

Institution: University of Portsmouth
Unit of Assessment: 12 - Engineering
<p>1 Unit context and structure, research and impact strategy</p> <p>1.1 Unit context and structure</p> <p>Engineering research in the Faculty of Technology (FoT) at the University of Portsmouth is a vibrant and diverse landscape united by a common strategic aim: to develop and apply fundamental engineering principles to key societal challenges.</p> <p>This submission includes 42.2 FTEs, compared to 18 FTEs in REF2014. It encompasses the School of Mechanical and Design Engineering (SMDE), the School of Civil Engineering and Surveying (SCES), and the School of Energy and Electronic Engineering (SEEE). The Faculty's Associate Dean of Research (ADR) provides overall leadership, working closely with the Associate Heads of Research and Innovation at the school level and the Research Leads responsible for each research group included in this UoA.</p> <p>We have grown from four research groups in REF2014 to nine currently. These groups reflect our historic expertise across vital engineering disciplines and targeted investment in areas where we have substantially grown our critical mass and capability. Our approach aligns explicitly with three of the five university-wide strategic research themes (REF5a paragraph 9): Future and Emerging Technologies (FET), Health and Wellbeing (HW), and Sustainability and the Environment (SUSENV). Our research activity addresses the societal challenges underpinning these themes, and our groups operate in an environment directly enhanced by their support. Staff work freely between groups, and leaders understand how their groups' work aligns with the university themes' objectives.</p> <p>Research groups:</p> <p><i>(FTEs include affiliated staff either not returned in this submission or returned in another UoA.)</i></p> <p>Advanced Polymers and Composites (8 FTE): focuses on exploiting natural composites to develop sustainable solutions for marine, aeronautical and construction sectors. The research covers the design, formulation, manufacture and optimisation of composite materials. Projects include working with partners across Europe to develop innovative, low cost, flax-fibre reinforcements to produce sustainable, lightweight composites, and the development and production of novel biobased thermoplastic composite materials with analytical protocols to evaluate long-term durability and minimise ecological impacts on the marine environment (Dhakal and Zhang). <i>(University Research Themes: FET, SUSENV)</i></p> <p>Building Information Modelling (BIM) and Building Performance (2 FTE): focuses on the gap between design intent and the in-use performance of buildings, and how technological approaches can help bridge that gap. Projects include working with architects to understand the</p>

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role of occupant preferences and the impact of adaptive comfort theories. This work has informed government guidance for school construction (Building Bulletin 101) (**Gaterell**). (*University Research Themes: FET, SUSENV*)

Biomedical Engineering (12 FTE): focuses on improving clinical care through four specific areas: musculoskeletal biomechanics, cardiovascular engineering, biomedical devices, and image processing. Projects include the development of a smart walking stick with partners in Malaysia, a smart system of sleep-apnoea assessment with colleagues in Vietnam (**Lee, Pani** and **Bucchi**), and work with partners in Uganda and Jordan to develop a new body-powered prosthesis optimised for adoption in lower- and middle-income countries (**Kyberd**). (*University Research Themes: HW, FET*)

Energy and Electronic Engineering (10 FTE): aims to minimise the use and impacts of energy consumption, encompassing electrical power systems, renewable energy, control systems, robotics, autonomous systems, intelligent systems and signal processing. Projects include working with partners in India to develop a control scheme for nuclear power plants that allows control systems to operate under fault conditions without the potential for catastrophic system failures, and facilitating the large-scale deployment of solar electricity/heat generation in Europe (**Becerra** and **Radulovic**). (*University Research Themes: FET, SUSENV*)

Environmental Technology and Management (8 FTE): focuses on improving our understanding of the fate and behaviour of various pollutants in the water environment. Projects include large-scale trials of wastewater technology and environmental monitoring of sustainable drainage systems in collaboration with Southern Water, and an evaluation of novel phosphorous-removal techniques with partners in Thailand (**Williams**). (*University Research Themes: FET, SUSENV*)

Innovative Industrial Research (IIR) (2 FTE): focuses on using artificial intelligence (AI) and machine learning (ML) to support industrial partners to improve their products and services. Projects include working directly with industrial partners to develop a patented, predictive monitoring system for marine engines which allows vessels to minimise downtime and reduce costs, and developing an automated tool to monitor rail disruption, predict its impact and produce optimal plans to resolve any delays, with substantial potential benefits for passengers and freight (**Smart** and **Ma**). (*University Research Theme: FET*)

Material Design and Characterisation (6 FTE): this newly-formed group focuses on materials design and process structure property relationships during advanced manufacturing and thermomechanical processing of metals and alloys. The group already collaborates with ten national and international universities to conduct experimental works (**Birosca**), and will be developing its profile over the coming REF period. (*University Research Themes: FET, SUSENV*)

Materials, Structures and Geotechnics (5 FTE): focuses on applying structural mechanics to develop novel materials to protect and preserve existing structures. Examples include collaboration with the Mary Rose Trust to monitor, model and manage the ship's movement while drying (**Begg**), and collaborative development and application of digital image correlation

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techniques with BAE Systems to passively monitor the structural integrity of ageing jetties (**Chen**). (*University Research Theme: FET*)

System Engineering (3 FTE): award-winning research focusing on assistive technology to improve mobility. Projects include using AI to share control of a powered wheelchair between a wheelchair user and an intelligent sensor system to ensure safe navigation and personalised assistance (**Sanders**). (*University Research Themes: FET, HW*)

1.2 Research Aim and Objectives: past and present

Our REF2014 submission set out one headline aim: **increase the volume and diversity of external research income.**

We have succeeded at this aim, increasing our research income by 462% over the census period and broadened the diversity of our funding sources by almost 40%.

In meeting this objective, we sought to increase staff engagement with research, raising the number of staff acting as PIs by 386% (from 7 to 27). We also supported and encouraged staff to develop international collaborations and tap into funding sources outside of the UK (e.g. Cartier, Biotrics and Stork).

In addition, we sought direct funding from industry (a 372% increase) and included them in collaborations with other funders (a 19% increase). We have undertaken a substantial number of collaborations with industrial partners (ranging from small/medium enterprises to multinational companies) in over 60 projects. One example is our strategic partnership with Southern Water, worth over £1.5M.

We delivered this aim through two objectives: **to establish new research groups, and to grow our existing ones.**

Our success at both these objectives was made possible through considerable investment in people, infrastructure and facilities that actively promoted collaboration, providing a stable, sustainable basis for research growth.

In relation to **establishing new groups**, we recognised the need for research leadership in a key societal challenge area - energy - and appointed **Becerra** to address this. Research in this area has since expanded to cover a broad range of activities, from the installation and evaluation of solar electric / heat-generation technologies to control systems for power stations. During this REF cycle, **Becerra's** group has led or collaborated on projects with a total value of over £11M, including those funded by EPSRC (£1.1M) and the European Union (£10M).

Similarly, the Faculty's £250k investment in infrastructure in **new capacity** through a redeveloped Environmental Technology Field Station (ETFS) led to a major collaboration with Southern Water worth over £1.5M, extending to 2025. In such a technically conservative industry, data derived from pilot-plant and full-scale trials are essential. Work undertaken at the ETFS meets this need, providing data with the potential to put this UoA at the forefront of the

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next generation of water and wastewater treatment technologies, and is the focus of one of our impact case studies (REF3 UoA12 Wastewater).

In terms of **growing existing groups**, our UoA strategy identified the potential for **interdisciplinary research in biomechanical and biomedical engineering**, which informed the joint investment in the Zeiss Global Centre (ZGC), as detailed in Section 3. The resulting state-of-the-art facilities host collaborations with a broad range of partners from various disciplinary backgrounds. These include clinicians from Portsmouth Hospitals University NHS Trust, the National Heart and Lung Institute, Royal Brompton & Harefield NHS Foundation Trust (**Anssari-Benam, Bucchi**), and the Royal National Orthopaedic Hospital (**Tozzi**) (REF5a para 16). Consequently, the group has grown from eight members in the REF2014 submission to 12 FTE, and its members have secured over £800k in external funding (EPSRC, £160k; Leverhulme, £34k; Royal Society, £30k; and industrial funding, £600k).

Our strategy also prompted us to develop our existing capacity in polymers and composites, combining our experimental and numerical approaches. To this end, we invested in employing researchers (**Barouni, Safuillah, Giasin**), developing infrastructure (such as the impact test and nano-indentation equipment), and leveraging investments made in the ZGC. Our aim was to provide a single entity to inform the design and manufacturability of polymers and composites by numerically-driven optimisation. Our investments have seen the group play a major role in collaborative European research projects, with an overall budget of £8.5M.

In addition, our UoA staff benefit from Faculty processes and support mechanisms that recognise and reward research activity, as outlined in Section 2. This combination of investments and support processes was instrumental in facilitating growth over this cycle.

1.3 Future strategic aims and goals for research and impact (2020-2025)

Our strategic objectives for engineering research and innovation build on the current period's growth and the maturation of our interdisciplinary themes. Our headline aim for this UoA is to continue **increasing the volume and diversity of external research income**.

To do this, we will broaden the potential funding streams we target and increase support and incentives for our staff to submit high-quality, internally peer-reviewed funding applications. Given how the UoA has matured over this REF period, we will achieve our aim through specific objectives that reflect a more nuanced approach than in REF2014.

Our specific objectives across the UoA are:

- To establish a **regional hub** for our existing network of small and medium-sized enterprises (SMEs) and academic partners to develop and test sustainable, biobased composites. We will base this on the continued expansion of our international collaborations and partnerships and our advanced manufacturing techniques.
- To establish a **centre of excellence for biomedical engineering**, focusing on health technology for surgical interventions, improving musculoskeletal health in older people, and cardiovascular engineering research.

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- To establish a **centre of excellence for monitoring the fate and behaviour of environmental microplastics** by utilising and building on our emerging work in this field, our state-of-the-art facilities, and our international links and networks of newly appointed staff.
- **To accelerate the growth** of condition monitoring, signal processing, control engineering and robotic-systems research and increase our responsiveness to external demand, connectivity with local industry, government and military organisations, and to other schools within the university. We aim to do this by appointing two new full-time staff in 2021-2026, including one at professorial level.
- **To establish a critical mass** for building-performance and building information modelling (BIM) research, focusing on applying advanced visualisation and modelling techniques to understand the interaction between the design and in-use performance of buildings. We will maximise the use of existing facilities within the university (e.g. the test house and associated monitoring equipment), and develop a local research base through our established MSc programme.

1.4 Supporting the sustainability of the research environment: impact, interdisciplinarity, open access and integrity

We support the sustainability of our unit's research environment by investing in services and roles at the university, faculty, school and research-group level.

Facilitating impact: This UoA addresses societal challenges through collaboration. It delivers economic, environmental and health-related impacts to beneficiaries that include industry, government agencies and wider society, as exemplified by the impact case studies included in our submission (REF3), which look at industrial applications of AI, bio-implants, and novel wastewater treatment. Successfully realising impact requires sustained identification, development and delivery of opportunities. To ensure the necessary environment, impact-facilitation support for UoA staff is both top-down and bottom-up.

Our top-down approach flows through the Faculty's Innovation and Impact Development Manager (**Hutchinson**), who champions impact through the University Impact Working Group and the Faculty Research and Innovation Committee (FRIC).

Our UoA staff actively engage with central training activities hosted by the university's Research Impact Manager (**Summers**) (REF5a para 57). Additional activities are run at faculty, school, and research-group level and draw upon centrally-provided impact resources (e.g. toolkits, exemplars and guidance notes).

Our bottom-up approach ensures our UoA staff understand and embrace responsibility for delivering impact as a crucial part of their role. Our Faculty peer-review process (FPRP) explicitly helps staff identify opportunities to develop and deliver impact from their research activities. The peer-review process takes a 'critical friend' approach, whereby the reviewers support colleagues to develop their proposals. All Faculty research proposals are subject to this process, ensuring active consideration of their impact from the start.

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The Faculty also makes staff aware of available impact-related resources, such as external training, seminars and grants to support impact development through school-level staff meetings, research group meetings and the FRIC.

Promoting interdisciplinary research: Interdisciplinarity is a central tenet of the UoA philosophy to translate research on fundamental principles into outcomes that address societal challenges. We actively encourage UoA staff to develop collaborative projects in conjunction with other disciplines, not least through the faculty peer review process.

The UoA has leveraged university theme funding and the support of theme Research Development Officers (REF5a para 12) to build new interdisciplinary capacity and support the development of less experienced researchers to win more substantial external funds. UoA staff successes in theme funding schemes include a project with the Faculty of Creative and Cultural Industries on developing resilient coastal cities (£22k) and with the Faculty of Business and Law on the impacts of climate change on polluted lagoons in Africa (£22k).

Engineering staff also collaborate with staff from other UoAs across the Faculty. Examples include collaborations with UoA10 (Mathematics) on applying AI to enhance traceability challenges and food authenticity in food supply chains (£9k), with UoA11 (Computer Science and Informatics) on noise management in intensive care units (£9k), and with UoA3 (Allied Health Professions) on characterising the mechanical response of cardio-pulmonary soft tissue (£12k).

In the last two years alone, UoA12 secured nine successful applications, attracting £102k of internal funding to support new research and capability in priority areas. Moreover, our Research Development Officers helped researchers establish new industrial contacts (e.g. £500k Innovate UK award for Smart and Sirius Insights) and prepare bids (£1.8M UKRI Industrial Challenge Fund - awarded and in negotiation (*Simandjuntak*)).

Open research environment: Our UoA has exceeded Research England's target of 95% compliance with open access. The vast majority of our outputs followed a 'green route' to open access. Where this was not possible, we dedicated funds to accelerate open access via a 'gold route'. We ensure open access requirements are met by responding promptly to a monthly report from the university research outputs team on published articles that need to be uploaded to the institutional repository (Pure). In accordance with the Concordat on Open Research Data and the UKRI Common Principles on Data Policy, we have also instituted a Research Data Management Policy to make research data publicly available (REF5a para 24).

Compliance of our outputs with Research Data Management requirements has grown from 59% in 2018 to 65% in 2020 against a nominal university target of 40%. Also, the percentage of outputs that (potentially) have shareable data that have been assessed as compliant has grown from 49% in 2018 to 60% in 2020.

Research integrity and ethics: Our UoA ensures research is conducted with integrity and according to appropriate ethical, legal and professional frameworks, obligations and standards. It draws on our dedicated Faculty of Technology Collaboration Manager (REF5a para 57), who advises on working with industry, due diligence and the necessary steps to establish contracts

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and manage intellectual property. Our centrally provided training familiarises all staff with procedures for handling research misconduct (REF5a paras 22, 23).

Several research activities across the UoA require detailed ethical consideration, including interacting with human tissue, developing interventions for critical infrastructure (wastewater systems, power stations etc.), collaborating with people with physical impairments, and dealing with commercially sensitive information. Consequently, the UoA takes its responsibility for adherence to strict ethical standards extremely seriously. As per the university's commitments under the Concordat to Support Research Integrity (REF5a para 22), all UoA research (externally/internally funded and unfunded) is reviewed by the Faculty Ethics Committee (FEthC).

The Faculty's FEthC comprises two staff members from each school, the ADR, Associate Dean of Students, university ethics representative and other staff with specialist knowledge, as required. It meets quarterly to consider issues of ethics policy and procedure and reports three times a year to the University Ethics Committee. All Faculty staff developing research proposals are required to complete an online form outlining their project, which is reviewed by three members of the FEthC.

This 'critical friend' process provides constructive feedback to ensure all potential ethical issues receive due consideration. We undertook 110 ethical reviews in the REF2021 period. Of these, 36 received immediate approval and 62 were approved after FEthC recommendations were taken into account. A further seven were either withdrawn before a final decision, are still pending, or were referred to other reviewing bodies.

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2 People

The changing profile of staff submitted in this UoA over the census period reflects our commitment to the development of research activity and our success in growing our research base (Table 1).

Table 1. Profile of submitted staff (headcount)

REF Period	Professor	Reader	Senior Lecturer	Lecturer	Research Fellow	Total
REF 2014	1	1	4	8	4	18
REF 2021	9	4	18	7	5	43

2.1 Staffing Strategy

Our staffing strategy in this UoA, which reflects the University Strategy (REF5a para 1), is to:

1. Recruit staff who can undertake both research and teaching
2. Recruit staff who share our goal to address societal challenges by applying fundamental engineering principles to real-world problems
3. Appoint staff at an early career stage into more mature research and teaching environments, so that they can receive the necessary support
4. Increase appointments at senior levels (e.g. reader/professor) to grow specific areas of research
5. Proactively support the development of all staff through the faculty's 'PhD-to-Professor' programme
6. Reward and incentivise performance through academic promotion and workload allocation
7. Maintain links with departing staff whose research remains relevant to our UoA.

2.2 Recruitment

Taking this strategic framework into account, we base our appointment of new staff members on a range of needs at the faculty, school and group level.

We recruit academics to expand and complement our existing expertise, and to bring leadership where it is required. Our strategic leadership appointments during this REF period include **Lee** (biomedical engineering), **Birosca** (physical metallurgy, advanced manufacturing), **Kyberd** (exo-prosthetics, robotics), **Becerra** (energy engineering), and **Gaterell** (building design and sustainability). Our junior appointments to boost critical mass and capacity in existing research

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areas include **Ma** (AI), **Giasin**, **Safuillah** and **Barouni** (natural fibre reinforced composite materials), **Zekonyte** (surface treatment), **Petkov** (biomedical devices), **Pani** (multi-scale modelling and meshless methods), **Khanna** (solar energy, thermal and energy engineering), **Cruddas** and **Roberts** (water and environmental engineering), and **Abrishami** (building information modelling).

We further enriched our UoA's interdisciplinary research via direct engagement with the international academic community, as evidenced by several external visitor appointments made during the REF period (outlined in Section 4).

2.3 Progression

The UoA maintains and enhances research leadership by supporting and developing internal researchers' careers. We actively encourage engagement with the 'PhD-to-Professor' programme and select staff to join the university's new Research Leadership Cohort programme (**Bucchi** is in the first cohort).

The considerable progression of Early Career Researchers (ECRs) from REF2014 (10 of 18 staff submitted in REF2014 were ECR) demonstrates the benefits of the UoA's nurturing environment. Some have remained at the university. **Barnett** has become Head of School (HoS) in SCES, **Bucchi** is Associate Head in the SMDE, **Radulovic** is HoS in the SMDE, **Simandjuntak** is a Senior Lecturer, **Tozzi** is a Reader and **Anssari-Benam** is a Senior Lecturer. Others have taken up positions at other Higher Education Institutions (HEIs). **Jadhawar** is a Lecturer at the University of Aberdeen, **Zhang** is a Postdoctoral Fellow at the University of Manchester and **Figiel** is an Associate Professor at Warwick University. While the UoA is always keen to retain the staff it supports and develops, it is gratifying to see colleagues move on to other HEIs and continue contributing to the field as part of high-performing research groups.

Based on research performance, we awarded several progressions and promotions during the REF period. These included progression to Senior Lecturer (**Anssari-Benam**, **Radulovic**, **Simandjuntak**, **Zekonyte**), progression to Senior Research Fellow (**Ma**, **Smart**), promotion to Reader (**Chen**, **Tozzi**), promotion to Professor (**Dhakal**, **Sanders**, **Williams**) and promotion to Associate Head of Research and Innovation (**Bucchi**). **Bucchi** is leading this UoA submission.

2.4 Reward and incentive

Our key mechanisms for helping UoA staff engage effectively with research include our annual Performance and Development Review (PDR) and the Workload Plan (WP) (REF5a paras 2, 3, 53). At their annual PDR, staff present an overview of their research activities for the past year and their plans for the forthcoming period. In discussion with their reviewer and their HoS, these documents provide the basis for the WP's formal allocation of research time. Depending on the extent to which their research-related activity satisfies a set of faculty-agreed criteria, 0%, 20%, 40% or 60% of a staff member's time may be allocated to research.

By continuing to develop these processes, we give individual staff members a central role in shaping their research future, provide due credit to a broad range of research-related activities, and reassure staff they are recognised appropriately for their work. In developing their research

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plans, staff are required to explicitly outline their contribution to their research group's strategy. The PDR process also requires them to assess how their activities contribute to the broader university strategies. Managers also have the facility to recommend colleagues for special contribution awards through the university's reward scheme.

2.5 Staff Development

We encourage staff to identify their specific training needs as part of the PDR process. Some can be met through the extensive provision of training workshops available through our central Research and Innovation Staff Development Programme (REF5a para 33), of which we provided 238 over the current REF period. Some 21 UoA staff attended a total of 162 training sessions. Where we cannot meet training or development needs internally, staff request support to attend external training courses or workshops. Members of the UoA have benefited from support to undertake external training, for example targeted grant writing courses and leadership training.

We facilitate staff mentoring throughout the Faculty of Technology, pairing experienced academic staff with new staff members to support the latter's research-career development. Staff can also register with the institutional mentor system (the Staff Mentoring Platform, REF5a para 37).

Staff receive 'on the job' grant-writing training through the Faculty Peer Review Process (see Section 1), which all research proposals go through. This 'critical friend' approach provides staff with constructive feedback from colleagues experienced in applying for and securing external funding. It is a key tool for the Faculty and the UoA to continue improving the quality of research submissions. For several funding bodies (e.g. UKRI), proposals also go through a university peer review process. Again, the focus is to provide constructive feedback to develop the investigators' proposal-writing skills, improve the quality of submissions, and ultimately improve our chances of securing funding. For research with the potential to create a start-up or business venture, the university-wide Entrepreneurs in Residence programme provides researchers with access to a pool of senior-level executives with business-development experience.

The Faculty hosts a yearly research conference inviting all researchers – from PhD to professorial level – to present their latest project outcomes. This UoA is a significant contributor, with 33 staff presenting over the last 5 years. The conference provides opportunities for staff at all development levels, with prizes awarded for the best presentation, paper, poster and 3-minute thesis presentation. Staff in the UoA won 9 of the 23 available prizes over this REF cycle. Our UoA members also have the opportunity to contribute to various seminar series run by schools across the Faculty. Since they also host external speakers, all researchers have access to the latest developments across subject areas. In addition, each research group organises subject-specific seminars for all researchers to present their latest work for further discussion.

2.6 Postgraduate Research Students

The UoA has a total of 64 current Postgraduate Research Students (PGRs). 61 students were awarded their degrees during the REF period. Of all students, 30% are funded by university

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scholarships, 46% are funded by industry and government and 24% are self-funded, representing 18 countries in total.

The Faculty used QR funds from REF2014 to support a PhD bursary programme (REF5a para 63). Bursaries are awarded based not only on a student's academic quality but also on how they fit with the strategic direction of the UoA and their ability to help develop or sustain activity beyond the bursary's duration. Both criteria have helped establish a broader base of research activities and further develop existing research strands. Through our staff-mentoring scheme, those less experienced in supervision have also been able to partner with staff with more PhD completions to their name, thereby expanding the pool of appropriately experienced supervisors and maximising overall research capacity.

The Faculty promotes the Postgraduate Research Experience Survey (PRES) within its PGR community. The survey is conducted at the school rather than the research-group level. Results from the most recent survey (PRES19) are a testament to the Faculty's commitment and UoA members' dedication. Each of the three schools linked to this UoA's research achieved an overall satisfaction rating in the upper quartile of the 107 higher education institutions that took part. For overall satisfaction, for example, the School of Mechanical and Design Engineering attained the top score of 100, the School of Civil Engineering and Surveying attained 89 and the School of Energy and Electronic Engineering attained 92.

Our recruitment of PGRs is rigorously based on their research skill and how well their research projects fit with the strategic research priorities and expertise of the UoA and the university. We assess shortlisted PGRs via an interview process involving at least three appropriately trained members of staff (gender-balanced where possible), including primary members of the supervision team.

In many cases, interdisciplinary research is accommodated with a supervision team spanning different schools and, in some cases, different faculties (e.g. Technology and Science). Depending on the nature of the research project, the supervision team might also include external experts with a relevant industrial background. The university sets minimum standards for the nature and frequency of PGR supervision meetings. PGRs also regularly attend research group meetings to participate in research discussions, present their research progress and interact with senior academics.

In addition to the Faculty research conference outlined above, PGRs are also strongly encouraged to attend one national and one international conference to present their first-year research outcomes. This invaluable opportunity allows them to engage in the research arena, invite feedback on their research, connect with the latest developments in their respective research fields, and engage in national and international networks and communities.

The Faculty runs induction programmes for new PGRs, providing an overview of the faculty's activities and structures and the university's higher research degree process and introducing key staff members such as the Dean, ADR, and Faculty Research Degrees Coordinator. New PGRs also attend a university-level induction programme to provide a broad overview of the institution. The university's Graduate School Development Programme (REF5a para 38) offers introductory courses covering research methodology, literature reviews, project management, record-

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keeping, data management, and health and safety, and international students can take advantage of the English for Academic Purposes course.

PGRs in each school attend regular meetings with the departmental PhD coordinator where they can report any issue that prevents the fulfilment of their research objectives. A student-elected representative for each school sits in the Faculty Research Degree Committee, where they can participate in the discussion and feedback about policies and decision-making.

The progress of PGRs is monitored via weekly meetings with the supervision team, where discussions are documented and recorded electronically on the Skills Forge system. PGRs are formally assessed via annual research student appraisals, which are critical in approving students' progression. These comprise a major review at the end of the first year and an annual review in subsequent years, each including academics independent from their supervision team as part of the panel. To continue their studies, all students must demonstrate sufficient progress during the year.

Before submitting their dissertation, students are offered a mock viva to build their confidence and to receive feedback alongside thesis-writing and viva-preparation training courses.

The Faculty also invested in the Horizon 2020 Marie Skłodowska-Curie COFUND "Doctoral Training Alliance - DTA3" programme (overall budget €6.5M). This programme enabled PGRs from across the EU to become internationally connected, independent researchers with interdisciplinary and intersectoral skills and experience, ready for industrial employment in European and UK priority-challenge areas of healthcare, clean energy and social policy. Building on existing doctoral programmes, a consortium of 12 universities across England and Wales and the University Alliance collectively delivered DTA3, fostering transnational mobility through an extended network of associate partners in Europe and Australia. As part of this programme, the Faculty funded 16 PhD studentships worth £960k.

2.7 Equality and diversity

Our engineering schools celebrate and advance equality and diversity amongst staff and students, championing and organising several affirmative events. Featuring female graduates, our celebration of the Year of Engineering and the International Day of Women in Engineering has attracted significant attention. Following the successful renewal of the institutional bronze Athena Swan award (REF5a para 44), the university is implementing an ambitious action plan to improve the equality balance further.

During this REF period, we facilitated female staff enrolment in Advance HE's Aurora leadership development initiative for women (**Barouni, Couceiro, Radulovic, Zekonyte**). **Radulovic** is now a role model and a mentor on the programme, having progressed to Head of the School of Mechanical and Design Engineering. During this period, **Barnett** also became Head of the School of Civil Engineering and Surveying.

Our current REF submission reflects our unit's proportional gender balance, with contributions from 44% of female staff and 43% of male staff. Contrary to the current national trend shown by HESA benchmarking for the sector, there is no gender pay gap within our unit.

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All selection panels for recruiting academics, technical staff and PGRs implement a gender-balanced approach. The overwhelming majority of staff attend relevant training modules, including 'Unconscious Bias', 'Bullying and Harassment' and 'Equality and Diversity' (REF5a paras 30, 47). All members of staff involved in the REF-outputs selection procedure also undertake a REF-specific training course.

Our policy for, and commitment to, recruiting staff with outstanding research profiles has enabled us to include 100% of our eligible ECR staff in this submission.

Our international staff profile is also reflected in this REF submission, showcasing 43 members from 15 different countries. Our submission includes 43% of eligible staff holding British nationality, 50% of those holding an EU nationality and 39% holding a non-EU nationality. We have also achieved a substantially more equitable ethnic balance than HESA benchmarking, submitting 38% of eligible BAME staff (almost double the benchmark proportion of 18%) and 62% of white staff (considerably lower than the 82% benchmark).

We have supporting policies in place for all members of staff requiring flexible working hours, facilitated and supported by the HoS and in line with university policies (REF5a para 46).

We encouraged all staff to disclose disabilities during the REF period and provided clear signposting to REF regulations and eligibility criteria.

3 Income, infrastructure and facilities

Our total research income for this REF period is £6 million, an increase of 462% compared with REF2014 (£1.3 million). Of this, RCUK, learned societies and trusts contribute 23%, and industrial collaborations contribute 77%. We have doubled the income generated per FTE in this REF submission (£141k per FTE) compared with our previous submission REF2014 (£72k per FTE).

3.1 Research Income

During this REF cycle, the funding profile we have secured indicates how different groups are collectively meeting our primary aim to develop and apply fundamental engineering principles to critical societal challenges. Three main categories of activity demonstrate how we are achieving this strategic goal. Development of **fundamental research** is the first. We secured ~£1M of fundamental research supported by Research Councils and learned societies during this REF cycle - for example, providing more industry-focused research. Our international connections are also reflected in our broad range of EU-funded research (worth £0.4M to the UoA). These projects allow us to work more closely with a range of academic and industry partners, bringing our research closer to resolving specific challenges.

The second category relates to industry-driven projects secured through **competitive bidding** processes, where members of the UoA are the preferred academic partner. For example, we secured ~£3M of funding through Innovate UK (or its predecessor, the Technology Strategy Board). Our success in this area reflects our industrial partners' confidence in our fundamental research credentials and our ability to help translate such research to help resolve real challenges.

The third category relates to projects where industry has **directly funded** UoA members. Their willingness to commit their own resources to support UoA members reflects the esteem with which our industrial partners hold us. Some £1.9M of directly-funded research has been enabled by a wide range of partners, including Southern Water, BAE Systems, DSTL, GlaxoSmithKline and Biotrics.

3.2 Organisational infrastructure

We develop and implement our Faculty research strategy, researcher-support mechanisms and research-related policy documents through our FRIC. The FRIC comprises the ADR, Associate Heads (Research and Innovation) at the school level, and staff representatives across the Faculty, who present all resulting research-related plans and policies to the Faculty Executive Committee (FEC) for approval. The ADR also sits on the University Research and Innovation Committee (URIC), ensuring all Faculty research policies align with the wider university research agenda.

The Faculty's investment in the processes, procedures and support mechanisms, enabling motivated staff to engage in research-related activities, was fundamental to our success over this REF cycle. Our leading principles guide our investments: to give staff the **opportunity to plan** their research future, duly **reward** them for research-related activity, make appropriate

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training available, and harness the **skills and expertise** of more experienced staff to support colleagues' development. For example, the Faculty's significant investment in developing its PDR and WP processes was essential to the UoA's performance over the current REF cycle. These processes ensure research activity is accounted for appropriately in the WP and provide a mechanism through which staff pursuing research-based careers are duly rewarded for their endeavours, further embedding a positive and enabling research culture within the Faculty that is of great benefit to this UoA.

Similarly, the Faculty's investment in developing the FPRP provides a basis for more experienced staff members to assist colleagues in developing research proposals, maximising the UoA's skill base and expanding research capability. It also allows issues such as ethics, impact, interdisciplinarity, and equality and diversity to be systematically addressed as part of the proposal-development process, embedding them in the heart of our research.

The UoA staff have invested significant effort inculcating a culture of research and a sense of community within our PGR cohort, e.g. through the PGR conference. These efforts have paid dividends, as demonstrated by the PRES 19 results outlined in Section 2.

3.3 Operational infrastructure: facilities

The Faculty has invested in expanding facilities and enhancing research capabilities to benefit UoA12 staff during this REF period. The total investment of £6M represents a 235% increment compared to the 2014 REF submission (£2.55M) and 545% compared to RAE2008 (£1.1M).

A significant investment of £12M (equally shared between the Faculty and the European Regional Development Fund) helped establish the Future Technology Centre (FTC) that houses the ZGC in collaboration with Carl Zeiss AG. This facility is equipped with two X-ray microscopes, providing outstanding non-destructive imaging performance (£1.5M). It features cutting-edge technology for additive manufacturing with a laser sintering machine (£500k) and a multi-material polymeric 3D printer (£200k).

Our investment in state-of-the-art testing material equipped the Faculty's laboratories even further. These include the new nano-indenter machine – the Hysitron TI Premier Dynamic (£276k) – that permits nano/micro-scale measurements in the load range from 10µN to 10mN and enables investigation of material not otherwise possible with conventional mechanical testing instruments, and the Instron 9340 Drop Weight Impact Tester (£75k), which is equipped with an environmental control chamber.

We expanded manufacturing capabilities with a 5-axis computer numerical control machine (£120k), electrical discharge machining apparatus (£160k) and a waterjet cutter (£140k), as well as bench-top X-ray fluorescence spectroscopy, X-ray power diffraction and scanning electron microscope apparatus (£350k) (REF5a paras 64, 65). These facilities are critical to the work of this UoA's researchers. We would not have secured such substantial increases in research income without them.

The Faculty's collaboration with Carl Zeiss, investment in the FTC, and establishment of the ZGC, was in direct response to the potential identified by UoA members' biomedical engineering

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research. This strategic foresight led to research as a direct consequence of this investment, the results of which form part of one of our Impact Case Studies (REF3 UoA12 Biomedical).

In this REF period, the Faculty also invested £250k in a major upgrade of the Environmental Technology Field Station we share with Southern Water at Petersfield Wastewater Treatment Works (20 miles from campus). This facility has large laboratories, offices and meeting rooms in a converted building at an operational wastewater treatment works. It offers a full range of water-quality testing equipment, including an autoanalyser for nutrients, a micro O₂ electrode and a microbiology laboratory. The group has access to more specialised equipment for extending their work on the main campus (inductively coupled plasma mass spectrometry, optical emission spectrometry, gas chromatography mass spectrometry, scanning electron microscope for energy dispersive X-ray analysis and metagenomic testing (REF5a para 64)).

This unique facility allows pilot plants to operate with real sewage, which is vital to account for wastewater's dynamic flow and composition changes. Several pilot plants can be operated simultaneously at a scale of several-hundred population equivalents, and effluents from trials are pumped back to the works inlet.

The site also has a large greenhouse, which we have recently used to study constructed wetlands and simulations of vegetated sustainable drainage swales. Two scientific officers funded by Southern Water are based at the site full-time, along with (currently) two PhD students.

The Faculty's strategic investment in this facility was also a direct response to the potential identified by UoA members' research. One of the UoA's impact case studies (REF3 UoA12 Wastewater) describes Southern Water's impacts in reducing operating costs, expanding markets and income for SME partners and contributing to national policy on roadside vegetated drainage systems.

Our UoA staff also make extensive use of the Faculty's centralised High-Performance Computing Cluster 'Sciama' (3702 cores, 4GB for core and 640TB of storage), supporting numerical modelling for biomedical engineering, environmental engineering and industrial applications.

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

We provide a stable, sustainable basis for developing collaborations and contributions across all our research groups via strategic investments in people, infrastructure and facilities. We actively promote collaboration in line with our UoA goal to **develop and apply fundamental engineering principles to pivotal societal challenges**.

4.1 Supporting research collaborations with other academics (local, national and international)

Our considerable national and international collaborations over the census period reflect our success in building and investing in a facilitative environment for collaborative approaches to fundamental engineering research.

Our investment in the FTC, ZGC and associated test equipment (REF5a paras 64, 65), and in polymer and composite researchers, facilitated engagement in two EU-funded projects worth over £8M (University of Portsmouth value = £434k). These projects aim to reduce the impacts associated with such materials. They benefit from collaborations with the University of Cambridge, the Sapienza University of Roma (Italy), the University of Borås (Sweden), and the Institut National de la Recherche Agronomique (France). We developed further international collaborations in this field with institutions including the Anna India University (India) and the University of Toronto (Canada) (**Zhang, Dhakal**).

Our investment in the FTC and ZGC provided a platform for developing collaborations in **biomechanical** engineering with the universities of Salford and Southampton and University College London (UCL) through an EPSRC-funded project researching affordable body-powered prostheses (**Kyberd**). It also facilitated collaborations to develop new superalloys and enhance the mechanical properties of the existing alloys used in jet engines. We developed the resulting EPSRC-funded projects with Swansea University, Imperial College London, the University of Cambridge and Worcester Polytechnic Institute, USA (**Birosca**).

Our investment in people has also provided the basis for extensive collaborations across both the EU- and EPSRC-funded projects, which assessed low carbon technologies and enhanced nuclear power-plant safety and security, respectively. Both projects have established links with the University of Southampton, the University of Liverpool, Salford University, UCL, Leeds Beckett University, the University of Reading, Katholieke Universiteit Leuven (Belgium) and the University of Picardie Jules Verne (France) (**Becerra, Radulovic**).

Facilities available at the FTC helped establish key partnerships for the Innovative Industrial Research group (REF5a para 65). These grew into an Innovate UK funded project focused on conditioning monitoring for marine applications in collaboration with the University of Southampton, and an EPSRC-funded project developing autonomous quality control in manufacturing environments in collaboration with the University of Sheffield (**Smart, Ma**).

Our collaborations with academic institutions over the census period include:

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- 35 in the UK (30 in England, 2 in Wales, 2 in Scotland and 1 in Northern Ireland)
- 26 in Europe (5 in France, 3 in Italy, 3 in Spain, 2 in Cyprus, 2 in the Netherlands, 2 in Portugal, and 1 in Austria, Belgium, Greece, Norway, Poland, Russia, Sweden, Turkey and Ukraine)
- 18 in Asia (8 in China, 2 in Malaysia, 2 in Vietnam, 2 in Pakistan, and 1 in Hong Kong, India, Japan and Thailand)
- 3 in North America
- 3 in Oceania.

4.2 Interaction and engagement with principal research users, beneficiaries and audiences to develop impact

Our effective engagement with users and beneficiaries is fundamental to the UoA's work addressing societal challenges. The investments outlined above also play a key role in enabling UoA research groups to interact and engage effectively with a broad range of research users, beneficiaries and audiences.

Our state-of-the-art facilities in the ZGC (REF5a paras 64, 65) have enabled biomedical researchers to engage directly with non-academic research users. This applies both nationally – including the Heart Science Centre, the National Heart and Lung Institute, Portsmouth Hospitals University NHS Trust, the Royal Brompton & Harefield NHS Foundation Trust (**Anssari-Benam, Bucchi, Lee, Pani, Tozzi**) – and internationally, including the Rizzoli Orthopaedic Institute in Bologna, Italy (**Pani**). Test equipment in the ZGC has also enabled researchers to work with Gallagher Aggregates Ltd. to develop aggregates from waste materials (**Ali**).

The broad range of activities supported by our investments is reflected in the types of organisations with whom research groups collaborate and, therefore, the broad scope of our potential impacts. For example, sophisticated portable monitoring equipment allowed the UoA to work directly with the Mary Rose Trust to preserve the 16th-century warship (**Begg**). Our investment in AI hardware and software enabled us to work directly with children and young people with complex neurodisabilities through the Chailey Heritage Foundation, to improve the autonomy and mobility of wheelchair users (**Sanders**).

These activities' influence is not limited to the direct beneficiaries; in many cases, it leads to members' appointment to advisory boards, broadening our audience and increasing our potential for impact. As a consequence of the above research, for example, the UoA is now represented on the Mary Rose Trust advisory board (**Mitchell**), as well as in the UK Government Advanced Research and Assessment Group and the Institution of Engineering and Technology Policy Committee (**Sanders**).

Besides facilitating engagement with non-academic institutions, our investments over the census period have also allowed us to foster considerable industrial partnerships. Using our AI-development resources, researchers in IIR collaborate directly with Tructyre Ltd. and RL Automotive Ltd to develop a predictive monitoring system for commercial vehicle tyres. This will

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allow operators of heavy goods vehicles and coaches to predict tyre pressure losses, saving fuel and preventing catastrophic accidents due to tyre blowouts (**Smart**). Moreover, **Smart's** work with industrial partners (supported by Knowledge Transfer Partnership funding) led to significant cost-saving impacts for Stork – one of the world's largest builders and sellers of food-filling machines in the world – of around £15M. Similarly, **Smart's** work on anomaly detection reduced flight recorders' fault-detection timescales from days to minutes, support an enhanced valuation of the collaborating company by an estimated £7M. This work forms part of two of our Impact Case Studies (REF3 UoA12 Anomaly Detection and REF3 UoA12 AI Application).

Our success in fostering collaborations across a broad range of stakeholders is typified by the establishment in 2016 of the South Coast Centre of Excellence in Satellite Applications (SCCOE), led by the University of Portsmouth (REF5a para 17). With our partners such as the University of Southampton, the National Oceanographic Centre and Hampshire County Council we have worked with 17 companies, generating £0.96M of research.

During this census period, the UoA established collaborations with 54 non-academic and industrial partners, representing 15 different countries across North America, Asia, Australia and Europe, and nine **national and international advisory boards**.

4.3 Indicators of wider influence, contribution to and recognition of the research base

Our WP and PDR processes ensure UoA members can plan their research future and receive the due credit and reward for their activities (REF5a paras 2, 53). Together with the investments that have driven our research collaborations and activities, the resulting environment provides the basis for meeting our strategic aim through high-quality and impactful scholarly endeavour.

The broad range of research activities engaged in by UoA members reflects our continued recognition from academic peers as scholars who deliver fundamental research. For example, the UoA has at least one representative on the **Peer Review College** for four of the **UKRI**-funding councils, including six for EPSRC, two for MRC, and one each for NERC and AHRC, with some members spanning two councils (e.g. **Lee**, MRC and EPSRC; and **Gaterell**, AHRC and EPSRC). We have raised our profile on international review panels, including as an expert evaluator for the Horizon 2020 SPACE call 2018 (**Becerra**), Marie Skłodowska-Curie scheme (**Couceiro**) and the Hong Kong Research Grant Panel (**Lee**).

Further discipline-specific recognition is reflected in our **membership of editorial boards** across a broad spectrum of peer-reviewed journals. These include *Advances in Mechanical Engineering* (**Bucchi**); *Applied Sciences* (Special Issue on 'Tribological and Mechanical Properties Studies of Smart Materials at Micro-Nano Scale') (**Zekonyte**); *Energies, Electronics* (**Becerra**); *Engineering Sustainability* (**Gaterell**); *Estuarine, Coastal and Shelf Science* (**Mitchell**); *Frontiers* (**Tozzi**); *Institute of Mathematics and its Applications Journal of Mathematical Control and Information* (**Becerra**); *Materials* (**Begg, Tozzi**); *Metals* (**Birosca**); the *Journal of Microscopy* (**Tozzi**); the *Journal of Prosthetics and Orthotics* (**Kyberd**); *Water Management* (**Mitchell**); *Smart and Sustainable Built Environment* (**Ali**); and *Energies* (Special Issue on 'Applications for Organic Rankine Cycle') (**Radulovic**).

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Our wide recognition is also reflected in the five conference-chair appointments and eight keynote speeches awarded to UoA staff. Notable examples include the **conference chair** for the Gender and Education Association International Conference (2019) (**Radulovic**), and **keynote lectures and invited speakers** for the Rolls-Royce/EP SRC Strategic Partnership Conference 2019.

The numerous **visiting professorships awarded** to our members show further recognition of individual contributions. **Dhakal** is a Visiting Professor of biobased composite materials at the University of Borås (Sweden), **Lee** is a Visiting Professor contributing to research development at INTI University Malaysia, **Sanders** holds a Visiting Professorship at Moscow State University of Technology STANKIN (Russia) and de-La Salle University in Manila (Philippines), and **Nassif** is a Visiting Professor in Structural Engineering at Ho Chi Minh City University, Vietnam.

4.4 Contribution to sustainability of the discipline and responses to national and international priorities and initiatives

This unit has significantly contributed to international research priorities, undertaking excellent research in EU Societal Challenges and UK's Grand Challenges areas. These include:

- Health, demographic change, wellbeing and ageing-population support (**Lee, Kyberd, Tozzi**)
- Food security, sustainable agriculture and forestry, marine-maritime and inland-water research, and the bioeconomy (**Williams, Couceiro**)
- Secure, clean and efficient energy/clean growth (**Becerra, Radulovic**)
- Smart, green and integrated transport and the future of mobility (**Smart**)
- Climate action, environment, resource efficiency and raw materials (**Dhakal, Gaterell**)
- Artificial intelligence and data (**Ma, Sanders**).

The majority of funding supporting these researchers' work was channelled through Innovate UK (£3M) or the EU (£0.4M) - see Section 3.

Our unit responded innovatively to the current pandemic, including:

- A recent BBSRC award (£288k) involving **Williams** and **Couceiro**, in partnership with colleagues from the Faculty of Science and Health, which supports the UK government's evidence-based approach to the COVID-19 pandemic. This project builds on UoA expertise in water and wastewater treatment (WWWT) to develop a robust spatial and temporal understanding of SARS-CoV-2 prevalence using the UK's 18,000 wastewater sites, by developing a sensor to detect the virus in wastewater (REF5a COVID-19 Annex).
- Collaboration with a medical company (Airway Medical Ltd.), supported by the University's Support Innovation and Growth in Healthcare Technologies programme, which led to an

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Innovate UK grant award (**Bucchi** £211k) on a novel portable airway suction device with anti-viral coating.

The Faculty's investment in infrastructure (e.g. the FTC) provided the facilities through which staff can contribute to our discipline's sustainability. For example, the UoA hosted the following conferences:

- The 5th annual conference on Tomography for Scientific Advancement ToScA 2017 (**Tozzi**), hosting 100+ delegates from the UK and internationally (e.g. France, Belgium, Germany, Austria and Australia) and supported by 12 industrial sponsors. **Tozzi** edited a special conference issue for the *Journal of Microscopy*.
- The High Temperature Defect Assessment International Conference HIDA-7 2017 (**Simandjuntak**). This conference included 53 presentations from industries including Integrity Cyfyngedig, ETD Consulting, Matelect, NPL (UK), Citgo Refinery (USA), Technical Research Centre (VTT) (Finland), Engie (Belgium), Eidgenössische Materialprüfungs- und Forschungsanstalt (EMPA) (Germany), Sumitomo Metals, Chugoku Electric Power Co, The Central Research Institute of Electric Power Industry (Japan) and academics from the UK, China, Korea, Japan, Germany, the Czech Republic and India. Twenty-two papers were selected and published in a *Materials at High Temperature* special issue.
- The 2nd FLOWER Project Conference on Advanced Biobased Materials and Composites for Engineering Applications was held online on 17 September 2020. This conference was organised by (**Dhakal**) the University of Portsmouth and co-financed by the ERDF within the framework of the INTERREG VA France (Manche) England Programme. Eighty delegates from different countries around the world attended, including India, France, Germany, Italy and the UK.