Institution: De Montfort University

Unit of assessment: 12

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

1.1 UNIT CONTEXT

The staff for UOA 12 are largely based in the Institute of Engineering Sciences (IoES), a part of the School of Engineering and Sustainable Development along with the Institute of Energy and Sustainable Development, whose staff are predominantly UOA 13 entrants. The School itself is part of the Faculty of Computing, Engineering and Media, which includes the School of Computer Science and Informatics, and the Leicester Media School.

The IoES was formed in 2018 as a joint response to providing an overall umbrella for the research growth, and to support early career academics in the four key thematic areas (emerging technologies in micro and nano technology; signal processing and communications systems; surface engineering and materials; and nonlinear flight dynamics). The Institute coordinates activities and supports development initiatives that span the Unit.

The REF submission for 2014 contained 25 Category A staff, of whom 17 are not entered this time in UOA 12 (some have retired or left DMU, others are entered into different UOAs). The current submission totals 27 FTE Category A staff. Two-thirds of the Category A staff are new academic posts compared to the previous REF. This substantial investment in staff across the thematic areas has provided vitality and a sustainable base for future growth.

1.2 UNIT STRUCTURE

The Unit is arranged in four groups, representing the thematic areas discussed above. These areas represent key strengths for the Unit, span the interests of the research-active staff and ensure that each area has both a variety of viewpoints as well as a critical mass to grow in impact and influence over the coming years. These groups address a variety of research challenges, as identified from the REF 2014 submission. The Institute is visualised in Figure 1.

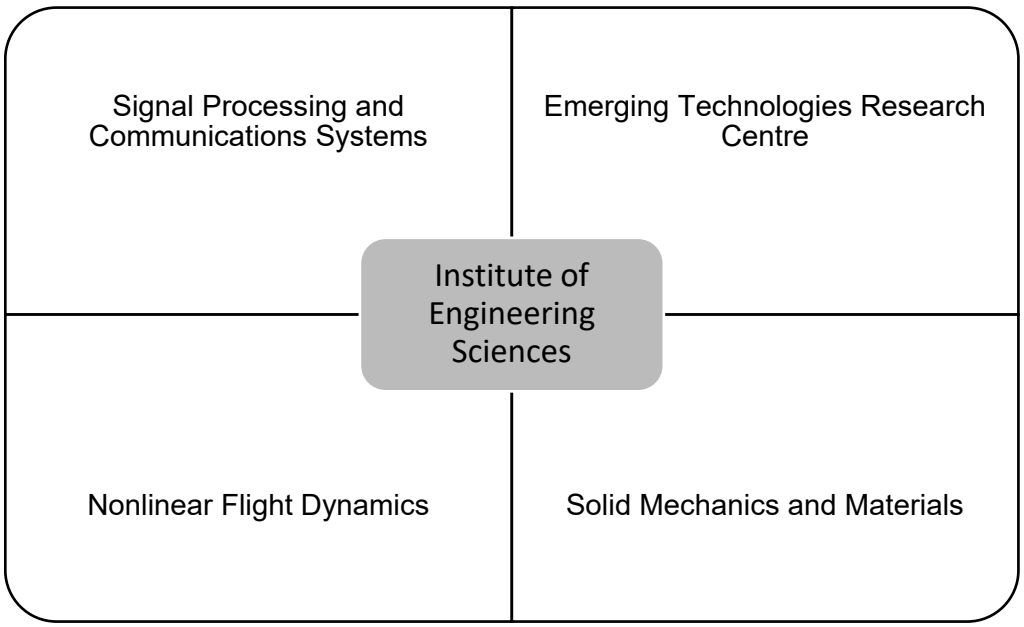

Figure 1: Structure of the Institute of Engineering Sciences and UOA 12

- The Emerging Technologies Research Centre (EMTERC) (**Cross**, **Govindarajan**, **Hamilton**, **Manjunatha**, **Paul** (leader), **Salaoru):** EMTERC works at the forefront of research in materials, devices, the nano-bio interface and printing applications. Of particular importance for EMTERC are low temperature growth of silicon structures for electronics and energy generation and storage applications. **Paul**'s recent EPSRC High Value Manufacturing Fellowship has been directed at

exploiting one patent (GB2482915) about Li-Ion batteries. Another highlight of EMTERC's research is the significant contribution to understanding nano-composite electronic memory. The proposed electrical bistability mode has been employed in different material systems including silicon nanowires.

- Signal Processing and Communications Systems (SPCS) (**Cosar**, **Duffy**, **Ghazal**, **Hamzaoui** (leader), **Maricar**, **Palusczyszyn):** SPCS focuses on video communication, computer vision, applied electromagnetics, wireless channel models, and RF and microwave devices and circuits. Recent research projects include 3D point cloud compression, perceptual image coding with just noticeable difference, computer-based human activity recognition, application of the Feature Selective Validation method in computational electromagnetics, partial discharge modelling, and channel modelling for high-speed train wireless communication systems. DMU launched a series of United Nations Sustainable Development Goals (UNSDG) Fellowships for the 2019/20 academic year as an internal competition. The Faculty won one such Fellowship (**Duffy**), which is based on applying a DMU-developed data comparison technique to validation of approaches for the detection of land mines using ground-penetrating radar, with partners in the Universities of Manchester and Kharkiv. This area is also host to one Marie Curie Research Fellow (1.4 and 3.1).
- Solid Mechanics and Materials (SMM) (**Abdel-Raheem**, **Abdi**, **Baserinia**, **Diao**, **Farukh**, **Kandan**, **Khoshnaw**, **Mba**, **Moroz**, **Sun** (leader), **Zahedi):** SMM includes mechanics modelling, manufacturing by 3D printing, surface engineering, tribology and bioengineering. An area of particular concern is the design and manufacture of prosthetic related products for low-income countries using recycled materials. The research is particularly well known for its surface engineering and tribological characterisation of metals and metal alloys, 3D printing of medical implants and prosthetics, and additive manufacturing of lattice structures using powder-based technologies. Control and dynamics is an important theme that runs through this group, which also embraces water control and dynamics. Advanced signal processing techniques are also applied for machinery health condition and remaining life prediction (prognosis) for critical machine elements, such as helicopter main gearboxes (**Mba**).
- Nonlinear Flight Dynamics (NLFD) (**Abramov**, **Goman** (leader), **Li**, **Yao):** NLFD has decades of active research and industrial applications in applied aerodynamics at high angles of attack and nonlinear flight dynamics, including the investigation of critical flight regimes. The group has completed many successful R&D projects in Russia, China, India and Europe and has developed a validated methodology for phenomenological modelling of aerodynamics in an extended flight envelope at stall conditions and beyond, based on experimental data from wind tunnel tests with the use of CFD simulation methods helping to compensate experimental limitations. A significant impact was made in the development of flight simulation models of transport aeroplanes for pilot training in Loss-of-Control In-flight (LOC-I) situations and Upset Prevention and Recovery Training (UPRT). For example, the extended flight envelope aerodynamic model SUPRA (FP7 EU research project SUPRA,) is currently used for pilot training for LOC-I and UPRT on a unique in Europe centrifuge-based flight simulator (DESDEMONA).

1.3 RESEARCH STRATEGY

1.3.1 Review of REF 2014 key strategic direction

The strategy outlined in REF 2014 identified two specific challenges that the Unit needed to address in the subsequent census period. The key achievements in these areas are to

- *build on the existing infrastructure:* the significant change in the staff base, with the focus on recruitment of early career academics, has resulted in a stronger, more vibrant and more sustainable staff base than was present in 2014, with better-defined research groups (thematic areas).
- *define clear research challenges in each area of the current submission:* the growth of the staff base coupled with the University's adoption of the UNSDGs has contributed to the ongoing development of the key themes in each of the four groups.

DMU's adoption of the UNSDGs, in particular, No Poverty (UNSDG 1), Industry Innovation and Infrastructure (UNSDG 9) and Responsible Consumption and Production (UNSDG 12), provided the Unit with a further focus for developing the impact of the work of the Unit.

1.3.2 Strategic focus

During the assessment period, the Unit's strategic aim was to undertake research that has an impact on industry and the professions, as well as benefiting society. This aim was achieved by

1 supporting and funding high-quality research that addresses key societal challenges, such as sustainability in energy, water, and transport. Examples include low-temperature silicon structures for energy generation and storage, manufacturing prosthetics with recycled materials, modelling water distribution systems, and flight simulation models for pilot training. Recently, UNSDGs were identified as part of all internal funding mechanisms with the intention of embedding them more widely in the University's research DNA;

2 developing stakeholder networks to increase the translational and transfer opportunities for the Unit (4.1 and 4.3);

3 increasing involvement with leadership in the profession. This includes membership in standards committees, as well as professional bodies and conference organising committees (4.2.6);

4 improving international recognition of the Unit's research through overseas honorary appointments, increasing citations with open access papers and data, as well as presenting and hosting webinars, topical meetings and conferences (4.2.6).

1.4 RESEARCH IMPACT

The development of impact is primarily generated through mutually beneficial stakeholder relationships. Over the assessment period our aims were to

1. recognise and reward industrial collaborations:
    - DMU runs an internally competitive Enterprise competition to award funding to take research further along the Technology Readiness Levels (TRLs) with external company support. Within the Unit itself, staff are directed to use the discretionary budget to support networking activities which will help build academic and industry networks. Technical networking events are organised on an occasional basis to bring industry and academics together with the view to finding areas of mutual interest.
    - In order to develop this further, the recent introduction of the PhD by Extended Professional Practice, championed by the IoES Director, is intended to develop mutually beneficial high level technical relationships with industry;
2. extend our alumni network to expand our industrial links;
3. ensure that internally funded projects demonstrate how they will develop and capture impact in its broadest form.

Examples of how these approaches are bringing benefit to the Unit are:

- **Palusczyszyn**'s Industrial Fellowship (The Royal Society Short Industry Fellowship, October 2019–August 2020), followed directly from the links made during a networking event with key technical staff in HORIBA MIRA;
- Initial meetings regarding the application for **Paul**'s High Value Manufacturing Fellowship were supported by the Unit with the Carbon Trust and Energy 4 Impact providing business support services to him to overcome barriers to commercialise his ideas; **Paul** was selected for the Ignite (2020) programme, funded by Innovate UK;
- **Maricar** and **Ghazal** are working with Leicester City Council on IoT-enabled environmental monitoring funded by Leicester City's and the University's 'Local+' scheme;

- **Duffy**'s Marie Curie Fellowship involves HVPD Ltd, a company where an alumnus is a Director.

As noted, the significant driver of impact is working with industry. Low technology readiness level (TRL) research is fundamental to our research inquiry. However, mid- to high-TRL research and translation is particularly encouraged. The three impact case studies are examples of this, with **Goman** being representative of the impact of the NLFD area, **Ulanicki** of SMM and **Oxley** representing the interface between SPCS and EMTERC. **Goman's** 'Enhancing pilot training and flight safety through improved aerodynamic modelling and prediction of nonlinear flight dynamics' addresses three types of impact: pilot training for the extended flight envelope (Desdemona, the Netherlands and CSIR-NAL, India), flight simulator development (AMST-Systemtechnik GmbH, Austria) and support for the development and testing of civil aircraft (TsAGI). **Oxley's** 'Infra-red micro-thermography for electronic devices' assists commercial organisations to develop more reliable semiconductor devices. **Ulanicki's** 'Improving Operation and Control of Water Distribution Systems' develops mathematical models and computer methods for improved control of pressure and flow, as well as burst detection in water distribution systems, addressing issues of water-supply reliability in conjunction with a number of utilities.

Support for impact development underpinning the three case studies submitted has included research leave scheme awards (**Goman**, **Ulanicki**), PhD bursaries/scholarships (**Goman**, **Ulanicki**), research capital investment funding (**Oxley**) and the employment of Vertigo Ventures-Impact Tracker.

Impact in the Unit, of course, is wider than these case studies, particularly in the form of engagement with industry. Industry engagement is encouraged as it provides value in both directions: providing industry with academic input and bringing impact opportunities, relevance and contextualisation to the work in DMU. For example:

- **Paluszczyszyn** holds an Industrial Fellowship with HORIBA MIRA, exploring issues of autonomous vehicle driving;
- **Maricar** (building on the work of **Oxley**, who recently retired and remains a visiting senior research fellow) undertakes infrared thermography measurements on active semiconductor devices (**Oxley**'s work is the basis of another impact case study);
- **Duffy** provides regular electromagnetic testing to industry as DMU is the only university providing assurance tests for the police's 'Secured by Design' accreditation;
- **Kandan** developed the first-of-its-kind prosthetic limb socket made from recycled plastic bottles, which could save healthcare providers millions and help tackle plastic pollution;
- **Sun** provides technical services to industry on materials characterisation and properties testing;
- **Paul** has developed an industrial manufacturing process to contribute to next generation photovoltaic solar cells and lithium-ion battery developments.

The Unit is committed to ethical and responsible research and works in accordance with the University's robust processes. The Unit is also committed to Open Access in both publications and data. All outputs that are not Gold Open Access are expected to be placed on DORA (DMU Open Research Archive) within three months of acceptance. The University uses Figshare for capturing wider research data and researchers are encouraged to make use of this. Its use will become mandatory over the subsequent five years as we embrace the principles of open research and research reproducibility.

1.5 RESEARCH AND IMPACT OBJECTIVES FOR THE NEXT FIVE YEARS

In addition to the above research aims, the specific objectives for the next five years are:

1 To increase externally obtained research funding (towards the prevailing sector norm), including funding for one or two postdoctoral research fellows per annum. The introduction of a 'peer review college' by DMU is being used as a basis to increase mutual support and mentorship in applications and thereby increase the reviewer scores and panel rankings.

2	To build networks of national and international research collaborators for every academic, resulting in journal outputs and/or external (and transnational) funding bids. Most academics already have an international network of collaborators and these networks will be used for mutual expansion (subject to domain similarities). Expansion of leadership in the profession will also expand international networks as well as national networks.
3	To increase the number of PhD graduates by at least 25%, mainly through recruitment of international PhD students and by recruiting to the PhD by Extended Professional Practice (validated in 2020). Work with the University's International Office is under way to help raise the profile of international opportunities, and the Industrial Liaison Committee of the School of Engineering and Sustainable Development is set to champion the PhD by Extended Professional Practice through its wider networks.
4	To see the result of staff development and mentoring reflected in the awarding of further personal chairs. The Unit would like to see at least two more. Senior staff within the UOA are providing guidance and mentorship to help with this process.
5	To enhance the gender balance and maintain the proportion of BAME staff. We will look to working with bodies such as the Women's Engineering Society to help us adopt best practice. While dependent on the potential for recruitment, the Unit would like to see more than 15% of its academics being women.
6	To strengthen links with industry and key stakeholders, developing demonstrable impact through translating research to evidencable benefit. Section 4.3 describes some of the ways that the Unit is currently working with such stakeholders.

Section 2. People

2.1 STAFFING STRATEGY

Our staffing policy is designed to recruit staff who have (or have the potential to develop, depending on the level of appointment) a reputation for internationally leading research that complements one of the four groups previously identified.

The recruitment of early career academics has been the core of the recruitment strategy. This has been with a view to long-term sustainability and vibrancy of the research environment. The main vehicle for this has been the prioritisation of the recruitment of early career academics through the Vice-Chancellor's 2020 (VC2020) and the Early Career Academic Fellow (ECAF) schemes. Both schemes recruited staff with significant potential, generally into their first academic post, and gave them 50% protected research time for their first year. Eleven VC2020s have joined the UOA (**Abdi**, **Abdel-Raheem, Baserinia**, **Farukh**, **Hamilton**, **Kandan**, **Khoshnaw**, **Manjunatha**, **Paluszczyszyn**, **Salaoru**, **Zahedi**). Two staff were initially recruited as ECAFs and promoted to VC2020 lecturers (**Ghazal**, **Maricar**). Two VC2020s have been promoted to associate professors (**Kandan**, **Salaoru**).

Internal support and mentorship have helped see the promotion of five of eight staff who were submitted in 2014: three staff to professorial level (**Duffy**, **Paul**, **Sun**) to join **Hamzaoui** and **Goman**, who already held personal chairs, and three staff (**Cross**, **Li**, **Moroz**) to the recently introduced associate professor grade. Two staff appointed as VC2020 academics have also been promoted to associate professors (**Kandan**, **Salaoru**).

DMU sees internationalisation and an international perspective as something to benefit students and staff. Recruitment to the Unit also seeks this international perspective with all but three Category A staff being born and/or educated outside the UK. Staff come from the UK, the EU, North Africa, sub-Saharan Africa, the Middle East, the Indian subcontinent and the Far East.

There is one woman submitted to this Unit. In 2014 there were two: one is submitted to UOA3 in REF 2021 and the other no longer works in higher education.

Over the current census period we have recruited a significant body of predominantly early career academics. This has resulted in increasing the number and improving the quantity of outputs and developing more technology translational activities. There was a short-term trade-off for this recruitment: the plateau of research degree awards and the decline in research income. However, the

Unit is recovering, with the support strategies previously described starting to show positive returns. Four early career academics submitted to UOA 12 are graduates from the Unit (**Manjunatha**, **Maricar**, **Paluszczyszyn**, **Salaoru**). Clearly, this helps demonstrate the Unit's commitment to sustainability in staffing.

2.2 STAFF DEVELOPMENT

The VC2020 academics have also been provided with ring-fenced individual funding (up to £5,000 per annum) in order to enhance their ability to produce high quality research outputs and to enhance their network building. The success of this can be seen through the variety of papers on the DMU open research archive, DORA, some of which are submitted here.

The IoES and Faculty have supported external reviews for external competitive research funding bids along with internal development assistance which has included facilitating discussions with relevant research council staff, partly for staff development (to understand the role and scope of the research councils) and partly to help in focusing the detail of the particular application being considered. The University has or had other competitive internal funding mechanisms such as HEIF (Higher Education Innovation Fund, targeted at knowledge exchange activities), RCIF (Research Capital Infrastructure Fund, which looks to build facilities), RIF (Research Investment Fund, intended to spur new research areas or accelerate existing areas) and the Global UNSDG Fellowship, previously the RLS (Research Leave Scheme) providing relief from teaching activities for a period of typically one semester, allowing the holder to concentrate on research activities. Some examples of these awards are:

- HEIF: **Duffy** 2014/15 Electromagnetic Compatibility Alliance (£6,000); **Salaoru** 2016/17 and 2017/18 3D Printing of Greener, Leaner and Flexible Electronic Memory Devices and Inkjet Printing of Graphene-based Materials (£15,300 and £14,300), **Manjunatha** 2019/20 Flexible and Foldable Electronic Appliances (£14,000)
- RCIF: **Cross** et al., 2015/16 Electron beam lithography (£41,300), **Paluszczyszyn**, 2015/16 Immersive Vehicle Virtual Reality Testbed (£24,172)
- RIF: **Paul**, **Sun** 2014/15
- RLS: **Ulanicki** 2014/15, **Duffy** (Global UNSDG Fellowship) 2020.

Further, funding was awarded to develop GCRF research capability in 2017–2019 (**Kandan**, £10,347; **Sun**, £32,710).

Early career researchers are mentored from their first day by experienced colleagues. The Research Services Directorate provides a local induction and ongoing training throughout their careers. A regular programme of training courses is produced which colleagues are encouraged to attend. Each research centre prepares research plans with measurable objectives in terms of published outputs, grant applications and PhD student recruitment/completion. The plans are reviewed and updated annually. Research-active staff are encouraged to request additional research time through Research and Innovation Allowances in which independent researchers are allocated, in addition to a 10% scholarship allowance, 320, 480 or 640 hours research time per year (1–2 days per week). The average across the Unit for 2019/20, excluding the scholarship allowance, is 492 hours or 0.3 FTE per academic (representing an equivalent of eight FTEs in the Unit dedicated to research).

Various workshops are run to provide broad development opportunities. Recent workshops have included how to present research, respond to rejection from publication, address challenges in research supervision, develop an elevator pitch for research projects, communicate the academic impact of research outputs.

DMU runs a competitively selected Future Research Leaders scheme, designed to improve the strategic competence base within the University. The scheme is limited to 12 places per year. The Unit has had three staff pass through this scheme (**Duffy**, **Cross** and **Kandan**).

The Faculty's Research and Innovation Office and the University's Research Services Directorate provide day-to-day support to all academics.

2.3 THE POSTGRADUATE RESEARCH ENVIRONMENT

The history of research degree completions can be seen in Figure 2.

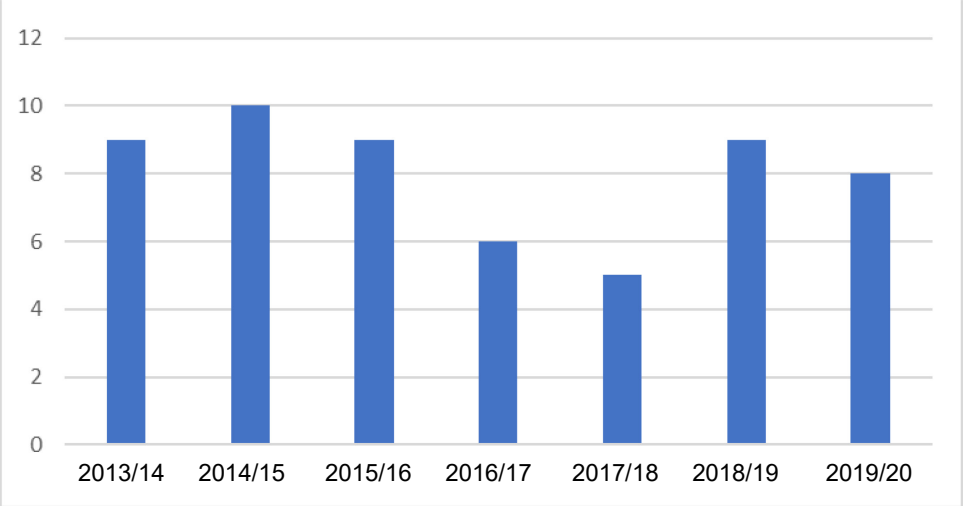

Figure 2: PhD Completions

The rise since 2017 reflects the gains being made by the re-staffing within Engineering. This represents just over two graduations per FTE member of staff at current numbers. It should also be noted that the 'international PhD' (iPhD) scheme graduations, where students study primarily in their home country and visit DMU for typically between one and two months per year, while not included in the REF return, provide a fuller picture of the graduation pattern (Figure 3).

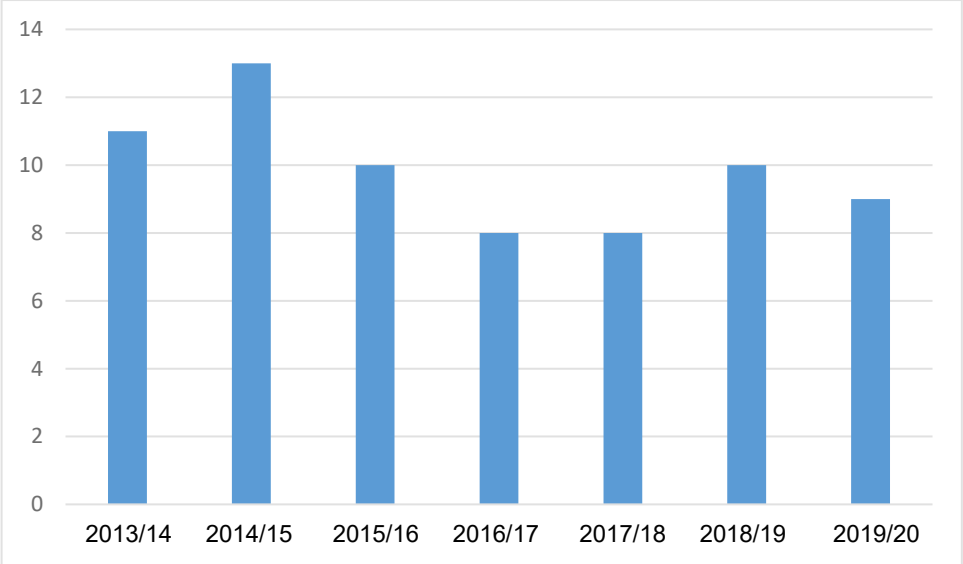

Figure 3: PhD Completions including 'international PhD'

This increases the graduation rate to approximately 2.5 per FTE academic or, on average, approximately one graduation per academic every 2.7 years.

For context, there was an average of 7.8 completions per year in REF 2014. However, in this census period that had dropped to 6.8 completions per year (without iPhDs), and this is particularly influenced by the drop in 2016–2018, but showed an increase to 8.7 completions per year with iPhD completions included.

The current number of first supervisions within the Unit is 27. The Institute is actively working with the International Office to enhance the recruitment of international postgraduate research (PGR) students and with a number of national and international partners to explore agreements for joint supervision, which helps address our strategic aim of growing the PGR community.

DMU runs an annual PhD bursary competition. During the assessment period, the Unit has benefited from 11 of these bursaries, with emphasis being given to supporting the development of early career academics as supervisors. **Farukh**, **Kandan**, **Paluszczyszyn** and **Zahedi** have all supervised (or are currently supervising) University-supported PhD students. One of the bursaries was awarded to a student for the project 'Development of aerodynamic model of a transport airliner in extended flight envelope using computational fluid dynamics methods'. He is currently continuing his research career as a postdoctoral researcher, working with **Goman**. Some students have been funded by Innovate UK and industry (e.g. Volvo car corporation), while many others received scholarships from overseas agencies, such as the Saudi Arabian Cultural Bureau, Indonesian Directorate General of Higher Education, CSIR-NAL (a government research centre in India), Iraqi Cultural Bureau, Embassy of the Libyan Arab Republic, and Ministry of Education and Training of Vietnam.

All PhD students undertake research training run by the University's Doctoral College and they are members of the School's Doctoral Training Programme, which organises various meetings, talks and workshops. The University's Researcher Development Programme is based around seven themes (core knowledge; research effectiveness; research governance; methods and tools; personal and professional development; engagement, influence and impact; and writing in academic contexts). Students are monitored throughout their programme via a PGR management system in which progress is recorded through records of discussion and mandatory annual reviews.

DMU operates a travel award scheme with the intention of supporting research students attend at least one academic conference during their studies (ideally presenting a paper). They can bid for up to £500. There are opportunities for students to present their work to and interact with other researchers at both Faculty and University level through the Three-Minute Thesis competition, the research poster competition and the Faculty's PhD Multidisciplinary Seminars, where, typically, several PGRs will present their work to other researchers.

Research students are encouraged to contribute to the teaching programme by delivering laboratories and tutorials, helping build their wider academic experience and communications skills.

Within three years of graduation, many of our doctoral graduates had academic posts in higher education in the UK or overseas (e.g. Al Muthanna University, Jiangsu Normal University, Taif University), or had taken up high-skilled jobs in industry, including senior principal scientist and head of UAV Division at CSIR-NAL, software engineer at Renishaw, research and development engineer at Panasonic R&D Centre Singapore, and Director Manufacturing Research and Concepts at Volvo Car Group.

Academics are required to gain a Certificate in Research Supervision before embarking on supervision. All supervisory teams are required to have at least one experienced supervisor in order to support any new supervisors. The PGR lifecycle is managed using a PGR management system, which tracks and shares key milestone dates and data, including monthly supervisory team meetings and annual reviews (undertaken by an independent, experienced, academic).

2.4 EQUALITY AND DIVERSITY

The staff base is multinational and multicultural: an ethnically diverse staff base able to provide a truly international perspective. Recruitment of academics has focused at School level on identifying the necessary expertise with consideration being given to under-represented groups. Table 1 provides a summary of the composition of the Unit.

Table 1: Equality and diversity summaries for UOA 12 (UOA 15 in REF 2014)

	M	F	White	BAME	Not disclosed	Profs/Senior staff	Readers/AP/PL	ECAF/L/SL	RF/SRF	Other
2014 (25)	92%	8%	72%	28%	0%	24% (F = 16%)	32% (F = 12%)	16%	20%	8%
2021 (27)	96%	4%	37%	63%	0%	22%	11%	67% (F = 5%)	0%	0%

Note: 'F' indicates the proportion of women returned.

The Unit is looking to address the recruitment of female researchers by seeking to attract suitably qualified female research fellows. For example, **Salaoru** was initially a PhD student and is now an Associate Professor.

The University has a number of Equality, Diversity and Inclusion (EDI) charters that guide our EDI actions. DMU was awarded a Bronze Athena SWAN and the first Athena SWAN Charter principle 'we acknowledge that academia cannot reach its full potential unless it can benefit from the talents of all' is an important guiding principle across the board.

The Unit has approximately 10% of staff from the UK, 20% from Europe, 7% from Africa, and 63% from Asia.

DMU has flexible working and leave policies to help support staff well-being.

Section 3. Income, infrastructure and facilities

Research is managed by the PVC Research at University level, with the Associate Dean for Research taking responsibility at Faculty level. The Unit (and Institute) are managed by the Institute Director with the help of the heads of groups. In addition, there is a Faculty Head of Research Students and School Heads of Research Students who oversee PGR students. The Unit is serviced by a Faculty Research and Innovation Office and a Research Development Officer.

3.1 RESEARCH INCOME

There is a clear rise in research income following the dip resulting from the staff-base change, previously discussed. The income shown in Figure 4 is for research only and does not include innovation, enterprise and knowledge exchange activities (such as the support for a UK test equipment manufacturer creating a new, high-specification EMC receiver).

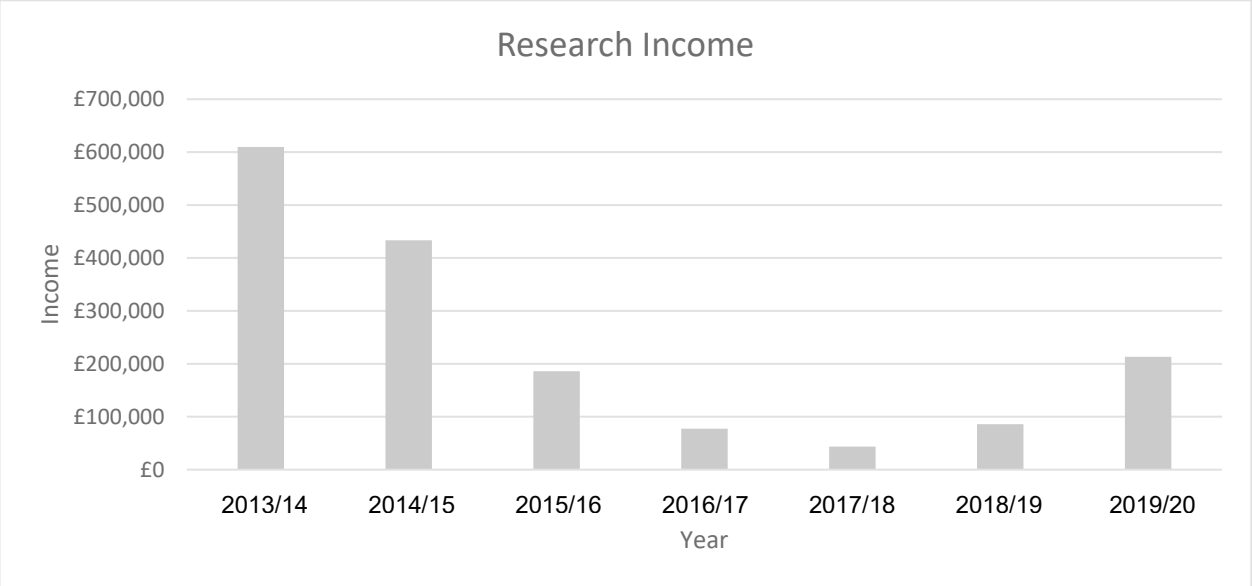

Figure 4: Research income

The Unit is now seeing successful bids coming through (for example ~£200,000 for **Kandan** and **Farukh** from the Royal Society; FF\1920\1\30) and anticipates the recovery to continue in the coming years.

Some funding highlights over this period reflect the strategic aims of delivering research that has impact on industry and the professions and benefiting society through addressing the UNSDGs; developing stakeholder networks and increasing translation opportunities; increasing involvement with leadership in the profession, and improving international recognition, are:

- **Cross** has recently been awarded ~£130,000 for a collaborative project between King Abdulaziz University and De Montfort University by the Saudi Arabian research funding agency.

- **Duffy** was PI on 'Development of an innovative Autonomous Model Development Tool (AMDT) for Boosting Manufacturing Process competencies' TSB call, EPSRC grant EP/K503678/1 (November 2012–October 2015) £230,114 and PI on the Marie Curie Individual Fellowship 'emiT' project 'Partial discharge modelling using the Transmission Line Matrix (TLM) method' (August 2014–August 2016) ~£200,000; Project EIPE14201 State Key Laboratory of Electrical Insulation and Power Equipment, 'Research in the analysis of electromagnetic coupling considering geometry randomness of cable bundles' (January 2016–December 2018), 290,000 RMB, National Science Foundation of China. He is an academic partner on EU ITN 'PETER' (Pan-European Training, Research and Education Network on Electromagnetic Risk Management), 2018–present.
- **Goman and Abramov** have received project funding for projects with CSIR-NAL, India (2014–2015, £200,000), EU H2020 SAFEMODE project (2019–2022, €202,000), AMST-Systemtechnik GmbH, Austria (2014–2018, £583,900).
- **Hamzaoui** was Co-I on the Royal Society International Exchanges 2017 Cost Share (China) project 'Privacy computing and protection research for IoT-enabled smart healthcare systems', IEC\NSFC\170067 (March 2018–March 2020), £11,980, collaborating with USTB (China) and is External Collaborator on the DFG (German Research Foundation)-funded Collaborative Research Centre (SFB-TRR 161) 'Quantitative methods for visual computing' (1 July 2019–30 June 2023), collaborating with the University of Konstanz (Germany).
- **Kandan** is PI on the project 'Upcycled plastic prosthetics' funded by the Royal Academy of Engineering (FF\1920\1\30), demonstrating the first-of-its-kind prosthetic limb socket made from recycled plastic bottles (March 2020–February 2022), £198,434.
- **Manjunatha** has received an external grant through Early Career Researcher's Sandpit Scheme (EPSRC), £5,100, to grow and integrate self-doped silicon nanowires for transferring heat into electrical energy for Micro-Thermoelectric Generators. He will be working with Southampton University.
- **Paul** was PI on Energy Catalyst-3 'Creating electricity by reducing cost, payback time and carbon footprint: an exploitation of a novel method into manufacturing crystalline silicon photovoltaic solar cells (EP/P020518/1)' (October 2016–September 2017) £34,196 and PI on the EPSRC High Value Manufacturing Catapult Fellowship 'Manufacturing silicon nano-structure at low temperature: route to increase charge capacity and lower the cost of li-ion batteries', held at WMG Catapult, Warwick University (2016–2018), £66,040.
- **Paluszczyszyn** was Co-I on 'Range extended engine management system for electric vehicles', Transport iNet grant (July 2013–April 2015) £127,663; Co-I on 'Water advisory demand evaluation & resource toolkit' (April 2015–April 2016), Innovate UK grant 132024, £80,803; and was awarded a Royal Society Short Industry Fellowship for the project 'immersive self-driving car virtual reality simulator' (SIF\R1\191025) (October 2019–March 2020) £11,198.
- **Sun** was PI on the Royal Society-NSFC International Exchange Cost Share programme IE161010 (2017–2019), collaborating with Hohai University (China).

3.2 FACILITIES

During the assessment period, the Unit benefited from capital investments of about £1,066,000 for 3D printers, five HP Z4 G4 workstations, PGR workspace improvements, reverberation chamber and physical layer lab adaptations, as well as aeronautical facilities for teaching and research, including an AIRFOX DISO flight simulator and a subsonic wind tunnel (TQ AF1300).

In addition to the physical resources described below, the Unit benefits from advice from the School's Industrial Liaison Committee (ILC), composed of industry-based leaders. The ILC includes three engineering alumni who current hold senior positions within their organisations.

The specialist facilities, grouped by research theme are:

3.2.1 EMTERC

Device fabrication

A clean room (with Class 100 under the benches), a double-sided EVG 620 mask aligner with 1 micron alignment capability and wet/dry benches, three deposition chamber PECVD/RIE systems, Langmuir-Blodgett trough for molecules and nano particles deposition, spin-coater, dip-coater, RF/DC magnetron sputtering, evaporators, vertical stack furnaces, small and large-scale nanomaterials printing machines, horizontal furnaces and electrochemical characterisation, including impedance spectroscopy.

DC and RF electronic characterisation

Including four wafer-level probe chucks for temperatures ranging from room temperature to 800 K. These are supported by HP4884 (an LCR bridge), HP4142B (modular DC source/monitor), HP4140B (picoammeter), Keithley 2634B dual SMU, a Lot-Oriel solar simulator and ancillary systems, LED wavelength controllable solar simulator, Li-ion battery test equipment with 4-port glovebox, precision ferroelectric test system, a deep level transient spectroscope (DLTS) and high frequency S-parameter measurement equipment.

Metrology

Scanning probe microscope (SPM) (up to 473 K) with numerous measuring modes including: atomic force microscopy, scanning tunnelling microscopy and electric force microscopy, plus further electrical, capacitance and magnetic modes; scanning electron microscopy for sample inspection down to ~ 30nm.

3.2.2 Signal Processing And Communications Systems

Device Thermography and Microwave Laboratory

This houses a state-of-the-art Quantum Focus infrared (IR) microscope, with its capability extended by proprietary IR micro-sensor technology. Research and commercial work is undertaken in thermal mapping of all types of electronic devices (MEMS, MMIC, PHOTONIC, DISRETE, etc.).

Physical Layer Laboratory

A 5m×3m×2.3m mode stirred reverberation chamber used for shielding effectiveness measurements, electromagnetic coupling and as a propagation channel analogue; microwave dielectric measurement test jigs, several vector network analysers, thermal chamber, ethernet cable testing.

Immersive Vehicle Virtual Reality Testbed

A portable testbed which uses a six-degree of freedom motion system enhanced by virtual reality headsets and driving controllers. Presentation of visual, acoustic, vestibular and haptic information to simulate a real driving experience. The testbed is integrated with state-of-the art self-driving cars software simulators such as LGSVL, Carla and Apollo. The facility also includes rapid control prototyping unit dSPACE MicroLabBox and galvanic skin response and electrocardiography sensors.

3.2.3 Nonlinear Flight Dynamics

While the bulk of the work is in aerodynamic modelling, flight simulation and computational analysis using high performance workstations, this research area also has a professional flight simulator AIRFOX DISO of AMST-Systemtechnik GmbH, Austria.

3.2.4 Solid Mechanics and Materials

Tribology and surface engineering laboratory

This houses a range of materials characterisation and testing facilities, including: electroplating equipment, a surface mechanical attrition treatment machine, surface topography devices, optical microscopes and associated image processing software, metallography facilities, hardness and microhardness testers, friction and wear testers, electrochemical corrosion testing unit, tribocorrosion test set ups, scratch tester.

Mechanical laboratory

This houses several tensile/compression testers, bending tester, fatigue tester, truss tester, stress concentration tester, and a range of non-destructive testers.

Additive manufacturing laboratory

This houses more than ten 3D printers ranging from powder-based printers to filament-based printers.

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

This section lists and evidences the contribution that IoES staff make to externally facing activities. The subsections below all contribute to the overall strategic aims of:

1 supporting and funding high-quality research that addresses key societal challenges;
2. developing stakeholder networks to increase the translational and transfer opportunities for the Unit;
3 increasing involvement with leadership in the profession;
4 improving international recognition of the Unit's research.

4.1 COLLABORATIONS, NETWORKS AND PARTNERSHIPS

It will be evident from the submitted outputs that collaborative work is regarded as highly important for the UOA, with many being co-authored by colleagues from other universities and industry, and in many cases these are international in nature. Some examples are included here to show the breadth of these collaborations and also to show how these productive collaborations extend beyond the submitted outputs. It also shows the strong networks that many of the early career academics already have.

Some examples from the early career academics include:

- **Cosar** co-authored papers with Prof. Mujdat Cetin (previously Sabanci University, currently University of Rochester), Dr Francois Bremond (INRIA), Prof. Vania Bogorny (Universidade Federal de Santa Catarina), Dr Nicola Bellotto (University of Lincoln), Prof. Adriana Tapus (ENSTA ParisTech)
- **Maricar** has jointly published with Prof. Josef Nossek (Technical University of Munich) and Sidina Wane (NXP, France)
- **Diao** established research collaborations with five universities in the UK, e.g., 10.1016/j.heliyon.2020.e05069 and internationally: Austria (10.3390/w11030567), China (10.1061/(ASCE)WR.1943–5452.0001164; 10.3390/w12061683), Italy, South Korea, the Netherlands and the US
- **Ghazal** has co-authored papers with Prof. Cheng-Xiang Wang (previously Heriot-Watt University, currently Southeast University), Prof. Harald Haas (previously University of Edinburgh, currently University of Strathclyde), Dr Yan Zhang (Beijing Institute of Technology), and Dr Yu Liu (Shandong University)
- **Kandan** has collaborated with the Bhagwan Mahaveer Viklang Sahavata Samiti (BMVSS) in Jaipur, India – the world's largest organisation for rehabilitating disabled people – as well as prosthetic experts from the Malaviya National Institute of Technology, Jaipur, India, University of Salford, University of Southampton and the University of Strathclyde
- **Khoshnaw** was a visiting professor at Mons University funded by the Belgian Science Research Foundation (two months during 2017/18) with Prof. Delaunois and Dr Vitry. A further joint collaboration was started following internal competitive funding with Prof. Zhang; Beijing Institute of Petrochemical Technology, Dr Yamanouglu; Kocaeli University, and Dr Aljohani (King Abdulaziz City for Science and Technology); these collaborations have resulted in several papers
- **Salaoru** has collaborated with Dr N. Iftimie from the National Institute of Research and Development for Technical Physics, Iasi, Romania, in the area of materials

- **Paluszczyszyn** is external supervisor and adviser to two PhD students from Wroclaw University of Economics. This scheme is carried out within the SIS PHD Economy+ project (POWR.03.02.00-IP.08-00-DOK/17) founded by the National Centre for Research and Development, Poland.

With regard to the senior staff, many of the collaborations are associated with joint proposals as well as publications. For example:

- **Duffy** has jointly published with, and won joint research proposals with, Harbin Institute of Technology and Xi'an Jiaotong University
- **Goman** and **Abramov** have undertaken a fruitful research collaboration with CSIR-NAL, India, in 2014–2017, and with the Central Aerohydrodynamic Institute (TsAGI), Russia, within a joint research group led by Prof. Goman. The outcome of this collaboration was a computational framework for nonlinear flight dynamics and an associated software system in MATLAB/Simulink
- **Hamzaoui** was involved in the MSCA ITN ACROSSING project (GA 676157) 2016–2019 as co-supervisor of one early-stage researcher, collaborating with CERTH (Greece), Austrian University of Technology, and Ulster University. He has also collaborated and jointly published papers with Prof. Dietmar Saupe (University of Konstanz), Prof. Pascal Frossard (EPFL), Prof. Gwendal Simon (IMT Atlantique, currently Huawei Technologies), Prof. Yun Zhang (Shenzhen Institutes of Advanced Technology), and Prof. Hui Yuan (Shandong University)
- **Paul** has ongoing collaborations with colleagues from Nanjing University of Information Science and Technology, Cambridge University and WMG, Warwick University
- **Sun** had an international exchange partnership funded by the Royal Society with Hohai University, 2017–2019, and was a development consultant with Hohai University, 2017–2020.

4.2 CONTRIBUTION TO THE RESEARCH BASE

4.2.1 Standards

Contribution to standards development is an increasing focus in the Unit and provides a vehicle for regulatory and conformity impact on the profession. Responsibilities include chair of the IEEE Standards Working Groups 1597.1 (validation of computational electromagnetics), P2710 (shielding of enclosures for portable electronics), and vice-chair of P1848 (techniques and measures for the management of electromagnetic risks) (**Duffy**), and membership of BSI IST/37 Coding of audio, picture, multimedia and hypermedia information (**Hamzaoui**).

4.2.2 Journal editorships

It is expected that all academics become involved in editorial duties. Editorial board duties are spread between early career academics and senior staff. For early career academics, this is an opportunity to develop reputations, broaden networks and gain valuable experience of the publication process. For senior staff, this is a contribution to leading the discourse in a particular subject.

Examples of guest editorships of our early career academics are:

- **Cosar:** *Frontiers in Robotics and AI* special issue on 'Advanced Vision Challenges for Social Robots'
- **Diao:** 'Resilience of Interdependent Urban Water Systems' in *Water* (MDPI)
- **Ghazal:** *Radio Science* (Wiley) special collection on 'Radio Channel Measurements and Modeling for Future High-speed Railway Communications'
- **Khoshnaw:** series editor for the forthcoming *Corrosion Atlas* (Elsevier)
- **Manjunatha** and **Paul:** the forthcoming 'Emerging Applications of Silicon Nanostructures' in *Crystals* (MDPI)
- **Salaoru:** the forthcoming 'Miniaturized Memory Devices' in *Micromachines* (MDPI)

Some examples of senior staff guest editing include:

- **Duffy:** *IEEE T-EMC* special issue on 'Validation of Computational Electromagnetics'
- **Goman:** the forthcoming 'Modelling of Aircraft Unsteady and Nonlinear Aerodynamics' in *Aerospace* (MDPI)
- **Mba:** 'Fault Diagnosis and Fault-Tolerant Control' in *Energies* (MDPI) and 'Condition Monitoring and Their Applications in Industry' in *Applied Sciences* (MDPI).
- **Sun:** 'Tribocorrosion of Surface Engineered Materials' in *Lubricants* (MDPI).

Staff at all levels have had editorial board responsibilities, predominantly Associate Editor roles during the assessment period. For example

- **Cross:** *Micro and Nano Letters* (Springer)
- **Diao:** *Water Supply* (IWA Publishing), *Engineering Sustainability* (ICE Publishing)
- **Duffy:** *IEEE Transactions on Electromagnetic Compatibility*
- **Hamzaoui:** *IEEE Transactions on Multimedia*, *IEEE Transactions on Circuits and Systems for Video Technology*
- **Mba:** *Machines* (MDPI, EiC), *Applied Condition Monitoring* (Springer, book series), *Lubricants* (MDPI), *Grey Systems: Theory and Applications* (Springer)
- **Salaoru:** *Electrochem*, *Micromachines* and *Polymers* (MDPI).

4.2.3 Fellowships

Promotion of the recognition of senior status of professional bodies is an area that the Unit is seeking to encourage for the coming period. Current fellowships are IEEE, IET and RSA (**Duffy**); IMechE (**Farukh**); RAeS (**Goman**); British Institute of Non-Destructive Testing and the International Society for Engineering Asset Management (**Mba**).

4.2.4 Prizes

The awarding of prizes is an indicator of the highest-quality research or outstanding service. The following list provides a good indication of the breadth of this recognition, spanning early career academics and established researchers. Awards to our young researchers include:

- **Baserinia:** the top PhD graduate of the School of Science and Engineering, University of Leicester (2018); Winner of the Reg Davies Best Poster Contest Joint IFPRI Robert Pfeffer Symposium & UK Particle Technology Forum, University of Surrey, UK (June 2016)' Winner of the Best Poster Award Powder Flow: Fundamentals to Applications, University of Leeds (April 2015)
- **Diao:** Outstanding Reviewer in 2015 for *Water Research* journal
- **Hamilton:** best paper prize from IEEE Transactions on Power Electronics (2017).
- **Kandan**'s 'Upcycled plastic prosthetics' has been shortlisted for Times Higher Education Awards in the category of Research Project of the Year (2020): STEM.
- **Manjunatha:** Best PhD thesis, DMU, 2018
- **Maricar:** Young Engineer Award from ARMMS (Automated Radio Frequency & Microwave Measurement Society) in 2014
- **Salaoru:** Outstanding contribution in reviewing Elsevier's *Additive Manufacturing* (March 2018).

A number of staff have been recognised for exceptional service in editorial board activities, including:

- **Hamzaoui:** best AE award for *IEEE Transactions on Circuits and Systems for Video Technology* (2014); and a certificate of merit for outstanding editorial board service for *IEEE Transactions on Multimedia* (2018)

- **Mba:** best paper prize from the World Congress of Engineering Asset Management (WCEAM), Norway (2018).

4.2.5 Membership of research council or similar national and international committees

One of the stated aims for the Unit is to increase leadership in the engineering profession. This not only gives back to the profession but opens up members to new networks, mentoring and collaborations. There is a broad range of activity at all levels. Some of the ways this currently happens are:

- EPSRC College Membership: **Duffy** and **Sun**, plus Associate Membership for **Zahedi**.
- Professional body leadership: **Duffy** is president of the IEEE EMC Society and past chair of the IEEE EMC Standards Development and Education Committee; IEEE Technical Activities Board's finance committee member; past IEEE EMC Society Vice President for Conference Services; and past chair of the IET Electromagnetics Professional and Technical Network Executive Committee. He is a Director of the International Wire and Cable Symposium; and **Maricar** is the IEEE EMC UK & Ireland Chapter's Membership Secretary.
- One of our group leaders, **Paul**, is part of the International Roadmap for Devices and Systems (IRDS) Beyond CMOS team and has contributed to the Emerging Electronic Memory Devices section of the roadmap (2017, 2018, 2019, 2020).
- Members also contribute to academic staff recruitment and promotions activities, such as **Sun**, who was a member of the International Selection Committee for recruiting academic staff, Serra Hunter Programme, Polytechnic University of Catalonia, 2017/18, and an academic reviewer for staff promotion, King Saudi University, 2018/19.
- In addition, **Diao** was an International expert for the recruitment process of the EU DOCC project (MSCA COFUND Doctoral Programme DOCC: Dynamics of Complex Continua).

4.2.6 Invited keynotes, lectures, conference roles and similar

Institute funds can also be used for conference travel where the academic is making a substantial contribution to the conference, such as part of the organising committee or delivering an invited notable contribution (such as a keynote or plenary talk). Some examples of achievements and activities over the current period are:

- **Cosar:** session chair of VISIGRAPP 2017
- **Diao:** one of the three CCWI (International Computing & Control for the Water Industry Conference) committee members responsible for coordinating bids for the CCWI-only conferences in the UK and liaise with Water Distribution Systems Analysis (WDSA) for the joint CCWI/WDSA events held internationally
- **Duffy:** general chair of the 2020 IEEE International Symposium on EMC + SIPI (successfully navigating its passage from in-person to virtual with both an increase in attendance figures and an increase in revenue), co-general chair for the 2021 Symposium on EM + SIPI, standing international chair of the Global EMC Conference (GEMCCon) series of conferences
- **Hamzaoui:** Technical Programme Committee co-chair for IEEE 19th International Workshop on Multimedia Signal Processing (2017), executive general co-chair for IEEE UIC 2019, and workshops co-chair for IEEE ICME 2020 (July 2020)
- **Paul:** Organising Committee member for ICREPQ (International Conference on Renewable Energies and Power Quality)
- **Salaoru:** one of the founder members of ICPAM (Interactions, Complex Phenomena and Advanced Materials) of the International Society (2016) and a member of ICREPQ.
- **Sun:** member of the academic committee for the 1st International Conference on Corrosion Protection and Applications.

Members of the Unit have given a large number of plenary, keynote and invited talks. Some of the highlights are:

- **Duffy:** plenary talk at the International Conference on Ultrawideband and Ultrashort Impulse Signals (Odessa, 2018)
- **Hamzaoui:** plenary talk at the 9th International Conference on the Developments in eSystems Engineering (Liverpool, 2016)
- **Maricar** has given an invited talk at the International Conference on Advanced Engineering and Technology (2014).
- **Mba**: keynotes at 32nd International Congress of Condition Monitoring and Diagnostic Engineering Management (COMADEM 2019), Sept 2019, Huddersfield, UK; Prognostics and System Health Management (PHM) Conference, Chongqing, China, 2018; Diamond Jubilee Convention of IIIE and International Conference ICIEIND, September 2018, Bhubaneswar, India.
- **Paul:** gave invited talks on 'No bits without nano-bits in insulating matrix: use of nanomaterials in two terminal electronic memory devices', 11th International Conference on Nanosciences & Nanotechnologies (NN14), 8–11 July 2014, Thessaloniki; 'Creating electric dipole in nano-composite: applications in information storage and energy generation', 8th International Conference on Advanced Materials, 7–10 July 2015, Bucharest; 'Growth of silicon nano-structures at low temperature and their application in electronic and energy-related devices', Nanotechnology Congress & Expo 11–13 August 2015, Frankfurt; 'Creating Electrical Bistability Using Nano-bits: Application in 2-Terminal Memory Devices', Materials Research Society, Fall 2016 Meeting, Boston, USA; 'Emerging applications of silicon nano-structures', 12th International Conference on Physics of Advanced Materials (ICPAM-12)and 3rd Autumn School on Physics of Advanced Materials (PAMS-3), 22–28 September 2018, Heraklion
- **Salaoru:** invited talk at the Collaborative Conference on Advance Materials and EMN meeting on 3D printing (CCAM & 3D Printing), August 2019, St Julian's, Malta
- **Sun:** keynote at ThinFilm 2018 International Conference

Invited talks at conferences are complemented by talks to industry. These include:

- **Duffy:** a talk on computational electromagnetics validation to the Singapore Chapter of the IEEE EMC Society and a keynote on innovation through standards at the Artesyn (a China, Hong Kong and Philippines–based engineering company) 'EMC Month' of professional development events
- **Goman:** an invited talk at NASA Langley Research Center (LaRC, USA) in July 2017, and at China Aerodynamics Research and Development Center (CARDC, China) in July 2016
- **Paul:** a talk on 'Low temperature deposition of silicon nano-structures for energy storage' at IDTechEx Show, 11–12 April 2018, Berlin.

Some of our early career academics have been active in organising workshops and topical meetings. These activities help raise awareness of the work they are doing; it helps in their network building and provides valuable opportunities to grow and develop as future senior researchers. For example:

- **Kandan** organised International Workshop on ARM (Accessible Recycled Material) Prosthetics at DMU (2019). He was selected to attend the Horizon Scanning workshop for 'research and innovation to transform the health of society by 2048', organised by the UK Academy of Medical Sciences (2018).
- **Paluszczyszyn** organised and chaired 'The use of game-based technologies in autonomous vehicles research' workshop held in May 2017 at DMU.

4.2.7 Refereeing publications and research proposals

All academics are expected to referee papers and competitive research proposals. The following list provides an overview of the activities spread between early career and senior researchers. It also shows the broad range of journals and funders.

Proposal reviewing activities include:

- a reviewer for UK NERC (Natural Environment Research Council) grant applications (**Diao**)
- EPSRC (**Duffy**, **Hamzaoui**, **Mba**, **Paul**)
- the Dutch Research Council (NWO) (**Duffy**, **Mba**)
- Czech Science Foundation (**Mba**)
- Qatar National Research Fund (QNRF) (**Mba**)
- French National Research Agency (**Paul**)
- Singapore Public Utilities Board (**Paluszczyszyn**)
- Polish National Science Centre (**Paluszczyszyn**).

Journal reviewing includes:

- *Engineering Optimization*, *Materials and Design*, *International Journal of Powertrains* (**Abdi**)
- *IEEE Trans. Circuits and Systems for Video Technology*, *Image and Vision Computing*, *Robotics and Autonomous Systems*, *Computer Vision and Image Understanding*, *Pattern Recognition Letters*, *Journal of Visual Communication and Image Representation*, *Sensors* (**Cosar**)
- *Scientific Reports*, *IEEE Trans. on Antennas and Propagation*, *Solid-State Electronics* (**Maricar**)
- *Water Research*, *Reliability Engineering & System Safety*, *Water Resources Research*, *European Journal of Operational Research*, *Physics A: Statistical Mechanics and its Application* (**Diao**)
- *IEEE Trans. EMC*, *IEEE Trans. Antennas and Propagation*, *IEEE Trans. Microwave Theory and Techniques* (**Duffy**)
- *IEEE Trans. Vehicular Communications*, *IEEE Trans. Wireless Communications*, *IEEE Trans. Intelligent Transportation Systems, IEEE Access*, *IEEE Communications Magazine*, *IEEE Trans. EMC* (**Ghazal**)
- *IEEE Trans. Multimedia*, *IEEE Trans. Circuits and Systems for Video Technology*, *IEEE Trans. Image Processing*, *IEEE Trans. Communications*, *IEEE Access*, *IEEE Trans. Human Machine Systems*, *Pattern Recognition* (**Hamzaoui**)
- Reviewer Board for *Crystals*, *Coatings*, *Materials*, *Applied Science* (**Manjunatha**)
- *Journal of Materials Engineering and Performance*, *Additive Manufacturing* (**Moroz**)
- *International Journal of Impact Engineering*, *ASME Journal of Applied Mechanics* (**Kandan**)
- *Nature Communication* (**Paul**)
- *Polymers*, *Machines*, *Sensors*, *Nanomaterials*, *Micromachines*, *Materials* (**Salaoru**)
- *Surface Technology*, *Journal of Biomaterials* (**Sun**)
- *IEEE Trans. Neural Networks and Learning Systems*, *IEEE Trans. Vehicular Technology*, *Journal of Hydroinformatics*, *Applied Sciences* (**Paluszczyszyn**).
- *Mechanical Systems and Signal Processing, Structural Health Monitoring, ASME Applied Mechanics Reviews, Chinese Journal of Aeronautics, IEEE Transactions on Industrial Electronics* (**Mba).**

4.3 INTERACTIONS WITH KEY RESEARCH USERS, BENEFICIARIES, AUDIENCE

Interactions and collaborations are important elements of creating impact from our work and one of our four strategic aims. Some examples to show the breadth of these interactions, and particularly some of the ‘firsts’ involved in work of the Unit include the following:

- IoES is currently the only recommended tester for and by the UK police's 'secure by design' approval for electromagnetically shielded enclosures (**Duffy**).
- A radio channel simulator developed by **Ghazal** is used by academic and industrial parties involved in 5G research as part of China's National 973 research project and the international FuTURE mobile communication forum, which consists of 26 mobile operators, mobile equipment manufacturers, research institutes and universities.
- An out-of-the-envelope flight simulation model, developed during the period 2014–2018 by **Goman** and **Abramov** for a class-specific transport aeroplane was used in the flight simulator Airfox UPRT. The flight simulator was designed and built at AMST-Systemtechnik GmbH, Austria, for Upset Prevention and Recovery Training (UPRT) and is the only commercially available UPRT flight simulator.
- **Kandan** was an invited member of the Frontiers of Engineering Development Symposium organised by the Royal Academy of Engineering, and an invited member the Global Public Health Networking Workshop organised by the Medical Research Council / Arts Humanities Research Council (2017).
- The Unit's Immersive Vehicle Virtual Reality Testbed simulator, developed by **Paluszczyszyn** was used by HORIBA MIRA Ltd to evaluate the operation of their cooperative platooning system for autonomous vehicles.
- **Paul** gave a public lecture entitled 'In search of immortal electronic memory – possible or not' organised by London Materials Society (2016).
- **Paluszczyszyn** has given invited talks on innovation in haptics at Royal Academy of Engineering HQ in London (May 2017), Immersive Vehicle VR Testbed for Autonomous Vehicles at IET/ IMechE Network (March 2018), IET Birmingham Network (Sept 2018) and IET Bedfordshire & Hertfordshire Network (Oct 2018).