributing to professional bodies).

Workload planning is proactively used to balance responsibilities. Staff with a SRR have reduced teaching and management responsibilities. The annual Performance and Development Review (PDR) provides staff the opportunity to reflect on their activities, set objectives aligned to the Research Centre, School, and University strategies, and identify development needs. An interim PDR is held to reflect on progress and update objectives. The PDR process prioritises discussion of career development and aspirations. All staff are encouraged and supported to undertake relevant training.

Key career stages for academics are Lecturer, Senior Lecturer, Associate Professor and Professor. Promotion to Senior Lecturer is through a formal HERA process. We have revised this process (led by Dodd) to take greater account of research contributions. Promotion to Associate Professor and Professor is through an annual call and includes external reviewers and members to ensure sector standards. Staff seeking promotion attend dedicated support sessions and receive mentoring from a senior member of staff. Staff promoted in the period: Chatzistergos, Healy, Griffiths, Asaduzzaman, Sedky, Soliman, and Ardekani (to Associate Professor) and Benkhelifa, Naemi, and Gohari Darabkhani (to Professor). Of the staff submitted: 3 are Lecturer, 1 Senior Lecturer, 1 Course Director, 7 Associate Professor, and 7 Professor.

95% of staff in the UoA hold a doctorate. Branthwaite and Healy both successfully completed PhDs by publication in the period (supervised by Chockalingam).

RIIS delivers a central research training and development programme based on the themes of You, Your Research and Your University. RIIS developed and now refines the programme's

content in collaboration with the ADREs. The programme draws on feedback from staff through the Professoriate and the Culture, Employment and Development in Academic Research Survey (since 2020), guidance from the Vitae Researcher Development Framework, and the principles of the UK Concordat to Support the Career Development of Researchers. The award of the HR Excellence in Research Award in 2018 reflects our commitment to developing our researchers.

Our research centres and principal investigators provide specific training and development opportunities for postdoctoral researchers. This training is tailored to the researcher and project. For example, CBRT provides training in biomechanics, equipment, and clinical practice facilitated by industry (e.g., Vicon, Cadscan Ltd) and NHS partners (e.g., King's College, Royal Stoke Hospitals) and by international collaborators.

RIIS and ADREs work with the research centres to provide connected university-level support for the development of funding applications and collaborative opportunities. We are planning to finalise a formal internal peer review college. Centres have dedicated seminar series and run their own research development opportunities, including 'writing retreats'. The University runs an annual research conference providing an opportunity to disseminate and share research and develop new internal collaborations. The ADREs have initiated internal interdisciplinary networks to bridge gaps between subject areas, e.g., computing and biology.

Staff are supported by a community of 26 Visiting and 11 Emeritus staff, who are active research collaborators and provide challenge and stimulation for our research work, e.g., Professor Joe Hammill (University of Massachusetts Amherst) mentors junior staff (Needham) and PhD students and contributes to the CBRT seminar series; and Simon Bartold (previously research lead at ASICS footwear) provides expert advice while being an advisor to NICE and MHRA.

### **c. PGR students**

A key area of growth has been PhD recruitment, enhancing our productive, dynamic research environment. 56 PhD students (plus 12 students not included in HESA data as they undertook PhD by publication (4) or distance learning (8)) successfully completed in the period (compared to 9.5 for UoA15 REF2014). To maximise flexibility, we offer full-time and part-time study, distance learning, and PhD by publication. We currently have 80 registered PhD students including 2 by publication, 7 professional doctorates, and 13 distance learning. Many of these students work in collaborating universities or industry and support long term collaborations (Section 4a).

Staff undertake mandatory training prior to supervising PhD students. Training covers best practice in supervision, pastoral care, regulations, and the examination process. All supervisors undertake mandatory annual refresher training including sharing of best practice. Supervisors are members of a University Supervision Training Network. Staff new to PhD supervision are allocated a mentor (through the relevant research centre) and all PhD students have at least two supervisors.

We select PhD students to ensure they have the relevant background, skills, and motivation. Development of PhD students starts with the application process, which requires a research proposal and interview with the supervisory team and an independent panel member (ensuring as far as possible a gender balance). Support of PhD students is the joint responsibility of the Graduate School, School PhD leads and supervisors. All students receive an induction together with students joining in the same cohort (there are three admissions points during the year). PhD students join the relevant research centre, which then provides specific training in relevant techniques (e.g., data analysis and statistics in CSSAIC) and equipment (e.g., shear wave elastography in CBRT).

PhD students undertake an early-, mid-, and late-stage review during the PhD. They are assessed on a portfolio and interview at each stage to support their development. The student, supported by the supervisory team, completes a skills appraisal and development plan based on the Vitae Researcher Development Framework.



The Graduate School (GS) (REF5a) was formed to ensure a consistent approach to PhD support across the University. The ADREs and School PhD leads work with the GS to support students and to shape and deliver the central research training and development programme. We subscribe to the ESRC funded University of East Anglia Online Training Series for PGRs and actively encourage our students to participate. The GS runs an annual Postgraduate Research Conference (now merged with the staff conference), providing opportunities to develop research communication and collaborations. Students are encouraged to participate in regular PhD social events and to join the Staffordshire University Postgraduate Society.

We provide career mentoring and tailored support for job applications and interview preparation. As evidence of our success in PhD development we recruited PhD students: Amjad (September 2017) and Komilian (July 2020) to the academic staff. Examples where our PhD graduates in the period have moved include: Nicola Eddison (Clinical lead, Orthotics Service, Royal Wolverhampton NHS Trust), Sara Behforootan (Researcher, Imperial College), Muhammad Kamran Naeem (Researcher, University of Wolverhampton), Raouf Abozariba (Lecturer, Birmingham City University), Siva Kartteek Boliseti (Infineon Technologies UK Ltd), Hesham Aly (Arab Academy for Science Technology & Maritime Transport), Thomas Welsh (Researcher, Lero Research Centre, University of Limerick), Oluwasegun Adedugbe (Researcher, Zayed University, UAE), and Ochai Oklobia (Researcher, Swansea University).

#### **d. Equality and diversity**

As outlined in the Code of Practice, the University has a comprehensive ED&I framework which we support throughout the UoA. We are a diverse staff. 54.3% of us are from a Black, Asian, and Minority Ethnic background and 18.5% are female (compared to 0% in UoA15 REF2014). We are committed to equality and diversity in ensuring a vibrant research environment and equality of opportunity. Since 2014 two (out of four) of our female staff have been supported to achieve a PhD by publication and two have been promoted to Associate Professor. The University has recently implemented a blended working framework and supports flexible working to support personal circumstances. It is compulsory for all staff to undertake unconscious bias training. Dodd is member of the University Inclusion Champions group. Griffiths is a member of Women in Science and Engineering. The University is a Stonewall Diversity Champion and in 2020 launched a comprehensive Race Equality Action plan.

### **3. Income infrastructure and facilities**

#### **a. Income**

Our research income in the period totalled £3,184,731 across 68 grants and represents an income of £173,083 per FTE (£69,843 in UoA15 REF2014). We have a diverse and robust income portfolio including awards from: EU government bodies, £1,061,204 e.g., EU Framework Programme 7 and Horizon 2020; UK Government, £1,206,833; EPSRC, £50,992; industry, £626,143; and UK Charities, £61,649. Overall, our research income increased by 442% (147% per FTE), reflecting our increasing research capacity and activity.

Key grant awards highlights:

- *EU FP7/Horizon2020*: £110,000 to develop Smartphone Thermal Analysis for Diabetic foot Ulcer Prevention and treatment ('STANDUP').
- *ERDF* (Section 4b): £1,064,910 to support regional growth in advanced manufacturing; £744,728 to support regional SMEs with digital innovation; £986,766 to support innovation in connected and intelligent mobility.
- *Innovate UK*: £91,798 for low-cost in-shoe pressure measurement; £97,188 to develop customised orthoses for the treatment of ulcerated feet; £55,760 to develop a system of 3D perfusion mapping for diabetic foot ulcer assessment; £204,206 to develop a Micro Turbine

## Unit-level environment template (REF5b)

- Renewable Energy Combustor (MiTREC); £44,200 to support feasibility research into Virtual Infrastructure Testing as a Service (ViTaaS).
- *KTP*: £101,625 for cloud based digital transformation for logistics and transport; £78,225; for mobile device routing using machine learning; £62,774 to develop Industry 4.0 concepts including smart sensors and control.
- *Newton Fund*: Institutional Development grant (£43,982) to develop an ultrasound-based diagnostic tool for the Peruvian population; Institutional Links funding (£143,686) to collaborate with Alexandria University, Egypt, to develop and install a solar organic photovoltaic facility.
- *NIHR*: Invention for Innovation grant of £57,770 for ViscoTurf, preventing secondary diabetic foot ulceration.

### b. Future income plans

We will capitalise on existing research strengths and links with partners to double our per FTE research income and ensure a robust range of funding bodies. We will target EPSRC, Innovate UK (including KTPs), Horizon Europe, Royal Academy of Engineering, NHS, industry, and relevant funding charities.

- Our stronger, new internal peer review processes and a strategy for a peer review college are key to our plan to increase our research income.
- We will prioritise sustainability by supporting early career academics, emphasising fellowships (in line with UKRI strategy), and building collaborations internally and with world-leading academic institutions and industry. We will target new academics who can submit high quality applications to the EPSRC New Investigator Award scheme to establish their track record and a platform for future funding (Section 2b).
- We will continue our success in international collaborations by applying for international co-operation funding including Horizon Europe, GCRF, and Newton Institutional Links. We will use our overseas teaching collaborations as platforms for building research collaborations (e.g., the successful collaboration with XUPT, China).
- Our recently established IEZ and knowledge exchange projects (Section 4b) are already building links with industry that will form the basis for Innovate UK (including KTPs), and direct industry funding in line with our Higher Education Innovation Fund Strategy. We will foster these relationships to underpin basic research funding applications (e.g., EPSRC) through pledges and letters of support.
- We will continue to seek funding for policy and advisory work, e.g., from our links to the World Health Organisation.

### c. Facilities and infrastructure

In *Digital Systems*, we have established a SmartZone including high-performance computing to support simulation work and facilities for AR, VR and 3D-scanning. Our work on AI and the IoT is supported by a dedicated lab space. The SmartZone provides facilities for advanced manufacturing and rapid prototyping that support our research in *Renewable and Sustainable Engineering*. This theme has received external investment of £779,500 to establish an advanced materials facility (Research England, SAMIAC – Section 4b) including Laser Induced Breakdown Spectroscopy, Micro Scratch Tester, Particle Size Analyser, and Quantum Efficiency Measurement. We established dedicated incubation space for new start-ups in advanced engineering. We received £1,064,910 funding (ERDF, SAMPID – Section 4b) to establish an advanced manufacturing and prototyping facility including 3D metal printing, gas turbine combined heat and power system, advanced automation, and robot arms. These investments are key to our future vision for sustainability and renewable energy and ensuring impact through collaboration with industry. In *Biomechanics* we invested in shear wave elastography, laser speckle contrast analyser, human performance testing, materials testing, and additive manufacturing. We advanced our research into modelling the eye by using the Spring-8 third-generation synchrotron radiation facility located in Japan.

We have invested £57,000 in dedicated space for postgraduate and postdoctoral researchers (172m<sup>2</sup>).

#### d. Future investments

We will purchase a high-performance computing facility to support research in all areas, including CFD, FEA, data analytics and large-scale simulations. CSSAIC will engage with regional partners to build research testbeds, e.g., Internet of Things, SCADA testbed with ABB and/or GE. The SCADA testbed empowers us to develop solutions to pressing problems in control and automation, cybersecurity, design optimisation, and simulation. CBRT will purchase a nano-indenter and hyperspectral imager to enhance our ability to study the effects of diabetes and ulceration on the foot. We will support recent appointments and future growth in CRSE by investing in smart grid, fuel cell, solar PV, and solar collector facilities and a low carbon electric vehicle testbed. To support collaboration with healthcare we have recently been awarded (August 2020) £2.8M funding from Stoke-on-Trent and Staffordshire Local Enterprise Partnership (£2.9M match) for a new Health Innovation Centre.

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

#### a. Research collaborations, networks, and partnerships

Interdisciplinary and international collaboration is at the heart of our research strategy. 67.4% (51.8% international) of our outputs were collaborative with 99 organisations from 31 countries. Key international collaborators were Amirkabir University of Technology, Iran (39 co-authored publications), Jordan University of Science and Technology (39 publications), University of Malta (26 publications), and University of Pretoria (18 publications).

##### *Indicative academic collaborators:*

UK: Swansea University; Bangor University; University of Wolverhampton; Birmingham City University; University of Glasgow; Middlesex University; University of Sheffield; Kingston University; Keele University; University of Dundee; Kings College London; Brighton and Sussex Medical School.

Europe: University of Malta; Koc University Hospital, Turkey; DLR-Institute of Solar Research, Germany; Istanbul Technical University, Turkey; University of Luxembourg; University Polytechnic of Valencia, Spain; Karolinska Institutet, Sweden; Linköping Institute, Sweden, Utrecht University, The Netherlands.

Middle East: Amirkabir University of Technology, Iran; Iran University of Medical Sciences; Jordan University of Science and Technology; Tehran University of Medical Sciences, Iran; Alexandria University, Egypt; King Abdullah University of Science and Technology, Saudi Arabia; Princess Sumaya University for Technology, Jordan; Mutah University, Jordan; Prince Mohammad bin Fahd University, Saudi Arabia; Arab Academy for Science, Technology and Maritime Transport, Egypt; University for Business & Science, Beirut, Lebanon; Yarmouk University, Jordan; American University in Beirut, Lebanon; Lebanese American University; Alexandria University, Egypt; Arab Academy for Science and Technology, Egypt; Pharos University in Alexandria, Egypt.

Asia: Diabetes Hospitals, Chennai, India; Mobility India, Bangalore, India; Sri Ramachandra University, India; Nanjing Tech University, China; XUPT, China; Xidian University, China; APU/APITT Malaysia; University of Technology Malaysia; Chengdu University of Technology, China; City University of Hong Kong; COMSATS University Islamabad, Pakistan; National University of Sciences and Technology, Islamabad, Pakistan; NED University of Engineering & Technology, Pakistan, Guangzhou Sport University.

South America: University of Sao Paulo, Brazil; Pontifical Catholic University of Peru; Pontifical Xavierian University, Colombia.

North America: University of Alabama, USA; Clarkson University, USA.

Africa: Mundiapolis University, Morocco; University of Pretoria, South Africa; Muhimbili University of Health and Allied Sciences, Tanzania.

Examples of collaborations:

- Working with Pontifical Catholic University of Peru (funded by a Newton Fund Institutional Links Programme), we developed and used an innovative method, ultrasound reverberant shear wave elastography, to assess soft tissue of the foot. This project established the ability of this technique to diagnose soft tissue abnormalities in people with diabetes. The technique is currently used by a hospital in Peru.
- QR-GCRF funds have supported: 1. Mapping user needs for a functional prosthetic knee joint: A sociocultural perspective with Mobility India; 2. Promoting best practice in diabetic foot care in India with Sri Ramachandra University; 3. Should we think beyond plantar pressure? with University of Sao Paolo; 4. Liquid air energy storage and regeneration (LAESR) with Istanbul Technical University; 5. Bio-Hythane ( $H_2+CH_4$ ) fuels from organic waste with Sao Paolo University.
- Teaching partnerships have been successfully extended to research: 1. Distance learning programmes in engineering, XUPT, China; 2. Soliman led a joint ERASMUS+ collaboration with Tafila Technical University and Mu'tah University (Jordan), which subsequently developed into research including a £80k RAEng grant; 3. Sedky led two Erasmus+ international credit mobility projects with Lebanese, Egyptian, and Moroccan universities.
- Soliman acted as the external foreign expert on a Technical Review Panel of the Department of Electrical and Computing Engineering at COMSATS University, Islamabad, Pakistan, and as Member of the Advisory Board to the Faculty of Computer Science at Modern University for Business & Science, Beirut, Lebanon.

Our collaborative working strategy values visiting titleholders (Section 2b). They expand our research environment through co-production, PhD supervision, joint grant applications, and their links to industry organisations, user groups, and policy makers.

#### **b. Relationships with users, beneficiaries, and audiences**

A strong philosophy of our research is co-creation and collaboration with users to ensure impact. We work with regional, national, and international partners to drive research direction, facilitate knowledge transfer, and ensure our work benefits the widest range of stakeholders.

Complementing our strong international collaborations, we work closely with regional partners in line with the University vision as a civic university (REF5a, Section 1). We have won substantial funding (£4,075,904) from Research England and the European Regional Development Fund to develop collaborative research and knowledge exchange. The University has committed matched funding (£2,819,868) to help us generate impact and supporting the regional economy.

**Staffordshire Advanced Manufacturing, Prototyping, and Innovation Demonstrator (SAMPID)** – ERDF funding (£1,064,910, matched funding £709,940, 2019-23) to support 45 regional SMEs with product design, development, and prototyping through mini-KTP type projects and access to a new advanced manufacturing facility in the University.

**Staffordshire Advanced Materials Incubation and Accelerator Centre (SAMIAC)** – funded by Research England (£779,500, matched £734,000, 2019-21) in collaboration with Staffordshire Business School, supports innovation in advanced materials. SAMIAC provides business incubation space, a new research, prototyping, and innovation laboratory for materials characterisation and testing, and a training academy in innovation and entrepreneurship.

**Staffordshire Digital Innovation Partnerships (SDIPs)** – funded by ERDF (£744,728, matched £496,485, 2019-21) is a collaboration with Staffordshire County Council to transform 36 regional



**Unit-level environment template (REF5b)**

SMEs through digital innovation. SDIPs has already created 26 new partnerships, a KTP, additional industry funding (£50k), and 11 new products.

**Staffordshire Connected & Intelligent Mobility Innovation Accelerator** – funded by ERDF (£986,766, matched £657,843, 2020-23) to support 45 SMEs to deliver innovation in connected and intelligent mobility. SMEs will be supported through mini-KTP type projects led by dedicated Innovation and Enterprise Fellows in collaboration with academics.

**Enterprise Collaboratory** – funded by Stoke-on-Trent and Staffordshire LEP (£500,000, matched £221,600, 2020-21) to develop dedicated space for ideation and brainstorming for new start-ups and local SMEs. The space will empower our existing students (including PhD students) to commercialise their work.

These initiatives have been brought together in the **Staffordshire University Innovation Enterprise Zone** (launched November 2020) to engage with regional and national businesses including research collaboration, knowledge exchange, innovation, and skills development.

Key exemplars of relationships with users, beneficiaries, and audiences:

*Biomechanics:*

- Our work on the biomechanics of the diabetic foot is motivated by a collaboration with AR Hospital, Sri Ramachandra University, and other leading diabetes centres in India. It has resulted in a significant improvement in the care for patients with diabetic foot complications.
- Working with the University of Malta and Abbas Medical Centre (Tanzania), the development of a robust prognostic tool has led to more accurate and efficient assessment of foot ulceration.
- Our work with Hospital Militar Geriatrico, Lima, Peru, led to greater understanding of the effect of diabetes on soft tissue mechanics of the foot, resulting in significant improvements in patient outcome.
- Our collaboration with Koc hospital, Turkey, led to significant improvements in prevention of diabetic foot ulcer, in patient outcomes, and quality of life in low- and middle-income countries.
- Our research of insoles has benefited Technofootbed S.L. (Spain), leading to their increased market share in Europe and the UK and a 10% increase in profit.
- Our collaboration with the NGO Mobility India surveys the quality of life of people with a lower-limb amputation and explores how prostheses affect their ability to participate in work and social activities.
- We have developed a novel computational method to customise shoe insole stiffness that can better redistribute pressure underneath the foot in diabetic patients. This research led to a patent (Customised Support Structure, Deformable Support Structure, PCT/5170/4243PGB) and to NHS England funding of £1.1M awarded to our collaborators Cadscan Ltd, who have commercialised an automated process for the low-cost creation of customised insoles. The Academic Health Sciences Network West Coast has invested £230k to test the feasibility of this system for adoption within NHS diabetic clinics.
- Commissioned by the NHS, the British Association of Prosthetists and Orthotists, and the Royal College of Chiropractors we regularly run CPD courses for podiatrists, orthotists, and chiropractors. Our research on foot biomechanics supports evidence-based training in the innovative clinical management of diabetic foot complaints.
- The annual Staffordshire Conference on Clinical Biomechanics provides a unique platform to train health practitioners (~150 p.a.) on state-of-the-art engineering methods and technologies including imaging systems, mathematical and numerical modelling, and data visualisation.
- Our research has informed a UK parliamentary enquiry (2016-17) on footwear choice and contributed to the World Health Organisation Standards for Prosthetics and Orthotics service provision implemented in all 195 member countries (May 2018).

- We have received funding of £70k from Zeiss Zeiss-Meditec to develop novel implant lenses that alter focus like the biological lens (£70k).

#### *Sustainable and renewable energy:*

- Funded by Innovate UK (total £935,600, SU £204,206), Gohari Darabkhani worked with Bladon Jets (UK) Ltd, Quality Transmission Equipment Ltd and Cranfield University to successfully design, manufacture, and validate a combustion system for small scale micro turbine power generators that can run on biogas. Bladon has subsequently commercialised a 12kWe biogas micro gas turbine with expected annual sales of 500 units (£10M).
- Gohari Darabkhani is working with DRM Technic Ltd on an ERDF funded project (£80,000) (as part of the SEND project, Keele University) to research novel methods for measuring particulate emissions from small/medium combustion plant processes with the aim of reducing emissions.
- Sadat-Shafai has received Newton Institutional Links funding (total £273,686, SU £143,686) to collaborate with Alexandria University, Egypt to develop, install and evaluate the socioeconomic impact of a solar organic photovoltaic facility in Egypt.

#### *Digital systems:*

- In collaboration with Yarmouk University, Jordan, Benkhelifa developed a prototype novel end-to-end wireless sensor network for on-the-fly early detection and warning LPG-leakage detection IoT system. This network is being piloted in food outlets in Jordan.
- Benkhelifa leads an initiative for enhanced cyber safety in businesses. Over 200 organisations in the Staffordshire region have joined the initiative. The evaluation research demonstrated significant impact in reducing cybercrimes in the workplace and improved productivity through digital adoption.
- Soliman received £14,000 funding (total award £80k) from the Royal Academy of Engineering to work with the University of Sheffield and Jordanian partners (Jordanian Ministry of Agriculture, Tafila Technical University, and Mu'tah University) to develop novel approaches to intelligent automation of olive harvesting.
- Sedky has been awarded two KTPs (total funding £164,035) to work on Industry 4.0 (with StormKing Plastics Ltd) and the use of AI and machine learning to train crime scene investigators (with Virtual Reality Simulation Systems Ltd).

### **c. Contributions to research base, economy, and society**

#### *Industry Work Groups and Professional Networks*

- Benkhelifa: lead research partner with Staffordshire Police Cyber Champion in the workplace initiative.
- Branthwaite: leads the strategy for the College of Podiatry Musculoskeletal Biomechanics.
- Chatzistergos: founding member of the Greek Society for Experimental Mechanics.
- Chockalingam: expert to the European Parliament in policy areas relating to the assessment of new and emerging technologies, and foresight on long-term scientific and technological trends; elected Secretary, International Research Society on Spinal Deformities.
- Gohari Darabkhani: team leader in the European Turbine Network; member of the Staffordshire Chambers of Commerce Energy, Environment & Sustainability Forum; and member of the UK Carbon Capture and Storage Research Centre.
- Dodd: advisor for the IET Reference on Autonomous Vehicles, 2015; and member of the IET Aerospace Technical Advisory Panel.
- Griffiths: mentor for the Women's Engineering Society and STEM Ambassador.
- Sadat-Shafai: member of the Engineering Gateways Advisory Group; and member of the Practice Transfer Partnership Engineering Council.
- Soliman: member of the Digital Agriculture Special Interest Group, UK.

#### *Conference Organisation, Keynote Speeches and Invited Lectures*

**Unit-level environment template (REF5b)**

- Submitted staff supported the delivery of over 50 national and international conferences, symposia, and other meetings in the period, acting as conference chair/co-chair (18) and membership of programme committees (32).
- Since 2002, CBRT has organised and hosted the annual Staffordshire Conference on Clinical Biomechanics (Section 4b).
- We organised and hosted the 2015 International Universities Power Engineering Conference.
- Staff delivered over 29 keynote and 46 invited lectures in the period.

*Editorial Activities*

- Ardekani: Editorial Board of Energy and Power Engineering; International Journal of Current Research in Engineering and Technology; and Journal of Atmospheric Science Research
- Asaduzzaman: Associate Editor of IEEE Access; and PLOS One.
- Benkhelifa: Editor of International Journal of Grid and High-Performance Computing; International Journal of Big Data Intelligence; International Journal of Artificial Intelligence and Application; and International Journal of Design Engineering. Guest edited special issues of IEEE Transactions on Industrial Informatics; Journal of Cluster Computing; Journal of Multimedia Tools and Applications; Journal of Information Processing & Management; and IEEE Transactions on Cloud Computing.
- Branthwaite: Editorial Board for Footwear Science and Journal Foot and Ankle Research.
- Chockalingam: founding Associate Editor for Footwear Science and Scoliosis and Spinal Disorders; Associate Editor for Prosthetics and Orthotics International and The Foot; Editorial Board for Frontiers in Rehabilitation Sciences.
- Healy: Associate editor for Assistive Technology Journal.
- Soliman: Editor of PeerJ Computer Science; Associate Editor of IEEE Access.

*Awards and Prizes*

- Ardekani: Green Talent 2015, Federal Ministry of Education and Research of Germany.
- Gohari Darabkhani: Best Presentation Award, 20th International Conference on CCS Technologies; and Ghana Institution of Engineers Engineering Excellence Award in 2017 for research on removing black powder impurities from natural gas transmission pipelines in collaboration with the Ghana Gas Company Ltd.
- Chatzistergos: 5 awards including Editor's choice award for 2018 from the Biomedical Engineering Society for the paper: 'Subject Specific Optimisation of the Stiffness of Footwear Material for Maximum Plantar Pressure Reduction'; and Research and Innovation Award, Institute of Physics and Engineering in Medicine.
- Pierscionek: Paper [6376] selected for inclusion in Optics and Photonics News's 'Optics in 2020' Best in Optics selection.

*Examples of Public Engagement*

- CBRT delivered National Biomechanics Day – 6th April 2017, 'Biomechanics: From Human Body to Sport to 3D Printing' to secondary school pupils in the Staffordshire region.
- Naemi et al delivered 'Translating Our Research for Public Consumption: National Biomechanics Day and Beyond', Brisbane, Australia, July 2017.
- Ardekani has been interviewed for 53 articles and reports in international newspapers, magazines, and TV programmes.
- Dodd has been interviewed by Newsweek on the topic of civilian drones.
- Healy delivered a public lecture titled 'Good Health and Wellbeing in an Unequal World' for the University's Profs in the Pav public seminar series.