Institution: Glyndŵr University

Unit of Assessment: UoA12 - Engineering

1. Unit context and structure, research and impact strategy

Structure

This submission is made within the context of a compact university with approximately 180 academic staff and 6,500 students. There have been two major university restructures since the last REF, the most significant in 2018 following the arrival of the new Vice Chancellor and leadership team and a reconfiguration from Schools to Faculties, creating larger, more cohesive academic units. There are two faculties: The Faculty of Arts, Science, and Technology and the Faculty of Social and Life Sciences, each led by a Dean and supported by a team of four Associate Deans and a Faculty Business Manager.

All submitted staff are members of the University's Faculty Research Centre for Arts, Science and Technology led by the Associate Dean for Research. There are distinct groupings of researchers within the UoA, which do not have formal status in the organisational structure of the institution, and which can and do change over time. In the previous REF submission in 2014, the comparable unit of assessment was 'Electrical and Electronic Engineering, Metallurgy and Materials'. For this submission, the unit of assessment is 'Engineering'. Research in this area has developed from the previous submission but still can be summarised as 'engineering and advanced materials'. The information presented below for the unit context shows the development and progress from the 2008 RAE and 2014 REF submissions in these areas. It encompasses four broad themes: composite and advanced materials, functional polymers, electrical and electronic engineering (including antennas), and ultra-precision surfaces and metrology.

The submission includes staff across these areas who are independent researchers with significant responsibility for research.

Composite and advanced materials – Professor Richard Day, Professor Alison McMillan, Dr Zheng Chen, Dr Xiaobing Huang

More recently, research in advanced composites and ultra-precision surfaces has been established as a result of collaboration with Airbus. In all cases, the research is underpinned with excellent facilities and high levels of funding with a close engagement with key manufacturing industries.

The Advanced Composites Training and Development Centre, a joint venture with Airbus, established in 2010 and supported by Welsh Government as part of a £28m investment into composites manufacturing has established its place as the go-to facility for out of autoclave processing of composites using microwave heating, reflecting the challenges in manufacturing needed to address the capacity and rate issues with existing manufacturing technology. This is recognised by the EPSRC Future Composites Manufacturing Hub, where **Day** has been invited to be the lead on the microwave stream of work. The team have been at the forefront of this technology and have developed new methods for processing carbon fibre composites and have undertaken research into understanding the properties and chemical structure of the materials, which are key to adoption in safety-critical applications. They can manufacture complex geometries with mixed composite and metallic structures using microwave heating, which leads to lower energy consumption. **Day** was appointed to a new Chair in Composites Engineering in 2010 as part of an agreement with Airbus and Welsh Government to expand the composites capability in the region. In early 2010, he oversaw the design and installation of Glyndwr University's (GU's) facilities in what became the Advanced Composites Training and Development Centre, a joint facility between Airbus and GU. The main thrust of the research in this purpose-built facility is around rapid curing of composite laminates to reflect the issues

which will delay the implementation of composite designs into transport. The challenge is to find manufacturing routes to provide the capacity for delivering composites at the rates required. The main part of the work in the centre is thus based around developing novel manufacturing technology for rapid manufacture of composites together with a deep understanding of the effects this has on the structure and properties of the materials. Microwave heating has been modelled in collaboration with colleagues at Bauman Moscow State Technical University, Russia (joint PhD student Rumyantsev) and the Advanced Manufacturing Research Centre with Boeing (AMRC). **Day** has collaborated with AMRC to understand a range of practical issues to enable manufacturing with industrial heating including tooling materials, control strategy, and use of microwaves absorbers.

Ultra-precision surfaces and metrology

The OpTIC centre in St Asaph has a similar focus in reducing the manufacturing time while maintaining quality, but in a very different area of manufacturing, ultra-precision surfaces for optical applications. The University purchased and refurbished what had been one of the Welsh Government's 'Technium' centres in 2008 with a £2 million initial investment to provide a focus for its research and industrial engagement in the field of opto-electronics. Two research groups initially based there won substantial grant and commercial contract income (including EU FP7, EPSRC, TSB) enabling investment in specialist resources underpinning the current focus of research activity and reducing the manufacturing time of ultra-precision optical systems from durations of years to days. The OpTIC Centre is now a world leader in this area of precision manufacturing of optical surfaces. That has been complemented by the recent £1.4 million investment in a unique thin film coating facility part-funded by ERDF.

A relatively new area is the application of composites in lightweight mirror systems, thus linking the expertise in ultra-precision surfaces into composites manufacturing, building on the collaboration between the composites and ultra-precision surfaces teams.

Rapid prototyping has become an important technology. When used for visualisation, the structural performance is immaterial but additive manufacture is now being considered for field replacement of components; **McMillan** is undertaking simulation of the lifetime from the distribution of defects.

Functional polymers - Professor Pete Williams, Dr Ian Ratcliffe, Dr Jixin Yang

This area was established at the University in the 1980s and has a world class reputation through a combination of fundamental research, enabling the underpinning of research capability, together with applied research in collaboration with industry. As set out in the research plans in REF2014, a key focus over recent years has been the extraction, physical and chemical modification and application of biopolymers from biomass and waste streams. Work on the modification of inulin to produce novel biosurfactants for encapsulation and delivery of water insoluble active compounds was initiated through a BBSRC funded project (BB/1005315/1; £477K) and has continued through several funded PGR studentships leading to research publications (e.g., Carbohydrate Polymers 201 615, 2018; Carbohydrate Polymers 238 116199, 2020). Work on chitosan from prawn shells has continued through a TSB project (Project no. 101440; £929K) involving Unilever Research, Croda Europe Ltd, Almac Ltd and Seagarden, Norway and has led to the production of novel chitosan derivatives, which are soluble across a broad pH range and which have application as thickeners and gelling agents in a range of commercial formulations. A collaborative project with Croda Europe Ltd was undertaken to extract proteins from rape seed meal, which is a residue from the rape seed oil industry BBSRC FoodWasteNet (2015, £40K). The proteins obtained were found to have good emulsification properties and on hydrolysis produced novel surfactants with commercial potential. Other projects have included the valorisation of pectin from broccoli stems (collaboration with University of Parana, Brazil) and from Creeping fig tree (collaboration with Nanchang University, China). Several projects have been undertaken on the characterisation and development of pharmaceutical formulations in collaboration with GSK (direct funding) and with Quay

Pharmaceuticals (Knowledge Transfer Partnership 009027, £107K). A current project has involved the development of technologies based on polysaccharides/proteins for application in the food industry to minimise food waste (Mimicalab Ltd; £39K) and this is expected to continue. The collaboration with the Phillips Hydrocolloids Research Centre, Wuhan, China has continued and has led to joint publications.

Electrical and electronic engineering (including antennas) – Dr Yuriy Vagapov (reader), Dr Sultan Shoaib, Dr Majeed Soufian, Dr Bo Liu (left January 2020)

There has been significant growth in research in this area since REF 2014 focussing on two distinct areas: electrically powered vehicles and antennae design. Predictions are that the requirements for charging, and particularly home charging of electric vehicles, will significantly change the requirements and configuration of the electricity grid. **Vagapov,** working with colleagues at Moscow Power Engineering Institute has proposed algorithms for the placement of charging stations. Electric power for flight is an important goal; **Vagapov** and Bolam have developed rim-driven fans with performance that exceeds that of centrally driven electric motors and applications in aircraft propulsion, particularly high speed uncrewed aerial vehicles. This has been funded by a Welsh Government SMARTexpertise grant. It is a collaborative project with industry partners in Wales and England. This recognises the growing importance of electrical propulsion as a research area at Glyndwr.

Another growing area of interest is antenna design, particularly for WiFi and 5G. **Liu** and Akinsolou have developed effective solutions using code they developed at Glyndwr University and work closely with software vendors to embed this code into commercial packages.

Digital Technologies in Design and Construction – Dr Colin Stuhlfelder

Stuhlfelder's current research interests focus on digital technologies in building design (including building information modelling, the use of digitisation in the creation of immersive environments, virtual reality, and data quality in digital environments), and the use of technologies such as drones, scanning, and various immersive technologies within the construction industry and the field of civil engineering. **Stuhlfelder** has a particular interest in the impact of design activity on end users (for example, in social housing).

Developments and progress have been shaped by staffing changes, increased collaboration (e.g., with computing) and a greater emphasis on the research-teaching nexus. One area of growth in this respect has been student and staff collaboration with research in electrical engineering. There has been some restructuring of the area in which the UoA sits meaning that all colleagues entered into this UoA are now part of the same organisational unit with frequent formal and informal interaction. There is a great deal of overlap with these areas in terms of research activity and staff. This has been encouraged in the university research strategy which has these principal aims:

- Develop research capacity and capability of the university by developing its staff
- Grow the post-graduate research community
- Increase the number of active industrial and academic research collaborations
- Grow outputs and income associated with research
- Increase the visibility, impact and value of our research

Overall responsibility for matters related to research rest with the University's Research Committee, which reports directly to the Academic Board. **Day** is Chair of this committee in his role as Pro Vice-Chancellor for Research and **Ratcliffe** is a member for the Faculty of Arts, Science and Technology. The committee's remit particularly concerns the development of relevant policies and procedures, the identification and dissemination of good practice in research across the University, and oversight of research governance matters. Informed by the University's Vision and Strategy Statement (2020-2025), an Action Plan for research is developed on an annual basis by the Research Committee; the current Action Plan has a

particular focus on supporting less experienced staff develop their research capacity and experience. The Associate Deans with responsibility for research are responsible for implementing the Action Plan. A recent development is the recruitment of 'Research Strand Leads' to champion, encourage, and co-ordinate research within and across disciplines. **Day** and **Ratcliffe** currently have this role; **McMillan** and **Vagapov** undertake substantial informal mentoring.

External Engagement

All current research activity at the University is underpinned by the University's Vision and Strategy Statement (2020-2025), which seeks to position the institution as an anchor point for the region with a distinctive applied focus and mission to inspire and enable economic, cultural and social success. Practitioner experience informs learning and teaching at the University and is leveraged to meet the economic needs and enrich the communities that the University serves. The research ambition is that the University will engage in 'Research that Transforms'. To this end, the University is seeking to improve its research capacity and performance in meaningful partnerships, with a strong emphasis on research that has an applied and/or commercial potential to support economic, social, and cultural development.

Academic staff across the University are encouraged and supported to engage in research related external engagement, such as collaborative research, external supervision and examining, knowledge transfer, public engagement, engaging in the work of professional bodies and subject associations. 9 of the 11 submitted staff in this UoA are active and recognised contributors to professional associations, learned societies or subject associations, as are two thirds of the broader cohort of academic staff associated with UoA12. Funded research is expected to have a pathway to impact.

The OpTIC centre in St Asaph is an exemplar of the University's ambitions and intentions. The main focus of the activity at OpTIC is the translation of academic expertise in optics and metrology into groundbreaking technological developments for government agencies and companies with a global reach. This is achieved in part through interdisciplinary working across the UoA, particularly in relation to Composite and Advanced Materials. The Impact Case Studies selected for this submission reflect the current and recent activity at OpTIC. The academic strength of OpTIC is growing over time, and it is expected that academic staff based there will be included in the next REF submission.

Open Access

The UoA is supported by the University's Research Office, which manages Open Access issues across the institution, and all submitted staff are represented in the online repository, Glyndwr University Research Online. The University's Digital Enhancement Strategy includes as one of its domains, 'To develop a digital research environment that will allow University staff to enhance their research capacity and capability in order to drive innovation and increase the visibility and impact of their research.' The Strategy is driven by the University's Digital Enhancement Programme Board, and the Priority Actions include, 'To ensure that information and research data management practices are appropriate and support knowledge creation and sharing.' The University has a policy on Open Access to Research Data, and a strategy and action plan for enhancing implementation are in preparation.

Research Integrity

The Research Office also supports staff across the UoA in terms of research integrity, including compliance with the Concordat to Support Research Integrity. The Research Office provides the operational support for the University's Research Ethics Sub-Committee (RESC, reporting to the Research Committee), which develops policy and guidance regarding research ethics, monitors policy implementation, and reviews applications for ethical approval in certain categories. **Stuhlfelder** is Chair of RESC and **Yang** is a member.

2. People

i. Staffing strategy and staff development

There were 28 members of academic staff associated with UoA12 at the REF census date, 11 of whom meet the criteria set out in the University's Code of Practice for inclusion in the REF submission.

The University's aims are aligned with the three principles of the Researcher Development Concordat:

1. **Environment and culture**: continue to build and enrich the research environment across all areas in the University through the Associate Deans (Research) and the Research Strand Leads, encouraging research groups to form and collaborate.
2. **Employment**: ensure a focus on recognition, explicitly including Postdoctoral Research Assistants (PDRAs), Graduate Teaching Assistants (GTAs), and colleagues at earlier stages of research careers in the University's processes for self-reflection, for the availability of critical friends, and for review of research ambitions and barriers.
3. **Professional and career development**: ensure PDRAs, GTAs and colleagues at earlier stages of research careers are included in all relevant opportunities to take part in events and training & development activities, supporting the acquisition of transferable skills and valuable experiences.

The University holds the HR Excellence in Research Award and has recently submitted a new Action Plan. The University's policies and processes are consistent with the principles of the Concordat to Support the Career Development of Researchers. The revised Concordat was published in 2019 and the University has revised its related strategy and action plan to more closely align with the stated focus of the revised Concordat. The focus of the University's strategy is on Research Assistants and GTAs, that is, individuals at very early stages of their research careers. Priority actions concern communications with staff regarding the Concordat, support for managers completing probationary reviews, with guidance provided to reviewing managers to include specific objectives around engaging with research activity and relevant training, and staff are contributing to a study of 'what makes a good research environment?' A PGCert programme, 'The Confident Researcher, is to be launched in 2021 in a pilot phase, and at least one of the UoA12 submitted staff will be involved in this pilot.

The university requires all new academic staff to have a doctorate, complementing their professional experience. This is to help achieve the desired aim of achieving growth of the research capacity and capability set out in our strategic plan. Between 2014 and 2017, the proportion of staff with a doctoral degree dropped, due to the restructuring and stabilisation of the university during that time. Following the introduction of the requirement for new staff to hold a doctorate, together with existing staff successes in their studies, the proportion has steadily increased; 36% of all academic staff and 41% of full-time staff now hold a doctoral qualification. 68% of all academic staff associated with UoA12 hold a doctoral qualification and all but two of the remaining staff are currently studying towards a PhD.

This policy is supporting an increase in PGR supervisory capacity. 46% of academic staff associated with UoA12 have either Principal or Secondary supervisor status (the former is the criterion set out in the Code of Practice for recognition as 'an independent researcher with significant responsibility for research').

Academic staff are normally appointed on indefinite (permanent) Teaching and Research contracts of employment.

The university now requires all its academic staff to have a personal research plan (PRP) as part of the Professional Development Review process. This plan is discussed during the review as a basis for supporting the member of staff and is also used by the university for planning of research spend priorities. 68% of the current PRPs of staff associated with UoA12 indicate research activity, and 71% provide evidence of personal experience of research in other institutions (e.g., collaborative research, contributions to seminars). PRPs include opportunities to comment on perceived barriers and requirements as well as providing a framework for setting out achievements and forward plans; they are a valuable resource for the Associate Deans in their ongoing assessment of the research environment.

There are 10 Visiting Professors associated with UoA12 from industry and universities in the UK and abroad; relationships include research collaborations and contributions to teaching and research student supervision.

The university has a work allocation model that is used to record, and moderate time devoted to teaching, research, and citizenship. Time allocated for research depends upon either the member of staff having funded work or a plan to undertake research, paper writing, or grant submission demonstrated through the individual's personal research plan. 68% of staff in UoA12 have produced peer reviewed research outputs in the past three years.

A programme of generic skills training and personal development events based largely on the Vitae Researcher Development Framework is provided for the research community. A joint faculty Research Seminar series includes talk from researchers within and outside the University. There are two staff conferences each year, which have a strong research component. Submitted staff have contributed to several such events:

Training events
McMillan: Identifying questions and testing strategies to drive your research; Preparing for conferences; Preparing conference papers; Workshop on using LaTeX
Vagapov: Writing for publication
Ratcliffe: Writing for publication

Joint-Faculty Research Seminar Series 2019
Day: Cooking up composites
McMillan: Towards a better understanding of fatigue life for additively manufactured high duty components

Staff Conferences
SpringBoard 2019 – **McMillan**: Ways & Means: Getting published
Engage 2017 – **Day**: Why do research? My research journey

The medium-term objective in developing research culture and capacity within the university is to achieve Research Degree Awarding Powers. Associated with this, there is a focus on supporting early career staff to gain doctoral qualifications and developing staff in posts towards holding significant responsibility for research. There is support for staff to take the first steps in collaborative projects with other universities and in presenting at conferences with three awards open to all staff and research students. The first is the ‘External Funding’ award, for staff who have an opportunity to bid for external research funding with colleagues in one or more other institutions, and who have not previously gained external research funding. The second is ‘First Collaboration’ award, for staff who have not previously undertaken a structured research project (funded or unfunded) with colleagues in one or more other institutions. The final one is the ‘Conference Contribution’ award, for staff to have the opportunity to present during the current year at an academic conference or a conference run by a professional body (including a poster presentation). This award is also open to Postgraduate Research Students. One early career researcher associated with UoA12 has benefitted from this scheme supporting research activity in the field of antenna design and optimization.

The Associate Deans for Research have a particular interest in encouraging interdisciplinary research links within and between academic fields. An example is the Computational Mechanics, Manufacturing Simulation, Design and Optimisation Group (CoMManDO) research group led by **McMillan**, with research themes covering simulation and analysis including fluid-structure interaction, fatigue and fracture mechanics, and system dynamics; and computational methods including algorithm development and application, computational intelligence and optimisation. **McMillan**, with the support of the Associate Dean for Research in FAST, is coordinating a project linking the life of Sir Francis Bacon and his contribution to science development to an updated version of his imperative: "for the relief of man's estate", bringing together scientists and engineers with those from the humanities and arts. In addition to the interdisciplinary engagement within Glyndwr, this activity also engages with external academics and industrialists including a company chief scientist from the USA, a retired research professor from CERN, an intellectual property lawyer, and a politics professor from the USA.

There is a 50% fee waiver for all staff wishing to undertake a PhD and all new members of staff have a lighter teaching load to encourage them to engage in research. There is also a sabbatical policy to enable time for research and informal mentoring arrangements are.

The University is a member of GuildHE Research, the research consortium for smaller and specialist higher education institutions. This organisation is a collegiate peer-to-peer network of 30 comparable institutions that supports its members to embed a positive research culture, develop robust research and innovation strategies, and establish appropriate infrastructure through which they can drive forward their ambitions. It provides researchers of all stages with opportunities to network and collaborate with peers across the UK and from a broad range of disciplines, facilitating activities face-to-face and virtually, including an annual doctoral summer school, training events, and opportunities to forge new projects and communicate their research.

ii. Research Students

Recruitment of doctoral students

The University's doctoral students in UoA12, as in other areas, have different pathways to joining the University. During the assessment period, enrolments have occurred through relationships with industry, through progression from PGT programmes, and through independent applications to the University. A number of students are University staff seeking to gain doctoral qualifications.

Although the University (and its predecessor, the North East Wales Institute of Higher Education) has been awarding research degrees since 1975 (more than 300), there was a student recruitment hiatus between 2014 and 2016 following the University of Wales's withdrawal from awarding research degrees for partner institutions. The University of Chester is now our awarding body, and the University's PGR student population is increasing again. 46% of academic staff associated with UoA12 are eligible to be nominated to supervisory teams. The 2019/20 HESA return reported 73 PGR students, 19 supervised by academic staff associated with UoA12. Increasing supervisory capacity is a priority to enrich the research environment and to support our aim of having more than 80 PGR students across the University by 2022/23. Academic staff without a doctoral qualification are supported in achieving that, and 8 staff (29%) associated with UoA12 are currently studying towards a PhD.

All PGR supervisors undergo Equality, Diversity, & Inclusion training as part of the preparation for that role; the HR department manages that process.

The total number of research degree awards during the assessment period where supervisory teams have been associated with UoA12 is:

Research Degrees awarded							
	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020
PhD	3	4	3	7	1	2.6	5
MPhil	0	1	1	3	0	0	0

One PGR student has been funded by a research council during the assessment period (Evans; BBSRC, Synthesis of biosurfactants based on fructans using green chemistry. Completed 2015/16, supervised by **Williams**).

UoA12 submitted staff are currently in Principal Supervisor roles for 20 doctoral students registered for University of Chester awards; there is also a small number of students completing their programmes of study for University of Wales awards.

Monitoring and Support

Administrative monitoring and support mechanisms are currently based within the University's Strategic Planning and Student Administration Directorate (SPSA). Progress is monitored initially by the supervisory team and then reported to SPSA. SPSA staff undertake twice-yearly audits to highlight cases where potential slippage is evident, enabling remedial action at an early stage. The two Associate Deans for Research provide an additional resource supporting and encouraging supervisory teams. SPSA maintains the formal register of PGR supervisors (linked to University of Chester criteria). New academic staff are assessed for eligibility as part of the joining process, and the Associate Deans for Research undertake an annual review of all current supervisors.

Skills Development

Support for PGR students in terms of induction and training is mainly provided at University level, led by the Researcher Development Tutor. All research students are required to take part in the University's research and transferable skills training programme. This has been mapped against the Vitae Researcher Development Framework and supports students throughout their programme of study. Feedback from students contributing to enhancement work is gained directly, through the Student Voice Forum, through student representation on University committees, and through analysis of responses to PGR student experience surveys. PGR students also have access to the Students' Union's 'Tell Glyn' and 'Ask Glyn' online contact services, and to its Postgraduate Students Officer, which together help the SU to be effectively informed about issues which it may take up with the University.

There is a rolling programme of generic and subject specific training event on the following themes:

- Student Induction Day
- Intellectual Property
- Identifying Questions & Testing Strategies (**McMillan**, Feb 2020)
- Effective Communications for Research
- Research Ethics
- How to Survive Your Viva
- Writing for Publication (**Ratcliffe**)
- Qualitative Methodology
- Visualising Research
- Researchers do Radio
- The Art of Research

The monthly 'Open House for Researchers' is an informal event open to all staff and PGR students and takes the form of a mini workshop/network opportunity whereby researchers are invited to talk about their research for 6 minutes without the aid of any visual props. This is particularly designed to support PGR students and staff at earlier stages of research careers,

and **McMillan** has been a speaker. There is also a Visualising Research competition once a year with a prize for the best photograph that depicts a research project.

For the Visualising Research Competition, we invited researchers to create a photograph that will 'inform, engage, and intrigue a non-specialist academic audience and offer a visual perspective on your current doctoral research'. This was first run in 2019, and ten very high-quality entries were received. These have subsequently been exhibited in gallery space and online.

In 'The Art of Research', PGR students are paired up individually with creative artists and asked to articulate their research aims and objectives in an accessible way. The artists then graphically illustrate their research journeys to produce large colourful posters. The aim is to immerse the students in an exercise that encourages them to think and work in a different way.

Until recently, the University hosted a community radio station (Calon FM) based in its Creative Industries Building. In February 2018, station editors ran a half-day 'Researchers Do Radio' workshop, including a communication seminar, script editing workshop and time recording in the studio. Calon FM staff then edited these recordings and distributed them back to the students. The feedback from students at the event was positive.

A PGR student experience survey conducted in 2018/19 found that all respondents were satisfied with their experience of their research degree programme. A follow-up survey was conducted in 2019/20 and again, feedback was positive. The relatively small number of students across the institution means that data cannot be reliably broken down by UoA.

iii. Equality and diversity

A commitment to promoting Equality and Diversity is inherent within the University's Strategic Framework, in particular its commitments to creating a community that welcomes students, staff and visitors from all backgrounds, placing them at the heart of what we do, treating them with dignity and respect and providing equality of access at all times. The University operates to nationally agreed standard recruitment practices, which do not discriminate on the grounds of protected characteristics. Equality data monitoring and action planning is embedded into the university's staff recruitment policy.

All University properties are accessible with adjustments based on individual needs considered and where possible put in place. Inclusivity in relation to disability is the responsibility of all staff, and of the Disability & Learning Support Team who provide guidance and support throughout a student's time at the University. The Assessment Centre provides a professional assessment, advice and training service to students with disabilities.

The University actively encourages staff and student applications from diverse national and ethnic backgrounds. The University's Welsh language policy commits the University to treating the Welsh and English language on the basis of equality and in accordance with the Welsh Language Act 1993. Sabbaticals and fellowships are available to staff in the University to pursue Welsh language training and awareness courses. Application forms received in Welsh can be processed in Welsh and any necessary interviews can be conducted through the medium of Welsh. Religious literature and faith-based support is available within the Learning Centre and Student Union, including a quiet room for prayer and reflection. An inclusion and diversity event including exhibitors and contributions from local organisations and charities takes place annually in November with members of the Chaplaincy and Equality & Diversity Action Group working collaboratively. The University achieved Stonewall Diversity Champion status in November 2016. The Stonewall index is used by the charity and the University to assess the progress the University is making towards LGBT+ inclusion. Since 2017, Wrexham Glyndŵr University has risen 60 places in the Stonewall Workplace Equality Index so that it is now placed at 180th place from a total of 550 organisations.

The University has conducted three Equality Impact Assessments during the development and implementation of its REF Code of Practice. The disclosed data suggest that the adoption of eligibility to be nominated as a PGR Principal Supervisor as the criterion for identifying 'staff who are independent researchers with significant responsibility for research' had no negative or positive impact in terms of the attributes considered in the EIA, except for age and gender. Older individuals and male staff were more likely to have PGR Supervisory status. Regarding sexual orientation, the proportion of individuals who had declined to provide information was greater amongst the group of staff with PGR supervisory status; the numbers of individuals are so small that no reliable conclusions could be drawn. Female staff did appear to be underrepresented in the group of staff eligible for nomination as a PGR Principal Supervisor (39% of that group, compared to 57% of all academic staff). This appears to be symptomatic of a broader gender issue in academic employment and not specifically related to PGR supervision (and so REF). Of the two female staff included in this UoA12 submission, one is a Professor. While not yet eligible to be included in the REF submission by the census date, the female Director of the OpTIC centre is now a Professor. Staff aged less than 51 years did appear to be under-represented in the group of staff eligible for nomination as a PGR Principal Supervisor (26% of that group were under 51, compared to 53% of the comparator group). This is symptomatic of the substantial restructuring which has taken place, with many less experienced academic staff not yet meeting eligibility criteria. The University's process for assessing staff eligibility for nomination as a PGR Principal Supervisor is robust and fair.

No statistical analysis was carried out at UoA level because of the small numbers of individuals involved.

Submitted staff were involved in selection of outputs, being invited to nominate outputs for inclusion. The University's Professorial and Readerships Committee undertook a further review of that shortlist to arrive at the final selection of outputs for inclusion. The distribution of outputs across staff is based on that process, and reflects the Code of Practice's statement that, 'This Code is based on the principle that the University has an overriding obligation to ensure that it best meets the generic and specific requirements of REF 2021 in terms of research quality in order to maximize the outcome for the University but with due regard to equality and diversity.'

3. Income, infrastructure and facilities

Income Generation and Facilities

Two research groups included in the University's REF 2014 UoA13 submission that were successful in being awarded significant grants and contracts have left the University since REF 2014, and the University's main focus is currently on supporting less experienced researchers to develop their research profiles and experience so that they become better placed to make successful funding bids.

There are exceptions to this, which play an important role in underpinning the UoAs future research capacity and performance.

The £5.6m Centre for Photonic Expertise (CPE) programme is led by Prof Gray with Prof Rees (ERDF Case ID 81400, 2018-2021) and involves three academic partners in Wales (Aberystwyth, Bangor, South Wales), through which the University's OpTIC facility has enhanced its facilities, including a £1.2M investment in a state of the art industry scale vacuum thin film coating. This facility will support the development of vacuum deposition techniques and processes for industrial applications. This type of facility is unique within the UK. The group have developed unique instrumentation for the measurement of large surfaces, including the deployable 2m scale NOM profilometer and a unique deployable beam expander system capable of delivering data for the stitching of complex convex surfaces up to 2m in size. The OpTIC facility has grown from an industrially focussed consultancy and specialist equipment facility. Collaboration with researchers in the composites and advanced materials field is

supporting OpTIC in developing its academic focus and staff based at OpTIC will in future meet the criteria for inclusion in the REF submission.

The Advanced Composites Training and Development Centre is a purpose-built centre that was built with Airbus and Welsh Government support to which Glyndwr University contributed £550k. This was to fit out a specialist composites laboratory, which is now an international leader in out of autoclave processing of composites with research led by **Day**, whose research collaborators include Boeing and University of Sheffield (through the Advanced Manufacturing Research Centre).

University Support

The University's Enterprise Team's role is to support academic staff across the institution in knowledge transfer activity through applied research, academic consultancy and training. The role of two members of the University's Enterprise Team is to identify research, commercial and capacity building opportunities and funded projects. These project managers work flexibly with colleagues responding to tenders, research calls and building projects from scratch; providing resources including strategic and administrative support covering budget, compliance, business case development; and project managing the application process according to the needs of the principal investigator/project delivery lead, liaising with Finance and Research Services as required. Here, the compact size of the university facilitates close and expedited conversations to meet the short deadlines often associated with procurement exercises and quality assurance.

In January 2021, the University appointed a Research Impact Manager to provide dedicated encouragement and support to academic staff across the University, complementing the existing support from the Research Office, Enterprise Team and the Associate Deans for Research. A number of developments related to UoA12 have already been identified in fields such as aircraft manufacture, hyperspectral imaging, rim driven electrical propulsion and food manufacture.

Evidence of Grant and Contract Capture

The total value of grants and contracts active during the assessment period and associated with UoA12 submitted staff is £605k. Total research income during the period, including work led by PIs who have left the University during the assessment period was £5.6million, from research councils, public bodies and industry.

Composites and advanced materials

Day: EPSRC (University of Sheffield): High Value Manufacturing Catapult Fellowship: Research into microwave processing of materials to deliver a scientific understanding and methods for large scale manufacture of composite materials (2016-2018, £50,000); EPSRC Manufacturing Hub: Microwave in line heating to address the challenges of high rate deposition (2019, £32,316). **Days'** work has resulted in significant progress in developing microwave processing as an out of autoclave process for manufacturing exploring issues such as tooling, machining, and simulation.
McMillan: Innovate UK: Consolidation of property data for the life cycle of a composite product (COMP-LIFE, 2016, £17,900) (collaborative project with colleagues in the University's Business School and two industrial partners).

Functional polymers

Williams and Ratcliffe: TSB High Value Chemicals by Biotechnological Modifications of Polysaccharide from Waste (2013-2015, £190,151) (Project no. 101440); KTP with Quay Pharmaceuticals: To develop a new dosage form technology platform for the administration of oral medicines for geriatric and paediatric patients (2013-2015, £107,200) (Knowledge Transfer Partnership 009027); SHELL: The performance of organic solvents in inverse polymerisation reactions (2014-2015, £36,018) [not Ratcliffe]; GSK: Characterisation and Study of the factors

affecting the stability of dermatological formulations (2015, £38,450); BBSRC: BBSRC FoodWasteNet (2015, £40,378) (BB/1005315/1); GSK: Chemical and physicochemical characterisation of Carbopol for application in pharmaceutical formulations (2016-2017, £53,093); Mimica Lab: Monitor the shelf-life of specific food products (2019-2020), £39,000).

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

Support for stimulating external engagement

Current data indicate that 68% of all academic staff associated with UoA12 and 9 of the 11 submitted staff make active contributions to the work of professional bodies and/or subject associations, and the same numbers are or have recently engaged in collaborative research with other institutions. The recently appointed Research Impact Manager's role in supporting academic staff's external engagement will increase these proportions. The Associate Deans for Research and the Research Strand Leads in specific subject areas give advice and encouragement; the Research Development Awards scheme, albeit modestly, supports staff particularly at earlier stages in research careers; the Enterprise Team support academic staff in business and community engagement (directly and through events such as Business Breakfasts) and IP/contract issues.

Composite and advanced materials: The support for collaborations and external engagement has led to SMARTExpertise (ERDF) support for a research collaboration with industrial partners into electrical lightweight rim-driven fan propulsion for UAVs (**Day**, **Vagapov**, Bolam, ERDF Case no. 82311, 2020-2022), and **McMillan** is a member of The Royal Society `Rapid Assistance for Modelling the Pandemic (RAMP)' project, Task 7: Environmental and aerosol transmission, which produced a consultative report in September 2020: 'The ventilation of buildings and other mitigating measures for COVID-19: a focus on winter 2020'. **Day** has held an EPSRC High Value Manufacturing Fellowship held at the Advanced Manufacturing Research Centre with Boeing (AMRC) and the National Composites Centre) and maintains a close relationship with AMRC. **Day** and **McMillan** work with Colleagues in Baumann Moscow State Technical university on manufacture and modelling of structures using microwave heating and on MEMS design optimisation respectively; Professor Sergey Vasilyevich Reznik, Head of Space-Rocket Composite Design Department is a Visiting professor at Glyndwr. Recently, joint students, Rumyantsev and Nikolaeva have successfully defended their PhDs. **McMillan** also works with colleagues in Samara University, Russia on fluid contamination inspection and space tether dynamics, and students Kornilin and Elenev have also successfully defended their PhDs. The close cooperation between the composites and optics activity in exploration of the manufacture of optical surfaces in composites linking **Day** and Prof Rees has led to the development of imaging systems for High Altitude Pervasive Surveillance (HAPS) with QinetiQ and Airbus. **McMillan** has been collaborating with colleagues at Lutsk University (Ukraine) resulting in two papers published in 2015. **McMillan** is a member of the Welsh Academic Space Partnership (WASP) and also of the Space Universities Network (SUN), with the aim of matching research capabilities to the developing space sector and supporting research informed teaching. **McMillan** collaborates with Rhys Jones AC at Monash University, Australia with whom she has co-authored 9 journal papers since 2016, on fatigue life in aerospace and civil engineering materials; with Dr Mark Jahanbin (Boeing) in USA on ultrasound NDE modelling; with Stephen Tsai and his group at Stanford, USA supporting research informed teaching about composites; and with colleagues at the Institute of Lightweight Engineering and Polymer Technology at Technische Universität Dresden, Germany, with one joint paper published in 2016.

Electrical and electronic engineering: Vagapov was Principal Supervisor for a joint PhD student with Moscow Institute of Electronic Technology (Analysis of impact of plug-in electric vehicles on performance of a residential power microgrid, 2019) and has continuing collaborations with Moscow Power Engineering Institute (electrical machines and drives) and Bonn-Rhein-Sieg University of Applied Sciences, Germany (renewable energy and manufacturing technologies) leading to joint publications.

Functional polymers: A key area of research has been the characterisation, modification and properties of water-soluble polymers (hydrocolloids) which has involved extensive collaboration with Industrial partners. Examples include the functionalisation of chitosan, (Unilever Research, Croda Europe Ltd and Seagarden ASA, Norway; TSB project no. 101440), valorisation of proteins from rape seed meal waste (Croda Europe Ltd; BBSRC NIBB FoodWasteNet POC14_01), characterisation and development of pharmaceutical formulations (GSK, direct funding; Maelor Pharmaceuticals, Knowledge Transfer Partnership KTP009027), use of hydrocolloids in food packaging to prevent food waste (Mimicalab Ltd, direct funding). Collaboration with academic partners at the Phillips Hydrocolloids Research Centre, Wuhan, China has continued and a new link with Jiangnan University, Wuxi, China has been developed funded through the Chinese Ministry of Education. These links have led to joint research publications, and **Williams** contributed to researcher training at Wuhan (How to get your paper published, 2018). Visiting researchers include Ruiyun Chen, Nanchang University. **Ratcliffe'**s international academic collaborations include IPT, Sao Paulo, Brazil and École des mines d'Albi-Carmaux (evaluation of the characteristics of starches from native Brazilian plants including the araucária tree—Araucaria angustifolia). **Yang's** international academic collaborations include three universities in China: Shanghai Jiaotong university, Hubei University of Technology, and Dalian Minzu University.

Ultra-precision surfaces and metrology: The group based at the OpTIC research centre (Prof Rees) have capitalised on their groundbreaking research into rapid manufacture of large (up to 2m diameter) ultra-precision surfaces and they are now supplier to companies across the world, including Trioptics (France), Thales (France), IDOM (Spain), and Qinetiq (UK). Backed by this is continuous research into the process and optical metrology; they have been developing optical systems for HAPS (with Qinetiq, Airbus). The group have developed a world leading optical metrology capability delivering unique solutions to the nanometre scale measurements of complex freeform surfaces. The group have also developed an ultra lightweight telescope system through a project funded through the CDE program. This has led to a strong joint Mod/industrially funded program with Qinetiq and Airbus to develop a commercial LIDAR system. The metrology group are also leading the research and development of a Hyperspectral imaging system funded through the Welsh Government/Airbus research program. This system is about to enter its second phase of development. The CPE programme supports industrial partners to develop their processes and products utilising Photonics based applications. Utilising the collaborative expertise of four partner universities, the program has so far started / completed 44 projects, introducing 32 new to the firm products and 17 new to market products.

Exemplars of contributions to / recognition by the research base

Day: Editorial Board member, Advanced Manufacturing: Polymer and Composites Science (Taylor & Francis), Member of Institute of Physics CPhys panel, 2 invited presentations at Moscow Baumann State Technical University (2018).

McMillan: Public Lecture, "Innovation and R&D in Aerospace", organised by IMechE North Wales and Merseyside, at Wrexham, 30 November 2017. Member of conference organising group for Society for the Advancement of Material and Process Engineering, 2018, Southampton; Conference Chair of three small international conferences held in Wrexham and St Asaph (Advanced Materials for Demanding Applications, 2014, 2015 and 2020 with peer reviewed proceedings published through IOP Conference Series). Co-Chair of Innovation in Material for Extreme Environment in Huddersfield 2017. Institute of Physics Vice-President for Business (2012-16); Chair of Institute of Physics in Wales committee 2017-present; Committee member of the Institute of Physics History of Physics Group (2020-). Member of IMechE Council, 2019-current. Editorial Board member of Advanced Manufacturing: Polymer and Composites Science (Taylor & Francis); Advanced Engineering Materials, Wiley-VCH (2014 – present); Proceedings of Higher Educational Institutions. Machine Building, Bauman Moscow State Technical University, (2015 - present); International Journal of Structural Integrity, Emerald Publishing (2017 - present); Electrometallurgy (Russian Academy of Sciences) (2020 - present).

Visiting Professor University of Ulster (2010-2016), Peer reviewer for journals published by Sage, Elsevier, Wiley, MDPI.

Ratcliffe: Peer reviewer for Carbohydrate Polymers and Food Hydrocolloids (Elsevier)

Shoaib: Invited lecture, National University of Sciences and Technology, Pakistan, June 2017, Antennas for mmWave communication; Member of organising group, International Conference on Applied and Engineering Mathematics, Taxila, Punjab HITEC University (2018); Peer reviewer for MDPI (Sensors, Electronics and Computers); Topic Editor of Electronics (MDPI).

Stuhlfelder: Invited speaker at CIAT events: a conference relating to Architectural Technology in India, held at the Vellore Institute of Technology, India, 2018; Ecobuild 206 Fringe, 2016, London, and Architectural Technology: Design Futures Reflecting and Projecting, London, 2015.

Vagapov: Editorial Panel Member, International Journal of Engineering Systems Modelling and Simulation (Inderscience); Programme Committee member for Universities Power Engineering Conference (2015-2020), IEEE Conference of Young Researchers in Electrical and Electronic Engineering (issues 2015-2021); IEEE International Workshop on Electric Drives (2018-2021).

Williams: Co-founder and Editor in Chief, Food Hydrocolloids (Elsevier, Impact Factor 7.053); Editorial Board Member Carbohydrate Polymers; Invited Plenary Lectures EPNOE 2015 Conference, Warsaw, Poland 2015; International Symposium on Bioinspired Macromolecular Systems, Aveiro, Portugal 2017. Co-Founder and Secretary of the Food Hydrocolloids Trust established to promote hydrocolloid research through conference organisation. Recent Conferences were held at Glyndwr University Wrexham, UK, 2015, Technical University Berlin, Germany 2017, Miramar Palace, San Sebastian, Spain, 2019 [www.foodhydrocolloidstrust.org.uk].

Yang: Peer reviewer for Food Hydrocolloids (Elsevier), Materials and Design (Elsevier), New Journal of Chemistry (RSC), Green Chemistry (RSC), RSC Advances (RSC), Journal of Materials Chemistry (RSC)