Institution: University of Northampton

Unit of Assessment: Engineering (UoA12)

1. Unit context and structure, research and impact strategy

1.1 Unit context and structure

Since REF2014 there have been major institutional restructures moving from an academic school to a faculty structure. Engineering has been largely unaffected by these structural revisions and now forms part of the Faculty of Arts, Science and Technology (FAST). Research within this subject area organises itself around three groups:

1. The Advanced Technologies Research Group (ATRG)
2. The Intelligent Digital Infrastructure Group (IDI)
3. The Institute for Creative Leather Technologies (ICLT)

The ATRG is an interdisciplinary group which includes staff from both Computer Science and Engineering. Within the ATRG research is focussed on two key areas:

1. Lift Technology and High-Performance Engineering (LTHPE)
2. Non-Destructive Testing (NDT)

LTHPE (**Al-Esawi**, **Ghaleeh**, **Kaczmarczyk**, **Khandan**, **Mills**, **Su** and **Torres Perez)** is focused on mathematical modelling, computer simulation, vibration testing, prediction and monitoring of the dynamic performance of vertical transportation (VT) systems, intelligent fault detection/artificial intelligent methods and asset management in the building of transportation systems, structures and materials, manufacturing, and corrosion engineering. These staff have strong national and international links that includes the Partnership for Research and Innovation and a joint research programme agreement with thyssenkrupp Elevator AG (tkE AG), Chartered Institution of Building Services Engineers (CIBSE) Lifts Group and the Lift and Escalator Industry Association (LEIA).

NDT (**Bennecer** and **Kaczmarczyk**) is centred on condition monitoring and fatigue life prediction of engineering structures, fibre optics, ultrasonic and electromagnetic testing techniques, structural health monitoring and non-destructive training networks. Key national and international links include collaboration with the British Institute of Non-Destructive Testing (BINDT), with Hindustan Institute of Technology and Science (India), Federal University of ABC (Brazil) and University of Biskra (Algeria).

IDI (**Ajit**, **Al-Sherbaz**, **Bakaoukas**, **Hill**, **Johnson**, **Kanakis**, **Mu**, **Opoku Agyeman**, **Turner**, **Xue** and **Zhang**) focusses on artificial intelligence, human-computer interaction, low power-high performance computer architecture (HPCA) design, future networks, embedded systems, Internet of Things (IoT), augmented reality, virtual reality and sustaining the future of computing through innovative STEAM education. The groups' focus is incorporated into four interweaved research themes: Intelligent networks, Smart and connected systems, Hub for creative technologies, and Immersive environment for education to apply research and development of intelligent digital infrastructure that directly benefits societies and businesses through consumer or business applications. Key national and international links include collaborations with the Hewlett Packard, IBM Cloud (UK), Ghana Institute of Management and Public Administration (GIMPA, Ghana), University of Babylon (Iraq) and GE Aviation Systems (USA).

ICLT (**Ballantyne**, **Davis** and **Wise**) has a focus on responding to the scientific and technological needs of the automotive, fashion, footwear and allied leather industries. This area has a large remit and a highly diverse research portfolio including investigations into the fundamental mechanisms underpinning the types of protein modification associated with the leather industry and associated biomaterials, as well as addressing the environmental sustainability of leather

manufacture. Improving understanding is key to the sustainability of the global industry and pushing leather to the extremes of performance for high-added-value applications. ICLT is only one of a handful of globally renowned centres delivering world class teaching and research.

1.2 Research objectives

Previous objectives for this area were:

1. **To build interdisciplinary research in the area of modelling, simulation, testing, prediction of behaviour of mechanical systems, artificial intelligence, high performance computing, embedded and distributed systems, 5G networks, IoT and, augmented and virtual reality.**

We have built upon our research activities focusing on collaborative industrial networks in mathematical modelling, testing, computer simulation of mechanical/mechatronic systems, natural language and image processing, IoT for medical applications, smart farming and smart cities, VLSI and Systems-on-Chp for HPCA, 5G, future networks, augmented and virtual reality. New academic staff have been recruited to develop these themes (**Al-Esawi**, **Ghaleeh** and **Khandan** for Engineering; **Bakaoukas**, **Kanakis**, **Mu** and **Opoku Agyeman** for Computer Science) alongside a new research associate to support modelling and simulation in the areas of Computational Fluid Dynamics (CFD), Finite Element Method (FEM) and Manufacturing.

tkE AG, a key strategic partner for the unit, have funded a number of research projects totalling GBP350,000 in the area of dynamics of VT systems with a focus on Lift Technologies. This has led to the development of new design guidelines implemented in high-rise projects worldwide (**Kaczmarczyk**, design guidelines for the world's first rope-less system that moves both vertically and horizontally (**Kaczmarczyk**) and new traffic control algorithms were developed to build novel controllers for circulating multi car lift systems taking passengers' perception into consideration (**Kaczmarczyk**). A further project has been funded through Microgen Engine Corporation resulting in the development of a novel control law to attenuate the engine vibrations at the fundamental operating frequency (**Torres Perez**).
Two of our four KTP's won over the period relate to the above themes: Innovative Design of New Range of Energy Efficient 'Green' Lift Systems (**Kaczmarczyk**) and 'The Modelling, Design and Development of a Fire-Proof Gate for the Installation, Modernisation and Servicing of Lifts' (**Kaczmarczyk**) partnering with ACE Lifts Ltd and Elevator Engineering Services UK Ltd respectively.

2. **To develop research into monitoring and testing of engineering systems and structures.**

The NDT and LTHPE have developed research into the field of asset management and structural integrity of engineering systems. Several projects have been developed in this area including a project funded through tkE AG resulting in predictive maintenance strategies detecting damage early to prevent faults developing (**Kaczmarczyk**), a Newton-Bhabha Fund project that produced a set of training materials for foundry workers in India in the application of non-destructive testing techniques involving novel 3-D ultrasonic measuring technology (**Bennecer**), a Science without Borders research scheme resulting in the development of a computer simulation model to predict thermal behaviour to ascertain it's safety (**Bennecer, Kaczmarczyk**) and an ongoing project with TfL/London Underground involving a novel distributed fibre optic sensor-based condition monitoring system (**Bennecer, Kaczmarczyk**).

3. **To create new theoretical models of the mechanisms of tanning to translate the understanding into new processes and reagents.**

ICLT has been a part of Knowledge Transfer Partnerships (KTPs) that were solely focused on technology transfer from one industry into the leather industry; particularly the transfer of a novel water reducing process used in the industrial laundry sector. These projects were successful in part because they utilised our understanding of the fundamental processes (including the tanning mechanism) to develop and exploit the inherent properties of the new reaction media. Our partner on these KTPs, Xeros, have commercialised this process and are now running full scale commercial trials in a number of tanneries.

4. **To enhance and develop national and international research collaborations, ensuring we seek opportunities to work with key national and international industrial partners through partnership agreements, KTPs and the licencing of patented technology.**

Members of LTHPE have developed national collaborations involving the CIBSE Lifts Group and the LEIA. Relationships have been developed with these partners in a number of ways including KTP knowledge base supervision, PhD supervision, Visiting Professorships and Visiting Fellowships. These collaborations have culminated in the formation of the *Symposium on Lift and Escalator Technologies*, an international annual conference series organised by LTHPE members, CIBSE Lifts Group and LEIA. This series brings together experts from the field of VT and has been running since 2011. The 12th event is planned to take place in Shanghai, China, in 2021 in partnership with Shanghai Jiao Tong University and Schindler Elevator Ltd. A strategic partnership has been formed with tkE AG, a leading international company in passenger transportation in buildings, in the area of Lift Technology (LT) and related scientific disciplines. This partnership involves a range of co-operation from sponsorship of PG projects (4 Doctorate and 5 Masters), visiting professorships (Dr Meier and Dr Smith), contracted research and consultancy projects. Alongside this key partnership we have carried out KTP projects with Ace Lifts Ltd, Elevator Engineering Services and EES Ltd UK.

Members of IDI have developed national and international collaborations with IRIS IoT, GE Aviation Systems, CityFibre, IBM Cloud and Dajo Solutions. These collaborations have resulted in the formation of the IoT Workshop's in 2016 designed to bring researchers and businesses together towards building a wider industrial network and infrastructure development. Relationships with Northampton County Council have resulted in the formation of Digital Northampton, an initiative that aims to make the county a home to vibrant digital ecosystem with a wide range of specialist digital companies. Digital Northampton holds the Merged Futures, an annual technology innovation showcase that brings together digital and technology experts in business, education, healthcare. Key partners include ASL, Intamac Systems, Irisys, Humley, Inferret, All Things Code, Full Metal Software, Novacroft, NT Assure and BTS UK. Merged Futures has been running since 2019 and hosted 600 participants in 2020. Our strategic partnership with GE Aviation Systems, GIMPA, Hewlett Packard and University of Babylon have resulted in sponsored PhD projects and joint supervisions.

As global experts in leather research, ICLT has an extensive collaborative network of industrial partners such as [text removed for publication]. These partners can form any part of the supply chain from chemical manufacturers, machine manufacturers to tanneries and manufacturers of leather goods in a range of sectors. The network of collaborative partnerships that ICLT has is constantly expanding as the research delivered continues to diversify. We have utilised our research outputs to foster relationships with industrial partners such as [text removed for publication]. There is demonstratable success through successful KTP projects; two with the same company addressing interindustry technology transfer and exploring the limits of what is achievable in a non-aqueous processing medium – both projects were highly rated by Innovate UK. IP that is developed by the ICLT team is routinely exploited; the process may involve protection such as patents and subsequent licencing deals, or it could be achieved by setting up collaborative research on mutually beneficial terms. An example of this is patent is PCT/GB2015/050915 which involves the processing of a biological substrate using at least one

ionic liquid or deep eutectic solvent, commonly designed to aid in the processing steps in converting animal skin into leather.

1.3 Future strategic aims and goals for research and impact

At the start of 2021, a restructure took place within the faculty merging the Engineering and Computer Science disciplines under the subject area 'Technology'. This enables these disciplines to continue to work together on a number of often overlapping research projects. Based on the University Research Plan for 2020 – 2025 the following key goals have been formed:

i. Expand interdisciplinary research in modelling, simulation and testing with a focus on mechanical systems and new material technologies (the Finite Element Method (FEM), Discrete Element Method (DEM), Computational Fluid Dynamics (CFD) and Manufacturing). The recent recruitment of **Ghaleeh**, **Al-Esawi** and **Khandan**, whose expertise is in FEM/CFD and Manufacturing forms the backbone of this goal with plans to expand staff recruitment further in this area. We will be upgrading existing laboratory and investing in new sensor technologies such as fibre optics sensors and continue to invest in commercial software licences (COMSOL Multiphysics, ANSYS, EDEM, MATLAB).

ii. To further develop research in the areas of artificial intelligence (AI), IoT, HPCA, Embedded Systems (ES), augmented reality (AR) and virtual reality (VR), with a focus on both theoretical and applied research in low power and intelligent systems, data science, user experience and industrial application. The recent recruitment of **Bakaoukas**, **Kanakis**, **Mu** and **Opoku Agyeman** who specialise in AI, IoT, HPCA, ES, AR and VR has been strategic towards the achievement of this goal. Furthermore, late 2020, we recruited two new staff (**Eldaw** and **Bahja**) who are experts in natural language processing, internet programming and data science to strengthen our research in AI. Plans are in place to invest into state-of-the-art high performance computers, IoT sensors such as LoRAWan Gateways, sensor nodes and to invest in commercial software licences (e.g. Unity).

iii. To increase the number of active researchers – PhD students and postdoctoral researchers – to support delivery of research projects with a focus on industry facing projects in particular. We will be utilising industrial contacts to sponsor researchers for industry focused project in the first instance, followed by an increase in applications to funding bodies to increase funding.

1.4 Open research

Staff receive training and support in open access, copyright and data-management. In 2019 the University launched its CRIS (Current Research Information System) enabling greater visibility of not only research outputs, but also research activities and datasets. In 2020 the University purchased a platform for digital preservation, and staff are now moving towards a more open research environment, where open research has progressed from being encouraged, to becoming an integral part of the research life-cycle. Staff within the computing area are encouraged to share their coding in Git Hub. Datasets are uploaded to the CRIS on submission, where they are checked for replicability and long-term digital preservation. A data management plan is required for all research projects as part of the ethical approval prior to any research being carried out. To facilitate this, staff are encouraged to use DMPonline and examples of well-written data management plans, and one-to-one training sessions are available to all staff. A strong emphasis is placed on ensuring that our data adheres to the FAIR (findable, accessible, interoperable and reasonable) principles of sharing of data, striving to be as open as possible, but understanding when necessary restrictions are required.

Staff have been provided with training in the selection of places for publication, use tools such as Sherpa/Romeo and the creative commons to check funder requirements, restrictions relating to copyright, and the selection of appropriate licencing of research outputs. An institutional fund is

available to cover the cost of open access where a green (non-payment) route is either not an option, or where the embargo period is extensive. This fund covers the payments for articles, chapters and monographs. This fund covers the payments for articles, chapters and monographs. Where publisher policies allow, scholarly chapters are made open access and disseminated through our public research portal. Research activities, such as presentations at conferences, workshops and educational resources are made available under a creative commons licence.

Our annual *Symposium on Lift and Escalator Technologies* promotes open research and innovation in the area of VT. The conference proceedings and presentations are published open access on the Symposium **resources pages**. Extended Symposium papers and new research articles on the subjects balancing the theoretical advances and practical new technologies and techniques in the area of VT systems in built environment and associated areas are published in our OA peer-reviewed journal ***Transportation Systems in Buildings (TSIB)*** which is edited jointly by **Kaczmarczyk**, CIBSE Lifts Group and LEIA.

1.5 Research integrity

Engineers support a culture of research integrity. It works within the UoN's Research Integrity Policy, which seeks to: maintain the highest standards of rigour and integrity in all aspects of research; ensure that research is conducted according to appropriate ethical, legal and professional frameworks, obligations and standards; support a research environment that is underpinned by a culture of integrity and based on good governance, best practice and support for the development of researchers; use transparent, robust and fair processes to deal with allegations of research misconduct should they arise; and work together to strengthen the integrity of research and to reviewing progress regularly and openly. Engineering engages with the university's processes for providing ethical approval for research by staff and postgraduates. **Bennecer** represents Engineering at the Faculty's Research Ethic Committee and acts as the first contact concerning any ethical issues that may arise.

1.6 Research impact

Our impact strategy in Engineering is to engage with non-academic users and beneficiaries of our work. These interactions with non-academic users and potential beneficiaries are through contract research and consultancy projects as well through running specialist seminar/conference events (such as the annual *Symposium on Lift and Escalator Technologies*), as well as R&D training programmes and spin out CPD courses such as the recently developed training provision in the *Finite Element Method / Analysis for Elevator Product Design* (**Ghaleeh**, **Kaczmarczyk**, **Al-Esawi**, commissioned by tkE AG/ Asia Pacific to train their R&D staff) and the *Lift Technology Familiarization* (**Kaczmarczyk**, commissioned periodically by the Health and Safety Executive to train their inspectors). Examples of impact being delivered can be seen in our case studies being submitted:

The Development of New Design Guidelines for High-Rise Vertical Transportation Projects Worldwide has its origins in the long-standing relationship between the University and the Lift Industry through partnership with the national industry association (LEIA) . This has led to the research / consultancy programme and the formation of the Partnership for Research and Innovation with a leading international elevator company (tkE AG).

The second case study on the **Application of Non-Destructive Testing for Metal Castings and Developing the Skills of Indian Foundry Workers** exemplifies the outcome of the Unit's NDT programme that has attracted users from within the international NDT academic community and their industrial beneficiaries.

2. People

2.1 Staffing strategy and staff development

While still a small Unit of Assessment, there has been considerable expansion in the number of staff submitted, increasing from 6.75 FTE in REF2014 to 20.8 FTE in REF2021. Appointing staff that develop the unit's research and teaching has been important in delivering teaching modules through the application of research-informed delivery. Staff recruitment criteria involve being close to completion or having earned a PhD (or equivalent), a robust publication record, a record of research bids, an ability to demonstrate an ambitious research plan and to enhance the knowledge of one of key areas of research.

New staff are welcomed to the centre by the Faculty Research Leader who signposts them towards discipline-specific research events and opportunities, fosters a friendly and inclusive disciplinary research culture and facilitates access to networks of external partners and organisations. Additionally, support is provided within the team through dedicated mentorship to help develop their research skills. Mentors are appointed on the basis of the staff member's research expertise and their career stage. New staff also have a lower workload to enable them to settle in and to begin establishing their research with the teaching timetable devised so that at least one day a week is allocated towards research activities.

Early Career Researchers (ECRs) are supported within the team through dedicated mentorship to help develop their research skills. The mentorship programme runs through a series of informal meetings where developmental matters are discussed, and appropriate support mechanisms are put in place. Further to this unit level support the centrally located Graduate School offers 40 sessions specifically targeted at ECRs (although these are available for all staff and PGR students to attend).

Recognising the need for senior research leadership to develop the university has the framework of the Associate Professorship scheme whereby colleagues are appointed to Associate Professor. This title recognises the achievements of individuals and provides a supported development pathway for academic staff to gain a full professorial role. Support includes a substantial institutional staff development programme focused on research leadership with ring-fenced hours for research leadership available on request and mentoring from a Professorial colleague from within their discipline (internal or external). As a unit we have had 3 staff appointed to Associate Professor (**Wise**, **Opoku Agyeman** and **Mu**) in the latest round of applications in 2020. **Wise** and **Opoku Agyeman** have already taken on research leadership position since appointment such as Research Degree Board Chair, Representative of Research Community at Senate and Faculty PGR lead.

For all colleagues, researcher development is principally managed and audited through the University's PDR process, whereby individual objectives and key performance indicators are agreed annually with line managers and appraised after six and twelve months. Since 2015, all colleagues are allocated at least one specific research-focused objective each year (objectives reflect current Faculty/institutional research KPIs and typically include targeted activity in terms of bidding, publications, impact or sectoral and international network-building). The PDR is also the process through which individual research training needs are identified and plans are made for dedicated 'research and scholarly activity' hours.

Supervisory teams are balanced around providing experience, subject expertise and a history of prior completions. All supervisors must complete the mandatory Graduate School ran Supervisory Training before they can form part of a supervisory team, with new supervisors initially joining research teams with experience colleagues. To date 16 members of the unit have completed the Supervisory Training with **Opoku Agyeman** completing the optional Post Graduate Certificate in Research Degree Supervision. This training includes attending workshops, observing and interviewing other supervisory teams, giving written feedback to PGRs and engaging in the pedagogical literature regarding research supervision and teaching practice.

An integral part of the unit's strategy has been to ensure that our work crosses traditional disciplinary boundaries. As such we have worked with colleagues in Education, Waste

Management, Geography, Fashion, Chemistry and Health. Alongside these internal collaborations we have also worked with external organisations such as the University of Leicester's Chemistry department (polymer and biopolymer research), Universities of Lancaster and Huddersfield as well as the Cockroft Institute on applied accelerator research.

We hold regular series of seminars attracting both staff and students with internal and external researchers encouraged to present. These seminars are led by a variety of different stakeholders including internal staff members, external academics and members of industry. This diverse delivery gives staff a wider understanding of the research landscapes we work in and contextualises the research being conducted. Highlights over the recent period include Professor Adali of the University of KwaZulu-Natal presenting on the optimization of nanocomposite structures and Professor Jarzębowska of Warsaw University of Technology discussing collaborations on projects in the area of multibody system dynamics modelling, simulation and control.

Engineering 'Champion' groups looking after several important areas within the subject area. These include the Research and Knowledge Transfer (RKT) group which is a collection of both NDT and LTHPE staff. It operates at a more strategic level with regular meetings taking place to discuss and plan RKT activities. The group has recently formulated an annual plan which is aligned with the Unit's REF strategic objectives.

A number of Visiting and Emeritus Professors have been appointed over the period to strategically develop areas of interest within Engineering. Visiting Professors include **So**, of the Asian Institute of Built Environment (AIBE), who facilitated international research collaborations with China and Hong Kong in the area of Lift Engineering, **Askar** develops and supports research in Building Information Modelling (BMI), **Smith** provides a direct link with the Lift Industry to support research projects and supervises PhD students and **Redwood** has acted as an ambassador for leather research to external organisations. Our most recent appointment **Cooper** is supporting the development of research in safety of VT systems facilitating national and internal links in this area. **Picton**, a former member of the Engineering staff, was appointed Emeritus Professor to provide support for research in NDT and AI/ Machine Learning.

2.2 Postgraduate research students

We have supervised 45 PGRs (14 completions, 31 ongoing) which represents a significant increase in the number of PGRs within the unit when compared to the 7.5 completions submitted to REF2014. This increase can largely be attributed to our focus on governmental partnerships, most notably a partnership with Iraqi universities (University of Babylon and University of Mosul), with 21 of the students over the period registered as a result of our strong partnerships. In addition to these government funded PhDs, we have a PGR funded through an EPSRC grant, a PGR funded through a university-industry Partnership, a PGR funded through international partnership with GIMPA, a PGR match-funded PhD with tkE AG, a PGR funded through the AHRC and British Museum, A PGR funded through a Knowledge Transfer Partnership and the remaining PhDs are self-funded students.

All research students undertake a comprehensive training programme to assist them in the successful completion of their research projects and to develop the skills to become independent researchers. The Graduate School offers a programme of practical workshops delivered by internal and external academics. Engineering has supported these central programmes providing guest facilitators from our international industry partner institutes (e.g. tkE AG) and consulting company. PGRs are encouraged to take part in software training seminars organised by research software providers (e.g. COMSOL, MATLAB, EDEM). In addition to these external and central workshops, we provide local training on all relevant equipment (e.g. analytical laboratory equipment, the microscopy suite and the pilot scale tannery), Health and Safety training, introducing students to staff beyond the remits of their research areas.

In 2018 all Post Graduate Researchers across the university were relocated to a designated space within the new Senate building. This has given them a dedicated research suite on campus facilitating a strong sense of community and contributed to collaborative works between them. Alongside this space Engineering PGRs have a specialist research laboratory where they can come together as a discipline base. This facilitates a greater discipline focus, and, in the lab, they have access to research hardware and computing facilities with specialist software tools. Within the ICLT building there is a write-up room, dedicated laboratory space for wet chemistry and full access to other lab equipment that is usually restricted to taught students (e.g. analytical lab).

We have invested in interdisciplinary research in a number of specialist areas, including support from industrial partners, resulting in an improved research environment for PGR students. This includes new software tools (such as ANSYS Finite Element Method package GBP7,500; EDEM Discrete Element Method software GBP9,000) and hardware equipment (B&K LAN-XI vibration DAQ system GBP25,000 and Fiber Bragg Gratings (FBG) sensor and DAQ system GBP6,500) to conduct research in LT and NDT.

Research workshops, seminar series and small conferences are held at unit level where PGRs are expected, and are encouraged, to contribute to these programmes. We organise an annual Internet of Things workshop for PGRs within the University with speakers from industry invited to present. Through these workshops, the academic-business partnership with IRIS IOT, CityFibre, IBM Cloud and DAJO Solutions have helped local businesses to build a wider industrial network and develop their infrastructure. The workshop provides PGR students the opportunity to build their wider research community and event organisation skills by providing them with the opportunity to get actively involved in the organisation and chairing sessions. Our PGR students are involved with the organisation of the *Symposium on Lift and Escalator Technologies* with the papers being published in the proceedings.

The University has a range of teaching training and opportunities for our PGR students to strengthen their theoretical underpinnings while developing skills to improve their career prospects. For example, our PGR students have assisted in teaching various computing modules (computer systems, networking, media technology, databases and computer architectures) at the Postgraduate and Undergraduate levels. Furthermore, our students have the opportunity of working as Academic Teaching Staff at University of Northampton International College (UNIC).

The university organises an annual research conference where PGRs are encouraged to actively participate, present and network. This conference gives PGRs an opportunity to improve their presentation skills receiving constructive critique from fellow students and supervisors. The series also features presentations from invited speakers and staff creating a forum for Engineering students to network and meet fellow student researchers and leading scientists across a broad spectrum of disciplines. UoN is a member of the East Midlands Doctoral Network (EMDoc) and the Midlands Doctoral Researcher Forum (MDRF) providing access to annual conferences, networking and support across universities in the East Midlands region.

The University of Northampton has a strong record of achievement in the Advance HE's Postgraduate Researcher Experience Survey ranking 1st overall in 2020 and 4th overall in 2018. We received excellent scores in the surveyed areas: 87% for overall, 93% for supervision, 86% for resources, 88% for progression, 91% for responsibilities, 93% for research skills and 91% for professional development (for purposes of PRES Computer Science and Engineering are separated out thus we have done a weighted average across the two for this submission).

Final year PGRs are encouraged to present their research findings at international conferences. Engineering students benefit from the university's annual allowance for all PGRs (GBP500 for FT, GBP300 for PT), to contribute to the costs of travel and other research expenses. The university runs a range of competitive bursaries. An example of this funding benefitting and being utilised within this area is an externally funded PGR student being awarded grant allowances to travel to attend and present a paper at the 10th *International Conference on Mathematical Problems in Engineering, Aerospace and Sciences*. The university provides several competitive bursaries,

scholarships and awards that are available annually or biannually (for example, the Chancellors fund, Dr Mike Daniel Research Degree Scholarship and T D Lewis Scholarship).

2.3 Equality and diversity

Engineering is committed to Equality, Diversity & Inclusion (EDI) in both recruitment and support of staff with significant responsibility for research and research students, whilst recognising and committed to developing further. Colleagues regularly participate in workshops on equalities and inclusion within termly Faculty staff development days and are signposted to focused institutional training on unconscious bias and other equality and inclusion topics via individual PDR objectives. **Opoku Agyeman** is a member of the University's Global Ethnic Majority (GEM formerly BAME) staff network and leads the Research & Evaluation strand of the University's Professional Learning Community (PLC) dedicated to Decolonising Education within the University.

In addition, many colleagues participate in a growing number of colleague-led institutional support and advocacy groups such as the BAME Staff Network, LGBTQ+ group and Staff Disability Network. Colleagues have also benefited from the University's Navigator (men and transmasculine) and 'Springboard+' (women, trans and non-binary) staff development programme for colleagues in academic or professional services roles which provides an opportunity for staff to undertake personal and professional development and support for leadership, goal-setting and strategic visioning skills.

The individual needs and wellbeing of all colleagues are supported through the PDR process, with sensitive, bespoke arrangements in place in the faculty to support, for example, flexible and remote working, career development for part-time and fixed-term researchers, purchases of assistive technologies, conference attendance for colleagues and PGRs with caring responsibilities, and appropriate adjustments for colleagues with disabilities, long-term illnesses, caring responsibilities and returning from leave periods. An example of this support is the department making adaptions to equipment and activities for a PGR undertaking a challenging Engineering project to help with and stimulate their condition.

We actively participated regularly each year in STEAM activities to encourage young people and women to pursue a career in computing. **Turner** and **Hill** have initiated code clubs and national coding competitions to help pupils develop their computing skills. Alongside this, **Turner** and **Ajit** have been involved in a funded 'Junkbots' project spawning workshops ran in local schools. We have an active involvement in the WISE Campaign (Women into Science and Engineering) working with the faculty to run a range of WISE outreach events. The unit staff contributed to the success of this campaign by running STEM/laboratory workshops and demonstrations for schoolgirls (the 'Any Way, Any How, Any Time, Any Place – Girls Can Do It Too' events). This resulted in the University being awarded the Best Engineering Event Award from National Science and Engineering Week (in 2015).

Gender diversity is an area that the team are keen to address with only 1 female staff member being submitted out of a total of 22. As such, a number of strategies are in place to address this issue. This includes supporting female staff to undertake PhDs to increase the research capacity within the unit and building on the teaching focused research that has been ongoing and published by female staff.

3. Income, infrastructure and facilities

3.1 Income

As a unit we have won GBP1,185,374 over the REF period which is a small increase on the GBP894,306 won in REF2014. Over the REF period we have been awarded prestigious grants such as **Mu's** EPSRC First Grant of GBP99,772 to work on Software Defined Cognitive

Networking and **Bennecer's** Newton Bhabha Fund project worth GBP49,500 to perform Ultrasonic Non-Destructive testing of austempered ductile iron castings.

Our strategy for generating research income has largely been based on collaborative contracted research and enterprise projects with industrial partners both nationally and internationally. In the current cycle this includes KTP work with Ace Lifts (GBP101,746), EES Ltd (GBP94,899) and tkE AG with the latter bringing in a steady research income stream.

Another strategy the unit has employed has been to bid for regular internal opportunities at an institutional level (e.g. Big Ideas Fund, Innovation Fund, URB@N Bursaries) and use these to establish collaborations and develop external funding opportunities. Examples of successes in these areas are Big Ideas project with **Wise** winning money to form a project with [text removed for publication] and **Opoku Agyeman** working with Kilimo to develop an initial prototype of the LoRAWan enabled IoT solution for hydroponics.

3.2 Infrastructure and Facilities

During the current REF period, all colleagues and PGRs moved to the new, purpose-built, GBP330 million, multi-award-winning Waterside Campus. Relocating the university involved the relocation and integration of its two main sites into one state-of-the-art centre for academic excellence. This investment in institutional infrastructure and facilities has fostered collegiate dialogue through physically locating staff closer together into relevant research groups.

A benefit of the new Campus estate has been the transformation of the experience and working environment of the PGR community. Previously PGRs would be across the campus and siloed away from each other, whereas now the new campus provides an impressive, purpose-built, co-designed suite for the University's whole multidisciplinary community.

As part of the university investment in facilities, the ICLT Building worth a total of GBP7 million was developed providing a dedicated space for leather specialisms in particular, but also for other engineering topics. This facility is equipped with a Microscopy suite, including a new Scanning Electron Microscope and a high magnification light microscope which both can be used by Engineering to powerfully supplement their non-destructive testing. We also have a pilot scale tannery, that is regularly used by industry, which is fully equipped to take raw skin/hide through to a finished piece of leather. Further facilities include an analytical suite which has a range of thermal analysis equipment, chromatographic techniques and UV/Vis and IR spectroscopy and a Potentiostat for looking into redox reductions. We have a Physical Testing Lab for testing all materials. This equipment is regularly rented out to industry with the most significant of these coming from [text removed for publication].

The campus includes a new laboratory room to house our vibration and non-destructive testing research facilities. We have 17 computer labs including one for computer networks. These facilities now all being on one site has had the advantage of having staff and research students in one physical area. Further laboratory space includes a wet chemistry lab with two fume cupboards allowing space for 14 researchers at any one time.

We have at our disposal laboratory hardware and computational facilities necessary for conducting high quality research in several key areas such as corrosion engineering, dynamics and vibration, LT and NDT. For example, the specialist hardware and software research tools include the B&K Pulse^{TM} and LAN-XI task-oriented systems for dynamic signal measurement, data acquisition and analysis. Our vibration testing facilities include LDS V406/PA500L and V721/PA1000L and TIRA TV51165-IN/BAA 1000 electrodynamic/ inertial shaker systems. These are complemented by Laser$_{USB}$ vibration control system and Polytec PDV-100 Portable Laser Vibrometer. Portable analyser tools include PMT EVA-625 and Henning LiftPC mobile diagnosis systems for lift ride quality measurement and analysis. Staff conducting research in NDT, Corrosion Engineering and protective coating technologies have at their disposal computer-controlled testing equipment provided for measurements of electrochemical Impedance spectroscopy (EIS), Electrochemical

Noise (ENM) and polarisation resistance. COMSOL Multiphysics and ANSYS FEM as well as EDEM Discrete Element Method modelling and simulation software are available to conduct simulation tests of complex Engineering and Multiphysics systems. Specialist computer simulation software tools include ELEVATE™ to conduct advanced studies in the area of elevator traffic control and dispatching technologies.

The team has a range of computing and gaming equipment including 5 NAO robots, a range of small robots, wired and wireless networking equipment (including Software Defined Networking) and Virtual Reality equipment. These are all used for both research and teaching. In addition, three leading organisations: Altera (now part of Intel), ARM, and Texas Instruments have donated hardware and software which is worth collectively over GBP553,000. They have been used for research in the areas of Embedded Systems, Internet of Things and High-Performance Computing. Specifically, they have been utilised in evaluating reconfigurable hardware solutions for emerging multi-core architectures and low power solutions.

Engineering staff are supported within the unit by technical and support staff composing of one full time and one part-time technician. This underpins the team's current activities and effort are being made to increase the support staff numbers by employing additional technical staff through contract appointments (funded from the research project budgets).

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

4.1 Research collaborations, networks and partnerships

Members of the Engineering subject have developed a range of collaborations with academic institutions in the UK and across the world. **Bennecer** and **Kaczmarczyk** developed international collaboration links with the Federal University of ABC, Sao Paulo, Brazil, which attracted Science Without Borders (Brazil) and Santander researcher grants. **Bennecer** worked with Hindustan University to carry out an international research project "Application of Non-Destructive Testing for Metal Castings and Developing the Skills of Indian Foundry Workers" funded by the Royal Academy of Engineering. He has also collaborated with the University of Biskra (Algeria). **Mills** has strong links with the Technical University of Gdansk, with which the University has an Erasmus exchange agreement. **Ghaleeh** has Individual research collaborations with researchers at the UK universities in the area of FEM/ CAD. His partners include Gulf University Bahrain, Leeds, Coventry, Aston, Heriot Watt, Wolverhampton. **Su** established cooperation with City University working on the development of the Dynamic Stiffness Method (DSM) for the structural analysis of Engineering systems.

Mu is collaborating with BBC R&D on a research project developing a range of innovative immersive media and human-centred designs to enable visual artists to create new forms of interactive artwork. **Mu** worked on the Software Defined Cognitive Networking (SDCN) project supported by EPSRC with Hewlett Packard and Lancaster University. **Ajit** has collaborated with BAE Systems and the University of York in the area of modelling and simulation of tactical data links for the defence sector. **Ajit** has collaborated with the SQUIRE Research Institute in Germany involving research on scoring models for group and peer assessment in software engineering education. **Opoku Agyeman** developed international collaboration with GIMPA, Ghana, which has attracted a funded PhD as well as Santander mobility and research grants. **Opoku Agyeman** has collaborated with and published recently in the areas of HPCA design with colleagues from a number of international and national institutions including California State University San Marcos, The Chinese University of Hong Kong, South China University of Technology, University of California, University of Southampton, University College London, Middlesex University and Newcastle University. **Bakaoukas** has been working with a local school on a Royal Society funded "Virtual Reality in Education" project. **Xue** has worked on joint projects with University of Warwick on developing mining association rules for e-commerce applications. **Al-Sherbaz** worked with colleagues in the University of Buckingham and secured a patent entitled "Method and process for Routing and Node addressing in Wireless Mesh Networks". **Al-Sherbaz** has also worked

collaboratively and published in the area of 5G Wireless systems with universities in Algeria (El-Oued and Biskra).

Kaczmarczyk has been leading a collaborative network in the area of mechanics of slender structures running under the auspices of the Institute of Physics (IoP) Applied Mechanics Group Committee. This network organises the international symposium series - the *Symposium on the Mechanics of Slender Structures* (MoSS). These activities resulted in collaborative links with universities in China and Spain (Hunan, Extremadura).

Kaczmarczyk and colleagues within the LT team (**Su** and **Torrez Perez**) continued collaboration with the CIBSE Lifts Group and LEIA to organize the *Symposium on Lift and Escalator Technologies* conference series. The series brings together national and international academic and industrial experts from within the field of VT engineering and resulted in a number of academic and industrial national and international links. This has led to collaboration with Changshu Institute of Technology (CIT) in China with **Kaczmarczyk** and **Su** being appointed Visiting Professors. Research in the area of systems design and dynamics of VT systems has resulted in the extension of the Partnership for Research and Innovation agreement with tkE AG, a leading international company in passenger transportation in buildings. This agreement has facilitated collaborative research work in the area of LT, NDT and related scientific disciplines.

Research activities have resulted in interactions and relationships with our industrial partners through consulting activities and knowledge transfer projects. **Bennecer** initiated a number of industrial links through his work with BINDT. **Ghaleeh** collaborated with Skyships Automotive Ltd UK on the design project to deliver a unique, innovative electric vehicle (EV) drivetrain package. His other collaborations involved the oil & gas sector: IK UK Ltd & Online Electronics Ltd (the development of high-pressure hydrocarbon pipe and Quick Opening Closure for a large diameter and high-pressure pipelines); CIRCOR Pipeline Engineering & Supply Co. Ltd (the development of pipeline pig signaller). **Kaczmarczyk** has been involved in a number of consulting contracts with international partners (Patriot Elevator Services in the US, tkE AG at their international project sites (Brazil, Canada, China, Germany, UAE, USA) as well as KTP projects with partners in the UK (EES Ltd). **Khandan** developed collaboration with Classic Cuisine of Northampton Ltd to enable their business to operate at its maximum efficiency, implementing a programme of lean manufacturing. **Mills** has facilitated industrial cooperation in the area of protective coatings with leading UK companies, including DC Voltage Gradient Technology and Supply Ltd. (the ProCoMeter development for Non-destructive Testing of the Painting/Coating of industrial objects such as bridges, tanks, ships, cars, aeroplanes, gates, metal fences). **Wise** has worked with [text removed for publication] and KTPs with Xeros.

4.2 Contributions to research base, economy and society

Engineering have contributed to several prestigious journals such as **Mu** on the Editorial Board for the Springer Journal on Multimedia Systems. **Turner** was editor for *Enhancing the Learner Experience* and was an editorial review board member for the *International Journal of Distributed Systems and Technologies* and *The Journal of Social Media for Learning*. **Turner** was invited to guest edit an edition of *Research in Education and Learning Innovation Archives*. Further experience of editorships involves **Ajit** forming part of the editorial board membership of *Computer Software and Media Applications*, Topic Editor of MDPI Sustainability Journal, **Opoku Agyeman** guest editing *EAI Endorsed Transactions on Industrial Networks and Intelligent Systems* and Topic Editor of MDPI Micromachines. **Kaczmarczyk** has been serving as a member of the Advisory Board on the Scientific Board of the Transactions of the Institute of Fluid-Flow Machinery (IFFM) journal. **Mills** served as Editorial Board Member for the Journal *Corrosion Engineering, Science and Technology*. **Bennecer** is a Member of the Education and Qualification Committee at BINDT. **Kaczmarczyk** is a member of the national BSI MHE/004 (Lifts, Hoists and Escalators) Committee. **Mills** is a member of the ISO committee TC 35 SC9 WG 29 developing standards for examination of anti-corrosive paints using AC Impedance (ISO 16773).

Several staff have been interviewed and given keynote speeches at conferences and other events. For example, **Mu** was interviewed by New Scientist magazine on ultrasound communications and was a guest speaker at the *Westminster Higher Education Forum: Technology in higher education*. **Kaczmarczyk** was invited and delivered a range of keynote/invited lectures including: the 13th International Conference on Dynamical Systems: Theory and Applications (DSTA), Poland, December 2015; the VIII Mechanical and Industrial Engineering Rio Grande do Sul Seminar – SEEMI and VI Materials and Industrial Processes Seminar at Feevale University in Novo Hamburgo, November 2014; invited lecture series in Brazil: Universidade Federal do ABC (UFABC), Santo Andre; Universidade Estadual Paulista (UNESP), Bauru, and at Pontifícia Universidade Católica (PUC) in Rio de Janeiro (March 2014).

Kaczmarczyk served as reviewer for a range of high impact scientific journals (including journals such as *Computers & Structures*, *Engineering Structures*, *International Journal of Mechanical Sciences*, *Journal of Sound and Vibration*, *Mechanical Systems* and *Signal Processing*). **Kaczmarczyk** has also been invited to chair technical sessions/mini-symposia and to sit on the Organizing/Scientific/Technical Committees of a number of international conferences and meetings.

Kaczmarczyk served as a member of the Scientific Committee of the DSTA conference in 2015 and 2019. He organized and chaired a technical session at the 10th International Conference on Mathematical Problems in Engineering, Aerospace and Sciences (Norway, 2014) and was a session chair at the International Conference on Modern Practice in Stress and Vibration Analysis, held at the University of Cambridge, UK in 2018.

Bennecer served as Vice Chair and evaluator for Horizon 2020 European funded projects. He also acted as an evaluator of Brazilian funded projects CNPq 'Science without Borders'. **Bennecer** and **Kaczmarczyk** served as reviewers of the Engineering and Physical Sciences Research Council (EPSRC) funded projects. **Kaczmarczyk** was invited and nominated as an assessor for The National Research Foundation (NRF) in South Africa.

Ali is a member of the British Computer Society, IEEE (Institute of Electrical and Electronic Engineering), IEEE Communication Society, IEEE Standards Associations and Member in the Institution Engineering and Technology IET. **Davis** is a member of the Royal Society of Chemistry and American Leather Chemists Association and a Council Member of the Society of Leather Technologists and Chemists. **Hill** is a chartered IT Professional, a Fellow of the British Computer Society and on the Council of Professors and Heads of Computing. **Kaczmarczyk** is a Chartered Engineer (CEng) and a Fellow of the Institution of Mechanical Engineers. **Mills** is a Fellow of the Institute of Corrosion. **Opoku Agyeman** is a Senior Member of the IEEE, a Chartered Engineer of the IET and a Chartered Manager of CMI. **Torres Perez** is a chartered Engineer and a Member of the Institution of Engineering and Technology.

Kaczmarczyk and **Su** have been appointed Visiting Professor at Changshu Institute of Technology (CIT), China. These roles are aligned to the memorandum of understanding we have with CIT, collaborating in joint research projects, publications, seminar presentations and lectures.