

<b>Institution: 10007140 Birmingham City University</b>
<b>Unit of Assessment: UoA 12- Engineering</b>
<ul style="list-style-type: none"> <li><b>Unit context and structure, research and impact strategy</b></li> </ul> <p><u>Overview and Research Structure</u></p> <p>The Engineering Department at BCU is an established centre for research and teaching in technologies and processes relevant to manufacturing, with additional expertise in applications of technology to environmental sustainability and the low carbon agenda. We are one of two departments in the School of Engineering and Built Environment (EBE), which alongside the School of Computing and Digital Technology (CDT) comprises the Faculty of Computing, Engineering and the Built Environment (CEBE).</p> <p>Since 1971 we have been key partners with the manufacturing sector of the Midlands. In REF2014, our distribution of expertise meant we returned members of our Knowledge-Based Engineering (KBE) group as part of the Computing UoA. Now, with 16 researchers holding significant responsibility for research (SIGRES), a further nine working towards independent researcher status, and 31 doctoral students, we make this return to UoA 12 as a fast-developing research cluster in our right. The recruitment of 14 talented researchers during the REF period has allowed us to bring fresh thinking to a group of staff rich in industry experience and partnership working, and to build the impact of our work nationally and internationally.</p> <p>Our research directorate is chaired by Athwal as CEBE's Associate Dean for Research and Innovation, with <b>Fourlaris</b> as UoA lead and <b>Melville</b>, <b>Proverbs</b> and <b>Ioannidou</b> leading on impacts and outputs. Oversight of Research Degrees is provided by a senior Faculty researcher who is returned to UoA13. The directorate is supplemented by a Technical Officer. Its brief is to set strategy and operational plans, and to consider the allocation of funds for equipment purchases, faculty-funded PhD scholarships, and travel and conference costs.</p> <p>Our cluster consists of four thematic groupings:</p> <p><b>Advanced Materials and Manufacturing</b>, led by <b>Krzyzanowski</b>, covers three core areas, namely (i) Materials: Processing and Design (ii) Engineering Systems, Logistics and Supply Chain Management, and (iii) Structural Integrity, with particular focus on multidisciplinary approaches to material design, innovation and intelligent manufacturing. Research within the first area (<b>Krzyzanowski</b> and <b>Ward</b>) is focused on the role of complex physical processes in the optimisation of additive manufacturing and metal forming processes, including the processing of polymers and composite materials. Key to their work is the development of new physically-based multiscale modelling methodologies for material characterisation and design, including microstructure development, fracture and surface finish aspects; and linking them with the global mechanical response of the developed material structures. The second area (<b>Orifaige</b>, <b>Annaz</b> and <b>Kalaitzi</b>) takes in manufacturing systems, robotics and haptics, supply chain management and procurement, with a particular focus on sustainability, resource efficiency and emerging technologies such as blockchain and EV supply chains, as well as the governance of inter-organisational relationships in supply chains. The third area (<b>Fourlaris</b>, <b>Krzyzanowski</b>, <b>Ward</b> and <b>Salami</b>) studies the application of new materials in engineering structures, such as novel steel automotive product development, finite element modelling, constitutive material modelling, structural dynamics and health monitoring, and earthquake engineering.</p> <p><b>Sensors and Control</b>, led by <b>Wu</b>, has gained international recognition for research leadership in sensors and their application in a variety of industrial environments. The group promotes both basic and applied research into digital sensor and communication technologies and methodologies. It comprises of two sub-groups: Smart Sensing and Communication; and Embedded System and Robotics. The first (<b>Wu</b>, <b>Ward</b> and <b>Annaz</b>) explores smart sensor technologies, energy harvesting, low power communication, computational intelligence and the</p>

industrial internet of things. The second (**Wu, Annaz and Gueniat**) specialises in mechatronics and robotics, digital signal processing and embedded systems.

**Computational Modelling**, led by **Hasan**, focuses on analytical, numerical and mathematical methods. Current activities include Computational Fluid Dynamics for thermo-fluid systems and computational engineering-enabled design optimisation (**Hasan, Khatir and Perera**), fluid structure interaction (**Flynn and Salami**), and mathematical modelling of control systems (**Gueniat**). The group's modelling expertise lends itself to multidisciplinary collaboration with the other Engineering research groups to tackle projects such as heat flow in automotive applications, hydrological water flow, design of microalgae cultivation systems, and the control of electrical microgrids.

**Global Environmental Challenges (Interdisciplinary Group with UoA13)**, led by **Melville**, explores issues related to energy and water, scoping long-term, sustainable solutions in partnership with industry, businesses, citizens and experts. The Bioresource and Bioeconomy subgroup (**Melville and Perera**) works on Biomass cultivation/processing (e.g. algae) for energy and high value products and materials, as well as Bioremediation of water and wastewater by characterisation, pre-treatment/ pre-processing and optimisation of technologies for Anaerobic Digestion. The adoption of these technologies is guided by Techno-Economic Assessment/ Life Cycle Assessment of technologies and processes, Socio-technical systems analysis and Decision support systems to encourage supply chain integration. The Water, Environment and Communities subgroup (**Proverbs, Ioannidou, Furlaris, Wu, Flynn, Perera and Hasan**) researches advanced technical and analytical tools to address a range of complex challenges facing the water industry. Their goal is to improve the quality, supply and management of water through study of hydraulics and fluid dynamics modelling, water distribution and engineering, and water quality testing and analysis, including tracer studies for contaminants and pollutants.

#### Research Objectives and Achievements 2014-20

Following REF2014, we set ourselves five key aims: (i) achieve critical mass in the Engineering cluster such as to permit an independent return to REF2021 (ii) leverage the University's developing infrastructure – as explained in 5a – to increase the volume and range of external grant capture (iii) build a sustainable doctoral community to encourage the exchange of ideas and nurture the next generation of academic talent (iv) mobilise impact opportunities to tackle major societal challenges, and (v) nurture a culture within the UoA based on values of strict integrity, peer review, and career development.

Table 1 outlines our achievements against each aim:

Aim	Achievement
Achieve critical mass in cluster	This submission has been facilitated by targeted recruitment campaigns in 2015, 2017 and 2019 for research talent, leading to the appointment of 14 staff qualifying for SIGRES; joining existing group of two research professors ( <b>Melville and Ward</b> ) and nine emerging researchers
Volume/range of grant capture	Indicative projects to the value of more than £1.5m include Insight-Connecting Autonomous Vehicles-UKRI with <b>Ward</b> , £388K, Alg-Ad,-European Union-Interreg North West with <b>Melville</b> , £269K, IOT4WIN-Internet of Things for Water Innovation Networks, European Union-Horizon 2020, with <b>Wu</b> , £458K, Lynemouth Mine Lagoon Hydraulic Modelling, The Coal Authority with <b>Ioannidou and Furlaris</b> , £106K). There has also been significant KTP Income (Brandauer-Innovate UK KTP with <b>Ward and Krzyzanowski</b> , £152K, Wilmat-Innovate UK with <b>Ward</b> , £203K).

Doctoral community	13 completions in this cycle compared with 4 in 2014, with a current doctoral population of 31, facilitated by studentships from Faculty (8), University (2), and Industry (3, part-funded)
Impact and challenges	ICSs in areas of international relevance (transforming waste to energy, and flood management); numerous workshops with regional stakeholders such as HSSMI consultancy, water agencies, JLR, Meridian Lightweighting, etc
Research culture	New internal/external peer review system covering outputs and grant applications; regular mentoring and co-authorship by senior staff; seminar series within and between research groups; support from developed BCU infrastructure as described in REF5a.

Our achievements have been facilitated partly by collaboration with companies, public sector organisations, but above all with other research groups in and beyond the University. There is overlapping membership and cross-cluster working with all the research groups in the School of Computing and Digital Technology: that is, Data Analytics and AI, Cyber Physical Systems, and the Digital Media Technology (DMTLab). Mentoring via work-in-progress sessions has supported the writing of publications in our cluster meetings, while the peer review system cited in Table 1 has fostered greater maturity and volume in our research, as evidenced in the range of work and the number of journal publications produced by Centre of Engineering members. Staff returned to REF2021 deposited 128 journal, 51 conference and 18 other outputs (such as book chapters and technical reports) in the BCU Open Access repository during this REF period, including the 40 journal outputs submitted for assessment.

#### Impact and interdisciplinary working

A major facilitator of interdisciplinary working for our cluster is the STEAM (Science, Technology, Engineering, Arts and Mathematics) programme, a £70m University and LEP initiative dating from 2016. As noted in REF5a, the project is specifically designed to support work across disciplinary boundaries. Our cluster has been a leading participant in STEAM initiatives such as the STEAM conference, STEAM doctoral scholarships and STEAM fellows schemes. This strand of activity will intensify when BCU STEAMhouse Phase 2 opens in December 2021 with parts of the CEBE Faculty being relocated there, sharing it with incubation spaces and other established corporate tenants. As REF5a explains, STEAMhouse India will open up new opportunities for international collaboration.

In keeping with one of the missions of our University (the self-styled University *for* Birmingham) in fostering economic growth regionally, nationally and internationally, much of our research is demand-led, entailing interdisciplinary working with industry partners and research users. Accordingly, impact most often arises from the co-creation of research carried out in those partnerships. As described in REF5a, partnership development is supported by the University's Research, Innovation, Enterprise and Employability (RIEE) professional service department, specialists in co-ordinating cross-institutional support for Knowledge Transfer Partnership development and delivery, commercial support for IP, commercialisation and consultancy, and leads on public and community engagement, including events and outreach. Academic staff are thereby assisted with pre-award collaborative funding and the brokering of research-led agreements across local authorities, LEPs, Chambers of Commerce, stakeholder groups and private sector industry partners.

CEBE has the benefit of four dedicated RIEE staff to support impact development: an Impact development support officer, a KTP development officer and two partnership managers, one of whom specialises in the manufacturing sector. In addition to mentoring from experienced staff, expert training in developing impact has been delivered by Saskia Walcott (Walcott Comms) and Professor Mark Reed (University of Newcastle).

Industry liaison has played a key role in the translation of research into real-world solutions.

Our Water Subgroup organised two day-long workshops (2018 and 2019) with regional stakeholders in the Water industry to identify areas for collaboration and impact. The Birmingham office of manufacturing consultancy HSSMI (averaging 6 staff) was hosted by the Engineering Department from 2016 to 2019; as well as a number of student internships and employment opportunities, this led to a successful joint bid with JLR to the Advanced Propulsion Centre for the £10M value Perseus project. The Institute of Technology and Perseus projects (see Section 3) have facilitated industry visits and workshops at strategic regional industrial partners such as JLR, Continental Engineering Services and Bosch Thermotechnology, leading to ongoing exploration of KTP funded projects. A series of visits and joint workshops with the UK's largest magnesium caster, Meridian Lightweighting Technologies, led to the joint publication of a book and the development of an interdisciplinary project with researchers from the School of Computing and Digital Technology, and a £3M automotive lightweighting bid to APC that was shortlisted to interview stage.

Our two selected impact case studies demonstrate the way our approach to impact has translated into reach and relevance.

**Melville's** case study is 'Mobilising the Bio-economy: Transforming waste to energy processes and practices'. Here, research into methods for optimising the anaerobic digestion of organic matter (particularly algae) has been used to design more effective treatments and operating plants by working directly with the multinational Doosan group in Europe, as well as a smaller bio-engineering design company (Kingdom Bioenergy) in India, and with fishing communities (via the Indonesian Seaweed Association) in Indonesia.

The second case study, focusing on work by **Proverbs**, is 'Establishing Property Flood Resilience (PFR) in Flood Risk Management'. Here, research has established new technical insights and revealed the effectiveness and benefits of property flood resilience. As part of a multi-disciplinary team, **Proverbs** provided the main technical input whilst others co-ordinated the co-production (Collingwood Environmental Planning) and provided behavioural (MDA Consultants) and economic expertise (UWE). The project took an action research approach, working with affected communities. The findings have driven Environmental Agency policy, leading to the implementation of resilient technologies in thousands of homes across the UK.

#### Research Integrity

Our research strategy is supported by robust and rigorous processes across the Faculty to ensure our research endeavours and activity are held to the highest standards in terms of compliance with ethical obligations and standards, while ensuring integrity with regard to legal and professional frameworks. CEBE has a well-established ethics committee which stipulates that 'All those engaged with research have a duty to consider how the work they undertake, host or support, impacts on the research community and on wider society' in a way that is ethically secure. All our research projects must receive ethical approval prior to commencement. Integrity is maintained in line with the Concordat on Open Research Data, and receives support from the designated Open Access Officer, as set out in REF5a.

#### Future Strategic aims (2021-2027)

During the current REF period we have built a strong foundation of discipline-based and interdisciplinary research, based on defined sub-groups that have produced outputs of increasing significance and attracted growing numbers of doctoral students. For the next cycle, we intend to build on that foundation as follows:

- Consolidate and continue to grow these groups via recruitment and development of our current emerging researchers (50% increase both in staff with SIGRES (to 24) and PhD students (to 45) and more than 100% increase in PhD completions (to 30).

- Increase the vitality and quality of the research groups' operation and activities by systematically adopting best practice from within the University and the wider sector.
- Be recognised as partners of choice for interdisciplinary projects in Manufacturing (with a growing digital focus), and the evolving Green Economy (with a growing focus on Electrification), and through such projects increasing research income by 100%.
- Increase the reach and significance of our research and impact activities by greater engagement and leadership within BCU STEAMhouse to build multi-disciplinary projects, including with STEAMhouse India (see section 4) for international activities.

## 2. People

### Recruitment

Crucial to the achievements of our five strategic aims was the recruitment activity outlined in Section 1. In this cycle we made five strategic leadership appointments: **Fourlaris** joined us from Swansea University to strengthen research expertise in Advanced Metallic Materials and Structural Integrity, and provide overall research leadership in Engineering; **Krzyzanowski** was recruited from Sheffield University to bring leadership in Advanced Materials Manufacturing research; **Oraifige** joined from the University of Derby to bring his expertise in manufacturing operations and to provide overall academic leadership as Head of the Engineering Centre; **Wu** joined from Staffordshire University to provide leadership in the applications of Sensor technologies; while

**Proverbs** moved from the University of West England to provide leadership to a wide group of researchers in the EBE School working on water-related topics.

Those leadership appointment were complemented by four mid-career appointments: **Hasan** and **Perera** joined us from Northumbria University, bringing their expertise on nano-fluids and providing leadership in the area of Computational Modelling; **Khatir** moved from the University of Leeds, strengthening our CFD expertise as well as bringing extensive experience in industrial collaborations; and **Annaz** joined us from Institut Teknologi Brunei, bringing expertise in Mechatronics. A further five junior researchers joined us during the cycle (**Ioannidou**, **Salami**, **Flynn**, **Gueniat**, and **Kalaitzi**).

With our two existing research professors, **Melville** (engineering solutions for bioresources) and **Ward** (materials, sensor development and physics-based modelling), together with a group of nine emerging researchers mentored by senior colleagues, we now have a robust, balanced team covering all career stages and nurturing a growing group of doctoral students. Because of the volume of recruitment during this REF cycle, team working and thematic coherence within research groups have been prioritised, with an onward impact on industry secondments and sabbaticals. Nevertheless, we remain in a strong position to grow to greater maturity during the next REF cycle.

### Staff development strategy

The primary aims of our staff development strategy are to:

- maintain and expand a vibrant and supportive research community
- make transparent allocation of workload and responsibilities
- support academic staff at each stage of their research careers, including clear progression pathways
- provide the mechanism to support emerging researchers who are already recognised as practitioners/enterprise active to pursue doctoral study and develop practice-based research.



Led by the the UoA Research Directorate and reporting to the EBE Research Committee, this strategy has been operationalized through the Research Group structure that promotes the cross-fertilisation of ideas, via a variety of dissemination mechanisms including hosting biweekly seminars, research group meetings, attendance and active participation in symposia and conferences.

Workshops are organised to support colleagues in peer review activity, practice based research, producing research outputs and applying for career progression. Staff benefit from a two-stage review process for both funding applications and publication submissions: firstly in a peer-to-peer exchange, both receiving and giving advice, and secondly gaining feedback from expert review by senior colleagues and external advisors.

We actively encourage participation of staff at every career stage in all aspects of the Research Groups' activities, promoting an open, transparent and collegiate atmosphere. Where possible, inhibiting hierarchies are diminished by the co-location of group members in our open office accommodation. We provide transparent annual competitions for all researchers to apply for their projects to be awarded Faculty-funded PhD Studentships (typically 10 annually throughout CEBE) and for the Faculty Small Research Equipment scheme (typically £65k per annum). All researchers including PGRs can also apply to our Conferences and Networking Mobility Scheme (typically £20k per annum) for consideration at monthly Research Committee meetings.

Our research culture is maintained by a transparent allocation of research workloads and responsibilities. As outlined in the REF Institutional Code of Practice, all academic staff complete an annual Personal Research Review that is considered by the Research Directorate (all of whom have taken Avoidance of Unconscious Bias training). Judged against University-defined criteria, staff qualifying as having Significant Responsibility for Research (SIGRES) are awarded 0.25FTE, 0.35FTE or 0.5FTE of their time to devote to research activities depending on demonstrated research productivity and career seniority. The total salary cost in 2019/20 of this allowance for the 16 staff with SIGRES was £395,440. Research time allocation is a ring-fenced entitlement recognised through BCU's Workload Allocation Model (WAM) framework. Additional time is allocated to account for PhD supervisions, externally funded research, knowledge exchange projects, pilot project awarding funding, or sabbaticals. This model protects research time as a departmental priority.

Additional support is tailored to the needs of staff at different stages of their research careers, as follows:

**New Staff:** All of the Department's research active academic staff members are involved in recruitment. Newly recruited staff are therefore quickly inducted and aligned in appropriate Research Groups so that they are able to fully participate in the cluster's research culture. All new staff are assigned a mentor through research group support activities, and supported to produce annual professional research development plans. New staff are given priority in the consideration of Faculty-funded PhD studentships and access to the university supervisor training programme.

**Emerging Researchers:** Those who do not have a PhD are mentored by senior research group colleagues to develop a proposal; currently, two staff are undertaking a PhD with their fees being funded by the Faculty and 0.2FTE time allowance. Academic staff with a prior career in industry are mentored to help them build upon their experience and develop a research career, potentially via the PhD by publications route. During the REF cycle, two originally appointed as Assistant Lecturer (a teaching grade) were promoted to Lecturer, primarily on the basis of their research achievement.

**Early Career Researchers** are strongly encouraged to present their work in Research Faculty Seminars and Workshops; they have access to a Research Group based mentoring scheme and are targeted for co-authored outputs and funding applications.

**Mid-Career Researchers /Associate Professor/Research Professors** are supported through bespoke workshops (including for promotion and professorial confirmation application), underpinned by a mutually supportive Faculty-wide mentoring scheme. A number of sub-groups have formed within the established research groups; emerging leaders of each sub-group are coached to succeed the current group leads or develop the sub-group into an independent research group. During the census period, one conferment has been made to Research Professor status.

### Research Students

As noted in Section 1, scaling up our postgraduate community has been a key strategic aim, with a view to developing our intellectual capital, strengthening ties with industry, and nurturing the next generation of Engineering academics from the most diverse backgrounds possible. At the census point in 2014 our doctoral community stood at a mere three students; now it has grown to 31. Then, we declared four completions; in the current cycle, we have had 13. That improvement has been driven by substantial investment. Each year over this cycle, the Faculty has committed £530k to support full bursaries for 20 students, as well as a further 30 fee waivers or part-waivers.

PGR Recruitment is pursued through a variety of channels: publicising opportunities via academic mailing lists, publicity to current UG and Masters students (helped by strong growth of our taught Master's programmes during this period); advertisements in official websites (findaphd.com and jobs.ac.uk) and via industrial partners. Postgraduate research students are recruited nationally and internationally, and are funded through a range of mechanisms including Faculty and University (STEAM) scholarships. Formal applications pass through a review by two academic members of staff to interview by three academics, including one independent of the proposed supervisors.

The PGR lifecycle is managed by the Director of Research Degrees and administratively supported by three Faculty-based research administrators from the University's Doctoral Research College (DRC). All students undergo a University-led induction that then divides into Faculty and School events. All new PGR students undergo formal research training as part of our career development support to them. Within the School, they are required to complete a PGCert in Research Methods which covers generic and engineering specific research skills. Additional generic training is provided via the DRC, which has a wide range of courses related to research and personal development. All PGR students are allocated a supervisory team comprising a first supervisor, one or more second supervisors and in some cases additional external (industrial) advisors. Beyond their supervisory team students attend workshops with, and have regular contact with, the Director of Research Degrees, who is available to them for additional academic and pastoral support. Support is also available from the DRC and from the University's Education Development Service (EDS).

All PGR students are offered opportunities to develop their teaching skills and supplement their income through Visiting Lecturer and Demonstrator schemes. Training is provided through dedicated Teaching for PGRs modules and through training within the School (providing subject specific guidance, for example in running lab sessions).

We view our PGR students as full members of our research community. All doctoral students are provided with a desktop or laptop computer and a desk within the same open office area as the academic staff and leader of their research group. This ensures that they are fully immersed in the workings and culture of their group, and facilitates opportunities for research discussions with fellow students and academic staff further to those that take place in scheduled supervision sessions. Students regularly present their research at the monthly research seminars, and participate in Faculty open days. Funds are made available on a competitive basis for students to attend conferences. Each one of our doctoral students has been funded to attend at least one conference during their studies.

Further support is provided by PGRNet, a University-wide network of PGR students. A student rep from our research cluster is appointed to represent student issues to DRC staff, the Director of Research Strategy and most crucially at Faculty Research Environment and Degrees Committee.

PhD supervisors are required to participate in the Faculty's supervisor development programme before being eligible to supervise. This ranges from attending a supervisor development day, through to undertaking the University's Communities of Practice supervisor training programme, which results in a SEDDA-accredited qualification.

Full-time PGR students submit progress reports at 12 months, 24 months and 30 months, with six-monthly reporting thereafter until completion. At the end of each academic year, FT PGR students undergo a formal assessment for progression, involving a written report, oral presentation and a viva voce examination by two independent assessors. Students who have difficulty at this stage are proactively supported in developing and delivering a research and study plan, overseen by the Director of Studies and the DRC. Arrangements for part-time students are similar but with appropriately longer timeframes. PRES results over successive years indicate strong levels of satisfaction with our various arrangements for supporting doctoral students.

#### Equality, Diversity and Inclusion (EDI)

The School has a strong commitment to equality, diversity, and inclusion and is in full compliance with established EDI principles. The University's EDI Committee was set up to establish good practice across all Faculties. For CEBE, it is chaired by the Associate Dean for Student Learning Experience & Academic Quality, and has representatives from all staff and student levels. The group meets monthly and leads on initiatives to address diversity issues locally and in the sector. The Faculty supports and implements EDI policies in Employment Policy, Trans Policy, the Equal Opportunities Policy, Maternity, Paternity, and Adoption Leaves for all staff, whether research or teaching focused. Alongside the EDI committee, School staff are encouraged and supported to engage with groups within the University such as the Black, Asian and Minority Ethnic (BAME) Steering group, the Disabled Steering group, the Mental Health and Well-being Network, and the LGBT+ Staff Network.

In line with BCU's code of practice, all engineering academic staff may apply for SIGRES status, including WAM remission and resources to pursue a research career. Applications are assessed by colleagues who have undertaken Advance-HE EDI training (including Avoidance of Unconscious Bias). As noted above, the same training is provided to our internal REF peer-review panels, which include a balance of senior (professorial and reader level) and junior researchers, aiming for gender and ethnicity inclusion wherever possible.

Among Cat-A staff in CEBE, 40% have identified as BAME, higher than the BCU average of around 25%; while 5.6% have declared a disability, which is close to the BCU average of 5.2%. Meanwhile 76% of Cat-A CEBE staff are male compared to the BCU average of 48%.

Gender equality is a particular issue in the discipline of engineering which, especially in the manufacturing related domains, is very male-dominated. We make significant efforts to redress the balance. BCU was awarded Athena SWAN Bronze Institutional award in recognition of its commitment to advancing gender equality through a four-year Action Plan (2016-2020). As a Faculty, CEBE is currently applying for a departmental Athena SWAN award. The School has encouraged and supported our female academics to participate in women leadership development programme such as the Aurora Leadership Program funded by Higher Education Academy. We also seek to ensure that our internal processes and culture are conducive to creating an environment in which women engineers can prosper and reach senior positions. We require that gender diversity issues are explicitly considered at all appointment and promotion panels, while flexible and part-time working is supported for parental/caring responsibilities. BCU's Programme for Women Achieving Excellence in Research (PoWER) provides a series of monthly sessions aiming to inspire and support female academics, building their skills, knowledge and confidence to increase research capacity and capability.



Out of our 16 staff submitted to REF, four are women: two professors (**Melville** and **Wu**) and two Lecturers (**Ioannidou** and **Kalaitzi**). Other female staff hold related senior academic leadership roles: Professor Hanifa Shah is the Pro-Vice-Chancellor & Executive Dean for CEBE, while Laura Leyland is Head of the Department of Engineering.

### 3. Income, infrastructure and facilities:

#### Strategies for research income generation

As noted in Section 1, our strategies for research and impact are intrinsically linked to the preponderance of our research that is co-created with industry and end-users. The same link is reflected in our funding and income generation methods. The Research Groups provide centres of disciplinary excellence, whilst our defined Impact Areas help interdisciplinary teams to coalesce to address industrial and societal issues.

#### Impact Areas

CEBE has developed three cross-Faculty Impact Areas: Digital Productivity in Manufacturing and Construction; Smart Cities and Sustainable Environments; and Smart Health. Our research cluster has provided leadership in the first two of those areas. Each Impact Area has at least two co-directors from across the Faculty, a designated business development support manager from the University's RIEE Service, and an impact representative from each research group in the Faculty. Each Impact Area has a responsibility to:

- Establish a strategy for funding and impact in the innovation area based on research groups' expertise
- Carry out business development activities, engaging especially with regional, organisations such as West Midlands Combined Authority, Birmingham City Council, Birmingham and Black Country LEPs and Chambers of Commerce, Engineering Employers Federation, Jaguar Land Rover, Rolls Royce, JCB.
- Create and maintain a pipeline of funded projects
- Monitor and run innovation projects.

This Research and Impact Strategy relies and delivers applied research close to market needs and that of the industrial sector, as typified by the capture of Innovate UK grants and especially KTPs. Four KTP projects with a cumulative £587k of value to BCU were started and completed during the REF cycle. The partner companies enjoyed, as a result, improved products, processes and profitability. The four projects were as follows:

- Brandauer, 2014 to 2015, KEEN grant funding of £21000; then 2016 to 2018, KTP grant funding of £172,033, to develop new press tool concepts through the application of advanced materials and design processes (**Ward** and **Krzyzanowski**)
- Surface Transforms, 2015-2016, grant funding of £59,543 to explore innovative solutions that reduce automotive and aerospace ceramic disc wear rates through benchmarking of existing designs, advanced material modelling and onboard wear sensing. (Adrian Cole and Hossein Saidpour, who have since left BCU)
- Nicklin, 2015 to 2016, grant funding of £152,235 to develop and implement new innovative optimal transit package design service. (Hossein Saidpour and Craig Chapman, who have since left BCU)

- Wilmot Limited, 2019 to 2020, grant funding of £203,249 to design, develop and exploit advanced low-cost sensor and control systems for enhanced safety and efficiency of remote controlled mobile lifting and handling equipment (**Ward** and **Oraifige**).

As well as supporting these small to medium sized companies, our cluster has also engaged with major regional Engineering companies, as follows:

- Advanced Propulsion Centre funded Perseus – Jaguar Land Rover (JLR) EDU Manufacture –2017 to 2020; project value £10,000,000, grant to BCU of £199,989. Alongside colleagues from the School of Computing and Digital Technology, **Oraifige**, **Gueniat** and **Krzyzanowski** are working with JLR and their machine tool suppliers (JW Froelich, Fives, Mapal and Horizon Instruments) and manufacturing consultants (MTC and HSSMI) on the Perseus project on methods to support the transition to Electric Drive Units for JLR and their supply chain.
- Innovate UK (ref 102583) funded INSIGHT - Connected Autonomous Vehicles, 2016 to 2019; project value £2,209,554, with grant to BCU of £387,539. Partnering with Westfield Sportscars, Fusion Processing, Conigital and Heathrow Enterprises to develop and assess the operation of existing autonomous vehicles for safe, slow speed operation on pedestrian areas and pavements. (**Ward**)
- Rolls Royce grant of £42,171 to support PhD Studentship, 2016 to 2019, in advanced cost models for application in composite aero-engine components (Craig Chapman, as above).

Engagement in these projects, with both small and large companies, serves to inform the Research Groups of the key strategic needs in manufacturing related industry, and thus to fertilise topics and priorities in their research agendas, not least by directing the choice and definition of projects offered for PhD recruitment.

Some of the above projects, especially Perseus, contribute to low carbon research, where we have been awarded further funding to support our sustainability agenda:

- EU Horizon 2020 (ref 765921) IOT4WIN (Internet of Things for Water Innovation Networks); project value £638,427, with a grant to BCU of £458,152, to study smart sensing and trusted communication with energy limited heterogeneous devices in IoT enabled urban water environments. (**Wu**)
- EU Interreg North West Europe Alg-AD; project value £4,443,234, grant to BCU of £268,888, 2017 to 2021, working with nine partners to develop new technology that can take excess waste nutrients produced from anaerobic digestion of food and farm waste to cultivate algal biomass for animal feed and other products of value (**Melville**)
- British Council/Newton Fund MacroBio – Evaluating the Valorisation of Macroalgae Biomass in Indonesia project, 2019-2020; project value £111,448, with BCU grant of £62,919 23 (**Melville**)
- The Coal Authority - total project value and grant value to BCU of £106,490, 2019 to 2020; Lynemouth Mine Lagoon Hydraulic Modelling, (**Ioannidou** and **Fourlaris**)
- Another notable award is from the Diamond Light Source (UK's national synchrotron facility); funding for 2 PhD Studentships from total project value £198,000, with grant to BCU of £87,184, (2014 to 2017); Optimisation of Monochromator crystal configuration for next generation Synchrotron Energies; and (2020 to 2023) Time resolved experimentation with acoustically levitated and manipulated samples (**Ward**).

Overall income earned by our UoA during this REF cycle amounts to £1.54m, while the amount of grant capture is £2.4m, however the scale of the projects involved is better indicated by the total value of more than £18m.

#### Facilities

Those funded projects and the many related PhD projects ongoing in our cluster are supported by excellent Engineering research facilities in the Millennium Point building. In 2016, a University-funded £6.5 million re-furbishment provided a new maker area, engineering labs, and sundry additional equipment. We have two fully commissioned Engine test cells with associated ventilation and safety features, equipped with 340 kW fully transient dynamometer, exhaust gas analysis both pre and post after treatment system including Signal Group Analysers in 3 racks with heated sample systems, Sierra BG-3 particulate mini-tunnel and AVL 415S smoke meter.

The Environmental Lab, home to the Bioresource and Bioeconomy research sub group, is divided into three main areas: a wet lab/pilot facility, a fully equipped analytical suite, and a microbiological lab offering state of the art analysis and testing of environmental samples, as well as scientific evaluation of lab scale and pilot scale technologies and processes. Facilities include a 600 litre photobioreactor and an analytical suite for measuring a range of physical, organic and inorganic parameters and featuring x-ray fluorescence, GCMS, calorimetry, spectrophotometer and microscopy technologies.

Metal machining facilities have benefitted from £420,000 invested in seven new machines from XYZ Machine Tools. There is a state of the art scanning electron microscope. There is also a MakerSpace equipped with a laser cutter, 3D printers, and a variety of electronic components such as motion, proximity, and humidity sensors. Further labs provide access to PCB and solder facilities as well as electronic equipment for signal measurement and analysis.

Our Engineering design facilities are supported by global technology providers such as PTC and Technosoft. They provide access, for research purposes, to computer aided design, product lifecycle management and knowledge-based engineering software. Cross-Faculty initiatives with Computing have led to the establishment of high-performance computing facilities (with an associated Faculty investment in excess of £100k), dedicated to computational research both for UoA11 and UoA12.

In 2020 our partnership in the establishment of the Department of Education funded Greater Birmingham & Solihull Institute of Technology (with associated funding in excess of £1.1m for capital equipment) has led to the commissioning of state of the art research facilities on additive manufacturing, so allowing 3D printing of a variety of complex alloys (£312K) and upgrades for our engine test cells to accommodate testing of electric drivetrains (£500K). The remainder of the funds are to be spent on a range of equipment including a metallurgical microscope, a machine tool heat shrink cooling system, a split zone furnace, and PCB machinery including a Pick and place/Reflow oven and a 3D scanner. The Institute of Technology is a major collaborative undertaking between ourselves, Aston University, Solihull College and University Centre, Bosch Thermotechnology, Salts Healthcare, Continental Engineering Services, Hydraforce, Malthouse Engineering, and Alucast.

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

We have actively implemented a number of policies and mechanisms that facilitate the development and success of research collaborations, networks and partnerships, for the greater good of our discipline and its multiple economic and social impacts:

- Dedicated partnership and engagement managers within RIEE who provide intelligence and support engagement with research partners on a regional, national, EU and now with a wider international emphasis.
- Organisation of workshops and industrial visits with industry and other stakeholders in research group interest areas
- Regular opportunities for faculty funding for conferences, and international study and field visits.

Our growing research culture has brought about a large number of collaborative research projects with national and international reach. 87% of the research projects cited here involve national collaborations, while 13% involve at least one international collaborator.

#### Collaboration and Manufacturing

As noted in Section 1, a core feature of our mission is to support the manufacturing sector. To that effect we have formed research collaborations with companies in all areas of manufacturing supply chains. Our partners have included Rolls Royce, Jaguar Land Rover, JW Froehlich, Fives Landis, Mapal, Horizon Instruments, Manufacturing Technology Centre (MTC), HSSMI, Brandeur, Surface Transforms, Nicklin Transit Packaging, Wilmat Limited, Westfield Sportscars, Fusion Processing, Conigital. Major projects of this nature are described in Section 3.

Manufacturing-based partnerships have been formed via the work of **Krzyzanowski** with Sheffield Forgemasters and the Universities of Sheffield, Birmingham, Manchester, AGH University of Science and Technology, Cracow, Poland and University of Technology of Troyes, France.

As noted in Section 1, STEAMhouse India, based in Ludhiana, will be a major focus for future collaborative work in the international sphere. The University has established a BCU India Group to co-ordinate links with this increasingly important economy. One of its earliest outcomes is a strong relationship since 2019 with the Hero Group, the world's largest (by volume) manufacturers of bicycles and motorcycles. STEAMhouse India will be located close to Hero's manufacturing base and will draw on research and innovation expertise from our cluster to support their supply chain and the wider manufacturing sector in their region. To support future research at this Institute this UoA has developed collaborations with several universities in the same region, including the Indian Institute of Technology Ropar, Panjab University, Lovely Professional University and Chandigarh University.

#### Collaboration and Low Carbon

Support for projects that pursue sustainability and low carbon is key to our mission. Here we collaborate with a multitude of organisations enjoying extensive international reach. Major projects of this nature are described in Section 3. Here we list many of the companies and organisations who have served as project partners:

**Melville** has been collaborating with Swansea University, University of Ghent and the Karlsruhe Institute of Technology since 2011 through the EU's Interreg IVB's Strategic Initiatives Programmes initially in the Energetic Algae (EnAlgae) project, which combined the expertise and resources of 19 partners in seven countries. In the current ALG-AD project there are 7 further partners: Langage AD, INNOLAB, Association des Chambres d'Agriculture de l'Arc Atlantique, Université de Bretagne Occidentale, Le Centre National de la Recherche Scientifique, Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail, and Cooperl arc Atlantique. As presented in her impact case study, Melville has also had fruitful collaborations with South Korean conglomerate Doosan, small UK company Kingdom Bioenergy working in India, and through the MacroBio project with the Indonesian Seaweed Association and Brawijaya University in Indonesia. Supported by QR GCRF funding in 2018-19, Melville has led a team of emerging researchers to support the sustainable redevelopment of a village in rural South Africa that had been recently devastated by wildfire; partners included Fruitful Futures, Heritage Western Cape, and the Universities of Cape Town and Stellenbosch. Again initially supported by QR GCRF and then by British Council/Indian Department of Science and Technology and internal PhD studentship funding, **Melville** and **Gueniat** are working with BCU Computing researchers and Panjab University to develop smart village microgrids in India, based on the integration of solar powered agricultural irrigation pumps.



**Wu**, with EU Horizon 2020 funding, is working with partners such as the UK-based United Utilities, the Greek and Romanian technology firm, Singular Logic, and Spanish ICT and water consultancy company Aqua-Consult Ingenieros, to study the use of smart sensors to improve the efficiency of water systems. **Wu** also has an established international network in the domain of smart water systems with Dalian University of Technology, China, the University of Toronto, the Norwegian University of Science and Technology, and the Indian Central Scientific Instruments Organisation. The network promotes study visits, joint bids and publications.

**Proverbs** has an extensive network in the domain of property-based resilience to flooding. As discussed in the impact case study, partners in the UK are DEFRA, RICS, UWE and Sedgwick Repair Solutions; in Brazil with the Santa Catarina Civil Defence Department; in Nigeria with Ibadan University with Professor Oladukon visiting BCU as a Commonwealth Academic Fellow. In Peru, funded through the British Council Newton Fund Researcher Links programme, **Proverbs** has collaborated with the Instituto Geofísico del Perú (IGP), the Universidad de Puria, and the Governor of the Piura Region, with the aim of improving the country's resilience to flooding.

**Ioannidou** and **Fourlaris** have established, soon after their appointment at BCU, new funding streams with The Coal Authority via their Industrial funded research project on 'Assessing the Hydraulic performance of mine discharge lagoons'. Such innovative collaborative work expands the funding basis and extends the research skills BCU engineering has to offer to a variety of Water Quality key stakeholders, such as BAUER Wetland Competence Centre (Oman), The Coal Authority, RSPB, Constructed Wetland Association, Wyre River Trust, Environment Agency, CIWEM, Syngenta, Thames 21. In addition, **Fourlaris** has an established long term partnership with key UK manufacturing businesses such as Tatasteel UK, Warwick Automotive Group, as well as the leader in electrical steel production in the UK, Cogent, mapping to UK leadership on electric car developments.

#### Contribution to the discipline

Five academic staff members act as international peer reviewers for EU grant proposals, while two professors have visiting professor appointments with overseas universities. In the REF census period, the School has hosted five International workshops, while six members of academic staff have delivered keynote presentations in International Congresses. All 16 academic staff members are reviewers in peer reviewed, high impact factor journals, while four members of staff act as members on advisory bodies.

**Krzyzanowski** has acted as member of 5 Scientific Committees/and organising Committees, in UK (OXI2018), Japan (Metal Forming 2018), Spain (Metal Forming 2016) and Greece (EUROMAT 2017). He is a member of the Editorial Board of Metals and a Visiting Professor at AGH University of Science and Technology, Cracow, Poland. **Melville** has been commissioned for and delivered four Technical Reports for Doosan (2016-17) and has acted as Expert Reviewer for Research England - 2019 including E3 Expanding Excellence in England (2019-2022). **Wu** has acted as a reviewer for the external selection board for professorship at NTNU Norway; for the external scientific evaluation committee for Research Promotion Foundation Cyprus; been Guest Editor for the IEEE Journal Special Issue on Advanced Internet of Things for Smart Cyber-Physical Infrastructure System, and for the International Journal of Applied Science; and served as workshop chair on Internet of Things and Big Data for Healthcare 2018 in conjunction with 16th IEEE International Conference on SmartCity.

**Fourlaris** is Visiting Professor at University of Oviedo, Spain, delivering summer courses in 2014 and 2016, on Electron Microscopical Characterisation Techniques in Metallic Materials'. He was honoured with the Microbeam Analysis Society of America Distinguished Scholar Award (awarded to PhD supervised work) for his work on High Strength Low Alloy Steels. Currently external examiner for the MSc in Advanced Materials, University of Limerick, Ireland, he served as Session Chair for the EUROMAT 2017 International Congress. **Perera** was Co-Chair of the

2nd International Research Conference on Sustainable Energy, Engineering, Materials and Environment at Polytechnic School of Mieres, University of Oviedo, Spain (2018) and an invited speaker and mentor for the Newton Fund Research Links Workshop 2018, Nairobi, Kenya.

**Hasan**, a member of the International Advisory Council of Ahsanullah University of Science and Technology in Dhaka, Bangladesh, has served as Editorial Board Member for the International Journal of Engineering Materials and Manufacture, Environmental Science and Pollution Research, and the Korean Society of Manufacturing Technology Engineers.

**Proverbs** is Editor of the International Journal of Building Pathology and Adaptation, a Trustee to the RICS Research Trust and a member of the Environment Agency's Regional Flood and Coast Committee. He was Chair of the 7th International Conference on Flood and Urban Water Management 2020. He is Visiting Professor at Santa Catarina State University (UDESC), Sao Paulo, Brazil, the University of the West of England and Xiamen University of Technology, China. **Khatir** is a Visiting Research Fellow, School of Mechanical Engineering, University of Leeds. In 2019 he was Guest Editor for Special Issue "CFD-enabled Design Optimisation of Industrial Flows: Theory and Practice" of International Journal of Computational Fluid Dynamics. He was Organiser and Chair of the Mini-Symposium in CFD-based Optimisation Methods as part of the ECCOMAS ECCM-ECFD 2018 International Conference, Glasgow; member of the Scientific Committee for the Sustainable Thermal Energy Management (SusTEM2015) International Conference, Newcastle; and member of the Organizing Committee for 9th CUTSE Conference 2014, Sarawak, Malaysia. He has reviewed grants for EPSRC, Leverhulme Trust and National Geographic. **Ioannidou** has been an invited speaker for The Coal Authority, Mansfield, UK, 2019 (Highlighting the merits of tracer analysis in mining lagoons), and a UK Workshop on Science and Innovation for Catchment Management, 2019, University of Warwick.