

Institution: Bournemouth University
Unit of Assessment: 12 - Engineering
1. Unit context and structure, research and impact strategy 1.1 Context and Structure: Bournemouth University's 2018-2025 strategic plan has identified four cross-university Strategic Investment Areas (SIAs): (i) Assistive Technology (AT), (ii) Animation, Simulation & Visualisation (ASV), (iii) Medical Science (MS) and (iv) Sustainability, Low Carbon Technology & Materials Science (SLCTMS). The Unit is contributing to all the above SIAs in terms of engineering, science and technology [cross-refer 5A]. Between 2005 and 2015 research in the Unit was organised within two research centres: (1) Sustainable Design Research Centre (SDRC) led by Professor Zulfiqar Khan and (2) Design Simulation Research Centre (DSRC) led by Professor Siamak Noroozi. According to REF2014 Panel Unit Feedback, "<i>SDRC had the highest proportion of outputs judged to be internationally excellent</i>". A merger between SDRC and DSRC led to the establishment of a Unit wide multidisciplinary research platform. The Unit has a multidisciplinary ethos, employing academic staff with diverse academic backgrounds, for example, engineering, design, and electronics. Research within the Unit is organised into research themes /groups: (1) Biomedical/Mechanical Engineering (BE/ME), (2) Materials Science & Testing (MST) and (3) NanoCorr, Energy & Modelling (NCEM) including Tribology and Design (T&D). This enabled more focused research such as lower limb prosthesis (industry funding), functional electrical stimulation (NHS collaborations), 2D material synthesis and process (industry funding) and nanocoatings and energy technologies (industry funding, patents and impact case study). These three major themes have cross-disciplinary research and cross-links for example, BE/ME and NCEM utilise and develop simulation and modelling techniques. MST and NCEM have cross links in terms of materials. MST has a focus on process and synthesis whilst NCEM investigates mechanics and failures. Both research groups have been developing energy storage techniques. MST focuses on chemical batteries research and development whilst NCEM has a focus on thermal and chemical energy storage. All three research groups are closely aligned with the university SIAs which enable them to capitalise on the BU platforms for furthering research and innovation. Our mission is to conduct internationally leading research to advance fundamental impactful research. There has been a period of rapid growth since 2014. For example, an increase in the numbers of research active staff, attributed to existing staff achieving PhD: workload balance (teaching Vs research), recruitment of research active staff, capital investment in resources, central support in terms of research bidding, encouraging industry collaborations and by providing anchors for staff in the form of university strategic investment areas, internal pump-priming initiatives such as internally funded studentships, structured mentoring and coaching of staff at all career levels. Staff in the Unit has almost doubled with 21 staff (19.3FTE) submitted compared to 12 (10.4FTE) engineering staff submitted in REF14 an 86% increase. Total research funding of £963,402 over the REF period has been secured, this is an increase of 20% since REF2014. A strong portfolio of industrial and charitable funding supports fundamental research that advances the intellectual boundaries of our engineering disciplines. There were 33 PhDs completions since 2014, represented which is an increase of 208%, see Fig 1. The vitality of the research environment has resulted in substantial growth in all areas of the Unit's themes. The research portfolio and activities within the Unit were also supported by significant investment (£5.63M) to enhance facilities (over £3.79M) new labs in material science, thermofluids and heat transfer and equipment (over £1.84M), material synthesis and process, corrosion testing, nano characterisation system, nanocoating and fluid characterisation and heat transfer equipment.

Unit staff produced 374 outputs during the REF period contributing to: engineering (29.5%), material science and energy (25%), physics, maths, computer science (22%), medicine, health and social sciences (17.1%) and other (6.4%). The Unit has contributed to over 70 topics in the top 10% of worldwide topics by prominence including; prosthesis, lubricants, coatings, nanofluids, corrosion protection and bearings etc. This underpins technological innovation, evidenced by 5 patents (2 international and 3 UK) in energy and corrosion monitoring. One international patent is pending. Energy patents are being commercialised by Future Energy Source Ltd (industrial partner).

We have developed a strong portfolio of international collaboration through the appointment of several Visiting Professors and Visiting Fellows who participate in the unit research and academic development. Research groups and the unit have also developed longstanding industrial collaborations with the Ministry of Defence UK, Future Energy Source Ltd, Schaeffler Technologies AG & Co. KG, SKF Engineering and Research Centre BV, ASM Assembly Systems Ltd, Balmain Environmental Conservation Trust, Royal Bournemouth & Christchurch Hospitals NHS Foundation Trust, Longitude Engineering, Odstock Medical Limited, Daido Metal Co Ltd, The European Technical Centre (UK), The Royal National Lifeboat Institution, Hyderco Hydraulics Ltd and Precision Acoustics Ltd. Industrial research funding forms a significant proportion (35%) of our research income.

Staff are recognised leaders in their field; 4 staff are Fellows of IMechE/ IET. Staff have 19 awards/honours, approximately 50 invited lectures, facilitated/organised 22 public engagement events and have been contributing to peer review such as EPSRC.

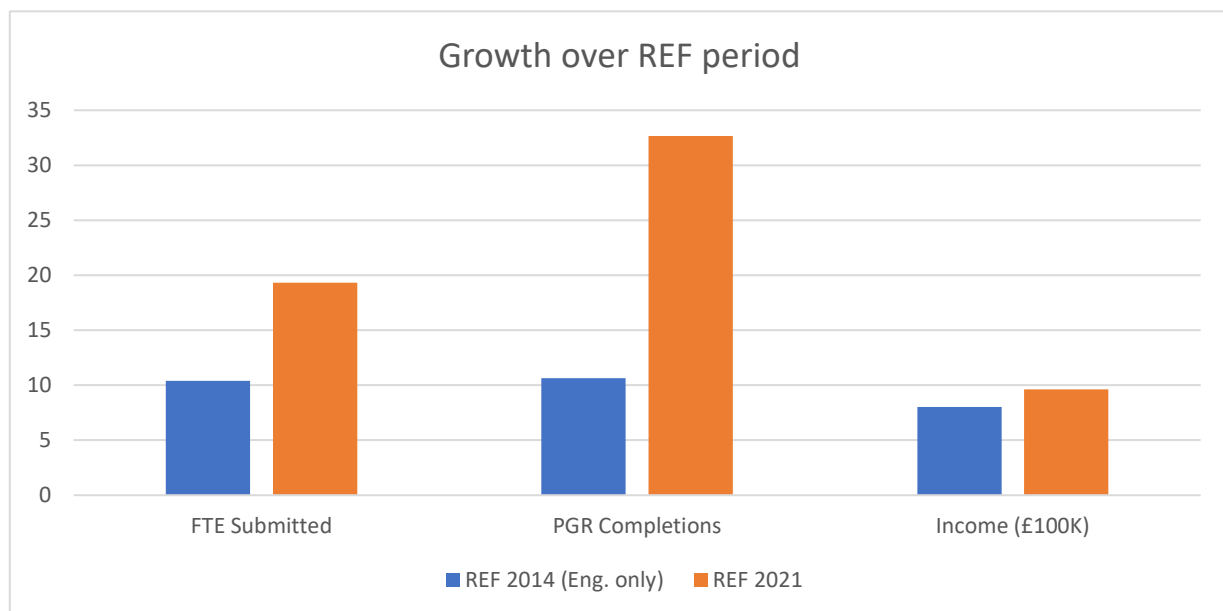


Figure 1. Comparison of REF 2014 (Engineering proportion only) and REF 2021.

1.2 Research and Impact Strategy:

All research groups share a common high-level strategy; to encourage growth and to achieve critical mass in targeted research areas, through two categories of scope and scale, explained as:

Exploratory Research, supported through investment of pump priming funds from university initiatives such as research fellowships, fusion investment fund, charity impact fund and Higher Education Innovation Fund for new ideas and research areas (typically up to a year duration, total investment since 2014 £103.4k), leading to developmental research. 8 staff were supported through the above strands in 6 exploratory research initiatives.

Developmental Research, larger projects, within or cross research groups, funded by industrial consortia, other external sources, university and industrial supported match funded studentships and research assistants (typically 1-3year duration, total external income since 2014 £963K). This includes strategic investment in staff, space and new laboratories. For example, BU invested £184K in 2018 to establish an Advanced Materials Laboratory to further support the MST group. This is aligned with the BU2025 'Sustainability, Low Carbon Technology & Materials Science' SIA. As a newly developed group there has been some progress mentioned below which has the potential to emerge as a key theme in REF2027.

The Unit has been investing QR funds (£222K) which is a 28% increase from REF14 (£159K) to accelerate, track and record impacts of our research. New researchers have been supported and encouraged to apply for university impact funding initiatives. Unit level PPDP have been continued over the REF period and have been facilitated by university, unit and external experts in research impacts. The Unit has invested in recruiting postdoctoral assistants to identify pathways to impact, track evidence and support staff in developing impact narratives. New staff Dr Diogo Montalvao was support by QR funding (£10,465) to establish research in fracture risk in NiTi endodontics and led to an Anglo-European College of Chiropractic match funded collaborative studentship. Dr Philip Sewell was supported by a Fusion Investment Fund and HEIF funding (£41,929) in collaboration with RNLI resulting in a delivery plan created for implementation of a fabrication lab within the RNLI to encourage innovation, prototyping and manufacturing amongst all departments of the organisation. New staff Dr Adil Saeed was supported by QR funding (£5,000) in magnetic flat cell corrosion condition monitoring which has led to the development of a proposal in Smart Systems Technology for Assessing and Monitoring Micro-Electromechanical Failures for Leverhulme call. QR funding (£1400) was used to support Dr Yi Huang's work on bimetallic composite, which led to two journal publications in collaboration with the: University of Southampton, Warsaw University of Technology (Poland) and Oxford University. Dr Kyungjoo Cha was supported by QR funding (£1600) to promote research in eco-design which led to Kia Motors funding (£86,000) to investigate digital life of Kia Z generation autonomous vehicle design. Dr Roya Haratian was supported by QR (£5,700) which has led to an EPSRC funding application.

1.2.1 Evidence of achievement of strategic aims for research since REF 2014

The unit has focused on four key priorities: (1) pursuing research excellence to enhance reputation and sustainability; (2) interdisciplinary research; (3) engagement with external stakeholders to facilitate societal relevant research, and (4) raising our international profile. These had been described in the REF2014 environment narrative (Unit15) and were aligned to BU's Strategic Plan (BU2018).

The Unit forward strategic direction (2018-2025) is informed by the 100 BU2025 actions, which make up the strategic plan. The unit has organised its research within key themes in alignment with the university strategic investment areas, incorporating: fusion of research, education and professional practice, leadership and impact, reputation and networks, people, performance & resilience. In turn, leadership and impact focuses on significantly improving our research performance in the unit. We are aspiring to: (a) grow our internationally excellent and world-leading research; (b) increase our research and knowledge exchange funding; and (c) develop impact. Long term strategic planning has led to publication of national and international patents and an average of 8 patent citations received per 1,000 outputs published by the unit. 20.9% of publications are in the top 10% most viewed publications worldwide with an average of 1.4 field-weighted views impact of unit. Collaborations have been extended to Asia (China, India, Pakistan, Malaysia), Europe (Italy, Poland, Portugal), the USA and UK HEIs.

Research in the Unit has been organised as follows to realise the unit strategic goals and enhance our portfolio from REF14.

Biomedical/Mechanical Engineering (BE/ME):

Professor Siamak Noroozi leads the BE/ME research group, which focuses on prosthesis.

Professor Ian Swain's research on Functional Electrical Stimulation, Tetragrip I INSPIRE project (£26,000) led to Tetra II INSPIRE PDRA (£157,440) and two further projects (£48,000), match funded by Dorset Creative and Odstock Medical Limited, in hip surgery simulator and a walking aid for stroke or multiple sclerosis affected people respectively. This has enabled the development of work on Functional and Neuromuscular Electrical Stimulation (FES and NMES) to expand into the field of Orthopaedics. Prof Swain established cooperation with the local NHS hospitals. Staff in the Orthopaedic Research Institute (ORI) consists of a part time Prof of Clinical Engineering, an Associate Professor, Research Manager, two Research Fellows, two Research Assistants, PhD students and 3 Hip Fellows who are Orthopaedic Surgeons undergoing research training just prior to taking up Consultant posts. This close cooperation between clinical and academic staff ensures that the research undertaken is of direct relevance to NHS patients and services.

External Prosthesis – Smart socket/Socket comfort:

BE/ME developed the first AI-based socket interfacial load transducer that can inform and facilitate the management of interfacial load distribution between a socket and the residual limb. This research was supported and funded by both Chas A Blatchford & Sons Ltd and the EPSRC. The smart prosthetic socket has been the subject of Blatchford research for the last 10 years and this prototype developed by BE/ME allows real time measurement and monitoring of interfacial forces on the socket leading towards the goal of assessing the socket comfort. This has led to further research (£78K) in collaboration with Zimmer Biomet and RBCH (Royal Bournemouth and Christchurch Hospital).

External Prosthesis – Deltoid Tension Meter:

BE has major contributions on the understanding and the science of amputee running, using High Tech Composite Energy Storing and Returning (ESR) Prostheses made by OSSUR. This research, supported by OSSUR and in collaboration with the University of Malaya enabled BE to develop the theory behind the Dynamic Elastic response of the ESR feet to impulse synchronisation. This research has helped in the identification of the dynamic characteristics of all OSSUR feet and the advantages of Bilateral amputee over Unilateral amputee in longer distance races due to the existence of beat frequency and symmetric gait as evidenced by the outcome of the 2012 London Olympics.

Internal Prosthesis:

BE are pioneers in the development of joint assessment transducer technologies. This work was sponsored by the NHS and in consultation with other interested parties. The first transducer artefact that enables surgeons to measure joint contact force and subsequently estimate the initial deltoid tension during total reverse shoulder arthroplasty (TRSA) has been developed at BU.

Another research programme at BE is the investigation of running gait in patients after total knee replacement. The "Orthopaedic Joint assessment Technology Research Group" is developed at BU and will concentrate on investigating different joints in the body to design & develop a range of transducers for joint assessment before, during and after operation. This work was jointly supported by Lima Corporate (Italy) and Royal Bournemouth and Christchurch Hospital.

The mechanical engineering research theme has established two research collaborations with Hydreco, a local hydraulics company, to design and develop the next generation of rotary hydraulic valves and the new generation of computer-controlled valve control systems.

Materials Science & Testing (MST):

The MST research theme is led by Dr Amor Abdelkader. This is an emerging theme in terms of materials synthesis and process and is currently being developed through university pump priming funding, including £184K in equipment and 3 x internally-funded PhD studentships. The current research focus is on batteries and material synthesis. In addition, MST is supported by PlanetOne Rotterdam (~£110K) for research in "Porous nanostructures from recycling materials and its application in energy storage", Ministry of National Education, Turkey (£50K) for research in "Nanostructured zirconium carbides and borides".

Northeastern University (China) and Bournemouth University established the NEU-BU Joint Research Centre for Advanced Materials in 2019. The Centre aims to build a strong link in developing novel materials with new properties. The Centre will be a platform for staff and student exchanges, in line with the Unit's strategy to increase international collaboration.

NanoCorr Energy & Modelling (NCEM)/ Tribology & Design (TD):

Professor Zulfiqar Khan established the NanoCorr, Energy & Modelling (NCEM) research group in 2015. NCEM's research portfolio of direct, capital and in-kind funding since 2014 is c. £1.3M. Professor Mark Hadfield leads the Tribology & Design (TD) strand of research in NCEM. Four staff members, Dr Adil Saeed, Dr Nigel Garland, Dr Ben Thomas and Dr Mehran Koohgilani work on cross-themes within NCEM/TD such as tribology and wear and corrosion engineering.

Following are the NCEM's wider Developmental and Exploratory Research activities:

Sustainability (Sustainable methodologies of preventing corrosion and coating failures in large complex interacting systems)

The main aim of this thematic research is to provide sustainable conservation methods applied to high value assets in the museum environment and extending these solutions to military applications. Research into sustainable methodologies to enhance corrosion resistance of large vehicles and coating failures mechanisms have been conducted since 2010. This area provides a strategic focus for inter-disciplinary *Developmental Research* in advanced materials, mechanical and chemical engineering. Research in this area was supported through several projects including: 2 x PGRs match funded by Defence Science and Technology Laboratory DSTL, MoD (£47K), 1 x PGR match funded by The Tank Museum (£25K) and 1 x PDRA by Wessex Institute of Technology (£20K). This theme and the Advanced Materials theme are supported by 2 x Global Visiting Fellows (£38K investment). Both Fellows are from [Tsinghua University Beijing PR China](#). Work in this theme has led to one patent in, "Telescopic Electrochemical Cell (TEC) for Non-Destructive Corrosion Testing of Coated Substrate, patent number GB2018/053368" and a 2nd patent is pending. BU has recently employed a commercialisation manager who has been exploring commercialisation of this patent.

Advanced Materials (Nanocomposite coatings for tribological applications)

The aim of this theme is to provide nanostructured surfaces and interfaces to reduce frictional losses and in turn energy recovery and enhanced durability within complex interacting systems. This area is mainly funded by ASM Assembly Systems Weymouth Ltd (1 x PhD project £51K direct funding, £170K equipment/patent), Schaeffler through 2 x PhD projects (£122K (£50K direct funding + £72K in-kind)) focusing on the development and application of novel non-corrosive, non-wearable nanocomposite coatings for bearing applications, and a 3rd PhD in modelling rolling contacts (£26K). Two x PhD exchange students from the University of Nevada, Reno, USA each spent 3-6 months at BU which led to joint publications and joint work is in progress in terms of exchanges. A 4th project is funded by Daido Metal Co Ltd, The European Technical Centre (UK) (£4K). This theme has overlapped with the Tribology & Design theme in terms of wear-corrosion study.

Low Carbon Technology (Energy generation, conservation and storage)

Energy conservation Developmental Research was established in 2012 and has since been funded by Future Energy Source Ltd UK. This area has been funded by Future Energy Source Ltd through fully funded 2 x PGRs, 2 x PDRAs, 1 x in-kind support for PGR, 1 x technician support, 1 x admin support, 1 x intellectual proprietary advisor and laboratories support (£533K direct and in-kind funding). One x PhD exchange visit from University of Sciences & Technology, Houari Boumediene (USTHB), Algeria has led to a joint publication with BU and University Miguel Hernández, Elche, Spain.

This research has led to the development of a novel solar collector design and the development of nanoenhanced thermo-fluids for sustainable and low-cost energy. Four patents have been granted in: (1) "A Solar Energy Capture, Energy Conversion and Energy Storage System, patent number GB2540670", (2) "A Working Fluid, patent number GB2557739", (3) "A solar energy capture, energy conversion and energy storage system, patent number WO2017221197A2" and (4) "A Working Fluid. Patent number WO2019106628A1". These patents are exploited by Future Energy Source Ltd for commercialisation; impacts have been tracked to develop an impact case study for REF2027.

Another Developmental Research programme on energy storage systems applied to solar collector design and nanocoatings and subject to Thermofluids lubrication are match funded (2 x £23K) by the National University of Sciences & Technology NUST Islamabad Pakistan. One PGR from this programme has been employed by Daido Metals Europe Ltd Ilminster Somerset with whom research collaborations are ongoing. A second PGR has been appointed by NUST as assistant professor which will further strengthen existing collaborations.

Tribology & Design (TD)

The Tribology & Design (TD) research theme is led by Professor Mark Hadfield. The area of concern generally is tribological studies (rolling element and hydrodynamic bearings) and design research (sustainable design education and design research methodologies). The principle aim is to undertake multi-disciplinary projects that extend knowledge in the areas of tribology and design to also include their interaction. The study here is cross-themed and is linked to NCEM in terms of a wear-corrosion study in nanocoating and modelling. Joint work between TD and NCEM will develop future impacts to inform relevant case studies. This area has been funded by industrial partners and key projects are: 1 x PDRA in "Finite Element Modelling and Analysis of Lubricated Silicon Nitride Rolling Elements with Surface Defects", funded by SKF Engineering and Research Centre (The Netherlands), 1 x match funded PhD in "Tribology of Sliding Contacts within Plain Bearing Overlays Subject to Corrosion" in collaboration with Daido Metals Europe (£25K), 1 x KTP in "Design Simulation Software" (KTP and Wessex Institute of Technology (WIT), (£100K) and 1 x PDRA in "Polarisation and Corrosion - An Experimental Approach" funded by Wessex Institute of Technology (£12K).

1.2.2 Future strategic aims and goals for research

The strategic vision for the Unit is to perform world-leading theoretical and analytical research in: materials, low to zero-carbon energy, nanocoating, tribology, biomedical and electrochemical engineering for wide ranging industrial applications. This research is supported by computation and experiments that address the most challenging engineering and design problems facing the world and to translate them into sustainable solutions to address energy demands, sustainability and enhance assistive technology. We will do this across length and time scales - from the sub-atomic to the industrial scale, and from the instant to long term with a focus on developing industry ready solutions.

The Unit has already been contributing to national and regional strategic initiatives including Grand Challenges. Research within the Unit will directly contribute to Dorset's [Local Industrial Strategy](#) informed by [Department for Business, Energy & Industrial Strategy](#) in terms of [Clean](#)

[Growth](#) and [Future of Mobility](#) and [Advanced Manufacturing and Engineering](#) in terms of providing sustainable solutions for clean production and curtailing carbon footprints, increasing skilled workforce, employability and entrepreneurial opportunities.

Each research group in the Unit has defined specific strategic goals to achieve this vision and to deliver industry ready and applicable solutions within the scope of each theme, and solve problems presented within BU's Strategic Investment Areas (SIAs), such as: (i) Assistive Technology, (ii) Animation, Simulation & Visualisation and (iii) Sustainability, Low Carbon Technology & Materials Science. Across the Unit, the key strategic goal for the next five years is to expand our research activity in the above areas.

The Unit will benefit also from the award of future competitive research funding and the resulting sustained growth in expertise especially in terms applied research. These research groups will provide high quality cohort-based PhD training to meet critical research and industrial needs.

The strategic goals for **Biomedical/Mechanical Engineering** for the next five years and beyond are to:

1. Develop image processing technologies applied in large orthopaedic joint implants using smart phones, making it both cost effective and readily available to GP surgeries. It is aimed that the work in this area will be commercialised.
2. Increase collaboration with major orthopaedic joint implant manufacturers to provide readily available prosthetic solutions.
3. Enhance end users' standard of life and increase reach of related impacts.
4. Integrate the developed of next generation rotary hydraulic and computer-controlled valves control systems.
5. Develop cost effective high precision machines for the future utilising Artificial intelligence, Image processing and Inertial Measurements.

The strategic goals for **Materials Science & Testing** for the next five years and beyond are to:

1. Engage and collaborate with materials, energy and nanotechnology industries.
2. Transfer knowledge to industry and society.
3. Develop new sustainable technologies.
4. Enhance our international reputation as a research institute.
5. Increase externally funded research to more than £500K per year.
6. Produce high-quality research outputs with world leading international collaborators.
7. Engage with multidisciplinary research across Bournemouth University.

The strategic goals for **NanoCorr, Energy & Modelling/ Tribology & Design** for the next five years and beyond are to:

1. Aspire for NCEM to become the National Centre of Excellence in interdisciplinary research focusing on sustainability, low carbon technology and nano materials by 2025.
2. Expand nanocoatings and nanotribology research to design for durability and reliability.
3. Develop nanocoatings for enhanced performance in non-conventional lubricants such as Thermofluids and marine environments.
4. Strengthen our research into the fabrication of corrosion and wear resistant coating materials and their performance in products and systems.
5. Excel in research in structural health monitoring by using micro sensors, systems control, design and optimisation platforms.
6. Further enhance our research portfolio in low carbon technology.
7. Double the number of PGRs and PDRAs from currently 5 and 2 respectively by 2025.
8. Sustain our current industrial and HEIs collaborations beyond 2021 with: DSTL MoD (PhD programmes/visiting fellow), Future Energy Source Ltd (PhD and Post Doc programmes), Schaeffler (PhD programmes), Analatom USA (joint bidding, licensing), The Tank Museum at Bovington (PhD programme), National University of Science & Technology, Islamabad

Pakistan (PhD programmes), Tsinghua University Beijing, PR China (Visiting Professor, joint research), Alliance University, Bangalore India (joint research/bidding), National Institute of Technology, Srinagar India (joint research), University of Nevada, Reno USA (exchange visit/joint research).

9. Establish new collaborations with both UK and International industries and HEIs.

1.2.3 Delivery of strategic aims and research goals

Progress and delivery of the research strategy for each theme is overseen by their leads. Theme leaders have the responsibility to deliver research objectives. The theme leaders serve as a conduit for information and provide strategic advice, mentoring and coaching. Sustained progress in terms of external funding opportunities, organising research away-days and coordinating communication and PR activities will be overseen by research leaders. Focus will be given to increasing critical mass in specialist subject areas such as corrosion engineering, Fluid & Thermodynamics and Tribology & Wear and it is aimed that NCEM and TD jointly become national centres of excellence through delivery of cutting edge applied solutions to bring socio-economic, environmental and business impacts.

2. People

Bournemouth University has fully implemented the Concordat to Support the Career Development of Researchers and has successfully retained the *HR Excellence in Research Award* since it was awarded in 2013. The university applies the Concordat to all academic and research staff. Specific instances of application of each of the 7 *Principles of the Concordat* in the Unit are indicated; the REF exercise addresses Principle 7.

2.1 Staffing strategy and staff development

Recruitment and retention of academic staff is planned strategically to maintain international excellence in current activities and ensure it is embedded in new activities (Concordat Principle 1). In each unit, strategic investment in salaries and facilities allows recruitment and retention of internationally leading researchers. Substantial investments in research funding and infrastructure are made regularly to attract new staff. Under the BU Workload Planning Framework all academic staff are allocated a minimum of 400 hours a year for research activities.

2.2 Evidence of Career Development Support for All Levels of Research Staff

There are rigorous processes for developing and supporting research staff careers at all levels. Career development of academic staff and research fellows is managed through the same consistent and transparent process.

2.2.1 Academic Staff

Mentoring and Support (Concordat Principle 2):

All academic staff have an academic advisor to mentor and guide them during their 12-month probation. ECRs for example, Dr Saeed and Dr Cha, have been supported in terms of progressing their research. For example, Dr Saeed has been participating in Schaeffler and ASM funded projects as a Co-I and co-supervisor, Dr Cha has obtained external funding (Kia Motors) enabled by preliminary QR funds. In addition to regular meetings, a formal performance review takes place mid-way and near the end of the probation period. All PDRAs are assigned an academic mentor to assist with career development.

Personal Review and Development Plan (Concordat Principles 4 and 5):

All staff produce an annual Personal and Professional Development Plan (PPDP) for discussion with their Line Manager when their overall performance is reviewed, targets for the forthcoming year are established and agreed, and their career development is planned. This encourages performance benchmarking, recognition of achievement and guidance for addressing weaknesses that need to be addressed for promotion or development. The PPDP process is independent of, but informs, the annual salary review and promotions processes.

Promotions:

An independent promotions panel reviews each case and interviews each candidate. The Panel provides feedback that may include improvements to the case or delaying the application, with specific guidance for strengthening their case. Mock interviews are provided with feedback. Some promotions include Dr Sewell and Dr Hunt (to associate professor), Dr Dyer and Dr Montalvao (to principal academics). Dr Saeed completed a PhD at BU in 2012-13 and was retained as postdoc through external / internal funding until Aug 2016. Dr Saeed joined BU as lecturer in Jan 2018 and has been a key contributor within the unit in terms of research in corrosion engineering and modelling in tribology. The unit impact case study is founded on Dr Saeed's PhD research.

Training (Concordat Principle 3):

The university, through RDS, offers a range of professional development courses that include writing research proposals, managing research budgets, staff and students. Mandatory courses for new staff include, for example, PhD student supervision. The research and teaching performance of new staff is formally reviewed, with feedback and a development plan. In cases of unsatisfactory progress, additional support or alternative roles are developed. All staff within the unit have been taking part in these programmes which have led to several research activities, for example: developing new funding proposals, participating in externally and match funded projects, contributing to internal REF review process as unit panel members and publications.

2.2.2 All Staff: Competitively won Fellowships and Chairs

There is a strategic effort to encourage and assist early career researchers to win competitive Fellowships to progress their careers (Concordat Principle 2). A rigorous process of identifying suitable candidates during their PPDP and linking them to opportunities (for example ERC, EPSRC, HLF, RAEng and Royal Society) is carried out, assistance is provided through development programmes for funding applications. The Unit has identified a candidate fellow for UKRI future leadership fellowship initiative, led and mentored by Prof Khan and an application, BU ID 12403 (£942.4K), has been developed in zero carbon energy.

2.2.3 International Staff Appointments (incoming & outgoing), international recruitment and visiting scholars

Bournemouth University also funds Research Fellowships through Global Visiting Fellowships to develop high profile research collaborations. Recent successes are BU (Unit), 2 x research fellowships awards with Tsinghua University Beijing, China (1st Asian, 14th World Reputation and 23rd World University [THE rankings](#)).

International recruitment:

Three strategic incentives have made a significant impact on our ability to recruit successfully exceptional candidates in the international market:

- (1) Fusion and investment: Providing an environment that engages and attracts staff, students and external stakeholders by making BU a destination of choice for international students, staff and visiting scholars by significantly increasing the services and support we provide.
- (2) Reputation and networks: Significantly develop our network of partners and be the partner of choice for businesses and organisations by engaging long-term and pro-actively with external funders and partners world-wide to seek opportunities for collaboration and develop sources of income, including internationally.
- (3) People and culture: Continue with our strong commitment to ensuring equality and diversity by continuing to recruit and support international students and staff.

Visiting Scholars and Professors:

The Unit welcomes visiting scholars from around the world for sabbaticals and academic visits. The research environment has been supported by external advisors, industrial supervisors, renowned visiting professors and visiting fellows. Over 9 visiting professors and 10 visiting fellows from institutions around the world stayed and supported research within the Unit for periods ranging from a few weeks to several years. This has led to sharing experimental and analytical resources, joint PGR supervision, joint Q1 journal publications and joint bids, for example EPSRC, invited research seminars and joint conference presentations. Visiting Professorships form part of our Programme Research strategic activities, to support the creation and sustaining of Centre scale activity. Eminent persons from industry, Government and other academic institutions that can add excellence to our research may be nominated as Visiting Professors. They are vetted at University and Faculty levels and are then appointed by the university.

2.3 Research students

We provide high quality education and training for PhD students, underpinned by career and pastoral support. The Unit awarded 39 (33 split-supervision) PhD degrees over the REF period; BE 13, ME 11, NCEM 11 and TD 4. A vast increase since REF2014 represented in Figure 2:

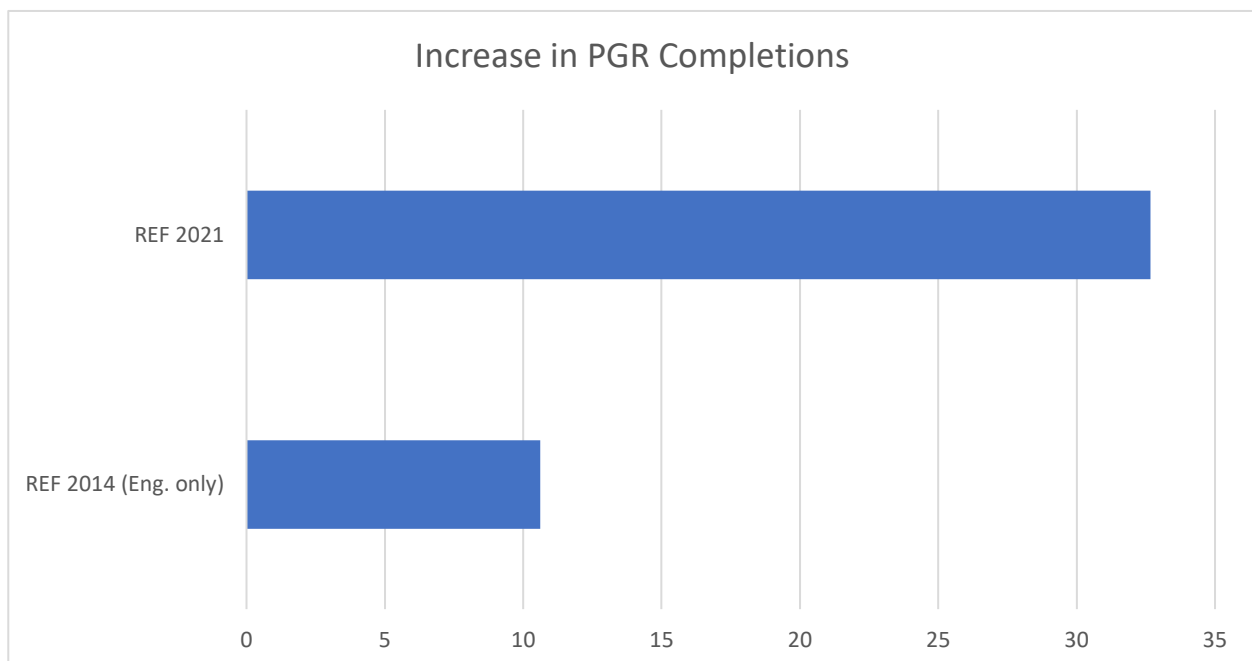


Figure 2. PGR Completions

A further 4 PhDs (NCEM/TD) were awarded, shared with other Centres (2 x Tsinghua University, 1 x School of Design, University of Limerick, Limerick, Ireland and 1 x DesignCORE, Institute of Technology, Carlow, Ireland).

2.3.1 PGR recruitment: approaches and discipline-related issues

A major strategic initiative has been taken to raise the number of PhD scholarships offered and support *Exploratory Research*. PhD candidates are vetted through a rigorous evaluation and interview, with the most excellent applicants being supported through their studies. The Unit has significantly benefitted from BU match-funded studentships, an initiative to develop and strengthen industrial partnerships. This has resulted in collaboration with the Defence Science & Technology Laboratory, Ministry of Defence and International collaborations such as, Schaeffler Technologies AG & Co. KG, Germany and SKF Engineering and Research Centre (ERC), Netherlands (Sec 4.1.2 and 4.1.3). Funding from industrial collaborations within the match-funded initiative have been a major part of our research portfolio (see Sec 3). This allows the recruitment of the very best national and international applications based solely on merit. This significant financial commitment is in line with our strategy; the Exploratory Research activity is supported so that it can grow into Developmental Research. These industrial collaborations have led to several UK and international patents and impact case studies. New research areas such as corrosion engineering, nanocoating and energy have emerged since REF14 and have been established since then, evidenced by new funding and publications.

2.3.2 Information on training and support mechanisms

Research students are given working space, separate from their laboratory, and a computer. They are encouraged to attend any relevant lectures in the Centre and the university. Vibrant seminar programs in each Centre expose all students to the very best researchers from around the world. To ensure significant progression of PhD students, they are encouraged to participate in these seminars. Seminars are held at least bi-monthly and monthly. Attendance at external conferences is actively encouraged and funded by the PhD external grant or internally by the Centre.

PhD students have a structured first-year training programme in research skills, planning, presentation, technical writing and other transferrable skills, delivered through the Doctoral College. All research students are encouraged to attend generic training and transferable skills courses provided by the Doctoral College. The Centre also provides specialist skills training and knowledge modules, details of which are compiled for safety and training records. Students who would benefit from English tuition, identified through a rigorous test, receive the necessary help through the Language Support at Bournemouth University. Safety training is given and recorded supported by the university and Faculty Safety Officers for example, fire safety training.

2.3.3 Research Student Progress Monitoring

PGRs are required to submit their Probationary Review within 3 months of enrolment. Probationary Review is informed by the PGR's early research activities. This is followed by a Major Review within 14 months of PGR's enrolment to ensure they are on track to complete their research degree in a timely and successful manner. The Major Review assessment process is centred on the submission of a briefing paper (up to 3,000 words), a brief presentation and discussion with an independent panel. The panel will comprise 2 independent academics, one of whom will act as Chair. These are nominated by the supervisory team and approved by the Faculty Research Degree Committee (FRDC).

PhD student performance and feedback on their research experience is monitored by the lead academic supervisor. All PhD students are expected to submit their PhD theses within 4 years, 29 completions. For exceptional circumstances, a special case can be made to the university for an extension. Research degree examining teams are formally approved by the Examiner Approval Panel, which is chaired by Academic Quality. The examination of a research degree thesis has two key stages: a) the preliminary assessment and b) the defence by oral examination – the viva voce examination.

2.4 Evidence of Equality and Diversity

The Unit works with the university Equality and Diversity Committee to promote and embed all aspects of equality. Within the Unit every attempt is made to ensure representative constitutions for all interview panels for appointments and awards.

The Unit has 5 FTE female academics (20.8%), of which 1 FTE is an Associate Professor (20%). Within the Unit 48.8% of staff are from ethnic minorities. Initiatives to further reduce traditional barriers to progress for members of the Unit included targeted support, such as writing retreats and pump priming funding, as well as initiatives to challenge structural barriers, such as diverse recruitment, promotion and review panels.

3. Income, infrastructure and facilities

The Unit has state-of-the-art facilities and equipment to support its researchers and the REF period has seen significant strategic investment.

3.1 Information on provision and operation of specialist infrastructure and facilities University Research Facilities:

Most of the research portfolio within the Unit is experimental and experimental/analytical. Research in nanocoating, thermal storage, nanofluids, biomedical, tribology and materials is supported by various mechanical testing facilities which comprise electromechanical and hydraulic Instron test machines (50–250kN), a 250t compression machine for stiffened panel testing, and an Instron low velocity impact test (2000J) with bespoke facility for loading panels in compression (150t) during impact tests, and a Scanning Electron Microscope (SEM).

An additional £228K was invested to enhance capabilities since 2015. NCEM's newly acquired resources include: pulse nanocoating facilities, nanotesting system, nanoindentation system, fluid property testing, frictional flow equipment, free & forced convection and thermal conductivity bench testing, solar simulator, thermofluids refrigeration test-bench, environmental simulation, salts spray chamber, prohesion testing and advanced analytical tools for thermal, stress and corrosion analyses. In addition to tribo-testing, interferometer, mechanical and chemical characterisation and optical microscopy are existing facilities. This has enabled new research in corrosion engineering, nanocoating and characterisation, heat transfer and thermofluids which have emerged during REF period and have been growing through industry funding, such as Schaeffler and ASM Systems.

FES Ltd has provided off campus a heat transfer and thermodynamics laboratory and on campus heat transfer bench testing and a fluid characterisation laboratory which are significant resources to support research in the areas of energy capture, conversion and storage which are new areas of research within the unit.

Research facilities within the Orthopaedic Research Institute (ORI) based at the university consist of a state of the art Gait Laboratory, a muscle force measuring system, clinic rooms, a surgical simulation laboratory, a electromechanical workshop and a wide range of physiological measuring equipment.

3.2 Evidence of Investments (both current and planned) in infrastructure and facilities**Capital Equipment**

BU has invested £184K to establish an Advanced Materials laboratory to further support low carbon technology development. This is aligned with BU2025 'Sustainability and Low Carbon Technology' SIA.

Laboratory and Facility Refurbishment

Poole House Innovation Centre is a major research support Centre in terms of labs and workshops for the unit. This has been developed through estates investment circa £3.36m, delivered in 2016 and includes the material workshops, 3D printing, heat transfer and nanotribology.

Materials science laboratory – estates investment of £180k plus equipment, lab completed in 2018. The Unit has been supported with material science research at BU, in line with BU2018 and the developing BU2025 strategy. The delivery of a new materials laboratory will enable research that lays at the boundaries between corrosion engineering and nanomaterials, to include nanocoating, tribology & wear and energy with the aim of delivering low dimensional materials.

The Innovation Centre (£3,558,000) houses research facilities and resources and provides additional facilities in 3D printing & prototyping, manufacturing and electronics, which support research activities within all themes. Part of this included the estates office accommodation refurbishment and staff centre but approximately 85% of the cost would be attributable to the Innovation Centre

3.3 Research Funding Portfolio and Future Plans

The research funding portfolio is described both in terms of recognised research income (see REF4), and value of grants awarded to demonstrate the vibrancy and sustainability of the research.

The Unit has a large and vibrant research funding portfolio, which has grown consistently over the REF period. Recognised income has grown by 20% over the REF period to £963,402. Income source has also diversified over the period represented in Figure 3:

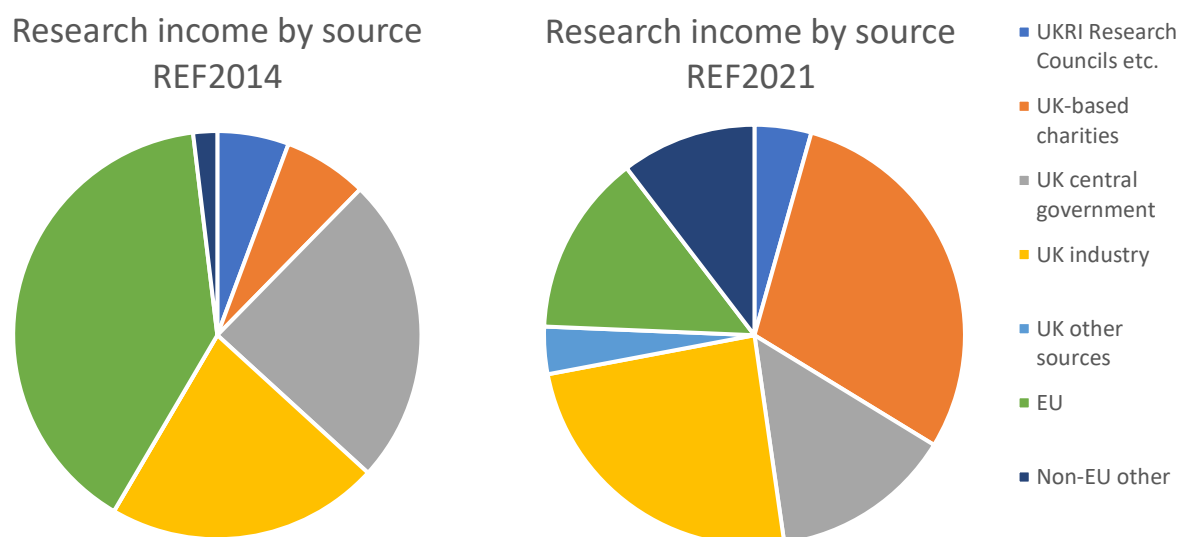


Figure 3. Research income by source

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

4.1 Research Collaborations

We pursue collaborations that enhance our research strategy; within the Unit, across university, with other universities and Industry. Collaborations, in line with the research strategy, are targeted in two categories:

- *Exploratory Collaborations* are maximum 1-year collaborative projects with other universities and researchers to establish research in new areas. These collaborations are encouraged through BU global visiting fellowships, staff/PGRs exchanges and industry contract research. Successful collaborations result in joint publications and winning Developmental Research funding. Virtually all staff have Exploratory Collaborations with other universities and industries.
- *Developmental Collaborations* are 3 to 5 years collaborative projects (mainly PhD studentships) between researchers, both within Bournemouth University and at other universities or industry. Establishing and maintaining Developmental Collaborations is a key strategic goal. Collaboration with industry is one of our great strengths and is evidenced by the significant proportion of our research income (38.47%, £0.68M in REF period). Most of our industrial collaboration is Programme Research; Future Energy Source Ltd, Schaeffler, Ministry of Defence UK, SKF, Hydreco Hydraulics Ltd and Lima corporate S.p.A etc. and together are worth £408.37K.

During the REF period, we have had 4 Exploratory and Developmental Collaborations with UK universities, 13 collaborations with International universities, 1 Research Institute and 13 industrial collaborations.

4.1.1 Collaborations

Unit collaborations range from Unit themes, within the university, to UK and International HEIs and industries. These collaborations are of strategic significance coupling Unit research to BU SIAs to enable applied research for realising socio-economic, environmental and business impacts in partnership with industry. Unit international collaborations account for 50.3%, national 24.3% and institutional 19.5% evidenced by the Unit output profile.

Several platforms such as the BU Festival of Learning, national and international workshops and conferences are used to initiate collaborative links. Several models such as BU match-funding initiatives, industry full funding programmes, external competitive funding are explored and utilised to kickstart research projects with strategic planning to sustain future projects. For example many of our industrial partners such as: Schaeffler Technologies AG & Co. KG, Germany; SKF Engineering and Research Centre (ERC), Netherlands; National University of Sciences & Technology, Pakistan; Hydreco Hydraulics Ltd, UK and Defence Science & Technology Laboratory, Ministry of Defence, UK have been collaborating in multiple projects. Projects with Odstock Medical Limited and Future Energy Source Limited have led to major commercial benefits, such as patents and 2 x impact case studies for REF2021. The Unit has also developed longstanding collaborations with UK charities such RNLI and The Tank Museum at Bovington. Collaborative research with The Tank Museum has led to an impact case study for REF2021.

4.1.2 Collaborations within Bournemouth University

Bournemouth University establishes and supports strategic cross-university and cross-faculty activities that act as a focus and facilitate *Developmental Collaborations*, which in many cases include industry.

Examples of cross-university Programmes are University Strategic Investment Areas (SIA), BU2025 (Sec1.1) in Units 3,12,23,24 and 32. Institutional collaborations account for 19.5% of total output portfolios.

4.1.3 Collaboration with Industry and other UK Universities

In many cases, the industrial Exploratory and Developmental Collaborations extend beyond BU to include other institutions, for example: (1) Defence Science & Technology Laboratory, Ministry

of Defence, UK; (2) Future Energy Source Ltd, Poole, UK; (3) Daido Metal Co Ltd, The European Technical Centre (UK); (4) Technology Design, UK; (5) PANalytical Ltd, UK; (6) PMI Analytical, UK; (7) Wessex Institute of Technology, UK; (8) Longitude Engineering Ltd, UK; (9) Hydreco Hydraulics Ltd, UK; (10) Naim Audio Ltd, UK; (11) Odstock Medical Limited and (12) BAE Systems, UK. Top 10 UK universities collaborations in terms of output profile include University of Southampton (106 outputs), University of Hertfordshire (22 outputs) and AECC University College (19 outputs).

4.1.4 International University and Industry Collaborations

In addition to the *Developmental Research* activities noted already, further examples of international collaborations include: (1) Schaeffler Technologies AG & Co. KG, Germany; (2) SKF Engineering and Research Centre (ERC), Netherlands; (3) NASA Materials Testing and Corrosion Control Branch, US; (4) Analatom, Inc. US; (5) Lima Corporate, Italy; (6) Tsinghua University Beijing, PR China; (7) PES IT Bangalore, India; (8) National University of Sciences & Technology, Pakistan; (9) National Institute of Technology, Srinagar, India; (10) University of Wisconsin, Milwaukee, USA; (11) University of Nevada, Reno, USA; (12) University of Oviedo, Spain; (13) University Miguel Hernández, Elche, Spain; (14) University of Sciences & Technology Houari Boumediene (USTHB), Algeria; (15) University of Malaya, Malaysia; (16) Northeastern University, PR China; (17) Zhongyuan University of Technology, PR China; (18) Chiang Mai University, Thailand; (19) Ghulam Ishaq Khan Institute of Engineering Sciences & Technology, Pakistan and (20) Peoples Education Services University of Technology, India. Top 10 international university collaborations include: 0 University of Southern California (40 outputs), University of Malaya (19 outputs), National University of Sciences & Technology Pakistan (15 outputs), Eotvos Lorand University (14 outputs), Warsaw University of Technology (13 outputs) and University of Lisbon (13 outputs).

4.2 Support for and Exemplars of Interdisciplinary Research

Developmental Research activities described above epitomise interdisciplinary research. Strategic support is given to these themes. Unit support includes: refurbished laboratories, specialised equipment and high-speed computation and PhD scholarships. In some cases, staff appointments have been made specifically to ensure sustainability and interdisciplinarity of the Unit research. Recent staff appointments were from a diverse range of engineering disciplines, for example, 2 x staff (electronics engineering), 2 x staff (design), 1 x staff (mechanical engineering) and 1 x staff (chemical engineering).

4.3 Research collaboration with Research Users (including industry)

Our *Developmental Research* activities generally have industrial involvement, and, in many cases, are fully industrially funded. Future Energy Source Ltd, UK and SKF Engineering and Research Centre (ERC), Netherlands are significant examples. The significant proportions of both research income and grants from industry attest to the close collaboration with research users.

In the Unit, the salaries of PDRAs during the REF period have been fully funded by industrial research partners. These positions ensure close collaboration and communication with the companies.

4.4 Leadership in the Academic Community

Over 70% of the staff in the Unit make a significant contribution to the wider research base and influence the discipline by acting as journal editors, organising conferences, and presenting keynote and plenary addresses. The scale and breadth of our research contribution to the discipline has been recognised through commercial patents yielding major impacts as evidenced by corroborating evidence from our industrial partners and end users.

During the REF period, Unit staff have served on funding panels and boards. Notable examples are: EPSRC (Professor Zulfiqar Khan, Dr Yi Huang), Romanian National Council for Scientific Research (Professor Zulfiqar Khan, Professor Mark Hadfield).

Chair Institute of Engineering Designers (IED) [Dr Tania Humphries-Smith]. Chair of the Education and Training Committee (2017), Vice-Chair of the Education and Training Committee (2014-2017), Institution of Engineering Designers (IED) [Dr Philip Sewell].

Medical Research Council MRC - (UK Research and Innovation Future Leaders Fellowships (UKRI FLF) programme Peer Review College (PRC), IUA Academic Leaders Mentoring Programme 2018/19, Mentor (2018-) [Professor Mark Hadfield]. Vice Chancellors Awards - Achievement (Bournemouth University, 2015) [Dr Bryce Dyer].

Several staff have achieved awards for example: Vice Chancellor Staff Award in Advancing Knowledge (Bournemouth University, 2018), Collaborative research award £15.5K (State Key Laboratory of Tribology, Tsinghua University, Beijing PR China, 2016), Highly Qualified Professional Award (President's Programme for Care of Highly Qualified Overseas Pakistanis (PPQP), 2015) [Professor Zulfiqar Khan], Westminster Insight, Chairman [Dr Diogo Montalvao] and Egyptian national pioneer award in advanced engineering science [Dr Amr Abdelkader].

The Unit presented more than 50 keynote and plenary lectures and was involved in organising over 100 conferences during the REF period. Examples of significant conferences with eminent speakers organised by the Unit are: International Workshop on Materials and Design (Prof Zulfiqar Khan, Prof Mark Hadfield); International Conference on Design and Production Engineering (Prof Zulfiqar Khan); Society of Tribologists and Lubrication Engineers (Prof Zulfiqar Khan, Dr Adil Saeed); Wessex Institute of Technology (Prof Mark Hadfield, Dr Adil Saeed and Zulfiqar Khan); World Tribology Congress (Prof Zulfiqar Khan, Prof Yonggang Meng, BU Visiting Professor); World Congress of Advanced Materials, Asia Conference on Power and Electrical Engineering (Prof Zulfiqar Khan) and American Society of Mechanical Engineers (Dr Zakir Khan and Dr Utku Helvaci).

4.5 Structures to support interdisciplinary research

Research themes/ groups within the Unit are aligned with BU2025 SIA, investment and funding as described above.

4.6 Open Research

Bournemouth University Open Access Publication Fund is a centralised fund both in response to and in support of various developments in research communication and publication trends. The funding application is managed by the Research Development and Support Office (RDS) and is designed to support researchers in complying with: (1) The REF2021 Open Access policy (via the Gold route), and (2) the Open Access mandate introduced by major funding bodies as a condition of their grants. BU supports open access publishing via a dedicated, central fund (c. £100k per annum). The Unit has been successful in securing OA funds for supporting Q1 journal publications. 20 staff/papers have been awarded funds to support OA Gold route which is 81.3% of the Unit headcount. OA funding has enabled making cutting-edge research widely available to research communities.