Institution: **Swansea University**

Unit of Assessment: **12 Engineering**

**Section 1. Unit context and structure, research, and impact strategy**

**1.1 Unit Context**

The College of Engineering (**CoE**) at Swansea University (**SU**) is a thriving multidisciplinary community that has firmly integrated subjects across traditional boundaries and delivers world-leading research and education. Over this census period, CoE has undergone substantial expansion, in line with the strategic aims identified in REF2014. Growth results from SU's long-term vision to establish the £450m **'Bay Campus',** where CoE relocated in September 2015, now occupying more than 45,000m$^2$ and hosting an extensive range of equipment worth an excess of £50m. Activities are currently spread over seven buildings, three of which funded and constructed within this census period. The availability of these state-of-the-art research facilities offered unprecedented opportunities to shape a cohesive and synergic environment that delivers adventurous and impactful research. Since 2014, CoE has enhanced its international reputation as a recognised centre for transformative engineering research and grown to be a focal point for international/national/regional R&D. Evidence of CoE's success is presented throughout the document. Notable achievements are:

- **Academic research staff (Cat. A):** from 79 (74.8 FTE) in 2013 to 120 (116.4 FTE) in 2020,
- **Research space:** from 18,326m$^2$ (2013) to 45,026m$^2$ (2020),
- **Spin-outs:** from 19 (2013) to 32 (2020),
- **Annual average research income**: £26.4m (120% increase from REF2014),
- **Annual average number of postgraduate research students (PGRs):** 258 FTE (38.4% increase from REF2014),
- **Annual average number of doctoral research degrees awarded:** 52 (49% increase from REF2014).

Following the move to new premises and expansion of activities, in 18/19, CoE began a comprehensive review of its research structure, strategies and support mechanisms. An analysis of established and emerging areas of strength mapped against national and international priorities, as identified by funders and global challenges, underpinned the review, leading to:

- **Defining 4 cross-cutting enabling strategic themes** for an inclusive multi-group approach to research challenges in key priority areas,
- **Restructuring of the unit from 3 to 5 Research Centres** as a response to the expansion and for enhancement of support mechanisms provided to staff and PGRs,
- **Creating 7 Centres of Expertise in established and emerging areas of strength** as flexible platforms to develop multidisciplinary networks to respond to new opportunities rapidly.

Through this synergistic and comprehensive effort, CoE will continue to deliver against its mission of empowering *world-leading research, innovation, and training*. ***The vision is to become a key international player that drives technological advances by delivering socially, economically, and environmentally impactful research.*** This overarching goal is accomplished by fostering fundamental and applied interdisciplinary research across the strategic themes, enabling innovation, and cultivating talent within student and staff communities (Figure 1.1).


Figure 1.1: Pillars of CoE's research structure as key conduits to delivering its mission.

**1.2 Unit Structure**

**Research Centres (RCs)**

In 2019, CoE reorganised into **five RCs** aligned with the established strategic research themes. RCs, led by a Head of Centre (HoCtr), are the backbone of the UoA and function as semi-independent units with their own allocated budget. Except for ESRI (see Table 1.1), the RCs are structured into research clusters with a nominated lead supporting and informing the HoCtr of ongoing activities. Each academic is a member of a cluster within a designated RC that reflects their individual core expertise. RCs provide line managing and administrative support for all staff. They are designed to encourage individuals at all levels to become part of a team by incentivising participation through robust two-way information flow and research support.

| RESEARCH CENTRE (RC) | Head | Cat. A Staff (Headcount) |
|---|---|---|
| **Energy Safety Research Institute (ESRI)** | Andrew Barron | 8 |
| **Future Manufacturing Research Institute (FMRI)**<br>**Clusters:**<br>• Advanced Manufacturing for Energy Applications<br>• Digital Manufacturing<br>• Net-shape Fabrication and Functional Device Printing | Serena Margadonna | 15 |
| **Materials Research Centre (MRC)**<br>**Clusters:**<br>• Advanced Characterisation<br>• Coatings, Corrosion and Electrochemistry<br>• Metallurgy<br>• Photovoltaics and Solar Energy<br>• Structural Materials | Geraint Williams | 30 |
| **System and Process Engineering Centre (SPEC)**<br>**Clusters:**<br>• Applied Biological and Chemical Systems<br>• Biomedical and Human Performance Analysis<br>• Complex Fluids<br>• Semiconductor and Electronic Materials<br>• Sensor Technologies | Paul Rees | 28 |
| **Zienkiewicz Centre for Computational Engineering (ZCCE)**<br>**Clusters:**<br>• Aerospace Engineering and Structures<br>• Biomedical Engineering<br>• Computational Methods in Engineering<br>• Energy & Environment<br>• Solids, Structures, and Coupled Systems | Dominic Reeve | 39 |

Table 1.1 CoE Research Centres and clusters

HoCtrs report to the Director of Research and are members of CoE Research Committee which is responsible for strategic decisions on investments, policies, budgeting, PGRs and research associate (RAs) affairs. Decisions are discussed and approved by CoE Executive Committee, chaired by the Head of College. A schematic diagram of leadership roles and decision-making process is presented in Figure 1.2 (p.4).


Figure 1.2 CoE leadership structure

**1.3 Research Structure**

**Strategic Cross-cutting Themes**

Following the review, the research strategy evolved with the definition of four cross-cutting research themes. These integrate academic strengths across RCs and identify growth areas that map onto CoE's vision. The themes, listed below, underpin all strategies as primary drivers.

| | |
|---|---|
| **T1. WATER, ENERGY AND SUSTAINABILITY** | **Engineering sustainable solutions for water treatment and supply, coastal erosion, pluvial flooding, low carbon energy production and storage.** |
| **T2. DIGITAL AND COMPUTATIONAL** | **Developing numerical methods and associated computational procedures to solve complex engineering problems.** |
| **T3. MATERIALS AND MANUFACTURING** | **Advancing sustainable integrated solutions for industrial needs through next-generation materials and processes.** |
| **T4. HEALTH, WELLBEING AND SPORTS** | **Applying the engineering approach for innovation in healthcare and solutions for biological, medical and sports applications.** |

**Centres of Expertise (CoExps)**

The review highlighted that academics from different RCs were autonomously coalescing into large networks, effectively tackling the challenges identified by the strategic themes. It also revealed that prioritising support for these efforts would enable a sustained stream of impactful research, creating a powerful conduit to deliver CoE's mission. CoE formalised these initiatives in 2019 by establishing a portfolio of CoExps as dynamic and inclusive platforms for researchers across RCs and SU to come together and initiate adventurous interdisciplinary research projects.

In the census period, CoE identified four established CoExps and enabled development of three. CoExps integrate into the research structure with an assigned RC of reference and an academic lead that directly reports to HoCtr and the Director of Research (Figure 1.3, p.6). Staff are given ample opportunities to be involved in CoExps through College-wide advertisement and transparent policies for establishment and review of outcomes.

**Established CoExps**

- **Advanced Sustainable Manufacturing Technologies (ASTUTE)** – (Lead: Prof. Johann Sienz, FMRI) *aligning T2 and T3*
  ASTUTE addresses Welsh industrial RD&I needs in advanced materials, computational engineering, modelling, and manufacturing. Since 2014, more than 75 industry-led research projects were completed with Welsh SMEs.

- **Centre for Nanohealth (CNH)** – (Lead: Prof. Huw Summers, SPEC) *underpinning T4*
  CNH is an SU intercollege initiative that clusters 20 engineers together with life scientists and healthcare researchers. The centre is developing innovative technologies and science for healthcare applications.

- **Institute of Structural Material (ISM)** – (Lead: Prof. Martin Bache, MRC) *underpinning T3*
  ISM includes the Rolls-Royce University Technology Centre (UTC) and the EPSRC Rolls-Royce Strategic Partnership in Structural Metallic Systems for Gas Turbines. Its mission is to generate critical technology advancement to improve the efficiency and environmental sustainability of gas turbine engines.

- **Sustainable Product Engineering Centre for Innovative Functional Coatings, Innovation and Knowledge Centre (SPECIFIC IKC)** – (Lead: Prof. Trystan Watson, MRC) *cross-linking T1 and T3*
  SPECIFIC brings together 12 universities and 54 businesses delivering fundamental research, scale-up and proof-of-concept of new solar technologies. These combined with novel storage elements convert buildings effectively into low-carbon, energy-positive power stations.

**CoExps Developed in the Census Period**

- **Active Building Centre (ABC)** – (Lead: Dr. Ahsan Khan, MRC) *cross-linking T1, T3 and T4*
  ABC, established through an initial UKRI grant received in 2018 (£36m), aims to revolutionise the construction sector through rapid roll-out of active buildings at scale, building on the success of individual technology demonstrators at SPECIFIC. ABC forms part of the £170m ISCF Transforming Construction initiative.

- **Centre for Integrative Semiconductor Materials (CISM)** – (Lead: Prof. Owen Guy, SPEC) *cross-linking T4 and T3*
  An offshoot of CNH, CISM is an intercollege initiative (CoE and College of Science), funded by a £30m UK Research Partnership Investment Fund (UKRPIF) grant, to strengthen the partnership between SU and the UK semiconductor industry. Its goal is to deliver a bespoke, integrated multidisciplinary facility for semiconductor research and technology development.

- **Steel and Metal Institute (SaMI)** – (Lead: Dr. Debbie Baldrey, MRC) *underpinning T3:* SaMI was established in 2017 following the donation of £5.2m in Tata Steel research equipment and a £3.8m Higher Education Funding Council for Wales (HEFCW) grant. The centre integrates a wide range of industrial partners led by Tata Steel with 25 industrial researchers and a matching number of university research staff and students. SaMI focusses on collaboration and innovation in metallurgy with emphasis on industrial decarbonisation. It incorporates the £10m EPSRC SUSTAIN Future Manufacturing Hub.

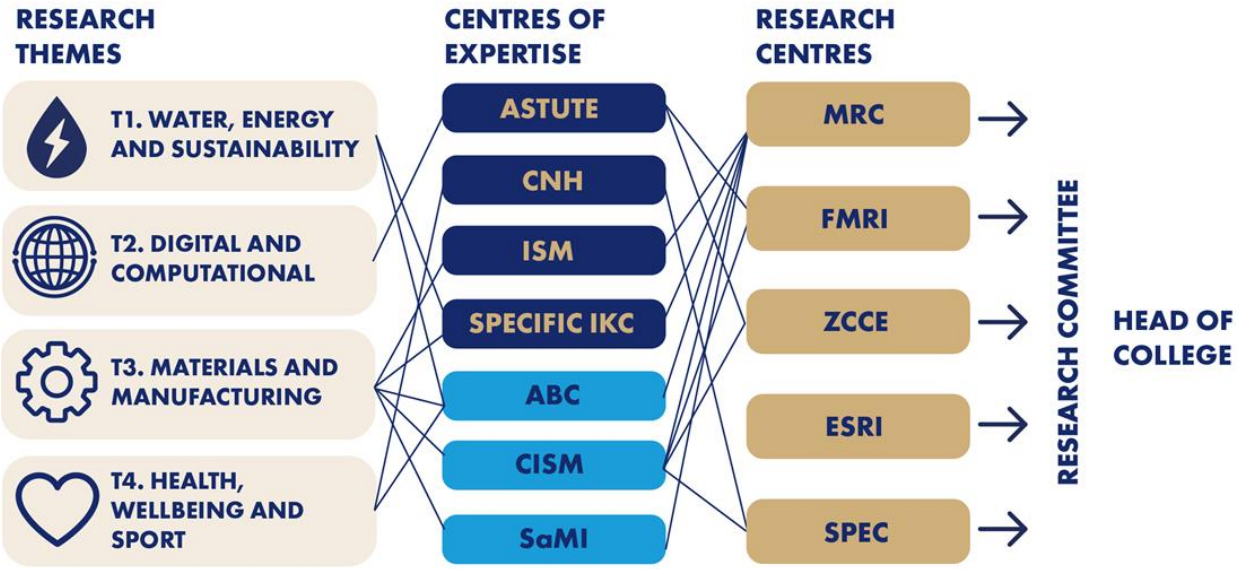


Figure 1.3 Connections between Strategic Research Themes, Centres of Expertise (dark blue – established; light blue – developed over the census period) and Research Centres.

**1.4 Planned changes in the unit structure**

CoE's organisational structure, as described in the previous sections, will be re-shaped in the next census period following the merger of CoE and College of Science (CoS) at SU into a fully integrated Faculty. The new entity, becoming operational at the end of 2021, aims at removing barriers to facilitate an interdisciplinary approach as a pathway to increase the scale, quality, and impact of research. The Faculty opens unparalleled opportunities for CoE to enhance the richness and significance of the current strategic themes through critical mass development supported by CoExps. The approach has already proven successful by CNH and CISM (Section 1.3). The Faculty's establishment sets the foundation for significant future growth, particularly in areas of climate change, green recovery, industrial decarbonisation, and medical engineering, in line with CoE's vision.

**1.5 Progress on targets set in REF2014**

The restructuring and definition of priority research areas led to the successful implementation of the strategic plans from REF2014 that focussed on augmenting number of academic staff, infrastructure, PGR recruitment and training (original goals are in italics).

- *Growth of academic staff in key priority areas coupled with appointments of Prof. James Durant (0.5 FTE) and Prof. Andrew Barron.*

  Since 2014, CoE made 46 appointments across strategic themes and RCs, including Prof. Durant, FRS, as Sêr Cymru Solar Energy Research Chair (0.5 FTE) and Prof. Barron (1 FTE) as Sêr Cymru Chair of Low Carbon Energy and the Environment (details in Section 2.1).

- *27% increase in total student numbers, including a 25% increase in PGR students and the establishment of the National Research Network (NRN) Graduate School.*

  Comparing to the previous REF period, the total number of students (UG, PGRs and PGTs) almost doubled. The number of PGRs increased from an average per annum of 186.5 FTE to 258.2 FTE (38.4% growth). Expansion was sustained through targeted strategies for the award of doctoral training programmes, including the NRN Graduate school (details in Section 2.3).

- *Establishment of the Innovation Hub, and the active seeking out of further funding to expand facilities on the new campus.*

  The Innovation Hub building at Bay Campus was completed in 2015. Now named Engineering Central, the facility offers a unique environment for the fusion of economic, research and educational communities. Since 2014, CoE has leveraged further funding for four new buildings (details in Section 3.2).

One additional objective that was not set in REF2014 was establishing the portfolio of CoExps and overarching research themes as primary conduits for delivering CoE's mission. Prioritising support to CoExps as dynamic platforms for developing collaborative landmark projects has resulted in a substantial increase in funding. Since 2014, SPECIFIC was awarded more than £55m, which enabled the development of ABC and SaMI. Likewise, investments in CNH resulted in a £30m award for establishing CISM. Furthermore, targeted support on advanced manufacturing, computational modelling, and industry 4.0 has guaranteed a continued stream of awards for ASTUTE. On average, CoE has benefitted from a 23:1 return on investment into CoExps (in terms of produced income), strongly contributing to steady growth in overheads generation that sustains the resilience of research efforts and allows investments in embryonic areas of excellence. CoExps strongly contribute to the CoE's aim of being a global player by increasing its international standing and leading new strategic partnerships with national and international industries and institutions (details in Section 4).

**1.6 Future Research Strategy**

Building on its success and taking advantage of new opportunities offered by the Faculty, in the next five years, CoE aims at accomplishing its vision through a set of specific actions:

- Invest strategic funds and grant awards to academic posts focussing on consolidating strengths across research themes and CoExps and targeting the Faculty's growth areas of green-recovery, climate change, data, artificial intelligence (AI) and modelling, and medical technology,

- Support the portfolio of established and emerging CoExps to forge an integrated, collaborative, and interdisciplinary environment leading to the award of substantial grants,
- Expand T2 by establishing a Faculty-wide CoExp in Advanced Data-Driven Engineering Design (ADDED) leveraging the already available £0.5m investment from UK Atomic Energy Authority,
- Strengthen the interface between T1 and T3 and the area of green-recovery by developing a new Faculty wide CoExp on sustainable energy storage (CAPTURE – Circular Applications to Utilise and Retain Energy) leveraging on the already obtained £1.2m investment from industry,
- Invest in T4 and expand the area of medical technology by supporting efforts to create a CoExp in Applications of Engineering in Sports, Exercise and Medicine (CAE-SEM) in partnership with the School of Sports and Exercise Sciences at SU,
- Augment activities cross-linking T3 and T1 by supporting the South Wales Industrial Cluster's decarbonisation initiative in collaboration with local authorities and as part of the Swansea Bay City Region initiative,
- Increase the number of high-quality research students by winning at least 3 new CDTs and securing collaborative industrial funding for PGR studentships by establishing long-term strategic partnerships,
- Increase global visibility by establishing at least 2 bilateral PGR exchange programmes with leading international academic institutions,
- Nurture talent by improving support for PGR and RA training and career development courses. Focussed investments will be available to attract successful research fellows.

**1.7 Impact**

Development of innovative technologies, processes and products that hold societal, environmental, health and economic benefits is at the core of CoE's mission. Impact is delivered across all four research themes and, as such, reflects a wide range of beneficiaries, from industry and policymakers to the general public. Successful implementation and effectiveness are evidenced by the creation of 43 spin-out companies, of which 24 during this census period. Many have acquired investments or secured additional funding since 2014 exceeding £3m.

Support mechanisms for impact generation include (i) seed-corn funding of up to £5k to assist development of embryonic research impacts, (ii) SU's EPSRC Impact Acceleration Account and (iii) a dedicated Impact and Engagement Officer (1 FTE). Furthermore, CoE works with a team of experienced professionals to support knowledge transfer and university-business interactions. SU's Research, Engagement, and Innovation Services (REIS) department provides CoE with dedicated IP and spin-out support. An IP Manager works closely with Dr. Adrian Walters, who was awarded the status of Royal Society Entrepreneur in Residence at CoE (2018) and is a Registered Technology Transfer Professional (2019).

**1.8 Impact Sectors**

Current main beneficiaries of CoE's research are the industry and health sectors, the public, and policymakers and governmental agencies, as evidenced by the submitted Impact Case Studies (ICSs). These represent a robust selection from the broad spectrum of ongoing activities across the four strategic research themes. Highlighted mechanisms of support have also catalysed a surge in impact-related research activities across CoE, which are still under development and led by early career researchers (ECRs), forming the basis for further expansion of the impact portfolio and future growth.

**Industry (overarching T1, T2 and T3)**

CoE has a strong history of industrial collaboration. Strategic partnerships with both large enterprise and SME partners were developed and continued throughout this census period, including those with Rolls-Royce, Tata Steel, Airbus and Haydale. These strong industrial links have established an area of impact that has both reach and significance across multiple industrial sectors. Our work with industry has resulted in an array of industrial-focussed ICSs, including research on an improved aerodynamic design process for the aerospace industry through the application of unstructured mesh technology (Hassan), the development of novel antennas for the defence industry (Mehta), advancement in printing technology and functional device fabrication (Gethin), and the application of membrane processes and their optimisation through fabrication (Wright and Hilal).

CoE also continues to develop its longstanding multifaceted partnerships with large industrial players such as Rolls-Royce. The ICS submitted for this REF period by Whittaker describes critical technology developments to produce efficient and robust gas turbine engines that are benefitting the aviation industry and environment by contributing to a significant reduction in fuel consumption. These advances have provided approximately £3.5bn in cost savings to Rolls-Royce over the lifetime of the engines.

**Health (underpinning T2, T4)**

Health is identified as a critical research theme and is a growing area of impact. Since 2014 CoE has been proactive in developing fundamental research, engaging with public sector bodies such as the NHS and industry to create impactful research. Work on advanced rheometry for complex fluids in manufacturing, pharmaceutical and healthcare applications has resulted in an ICS (Williams) and is a powerful example of the application of our research within current medical practices. Our health work with the private sector has also contributed to an ICS which highlights the impacts of collaborative microneedle research between Innoture Ltd and SU (Guy). Other ongoing impact activities within the healthcare sector include (i) work on green-superhydrophobic coatings for patients with a stoma (Alexander); (ii) heart disease diagnosis using modelling (Nithiarasu); (iii) the development of a low-cost, point-of-care device for the detection of human cytomegalovirus (Teng).

**Public Engagement (overarching T1, T2, T3 and T4)**

CoE has identified our impact on public engagement to be an embryonic area and one in which growth can occur facilitated by the Faculty's establishment. Within the census period, CoE developed public engagement projects to share our research, engineering concepts and knowledge. An archetypal example is our work with Bloodhound Land Speed Record, a UK-based project aiming to break the world land speed record using the most advanced straight-line racing car ever built. Furthermore, the development of ABC, Active Office and Active Classroom has enabled the adoption of new technological concepts for the creation of teaching space at Bay Campus as well as trials for social housing. A collaboration between ABC, Pobl Construction Group, Neath & Port Talbot County Borough Council, and SPECIFIC IKC has established 'Active Homes', a project which built a community of 16 social houses, as described in one of the ICS submitted (Jewell). The project also resonates outside the UK through the GCRF-funded SUNRISE network, which is deploying the fundamental principles developed at CoE to provide secure energy supplies to community schools and health centres in rural India.

**1.9 Future Impact Strategy**

CoE's strategy for impact reflects its vision of driving innovation through excellent research. CoExps are archetypal examples of the successful implementation of the approach. They currently play a pivotal role in enhancing the engagement ecosystem by creating a common platform for knowledge diffusion and transfer among academics, stakeholders, and end-users. Building on this thriving landscape, CoE will continue to foster the development of impact and aims to:

- Support a switch from individually driven to a more effective and robust multidisciplinary group approach to impact generation taking advantage of the opportunities offered by the merger with CoS. Funds will be available for Impact and Engagement Officers to coordinate activities within the newly developed CoExps (ADDED, CAPTURE and CAE-SEM),
- Strengthen the mechanisms of support for embryonic impact through CoE's Impact and Engagement Officer, which will foster development of impact, starting from the early stages of proposal submission, in line with UKRI's recent change in emphasis on impact generation,
- Grow impact-related activities in areas of health, environment, and public engagement by augmenting our relationship with medical regulators such as NICE and FDA,
- Provide purpose-designed training on IP, spin-out and knowledge transfer, focussing mainly on ECRs, to build a comprehensive culture of sustained impact generation,
- Enhance impact generation by making knowledge diffusion and translation key criteria of selection procedures for any future appointments,
- Increase the recognition, influence, and weight of impact generation on career progression and remuneration by introducing specific KPI's on ICS authorship and the consistent delivery of meaningful impact.

**1.10 Interdisciplinary Research (IDR)**

IDR is embedded in all CoE activities, building on an environment that clusters engineers together with researchers from multiple disciplines, including biologists, chemists, and physicists. This is evidenced by two submitted ICSs (Williams and Guy) highlighting the strong links with the Colleges of Medicine and Science at SU or the STREAM (Sensor Technologies for Remote Environmental Aquatic Monitoring) project, which connects CoE with researchers in Ireland working on the effects of climate change on marine life. The strategic importance given to IDR has permeated restructuring and is at the heart of the new Faculty's vision. Effectiveness is evident from the current portfolio of activities, including:

- CNH benefits from a strong collaboration between CoE, CoS and School of Medicine at SU, reinforcing T4,
- ABC's aim to enable energy-resilient communities is achievable only through interdisciplinary collaborative projects between engineers and social scientists in close partnership with local authorities and policymakers (overarching T1 and T4),
- The EPSRC CHERISH-DE project, led by CoS, is a powerful example of how researchers across computer science, social sciences, and engineering (SPECIFIC) have established an interdisciplinary effort addressing the human perception of self-powered devices (T3 and T4),
- The planned CoExp CAE-SEM (T4) cements the established links between the CoE and the School of Sport and Exercise Sciences at SU, which are already sharing facilities, infrastructure, and projects such as the Welsh government funded £1.8m project on sport materials,
- The emerging CoExp CAPTURE (T1 and T3) involves collaborations with the School of Law at SU on policies and regulations for battery recycling and large-scale energy storage.

Since 2014, 12 interdisciplinary PGRs were supported through joint supervision between CoE and other disciplines. In addition to events organised by SU such as sandpits organised by REIS, CoE fosters an interdisciplinary culture through a series of **Centenary Interdisciplinary Research lectures** and sandpit events. Speakers have included Dr. Langlands (SU College of Arts and Humanities) on the topic of heritage assets and Prof. Soyer (SU School of Law) on technology-driven policy challenges.

**1.11 Future IDR Strategy**

CoE will broaden existing IDR efforts to maximise opportunities for advancing knowledge by strengthening synergies with social sciences, arts, and humanities. The aim is to enable a paradigm shift within the research base from single-project-driven activities (mainly involving STEM disciplines) to a broad knowledge framework as a fundamental step to provide solutions to complex societal challenges. To this end, CoE will take full advantage of new opportunities offered by the Faculty. Furthermore, it will partner with the Morgan Institute for Advanced Studies - a research-based think-tank that aims at promoting overarching interdisciplinary approaches across the full spectrum of disciplines at SU. CoE will foster IDR by:

- Using the CoExps' organisational structure to integrate and synthesise interdisciplinary interests. Within each CoExp, an identified member of staff provides clear leadership for developing IDR networks and projects,
- Encouraging participation in the SU Research Grant Enabler (SURGE) fund to initiate interdisciplinary activities aimed at grant applications,
- Increasing recognition for staff undertaking IDR through development of well-defined strategies that can evaluate each individual's contribution within the project team regarding promotion and remuneration,
- Promoting use of sabbaticals to allow academic staff to develop the necessary network and culture of other disciplines,
- Creating a team of experienced academic staff to provide dedicated support to ECRs that intend to establish IDR projects in close partnership with the Morgan Institute,
- Prioritising support for PGRs and RAs to participate in interdisciplinary projects involving supervisors from different disciplines.

**1.12 Open Research Support**

**Open Access to Outputs**

SU has an Open Access deposit policy, ratified in March 2015, that requires all published research outputs to be deposited in the institutional Research Information System (RIS), which feeds the repository, Cronfa, with an Open Access copy of each full-text article (REF5a). The REF Officer for CoE provides a mediated deposit service to help staff comply with university and REF Open Access requirements. Since 1st April 2016, on average 94.8% of all outputs needing to comply are REF 2021 Open Access compliant.

CoE has a 0% Open-Access-Noncompliant output submission (REF 2), as defined by the REF2021 guidelines. Compliance has mostly been achieved via the Green Open Access route, with 34.0% of the output submission available through Gold Open Access. Gold Open Access is made possible via a fund of £100,000/annum provided by CoE for its active research staff and a UKRI grant held within the Library.

**Research Data – Sharing and Management**

Data requirements for all researchers are outlined in SU's 'Research Integrity: A Policy Framework on Research Ethics & Governance' document. Staff receiving grant awards from

UKRI councils must comply with funder data requirements. SU has a Research Data Manager who supports the ethical, open, and compliant production, use, and discovery of research data for all staff. Researchers are encouraged to apply FAIR (Findable, Accessible, Interoperable, and Reusable) data practices as a matter of normal research practice. Beyond funder requirements, CoE advises staff to deposit their data in the Zenodo repository and to record the location of datasets that underpin research outputs in the RIS.

**1.13 Research Integrity**

CoE follows SU's 'Concordat to Support Research Integrity' and 'Research Integrity: A Policy Framework on Research Ethics & Governance'. An Academic Dean for Research Integrity is also available, aided by a Research Integrity team led by the Research Integrity Manager based in REIS (REF5a). This team provides an annual report outlining activities undertaken through the year, reports progress at both the College and University levels, and indicates future initiatives.

Sitting on CoE Research Committee is a member devoted to Ethics, which ensures that college activities and research practices abide by all the relevant Ethics Codes set out in the SU Institutional Environment Narrative.

SU mandates that all staff complete discipline-specific research integrity training by passing an Epigeum online course exam on Research Integrity.

**Section 2. People**

**2.1 Staffing Strategy (2014-2020)**

Implementing strategies set in REF2014 enabled significant growth across research themes and Centres of Expertise (CoExps). Recruitment aimed to enhance academic leadership in established areas of excellence and nurture embryonic but potentially game-changing research efforts in line with research and impact strategies. The focus was on attracting internationally recognised leaders and talented early career researchers (ECRs) to fill gaps of expertise and create bridges across research areas to foster a multidisciplinary and inclusive group approach to research challenges.

Academic staff on the research career pathway (Cat. A) has increased by 28% FTE since 13/14. CoE has recruited leading academics at all levels: **21 lecturers, 14 senior lecturers, 3 associate professors and 8 professors.** Of the appointed individuals, 24% were female, 50% non-UK nationals, 37% self-classified as BAME, and 52% with no previous positions at SU. Examples of the appointed staff and how they integrate into and strengthen strategic research themes and CoExps include:

**T1** - **Water, Energy and Sustainability**

At the end of the previous census period (2013), CoE was awarded £6m from Welsh Government (WG) under the Sêr Cymru Solar programme to establish a research cluster focussed on developing low-cost, large-area photovoltaic technologies. The award led to the appointments of Durrant, FRS (0.5 FTE) and **Nelson**, FRS (0.2 FTE) from Imperial College London to establish a world-class research programme in printed photovoltaics. The programme also underpinned three additional junior appointments: **Carnie, Charbonneau, and Davies**. Their collective expertise has broadened the scope of research on the circular economy of photovoltaic devices,

thermoelectrics, and dye-sensitised/organic solar cells. All appointments aimed at strengthening SPECIFIC and at enhancing a cross-disciplinary approach between T1 and T3.

The Sêr Cymru programme also awarded CoE a £3m grant to support the appointment of **Barron** (1.0 FTE) for the applications of nanotechnologies to energy and water issues. He established the Energy Safety Research Institute (ESRI), which was further supported by the appointment of four academics since 2014 (**Alexander, Andreoli, Dunhill, and Orbaek-White**).

**T2** – **Digital and Computational**

**Thomas**, FRS was appointed as Distinguished Research Professor (0.2 FTE) in 2019. His pioneering research on land regeneration, ground source heat and exploitation of unconventional gas and carbon sequestration in coal seams, is catalysing efforts on energy systems and decarbonisation. **Evans** joined SU in 2018 as an EPSRC Manufacturing Research Fellow from the UK Atomic Energy Authority. He focuses on using image-based finite element methods to develop new software for high-value manufacturing cross-linking with T3. **Giannetti** was recruited as a senior lecturer in 2016, after almost a decade in industry, for her extensive knowledge on the development of autonomous and intelligent production systems. She won an EPSRC Innovation Fellowship award and gained promotion to associate professor in 2019.

**T3** – **Materials and Manufacturing**

**Holliman** was appointed in 2017. He opened new research avenues on surface and interface engineering of photovoltaic devices and next-generation steel products, cross-linking with T1 and SPECIFIC. **Irvine** was recruited in 2017 to support and augment efforts towards thin-film materials for the semiconductor, optoelectronics, and photovoltaic industries. His internationally recognised research on thin-film deposition enhances current capabilities in semiconductor technology and surface modifications supporting CISM's growth. **Palmer** (0.8 FTE), appointed in 2018, is an internationally recognised expert in the production, synthesis, and characterisation of nanoparticles. He held an EPSRC Fellowship between 2017-19, and his arrival augmented research efforts in nanomanufacturing (CNH).

**T4** – **Health, Wellbeing and Sports**

Various research areas within the strategic theme were reinforced through junior positions. Lecturer positions were awarded to **Del Giudice** (2017) in the fields of complex fluids, rheology and microfluidic devices for healthcare diagnostics, and **Barnes** (2019), for her work on Human-Centred Data Science and Artificial Intelligence (AI) tools for bioimaging. Both cases are strengthening ongoing efforts at CNH as well as branching into T2.

**Fellowships**

Staffing strategy has also focussed on promoting applications for competitive fellowships by excellent candidates. In this census period, 16 fellows joined CoE through Sêr Cymru/COFUND programmes, 4 through the European MSCA individual fellowship scheme, 5 with EPSRC Research Fellowships and 1 with an MRC Research Fellowship. Between 2017 and 2019, CoE appointed 4 of these fellows to academic positions (**Alexander, Evans, Orbaek-White and Zhang)**.

**2.2 Future Staffing Strategy**

The substantial increase in staff numbers across all strategic priority areas has allowed CoE to shape an ecosystem to deliver its mission objectives. In the next five years, appointments will focus on supporting the growing portfolio of CoExps, targeting areas of green-recovery, medical

engineering, and industrial decarbonisation – in line with research, impact, and IDR strategies. Retaining and supporting current staff will also be a priority to build a solid foundation for future sustainable growth. CoE will continue to invest in fellowship applications.

**2.3 Staff Development**

SU is firmly committed to providing an environment and culture for all staff to succeed both professionally and personally, independently of their career stage or pathway. A wide range of courses and workshops are offered centrally by the Development and Training Services (DTS) and are mapped to the Vitae Researcher Development Framework (RDF). Research integrity, data protection, equality and diversity in the workplace, and sustainability training are compulsory for all staff.

**2.3.1 Support Mechanisms for ECRs**

Each ECR undergoes a CoE-specific induction week. Training is provided on all aspects of academic life, including College structure and policies, research aids, PGR supervision, academic performance, teaching, career development, and wellbeing. These junior staff are allocated a mentor at senior level and a line manager to help develop successful research strategies. Progress is discussed during formal reviews biannually. All academic appointees are guaranteed a start-up package comprising £5k, a PhD studentship, reduced teaching load, and minimal administration duties for the first two years. Focussed support is also provided for initial grant capture. The Research Hub (Section 3.2) collaborates with line managers and mentors, offering ample guidelines, proof-reading and internal peer review. For proof-of-concept work and networking meetings, ECRs can seek further funding from their Research Centre (RC).

All ECRs have ample opportunities to enhance their career development. Particularly encouraged is the participation in (i) **Welsh Crucible,** a pan-Wales development programme for future research leaders that fosters IDR collaborations with policymakers and the media (13 CoE researchers took part since 2014) and (ii) SU's **Florence Mockeridge Fellowship** scheme - a six-month mentorship programme designed to develop successful fellowship applications (4 CoE researchers participated since its establishment in 2018).

**CoE has instituted a College-specific policy in which 20% of overheads raised by grant income is returned as flexible spending budget to the PI**. While the policy applies to all staff, it has proven to be extremely helpful to ECRs. They can use the extra funding for equipment or an additional PhD studentship enabling a timely expansion of their research profile.

Examples of the implemented support mechanisms' success since 2014 include 8 EPSRC New Investigator Awards/First Grants and successful application to fellowship schemes including **Baker** and **Evans** (EPSRC Research Fellowship), **Davies** and **Giannetti** (EPSRC Innovation Fellowship), **Carson** (MRC Innovation Fellowship), and **Jennings** and **Ransing** (RAEng Industrial Fellowship). Furthermore, 10 ECRs appointed since 2014 have been promoted to either senior lecturer (4, of which 3 female) or associate professor (6, of which 2 female).

**2.3.2 Support Mechanisms for mid-career and senior academics**

Academic staff performance and development is monitored through the University online Professional Development Review (PDR) system. Each academic receives two face-to-face PDR meetings per year where performance, support, and overall allocation of duties are discussed. On average, staff reported that they could devote over 60% of their time to research

and PGR supervision, in line with CoE's 'Staff Working Load' model (2019, Time Allocation Survey).

CoE has established policies to support specifically mid-career and senior academics. Those with an extensive portfolio of research activities see their workloads reduced from other responsibilities. Emphasis is also placed on training senior academic staff and attendance to the SU Research Leadership course is strongly encouraged. Ample opportunities are offered to engage in research leadership roles. Two female professors have recently successfully applied to become Research Cluster Lead (ZCCE- Karunarathna) and HoCtr (FMRI- Margadonna).

CoE considers academic promotion as a pathway to reward successful staff members. Career progression in the REF period was marked by **13 promotions to Professorships, 21 to Associate Professorships and 8 to Senior Lectureships**. CoE celebrates all staff achieving promotion, recently establishing the **Centenary Inaugural Lectures**, where newly promoted professors are invited to present their successful research and careers to colleagues.

CoE recognises sabbatical leave as a pathway to enhance researchers' profiles and supports them with £5k for travelling expenses. Staff are entitled to one term of leave on full pay for every six terms of service. The move to Bay Campus has limited the uptake due to the organisation of the new infrastructure. However, the number of applications has increased in the last two years with 6 applications in 19/20, of which 4 were granted.

**2.4 Research Staff**

SU implements the '2008 Concordat to Support the Career Development of Research Staff' and holds the European Commission HR Excellence in Research Award in recognition of its commitment to support the career development of research staff.

Research staff are a vital resource for CoE, strongly contributing to its strategic vision. Providing support for their personal and professional development is key. CoE currently employs 175 research staff (20% female, 36% non-UK nationals, 37% self-classified as BAME). They are allocated a line manager and a mentor, typically a senior academic outside their research group, to provide non-project-specific support. Research staff are subject to an annual appraisal, where their performance and career plans are discussed.

CoE aims to support all researchers to pursue their career aspiration and goals. During the assessment period, the majority gained positions either in academia or industry and 23 were promoted to senior researcher positions. Further evidence is the continuously increasing number of successful applications for independent research fellowships (22 since 2014). Many of these talents were recently offered academic positions either at CoE (details in Section 2.1) or at other national/international institutions. Examples include 2 Sêr Cymru NRN fellows that are now lecturers at Glasgow University (**Aggarwal** and **Lee**) and 2 Sêr Cymru fellows, **Dimitrov,** presently a lecturer at Royal Holloway, and **Taddei,** who was appointed as an associate professor at the University of Pisa (Italy) in 2019.

In the census period, CoE has established a Research Staff Working Group led by the Director of Research Staff that meets quarterly to provide a pathway to update College-specific strategies and policies. The working group has been instrumental to change; revisions were made to CoE's REF open-access funds policy and transparency around the Code of Practice, with the induction process refocussed. A CoE research staff intranet page has been created highlighting support

mechanisms, career development schemes, professional enhancement programmes, funding opportunities, and dedicated policies. In 2019 a researcher mentoring scheme was also implemented where research staff act as mentors to PGRs. This approach allows research staff to gain mentoring experience and leadership skills and enables PGRs to receive advice and support from those closer to their development stage. The scheme is gaining momentum with 22 trained mentors and 36 aligned mentees.

**2.5 Portfolios of CDTs for PGR Training**

Since the move to the Bay Campus, the CoE's PGRs cohort has grown by 25% across the EngD, PhD and MSc by research programs. The annual average ratio of PGRs to academic staff (headcounts) is 2.7:1, considering only the last four years. A yearly average of 52 PhD and EngD students graduated each year, up by 42% from the previous census period. Growth was sustained by a stream of successful PGR training grants (UKRI, European Social Fund (ESF), and Welsh Government (WG)) totalling £10.5m. These programmes span the strategic research themes and underpin research activities across RCs and CoExps. Programmes active in the census period are:

- **EDT MATTER** – **Manufacturing Advances Through Training Engineering Researchers** (2010-2018) provided a total of 26 EngD scholarships,
- **Doctoral Training Partnership in Structural Metallic Systems for Gas Turbine Applications** (2011-2020) shared with Birmingham and Cambridge. The scheme is part of the EPSRC and Rolls-Royce strategic partnership. 25 EngD students were trained at CoE within ISM,
- **COATED** – **Centre of Advanced Training for Engineering Doctorates** (2012-2019) in collaboration with Oxford, Imperial College and Bath, funded by EPSRC, industry and WG. The programme provided 21 EngD scholarships,
- **COATED2** – **Centre for Doctoral Training in Industrial Functional Coatings** (2015-2023), provided a cohort of 10 EngD scholarships per year for 4 years,
- **Materials and Manufacturing Academy (M2A)** (2015-2024) offers 24 EngD and 8 MSc research studentships every year,
- **Centre for Doctoral Training in Functional Industrial Coatings** (2019-2028) is currently providing a cohort of 10 EngD scholarships per year for 5 years,
- **Sêr Cymru NRN in Advanced Materials** (2013-2018) is a pan-Wales initiative funded by WG. The network established a graduate school, awarding 42 PhD scholarships (16 to CoE), and runs an extensive programme of seminars, training workshops, conferences, and outreach activities,
- **Wales Knowledge Economy Skills Studentships (KESS)** initiative has funded 19 PhD and 22 MSc research scholarships. In 2015, the programme was renewed by ESF (KESS II) and will run until 2021, providing an additional 25 PhD and 24 MSc places for industry-led projects with Welsh SMEs,
- '**Zienkiewicz Scholarships**' provided 20 PhD scholarships covering all areas of research funded entirely by CoE (2015-2018) to attract the highest-calibre international applicants, with full fee and stipend support,
- **Centre for Doctoral Training in Enhancing Human Interactions and Collaborations with Data and Intelligence Driven Systems** (2019-2028), a CDT shared with the College of Science at SU, which is currently supporting 15 PhDs within CoE.

CoE's cohort of PGRs also includes scholarships funded through the SU-Grenoble partnership (7), Doctoral Training Partnerships (DTPs) (50), ICase (18) and self-funded students.

**2.6 PGR Support and Development**

The Director of Postgraduate Research, who chairs CoE's PGR committee and sits on 'CoE's Research Committee, oversees PhD, EngD and MSc programmes. All research students are closely supported, with their development carefully followed by their assigned supervisor and co-supervisor. PGR development is monitored every month through an online platform where attendance, engagement and progression on targets are registered.

All EngD programmes on materials and manufacturing are combined under the M2A umbrella, creating a large cohort (100+) with shared training courses, support, and facilities. Modules for 120 credits were developed and form an integral part of the degree. These include subject-specific and general interest courses such as effective management, entrepreneurship, and employee research awareness. **96% of EngD graduates have subsequently moved to careers in industry,** demonstrating the success of the M2A model as a pathway for research translation and the creation of a pipeline of skilled people. The EngD modules are also open and highly recommended for students on PhD and MSc programmes. SU also offers a broad range of PGR courses and workshops focussed on skills and personal development through the Postgraduate Research Training Framework.

All PGRs attend their RC's seminar series and College-wide poster competitions. M2A organises an annual conference where all students present their research progress in posters, short presentations, or research colloquia. Industrial supervisors and sponsors are invited, offering an ideal forum for networking, and exploring future projects or employment. Each RC runs similar events (PGR research day) for its students. Many opportunities are offered to serve as members on committees, engage in undergraduate teaching, and participate in entrepreneurship and outreach activities.

Since 2014, CoE has further enriched PGRs' experience by targeting inclusivity, sense of community and wellbeing. The move to Bay Campus has guaranteed each student a desk in open-plan offices alongside colleagues with similar research interests. Shared break-out areas and collaborative workspaces facilitate research development and foster collegiality. The induction process was enhanced, with focussed online sessions on College-specific policies, information on finance/procurement processes, access to laboratories, and general H&S procedures. A new PGR College-intranet page was launched with links to all necessary information on resources, available infrastructure, social events, local engineering societies and a continually updated FAQ section. Furthermore, CoE has been promoting additional experience through journal reviewing clubs, enhanced demonstrator training, peer observation, and the researchers' mentoring scheme (details in Section 2.4). These targeted strategies have been highly successful. A substantial and continuous year-on-year improvement is evidenced by the Postgraduate Research Experience survey (PRES) for all categories. Prominent is the 11% increase in student satisfaction of the induction process (2019 and 2020 results).

**2.7 Equality and Diversity**

SU was ranked 47$^{th}$ in the 2019 Stonewall's Top 100 Employers List and is a charter member of Athena SWAN, holding an Institutional Silver Award since 2017. CoE is a leading ambassador of the SU Strategic Equality Plan and, in 2019, received the Athena SWAN Silver Award for its achievements in developing a culture of inclusivity. As part of its continuous efforts to enhance equality and diversity, CoE appointed an inclusivity support officer (1 FTE) in 2017 to organise activities and ensure implementation of policies. CoE provides extensive unconscious bias training to all staff, targeted recruitment policies for female academics and research staff, an

outreach programme, and series of seminars given by inspirational female engineers open to all staff and students. These efforts are part of a comprehensive strategic plan aiming at the submission of an Athena SWAN Gold Award application in the next census period.

The implemented policies' success is evidenced by substantial growth of female academics (+114%), research staff (+37%), and PGRs (+20%) since 2013. Furthermore, the percentage of female academic staff submitting applications for promotion has seen a dramatic increase, with at least one successful promotion per year. Many promotion-mentoring programmes are available to female staff including (i) the pan-Wales 'Women in University Mentoring Scheme', (ii) SU's Mary Williams Mentoring Scheme and (iii) CoE-specific promotion mentoring programme, which also targets female research staff.

CoE recognises that one of the most direct pathways to achieve research excellence is to attract exceptional talents with diverse backgrounds independent of their origins. As a result, a truly multi-ethnic and international community enriches CoE, with 34% of returned staff classifying themselves as non-UK nationals and 36% as BAME (Table 2.1).

To raise awareness, address challenges and remove barriers, CoE has established the **BAME Student in Engineering Network**, which clusters together undergraduate and postgraduate students, research staff, and academics. The network aims to provide knowledge and solutions for a more inclusive environment in engineering. Since 2019, CoE has supported activities such as a series of talks on topics including organisational culture inequality (Prof. Ogbonna, Cardiff Business School) and the intersectionality of gender and race (Dr. Prakasam, SU). The network collaborates with the Ethnic Minorities and Youth Support Team in Wales regarding outreach and engagement activities.

| | Total | Female | BAME | Non-UK Nationals |
|---|---|---|---|---|
| Professors | 44 | 3 | 12 | 8 |
| Ass Professors | 29 | 3 | 9 | 10 |
| Senior Lecturers | 26 | 6 | 11 | 12 |
| Lecturers | 16 | 3 | 10 | 10 |
| Research staff and Fellows | 185 | 38 | 64 | 59 |

Table 2.1 CoE diversity data - June 2020.

Promoting and supporting diversity permeates all CoE's policies, procedures, and practices. Specific training is obligatory for staff with recruitment, management, and leadership responsibilities. For example, the CoE's REF team selecting outputs and ICSs for this submission undertook mandatory specialised training on equality and diversity and unconscious bias (in line with SU Code of Practice). The submission comprises the one best-quality output from each Cat. A staff member with the remaining chosen from the available pool of outputs, including those of former eligible colleagues.

**2.8 Staff and Student Wellbeing**

CoE is fully committed to the health and wellbeing of its staff and students and is constantly updating its policies to ensure a safe, healthy, and enjoyable workplace. In 2019, CoE established the new role of **Director of Health and Wellbeing** (Prof. Stratton), who sits in the Executive Committee and shapes specific strategies and practices in this area. In addition to

services provided centrally by SU, CoE has appointed Dr. Minou as **Wellbeing Promotion Officer** (0.7 FTE) and runs a series of courses, including weekly mediation sessions and wellbeing surgeries for staff and students. Following the COVID-19-related lockdown, CoE has continued to provide support through specifically designed online sessions on topics such as occupational health when working from home, home-schooling and social isolation.

**Section 3. Income, infrastructure, and facilities**

**3.1 Income Strategy**

Since 2014, CoE aimed to increase the number of substantial long-term awards. The strategy was empowered by facilitating coalescence of staff around strategic research areas, a focussed recruitment campaign, and unparalleled availability of continuously expanding state-of-the-art infrastructure at Bay Campus. In addition, CoE placed a large emphasis on income diversification targeting UKRI and industry. Results of the implemented strategy are given in Table 3.1

| | REF 2014 (average p.a.) | REF 2020 (average p.a.) | Growth |
|---|---|---|---|
| Income per FTE | £157k | £224k | 43% |
| Number of awards > £1m | 2 | 6 | 200% |
| Research income – UKRI | £3m | £6.3m | 110% |
| Research income – Industry | £1.1m | £1.9m | 73% |

Table 3.1 Comparison of metrics relative to the implemented income strategy. Data refer to reported HESA income spent.

In the next 5 years, CoE will continue to prioritise resources to support large bids by enabling staff to create partnerships and extend their network of industrial and academic collaborators. This approach will allow CoE to achieve its goal of further income diversification in a post-Brexit scenario, shifting from EU sources to industry and UKRI. As already mentioned in Section 2, CoE will continue to prioritise support for fellowship applications as a basis for further growth.

**3.2 Support for Income Generation**

CoE delivers its income strategy through the Research Committee and a dedicated Bay Research Hub. The Hub is a significant resource that supports staff throughout the process, from grant application to post-award reporting. Expert service is provided to PIs for preparation of high-quality proposals and to ensure compliance. Rigorous mock panels for fellowships and strategic grants are organised.

**3.3 Analysis of Income Data**

Since 13/14, CoE secured more than 700 research grants and contracts worth an excess of £220m. Compared with the previous census period, the average per annum income more than doubled from £11.8m to £26.1m, excluding in-kind. The annual average income rises to 245k per FTE if changes in staff numbers are considered. The total value of grant awards per year shows a general upward trend, with a decrease in 2016/17 resulting from a temporary slowing-down of research activities linked to the move to Bay Campus and organisation of infrastructure and facilities (Fig. 3.1).

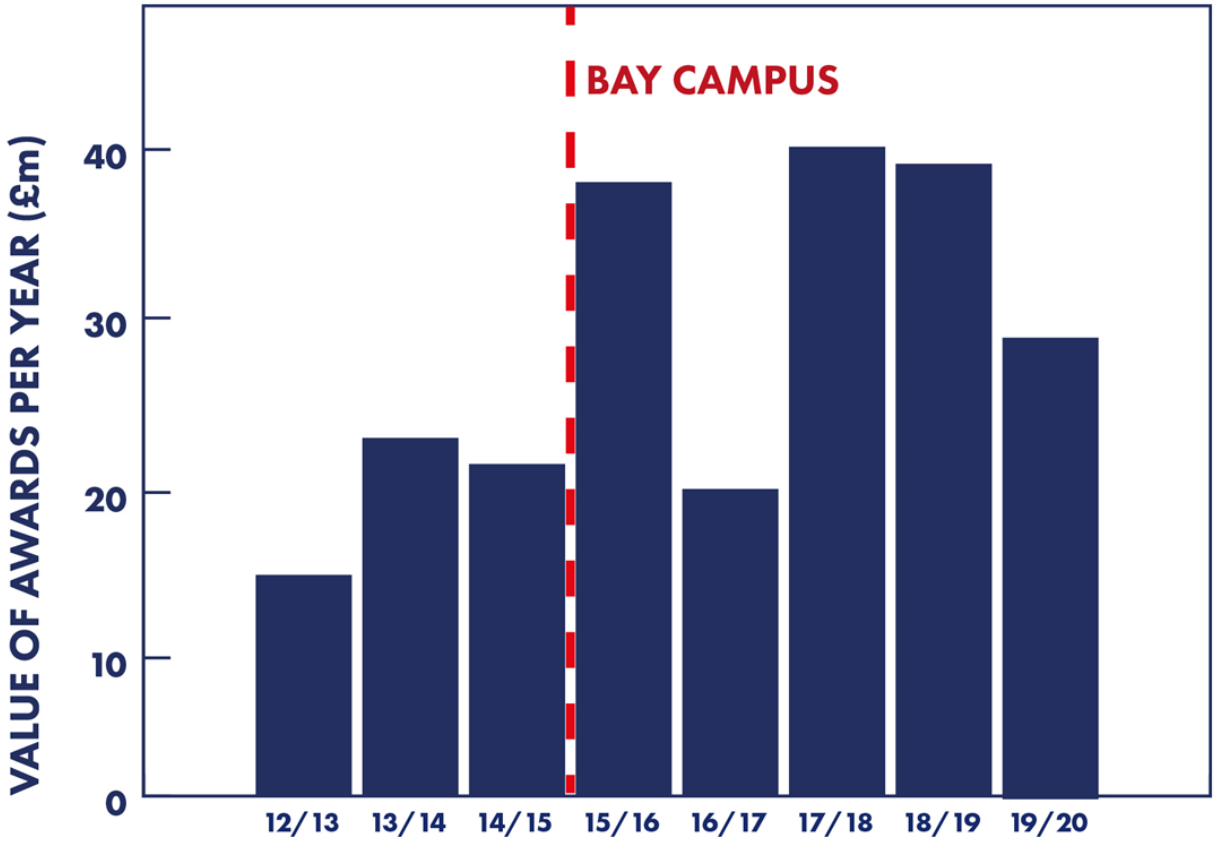


Figure 3.1 Total value of research grants awarded to the CoE since 2012/13

In 17/18 and 18/19, CoE benefitted from the award of a stream of substantial grants, notably, (i) EPSRC Global Challenge Research Fund **SUNRISE**- Strategic University Network to Revolutionise Indian Solar Energy (£6.6m total, £3.2m CoE 2017), (ii) EPSRC **Rapid Alloy Prototyping Prosperity Partnership** (£2.5m 2018) and (iii) EPSRC **Future Steel Manufacturing Hub** 'Sustain' (£10.5m 2019).

An analysis of the grants awarded shows a general increasing trend in the total value of awards across all funder types compared to the previous census period. Since 2013 direct industrial cash support for research has almost doubled. The total amount of Innovate UK income amounts to £12.5m with more than 40 awards, and 193 research contracts with commercial and public sector entities.

| | % UK RC | % UK Gov | % EU Gov | % Industry |
|---|---|---|---|---|
| 12/13 | 22.2% | 12% | 50.2% | 10.4% |
| 15/16 | 21.3% | 10% | 57% | 8.6% |
| 17/18 | 38.4% | 21% | 21% | 13% |
| 19/20 | 47.2% | 12% | 28% | 6% |

Table 3.2 Distribution of income for selected years of the census period, considering the last reported year in REF2014 as a baseline. Values refer to research awards won not income spent.

Considering the relative percentages of awards from different funding bodies, the proportion arising from UK Research Councils has seen the largest increase (Table 3.2). This can be considered as one of the significant achievements of the implemented policies and a direct consequence of investments made in areas of excellence across strategic research themes. Awards from EU-related structural funds have also been substantial, with CoE securing large European Regional Development Fund (ERDF) grants (including capital and infrastructure). However, since 2014, CoE has become less reliant on ERDF funding streams as reflected by the sustained increase in awards from other sources, **setting the scene for a sustainable post-Brexit future**.

**3.4 In-kind and Other Sources of Income**

CoE has enormously benefitted from access to the Science and Technology Facility Council (STFC) large-scale facilities, particularly ISIS, DIAMOND and ESRF (total awarded beamtime income > £2m). The special relationship between CoE and STFC is demonstrated by the recent award of a £0.7m grant to create a beamline-bridging industry-focussed centre for Wales that will support access to STFC's facilities for Welsh manufacturing. Other in-kind contributions include donations from companies, such as an extensive suite of equipment from Tata Steel to SaMI, valued at £5.2m.

**3.5 Infrastructure and Facilities**

The substantial investments in relocation and expansion of CoE facilities at Bay Campus (Figure 3.2) described in REF2014 were realised in September 2015 when staff and research laboratories moved into the four planned buildings, Engineering Central (7,890m$^2$), Engineering East (8,258m$^2$), ESRI (4,139m$^2$) and ISM (2,320m$^2$). Each building houses new state-of-the-art equipment, purpose-built laboratories, modern office space, and common areas for staff and students that are shared between RCs, CoExps and research groups.

Since 2014 CoE continued to support investments to expand specialised research and teaching infrastructure across all research themes. Further funding was secured from UKRI, ERDF and Welsh Government (WG) for capital equipment, buildings and infrastructure dedicated entirely to delivering research, impact, and engagement activities. These include:

- **Engineering North** (7,126m$^2$, 2019) - constructed through joint WG/SU 'The Institute for Innovative Materials, Processing and Numerical Technologies (IMPACT)' initiative, with a project value of £35m. The new facility, which includes purpose-built laboratories (1,600m$^2$) and a specialised workshop, offers a flexible cross-disciplinary environment serving a vast network of industrial collaborators. It comprises 248m$^2$ of dedicated space to foster academia-industry co-location partnerships. Three companies have now established their R&D base in the building. The IMPACT project also provided funds to acquire state-of-the-art equipment to augment the robotics laboratory and energy storage research.
- **The Active Classroom** (144m$^2$, 2016) - designed with most advanced renewable energy technologies, developed in partnership with businesses, and has been an exemplar demonstration facility catalysing a surge of research, impact, and collaboration activities, including ABC. This building is regularly used for PGR teaching and engagement activities and has received several high-profile awards within the construction industry (Constructing Excellence in Wales Award for Innovation in 2017 and the Royal Institute of Chartered Surveyors Wales Award for 'Design through Innovation' and 'Project of the Year' in 2018).
- **The Active Office** (206m$^2$, 2018) builds on the success of the Active Classroom and was constructed through an Innovate UK £0.8m award. It hosts **SPECIFIC** staff and offers co-location space for industrial partners.

- **CISM** activities will be carried out in a 4,320m$^2$ purpose-built facility (planned completion: 2022) with ample research space, including state-of-the-art clean rooms and office space for staff.

Figure 3.2 Aerial Photograph of Bay Campus – June 2020.

A brief account of CoE's key existing facilities is given below, organised by RC.

**Materials Research Centre (MRC)**

| | |
|---|---|
| Areas of Research | Photovoltaics<br>Functional Coatings<br>Corrosion and Electrochemistry<br>Characterisation of Materials<br>Metallurgy<br>Steel Process and Technology |
| Centres of Expertise (MRC lead) | SPECIFIC IKC, ISM, ABC and SaMI |
| Strategic research themes | T1 and T3 |
| Number of PGRs | 90+ |
| Values of grants awarded since 16/17 | >£70m |
| Dedicated Infrastructure at Bay Campus | Engineering East, The Active Classroom, The Active Office, ISM |
| Infrastructure Outside Bay Campus | Baglan Bay Innovation Campus<br>Port Talbot Technology Demonstration Site<br>SaMI (Singleton Campus) |
| Main Facilities for Research/Impact | Advanced Imaging of Materials (**AIM**) Facility<br>PV Manufacturing Facilities<br>Clean Rooms for Device Fabrication<br>Corrosion and Electrochemistry Lab<br>Mechanical Properties Testing Facility<br>Demonstration Facilities |

**MRC** hosts a large suite of purpose-built spaces for materials synthesis, characterisation, and testing, as well as facilities for device fabrication. These include dedicated laboratories for materials characterisation such as X-ray Photoelectron Spectroscopy (XPS), micro- and nano-X-ray computed tomography, state-of-the-art transmission electron microscopy (TEM), scanning electron microscopy (SEM) and focussed ion beam nano-fabrication. This suite of equipment is the Advanced Imaging of Materials (AIM) facility's backbone, enabling a fully coupled micro/nano-analysis workflow via state-of-the-art advanced correlative imaging. AIM is a unique facility in Wales funded through a combination of successful grants awarded by EPSRC and WG (£10m). In 2020, AIM received further funding (£0.7m) through the Sêr Cymru programme for maintenance and upgrading.

Within **MRC**, research on energy production and photovoltaics is developing in a series of state-of-the-art laboratories shared by SPECIFIC staff. The laboratories are designed for PV scale-up and processing, PV materials, photochemistry, device fabrication, and manufacturing, including state-of-the-art clean rooms. SPECIFIC also has facilities outside Bay Campus for technology demonstration purposes. Particularly, the Baglan Bay Innovation Centre is an open innovation space that includes laboratories and pilot-scale reel-to-reel manufacturing facilities (> 1000$m^2$). The centre was established in 2014 through £1.9m awarded by the Academic Expertise for Business (A4B) programme (WG).

ISM has a dedicated building specifically designed to research high-performance materials at extreme conditions, focussing on the aerospace and power-generation industries. Research activities involve four dedicated mechanical testing laboratories: (i) **the Universal Lab**, which houses the majority of the uniaxial electric and servo-hydraulic test frames; (ii) **a Creep Lab**, which is structurally isolated from the rest of the building to reduce potential vibration effects; (iii) a **High Cycle Fatigue Lab**, which is isolated to contain noise, and (iv) an **Environmental Lab**, where hot gas corrosion testing is conducted.

**Zienkiewicz Centre for Computational Engineering (ZCCE)**

| | |
|---|---|
| Areas of Research | Aerospace Engineering<br>Biomedical Engineering<br>Coastal Engineering and Marine Energy<br>Computational Methods in Engineering<br>Modelling of Materials and Structures |
| Centres of Expertise (ZCCE) | ADDED |
| Strategic research themes | T1, T2 and T4 |
| Number of PGRs | 80+ |
| Dedicated infrastructure at Bay Campus | Engineering central and ESRI |
| Values of grants awarded since 16/17 | >£8m |
| Main Facilities for Research/Impact | High-Performance Computing<br>Coastal Engineering Laboratory<br>Hydrometeorological Facilities<br>Experimental Aerodynamics Laboratory |

**ZCCE** benefits from its own high-performance-computing (HPC) cluster and access to those at ASTUTE. Research is also supported by access to **Supercomputing Wales**, a £15m project partly funded by ERDF, which provides HPC infrastructure to researchers in Wales. One of the two supercomputing systems, i.e., SUNBIRD, is hosted at the Computational Foundry of SU.

Within **ZCCE**, research areas include the computational modelling of coastal and hydrological processes, morphodynamics, hydrometeorological modelling and CFD modelling of marine energy devices. The coastal engineering laboratory houses a 30m x 0.8m x 1.2m state-of-the-art wave flume that can generate wave heights up to 0.45m. Research infrastructure also includes a set of facilities (not available anywhere else in the UK) for hydrometeorological modelling, including specialised precipitation devices in a conventional C-band rain radar.

The move to Bay Campus has also enabled construction of space designed to host a £1.2m state-of-the-art wind tunnel to drive expansion of **ZCCE's** activities in the field of Experimental Aerodynamics. This unique facility allows research in advanced 2D airfoils, 3D wings, model aeroplanes with working engines, wind turbine blade sections, and small-scale automotive testing over a wide range of flow conditions and Reynolds numbers.

**Systems and Process Engineering Centre (SPEC)**

| | |
|---|---|
| Areas of Research | Nanomedicine and Bio-nanotechnology<br>Nano-materials and Nanosensors<br>Complex Fluids and Rheology<br>Semiconductors<br>Photonics<br>Interfaces and Thin Films |
| Centres of Expertise (SPEC lead) | CNH, CISM |
| Strategic research themes | T4 and T3 |
| Number of PGRs | 70+ |
| Values of grants awarded since 16/17 | >£11m |
| Dedicated Infrastructure at Bay Campus | Engineering Central and East |
| Infrastructure Outside Bay Campus | CNH (Singleton Campus)<br>Haemorheology Laboratory (Morriston Hospital, Swansea) |
| Main Facilities for Research/Impact | Micro-fabrication Clean Rooms<br>Biomaterials Clean Rooms<br>Cell-culture Laboratories<br>Clinical Haemorheology Laboratory<br>Biomaterials Laboratory |

**SPEC**'s activities towards advanced technologies for water treatment (drinking, waste, and process-water) and desalination constitute a major area of strength for CoE. Attention is paid specifically to a multidisciplinary approach encompassing membranes' development, modelling and characterisation of their processes, and pilot-scale studies for membrane fabrication. Activities benefit from dedicated infrastructure (The Water Advanced Technologies and Environmental Research Laboratory) and extensive membrane and desalination equipment, including ultrafiltration and microfiltration equipment at the lab and pilot scales.

**SPEC** houses the Biomaterials, Biofouling and Biofilms Engineering Laboratory (B3EL) facilities, which exploit a range of techniques for characterisation and control of biological interfaces. Further specialised infrastructure includes bioprocess equipment such as a suite of fermenters that are regularly used by industry and academia to harness the metabolism of microbes to produce proteins for commercial applications.

**SPEC's** activities towards technology and science for healthcare applications have strengthened during the census period. The established cross-institutional CoExp CNH offers a set of dedicated infrastructures including micro-fabrication and bio-material clean rooms, nanoscale imaging and fabrication facilities, cell-culture laboratories, a 10-bed clinical research ward and a research-dedicated MRI facility. CNH contains the EPSRC-NHS Clinical Haemorheology Laboratory established at ABMU NHS Trust Hospital in Morriston, Swansea in 2005. The laboratory has served as a resource for pre-clinical translational research based on new haemostatic biomarkers under successive EPSRC and NISCHR awards, including an EPSRC Healthcare Impact Partnership (HIP), which was placed first in EPSRC's HIP funding priority list in 2014. The laboratory houses a comprehensive suite of rheological and haemostatic equipment and provides infrastructure for conducting near-patient work in collaboration with NHS consultants in several patient clinical care pathways. CNH facilities are vital in bringing together academics, clinicians, and industrialists in a single R&D environment where technology innovation can be directly translated and evolved to higher TRLs.

**The Future Manufacturing Research Institute (FMRI)**

| | |
|---|---|
| Areas of Research | Additive Manufacturing<br>Printing and Coating<br>Robotics and Automation<br>Artificial Intelligent for Manufacturing<br>Energy Storage |
| Centres of Expertise (FMRI lead) | ASTUTE, CAPTURE |
| Research Themes | T2, T3 |
| Number of PGR | 40+ |
| Value of grants awarded since 16/17 | >£19m |
| Dedicated Infrastructure at Bay Campus | Engineering North, Engineering East |
| Main Facilities for Research/Impact | Swansea Additive Manufacturing Research Centre<br>Materials Advanced Characterisation Centre<br>The Welsh Centre of Printing and Coating<br>Robotics and Automation laboratory |

**FMRI's** facilities include **The Swansea Additive Manufacturing Research Centre (SAMR)**, with its two new Renishaw laser powder bed fusion additive manufacturing systems and support apparatuses such as isostatic press and coordinate measurement machines, and the **Materials Advanced Characterisation Centre** (**MACH1**) which was funded through the ERDF Academic Expertise for Business A4B programme with provision of high-throughput technologies for materials characterisation, selection and analysis. Equipment includes a multi-sample laser flash system for measurement of thermal diffusivity, multi-sample thermogravimetry (TGA), and a small-disk punch tester for high-speed small-sample tensile testing. **MACH1** was awarded the Prosperity Partnership in collaboration with Tata Steel and attracted direct investments from Sandvik-Osprey, Renishaw, and Kennametal while additionally acting as a stepping-stone for receiving the COMET Combinatorial Metallurgy project, funded through a £1.4m SMARTExpertise grant.

**FMRI** hosts the **Welsh Centre for Printing and Coating (WCPC)**, which focuses on integrated manufacturing by printing with expertise in screen flexographic, lithographic, rotogravure, digital, pad printing and 3D printing processes. WCPC partners with the EPSRC **Centre for Innovative Manufacturing in Large-Area Electronics** owing to its unique expertise in manufacturing

techniques based on large-area printing and coating. WCPC research infrastructure is located in a set of purpose-built laboratories with state-of-the-art facilities for liquid and paste-ink manufacture and characterisation, as well as device production and prototyping. Pivotal for WCPC research is the availability of industrial-scale equipment such as the roll-to-roll flexographic press for printed electronics, which resulted in the award of a £1.8m SMARTExpertise project 'Application of Functionalised Micro and Nano-Materials – scale up to volume production', a development of one of the submitted ICSs.

**FMRI** research benefits from a collaborative robotics research laboratory for industrially informed research and skills development, which provides resources that strengthen existing partnerships with Airbus on a wide range of aerospace automation activities, including novel machining and metrology and process optimisation.

**The Energy Safety Research Institute (ESRI)**

| | |
|---|---|
| Areas of Research | $CO_2$ Capture<br>Catalysis<br>Membranes and Filtration<br>Hydrogen Production and Storage<br>Nanoparticles and Nano-materials<br>Modelling and Assessment of Power Grids |
| Strategic research themes | T1,T3 |
| Number of PGRs | 20+ |
| Value of grants awarded since 16/17 | >£8m |
| Dedicated Infrastructure at Bay Campus | ESRI |
| Infrastructure Outside Bay Campus | Bay Studios Pilot Line |
| Main Facilities for Research/Impact | State-of-the-art Chemistry Laboratories<br>Scale-up Facilities |

The appointment of Prof. Barron resulted in further funding from HEFCW to establish a dedicated research infrastructure for energy safety research. The 4,139m$^2$ **ESRI** building houses state-of-the-art laboratories for the synthesis and production of compounds in nano and bulk form as well as a variety of equipment for material property characterisation. ESRI's staff also benefits from a large-area laboratory outside Bay Campus for scale-up and demonstration of technological innovations. Integration of laboratory and pilot line facilities enabled the award of large projects funded by the WG and the ERDF on industrial decarbonisation of the South Wales corridor and on the commercialisation of energy technologies totalling £6.6m.

### 3.6 Technical Support

A multidisciplinary group of laboratory technicians, including a dedicated IT team, supports the vast infrastructure and specialised equipment available at CoE. Engineering East hosts a workshop that provides specialist services in designing, drawing and manufacturing bespoke items required by research projects. Other smaller satellite workshop facilities also provide project-specific support. CoE continues to embrace the culture of employing apprentices, with three joining the technical team in 2018 on a 4-year apprentice scheme.

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

CoE is continuously expanding its ecosystem of strong international, national, and regional partnerships. The move to the Bay Campus, establishment of strategic research themes and CoExps portfolio have catapulted CoE to the global scene and augmented its influence on a wide range of beneficiaries, including academics, end-users, policymakers, and stakeholders. As highlighted in Sections 1 and 3, CoE has developed a range of engagement pathways, forging, and fostering collaborations across the board. Evidence is provided, by an analysis of outputs published during the census period of which 77% result from collaborations with other institutions, 58% through international partnerships (82 countries) and 10% are co-authored with industry. CoE currently manages a directory of over 250 relationships with companies spanning from regional SMEs to large multinational enterprises.

**4.1 Collaborations with academic institutions**

CoE benefits from a diverse range of collaborative projects with other leading institutions, many of which are highly interdisciplinary (Section 1.11), spanning all strategic research themes. Some involve large consortia within Wales (5 pan-Wales projects currently active), the UK (12 large EPSRC collaborative awards) and worldwide (16 H2020 ongoing research programmes). A selective catalogue of significant initiatives is:

- GCRF-funded **SUNRISE** Network involving 11 academic institutions in India and UK with eight global industrial partners. The project was awarded the 'International Collaboration of the Year' by the Times Higher Education in 2020,
- **SELKIE** project funded by EU Ireland-Wales cooperation programme, bringing together researchers of the CoE and Cork University with four SMEs on marine energy research*.*
- H2020 **SABRE** Shape Adaptive Blades for Rotorcraft Efficiency project joining together institutions from 5 different countries,
- The EPSRC Programme Grant **ATIP**- Application Targeted and Integrated Photovoltaics – Enhancing UK Capability in Solar energy- led by CoE with Imperial College and Oxford University,
- The EPSRC and ICSF-funded **ABC Research Programme** led by CoE in collaboration with Sheffield, Newcastle, Imperial, Cardiff, Nottingham, Birmingham, Loughborough, Bath and UCL,
- The EPSRC **Supergen Solar Network+** led by Loughborough University in collaboration with CoE, Bath, Cambridge, Imperial College, Liverpool, Oxford, Sheffield, and Southampton,
- The NERC-funded project **CoastWEB** 'Valuing the contribution which coastal habitats make to human health and wellbeing' led by Plymouth Marine lab in collaboration with CoE, and other 7 partners (2016-2020).

**4.2 International Partnerships and training networks**

In the census period, CoE devoted significant efforts towards internationalisation in line with its mission. Partnerships are encouraged and sustained through various mechanisms, including sabbatical leaves, honorary appointments, distinguished visiting fellowships, PGRs and RAs exchanges and collaborative supervision.

CoE is currently benefitting from SU's international strategic links, including (i) **Swansea's Texas partnership** that involves eight leading institutions in Texas, and (ii) **Swansea's Grenoble partnership** with Grenoble Alpes University, which is a consortium of higher education and research institutions in the Grenoble area. Both include shared research programmes, joint MScPGR degrees, and staff exchange visits enabled by dedicated resources. ESRI has several

collaborative projects with Rice University as part of a global energy safety network. CNH is developing innovative techniques for treating cancer tumours with the Houston Methodist Research Institute (HMRI) and Baylor College of Medicine. In addition to SU partnerships, CoE has developed several bilateral collaboration and exchange PGR agreements since 2014. These include Tsinghua University, Indian Institute of Technologies, Karlsruhe Institute of Technology (KIT), International Centre for Numerical Methods in Engineering (CIMNE).

Other examples of extensive international partnerships include the GCRF-funded **SUNRISE** project**,** which started as India-UK cooperation but has since been expanded, through a stream of connected initiatives, to other countries, including Mexico, South Africa and Kazakistan. The project also leverages other activities such as the EPSRC Joint UK-India Clean Energy Centre JUICE, a consortium of nine UK leading institutions (including CoE). **Hilal** received a Royal Society GCRF award to address water sustainability within the palm oil industry in Malaysia. **Karunarathna** is collaborating with the School of Art Design & Architecture University of Huddersfield on a NERC funded project that aims at mitigating the hazards of floods in the Jakarta metropolitan area -Indonesia.

CoE has been participating in the Erasmus+ programmes throughout the census period and organising a collaborative Erasmus Mundus MSc in Computational Mechanics with Universitat Politecnica de Catalunya (UPC) since 2006. In addition to funded research grants, CoE is part of two European training networks (H2020), **MAESTRO**, making perovskites truly exploitable, and **ProTechTion**, enabling industrial decision-making on complex production technologies supported by simulation-based engineering.

Effectiveness of implemented strategies to increase international visibility is also evidenced by the number of links established through incoming and outgoing honorary appointments:

- **Hilal** was appointed the Global Network Professor at New York University, Abu Dhabi, United Arab Emirates, to establish a collaborative research programme in desalination and water treatment (secondment 2019). He received sabbatical leave (2014-16) for leading the Qatar Foundation Research and Development regarding water poverty.
- **Summers** and **Rees** are Senior Affiliates of the Texas Methodist Hospital Research Institute as part of Swansea's Texas partnership. **Rees** is also a Visiting Professor at the Broad Institute of MIT and Harvard.
- **Nithiarasu** has served as an Adjunct Professor both at the Indian Institute of Technology, Madras, since 2018 and Moscow Institute of Physics for collaborations in computational engineering (2014-17).
- **Barron** holds the Charles W. Duncan Jr.-Welch Foundation Chair in Chemistry at Rice University, Texas, USA, actively reinforcing the SU-Texas partnership.
- **Adhikari** is currently a Distinguished Visiting Professor at the University of Johannesburg (South Africa) and in 2018 was awarded a RAEng Distinguished Visiting Professor grant to host **Prof. Ganguli**, the Satish Dhawan Chair in Aerospace Engineering at the Indian Institute of Science.
- **Palmer** has been Honorary Professor at Nanjing University, China, since 2015, strengthening knowledge transfer between the UK and China on large-scale manufacturing of nanostructures.
- Prof **Gareth Huw McKinley FRS** professor at the Department of Mechanical Engineering, MIT, received an Honorary Professorship at CoE in 2018 to strengthen collaborations between the two institutions in the field of rheology.

- Profs **Steffen G. Scholz** and **Maximillian Fitchener**, from the Karlsruhe Institute of Technology (KIT), were elected Honorary Professors at CoE in 2020 for collaborations on smart manufacturing and energy storage. KIT and CoE have just signed a memorandum of understanding for student exchange programmes supported by the Welsh Government through the EU Vanguard initiative.
- Honorary Professorship to Prof. **Kantharaj Murali** (2020) from the Indian Institute of Technology Madras to reinforce collaborations in computational engineering through bilateral student exchange programmes.

**4.3 Collaborations with Industry**

CoE has a long history of strong industrial collaboration. In the census period, those with established partners have been strengthened and extended, while a plethora of new relationships with end-users have been forged across research themes. A selection of major collaborations is:

- **Tata Steel** – CoE benefits from a strong and enduring partnership with Tata Steel, which has grown over the years and reinforced through a stream of collaborative projects covering all research themes. In this census period only, Tata Steel provided a total of £9.3m direct funding for 15 projects (excluding in-kind), sponsored academic positions (Worsley, Pleydell-Pearce, and Cockings) and funded >30 EngDs. In support of the collaboration, CoE awarded Honorary Professorships to Profs. Sridhar Seetharaman (Colorado School of Mines), Claire Davis, (Tata Steel at WMG -Warwick) and Martin Brunnock (Managing Director, Tata Steel). Dr. Debbie Baldrey is currently seconded from Tata Steel to lead SaMI. The relationship's strategic nature is also evidenced by the number of collaborative papers produced (54) and participation in 2 submitted ICSs. Flagship projects include: (i) co-creation of SaMI resulting in the secondment of 20 researchers from Tata to CoE, (ii) EPSRC Rapid Alloy Prototyping Prosperity Partnership; (iii) SPECIFIC IKC and ABC, with collaborations and initiatives to develop coatings and steel claddings and (iv) co-creation of Coated2, M2A, and METaL training projects. The latter is designed explicitly for upskilling the workforce in steel manufacturing through CoE's learning programmes.

- **Rolls-Royce** UTC in Materials, hosted by ISM, is a key member of the Materials Partnership, including Birmingham and Cambridge Universities. The partnership started in 2009 and continues to flourish during this REF period through the EPSRC and Rolls-Royce DTP (£2.5m EPSRC contribution to CoE and a £1.5m match funding from Rolls-Royce 2014-20). Rolls-Royce also directly funded projects over £2m during this assessment period. The Strategic Partnership was awarded the IOM$^3$ Gold Medal for industrial knowledge transfer in 2018, produced 77 research papers since 2014 and forms the basis of a submitted ICS. Furthermore, it operated at a strategic leadership level, with three ISM members (Bache, Lancaster, and Jones) serving on international test committees. Flagship projects include (i) SILOET2 Innovate UK framework (£18.1m; £3.2m to the CoE) and (ii) CAJoRR an Innovate UK project focussing on the development of new high-temperature nickel alloys (£0.7m to CoE).

- **Airbus** is a vital partner in significant awards (EPSRC platform grant ATIP and the Innovate UK FAST- Fuel Architecture and Systems Technology- project). Over the years, the collaboration has been further cemented through Airbus Endeavr, a joint initiative between Airbus and the Welsh Government, to support innovation in Wales. Since 2014 Airbus

Endeavr has partnered with CoE on 8 different research projects. The total contract value of Airbus of supported projects in the census period is > £1.5m.

The portfolio of CoExps is a primary enabler for knowledge transfer to industry and creating partnerships among stakeholders to cover the entire value chain. The following examples demonstrate the efficacy of the approach:

**SPECIFIC** has fostered new industries' development by closing the gap between scientific research and its commercial exploitation. Initial key industrial partners included Tata Steel, AkzoNobel and the NSG group. Building on this robust industrial network in this census period, SPECIFIC has grown the ecosystem of stakeholders from all levels of the construction industry supply chain, including contractors (Coastal Housing Group), infrastructure operators (transport for Wales), and materials and technology providers (BASF). The success of the active building demonstrators seeded the ABC programme, which now adds global players such as CISCO, NISSAN, and SIEMENS to CoE's network of collaborations. ABC links with the Core Innovation Hub and its partners, Manufacturing Technology Centre, and Cambridge University Centre for Digital Built Britain. Furthermore, through two consecutive grants from ERDF (£21m), SPECIFIC has partnered with over 70 Welsh and UK SMEs on commercially focussed projects.

**ASTUTE** was established to support companies across Wales. Since 2014 more than 75 industry-led research projects were completed with 45 industry partners spanning the automotive (Toyota and Ford) to health (Frontier Medical Group and Calon Cardio-Technology Ltd), energy (Marine Power Systems, Cross-Flow Energy Company Ltd), and re-use and recycling sectors (British Polythene Limited RPC-bpi Recycling Ltd and EnviroWales Ltd). Through delivery of these projects, ASTUTE has created more than 200 skilled jobs and £10m of revenue within the Welsh manufacturing ecosystem.

**CNH** – Since 2014, CoE staff in CNH have established a variety of collaborative R&D projects with industry. Notably, these include knowledge transfer partnerships (KTPs) in collaboration with Innoture (see submitted ICS), Perpertuus Advanced Materials PLC, and SPTS Technologies – a world-leading manufacturer of equipment for the semiconductor industry. CoE development of thick GaN epitaxial materials to manufacture vertical transistors (which was recognised with the TechWorks University Research Group of the Year award in 2016) has enabled a stream of new collaborations and several industry-led projects resulting in more than £1.3m from Innovate UK in partnership with organisations across the power electronics supply chain, including the Compound Semiconductor Application Catapult. The growing impact and network of CNH in semiconductor and (micro)electronic devices have catalysed the coalescence of research efforts throughout SU to establish CISM (£30m UKRPIF grant and £30m industrial funding).

**4.4 Other Beneficiaries**

Relationships outside industry and academia are essential to broaden research impact and inform and steer CoE strategies to better respond to societal needs. CoE benefits from a long-term relationship with Abertawe Bro Morgannwg University and Hywel Dda Health Boards (NHS Wales) through CNH's R&D facilities based in hospital environments. Research in SPECIFIC and SaMI informs UK government policies such as the ISCF Transforming Construction initiative, Prospering from the Energy Revolution Challenge, and the Construction Sector Deal. SPECIFIC and the ABC programme shape the housing policies of Welsh local authorities (Swansea City, Neath Port Talbot, Pembrokeshire, and Carmarthenshire). In partnership with other organisations, including Industry Wales, the Welsh Automotive Forum and Aerospace Wales,

ASTUTE plays a significant role in informing and steering the Welsh Government's industrial policies and roadmaps. ZCCE's strategic partnership with the UK Atomic Energy Authority is leading the way to digital twin technologies in energy sector enabled by £2m support.

An example of the significant role that CoE plays within Wales is its response to the COVID-19 crisis evidenced by regular appearances in online, TV, radio, and print media. Building on the existing network of local industries and governmental bodies, SPECIFIC was able to diversify its research facilities and enable the production of 500 litres of WHO-recommended hand sanitiser a week, which was delivered to two local health boards. Within two weeks, CoE devised a solution for COVID-19 decontamination through a rapid-release ozone gas treatment of surfaces and air, which removes the need for human cleaning intervention. The initiative has been embraced by the Welsh Ambulance Service through successful trials and is awaiting final approval for full-scale deployment in the entire fleet. Further tests will enable the system to be rolled out for other blue light emergency services, schools, public transport, and hospital wards. The project is the result of the strong link between CoE and NHS. The Welsh Government has highly valued the impact of CoE's research on the regional response to the pandemic, being subsequently awarded a total of 8 grants to fast track the translation of current efforts in self-disinfecting coatings, numerical modelling, and medical devices.

**4.5 Contribution to the discipline**

CoE continuously demonstrates international leadership by significantly contributing to the discipline's growth through participation in committees, conferences, editorial, learned society activities, and research council programmes. In the census period, success is demonstrated by (all data are compared to REF2014 and scaled per FTE):

- 72% increase in awarded fellowships of internationally recognised learned societies,
- 18% increase in contributions to UK and international Research Councils,
- 10% increase in editorial duties for international journals,
- 14% increase in participation in leading international conferences.

**Exemplars of leadership** in the academic community include 41 (25 in the census period) elected fellowships of learned society and professional institutions. These include, among others:

- 3 Fellows of the **Royal Society** (Durrant, Nelson, Thomas),
- 5 Fellows of the **Royal Academy of Engineering** (Cluckie, Hassan, Morgan, Thomas, Lewis),
- 14 Fellows of the **Learned Society of Wales** (Brown, Durrant, Gethin, Hassan, Hilal, Lewis, Morgan, Thomas, Nithiarasu, Palmer, Peric, Reeve, Williams, Worsley),
- 1 Fellow of the **Royal Aeronautical Society** (Adhikari),
- 1 Fellow **Royal Society for the Arts, Commerce and Manufacture** (Williams),
- 3 Fellows of the **Institute of Physics** (Friswell, Palmer, Williams),
- 9 Fellows of the **Royal Society of Chemistry** (Barron, Carnie, Davies, Dunnill, Guy, Holliman, McMurray, Palmer, Watson),
- 2 Fellows of the **Institution of Mechanical Engineers** (Gethin, Nithiarasu),
- 3 Fellows of the **Institution of Civil Engineers** (Hassan, Morgan, Reeve).

CoE contributed to institutions such as those listed above, together with research councils, associations, and governmental bodies, by serving on 108 committee posts (57 new since 2014). Highlights include:

- many academics participating in **UKRI panels** (Summers, Williams) and strategic advisory committees (Williams),
- **Royal Society** Honorary Candidates and Research Professorship committees, Newton International Fellowship Committee and Royal Society chair of Low-Carbon committee (Thomas),
- member of fellowships (Hassan) and joint Academic committees of **Royal Academy of Engineering** (Thomas),
- member of the **European Research Council** Advanced Grants Evaluation Panel and chair of the **COST** action on nano-spectroscopy (Palmer),
- **BEIS** member - carbon capture (Thomas),
- member of **National Assembly of Wales** - Expert Reference Group on Climate Change (Irvine),
- member of **Department for Environment, Food and Rural Affairs (DEFRA)** Chemicals Strategy Focus group (Davies),
- Cockings led the Steel Innovation in the South Wales Science and Innovation Audit commissioned by **BEIS**,
- member of the **Welsh Government** Well-being of Future Generations National Advisory Forum (Bunting),
- Hassan and Morgan as **REF2021 UoA12** panel members.

Contribution to the discipline was recognised with >20 **honours, prizes, and awards** in the assessment period. Examples include:

- **Worsley**, Tata Steel Sponsored Professor at the CoE and Vice President at SU, received the St. David Award for his contribution to innovation, science, and technology in 2020 and the Hadfield Medal and Prize from the Institute of Materials, Minerals and Mining ($IOM^3$) in 2015,
- **Durrant,** was awarded the Hughes Medal of Royal Society for 'Photochemical studies of solar energy conversion devices' in 2018,
- **Gil**, was awarded the Zienkiewicz Award for Young Scientists in Computational Engineering Sciences (2015) and the Lions Award (2016) by the European Community on Computational Methods in Applied Sciences (ECCOMAS),
- **Hilal** received the Menelaus Medal for excellence in engineering and technology from the Learned Society of Wales (2020),
- **Thomas**, UNESCO Professor in the Development of a Sustainable Geoenvironment, has been elected President of the Learned Society of Wales in 2020,
- Frank Fitzgerald medal from $IOM^3$ to **Penney** (2015) and **Cockings** (2019).

A further measure of CoE contribution to the discipline is the listing of 10 staff among the top 2% world's most-cited researchers across 22 subject areas according to a study conducted by Stanford University (doi:10.1371/journal.pbio.3000384), with Friswell and Adhikari ranking 8$^{th}$ and 10$^{th}$ respectively in the subfield of 'Acoustic', Hilal 127$^{th}$ in 'Chemical Engineering' and Nithiarasu 179$^{th}$ in 'Applied Mathematics'.

CoE engaged with the **process and quality of academic publication** by holding 15 positions as Editor/Editor-in-chief, 23 as Guest Editors of themed issues, and 76 as editorial board members. Examples include Editor in Chief of the journals:

- Desalination (Hilal),
- Applied Mathematical Modelling (Sienz),
- Numerical Methods in Biomedical Engineering (Nithiarasu),

- Computers and Geotechnics (Thomas),
- Numerical Methods for Heat & Fluid flow (Lewis),
- Engineering Computations (Li and De Souza).

Evidence of leadership is also provided by CoE delivering over 260 invited papers, speeches, lectures, and seminars in the census period, receiving 28 best paper awards. These include 57 plenary addresses and 168 keynote/invited seminars in established conferences organised, for example, by the Chinese Academy of Engineering, Royal Society of Chemistry, Electrochemical Society, American Chemical Society, Gordon Research Conferences, Institute of Physics and IOM$^3$.

Building on its strengths, CoE will accomplish its vision by consolidating and expanding national and international collaborations with academic and non-academic partners. This will ensure that CoE's reputation for world-leading research and innovation in an inclusive and supportive environment will continue to raise.