Institution: University of Plymouth

Unit of Assessment: 12 Engineering

1. Unit context and structure, research and impact strategy

Introduction

During the REF 2021 period, the 36 academics who comprise the University of Plymouth UoA 12 have made significant progress in research activity. Highlights include:

- an increase in annual research income from £0.9m in 2013/14 to £2.3m in 2019/20 (Section 3);
- publication of 17.0 outputs per member of staff, 36.0% of which were in the top 10% of journals by CiteScore (SciVal 08/01/2021), with highly cited outputs in wave & offshore wind energy, nanoparticles, and neural networks ('REF2');
- being awarded leadership of large research networks (*e.g.* UK Supergen Offshore Renewable Energy hub) and multi-partner research projects (*e.g.* EU Diagnostic Tools for Early Stage Alzheimer's Disease) (Section 1);
- being awarded an EPSRC Doctoral Training Partnership in Offshore Renewable Energy and Health Technology;
- being ranked first in the UK and 8th globally, in marine/ocean engineering in the Academic Ranking of World Universities during the REF 2021 period;
- securing significant investment in infrastructure (*e.g.* £50m New Engineering & Design Facility) and equipment (*e.g.* UK Floating Offshore Wind Turbine Testing Capability) (Section 3); and
- commercialisation of research findings (*e.g.* PulsiV Solar Ltd, based on novel power conversion technology) (Section 1).

Structure of the unit

Figure 1 illustrates organisational changes made during the assessment period, providing context for the merger of the REF 2014 UoA 13 and UoA 15 into the REF 2021 UoA 12.

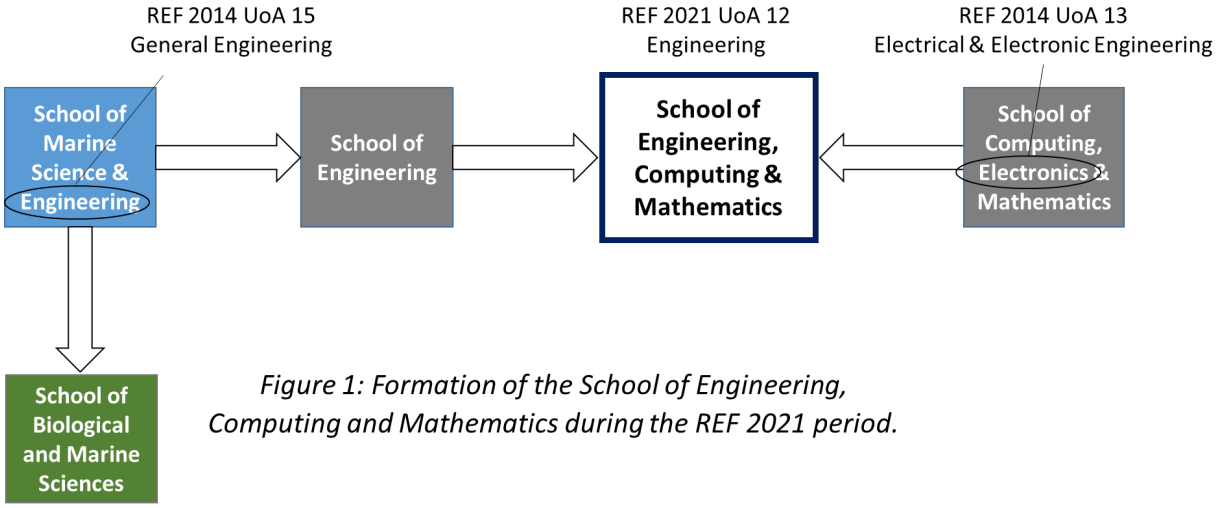

Figure 1: Formation of the School of Engineering, Computing and Mathematics during the REF 2021 period.

In 2014, Civil and Mechanical Engineers were members of the School of Marine Science and Engineering, which co-located marine-themed scientific and engineering disciplines, marine being one of the University's strengths. This encouraged cross-disciplinary collaboration as exemplified by the SOWFIA, MERiFIC and THESEUS projects which combined engineering, environmental science, marine science, and renewable energy policy. However, to enhance the external visibility of Engineering, the School separated in 2017 into the more cognate Schools of (i) Engineering and (ii) Marine and Biological Sciences. Two years later, the School of

Engineering merged with the School of Computing, Electronics and Mathematics (which had been the home of the Electronics Engineers) to form the current School of Engineering, Computing and Mathematics (SECaM). This created a synergistic mix of academic disciplines and strengthened research through new interdisciplinary collaborations, aligned with challenges of the fourth Industrial Revolution, and EPSRC priority areas of clean growth, digitalisation, autonomy, and health technology, aligned to University research institutes.

Strategic aims for research and impact during the assessment period

The over-arching research and impact strategic aims of the unit were as follows:

1. Create effective research environment, grow our research culture, and nurture research strength and breadth.
2. Make space for research and development.
3. Invest in facilities to support research and development.
4. Grow PGR through new and innovative funding streams.
5. Grow research impact through industry and regional partnerships.
6. Pursue synergetic research partnerships and collaborations with other universities and with regional, national and international organisations and businesses.

Review of the research plans described in REF 2014

The vision for Civil and Mechanical Engineering in REF 2014 UoA 15 was to build upon critical mass in key areas and to increase interdisciplinary collaboration. Specifically the ambition was to have greater national and international presence in the areas of marine systems and energy generation technology. Investment into infrastructure and equipment in the previous period, including the world-class COAST (Coastal, Ocean And Sediment Transport) Laboratory in 2012, designed by **Greaves**, **Simmonds** and **Raby**, were instrumental in achieving this ambition. Directly arising from this laboratory and the complementary research activities, **Greaves** now leads the UK's Supergen Offshore Renewable Energy hub. Opportunities unlocked by research into novel applications of friction processing and optimisation of structural performance (**James**), strengthened collaboration with industrial partners leading to cost benefits and improved creep condition monitoring in thermal power plant. The COAST Laboratory and solid-state joining research have both led to Impact Case Studies (ICSs), demonstrating tangible and significant industrial gains from our investment and research expertise. Furthermore, investment in collaborative research across disciplines *e.g.* materials and manufacturing in wave energy, has led to funding in the area of materials for: the marine environment (**Summerscales**) and in marine renewable energy applications (**Cheng**).

The vision for Electronic Engineering in REF 2014 UoA 13 was to unify nanoscience and technology research groups to create multidisciplinary collaborations and training of research students, particularly in graphene electronics, biosensors and spintronics. This has been achieved by (i) the creation of SECaM, (ii) the planned move into a New Engineering & Design Facility (Section 3), and (iii) most significantly by a major research transition, where **Pan** has overseen the shift in focus from information storage technology to nanomaterial and device-based interdisciplinary research, including graphene biosensors for disease diagnosis (notably gaining substantial funding from EPSRC and EU for dementia diagnosis (**Ifeachor**)). As a critical part of the group's research capability, the Wolfson Cleanroom was re-launched as the Wolfson Nanomaterials and Devices Laboratory (Section 3).

Future strategic aims and goals for research and impact

The launch of SECaM in 2019 provided an opportunity to revisit its research and impact strategy for the next 5 years. The professional disciplines are changing to embrace new opportunities in digitalisation, materials technology, artificial intelligence, robotics, etc., emerging in the 4th Industrial Revolution and identified in the UK Industrial Strategy. As a result, the following 4 aims were added to the 6 on-going above-mentioned ones:

- Collaborate across disciplines for the Digitalisation and Industry 4.0 drivers, taking a whole-systems approach to sustainable development and the mitigation of climate change and biodiversity emergency. Recent success (June 2020) came with seedcorn funding from the UKRI Strength in Places Fund bid, bringing together robotics, data analysis, hydrodynamics, structures and materials in Offshore Renewable Energy.
- Create a beacon for equality, diversity and inclusion, encouraging representation from across society in Science, Technology, Engineering and Mathematics (see Section 3).
- Align our research with the strategic direction of the University: mapping to the Marine Institute, the Sustainable Earth Institute and the Institute of Health and Care Research.
- Create an environment for research impact generation by establishing an Industrial Strategy Group comprising representation from industry leaders and end-users (*e.g.* AECOM, Met Office, Network Rail) to identify emerging priorities.

Research structure

Since August 2019, the new School of Engineering, Computing and Mathematics (SECaM) comprises nine research groupings, four of which are within UoA 12 (Figure 2).

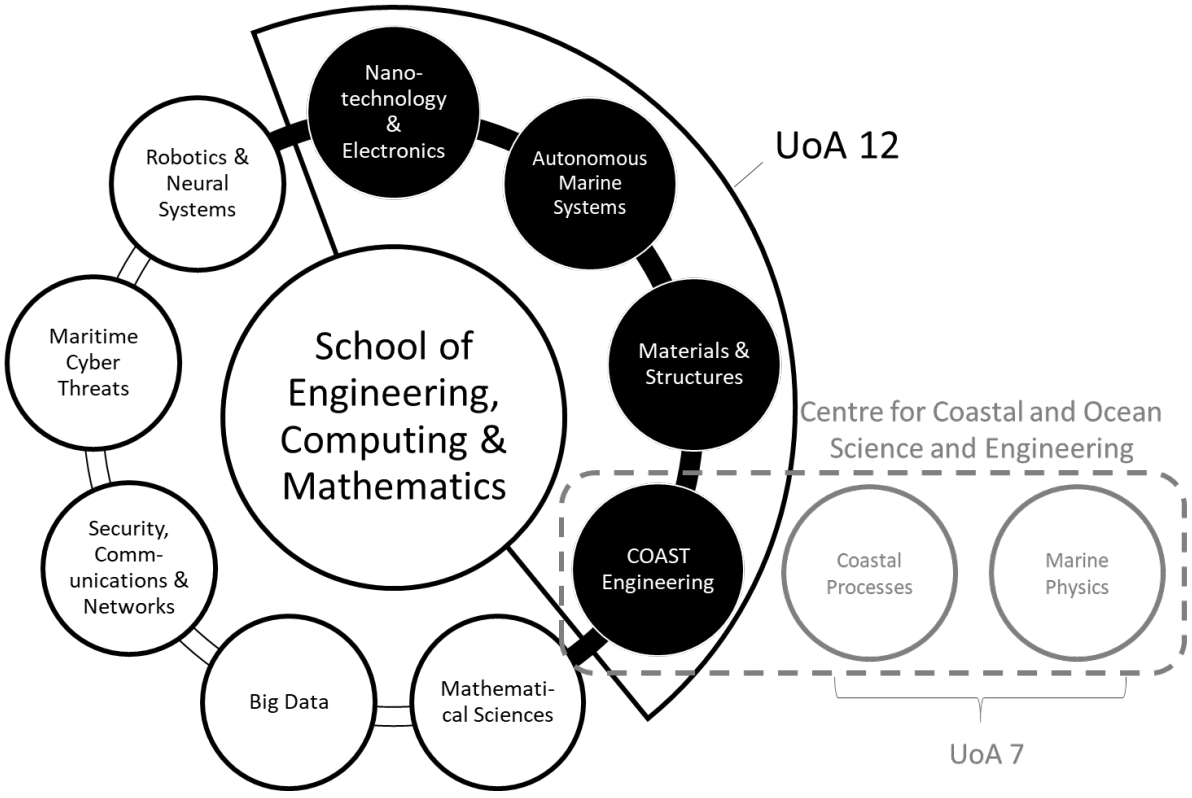

Figure 2: Research groupings within SECaM and the sub-set within UoA 12.

Descriptions of the research groups follow, including more details of how the research and impact strategic aims have been achieved. *N.B.* Due to our interdisciplinary research, some staff are members of multiple groups.

Coastal, Ocean and Sediment Transport (COAST) Engineering (**Collins**, **Dai**, **Greaves**, **Hann**, **Kyte**, **Miles**, **Pemberton**, **Raby**, **Ransley**, **Simmonds**, **Stripling**)
This group tackles climate change threats to energy security and coastal infrastructure, providing sustainable solutions to real-world challenges. The COAST Laboratory (Section 3), the key facility in the £19m Marine Building, has been transformational for UoA 12. Together with a targeted research strategy, the facility has greatly enhanced collaborations, both nationally and internationally (Section 4), and led to the COAST Engineering Research Group being recognised as a key player in the UK offshore renewable energy (ORE) sector. Membership also includes the DesignFlow consultancy group (**Kyte**) https://www.plymouth.ac.uk/research/designflow that conducts Computational Fluid Dynamics for commercial clients; this strategic engagement with industry has resulted in research collaborations *e.g.* Subsea Decommissioning Pile Cutting System - Embedment Cutting Head, and Wave Energy Converter for small communities. Membership also includes the Defra-funded Plymouth Coastal Observatory whose data collection along the coast supports the Environment Agency, maritime local authorities *etc*. This strategic collaboration has been valuable in supporting the group's research projects *e.g.* ENFORCE (doi.org/10.1016/j.coastaleng.2016.04.009). The research group is part of the cross-school Centre for Coastal and Ocean Science and Engineering (C-COSE), one of the largest groupings of coastal science and engineering in Europe. C-COSE provides COAST Engineering with opportunities for collaboration and equipment-sharing with its two other research groups (Coastal Processes and Marine Physics).

The research group has secured competitively-awarded internal investment for topics including: extreme responses in coastal engineering on steep structures; evaluation of a new hybrid wave/wind energy converter; structural performance of floating marine energy devices; impact of marine energy converters; and development of COAST Laboratory wind generator for testing offshore wind devices. This last project led to the EPSRC-funded Extreme Loading on Floating Offshore Wind Turbines (FOWTs) under Complex Environmental Conditions project (below) and the recent EPSRC UK Floating Offshore Wind Turbine Test Facility grant (**Hann**) (Section 3).

External award highlights during REF 2021 are given in Table 1.

Table 1: Examples of COAST Engineering research projects.

Topic	Project name	Funder	UoP Award	UoP PI
Cross-cutting Offshore Renewable Energy	Supergen Offshore Renewable Energy Hub (incl. Supergen Leaders call)	UKRI	£3,710k	**Greaves**
	MaRINET2 - Marine Renewables Infrastructure Network	H2020	£2,656k	**Greaves**
	ICE - Intelligent community energy for isolated territories in English Channel	EU Interreg	£245k	**Miles**
	PRIMaRE - Partnership for Research in Marine Renewable Energy	EPSRC	£241k	**Greaves**

	PORTOS - Ports towards energy self-sufficiency	EU Interreg	£199k	**Simmonds**
Natural Hazards	C-FLOOD - Compound flooding from tropical cyclone-induced sea surge and precipitation in Sri Lanka	NERC/DFID	£87k	**Raby**
Offshore Wind Energy	Extreme loading on floating offshore wind turbines under complex environmental conditions	EPSRC	£390k	**Hann**
Tidal Energy	MTG tidal raft platform concept followed by MTG platform concept 2	Innovate UK	£93k, £256k	**Greaves**
	TIGER - Tidal Stream Industry EneRgiser	EU Interreg	£221k	**Miles**
Wave Energy	WETFEET - Wave Energy Transition to Future by Evolution of Engineering and Technology	H2020	£213k	**Greaves**
	Wave energy converter for small communities	Innovate UK	£99k	**Kyte**
	Can individual wave energy converters effectively share power take offs to reduce costs within arrays?	EPSRC	£124k	**Hann**
Wave-Structure Interaction	STORMLAMP - Structural behaviour Of Rock Mounted Lighthouses At the Mercy of imPulsive waves	EPSRC	£453k	**Raby**
	L&R – A zonal CFD approach for fully nonlinear simulations of two vessels in Launch and Recovery operations	EPSRC	£446k	**Greaves**
	Collaborative Computational Project in wave Structure Interaction (CCP-WSI and CCP-WSI+)	EPSRC	£276 and £313k	**Greaves**
	ENFORCE - Extreme Responses using NewWave – Forces, Overtopping and Runup in Coastal Engineering	EPSRC	£179k	**Raby**

The group supports the growth of the emerging offshore and marine renewable energy industry in the UK, which is the basis of **Greaves**' ICS: *Enabling the growth of the emerging Offshore and Marine Renewable Energy industry in the UK through increased technological understanding*. The ICS arises from UoA 12's strategic aims (to invest in facilities, to generate research impact through industry and regional partnerships, and to pursue collaborations with other universities and organisations/businesses). It consists of interwoven elements: the COAST Laboratory, research leadership (**Greaves**' directorship of the Supergen ORE), collaborative partnership, and education/public/policy impact. Since July 2017, **Greaves** has led the £9m, 4-year Supergen ORE https://supergen-ore.net/, developing the strategy and consortium for the new ORE Hub that brings together Offshore Wind and Marine Energy sectors. The hub connects cutting-edge research, partners and shared strategy with policy makers to accelerate development of the emerging ORE and Marine Renewable Energy industries.

The group is also at the forefront of wave loading of rock lighthouses through the STORMLAMP project, the subject of another ICS, by **Raby**: Provision of tools, techniques and international standards guidance for the maintenance of historic rock lighthouses under extreme wave loading. The project built on strategic investment of a PhD studentship at the end of the REF 2014 period.

Further selected research and impact highlights evidenced by REF 2021 outputs include:

- Offshore and Marine Renewable Energy
  - Consultative responses to Government on low-carbon electricity generation (**Greaves**);
  - Wave Energy Roadmap and Innovation Position Paper (**Greaves**);
  - Understanding of Vessel-to-Vessel transfer at sea (**Pemberton**);
  - Understanding of current/wave effects around windfarm monopile foundations (**Miles**);
  - Predictions of tidal turbine performance, wake field and scour (**Dai**); and
  - Understanding of extreme loads on wave energy converters (**Hann** and **Ransley**).
- Coastal Engineering
  - Flood-risk fieldwork, winning Horizon Impact Award for multidisciplinary research (**Simmonds**); and
  - Motion predictions of water-borne debris, pollutants and sediment in waves (**Raby**).
- Marine hydrodynamics
  - Benchmarking of wave-structure interaction computational models through Blind Tests (**Greaves**, **Ransley**); and
  - Quantitative metrics for evaluation of wave basins (**Collins**).

Nanotechnology & Electronics (**Ahmed**, **Ambroze**, **Asad**, **Awan**, **Chaudhuri**, **Davey**, **Ifeachor**, **Jenkins**, **McCulloch**, **Pan**)
This research group brings together expertise in nanomaterials and devices, signal processing, artificial intelligence (AI) and data science, and their applications in healthcare, sensing, communication, audio, renewable energy, and clean water technologies. The group exploits interdisciplinary research opportunities at the interfaces of nanotechnology, electronics and other disciplines, with a focus on Ageing Society, Clean Growth and AI/Data-driven technology. This has led to major multidisciplinary research projects (Section 4). The Wolfson Nanomaterials and Devices Laboratory, a clean room-based nanomaterials and devices facility (Section 3), is an important resource for many of the projects. The group has strong links with the Medical school, Business School, the NHS, industry and with India via Global Challenge Research Fund workshops and a visiting professor appointment.

The group has secured competitively-awarded internal investments on topics including: graphene-based sensors for early detection of Alzheimer biomarkers; graphene antennas and multifunctional sensors; graphene solar cells; breath-based non-invasive diagnosis of Alzheimer's disease; biomarkers of Alzheimer's disease by statistical learning; graphene oxide biopolymer aerogels for removal of lead from drinking water; portable device for multiplexed detection of water-borne pathogens and heavy metals using functionalised nanomaterials.

External award highlights during REF 2021 are given in Table 2.

Table 2: Examples of Nanotechnology & Electronics research themes and projects.

Topic	Project name	Funder	UoP Award	UoP PI
Biosensors and Disease Diagnostics	AiPBAND An Integrated Platform for Developing Brain Cancer Diagnostic Techniques	EU H2020	£586	**Pan**
	BBDIAG Blood Biomarker-based Diagnostic Tools for Early Stage Alzheimer's Disease	EU H2020	£568k	**Pan**
	Novel Point-of-Care Diagnostic Techniques for Dementia	EPSRC	£581k	**Ifeachor**
Solar Cells and Energy Conversion	High power factor single phase rectification techniques with reduced line current harmonics	KTP – Fairford Electronics Ltd	£96k	**Ahmed**
	Development of a new type of quantum thruster for satellites	US Defense Advanced Research Projects Agency	£915k	**McCulloch**
Communica-tion	QoE-Net Innovative Quality Of Experience Management in Emerging Multimedia Services	EU H2020	£390k	**Ifeachor** (Co-I) UoA 11 PI

This group has demonstrated impact in improved efficiency power conversion approaches, developed in **Ahmed**'s research, leading to spin-out company PulsiV Solar Ltd. The company has developed power conversion products including a new micro-inverter technology (with Robert Bosch GmbH) for solar panels, which can extract 30% more energy compared with existing micro-inverters. It has applications for white goods, portable tools, electric vehicles *etc*. PulsiV has received equity investment £1m+, product development support of £250k from Innovate UK and the granting of five patent families on renewable energy and energy converters.

Further selected research and impact highlights evidenced by REF 2021 outputs include:

- Biosensors and Disease Diagnostics
  - Development of graphene sensors for early diagnosis of Alzheimer's disease, cardiovascular disease, and cancer (**Awan**);
  - Technique for large-scale inexpensive production of ultrahigh sensitivity graphene-based biosensors for medical applications (**Davey**);
  - Biomarkers for accurate diagnosis of Alzheimer's disease, embedded in a diagnostic point-of-care device (**Ifeachor**);
  - Electroencephalogram (EEG)-based methods for dementia assessment (**Ifeachor**); and
  - Patent for point-of-care devices for blood biomarker-based diagnostics of diseases including Alzheimer's disease and brain cancer (**Pan**).
- RF Sensors and Technologies
  - Log-normal model solution technique for indoors ultra-wide band channel, leading to a UK patent (**Ambroze**); and
  - Sound, symbolic-numeric, deductive approach for formally verifying the global convergence property of a ring oscillator (**Asad**).
- Solar cells
  - Graphene-based solar cell with enhanced power conversion efficiency (**Jenkins**); and
  - A technique to enable pristine monolayer graphene to be transferred to silicon, relevant to graphene field-effect transistors and solar cells (**Jenkins**).

MAterials and STructures (MAST) (**Awan**, **Besinis**, **Chaudhuri**, **Cheng**, **Cree**, **Durndell**, **Easterbrook**, **Graham-Jones**, **Hatton**, **James**, **Jenkins**, **Kim**, **Kyte**, **Li**, **McCulloch**, **Meng**, **Pemberton**, **Rizvi**, **Robotham**, **Summerscales**)
MAST brings together researchers from the civil, marine, mechanical, structural, electronic engineering, health and process engineering disciplines. The strategic objective of MAST is to become a leading research centre for durable materials and structures in applications covering sustainable energy, the marine environment and medical technology.

External award highlights during REF 2021 are given in Table 3.

Table 3: Examples of Materials & Structures research themes and projects.

Topic	Project name	Funder	UoP Award	UoP PI
Civil and Structural Materials	PRIGeoC - Partnership for research in geopolymer concrete	EU 2020	£126k	**Li**
	Tailor-made recycled aggregate concrete	EU H2020	£103k	**Cheng**
	RESET - Reliability and safety engineering and technology for large maritime engineering systems.	EU H2020	£98k	**Li**
Composites Engineering	INdIGO - Channel|Manche Circular Seas - Innovative fishing Gear for Ocean	EU Interreg	£337k	**Graham-Jones**

	2 Seas Mers Zeeën SeaBioComp - Bio-based materials	EU Interreg	£276k	**Summerscales**
	Composite repair kit solutions	KTP – Alan Harper Composites	£148k	**Summerscales**
	Atlantic - CircularSeas Recycling waste plastics for additive manufacture	EU Interreg	£144k	**Robotham**
Surfaces and Coatings	Development of IoT structural health monitoring system integrated with self-sensing concrete structures for smart cities	Korea Agency for Infrastructure Technology Advancement	£93k	**Li**

The group has demonstrated impact and global reach through **James**' ICS: A transformation in creep monitoring for high temperature, high pressure components in power generation and chemical process plant in South Africa. ICS support included hosting visiting collaborators and providing dedicated administrative staff for dissemination. Impacts include savings of millions of pounds in delayed procurement costs of power generation components by ESKOM, as well as increased power generation availability.

Further selected research and impact highlights evidenced by REF 2021 outputs include:

- Concrete
  - Constitutive model of recycled aggregate concrete leading to improved building sustainability (**Cheng**); and
  - Model of chloride penetration in concrete, applicable to chloride removal from concrete using electrochemical methods (**Li**).
- Steel
  - Methodology for investigating buckling behaviour of steel building elements under fire conditions (**Kim**); and
  - Engineering tool to predict the critical stress in distortional buckling of cold-formed steel (CFS) beams, now used for designing CFS zed-, channel- and sigma-section beams (**Li**).
- Composites
  - Models of the effect of composite fibre lay-up on flexural failure mechanisms, leading to improved design (**Meng**);
  - Numerical simulation technique that coupled moisture diffusion and stress concentration to identify failure mechanism of composite materials (**Rizvi**); and
  - >98% reduction in styrene levels using in-mould gel-coating, lowering exposure and environmental release of styrene (**Summerscales**).
- Nanomaterials
  - Successful application of a novel antibacterial nanocoating to dental implants, reducing infection risk (**Besinis**) (biomedical engineering was a strategic priority area during the REF 2021 period);
  - Determination of the performance of carbon nanotubes for (electrically conducting) self-sensing smart nanocomposite material (**Cree**) and self-heating nanocomposites to oil and chemical plant walls (**Graham-Jones**); and
  - Identification of a new pathway to achieve modular catalytic cascades in organic synthesis (**Durndell**).

- Material failures
  - Cost-effective crack repair procedure for turbine blades and disc failures (**James**); and
  - Determination of ice internal friction parameters of relevance in circulation models, to inform decisions about flood defences, building regulations, and residential development (**Hatton**).

Autonomous Marine Systems (AMS) (**Dai**, **Khan**, **Pemberton**, **Rizvi**, **Sharma**, **Sutton**, **Wan**)
This group is a focus for interdisciplinary studies and inter-school collaborations, particularly with the Centre for Robotics and Neural Systems (CRNS), but also with other universities and industrial partners nationally and globally. Specifically the group considers the application of Artificial Intelligence techniques to the navigation, guidance and control of autonomous vehicles, wave energy devices, and marine propulsion systems. The group has been expanded to include the Maritime Navigation Group to bring in expertise in meteorology and navigation techniques, maritime operation laws, position determination (including celestial navigation), ship construction, stability, and cargo operations. The group are contributors to the ERDF-funded Smart Sound project https://www.smartsoundplymouth.co.uk/Home, to Marine-I (Section 4) and they support large regional bids in ORE. They have been active in pursuing seedcorn projects in support of Global Challenge Research Funding (GCRF) bids (Table 4).

Internally-awarded GCRF support was secured by **Sharma** for a marine monitoring and forecasting system to support sustainable deep sea fisheries in the Indian Ocean (Section 4).

External award highlights during REF 2021 are given in Table 4.

Table 4: Examples of Autonomous Marine Systems research themes and projects.

Topic	Project name	Funder	UoP Award	UoP PI
Control Systems	Hybrid Set-theoretic Approaches for Constrained Control and Estimation	EPSRC (First Grant)	£91k	**Wan**
Sensor Fusion & Navigation	Develop enhanced automation, mobile navigation and situational awareness for remotely operated vehicles	KTP – AB Precision (Poole) Ltd	£183k	**Khan** and **Sharma** (co-Is)
Guidance & Path Planning	Variety of seed corn projects during this period (see Section 4)	RAEng/Royal Society	£44k	**Sharma** and **Wan**

The strategic ambition for greater national and international presence in marine systems has progressed, as evidenced by securing the hosting of the CONTROL conference hosting in 2020 (Section 4), as has the collaboration in health with **Khan** as the Co-Investigator on the EU ERDF-funded project: ehealth Productivity and Innovation in the Isles of Scilly and Cornwall.

Selected research and impact highlights evidenced by REF 2021 outputs include:

- Algorithm to determine trajectory with dynamic obstacles and spatially variable ocean currents, to prevent collisions at sea (**Khan**);
- Development of the UK's first electric sea-going passenger boat in an ERDF-funded project, working with six organisations across Europe and the Marine Business Technology Centre (Section 4) (**Pemberton**);
- Proof that a weighted-interval Kalman filter is superior to a traditional Kalman Filter in terms of track deviation, energy consumption, waypoints missed and distance travelled (**Sharma**);
- Exact polytopic set computation for nonlinear discrete-time systems, leading to research on bounding uncertainty evolution and robust control (**Wan**); and
- Platooning control for a fleet of sailboats to maintain constant time headway and avoids collisions, useful for long-duration ocean exploration (**Wan**).

Support for interdisciplinary research

Interdisciplinary research in the University is facilitated through the 3 strategic Institutes (more detail in REF5a):

- **Marine Institute** - advances knowledge and understanding of our seas and coastlines.
- **Sustainable Earth Institute** - focuses on cutting-edge research and innovative approaches that build resilience to global challenges.
- Plymouth **Institute of Health and Care Research** - integrates basic and applied science, transcending barriers between professions and between health and social care.

Each UoA 12 research group has strong connections to one or more of the Institutes as shown in Figure 3. This ensures agility in applying for interdisciplinary research funding *e.g.* GCRF.

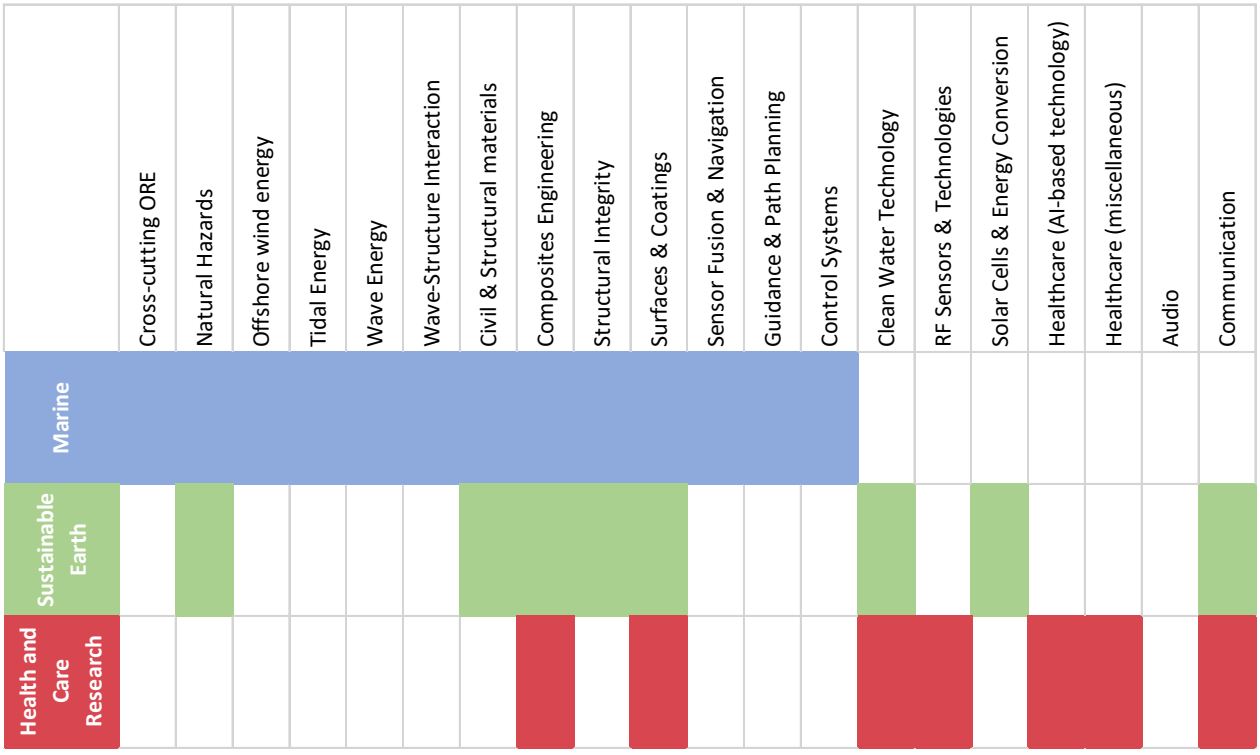

Figure 3: Mapping of UoA research topics to the trans-disciplinary institutes.

Examples of interdisciplinary working are as follows:

- Members of UoA 12 have developed strong collaborations with the Medical and Business Schools in EU H2020 and EPSRC projects (**Pan** and **Ifeachor**). **Besinis** organises regular meetings (seminars and 'speed-dating') to identify specific common research

themes across disciplines between SECaM, the Faculty of Medicine and Dentistry, and the School of Biomedical and Healthcare Sciences, particularly in Health Technology, an area of strategic cross-disciplinary growth (https://www.plymouth.ac.uk/research/centre-for-health-technology). The forums are particularly beneficial for scoping joint PhD applications for the EPSRC-funded Doctoral Training Programme that covers Health/Medical Technologies (in addition to Offshore Renewable Energy) (Section 2). Also, through the EU-ERDF EPIC 2 project, members of UoA 12 are partnered with the Medical School on the eHealth Productivity and Innovation in Cornwall and the Isles of Scilly, providing research support in digital health and care to Cornish industries.

- UoA 12's current collaborations on preventing plastics pollution in the marine environment complements the work of both the Marine Institute and the Sustainable Earth Institute. Three projects (INdIGO, SeaBioComp, CircularSeas) underpin this work and align with the Preventing Plastics Pollution project in the School of Biological and Marine Sciences in the same faculty.
- UoA 12's research has benefitted from membership of the Centre for Coastal and Ocean Science and Engineering *e.g.* the STORMLAMP lighthouse project had input from the Marine Physics research group on the design of a stereo camera system for the Wolf Rock lighthouse, and it used the Coastal Processes group's drone to obtain Wolf Rock lighthouse topography for scale-model building in the COAST Ocean basin.
- Civil Engineers within UoA12 have growing collaborations with Earth Sciences in natural hazards *e.g.* NERC-funded SENSUM grant (smart SENSing of landscapes Undergoing hazardous hydrogeologic Movement), using COAST Laboratory facilities.
- We also collaborate across disciplines through the New Engineering & Design Facility (Section 3) which is being developed jointly with Arts and Architecture (*e.g.* digital design and manufacture (**Robotham, Cree**) and with Earth Sciences (*e.g.* landslide/tsunami natural hazards, **Raby**).
- Finally we are also building on ORE with a collaboration in offshore subsea systems (using the NEDF virtual engineering suite) with the ORE CATAPULT, with strong links with COAST through simulation and visualisation, prototype design, fabrication and dry testing (**Greaves, Hann, Meng**).

Further evidence of the interdisciplinary nature of the unit is provided in Figure 4.

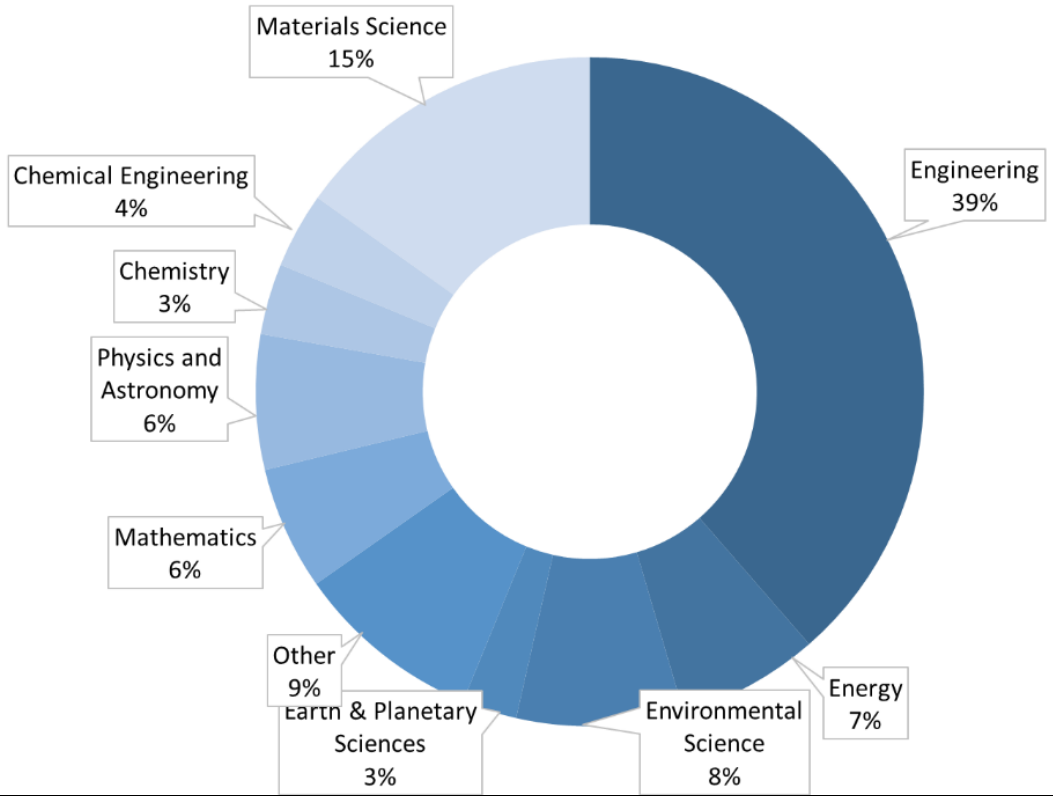

Figure 4: Journal paper outputs from UoA 12 by discipline during the REF 2021 period (SciVal).

Open research and reproducibility

We follow the Institution's procedures (REF5a) *e.g.* UoA 12's Collaborative Computational Project in Wave Structure Interaction (CCP-WSI) which has a key goal to bring together the WSI community to place code development activity on a firm and sustainable footing within the context of a single central code repository. The resulting computational facility is open to all groups, and complements corresponding national laboratory facilities. Regular meetings are held for software development, and the CCP-WSI achieves reducibility by running blind tests of software on physical model benchmark cases. These activities have been organised through special sessions of international conferences and published as journal papers *e.g.* https://doi.org/10.17736/ijope.2019.jc748.

Research integrity

As a unit we adhere to the University's approach to research integrity covered in REF5a and the EPSRC Framework for Responsible Innovation. Where research requires ethical approval, this is obtained from either the Faculty of Science & Engineering Research Ethics and Integrity Committee or a relevant national committee (*i.e.* the Health Research Authority for our medical engineering activities). Where internal research funding is distributed *e.g.* small travel or equipment grants, or PhD studentships, this is undertaken by the School Research Committee. The Committee comprises research group heads, with additional representation from ECRs, PGRs, Research and Innovation department, Library *etc*. All academic members of staff rank applications, with the decision then ratified by the Committee.

2. People

i. Staffing Strategy and Staff Development

The University holds the *EU Commission HR Excellence in Research Award* for upholding the principles of the *Concordat to Support the Career Development of Researchers*. UoA 12's strategies to support career development include:

- membership of a research group to create a supportive and rich research environment for all academic staff, postdoctoral researchers, PhD and Masters students through regular meetings, opportunities for presentations and research proposal development;
- providing funds in support of impact activities *e.g.* during REF 2021 the School's *Research Impact Leverage Fund* was used to support five academics in the development of potential ICSs (from which three were ultimately selected) and a future one (the Coastal Marine Applied Research consultancy were commissioned to model tsunami risk in the SW UK in support of **Raby**'s ongoing tsunami hazards research doi.org/10.1680/jcien.17.00043);
- access to the University's Research and Development Solutions Fund (£200k), designed to stimulate industrial collaborations and knowledge transfer opportunities between university researchers and businesses;
- access to the University's Research and Commercialisation Office in support of commercial spin out companies *e.g.* PulsiV Solar Ltd (**Ahmed**);
- being a beacon for Equality Diversity and Inclusion (Part iii below);
- a sabbatical scheme, including industrial placements *e.g.* **Kim** visited Shenzhen University, China to develop a Royal Society Cost Share programme application and co-authored several papers;

- recruitment of a new generation of Early Career Researchers (ECRs) supported by a school-based ECR forum *e.g.* 8/11 new academics within the REF2021 period were ECRs (data below); **Wan**, who was awarded an EPSRC First Grant, was also awarded an internally-funded PhD studentship;
- following the University's One Team approach that nurtures outstanding teaching, research and development, to exploit synergies and efficiencies and share good practice through regular school meetings *e.g.* fortnightly Zoom meetings during the pandemic and the provision of Common Rooms;
- undertaking an annual Performance Development Review where academics and postdoctoral research staff produce a Personal Research Plan that includes short-term (12 months) or long-term (~3 years) research objectives regarding publications, grant applications, planned conference activities *etc*. for discussion and to identify necessary support;
- meaningful staff induction followed by a period of probation, in a process led by the line manager. SECaM has a comprehensive repository of information on *e.g.* training, H&S, employment terms and conditions including flexible working *etc*. accessible via a module in the University's Digital Learning Environment;
- staff mentoring where all new staff are given a long-term mentor whose remit is to cover the whole academic mission. ECRs are offered mentoring by experienced academic staff members who provide independent, supportive advice on a range of issues, including career expectations, time management, project management, and professional research plans;
- organising twice yearly Research Planning Days (online in 2020 due to COVID-19) where sessions include:
    - grant writing tips from senior staff,
    - discussion of the latest research activities by research group leaders and members,
    - research training from the University Research and Innovation office,
    - explanation of facility access such as the Electron Microscope, COAST Laboratory *etc*.
    - cross-disciplinary activities;
- providing opportunities to learn about funding mechanisms from external parties *e.g.* the EPSRC Energy team visit to SECaM in 2019, DFID/NERC visit to the Sustainable Earth Institute in 2019;
- supporting the promotion process with an annual SECaM workshop where the Head of School and Human Resources explain the process and highlight what makes a successful application, and at which recently promoted staff members share their experiences. During the REF 2021 period **Kim** was promoted to Associate Professor and **Raby** and **Summerscales** were promoted to Professor.

UoA 12 comprises 36 members of staff (34.3 FTE), plus 14 research assistants/fellows employed across the 4 research groups. New staff appointments to this unit are on balanced contracts only (Teaching *and* Research). In the REF 2021 period these have included:

- Antonini – Coastal Engineering (M - ECR),
- **Besinis** – Nanotechnology and Biomaterials (M - ECR),
- **Cheng** – steel/concrete structures (F - ECR),
- **Collins** – hydrodynamics (F - ECR),
- **Hann –** offshore renewable energy (M - ECR),
- Jang – smart materials (M - ECR),
- **Meng** – composites engineering(M - ECR),
- **Pemberton** – marine design (M),
- **Robotham** – engineering design (M).

where M – male; F – female and ECR is Early Career Researcher.

New academic appointments in September 2020: Simone Michele – Fluid-Structure interaction (M – ECR) and Yeaw Chu Lee – Fluid Mechanics (M). Laboratory Technician appointments during REF 2021: Monk (M) (a PhD graduate of the COAST Engineering Research group), Poulson (F) and Buriani (F). New technician appointed in September 2020: Mitchell (F).

Members of staff previously employed as fixed-term researchers now with permanent positions (awarded in open competition) include:

- Antonini (EPSRC-funded STORMLAMP Research Fellow, then Lecturer in SECaM, now Lecturer at TU Delft)
- **Cheng** (Plymouth PhD student now Lecturer in SECaM, after Research Fellow elsewhere)
- **Collins** (COAST Lab Research Fellow, now Lecturer in SECaM)
- **Hann** (EPSRC-funded X-MED Research Fellow, now Lecturer in SECaM)
- **Meng** (Plymouth PhD student, now Lecturer in SECaM, after Research Fellow elsewhere)
- **Ransley** (Plymouth MSc graduate, then PhD student in SECaM, now permanent Research Fellow in SECaM)

Whilst the groups are invigorated with early career staff, we have ensured that valuable experience is not lost through having:

- Emeritus Professors (Bullock (COAST), Sutton (AMS));
- Visiting Professors: Paul Taylor (University of Western Australia, formerly University of Oxford), Alistair Borthwick (University of Edinburgh, formerly University College Cork and University of Oxford), Robert Rawlinson-Smith (Garrad Hassan, DNV GL).

ii. Research students

Recruitment

PhD studentships are widely advertised, and candidates short-listed and interviewed by gender-balanced panels, with reasonable adjustments made for any other protected characteristics (see EDI sub-section).

Funding

During the REF 2021 period, UoA 12 had 88 PhD completions, a 25% increase in completions per FTE compared to the combined units in REF 2014. Funding for PGR has come from strategic internally-funded studentships (with project selection criteria addressing interdisciplinarity and potential for impact), self-funded students, two regional FE college-funded students, UAE-Ocean, Iraqi Government-funded studentships, the China Scholarship Council, employer-funded and a growing number of Commonwealth Scholarships. In September 2019, UoA 12 was awarded an EPSRC Doctoral Training Programme in Offshore Renewable Energy / Medical and Health Technologies, contributing to its strategic aim of increasing PGR students from new funding streams. A newly-approved Engineering Doctorate scheme should also attract industry-funded PhD projects.

Monitoring and Support

UoA 12 PGR students have dedicated desks in shared or open plan offices. They have access to advanced facilities (Section 3), ICT and extensive electronic and physical library facilities. They typically meet with their supervisory team (Director of Studies plus at least one further supervisor) on a weekly basis, and are involved in their research group for: (i) collegial support *e.g.* the COAST Engineering Research Group has informal Friday breakfast meetings (on Zoom

during the pandemic), with the option to join a student-led WhatsApp group, and (ii) opportunities to attend regular presentations by guest speakers and group members. Formal monitoring, by the Doctoral College, uses the GradBook system, which requires periodic progress reports to be lodged by PhD supervisors and students. Students undergo a rigorous transfer process from MPhil to PhD at 12-15 months, which in SECaM has a policy of mixed gender assessment if requested by the student; this extends the university policy of gender-balanced PhD examinations.

The Doctoral College runs inductions for new students, providing cohort development, networking opportunities and mentoring. Connectivity between the students and the Doctoral College is ensured by a staff Postgraduate Research Coordinator for each school (**Sharma** in SECaM). The coordinator offers tailored support for subject areas and provides additional pastoral support where necessary. Students have representation via the SECaM Research Committee, attendance at the Research Planning Days, PGR survey feedback, and through membership of the Postgraduate Society.

Skills Development and Career Preparation

PGR students, with support from their supervisors, select training courses from the Doctoral College's comprehensive Researcher Development Programme. This programme is supported by UKRI, Vitae and employers and has four domains:

- Knowledge and Intellectual Abilities *e.g.* LaTeX, Matlab, Python.
- Personal Effectiveness *e.g.* Working with feedback and setbacks, Preparing for the viva, Careers.
- Research Governance and Organisation *e.g.* Research integrity, Project management.
- Engagement, Influence and Impact *e.g.* Using the media to publicise research, Introduction to podcasting.

Engineering students also benefit from connections gained through research networks *e.g.* the Supergen ORE provides a large industry network, particularly with SMEs including Marine-i (https://www.marine-i.co.uk/) and PRIMaRE (Section 4). Examples of PhD collaborations during REF 2021 include DNVGL, Pelamis and Wave Roller, and CASE studentships with Arup and HR Wallingford. Additionally we have collaborated with Ocean University China in PhD exchanges since 2017 (Section 4). Finally, our engineering students also have access to collaborative environments provided through the three University Research Institutes, which run periodic research events.

iii. Equality and diversity

SECaM has strong leadership on Equality, Diversity and Inclusion (EDI) from the Head of School, **Greaves,** who was awarded an OBE in 2018 for services including Equalities (Section 4). The school follows the University's policies to provide equality of opportunity for staff and students, applicants and visitors, and its REF 2021 Code of Practice *as a minimum*. In line with the University's EDI policy, full support is provided for staff, PGRs and spouses during pregnancy, nursing, adoption, and for compassionate and religious purposes. During the REF 2021 period, the collegiate nature of the unit has led to staff members altruistically covering for colleagues over extended periods of time. The university has robust wellbeing support for staff and students for advice, including during the pandemic lockdown on a wide range of issues including domestic abuse, parenting, LGBT support, sex and relationships advice and disability support.

An ambitious strategic priority for SECaM is to become a beacon for EDI; both schools that merged to form SECaM have the Athena Swan charter Bronze, and the combined school successfully achieved the same award in October 2020. SECaM is now working towards the Silver award, and we are inviting staff from Silver Award holding departments, and from external groups and societies, such as Women's Engineering Society, the British Computer Society, and Women in Mathematics of the London Mathematical Society, to share best practice in developing and implementing actions. The implementation of the Bronze action plan should ensure that the School is well-placed to apply for a Silver award in 2023.

Figure 5 shows that despite having a fairly low representation of women (17%), and with considerably more women employed at Assistant Professor than at Associate Professor compared with their male colleagues, 25% (2/8) of the women in UoA 12 are employed at professor level, compared to 19% at professor level for male members. Also notable are that 22% of the REF 2021 outputs are attributed to women and 2/3 of the ICSs. *N.B*. Outputs and ICSs followed the University's processes, which included internal and external reviews, irrespective of seniority or other forms of difference. BAME members, who make up 42% of UoA 12 (*c.f.* 17% in UK HESA data 2018/19), are also disproportionately represented at Assistant Professor when compared with their white counterparts, though again not at professorial level, where they make up 50%. Of note is that each of the four research groups is led (or co-led) either by a female or BAME member of staff. With their seniority, the professors and research group leaders positively influence the culture and act as inspirational figures for junior members of staff. In UoA 12, flexible work patterns are offered, but 92% of staff work full-time compared to a UK-wide figure (HESA data 2018/19) of 82%; however, since 83% of the unit is male, this may skew the situation.

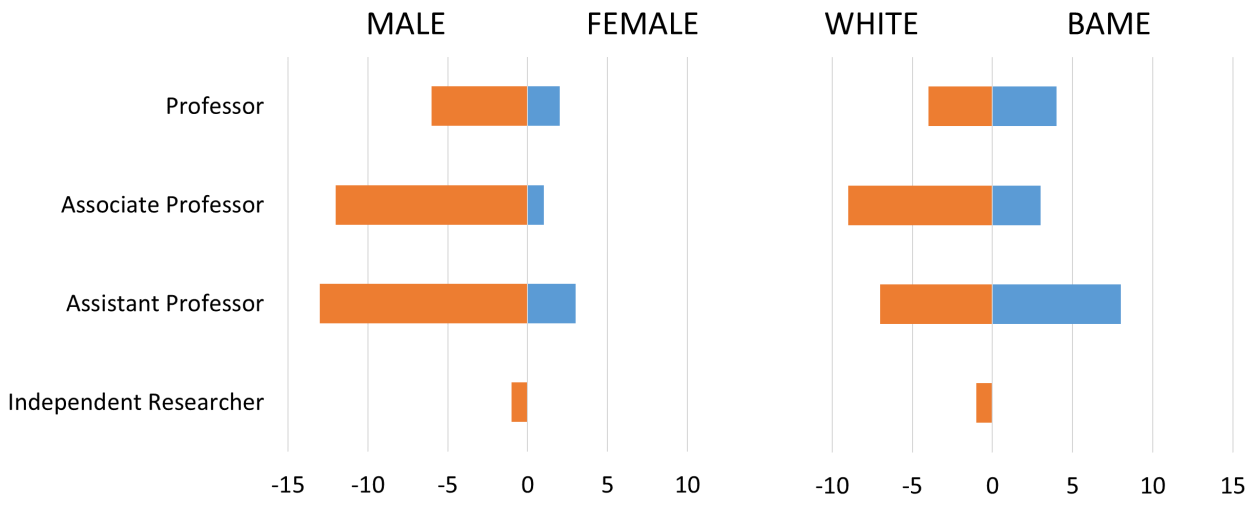

Figure 5: Breakdown of gender and ethnicity at different career grades.

During REF 2021, our efforts to address the challenge of under-representation of women in engineering, which particularly affects the Southwest region, are supported by several initiatives, including the Plymouth STEM forum, Women in STEM Plymouth and 500 Women Scientists. In 2017 we hosted the Women in STEM conference and in 2020 **Greaves** was named in the Top 50 Women in Engineering 2020: Sustainability by the Women's Engineering Society. In accordance with the 2018 Athena Bronze action plans we publicised vacancies through female networks, such as Women in Science & Engineering and Women's Engineering Society. The percentage of female applications to STEM vacancies in SECaM is increasing, with 12% in

2017/18, 13% in 2018/19, and 18% in 2019/20. Since 1 August 2018, there were 24 new appointments (25% female) to academic positions in SECaM, which is an increase compared to 17 new appointments (12% female) in 2017/18. In UoA 12, 2/3 of the new technician appointments were to women. We are also implementing action plans to support women in their careers and to encourage more girls to study engineering. For example, we presented and hosted an exhibition stand with a wave energy demonstration tank at New Scientist Live 2018.

In an effort to address *all* protected characteristics:

- SECaM have appointed an EDI champion to the School Management Team and ensure that recruitment to School leadership roles is transparent and open to all and that deputy Chairs (of a different gender to the Chair where possible) are appointed to senior committees;
- SECaM has a dedicated EDI page to update staff and students on news and events https://www.plymouth.ac.uk/schools/school-of-engineering-computing-and-mathematics/equality-diversity-and-inclusion;
- EDI is a standing item on the School Research Committee agenda, the body which disburses internal funds and PhD studentships;
- there is mandatory training for all staff and PGRs on EDI (supported by documentation provided by the Advance HE Equality Challenge Unit) and on Unconscious Bias;
- all advertisements for staff and PGR include the text: *applications from people who are currently under-represented in our university community, and from suitably qualified people with disabilities*;
- there is gender representation on all recruitment panels and in PhD transfers and vivas, as mentioned in the above sub-section; and finally,
- an EDI support strategy is a key feature of the EPSRC-funded ORE Supergen hub, where lack of diversity in energy research is an issue, and in the newly-awarded DTP.

3. Income, Infrastructure and Facilities

Income

During the REF 2021 period the research activity of UoA 12 staff increased. Figure 6 shows annual income (REF4b data) for the REF 2014 (upper charts) and REF 2021 (lower chart) periods. It shows a virtually year-on-year increase in research income during the most recent REF period, particularly from the BEIS Research Councils. Total income in the REF 2021 period is £9.636m.

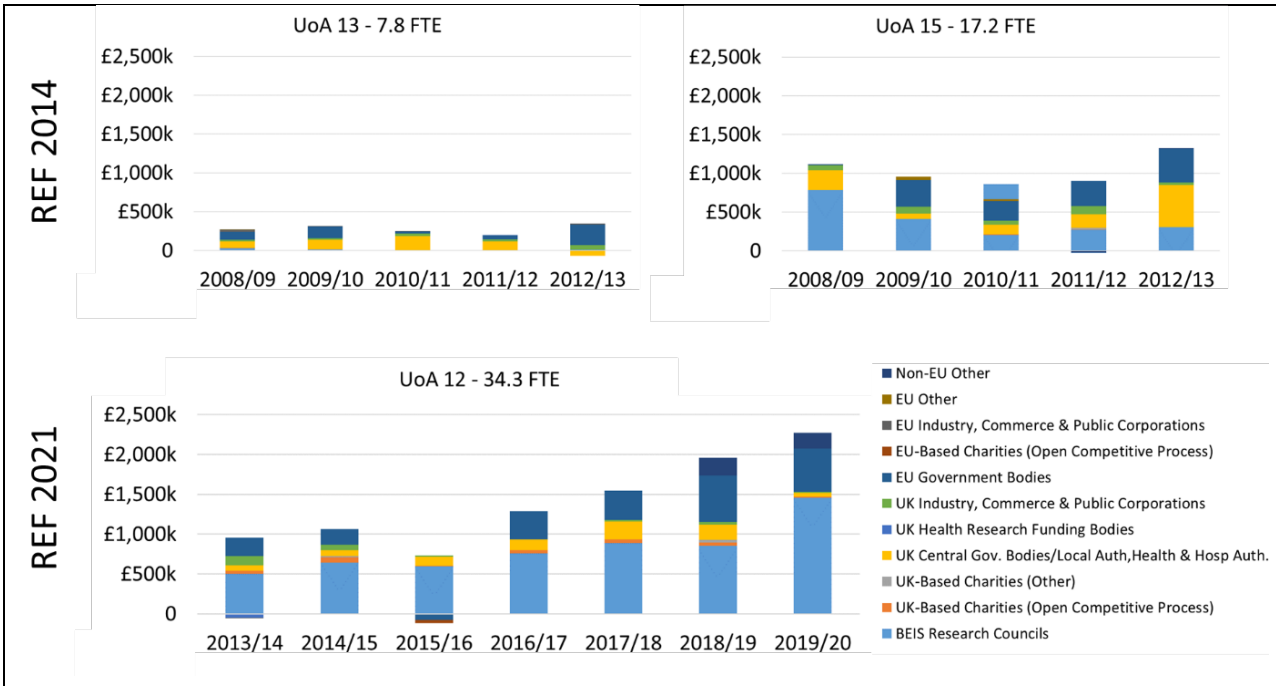

Figure 6: Research income for the REF 2014 and REF 2021 periods[1].

Facilities

COAST Laboratory

The COAST Laboratory (www.plymouth.ac.uk/coast-laboratory) is a state-of-the-art facility for the study of wave and current interaction with offshore and coastal structures using medium-scaled physical modelling. It gives developers access for testing and expertise to shorten time-to-market and reduce prototyping costs. It consists of the 35m x 15.5m x 3m Ocean Basin, a 15m x 10m x 0.5m Coastal Basin, two 0.6m wide wave flumes and various smaller hydrodynamics facilities. Since opening in 2012, COAST has been instrumental in the UK maintaining its world leading position in the ORE sector, playing a key role in testing novel ORE devices and platforms through UK and international collaborations. The facility is available for international access by academic researchers via the EU-funded Marinet, Marinet2, and Hydralab schemes. Through these schemes and private contracts, 69 industrial projects for 41 businesses have been undertaken. There is a global interest in the facility, with commercial users hailing from Australia, Belgium, Denmark, Finland, France, Ireland, New Zealand, Norway, Portugal, Sweden, UK, and the US. Over the past 6 years, one of our research and impact strategies has been to develop the capability to generate wind over the Ocean Basin in the COAST Laboratory. We undertook this, first through internal investment and recently (October 2020 announcement) through £1.1m EPSRC funding for the UK Floating Offshore Wind Turbine Test Facility. The successful development of the facility will enable scale testing to meet the 2019 Offshore Wind Sector Deal commitment to build up to 30GW of offshore wind devices by 2030 and achieve net-zero greenhouse gas emissions by 2050.

High Performance Computer Centre

This provides supercomputer access for nine research areas across the university including the topics of Coastal Engineering and Marine & Offshore Renewable Energy, complementing the COAST Laboratory physical modelling. The most recent additions to the cluster include 320

[1] Some years show small negative values as the University's financial statement include costs as well as income.

cores using Intel Xeon E5-2650 (SandyBridge) 8 core 2.60GHz processors. The facility underpins the CCP-WSI and Big Data research.

Wolfson Nanomaterials and Devices Laboratory
This is an essential facility for undertaking research in nanoscience and nanotechnology with equipment for thin film deposition, microfabrication and characterisation of nanomaterial-based devices. It puts the University amongst only a few UK universities which have such high-level research facilities.

Marine Business Technology Centre (MBTC)
Staff from the AMS research group, are involved in the MBTC project, headquartered from Oceansgate in Plymouth, the UK's only Marine-dedicated Enterprise Zone. MBTC offers in-depth product testing and development of marine-related technologies. Members of the research group were involved in securing a state-of-the-art unmanned marine vessel, the C-Worker 4, developed and supplied by L3Harris. Sharing of marine facilities is also possible through the NERC pump-primed Marine Research Plymouth project, a partnership between the University, the Marine Biological Association and the Plymouth Marine Laboratory which aims to 'further strengthen the partnership to grow marine science and technology in Plymouth through the sharing of resources, the coordination of marketing and knowledge exchange and the exploitation of complementary research skills and facilities'.

New Engineering & Design Facility
On the basis of the business case for a state-of-the-art engineering building, developed as part of the research and impact strategy, the University is investing in the £40m landmark New Engineering & Design Facility. The research vision is to: re-equip laboratories with advanced resources that will enable our engineering research to underpin the fourth Industrial revolution; create the attractive environment necessary to attract and retain high-calibre, research active staff; and develop new inter-disciplinary activities. This facility, which will be available in Q2 2023 expands the floor area of the engineering labs from 2400m^2 to approximately 5000m^2. There will be £11m in new equipment to provide additional capabilities over and above those in existing labs (precision manufacturing, materials characterisation, composites, control/autonomous systems, energy/sustainability, structures/materials testing) with the following new facilities:

- Control and Autonomous Systems Laboratory for the testing of autonomous vehicles with 6-DOF motion platform and water tank.
- Virtual Engineering Suite to enable 3D immersive virtual reality and augmented reality simulations linked to hi-fidelity physics-based computer-aided simulations of advanced engineering technologies and environments, involving interaction with "big data" sets.
- Energy and Sustainability Laboratory with new wind tunnel for ORE research and structures environment chamber.
- STEAM^2 Room for promoting collaborative working in mixed-use and social space, supporting serendipitous interaction between students, researchers and academic staff.

Staff members have also performed and led experiments, in collaborative research projects at nationally and internationally leading strain scanning facilities, such as the Diamond Light source near Oxford (**Awan**), and the Institut Laue Langevin and European Synchrotron Radiation Facility in Grenoble, France (**James**).

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

Collaborations

The breadth of our collaborations is indicated by the co-authored research outputs illustrated in Figure 7, which shows, for example, that 60% of outputs are co-authored with international researchers and that 5% involve industrial collaborators.

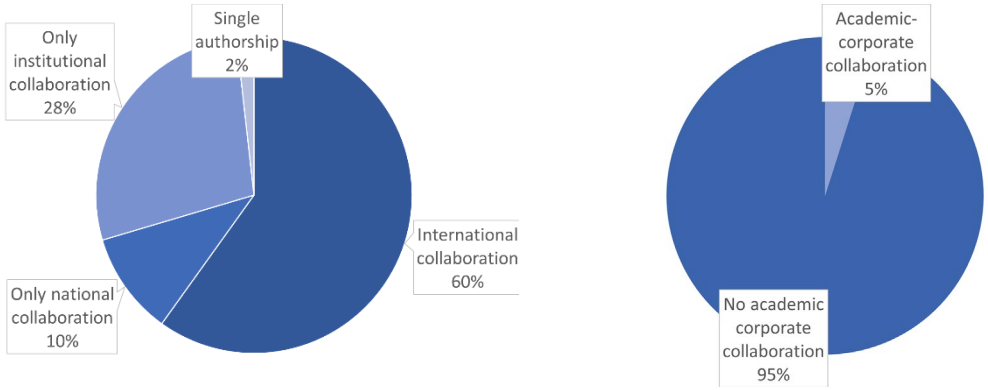

Figure 7: University of Plymouth UoA 12 collaboration data from SciVal.

Figure 8 provides a breakdown of outputs by collaborator country. There were also single outputs arising from collaborations with: Bangladesh, Brazil, Croatia, Hong Kong, Iran, Oman, Pakistan, Taiwan and Turkey.

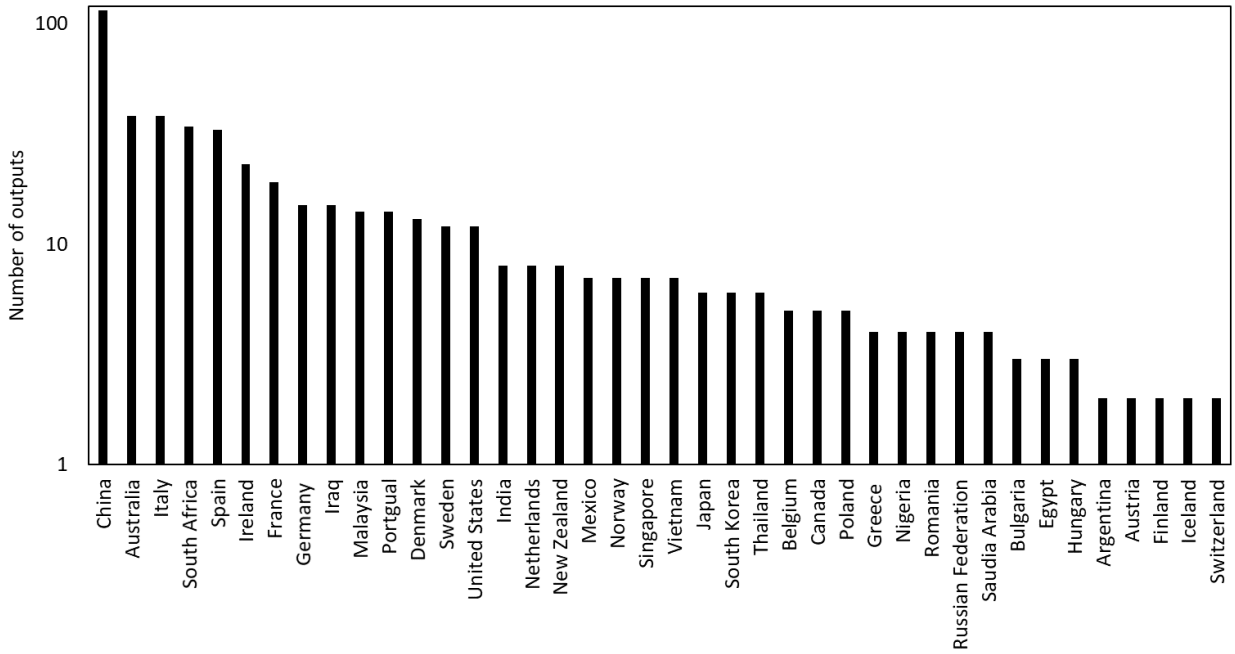

Figure 8: Geographical distribution of UoA 12 outputs (SciVal, 16/11/20).

Many collaborations are underpinned by state-of-the-art facilities *e.g.* since 2012, the COAST Engineering research group's research profile and portfolio grew significantly, with 18 research projects of over £41m underpinned by the COAST laboratory, resulting in 60+ publications concerning ORE, sediment transport, and wave impacts on structures. The EU-funded Hydralab, Marinet and Marinet2 access to infrastructure projects have also led to collaborations *e.g.* WETFEET and joint PhD with UCC. Additionally the facility has hosted more than 50 public

engagement events and has featured in several media outputs (Section 4). The Wolfson Nanomaterials and Devices Laboratory facilities and the research portfolio in graphene biosensors have played a key role in helping to secure three major research projects (EPSRC EP/M006301/1 and EU H2020 BBDiag and AiPBAND) with total funding of over £8m, and involving about 30 collaborators from UK, Europe, China, and the US. Industrial collaborations arising from the Wolfson Laboratory include a proof-of-concept investigation of Perovskite solar cells funded by Advanced Nano Industry of France. Collaborative research between academics in engineering and medicine takes place in the University's Plymouth Electron Microscopy Centre (*e.g.* **Besinis**).

Our influence within national and international consortia has also grown through the REF 2021 period, evidenced by leading the following UKRI-funded projects, arising from our strategy to pursue collaborative research:

- The £9m ORE Supergen Hub, bringing together two hubs in Marine and Wind previously led by Edinburgh and Strathclyde universities. The consortium universities are Edinburgh, Oxford, Manchester, Exeter, Hull, Southampton, Warwick, Strathclyde and Aberdeen. The role of the hub is to provide leadership for ORE research in the UK.
- PRIMaRE (Partnership for Research in Marine Renewable Energy), with the universities of Bristol, Bath, Southampton, Exeter, Cardiff, plus the Plymouth Marine Laboratory and Marine Biological Association. Plymouth organised the annual PRIMaRE conference in 2020, a two-day virtual meeting with contributions from 32 speakers, and about 200 international delegates *e.g.* the UK, the US, Europe, China, Indonesia, Malaysia, India, Mexico, Brazil and Australia.
- CCP-WSI+ (Collaborative Computational Project on Wave Structure Interaction) for sharing and future-proofing EPSRC-funded code developments in wave-structure interaction.

Furthermore, Plymouth is scheduled to host the European Wave and Tidal Energy Conference in 2021, bringing about 600 delegates to Plymouth, and were scheduled to host the 13th United Kingdom Automatic Control Council International Conference on Control, postponed due to COVID.

Academics from UoA 12 are also developing collaborations for GCRF via seedcorn grants *e.g.*

RAE Frontiers of Engineering for Development:

- Ahmadu Bello University, Nigeria (**Kim**);
- Nelson Mandela University, South Africa (**Kim**);
- Universiti Sains Malaysia, Malaysia and CSIR, South Africa (**Wan**);

RAE Newton Research Collaboration:

- NIT, India (**Sharma**);

Royal Society International Exchange:

- Zhejiang University, China (**Sharma**);

Newton Fund Workshop Grant:

- Nanomaterials for water and affluent purity for life (**Jenkins**).

Additionally, **Kim** is an RAEng Frontiers Champion for *Recycled Aggregate Concrete in SE Asia*.

We have Memoranda of Understandings arising from our strategy to support international collaborations *e.g.* Ocean University China (10 PhD students per annum); Harbin Institute of Technology, China (establish a joint lab on Autonomous Intelligent System at HIT for collaboration in autonomous intelligent systems); and Universiti Sains Malaysia, Penang, Malaysia (promote further research and education collaboration in the fields of engineering and marine conservation). We also have an agreement with Southwest Jiao Tong University to send PhD students funded by the China Scholarship Council, and we are applying for International Cooperative Program for Innovative Talents administered by the China Scholarship Council. Finally, we have a formal agreement with UAE-Ocean for the development, establishment and operation of a UAE oceanographic centre which has led to a number of PhD studentships.

Regionally, staff from UoA 12 are supporting the City Council's ambitions, *e.g.* the Marine Business Technology Centre (Section 3) and Mayflower 2020 (Quatercentenary of the Pilgrim Fathers leaving Plymouth for the United States) involving development of autonomous sailing ship (**Wan**, **Sharma**). Academics are actively involved in Marine-i/Marine-i2, funded by the European Regional Development Fund to connect business with university expertise and facilities for local economic benefit (*e.g.* **Greaves**, **Hann**, **Sharma**). **Pemberton** is working with regulatory bodies on a high-profile MarRI-UK project which is converting an existing network of passenger ferries to be all-electric to meet the UK Government's Clean Maritime Plan. Investment for the New Engineering & Design Facility supports the Plymouth Manufacturers' Group, which has 59 members from Plymouth and the surrounding area with a collective turnover of £1.6 billion, contributes 15.3% to the local economy, and employs 12,000+ people. The University Vice Chancellor is also board member of The Heart of the South West Local Enterprise Partnership, which is seeking inward investment in precision engineering and advanced manufacturing, including in the aerospace, nuclear, marine and agri-tech sectors. Finally, **Sharma** is a founding member of the Future Autonomous at Sea Technologies Cluster, which provides collaborations with leading industrial and academic partners specialising in the delivery of innovative marine autonomous solutions, such as: surface and sub-surface autonomous systems, advanced manufacturing, smart ports and cyber security.

Indicators of wider influence, contributions to and recognition by the research base include:

- Journal Editorship *e.g.* Editor-in-Chief of Source Code for Biology and Medicine (**Ifeachor**); Co-Editor of International Journal of Fatigue (**James**); Associate Editor of Proceedings of the Institute of Mechanical Engineers, Part M: Engineering for the Maritime Environment (**Sharma**); Associate Editor of Frontiers in Built Environment: Coastal and Offshore Engineering (**Simmonds**).
- Journal Editorial/Advisory Board Member *e.g.* Engineering Failure Analysis (**James**); Ships and Offshore Structures (**Rizvi**); Cement and Concrete Composites (**Li**); Editorial Board of IET Journal for Science and Technology (**Ifeachor**); Composites Part A (**Summerscales**); Proc. ICE Engineering and Computational Mechanics (**Greaves**); Biotechnology & Bioengineering (**Chaudhuri**); Journal of Sailing Technology (**Graham-Jones**).
- Journal Guest Editorship *e.g.* Philosophical Transactions of the Royal Society A: *Environmental Loading of Heritage Structures* (**Raby**); Micromachines: *Functional Materials Based Microsystems* **(Jenkins**); Applied Ocean Research Special Issue on *Wave Energy Utilization* (**Greaves**); Journal of Marine Science and Engineering: *Big Data Analytics for Marine Shipping and Ship building Industries* (**Rizvi**).

- Conference Organising Committee *e.g.* Control 2020 **(Khan**), Board and Technical Committee of EWTEC and the Host for EWTEC21 (**Greaves**), Local organising committee for EWTEC21: **Collins**, **Hann**, **Meng, Miles**, **Ransley**, **Simmonds**.
- Conference Technical Programme Committee *e.g.* IEEE ICC CSMA 2018-date (**Khan**).
- Conference Session Chair *e.g.* IntelliSys 2019 (**Khan**); International Association for Dental Research, 2014, 2015 (**Besinis**), Inaugural member of the World Association of Natural Fibers Research – Portugal (**Summerscales**).
- Invited keynotes or plenary lectures *e.g.* 5th Int. Con. On Durability of Concrete Structures, Shenzhen (**Li**); RILEM (Concrete Modelling Symposium 2018) (**Li**); Annual FDI World Dental Federation, Buenos Aires, Argentina (2018) (**Besinis**); Antibacterial Biomaterials workshop; Lancaster, UK (2018) (**Besinis**); 1st Virtual European Conference on Fracture 2020 (**James**); 8th International Conference on Materials Structure & Micromechanics of Fracture, Brno, Czech Republic 2019 (**James**); NANO-15, Tamil Nadu, India (**Jenkins**); ICNAN '16, Vellore, India 2106 (**Jenkins**); International Conference on Sonar Systems & Sensors, Kerala, India 2018 (**Summerscales**); 4th China International Composites Technology Conference, Guangdong, China 2019 (**Summerscales**); 1st International Lighthouse Symposium, University of Hong Kong, 2017 (**Raby**).
- Invited membership for international workshops *e.g.* EPSRC-funded Sweden-UK Ocean Energy Technology Workshop (**Greaves**); EPSRC UK-China Marine Energy Workshop (**Greaves**); RCUK UK-Hong Kong Newton Fund Sandpit (**Greaves**, **Hann**); British Council/Newton Fund China-UK workshop on Coastal and Offshore Renewable Energy Systems under Extreme Events in Dalian, China (**Raby**) (2019). UKRI US delegation to International Partnering Forum in Offshore Wind, New York 2019, leading to organisation of Supergen ORE workshop with US academics at University of Massachusetts in Amherst, and new research collaborations between UoP and UoMass (**Greaves**).
- Participation on International grants committees *e.g.* Academy of Finland (**James**); European Metrology Programme for Innovation and Research (**Awan**); German Academic Exchange Service (**Greaves**); H2020 Marie Sklodowska Curie Career-FIT ~ Enterprise Ireland (**Summerscales**); Netherlands Organisation for Scientific Research (**Greaves**); Norwegian Research Council (**Li**); Portuguese Foundation for Science & Technology (**James**); Singapore A*STAR Science & Engineering Research Council (**Greaves**); US DOE Water Power Technology Office Foundational Research Funding (**Greaves**).
- Participation on National grant committees *e.g.* EPSRC Peer Review College (**Awan**, **Chaudhuri**, **James**, **Jenkins**, **Greaves**, **Li**, **Summerscales**); NERC Constructing a Digital Environment Demonstrators call (**Sharma**); expert reviewer for UKRI Strength in Places Fund (**Rizvi**); NERC Pool of Technologies Reviewers (**Greaves**); Royal Society's research Grants Board 20K (Physical Sciences) (**Greaves**).
- Membership of Research Council or similar national and international committees *e.g.* Athena Swan panellist for Equality Charter Unit (**Khan**); subcommittee UK Engineering Professors Council for Research, Innovation and Knowledge Transfer (**Li**); RCUK Energy Programme's Scientific Advisory Committee (**Greaves**); UKRI Collaborative Computational Projects Steering Committee (**Greaves**).
- Reviews for overseas grant organisations *e.g.* Flanders Innovation & Entrepreneurship Agency, Belgium (**Pemberton**), International Research Infrastructure Belgium (**Raby**), Research Council of Norway (**Sharma**), Swiss National Science Foundation (**Summerscales**), National Research Foundation of South Africa (**James**), Natural Sciences and Engineering Research Council of Canada (**James**, **Summerscales**), National Centre of Science and Technology Evaluation, Republic of Kazakhstan (**James**), Kuwait Foundation for the Advancement of Sciences (**Raby**), Sultan Qaboos University, Oman (**Summerscales**).
- PhD/EngD Examinations during REF 2021 *e.g.* UK: Birmingham (**Li**), Bristol (**Raby**), Cranfield (**James**), Exeter (**Awan**), Imperial (**Summerscales**), Leicester (**Li**), Liverpool (**James**), Manchester (**Greaves, Li**, **Pan**, **Raby**), Nottingham (**Simmonds**, **Summerscales**), Oxford (**James**), Sheffield (**Li**, **Summerscales**), Southampton

(**Greaves**, **James**), UCL (**Dai**, **Raby**); International: Auckland (**Raby**), Bologna (**Greaves**), Delft University of Technology (**James**), Groningen (**Greaves**), Australia National University (**Li**).

- Fellowships *e.g.* Royal Academy of Engineering (**Greaves**); Institution of Structural Engineers (**Li, Kim**); Institution of Civil Engineers (**Greaves**, **Kim**, **Raby**); Institute of Physics (**Cree**); Institute of Materials Finishing (**Cree**), Institute of Materials, Minerals & Mining (**James**, **Summerscales**), British Institute of Non-Destructive Testing (**Summerscales**).
- Prizes *e.g.*
  - **James**: recipient of 2020 Robert Moskovic award from Technical Committee 12 of the European Structural Integrity Society, in recognition of an outstanding contribution to Fatigue and Fracture of Structural Alloys and Materials.
  - **Robotham**: Royal Academy of Engineering President's Special Award for Pandemic Service, in recognition of the design for a low environmental impact protective face shield for frontline staff. **Robotham** (PI for CircularSeas project (Section 1)), developed a recyclable face shield, liaising with the university's Centre for Health Technology, International Marine Litter Research Unit and Research and Innovation Directorate. Prestige Packaging turned his concept into a high-speed manufactured product. Within a month it had BSI approval for healthcare workers, first responders and other personnel, with 20,000 initially manufactured, and the potential for 100,000 shields/week.

Figure 9: Environmentally-friendly face shield

  - **Chaudhuri:** Institution of Chemical Engineers Davidson Medal, 2017, for mentoring early career chemical engineers.
  - **Wan** and team: 'Second Prize' in the World Robotic Sailing Championship in 2019, building on third place in 2018, developing autonomous sailboats for teaching, research and PhD student training.
- Media prominence *e.g.*
  - Institution of Civil Engineers 2020 President Inaugural address video (**Greaves**, **Raby**);
  - Institution of Civil Engineers promotional video https://www.ice.org.uk/news-and-insight/latest-ice-news/engineering-plymouth-film-launched;
  - *UK's first sea-going electric ferry sets sail in Plymouth* https://www.itv.com/news/westcountry/2020-10-13/uks-first-sea-going-electric-ferry-sets-sail-in-plymouth (**Pemberton**);
  - The One Show feature https://www.youtube.com/watch?v=Vk4TRXxR7Vk (**Simmonds**);
  - TEDx talk *How quantised inertia gets rid of dark matter* https://www.youtube.com/watch?v=fnNKC82wUmY (**McCulloch**);
  - Panellist on NetZero on Mariella Frostrop Times Radio (**Greaves**);
  - National Geographic *Drain the Bermuda Triangle* documentary (**Raby**);
  - Channel 5's *The Secret Life of Lighthouses* (**Raby**);
  - BBC Weather World feature (**Greaves**);
  - BBC Radio Devon Interview *ICE 200 Lighthouses, Bridges and Breakwaters exhibition* (**Simmonds**).
- Visiting professor positions *e.g.* Adjunct Professor VIT University (**Jenkins**); Hon. Visiting Professor, Saveetha University, India (**Graham-Jones**, **Jenkins**); Affiliate Professor, BS Abdur Rahman, Visiting Professor, University of Bath (**Chaudhuri**), Advisory Professor, Southwest Jiaotong University, China (**James**).

- Published books *e.g.*
  - Wave and Tidal Energy, John Wiley & Sons Ltd, edited **Greaves** and Iglesias;
  - Reeds Vol 4: Naval Architecture for Marine Engineers, by **Pemberton** and Stokoe (recommended Marine Engineering reading for MCA qualifications);
  - Marine Composites: Design and Performance (Woodhead Publishing Series in Composites Science and Engineering), edited **Pemberton, Summerscales**, **Graham-Jones**, **Sharma**, Subudhi;
  - Navigation and Control of Autonomous Marine Vehicles. Institution of Engineering and Technology, edited **Sharma** and Subudhi;
  - Marine Applications of Advanced Fibre-reinforced Composites, Elsevier, Woodhead Publishing, edited **Graham-Jones** and **Summerscales.**
- Invitation for Chair appointments *e.g.* University of Edinburgh Chair in Renewable Energy, 2019 (**Greaves**).
- Report authorship *e.g.* Position paper on electroencephalographic biomarkers in dementia diagnosis for International Society to Advance Alzheimer's Research and Treatment Electrophysiology Professional Interest Area doi.org/10.1016/j.neurobiolaging.2019.09.008 (**Ifeachor**).