Institution: University of the West of Scotland
Unit of Assessment: 12: Engineering

1. Unit context and structure, research and impact strategy

1.1 Context and Structure of Research

In this REF period, engineering research has been structured within the Institute of Engineering & Energy Technologies (**IEET**), Construction Innovation and Built Environment Research Group (**CIBER**), and the Institute for Thin Films, Sensors and Imaging (**ITFSI**). The UWS engineering research community engages in interdisciplinary research, focusing on world-class contributions to:

- Standardisation (influencing the development of new standards on FM technology; ISO 410016),
- Commercialisation of research (product development research in support of our spin-outs across UOAs),
- Knowledge exchange (significant share of the UK's fastest-growing portfolio of Knowledge Transfer Partnerships (KTP))

Engineering at the University of the West of Scotland (UWS) resides within the School of Computing, Engineering and Physical Sciences (CEPS). The School, formed in 2018 from the merger of two previous Schools, synergistically bringing together staff in Divisions of Engineering and Physical Sciences. Specifically, this now includes research in aerospace engineering, chemical engineering, civil engineering, construction management and education, energy, manufacturing/remanufacturing, project/quality management, rapid prototyping, robotics/automation, smart asset management, and thin film material science and applications.

1.2 Research objectives: past and current

1.2.1 Current REF period: Review of REF2014 objectives

The key objectives in REF2014 were to:

- Increase the volume, quality and impact of research;
- Improve international reach and significance beyond academia and for the benefit of society.

We have achieved all of these objectives during this REF period, with several external awards for the translation of our research into world-leading innovations. In addition, in this period, staff have developed two flagship Graduate Apprenticeships Programmes, funded by Skills Development Scotland (SDS) in Civil Engineering, and Engineering, Design & Manufacture, to the total award value of GBP5,269,909.

Volume, quality and impact of research: In REF2021 submission, we return 34 staff, representing 90% of eligible Category A staff, against the REF2014 submission, which included 13 staff with ten from Engineering and 3 from Nuclear Physics. Nuclear Physics research has since expanded and UWS is submitting Physics separately in the REF2021 submission. Since 2014, notwithstanding the separate Physics submission, UOA12 has produced approximately 300 high-quality peer reviewed outputs during the submission period and therefore increased research activity significantly. This is the result of a strategic and continuing investment in Engineering and a supportive staffing recruitment policy giving priority to research activity. In the current assessment period, 41 research students have been supported with 23 successfully completed (15 submitted to REF4a). Compared with the previous REF assessment period where eight completions in General Engineering (which included Nuclear Physics) were recorded, this demonstrates a significant improvement in supervisory capacity (concomitant increase in research active staff). This has been a key element in increasing output volume and the achievement of the unit's strategic aims.

Improve international reach and significance: World-class research across Engineering has underpinned award winning Knowledge Transfer Partnerships (KTP), standardisation and spin-out activities, significantly exceeding the original objectives in REF2014. This has included the **multiple-award-winning Novosound Ltd.**, KTP project with **Phoenix Instinct Ltd.**, the winner of the global **Toyota Mobility Unlimited Challenge**, receiving USD1,000,000

(GBP736,000) to further develop their intelligent ultra-light carbon fibre wheelchair. Engineering staff are now engaged in 24 KTP projects nationally and internationally (including 1 management KTPs) and significantly contribute to UWS attaining the fastest growing Higher Education Institution (HEI) by number and volume of KTPs. Most recently, jointly with International Islamic University (Islamabad, Pakistan), we have successfully secured funding under the Innovative and Collaborative Research Partnerships Grants (Pakistan UK Education Gateway with British Council) on advanced energy harvesters and energy storage devices for self-powered flexible energy systems.

1.2.3 Strategy for the next five years

Vision: Engineering divisions lead and engage in globally-impactful research in support of United Nations Sustainable Development Goals (UN SDG), achieving this through knowledge exchange, commercialisation and leading-edge education. Our research groupings (**IEET**, **CIBER** and **ITFSI**) will live the vision by boosting their activity across the substantially interlinked themes: (1) Materials and mechanics, (2) Energy and environment, (3) Construction and built environment, and (4) Engineering process management. Our vision and the key themes demonstrate commitment to the UWS Strategy 2025 and are closely aligned to Scottish and UK government strategic priorities, and Horizon Europe mission areas.

Strategy: Considering our recent successes, our research strategy is to target larger projects (approximately GBP500,000), increase research outputs of the highest quality and develop impactful collaborative partnerships at all levels. Specific objectives for the next five years are:

- to increase world-class signature research where we are sector leaders across all research groupings;
- to boost recruitment and increase our postgraduate research community to 120 PhD students by 2025;
- to develop significant new international research alliances through large interdisciplinary consortia via UKRI, Horizon Europe and bilateral funding schemes;
- to expand exemplary academia-industry research collaboration, translating into world-class knowledge exchange and continuous professional development;
- to expand our engagement and involvement in collaborative initiatives and partnerships in Scotland, UK and internationally;
- to translate developed signature research capabilities into flagship industry-leading education programmes across all areas of Engineering.

1.3. Achievement of Impact

Engineering at UWS has a long tradition of applied research through model collaborations with industry and a richness in knowledge exchange activities. Increasing the translation of research output to impact through industrial collaboration has thus been at the heart of our ability to achieve impact. Another aspect to impact realisation is the synergy between different areas of expertise. The strategy encourages the development of interdisciplinary broad-based and resilient solutions to real-world grand research challenges. The University actively encourages interdisciplinary collaboration. As such, the emphasis on research activities has evolved to make the participation of industry stakeholders a matter of day-to-day activities. This has further facilitated our ability to rapidly involve stakeholders at the inception of any emerging research activity. The University is committed to addressing UN SDGs, in which a global sphere of influence opens allowing more areas of research to target potential impacts such as addressing climate change and cultural heritage, renewable energy technologies, sensors for better mitigation efforts in infrastructure and monitoring, water purification.

1.3.1 Impact Case Studies and Impact Approach

The strategic impact approach includes KTPs, the creation of spin-outs along with other university and externally supported initiatives to facilitate collaboration with the private and public sectors. The unit currently has had 24 KTPs, in the areas of built asset management, sensor development, robotics, mechanical engineering and manufacturing. These translate world-

class research and facilitate direct economic and environmental impact within external organisations. Short lines of communication in the School encourage and facilitate cross-UOA collaboration as exemplified in our Impact Case Studies (ICS) with links to UOA9 and UOA11.

For the built asset management (**CIBER**) ICS, there is a natural need for interdisciplinary research across the academic divisions of the School. This has enabled individual expertise to be interwoven into impact-generating internal consortia, resulting in innovative solutions to major societal challenges (i.e., sustainable built environment). The same internal consortia-forming approach has been applied across all ICS' and impact generation in general. The case study in rapid prototyping for manufacturing includes fundamental research in both research Institutes (**IEET**, **ITFSI**), developing our capacity has led to applications involving highly innovative prototypes and process development with impact in environmental, economic and health (See Section 3). The disruptive piezoelectric thin film technology ICS, on the other hand, has benefitted from seamless collaboration between staff in UOA9 and UOA12, enabled through a truly interdisciplinary nature of **ITFSI**. These non-linear routes to impact are a norm within UOA12 and the emerging research on advanced energy harvesting and storage devices, hydrogen along with our significant involvement in the regional economic partnerships are key to sustainable impact generation for the future (e.g., staff directly involved in Ayrshire Economic Partnership, Lanarkshire Economic Forum and Consortium on Applied Research and Professional Education - CARPE).

1.4 Interdisciplinary Research

Interdisciplinarity is inherent in the research within the engineering disciplines. Internal and external collaboration is evidenced in the outputs presented, and in our ICS'. Staff are also active in interdisciplinary work across the university and externally with industrial and academic partners both nationally and internationally. It includes bringing together engineering, natural sciences, social sciences and humanities such as in the built cultural heritage (**Hughes)**, built asset management (**Konanahalli, Radosavljevic**), and rapid prototyping (**Vichare, Marzano**). The University strategy looking forward to 2025 also drives, and will reward interdisciplinary working to address the challenges of the UN SDGs. Interdisciplinarity embedded in our research is encouraged through institutional support. For example, staff returned in the unit from the ITFSI (**Garcia, Hutson, Song**) benefitted from GBP700,000 investment from the 'Vice Principal GBP1,000,000 Fund for Research and Enterprise Excellence'. The scheme explicitly emphasised requirements around equality and diversity, the inclusion of Early Career Researchers (ECR). Interdisciplinary staff from three academic schools are involved in applied research in health, sport, built environment, astronomy and electronics are also included. A significant example of interdisciplinary research involves ITFSI staff (**Gibson, Hutson, Song**) also being involved in the development of novel coatings used in one of the world's largest research consortia: Laser Interferometer Gravitational-Wave Observatory (LIGO).

1.5 Open research environment

Working with the University library, all research outputs, whether submitted for REF or not, are made available through the University's research portal, PURE. We also aspire to ensuring the openness of research data and aim to meet the requirements of external funders even when not mandated, ensuring research projects have data management plans in place. With a high proportion of KTP projects, data management arrangements are also cognisant of commercial sensitivities. As standard, the University has put in place resources and support for compliance with the REF Open Access (OA) policy, via centralised Research Services and the University Library. Since 2016 the requirement for OA compliance has been communicated to staff within the unit, and OA routes to publication are favoured and supported by the School. This has included funding publication processing charges and guidance on the most appropriate OA route. An increasing number of outputs is being published Gold open access, thanks to the transformative agreements the UWS Library has signed with numerous publishers.

1.6 Research Integrity

The University publishes a code of ethics; embodied operationally in a University Ethics Committee (UEC), reporting to Senate. School-level ethics committees are responsible for the development and embedding of a culture of ethics for research activities. It is mandated that all research activity must be scrutinised for ethical dimensions and where required subjected to ethical approval processes. The work of the submitting unit is overseen by its relevant school committee (Chaired by **Hughes**), which scrutinises activity where required, overseen by the UEC to ensure consistency across the whole university. With regard to professional frameworks, working within the oversight of the various institutes for engineering (of which many staff are members), we are held to high standards of professional conduct and integrity. This is borne out through the professional institutions' accreditation of our UG and PGT programmes, which incorporate significant elements of research-informed teaching, and student dissertation work. The University also fully supports adherence to the concordat on research integrity and open data, and is also a signatory of the Declaration on Research Assessment (DORA).

2. People

Staff recruitment and development strategies in the School take the lead from the values advanced across the University in the Corporate Strategy. The University is committed to providing a working environment designed to ensure openness, equality of opportunity and fairness in recruitment and staff development.

2.1 Staff Recruitment Strategy

Engineering has been transformed during this REF period with a goal to develop leadership from within the unit on the basis of exceptional support for ECRs. Of the 34 staff in this submission, there is one Professor, four Readers, eight Senior Lecturers and twenty-one Lecturers. All are on full-time permanent research and teaching contracts, and nineteen are appointments since the start of 2014. Eleven are ECRs (32% of the total) and eight are female (24%, including the Head of Division of Engineering (**Cano**), and a Reader and Deputy Lead for CIBER (**Konanahalli**). Since 2014, a further seven non-ECR staff have been appointed, two at Senior Lecturer, the remainder at Lecturer, one subsequently achieving promotion to Reader. The profile of staff is diverse, evidencing a global recruitment policy of the University that values and fosters a plural, inclusive, multicultural environment. Maintaining staff numbers, and enhancing research and teaching provision, has been a priority in which staff are recruited to fulfil roles in programme provision, concomitant with proven ability and potential to meet the unit's and institution's objectives for increasing research activities within its cognate areas.

The transformation has been a direct result of the constructive policy of recruitment that has led to the highest proportion of research active staff in Engineering in the history of the University. A priority in recruitment is a combination of requirements for taught programme development, with preferred experience in industry essential for a positive student experience and stimulus for applied research development. We have also recruited early career academic staff from our own PhD students (**Awotwe, Rodriquez Nunez)**.The strength of the unit is exemplified by the senior executive position (**Radosavljevic**, University's Vice-Principal for Research, Innovation & Engagement).

2.2 Staff Development Strategy

Considering the successes so far and the substantial pool of ECRs and mid-career academics, the School is committed to developing academic leadership internally as well as through recruitment at a Professorial level in areas of research aligned with aspirations in UWS Strategy 2025. Training and development is thus focused on developing abilities to: (**1) lead independent research**, **(2) research grouping leadership**, (**3) manage projects, budgets and staff**, and **(4) to balance academic portfolio** by maintaining world-class research alongside exceptional teaching.

Staff activity is managed through quantitative activity planning and the University's '*My Contribution*' process. Research is a clearly identified activity aligned to the University's objectives

and enabling plans. The minimum developmental time allowance of 10% is provided for research, and is in general far greater across the entire staff. This brings responsibility, related clearly to objective setting for publication, supervision, and funding applications. This approach offers flexibility, and in many cases, time-based support for varying intensities of research activity. This acknowledgement of research activity is further enhanced by institutional facilitation, particularly for ECRs, for whom time for research is protected. The University provides centralised development mechanisms and operates an open promotions scheme with research activity a key criterion for promotion. In the period, the Unit has seen a number of promotions: 4 to Readership, recognising research performance; and 3 staff promoted to Senior Lecturer. The Staff Appreciation and Reward Scheme (STARS) was created specifically to recognise outstanding staff contribution that recognises contributions over and above the normal expectations, encompassing research and impact achievements (**Radosavljevic, El-Hassan)**.

Staff development opportunities within the School and the University are promoted proactively. New staff are required to enrol on the PGCert in Academic Practice offered by the UWS Academy. This programme incorporates research practice as well as research-informed teaching and learning. All staff undertake training courses in addition to those stated above, as identified by the '*My Contribution*' process (e.g., Time Management, Risk Management, Impact Development). Staff have access to a training portal to manage personal training and includes a Development Toolkit offering a wide range of resources, guidance, and advice through short videos and podcasts.

In line with the University's staffing and equality practice and policy, the School facilitates a family-friendly option for extended leave such as career breaks and annual leave purchase. Staff can benefit from the Returners Scheme, which provides funding support to cover essential teaching and research activities. Staff are also able to arrange for flexible working arrangements, job-share, and reduced hours contracts. The University emphasises the need to engage in useful, applied research activities. The Unit evidences ample active connections and opportunities for staff to engage in interactions between academia and industry, in the impact case studies that comprise this submission and in the 10+ KTPs. The University provides a centralised support for knowledge transfer activities and advice and information on commercial activities.

2.3 Support for Early Career Researchers

The profile of the Unit is intentionally developmental with a relatively large cohort of ECRs. This provides significant opportunities for ECRs to shape School research, develop signature research and leadership in emerging areas of strength. Staff development with mentoring of ECRs by experienced colleagues is formally established and normal practice. This is intended to form a foundation for the development of future research leaders, as part of succession planning. For example, ECRs are proactively involved in supervision of doctoral students while benefitting from co-supervision support from more established colleagues (i.e., applies to all UWS internally funded studentships, prioritising ECRs in adherence to Equality, Diversity and Inclusion (EDI) requirements).

During this period 6 RAs have been recruited, in addition to nine KTP associates. The care and career development of RAs is managed through the same procedures as for permanent academic staff (see below). The academic skills of RAs are developed through a spectrum of academic activities (including teaching) and they are encouraged to think and act as independent researchers, taking the lead on publications and involvement in research bid preparations.

The University is also fully committed to implementing the UK Concordat to support the Career Development of Researchers and has embedded the principles of this in strategies to support staff and research students. The University subscribes to the Vitae researcher development programme, and has been the recipient of the EU HR Excellence in Research award, initially

in 2016, retained in 2020. ECRs can benefit further from training opportunities: the UWS Crucible, Grant Accelerator Programmes (9 of 11 ECRs in the submitting unit have participated in these - the remainder being recent appointments who will be encouraged to take advantage), and mentoring schemes to assist with grant applications and supervisory skills. A university-wide Early Career Researcher Forum, now Staff Forum for Research was launched in June 2018 to bring together new researchers across the University to foster cross-school partnerships and build networks to encourage multi-disciplinary projects and funding bids. The GBP1,000,000 VP Fund for Research and Enterprise Excellence (mentioned above), established in 2017, offered targeted support for research activities, applications for which were contingent on ECR participation. One of our ICS' originated with the research work of an ECR in ITFSI (for which **Hughes**, is a spinout company director), exemplifying the open pathway to development and reward that the Institution endorses. Additional key skills development support is offered routinely, in for example, project management, research student supervision, in addition to mandatory coverage of health and safety, ethics and integrity, and equality and diversity training for all staff. These initiatives are also available to postdoctoral researchers.

2.4 Research students

The structures for monitoring, training and support outlined here were put in place at the beginning of 2013 to improve completion rates. As related elsewhere (REF5a), there has been a concomitant improvement in completion rates and also outcomes such as student success in awards, and significantly, in student productivity as contributions to peer reviewed outputs. **Postgraduate Research Community:** In Academic Year 2020/21, the School of Computing Engineering and Physical Sciences, has been home to over 100 PGR students. Of these, currently 21 students are supervised or co-supervised by 15 staff in the submitting unit. During the period of assessment, 41 PGR students have been recruited with 23 completing (15 submitted to REF4a). 11 staff members have been Lead Supervisors for these completing students. With eight completions prior to REF2014, this represents a considerable increase. Research students are a vital part of our community; one of our key objectives for the forthcoming period is to increase the community further. Five students are currently enrolled and co-supervised through established relationships with German Universities of Applied Sciences (e.g., Deggendorf, Hamburg, Leipzig, Mittweida). These vibrant postgraduate research partnerships benefit from extensive facilities in partner institutions, industry-embedded research projects and joint supervisory arrangements. Through online community building, annual conferences and partner institutions developing UWS-compliant support for students, the students are an integral part of our wider research community.

Recruitment and Progress Monitoring: We have consistently recruited high-quality postgraduate research students. Project opportunities in the School are promoted on its webpages and staff are also able to recruit doctoral students through their relationships with international research community and in response to direct online applications. To channel applications, staff profiles on our research portal indicate our expertise. The application process includes a formal interview prior to an offer to study being made. Appointment criteria are cognisant of requirements for equality, diversity and inclusivity and focus on commitment to the topic of research, previous academic performance and approach to research in general. Recruitment also takes place through specialist agencies. Depending on circumstances and for academically outstanding applicants, the School offers studentships to cover part of the study costs. Most of our research students are self-funded but the University provides a number of studentship opportunities: (1) fully funded doctoral studentships, distributed on a highly competitive basis for which the unit has benefited from 4 awards; (2) match-funded doctoral studentships where sponsorship support of at least 30% comes from industry or another external body, including the public sector and (3) fully funded studentships pledged within letter of support for successful large grants funded by research councils or European Commission. Fully funded studentships are publicised on the University's webpages and also through academic networks and other web resources (e.g., findaphd.com), and allocated on a competitive basis following interview by the supervisory team.

Research students are supported in supervisory teams comprising of a Lead Supervisor, a Second, and sometimes an Additional Supervisor. At least one member of the supervisory team is expected to have supervised previously to completion; if the lead supervisor is inexperienced, an experienced second supervisor is appointed to the team. In this way, staff receive mentoring and direction in supervisory skills, to the benefit of the student, staff and the research project. Staff are allocated time in their activity plans for supervision. External advisors, from other HEIs, industry, civic or third sector organisations, are encouraged to ensure the relevance of the research to external interests and to allow for effective dissemination of results. Collaborative postgraduate research projects benefit from joint supervision between two partner institutions. A member of academic staff is also appointed as an Independent Assessor, to oversee progress and to authorise progression to PhD registration. The assessor is not part of the supervisory team and can be from a related or unrelated discipline. This has the effect of encouraging interdisciplinary thinking (and often future projects) by staff and students, and the use of clear language in communication.

The School appoints PGR Student Coordinators who take academic responsibility for student issues, welfare and progress monitoring, approve and facilitates viva arrangements and act as intermediary with the UWS Doctoral College. The PGR coordinator is a critical role that sits on the School Board, the School Ethics Committee and the Doctoral College Board. Doctoral students' academic progress is administered through the University's Doctoral College which is responsible for enrolment and processes of assessment, delivered in cooperation with the academic schools. The University has adopted a centralised online system for research student monitoring and recording (MyPGR Platform; moving to SkillsForge in 2021). Reports are due at regular intervals (6 weeks, 6 months and annual in the first year and 6 months and annually thereafter), considered by an independent assessor, who is not part of the supervisory team. MyPGR Platform sets out milestones and reporting deadlines, and is facilitator of formal communication between the supervisory team, students, PGR coordinators and the Doctoral College. It also facilitates requests for modification of registration, such as interruptions to study and changes in supervisory teams, which are approved or otherwise by the School's PGR coordinator and the Progress and Award Boards (PAB) on behalf of the Doctoral College Board.

Training: Rigorous monitoring and training have subsequently led to more than 90% of PGR students being within the maximum period of registration, significantly improving our completion rates. Generic research skills, language and writing skills and continuous professional development are offered in a structured package of support for doctoral students, from the Doctoral College and the UWS Academy. Student-led induction events for new intakes, which incorporate an array of information sessions and training take place several times per year. Development support also exists for staff, in supervisory skills, assessor, and *viva* chair training. Staff in the UWS Academy provide support for the development of the careers of PGR students, postdoctoral researchers and academic staff, which is supported also by the School and the submitting unit. The University organises an annual learning, teaching, and research conference, at which PGR students present posters or take part in a highly competitive '3 minute thesis' competition. Research students are encouraged to attend school research seminars, and to present where possible, and are expected to make a public presentation as part of their transition from MPhil to PhD registration. Where research is associated with the Energy Technology Partnership (ETP), Scottish Alliance for Geosciences, Environment and Society (SAGES), and Scottish Research Partnership in Engineering (SRPe) pooling, for example, funded places are available for students to attend Summer Schools, annual postgraduate conference and other training. A student in Civil Engineering was funded from such sources for international exchange work and hosting a workshop, won a best post-graduate student publication at the 2018 and 2019 SAGES Annual Science Meeting. All of the research pooling studentships benefit from joint supervision between a minimum of two collaborating institutions.

2.7 Equality and diversity

Supporting and promoting equality and diversity is enshrined within the principles of the UWS strategy; "*…an inclusive organisation that welcomes and values diversity*". A key part of this is the Institution's outlook to be a global organisation, something that is reflected in the diversity of both our students and staff, and in the UWS Strategy 2025, focussing on the UN Sustainable Development Goals. The University has a long tradition and a high achievement in widening participation in higher education of students from deprived backgrounds. The University holds an institutional Bronze Athena SWAN award, in which half the academic staff are female. UWS are also Stonewall Diversity Champions and are Disability Confident employers.

The submitting unit operates in this context with centralised support, from the University as a whole, and its host school, across staff activity in teaching and research. As research has increased in importance, becoming an integral academic pursuit for most staff in the submitting unit (90% of eligible staff), the implications for equality and diversity are addressed in relation also to research activity. In response to this context, the School appoints an Equality, Diversity and Inclusion (EDI) Champion from the academic staff and convenes an Athena SWAN self-assessment team. This collates information on gender representation across the academic school from which this submitting unit is drawn. The group monitors PGR student recruitment, KTP and other research associates, academic staff recruitment and promotions, and draws up action plans to tackle deficiencies. Equality, diversity and inclusion training is mandatory for all staff. Female staff are also able to participate in a Women's Leadership and Development Programme. According to the terms of the University's REF2021 Code of Practice all staff associated with the exercise must undergo equality training. There is a commitment in the code of practice to ensure cognisance of EDI in the delivery of this submission. A representative cross section of our staff in the unit (20/34) were involved in peer review for the selection of outputs for our submission, ensuring a diversity of perspectives.

In the submitting unit, eight staff are female, representing 23% of the total. While this is below the Athena SWAN benchmark of 26%, this is a significant improvement, as the percentage was only 7% across both UOA13 and UOA15 in REF2014. Importantly, this includes the Head of Division of Engineering, a Reader and a Senior Lecturer. Staff in the unit are drawn from both divisions of Engineering and Physical Sciences. When considering the staff from Engineering alone the proportion of female staff increases to 28%. In terms of diversity of origin, 67% of the unit's staff are non-UK and 50% non-EU. This in summary demonstrates the unit's in-practice commitment to diversity and equality in recruitment and appointment of staff. Amongst PGR students recruited in the assessment period, 79% have origins outside the EU, but only 8% were female implying that our recruitment efforts need to be further improved.

The Unit's commitment to Equality, Diversity and Inclusivity (EDI) is also demonstrated by staff involvement in outreach activities both within and outwith the University in support of inclusion of women and ethnic minorities in the STEM disciplines. For example, at EDI related conferences and workshops ("*Tackling the Gender Gap Together*", "*Improving Outcomes for Ethnic Minority Students in HE and FE*"). Funding was also received from the Scottish Funding Council (SFC) for "*Changing the landscape within Engineering and Physical Sciences (Equality and Inclusion in industry, academia and research)*" (**Viza**). Other research projects have also included an interdisciplinary work on raising the profile and example of historic female engineers (**Kirk**), and Global Challenges Research Fund (GCRF) and Royal Academy of Engineering (RAEng) funding for development of manufacturing capacities amongst women in developing African economies (**Viza**). The University sponsors the Council of Ethnic Minority Voluntary Organisation's (CEMVO) Race Impact Awards.

The University actively promotes a culture of flexible working, supported across the School as part of our inclusive approach to well-being, family friendly and carer initiatives. The Unit recognised the need for remote working to meet various staff circumstance, even before the current COVID-19 precautions led to the entire staff cohort working essentially in a completely flexible manner. The University has a long record of individually supporting students and staff,

in all capacities and levels, with specific needs (e.g., caring responsibilities). The Unit's primary response to this, enacted through line management arrangements, is to facilitate an individual's own arrangements for research and other responsibilities. This includes recognising the need for as much flexibility as possible in response to considerations such as caring responsibilities, illness, and to facilitating work flexibility for colleagues with disabilities, and particularly for our staff who are parents. This primarily allows for working hours variations (patterns and amounts of hours) and special leave (including holiday purchase). Staff can also apply for our Returner's Scheme if they have had a long term absence due to illness or pregnancy and maternity. This provides funding to support staff get their research career back on track.

3. Income, infrastructure and facilities

3.1 Research Income and Funding Strategy

Diversification of funding sources and activities has been the key institutional priority in this REF period. This has included UKRI, BEIS, SFC including Innovation Centres and research pools, third and public sectors, and the EU in addition to maintaining the currently high engagement through collaboration with industry through Knowledge Transfer Partnerships (KTPs), and further spin-outs.

During the period of assessment, the submitting unit was in receipt of an external income of **GBP1.85M**. Of this sum, approximately GBP359K is attributable to staff from the ITFSI (**Garcia, Hutson and Song**), GBP88K to colleagues from chemistry **(McHugh)**, and the balance to the remaining staff in **IEET** and **CIBER**. In the previous submission to UOA15 in REF2014 Engineering staff won ~GBP630k worth of grants (excluding Nuclear Physics Group who are now returned to UOA9). Therefore, for the current submission there has been a notable increase in funding to Engineering subjects at UWS, compared with the previous period. Adding other sources of external income during this period (i.e., research, consultancy and commercial research-informed CPD delivery), the total funding won is GBP3.26M.

UKRI funding has supported research during the assessment period on; hyperspectral camera sensor development (**Hutson**, NERC; **Song**, BBSRC), optoelectronic sensors for explosives detection (**McHugh**, EPSRC), laser manufacturing control (**Kirk**, STFC), Historic Built Environment- heritage science (**Hughes**, AHRC- Heritage Science Programme). In-kind facilities access support was also awarded in chemical engineering for work on supercapcitor electrodes (**Mirzaeian**, STFC ISIS beamtime RB2010730, RB1920450).

Funding from charities includes from the Carnegie Trust, for research reducing thermal noise in gravitational waves detectors (**Garcia**), coatings for medical devices (**Song**), dynamics of long span bridges, and CFD (former staff **Xia** and **Wu**, respectively). Funds have also been obtained from charity sources for collaboration development activities, for example from the Royal Society, for an India-UK green construction seminar (**Zhu**), imaging and sensors (**Garcia**); research in fluid flow and heat transfer (**Wu**); the Royal Academy of Engineering for climate change impacts on cultural heritage (**Hughes**); action on diversity in engineering and capacity building of women's enterprise in developing countries (**Viza**, several awards); history of women in car manufacturing/design (**Kirk**). Funding from the British Council facilitated research on water purification (**Altaee**); an exchange with the Central Building Research Institute, India on nano-engineered cementitious binders (**Zhu**). Additional funding from the British Council and the Higher Education Commission of Pakistan was secured in 2019, for research on self-charging energy storage (GBP250k, **Garcia**). In 2016 the RICS supported a project on Big Data in Facilities Management (**Konanahalli**), which underpins an impact case study and led to KTP funding. IAESTE funded student research on construction management (**Abdel-Wahab**).

The largest source of income has been from government bodies, notably Innovate UK supporting Knowledge Transfer Projects (KTPs). The headline awarded amount, including current projects, is **GBP4.8M**. There are 24 active projects involving staff from various disciplines

within the unit (P/Co-Is: **Docherty, Durrant, Konanahalli, Leslie, Marzano, Murmu, Obied, Rolland, Song, Vichare***)* with a further four completed projects in the period of assessment (**Mirzaeian, McHugh**, **Olabi**). Staff also act as Co-Is in projects managed outside the submitting unit, collaborating within the school with the Institute for Thin Films Sensors and Imaging (ITFSI), staff in the Division of Computing and in the School of Business and Creative Industries through management KTPs.

Additional government body support has been provided by SFC pooling initiatives for collaboration development (e.g., SAGES, **Hughes**: climate change/cultural heritage; SRPe, **Garcia**: sensors). Funding has also been secured from SFC funded innovation centres, notably CENSIS for sensor research also in collaboration with our impact case study spin out Novosound (**Garcia***,* **D. Hughes, Hutson, Song**). **Radosavljevic** benefitted from support for industrial collaboration on built asset life-cycle intelligence from Innovate UK (which contributes to an Impact Case Study); **McHugh** for thermal conductivity of powdered materials (in relation to explosives) from Cranfield University and the DSTL. **Vichare** received support from the Scottish Institute for Remanufacturing, for work on remanufacturing street lamp housings in collaboration with industry (WEEE Scotland) and Glasgow City Council, work that underpins an impact case study.

Industry collaboration activities also benefited from SFC funded Interface Innovation funds (**11 awards**), in addition to direct funding from industry for consultancy and international CPD delivery (**22 projects, GBP234,000**) where expertise and research in the unit is applied to solve real world industry problems and provide industry-relevant training. The Unit has been the executive lead (**Radosavljevic**) to establish the UK's fastest growing and Scotland's only HEI to lead CPD for the China's State Administration of Foreign Experts Affairs (**SAFEA; GBP1,200,000**) Projects span from management consultancy to aeronautical, energy, environmental and coatings engineering, and the aforementioned remanufacturing capabilities.

Funding from the EU was obtained for heritage science work on the development of multifunctional material treatments for historic buildings (**Hughes** EUR2,592,189*,* 7th FP, HEROMAT), and the effects of fire on building stone at the Mackintosh Building at the Glasgow School of Art (**Hughes***,* in-kind EUR25,000 EU IPERION CH-MOLAB). Both awards involved extensive international collaboration, and in the case of HEROMAT led to subsequent grant proposals. The MOLAB project is influencing decision making for the restoration of the Mackintosh Building.

The Unit's funding will continue to focus on these sources, particularly for proposals by established senior staff, who have networks and collaborations to support large scale applications to the research councils, Innovate UK and the EU. We are committed to mentor, support and encourage, and facilitate ECRs to learn the skills to develop successful funding applications, for example, through the previously mentioned "Crucible" and "Grant Accelerator" programme. Pursuing and obtaining knowledge transfer funding is a key part of the Unit's income strategy, to realise an increase in the amount of research activity, the number of outputs and the potential for commercialisation. A key objective is to secure increased future impact as a result of collaboration with industry. An example of this in-practice is one of the KTP projects recently awarded in collaboration with the spin-out Novosound, the subject of one of our impact case studies, supported by research from staff **Garcia, Hutson and Song** in the ITFSI. The increase and improvement in the research base (facilities, staff participation, output and impact) as a result of this strategy is intended to provide an underpinning to drive funding applications in more fundamental research. In this REF period, the Unit has also responded to calls for proposals to GCRF (**Viza**). The University's strategic plan to address the UN Sustainable Development Goals (SDGs) aligns our research increasingly with the funding to address global challenges. Several of our research areas, for example remanufacturing, renewable energy, hydrology, heritage science, and engineering management are already well aligned with specific SDGs. Given the current success in KTPs, diversity of funding sources and the developing capacity within the ECR staff profile the realistic income objective for the unit is to double external funding over the next REF period.

3.2 Organisational Investment

During the period of assessment laboratory facilities available to the unit have seen investment of GBP643,000. This includes GBP315,000 for new laboratory equipment in support of: geotechnical research (shear, consolidation, triaxial tests), microscopy (a petrographic microscope), hydrology (flume construction and profiler), construction materials preparation and testing (mixers, destructive and non-destructive mechanical/physical testing), a FARO 3D laser scanner, manufacturing/prototyping (new CNC, metrology, 3-d printing, composites preparation), bioenergy research (distillation, combustion, paper beaters), and a DSC for chemical research work (with Cranfield University).

Laboratory refurbishment has amounted to GBP246,000 invested, with an additional GBP80,000 on equipment repairs/maintenance. The laboratory space developed is in support of geotechnical research, construction materials, composites research, chemical engineering/ renewable energy research and robotics/automation and includes our specialist nano/micro-mechanical nanoindentation facility. During the period of assessment, the University consolidated its laboratories for manufacturing and automotive engineering to one location meaning all engineering laboratories are now accessible at one campus, offering utilisation benefits and convenience. Following the consolidation, our brand new and award-winning **GBP110,000 Lanarkshire campus** now includes the state-of-the-art Advanced Laboratory for Manufacturing and Autonomous Digital Applications (ALMADA), which is jointly developed by CIBER (**Radosavljevic**) and the Division of Computing (UOA11, **Riordan**). It is currently a home to approximately GBP200,000 in equipment and infrastructure and is a home to UOA11 flagship EU-funded RAPID project (EUR4,997,133). The laboratory has been specifically developed as platform for interdisciplinary world-class research that spans across UOA11 and UOA12.

This interdisciplinary nature of the unit can also be seen in cross-fertilisation with activities in ITFSI. As mentioned above ITFSI staff are submitted across UOAs 12 and 9 (Physics), dependent on disciplinary alignment of staff, and three staff contribute to the submitting unit (**Garcia, Hutson and Song**). ITFSI is notable for its strong performance in outputs, impact and its record in research income generation. Underpinning this research is a significant strategic investment, from 2016, by the University of GBP700,000 (VP Fund), for laboratory resources (plus space refurbishment a further GBP500,000) which has resulted in a world-leading infrastructure for thin film and sensor technology development. This strategic investment has levered a further headline amount of GBP2,400,000 of external research income to the ITFSI, of which some GBP359,000 awarded can be attributed within UOA12, associated with the three staff returned (**Garcia**). Projects in this area typically involve one or more industrial collaborators, aiming to ensure impact is realised from an early stage of research.

3.3 Support staff and infrastructure for impact

The Unit is supported by 6.4 FTE technical support staff dedicated to civil, mechanical and chemical engineering and is also amongst **only 10% of UK HEIs with a female chief technician**. Research in ITFSI is further supported by 3.6 FTE technical support staff, including a specialist senior technician for SEM microscopy. Elsewhere in the School, the Unit can call on a dedicated administrative support post, dealing with research matters, including finance administration and PGR student issues. In addition to the physical infrastructure that facilitates research activity, discussed below, the support for research activity amongst the Unit's staff is possible due to a supportive environment in terms of expectations of staff activity planning processes, that recognise, promote and reward research activity (Section 2), but is also due to an underpinning space and laboratory infrastructure. The following resource that is described has been utilised and is integral to the unit's achievement of impact.

The Unit is well served by approximately 2,500 m^2 of dedicated civil engineering, manufacturing and chemical engineering laboratories. The laboratory space incorporates comprehensive materials testing facilities, including a strong wall and 200 te ESH testing machine, capable

of testing full-scale building elements and other components. This is complimented by capability for variable scale mechanical testing from the macro to the nanoscale. This includes the **first nanoindentation facility in academia in Scotland** established by **Zhu** in the 1990s that has been utilised in research on a wide variety of materials including cementitious and carbon fibre composites for construction and aeronautical applications, and natural biomaterials. This is supported by a metrology laboratory and a fully equipped petrographic (for thin and polished sections) and metallurgical preparation workshop. The Nanoindenter G200 system was upgraded in 2015 to 2016 to permit state-of-the-art rapid testing. This greatly increases the rate of data acquisition and improves statistical outcomes of testing.

To support mechanical engineering research, the Unit has a fully equipped fabrication workshop, welding and assembly facility and rapid prototyping laboratories (design, scanning, 3D printing and CNC). The Unit also possesses a room-sized anechoic chamber. In the area of renewable energy research, we maintain a Biomass laboratory (anaerobic digestion, homogenizer, Hollander beater, combustion gas analysers); an energy storage laboratory with environmental and vacuum ovens, environmental furnace with variable gas inputs and BET, for the preparation of porous gels and carbon. Furthermore, our facilities include a membrane separation laboratory for desalination and wastewater treatment.

In a true spirit of interdisciplinarity, the unit has access to facilities in the ITFSI, that have been maintained and enhanced and are available for use in research - AFM, FE-SEM-EDS, Auger and Raman Spectroscopy, contact angle measurement and XRD, and more. In particular the SEM benefitted from approximately GBP60,000 investment in 2015 (EDX detector upgrade, new backscatter detector\chamber scope and stage controller, OXFORD control software). Investment in laboratory space also accompanies grant success, where facilities are required such as the lab refurbishment for an EPSRC project (**McHugh**). Across the School there are well equipped chemistry laboratories with standard analytical facilities, including the approximate GBP600,000 investment in the new NMR and ICPMS, which is accessible to staff in the submitting unit.

The success to date with KTP funding and the activity submitted in our ICSs, and in the wider impact of our research that is achieved in working with collaborators and stakeholders, is due in large part to the supportive environment described above, but also the focus of our infrastructure, that has been invested in to have benefits for generating impact. The infrastructure supporting impact is not only physical, but human and organisational. This is exemplified in our case study on product design and process development led by **Vichare***.* In this, a multidisciplinary approach was adopted that combined several areas of staff expertise across UOAs to realise impacts on the development of new concepts in manufacturing design and prototyping, but that also effectively translate to real world production and impact, in several projects. Key to this is a flexible unit structure to allow new teams to be incorporated rapidly, in this case bringing together product design and data management, process/work-cell design with work-study analysis, digital mock-up tools and environmental impact analysis. The physical product mock-ups were possible using industry standard design software (CREO), CNC machines, workshop machining and metrology resources, 3D printing and injection moulding capabilities.

This infrastructure was combined with skilled technical support without which the impact could not be realised. This inter/multidisciplinary approach has relied on several academic staff (**Vichare, Marzano***,* **Olabi**), and cross-institutional collaboration, in this case with the ITFSI (**Gibson***,* returned in UOA9). This led to impacts in health, coatings and remanufacturing (with stakeholders: Histocell, Helia Photonics Ltd, Shenghai JAVAC (China), WEEE Scotland Ltd, Glasgow City Council), and to further KTP projects. The industry-leading coatings technology at ITFSI Specialist infrastructure includes unique resources: RF and DC magnetron sputtering, electron-beam and thermal deposition, plasma assisted physical vapour deposition, microwave assisted reactive sputtering, ion beam sputtering, hollow cathode plasma enhanced chemical vapour deposition and molecular beam epitaxy in addition to several characterisa-

tion methods previously mentioned. These resources have been extensively used in the development of new technologies and form a key element in UWS's impact strategy. For example, ITFSI facilities have enabled the partnership with Glenrothes-based semi-conductor foundry Semefab Ltd that has used ITFSI novel thin film technology, leading to improved performance of infrared detectors embedded in non-contact thermometers. This has now led to a KTP application submitted in January 2021. Another example involves commercial exploitation of UWS research by Helia Photonics Ltd of patented plasma-assisted deposition technology. This KTP was recognised in winning the Centre for Engineering Education and Development's (CEED) Knowledge Exchange Award 2020.

3.4 In-Kind Benefits

The Unit has been the beneficiary of multiple donations (approximately GBP200,000) for equipment from our Alumni including the purchase of concrete crusher, In addition, other donations have included bursaries and equipment for the area of colour science, technology and formulation chemistry, from the multinational company BASF, with which unit staff member **McHugh** has a collaborative relationship. The facilities donated include a gas chromatograph, HPLC, FT-IR, GCMS and a UV-Vis Spectrophotometer, together worth approximately GBP80,000. This equipment has been heavily utilised in both teaching and research by a number of colleagues across the unit's host School. The school structure also permits access to a wide range of laboratory resources across divisions.

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

The projects above clearly demonstrate that staff in the Unit participate in a full spectrum of external collaborative activity in support of research. We have become a major international player, contributing to the health of our disciplines as members of professional networks and societies, attend, present at and organise conferences in their respective fields. Staff are contributors in reviewing academic publications, research proposals, external evaluations, and acting as external doctoral examiners at numerous HEIs.

4.1 Research Collaborations, Networks, Partnerships and Communities

Scottish Research Pools and Innovation Centres: The research environment has been significantly enhanced by our membership in the SFC supported pools: **ETP**, **SRPe** and **SAGES**, and we have been the beneficiary of funding from all of these within the period of assessment. Staff and students have benefitted from involvement, PGR students from support from the University's Doctoral College in each and staff from pooling funding support, for proposal development (known as PEER) and networking/professional development (known as PECRE). In the areas of Civil Engineering and Construction the Unit is a member of the Construction Scotland Innovation Centre (**CSIC**, Konanahalli is an Innovation Champion). Our MSc programmes in Civil Engineering and in Construction Management have a 100% record in attracting fee support from the CSIC for dissertation research projects pursued in collaboration with industry partners. In relation to ITFSI, staff are involved with the Innovation Centre **CENSIS**. Colleagues in manufacturing have obtained support and worked with the Scottish Institute for Remanufacturing.

National and International Partnerships and Networks: The Unit has collaborative agreements with external academic institutions for co-supervision of PGR students. Well-developed formal agreements and relationships exist with several German and Austrian Universities of Applied Sciences (e.g. Hochschule Mittweida,). Educational collaborations are also in place with the Rostov State University of Civil Engineering and with the Changchun Institute of Technology and in research with the Changchun University of Science and Technology. Staff in the Unit have collaborated with more than 60 UK and overseas academic institutions in research projects and subsequent publications. This reflects work developed both from activity originating at UWS, but also a legacy of staff experience brought to the unit. It is a clear benefit to the Unit to have a diverse cohort of staff, and an open, internationalised recruitment policy. During this REF period, collaboration has occurred with the following universities: Aston; Auckland; Bath; Beihang; Beijing Univ. of Aeronautics and Astronautics; Belgrade; Brunel; Cambridge, Changchun Institute of Technology; CNR Institute of Atmospheric Sciences

and Climate, Bologna; Coventry; Cranfield; Curtin Sarawak; Dalian; Darmstadt; De Montford; Dublin City; Durham; Ecole Nationale Polytechnique d'Alger; Ecole Polytechnique de Montreal; Edinburgh; Edinburgh Napier; Extremadura; Farahan; Gadjah Mada, Indonesia; Glasgow Caledonian; Glasgow School of Art; Glasgow; Heriot Watt; Hertfordshire; Highlands and Islands; Hong Kong; Kazakh National Research Technical University; Kingston; Leicester; Liverpool John Moores; Loughborough; Malaga; Malta; Manchester; Maribor; Memorial, Canada; Naples; Newcastle (Australia); Nis, Serbia; Northern Artic Federal University, Russia; Northumbria; Nottingham; Novi Sad; NTNU; Queen's Belfast; Reading; Sharjah (UAE); Shiraz, Iran; Slovenian National Building and Civil Engineering Institute; South Wales; Stirling; Strathclyde; Surrey; Swansea; Trinity College Dublin; University College Dublin; Warwick; West of England; Wolverhampton; Wroclaw. In addition, collaboration has been established with international umbrella organisations for research, including the Central Building Research Institute, India; Eduardo Torroja Institute; Czech Academy of Sciences; Serbian Academy of Sciences and Arts; the Getty Conservation Institute and industry (>30 companies, including BAE Systems, BASF, QinetiQ and Spirit Aerosystems, and in addition those outlined in our ICSs). Further, we have collaboration with Historic Environment Scotland and the National Trust for Scotland. Staff in ITFSI, have a number of notable academic, industrial national and international collaborations. Foremost is the partnership with Glasgow University's Institute for Gravitational Research and other UK and international academic partners. The ITFSI contribution is on optical coatings for use in detector apparatus. Together with Glasgow and Strathclyde Universities, ITFSI is a partner in a National Manufacturing Institute Scotland-sponsored project "Excellent Performance Optical Coatings" (GBP2,000,000). Collaborations with overseas universities include Changchun University of Science & Technology, Tong Ji, Fudan, Rochester Laboratory for Laser Energetics, Stanford; and in the UK: Glasgow, Strathclyde, St Andrews, Lancaster, Birmingham and Cambridge. Industrial collaborators include Qioptiq, Teer Coatings, Helia Photonics, Wideblue, Gas Sensing Solutions, Novosound, Leonardo, Thales, Integrated Graphene, Pyreos, Alphasense, Key FM, CST Global, Umicore Coating Services, Gooch & Housego (with which there is an equipment sharing agreement) and Rolls Royce.

Professional Communities Nationally and Internationally: Staff are engaging with users, beneficiaries and communities nationally and internationally (from Historic Environment Scotland to the International Organization for Standardization). Staff contribute to communities through numerous external advisory groups and organisational committees. The highlights are: **(Hughes)** International Advisory Committee, Academy of Sciences of the Czech Republic, Institute of Theoretical and Applied Mechanics, Board of ICOMOS International Scientific Committee for Stone; **(Konanahali)** Scottish Future Trust: BIM 4 Academia Group; **(Tennant)** Cross Party Group in the Scottish Parliament on Construction; **(McHugh)** RSC Scotland Regional Committee; **(Walker)** Scottish Mathematical Council (treasurer) and Scottish Mathematics Support Network; **(Radosavljevic)** CARPE (Board member); Zhejiang (China)-UWS Innovation Base (Founder and Co-Chair); Energy Technology Partnership (Board member), Lanarkshire Economic Forum (Chair), Ayrshire Economic Partnership (member and Chair: Clean Growth Workstream), Universities Scotland Research and Knowledge Exchange Committee (member). All staff are also active members of professional institutions and organisations, including ASCE, Concrete Society, CIOB, Geological Society, IAENG, ICE, IChemE, ICOMOS, IEEE, IMMM, ISO, MIMA, RIBA, RILEM, RICS, RSC).

4.2 Contribution to Economy and Society

Our Impact Case Studies in rapid prototyping/remanufacturing, smart built asset management and ultrasound sensor commercialisation exemplify the Unit's contributions to the economy and society, principally through increases in gross value added (GVA), environmental, economic and social benefits. As described above, key to the achievement of impact is our focus on knowledge exchange. Adding our involvement in KTP projects with Innovate UK assessment of GBP7.5 gross value added GVA for every GBP1 investment, we have directly contributed to the generation of **>GBP18,000,000 GVA to the UK economy**. Further examples of contributions to economic and social impact include: **(1) Mirzaeian** has developed production of controlled nanoporous gels/carbons for use as functional materials. This has led to new

carbons for battery and supercapacitor electrodes to make electrified transport more affordable, electrodes for water electrolysis cells for on-site hydrogen generation and the design of new carbon electrodes and electrochemical cells for the recovery of metals from waste electronics. Knowledge transfer has led to industrial process improvements and contributed to European policy recommendations for the increased recovery of materials from Waste from Electrical and Electronic Equipment (WEEE). The results of this research are included in **EU Policy and Infrastructure Recommendations** reports. **(2) ITFSI** partners with Glenrothes-based semi-conductor foundry **Semefab Ltd**, working to improve performance of infrared detectors embedded in non-contact thermometers. This led to **>12,000,000 detector chips being ordered during the COVID-19 pandemic**. With collaborator Helia Photonics Ltd the group exploited knowledge transfer in patented plasma-assisted deposition technology through a KTP that won the Centre for Engineering Education and Development Knowledge Exchange Award 2020. **(3)** Staff also engage in **outreach activities**, focussed on STEM engagement, **Walker**, (numerous mathematics-focussed STEM events for schools across Scotland); **Bae** ("Gateway to Engineering"), **McHugh** (Wellcome/STFC, RSC). Conference hosting (see below) has made an economic impact on the local economy of the University, approximately at several GBP100,000.

4.3 Wider Influence and Contributions

Major editorial contributions: Staff serve on editorial boards (>10), as committee members and special edition editors for peer-reviewed journals, including: *International Journal of Architectural Technology and Sustainability, Heritage* **(Hughes)**; *International Journal of Civil Infrastructure, Sustainability, Journal of Innovative Engineering* **(Zhu)**; *Energies* **(Mirzaeian)**; *Energy* (**Olabi**); *Applied Sciences Journal*, *Organization, Technology and Management in Construction: an International Journal* (**Radosavljevic**). On average each staff member serves on at least one conference scientific and/or organisational committee annually (>34 in total).

Peer review of research outputs: Staff review for numerous international peer reviewed journals (>50), which among others include: InterAlia, Acta Crystallographica (IUCr), American Institute of Physics (AIP), Applied Surface Science, Archaeometry, ASCE Journal of Materials in Civil Engineering, Atmospheric Environment, Automation in Construction, Buildings, Journal of Building Construction and Planning Research, Bulletin of Engineering Geology and the Environment, Cement and Concrete Research, Chemical Communications (RSC), Chemistry Society Reviews (RSC), Climate, Coatings, Construction and Building Materials, Construction Management and Economics, Dyes and Pigments, Engineering, Construction and Architectural Management, Environmental Earth Sciences, Heritage Science, Materials and Structures, Industry and Higher Education, International Newton Fellowship of Royal Society, Isotopes in Environmental & Health Studies, Journal Materials and Environmental Science, Journal of Construction Engineering and Management (ASCE), Journal of Cultural Heritage, Journal of Management in Engineering (ASCE), Journal of Materials Chemistry A (RSC), Journal of Materials Chemistry C (RSC), Journal of Physical Chemistry C (ACS), Journal of Purchasing and Supply Management, Journal of Performance of Constructed Facilities (ASCE), Journal of the Institute of Conservation, Materials and Structures, Nanotechnology (Nature), Optics Communications, Physical Chemistry Chemical Physics (RSC), Quarterly Journal of Engineering Geology and Hydrology, Radiocarbon, RSC Advances (RSC), Sensors, Studies in Conservation, Studies in Higher Education, TQM Journal, Ultrasonics, Journal of Zhejiang University-SCIENCE C.

Peer review of research applications: Staff participate as reviewers for several funding bodies, including the UKRI (**Hughes, Konanahalli, Radosavljevic, Song, Zhu**), and also for overseas research bodies (**Hughes**: Belgian Science Policy Office, Science Centre Poland, Austrian Academy of Sciences Grants Panel, EU-ERC, Latvian State Education Agency; **Radosavljevic**: EU, Croatian Science Foundation).

Dissemination, prizes and awards: Staff have given in excess of 110 conference presentations, >30 invited presentations, including several keynotes, during the period. The hosting of

conferences is actively encouraged with support coming from the School service delivery and the University support departments. Staff time allocation is permitted for this and the opportunity is taken for the involvement of research students for networking and personal development. Examples in the assessment period include the 13th International Congress on the Deterioration and Conservation of Stone (**Hughes**, Chair 2016) and the 11th international conference on Sustainable Energy & Environmental Protection (**Olabi**, Chair 2018). Conference hosting brings raises the profile of the staff involved internationally, generates commercial income (in the assessment period approximately GBP100,000) and results in widely read publications including journal special issues and edited volumes. **Hughes** has been awarded a prestigious Getty Conservation Institute Guest Scholarship (2020, COVID-19-postponed to 2022). **Walker** is a visiting research fellow at the University of South Wales. **Bae** is a visiting lecturer at Texas A&M University. **Zhu** is Visiting Professor at Changchun Institute of Technology. **Wrzesien** is a Member International Advisory Panel, Malaysian Cold-formed Steel Institute. **Cano** was a visiting Professor at the University of Angers (2015).