

Institution: Ulster University

Unit of Assessment: Engineering - UoA 12

1. Unit context and structure, research and impact strategy

1.1 Research Structure

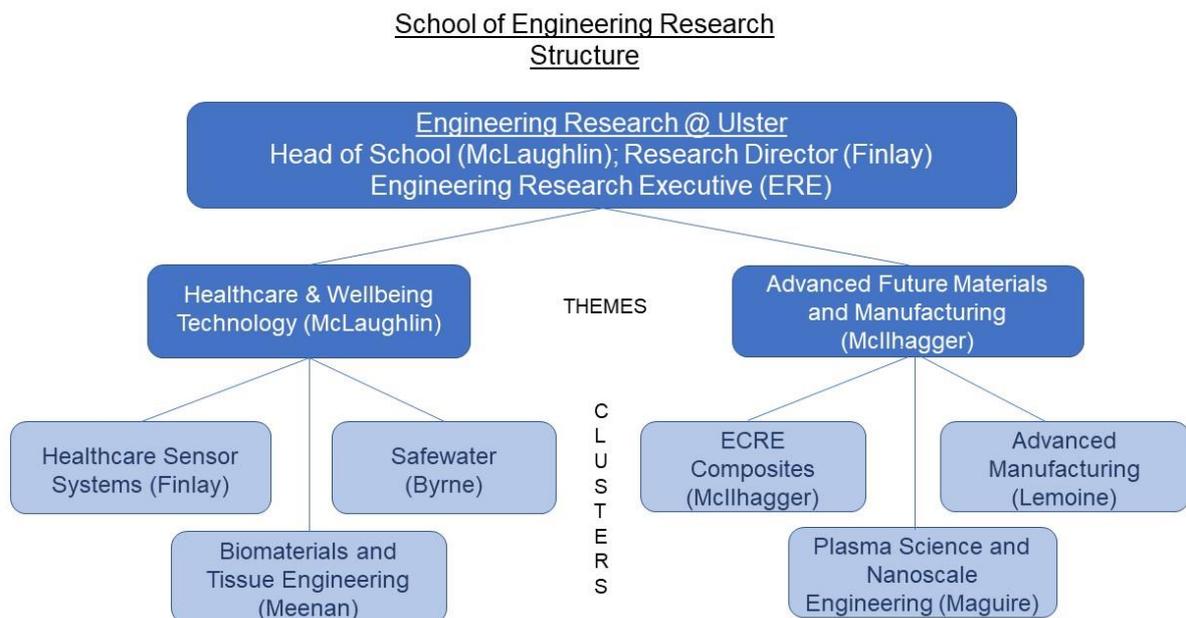
Engineering Research at Ulster, established 30 years ago within the School of Engineering (SoE), is based at the Jordanstown Campus with recent adjunct activity at the Magee Campus. Increasing our **SRR cohort from 19 to 42**, with notable **strong ECR recruitment (17) since REF2014**, the unit now brings together a **150 strong multi-disciplinary team** of researchers led by **9 renowned Professors** from a range of engineering and scientific disciplines. Since REF2014 our funding is up 83% to over £37m and we have continued our strong performance across all indicators; impact, outputs & research environment, **to create a highly sustainable Engineering research base at Ulster.**

Our two main research buildings, the **Nanotechnology and Integrated Bioengineering Centre-NIBEC** and the **Northern Ireland Advanced Composites and Engineering Centre-NIACE**, underpin our materials discovery to product development. The School's major research is undertaken under **two major themes**, namely:

- **Health and Wellbeing Technology**
- **Advanced Future Materials and Manufacturing (AFM2)**

Day-to-day operation of Engineering Research is managed by a **leadership team** consisting of the **Engineering Research Director (RD - Finlay)** and the **Head of School (HoS - McLaughlin)**. This is supported by an **Engineering Research Executive (ERE – Byrne, Finlay (RD), Harkin-Jones, McLaughlin (HoS), McIlhagger, Meenan, Maguire)** who provide input on the formulation and execution of the Engineering Research Strategy. In addition, the Associate HoS of Engineering (currently Dr Margaret Morgan) holds ex-officio membership to ensure full alignment of research within the broader academic function (staff teaching/admin responsibilities, etc.). The Unit is allocated an **annual research strategy budget** by the University (~£80k).

The overall unit structure, themes and clusters are depicted in Figure 1.



	Health & Wellbeing Themes - Lead - McLaughlin	SRR Academic Staff Members
CLUSTERS	Healthcare Sensor Systems	Finlay, Bhalla, Davis, Escalona, Fishlock, McLaughlin, Bogaraju, Cheema, Soin
	Safewater	Byrne, Dunlop, Fernandez, Nolan, Rahimian, Opiyo, Biglarbeigi
	Biomaterials and Tissue Engineering	Meenan, Acheson, Boyd, Burke, Mancuso, Chang, McConville
	Advanced Future Materials and Manufacturing - Themes - McIlhagger	SRR Academic Staff Members
CLUSTERS	ECRE Composites	Harkin-Jones, McIlhagger, Archer, Ralph, Quinn, McGarrigle
	Advanced Manufacturing	Dixon, McFadden, Sun, Golbang, Ng, Brown, Lemoine
	Plasma Science and Nanoscale Engineering	Maguire, Mariotti, Papkonstantinou, Chakrabarti, Petrovic, Farokh-Payam

Figure 1. Unit structure illustrating themes, clusters and academic members.

1.1.1 Health and Wellbeing Technology Theme

NIBEC was established in 1991 and is a purpose-built multi-disciplinary research centre that combines skills in engineering, physical and biological sciences, IT and medicine. Within the REF reporting period, NIBEC has secured external grant income of approximately £19m from prestigious funders and supports over 100 researchers. NIBEC research has seen very successful commercialisation with spin-out companies progressing to substantial commercial success, the most recent examples being the acquisition of Intelesens by Ultralinq-USA in 2017 and acquisition of Heartsine by global leader Stryker in 2015 thus creating over 200 high value jobs in NI. Key industry led research centres that have been developed during the period include: €8.4m Eastern Corridor Medical Engineering Centre (ECME); £9.3m Connected Health Innovation Centre-(CHIC) and £7.3m Biodevices Proto-Typing facility, all of which underpin our strong links with industry, clinicians and international collaborators.

Research within NIBEC is carried out in 3 core clusters with the academic membership of each provided in Figure 1. The activities of these groups are further detailed below:

Healthcare Sensor Systems

This cluster has 30 years of internationally recognised experience in Healthcare Sensor and Diagnostic Systems. It carries out fundamental nanoscience leading to FDA approved commercial Sensor Systems via highly successful spin-outs as well as competing globally in Grand Challenges (finishing joint 3rd out of 300 in the Tri-Corder Xprize Global Competition-McLaughlin-2017). The cluster's applied focus is on sensor driven data analytics (Artificial Intelligence & Machine Learning); cardiac mapping; clinically relevant wearables for IOT; wireless sensing/networks; point-of-care diagnostic systems; cardiac monitoring; cardiac defibrillation /pacing; cardiac signal analysis and algorithm development.

Examples of strategic funding include - Radox Technologies-Centre of Excellence (2017-ongoing) £1.04m; (EPSRC VIPIRS – Virus Identification via Portable InfraRed Spectroscopy

£411k EP/V026488/1 (2020-ongoing); (EPSRC EP/T022175/1 Kelvin-2) £495k; (EPSRC EP/T04437/1 Multi-User XRD 2020-ongoing) £100k; (EPSRC EP/TO15470/1 & (EP/PO32427 Water Diagnostics 2017-21) £837k & £4.71m); (Heart UK RG2678/19/21) £248k.

Safewater Research

This cluster is internationally recognised for research **focusing on water treatment and analysis**, with broader reach into energy and environmental research, including solar fuels and energy recovery from wastewater. Specifically, the group is internationally-leading in photocatalysis research including novel nano-photocatalytic materials and their use in environmental remediation, disinfection of water and surfaces and solar energy harvesting. Also in solar reactor technologies for water disinfection (no 1 in Scopus for papers and citations) which have been successfully demonstrated in communities and schools in sub-Saharan Africa. Byrne is PI on the **GCRF SAFEWATER GROW project (EPSRC (EP/PO32427) 2017-21 £4.71m)** with a transdisciplinary team of more than 50 researchers, developing technologies for safe drinking water in Brazil, Colombia and Mexico. Fernandez is SAFEWATER WP lead on household water treatment technologies. Both are CIs on the GCRF GRTA SAFEWATER Translate project **(EPSRC (EP/TO15470/1) 2019-21 £837k)** accelerating the exploitation of devices for microbiological water quality analysis. Dunlop's expertise in photocatalytic disinfection has led to his appointment as chair of the NI-AMR network. The group has a large international network and other active projects include **H2020 PANIWATER** (water solutions for India-£330k); **H2020 MSCA REWATERGY** (energy recovery and emerging contaminants-£247k); Byrne's nanomaterials research has translated to significant impact in Industry with AVX (**£3m Invest-NI**).

Biomaterials and Tissue Engineering Group - BTEG

This cluster undertakes internationally-leading research in the development of functional biomaterials for applications in medical-implant technologies, diagnostic substrates and tissue engineering applications. Key projects undertaken within the reporting period include: 3D printing of novel polymer/ceramic bio-composites, point-of-care biosensors and airway management devices (**NWCAM, Interreg VA**); convergence of tissue engineering and lab-on-a-chip technologies for advanced *in vitro* cardiac tissue models and dynamic blood platelet assays (**ECME, Interreg VA**); directing and controlling bioprocesses at the material-tissue interface using surface engineering strategies that create chemical and/or topographical effects at the sub-micron to nanoscale ($\leq 100\text{nm}$) (**BioDevices Lab, Invest NI £2.04m**); innovative atmospheric pressure plasma processing technologies to enhance specificity of antigen-antibody multi-array diagnostic systems (**Radox Technologies BME Centre of Excellence (WP2), Invest NI**); substituted calcium phosphate coatings to control the bioresorption of magnesium alloy orthopaedic fracture fixation devices (**NSF-DfE-SFI US-Ireland Centre-to-Centre, £300k**). The group has extensive expertise in surface analysis techniques (XPS, ToF-SIMS, XRD AFM, etc.) applied to advanced biomaterials research with significant investment having been made in relevant infrastructure and dedicated in-house cell culture facilities over the last 5 years (**EPSRC Core-Capital Award, £100k; FE-SEM DfE-HERC £300k**) & **BioDevices Lab-WPs**.

1.1.2 Advanced Future Materials and Manufacturing (AFM2)

The AFM2 theme encompasses advanced composites and polymers, plasmas and nanoscale materials, additive nanomaterials, process development and control, process simulation, material modelling, sensors and data-analytics, structural health monitoring, sustainable manufacturing and digital manufacturing. AFM2 has secured funding of **approximately £20m in the reporting period including the North-West Centre of Advanced Manufacturing-NWCAM (McIlhagger INTERREG 2017-2022 €8.7m)**.

The **activities of AFM2** are focused **into three distinct clusters**, described as follows:

Engineering Composites Research Centre - ECRE

ECRE has been at the forefront of engineering excellence for **textile weaving and composites since 1983**. ECRE is widely recognised as a national and international leader in the design and manufacture of advanced textile preforms, with particular expertise in 3D woven fabrics for structural composites (**EPSRC - EP/N034783/1, EP/L02697X/1 MCMITP**). This cluster has attracted significant funding as a Centre of Excellence in the area, from programmes involving

simulation and modelling (**Technology Strategy Board, Innovate UK, RAEng Industrial Fellowship, RAEng Professorial Appointment with Bombardier**), and industrially led programmes focusing on the design and manufacture of specialist preforms (**EU-Marie-Curie £504k MARINCOMP-612531 (2014-2018) and EU-ITN £193k ICONIC-721256 (2016-2020)**). Associated work in the modelling and integration of sensing technologies, as well as the development of hybrid structures (metallic and thermoplastic yarns), have developed from the core textile capability in collaboration with other international hubs.

Advanced Manufacturing (AM)

Ulster AM is built on long-term engagement (pre-1990) with industries such as Bombardier Aerospace (Spirit-AeroSystems), Denroy, Thales, Collins and LPE, and has resulted in new patented technologies, significant cost/performance improvements in manufacturing, delivery of on-site industrial training, new material/process integration, as well as the continued success of spin-out companies (e.g. **Axis Composites Ltd.**). In the reporting period, key projects delivered through NIACE/NI Advanced Engineering Competence Centre (NIAECC) have directly assisted in the reshoring of commercial contracts into NI from overseas (**Artemis & Eirtech- 150 new skilled employees in the composites sector**). This in turn has led to a successful **£33m UKRI Strength in Places (SIP) Industry-led Collaborative Award (Ulster £3m in autonomous vessel design/materials)**. Ulster research has been, and continues to be, instrumental in assisting Bombardier in the development of new manufacturing processes, through patented dry-fibre use and preforming technologies. This has underpinned their commercial entry into the narrow-body-aircraft market with the C-Series/Airbus 220. The wing programme employs 1000 people in Belfast at full production, with a further 2,000 employed in the supply chain (**net orders of 630 aircraft Jan 2021**).

Plasma Science and Nanoscale Engineering-PSNE

PSNE has world-class expertise in the science and applications related to non-equilibrium low temperature plasma devices operating at atmospheric pressure. Their scientific themes focus on (i) plasma-liquid interactions, radical-driven chemistries and synthesis of high-performance nanomaterials and (ii) emergent nanomaterials via gas phase cluster and nanoparticle synthesis. In particular, they have developed a **unique Droplet in Plasma (DiP) system (EPSRC award n.EP/K006088/1) for rapid and on-demand delivery of reactive plasma activated liquids**, radicals and pristine nanomaterials which is currently being investigated for exposing and treating tumour cells in vivo and antibiotic resistant microbial infections of surface wounds. Droplet-in-plasma synthesis of polymer nanocomposites integrated into microfluidic nanovalves is being investigated for remote ocean chemical analysis (**EPSRC EP/T016000/1 and SFI Ireland**). Integrating plasma and NIR spectroscopies and machine learning for detecting airborne viruses (EPSRC Award n. EP/V026488/1), trace gases and VOCs has recently commenced.

PSNE have developed new classes of **inorganic nanomaterials for energy** (Leverhulme Trust award n.IN-2012-136) and environmental applications (**EPSRC EP/M024938/1**) including third-generation inorganic solar cells (**EPSRC EP/K022237/1**), new solar thermal technologies and low-cost high-efficiency solar desalination. Current projects include **Advanced Nanotube Application and Manufacturing (ANAM) Initiative (EPSRC EP/M015211/1)**, Emergent Nanomaterials (**EPSRC Critical Mass Award EP/R023638/1**) and Center-to-Center (C2C) International Collaboration on **Advanced Photovoltaics: Electrode Manufacturing and Indoor Power Applications, (NSF (USA)/SFI (Ireland)/DFE (N. Ireland)**. Scaling plasma facilities to prototype manufacture is under development via ANAM (**EPSRC EP/M015211/1**), EU-FP7 (**award n.606889**), InvestNI (awards **PoC-325 and PoC-608**).

1.2 Strategic Vision

Our vision is to continue to exploit our unique ability to **merge the disciplines of health and wellbeing technology and advanced future materials & manufacturing**. In turn, creating successful research with impact, in highly important **global challenge areas** and promoting a **healthy and sustainable future for all citizens**.

1.2.1 Future Strategy

To help realise this Vision we have formulated an on-going mission which aims to:

- Continue to deliver **world-leading research outputs** that are aligned with the evolution of our core research themes.
- Further strengthen the **commercial exploitation** of our engineering and science-based research through knowledge transfer (e.g. KTP's, spin-outs and spin-ins) in relevant areas of the **clinical-led application domain** and **manufacturing sectors**.
- Maintain and build on our significant portfolio of **interdisciplinary activity** and enhance regional, national and **international collaborations**.
- To deliver on **global grand challenges** associated with **healthy ageing, sustainable design, pure water and efficient energy sources via new materials & processing**.
- **Enhance our capacity and capability** to conduct **unique and specialist research** via new major multimillion pounds **City Deal projects across Engineering**.
- **Attract diverse sources of funding** to allow us to sustain our research activity and promote its impact across a range of TRLs.

Going forward these aspirations are specifically evidenced by key roles in leading Innovation Projects as part of the **Belfast Region City Deals (BRCD)** and the **Derry City and Strabane City Deal (DCSCD)**. Specifically, members of the unit are central to the BRCD which will see the establishment of the **Centre for Digital Healthcare Technologies - CDHT** (£42.9m, McLaughlin PI) and the **Advanced Manufacturing Innovation Centre - AMIC led by QUB in partnership with UU** (£87m, McIlhagger Ulster PI). The DCSCD will see the establishment of a **Centre for Industrial Digitalisation, Robotics and Automation (CIDRA)** led by Ulster (total value £25.5m, Quinn, Co-PI). These **once-in-a-lifetime capital** investment projects are underpinned by significant ongoing engineering research activities at Ulster. A recent example of this is the £33m UKRI-SIP **Artemis Technologies project** which is a Belfast Maritime Consortium with Ulster (McIlhagger Co-PI) as a core partner to **develop zero-emissions and autonomous-ferries**.

In order to further our aims beyond the REF2021 timeline, we have set out the following measurable **objectives/targets that we intend to meet over the next five years**:

- A **20% increase in SRR** staff
- A **33% increase in the number of PhD** researchers enrolled in the Unit
- To increase to **80% the proportion of research outputs** appearing in the **top 10%** of academic journals/forums (based on relevant metrics e.g. SciVal)
- To maintain an **international collaborative presence** in at least 50% of our research outputs
- To **grow** our entire **funding base by 50%** with a particular focus on funding from **prestigious (QR)** sources (RCUK)

1.2.2 Reflection on Delivery of the Unit's plan as laid out in REF2014

The **strategic aims stated in REF2014** have shaped and informed our Research Environment over the last 7 years. In this period, **we have met and exceeded all of these** metrics as summarised in Table 1:

	2014	2021	% Increase
UoA Staff Numbers	19.00	39.6	108
Overall funding attracted	£20,215,116	£37,048,422	83
Funding Spend	£11,516,221	£30,546,327	165
UKRC Funding spend	£2,487,209	£8,289,201	233
EU funding Spend	£1,305,307	£5,257,697	303

Table 1. Indication of quantifiable achievements between REF2014 and REF2021

Aims set out were as follows:

Aim: To increase research staff and student numbers:

Research active **staff (now SRR)** numbers in the unit have increased from **19 to 42 (39.60 fte)** in this submission representing a **108% increase (fte) in the period**. **Contract Research Staff** numbers have increased from **17 to 41 (a 140% increase)** within the reporting period **69 PhD Researchers** enrolled reflecting a **33% increase since the 2014** census date.

Aim: To improve publication rankings and citations:

Based on Scopus.com metrics for publication quality and reach, there has been an increase in **international collaboration** within our research outputs from **44.1% in 2014 to 56.1% in the current set of outputs**. A higher percentage of these outputs are also in the top 10% of published works worldwide in relevant subject areas (30.9% for 2014 outputs and 32.3% for current outputs). Journal publication, conference and patent outputs have all improved in quality with average journal impact factor along with **increase in quantity (up 30%)**. For outputs published in the Top 10% of Journals by **CiteScore Percentile** we had **41.2% in 2014 v 61.8% for the current outputs**.

Aim: To grow funding and further international links:

Compared to the 2014 submission, **our overall awards are up by 83% in the current period with the associated external research funding spend up by 165%**. Of this, **UKRC funding spend is up by 233%**.

In regard to **funding related to international collaborations** we have seen a **303% increase in EU funding spend** (see table 1). The outputs submitted for this exercise also show a **12% increase in international collaboration**. We have launched **9 KTPs (£1.06m)** across the unit during the period, **12 Cross Border Fusion-Project (NI-ROI type KTPs)** and **15 Proof of Concept/Principle Projects-£20k-100k**.

Aim: To improve building resource infrastructure

Detailed in section 3. Highlights include final development of new **£365m Greater Belfast Campus**, **£6m investment in equipment since 2014** and the ongoing **City Deal developments**.

Aim: To develop additional industry and clinical MoUs

Over the period we have developed strategic **MOUs** with companies such as Dell-EMC and Belfast HSC Trust. We have consolidated our fundamental research funding via collaborative projects involving industry, the clinical sector and other stakeholders. In particular, our vision to be an **internationally leading engineering-led innovation hub** is underpinned by strong and vibrant material science and engineering device fabrication capabilities. This strategic approach has delivered significant benefits in the reporting period with our **CHIC, ECRE and Biodevices Lab** activities **engaging with over 100 SME and multinational companies** (section 4.3).

1.3 Research with Impact

Engineering research at Ulster has an **exemplary track record in research impact** and is now part of a focused innovation eco-system to commercialise innovative products through knowledge transfer, technology-licensing, patents and more recently, through spin-out ventures. There is a strong, successful track record of these activities with our research having led to the development and **market launch of numerous internationally successful and award-winning medical devices** (e.g. the Stryker mobile portable defibrillator and the Intelesens wireless vital signs patch), **electronic components** (Seagate HDD read-write head coatings and new improved AVX ceramic capacitors) and **composites technologies** (C-Series Bombardier/Airbus 220 aircraft).

1.3.1 Approach to achieving impact

We have established two state-of-the-art industry-led innovation centres; **CHIC** and **NIACE** which allow our research to be translated into impactful innovation. Similarly, the **Biodevices Laboratory** established in 2016 enabled efficient and robust **one-stop rapid-prototyping of advanced products from initial design to final device for 80 companies to date**. These

platforms also allow us to create impact in other areas e.g. clinical and regulatory practice. In total, this approach has resulted in **53 ongoing patent applications** plus numerous invention disclosures generated since REF2014. The **infrastructure within these research and innovation centres is also made available to partners through collaborative projects** which further enhances our ability to translate research into innovative processes, platform technologies and new product prototypes that can be taken forward to commercialisation. An **International Engineering Advisory Panel** assists with our industry engagement which helps to advance STEM initiatives, identify and meet skills requirements as well as delivering workshops, knowledge-based seminars and enhanced access to Ulster's breadth of academic expertise.

Since 2015 our unit has operated a "**NIBEC Hatchery**" **spin-out** company concept. This initiative provides a strongly supportive environment for the commercialisation of research via **spin-out/spin-ins**. The approach has empowered and supported innovative academics to more rapidly develop and test the market for their ideas within an appropriate entrepreneurial pathway. This clear, simple approach has supported academics to develop their skills as well as address barriers to success. Currently, **start-ups such as 2DTech, S2ACK, SiSaF, JFI and Pulse-AI** utilise the eco-system with **new developments** in water diagnostics, smart bandages, lateral-flow devices, carbon in the ocean monitoring, wrist pulse-monitoring, wireless heart-pump development, composite health-monitoring **currently being developing to the commercialisation stages**.

1.3.2 Research with impact examples

In the current reporting period, our ability to produce research with impact is evidenced by a portfolio of **strong impact case studies (ICS)** in health technology (2), aerospace composites (1), and nanotechnology (1). The significance and reach of the evidence-based impact include: strong economic benefit, significant improvements in patient-health and quality-of-life, impact on standards and regulatory processes. Our **strategic focus on encouraging spin-out and start-up activity** has facilitated eight commercial entities during the reporting period as outlined in Table 2.

Company	Classification	Comment
Pulse-AI	Spin In	Kennedy (PhD student SoE 2013-2018)-Founder/CEO Finlay and McLaughlin – Scientific Advisors
Axial 3D	Graduate start-up	Crawford (undergraduate student 2008-2011) - Chief Strategy Officer & Founder. Boyd -Advisor
Surf-Spec	Spin Out	Meenan – Founder/Director
Metal Forming Innovations Ltd	Spin Out	Leacock (Reader SoE -2016) – Founder/CEO Finlay - Director
Axis-Composites	Spin Out	McIlhagger - Research and Development Director Archer Technical Director
SISAF	Spin Out	McLaughlin – Founder/Director -2018
Heartsine	Spin Out	Anderson (Professor - SoE -2012) – Founder/CTO; McLaughlin Early-stage consultant. Stryker buy-out and successful University exit-2015
Intelesens	Spin Out	McLaughlin – Founder/CTO Ultraling buy-out and successful University exit-2016

Table 2. Start-up/Spin-out activity during period

1.4 Approach to Interdisciplinary Research

Significant emphasis has been placed on **increasing the level of multi- and inter-disciplinary work conducted by the unit** during the reporting period, based on **collaborations between groups** and other units **throughout the university** and **externally**. **Cross-disciplinary sandpits** and **workshops** plus internal **PhD-funding and strategic project-funding** are now core-initiatives. Examples of such collaborations within the unit include: 1. ECRE and CHIC developing innovative **AI inspired sensor systems for monitoring the structural integrity of engineering composite materials** in aerospace applications and 2. The Advanced Manufacturing Cluster and the Biomaterials and Tissue Engineering Groups developing **additive manufacturing materials**

and printing techniques for next generation medical implants. Beyond the unit but within the Faculty, significant interdisciplinary collaboration is evident across **many large-scale funded projects including:** ECME and CHIC working across their respective research areas (Engineering, Computing and Life & Health Sciences/Medicine) to enhance external involvement from the medical device industry and clinical partners. The **GCRF-Safewater project** involves core contributions from Biomedical Sciences-Microbiology, Psychology-Behaviour analysis, Law and Management, Leadership and Marketing along with significant external involvement from **international NGOs** in Mexico, Brazil and Columbia.

1.5 Progress towards promoting an Open Research Environment (see Institutional Statement, section 2).

The unit contributes fully to the institutional drive towards an 'Open Research Environment'. A key enabler has been investment in the Elsevier '**PURE**' software platform to support open research activities ranging from open access publications to research data management. At unit level, a dedicated strategy has been established to ensure researchers are fully compliant with **open access policies**. This strategy includes provision of training and drop-in support sessions. Researchers are actively encouraged to publish in **open access journals and make available strategic compliant datasets/open research-data where IP is fully considered**. Where possible, budget allocations are requested for open-access fees in research grant proposals and when not, staff may submit requests to the ERE for funding from research strategy budget. Ulster is a **signatory of DORA** and supports the principles the **Leiden Manifesto** and **Metric Tide**.

1.6 Supporting a culture of research integrity

Engineering research at Ulster **supports a culture of research integrity** aimed at ensuring that research is conducted according to appropriate ethical, legal, professional frameworks. In order to achieve this goal, the unit adheres to the relevant procedures that operate at an institutional level. Specifically, the unit follows the procedures set out in the **University's Code of Practice for Professional Integrity in the Conduct of Research**. Core to this is the mandatory training of staff, during probation, and students on **research integrity - 100% of FT staff have completed this online mandatory training**.

2. People

A highly notable achievement is the **School's Silver Athena-Swan Award (2019)** based on a strong **increase in female academics**, research staff & students, plus the international **diversity of our staff now from 19 countries**. The strategy and policies below apply widely across the school covering academics, research staff, technicians and support staff.

2.1 Staffing strategy and staff development:

Engineering research has seen a **more than 100% growth in academic staff numbers** submitted in REF2021 (SRR status) compared to REF2014 (**up from 19 to 42**). This growth has been realised mainly through the University **targeting investment** for the **appointment of new staff**. We aim to **attract the highest-calibre academic staff globally**. The **staffing strategy** underpinning the unit seeks to grow Ulster's engineering base by attracting and nurturing those who are passionate about contributing to the **Global Grand Challenges for Engineering** that have been prioritised by Ulster.

2.1.1 Recruitment

In addition to our normal appointments, we have undertaken **strategic investment** in priority areas including:

- **Bombardier-Royal Academy of Engineering Chair in Composites Engineering**

In conjunction with the **Royal Academy of Engineering (RAE)** and **Bombardier Aerospace**, the world's third-largest civil aircraft manufacturer (now Spirit AeroSystems), we invested in a permanent **Professorship in Composites Engineering (Harkin-Jones)**. The associated work programme has developed new methods to process advanced thermoplastic polymers and carbon composites materials with consistent, reproducible properties. The collaboration with Bombardier

and other companies has developed materials and processing strategies that enable the manufacture of high performance, multifunctional, thermoplastic composite parts.

- **Health Technology Hub**

Recognising the need to accelerate the development of our Healthcare Technologies research, four new permanent academic positions were created in 2018 as part of a Strategic Investment initiative. These positions were created to support the establishment of a **Digital Health Technologies Hub** at NIBEC and eventually **City-Deal CDHT**. The **four posts (1 professor, 3 lecturers)** are focused on healthcare technology within underpinning engineering areas that include: Embedded-Systems, Software Development, Imaging and Mechatronics.

- **Advanced Manufacturing recruitment drive**

In supporting advanced manufacturing nationally and internationally, four new academic posts were created in 2019. These **four posts (1 professor and 3 lecturers)** are focused on areas that emerged from an internal strategic review of forthcoming opportunities, including City Deals. Appointments to these posts have commenced addressing research challenges in the areas such as Multi-Physics Simulation Methods, Digital Manufacturing/Materials Processing, Industry 4.0, and Intelligent AI based Manufacturing Systems.

- **Encouraging the local talent pool**

The strategic initiatives outlined above are all designed to attract the highest calibre scientists. A number of initiatives have been set-up to ensure that an academic/research career is seen as a tangible option across all educational and training levels at Ulster from undergraduate student right through to post-doctoral research staff. In the first instance, undergraduate students in their second year are encouraged to enrol for a **“Pathway to PhD” scheme**. This allows them to **shadow a currently enrolled PhD student** over a number of weeks to get an insight into what PhD study entails and encourage students who have an aptitude for a research career.

We have also established a **“Graduate Engineer” program** where we offer short fixed-term research contracts to our final-year students who wish to gain work-experience in a research environment upon completion of their studies. In a similar way, we have an **“Associate Lecturer” scheme**, which is designed to appeal to those who are approaching the latter stages of postgraduate research studies. These are **University funded fixed-term positions** (ca. 6 months) designed to provide researchers with an insight into the full portfolio of academic activity.

In the current REF period 9 **Ulster Engineering Contract Research Staff/PhD Researchers** (Golbang, Acheson, Fishlock, Chakrabarti, Ralph, McGarrigle, McConville, Soin and Biglarbeigi) have gained Academic positions.

2.1.2 Support for new staff and those who are early in their academic career

All researchers appointed to the Engineering unit receive **formal and informal induction and training**. An induction checklist is provided by our People & Culture (HR) Department and staff are also allocated a **‘buddy’** from within the unit. Having made contact on day 1, the buddy provides informal support for up to six-months, but in reality, these relationships often extend far beyond this initial interaction. Line-managers within the unit identify individual training needs and make arrangements to address these either through **informal job-shadowing, mentoring or one-one instruction**, and/or attendance at formal training courses, as necessary. All new staff are encouraged to explore the University’s online induction site which is sign-posted with links to relevant policy and practice.

The unit prides itself in having a long track-record of nurturing academic staff in the early stages of their academic career. All those who take-up a permanent appointment as new academic staff are assigned **Early-Career Academic (ECA)** status which corresponds with a standard probationary period of 3 years. **Since 2014, within the Engineering unit a total of 18 new staff have been given ECA status**. During this time the ECAs are assigned a mentor whose role is to provide support on all academic activities ranging from teaching administration through to research proposal development.

Upon appointment, ECAs are also **appointed to existing research groups/clusters**. Whilst this provides an opportunity to avail of the collegiately that a group/cluster structure brings, ECAs are encouraged to **not let this inhibit their ambitions** and to grow as leaders in their own area. Indeed, the latter is strongly encouraged and supported. Staff with **ECA status are given preference in the allocation of annual PhD studentships**. Given the growth in Engineering ECA staff, all centrally funded PhD studentships in the 2019/20 year were exclusively awarded to projects submitted by these staff. This led to **9 members of ECA staff commencing PhD Researcher supervision** (as lead supervisor) supported by more senior academic staff on the supervisory team. This has given **new members of academic staff** the opportunity to gain experience in PhD supervision while providing support for their on-going research. The scheme was repeated in 2020/2021, with all studentships allocated to projects led by an ECA and this is being repeated in 2021/2022. ECA staff are also provided with prioritised access to the **Unit's Research Strategy Budget**.

2.1.3 Staff development, training and appraisal

Extensive staff development and training opportunities are in place at both unit level and from the broader University base. These range from mandatory **training on broader workplace conduct** to a diet of research **domain specific training**. All staff undertake **Equality and Diversity, Disability Awareness, Research Integrity and Unconscious Bias & Recruitment Training**. At a Unit level **Continual Professional Development** is supported through training activity that includes unit specific Health & Safety training, research grant development training and REF related training. **Specialised research topic training** is also offered on topics ranging from AI and statistics to new Industry 4.0 developments. A specific necessity in the unit is the provision of **specialist training** on the large **state-of-the-art materials characterisation facilities** that are available (XPS, ToFSIMS, TEM, SEM, AFM, etc).

At University level, a range of initiatives relating to research training have been put in place. These include: **RIGOUR (Grants) and SOARING (Outputs) (see Institutional Statement, section 3)**. Additionally, the **Impact Development Series** and the **Aurora programme** (a leadership course specifically for women in HE), are available for both academic and research staff. **Research Communication Training** is also provided to develop the skills of researchers in communicating the purpose, meaning and impact of their research. The **majority of the unit staff** have participated in these programmes.

2.1.4 Staff appraisal, progression and recognition of achievement

Annual appraisals are conducted with all staff as a trilateral process with the HOS and RD. This process is facilitated differently for staff at different levels. ECA staff annual reviews take place as part of the **probationary process** which is designed to review ECA performance against agreed targets that have been set during their initial appointment. For staff who have progressed beyond probation (other than Professors) this process runs as a **Developmental Appraisal Review (DAR)**, conducted to assess staff performance against institutional criteria which also relates to promotion criteria and performance targets. In the case of Professors, the annual review is via the University-wide **Professorial Progression Review** process with agreed criteria for advancement within or between the 4 bands of the system, with HoS/RD and/or Executive Dean input throughout the advancement process.

All staff are eligible for **promotion** once any probationary period has been completed. Whilst the department sets ambitious expectations for staff performance there is a firm track-record of rewarding staff who meet these institutionally regulated expectations. Since REF2014 seven of the nineteen staff have **advanced to senior lecturer/reader** (Burke, Dunlop, Archer, Dixon) and **Professor** (McIlhagger, Mariotti, Finlay). In addition, most staff have progressed through Professorial Bands. The promotions process itself is continually reviewed to ensure fit-for-purpose and is promoted through various university-wide workshops and events that aim to assist anyone considering or preparing for promotion.

Staff in the unit can also avail of a number of University level initiatives which serve to recognise, reward and promote achievements in research and impact. These include the **Distinguished**

Research Fellowship Awards offered annually to recognise outstanding research and scholarly activity. In the current reporting period, members of the unit have had significant success with a **total of five awards** being attained (**Main-Category:** Dunlop, **Senior-Category:** Mariotti, Finlay, Maguire, Byrne). The University also recognises the impact via its Research Impact Excellence Awards (McLaughlin, 2017). Research collaboration with industry in the units has been recognised in the period, as follows:

- Healthy Communities Impact Excellence Award (2017)– Intelesens Ltd and Heartsine Technologies in collaboration with McLaughlin team
- Sustainability Impact Excellence Award (2017)– AVX Ltd in collaboration with Byrne team

2.1.5 Sabbatical and Impact leave

In 2018 Ulster introduced a new **University Sabbatical Leave** scheme. This initiative (further detailed in the Institutional Statement, section 3) allows for academic and research staff, to apply for 16 weeks paid-leave, free from normal teaching and administrative duties, to focus on research or teaching excellence activities. A number of members of the unit (Maguire, Mariotti) have availed of this scheme in its first 2 cycles.

Staff in the unit have also availed of additional opportunities to facilitate leave opportunities and to stimulate links between the unit and externally, including: a **Royal Academy of Engineering Industrial Fellowship** (McIlhagger, 2018) and the **EPSRC High Value Manufacturing Catapult** (Leacock, 2015). These initiatives have enabled staff members to develop **commercialisation opportunities** and create impact related activity (McIlhagger spinning-out Axis-Composites Ltd and Leacock MFI Ltd., see table 2, section 1). In this regard, the unit has a **policy where all start-up/spin-out activity is considered during the agreement** and allocation of teaching and administration of duties. Subsequently, Leacock was further supported in the provision of a **career-break** (2017) to focus on **developments with MFI Ltd**. Due to the success of that venture he subsequently resigned from his university role in 2019 to focus on the company.

2.2 PhD Researchers

The unit works in conjunction with Ulster's newly formed **Doctoral College (DC)** in all matters that relate to PhD researcher administration, from recruitment to graduation. The DC provides the central resources to oversee and support postgraduate research degree provision providing a focal point for doctoral training and researcher development. This is supported via a dedicated software-portal (PhD Manager) that provides coordination and documentation management for all activities (reporting, assessment, meetings, etc). The unit has also a Postgraduate Tutor who is the first point-of-contact for all aspects of studies advice and pastoral care for PhD researchers.

2.2.1 PhD researcher recruitment and Unit profile

Engineering at Ulster currently has a total of **69 registered PhD students**. In the NI context, the University avails of the allocation of studentships from the Department for the Economy (DfE-NI). Since 2014 Engineering has typically been granted between 5-10 of these studentships per year. In addition to this core-allocation, staff are encouraged to secure PhD studentships from other sources. This has resulted in a growth in the number of PhD studentships through programmes such as the H.2020 Marie-Curie training scheme and PhD training via large INTERREG-VA funding initiatives. Since REF2014 a total of 6 Marie-Curie studentships have been secured (1 completed; 5 active). Success in the Interreg-VA competition has established a number of engineering doctoral-training initiatives including: the **Ulster led €8.4m ECME** which provides **multidisciplinary future leaders PhD training 24 PhD researchers based across 6 institutions** (NI, Scotland & ROI) and healthcare trusts, with 9 based within Engineering and the **€8.7m NWCAM**, which is delivering quality translational engineering research within the **L&H Science's Manufacturing sector** and supports **8 Engineering PhD Researchers at Ulster**.

Furthermore, the University has provided "**matched**" **funded PhD studentships** for strategic projects including Safewater (4 matched) and US AirForce (1 matched). Further studentships are also made available by the University in order to support attracting high calibre international candidates. These are known as "**Vice Chancellor's Research Studentships**" and a small

number (2-3 per annum) are made available to Engineering annually to attract the best possible international talent. Finally, Engineering has a strong track record of securing PhD studentships through the **CAST Award** program, which promotes academic/industrial partnership with 8 studentships offered in conjunction with companies such as Heartsine, Intel, Abbott, Dell, Bombardier, Kimal Ltd, EC Labs during the period.

2.2.2 Skills development and training

PhD researchers are encouraged to undertake **training and skills development** via the DC where a range of generic research skills and training programmes are offered via the Researcher Development Programme (RDP). The RDP suite of workshops, specialist skills sessions, online courses (**research integrity, diversity awareness, H&S**) and personal development planning activities (**Annual PhD Festival, 3-Minute Talk,**) provide students with opportunities to gain the experience and skills required to be a competent and professional researcher. **Employability skills** development is also available and includes **innovation/entrepreneurship training, how to pitch, how to improve report writing, CV development through to specialist training such as coding and data analytical skills**. As part of their annual reporting and assessment milestones, PhD researchers are required to reflect on their interaction with the various training on offer. In order to give students the opportunity to gain insight into broader academic duties all are encouraged to avail of the opportunity to **deliver tutorials, laboratory-sessions, outreach initiatives and specialist** events (e.g. workshops, conference organising and in-house presentations), for which they are fully remunerated. As indicated earlier (section 2.1.1).

2.3 Supporting Equality, Diversity and Inclusivity

Engineering is a supportive and inclusive environment and adheres to the University's policy to provide **equality of opportunity to all and to ensure consistency, efficiency and effectiveness** throughout its operations. Diversity and inclusivity are valued, actively promoted and embedded in all research processes and policies as outlined in our REF2021 Code of Practice. This places **people at its centre, is mindful of the needs of all staff and ensures barrier free processes to maximise inclusivity and participation in REF**. We used it as our **roadmap for identifying SRR staff and selecting outputs for REF2021**. Engineering also supports the University's **work-life balance policies in line with our AS policy**. These policies include **flexible working, job-sharing, career-breaks, emergency-leave and shared parental-leave**.

2.3.1 Recognition for EDI achievements

Ulster University holds an **HR Excellence in Research Award** (Institutional Statement, section 3) in recognition of its commitment to improving the working conditions and career development of its research staff. The Unit adheres to the principles set out on the achieving this award relating to:

- Positive actions taken to support the **career-development of researchers**
- Implementation of the **Concordat to Support the Development of Researchers**
- Alignment with the principles of the **European Charter for Researchers and Code of Conduct** for their recruitment

In 2019 the School of Engineering became only the second unit in the University to be awarded the **Athena Swan Silver Award**. This silver level award puts us in a small group of Engineering Schools in the UK who have received the honour (**only 13 Universities in the UK currently hold an Athena Swan Silver award within an Engineering discipline**). The silver award builds on our earlier bronze level recognition and clearly **shows the progress that has been made** and the effort expended to ensure that **equality and diversity are at the forefront of everything we do**, and this is reflected in the way we support our staff and students. Notably, the percentage of female staff has increased from **5% in the REF2014 submission to 14% in this submission for REF2021**.

2.3.2 Workload Management

The workload of staff in the unit is managed using an **online workload-allocation system** that is overseen by the HoS, Associate HoS and RD. The model considers **teaching-load, research-activity and contribution to the University** in a manner aligned with promotion criteria and the REF, TEF, University and SoE strategies. The **model addresses research success by allowing for teaching load adjustments** as well as taking account of sabbaticals, secondments, outreach, parental leave consideration, part-time work, study-leave, including a back-to-work scheme, and in the case of ECAs, allocated time to prepare teaching materials and develop early-career targeted grant proposals. It is also used to highlight **staff suitable for promotions**, via reviews and provides the School Executive with the ability to see how we might further improve work-life balance for all staff.

2.3.3 Flexible working arrangements

Formal **flexible-working arrangements** are facilitated on a case-by-case basis and are progressed through the HoS and RD, as appropriate, in conjunction with colleagues in People & Culture (HR). All requests for short notice leave for **caring responsibilities** are agreed directly with the HoS and RD. The nature of other flexible working requests mainly concern reduction to contracted working hours, adjustments to working, teaching or meetings times or other events and working location. Reasons for flexible-working requests mainly consist of **childcare and caring responsibilities for family members**. Arrangements in place to accommodate flexible working include: the ability for staff working from home to join meetings via corporate teleconferencing tools (e.g. Microsoft Teams). Many members of staff work flexibly without making formal requests and working-from-home days are granted when requested. Unit meetings and social gatherings are scheduled during the hours of **10am to 4pm**. Further accommodation of individual staff requests is met on an *ad hoc* basis outside of these hours, as required, plus special cases are made to **help staff participate in conferences** etc. whilst carer duties are maintained. During the **Covid-19 Pandemic** higher levels of flexibility and use of rota-systems/video-conferencing have been developed to aid staff with research commitments whilst maintaining safety-levels and caring duties.

2.3.4 Return to Work

In the event of a staff member returning from a **career break or an extended period of absence** (e.g. due to sickness, maternity/paternity leave or adoption leave) the unit's policy is to **reduce the workload** in order for them to **re-focus on research**. Accommodation of individual requests and associated return to work requirements are considered on a case-by-case basis. Transitional (phased) and/or longer-term arrangements are offered in consultation with People & Culture (HR), including flexible working arrangements and P/T hours. The HoS and/or RD meet with individual staff returning from leave in advance to provide support for their return to work. Staff are reminded at this point that a **Returning Carers' Scheme** is available, **as are schemes for staff with protected characteristics** – the Scheme offers financial assistance to help staff on their return to work and has been availed of regularly in Engineering.

3. Income, infrastructure and facilities

Since 2014, the implementation of the Engineering unit growth strategy has delivered research **awards in excess of £37m**. For a relatively small cohort of staff this is a significant achievement. Income streams have been strategically targeted and prioritised to ensure a **well-balanced portfolio of core scientific research whilst not neglecting higher TR level collaborative work** that is closer to attaining commercial or clinical impact.

3.1. Research Income Strategy

The ERE have put in place a proactive process to support researchers in attaining external research funding. This process is at the discretion of the PI and is in no way restrictive. It has a **particular focus on supporting staff** who are in the earlier stages of grant funding experience and most frequently **availed of by ECAs**. The process facilitates several stages of internal appraisal and review with the aim of ensuring that resources are aligned with the **best proposals going forward by prioritising support** for their development.

The **internal review process** invites investigators with early-stage project ideas to pitch their research concept to both the RD and HoS. These concepts are reviewed based on their scientific integrity, potential for impact and strategic fit with the relevant core theme of the unit. Once ratified candidates are invited to develop a draft case for support. At this stage the Associate Dean for Research and Impact (ADRI) can, following a costings review and in the case of research with exceptional potential, **offer additional support for the project**. Such support has been secured in a wide range of projects over the current REF period and examples **include fully funded PhD** studentships (typically to the value of £70,000) to assist in the execution of the project work plan and in some cases financial support/match-funding for the project. As part of the proposal development process, the PI is assigned support from a specific member of the **University's Research Development Team**. The final draft of the proposal is **assessed internally** by three reviewers: typically, the RD, a subject expert and a member of the University's Research Development team. These reviewers focus on the **scientific aspects of the work, the strategic fit and compliance with the funding call/scheme** support process, respectively.

Funded investigators have access to all necessary multi-user resources and equipment available at our various multi-million-pound facilities. Once an award is secured investigator workload is adjusted in compliance with the work-load allocation model described earlier which ensures a healthy balance of academic duties whilst promoting well-being. Specifically, staff benefit from an allocation of teaching duties that are compatible with facilitating significant time for research, as well as **access to funds to support travel, conference attendance and other networking opportunities as well as further mentoring**.

3.2 Support for seeking research funding

The **University's Research Development Team** is Faculty-facing and provide a continuous and effective pre- and post-award service to Ulster researchers. The **Department for Research & Impact** also provides an open and competitive opportunity to secure seed-funding and pump-priming for identification and development of projects and bids through a **Research Development Strategy fund, Collaborative Research Fund and GCRF pump priming**. In addition, the Department offers expert review services and PhD match funding to **strengthen strategic, prestigious and inter-disciplinary** grant applications. The **University's Thematic Leads** (in both Engineering and Health Tech) work closely with the Faculty ADRI and the RDs to promote and **identify opportunities for greater interdisciplinary** research collaborations across the units, as well as with external partners and with international collaborators.

3.3 Research funding growth during the period

Outline details of the unit's growth in funding in the period have been highlighted in Table 1. Additional details of significant Ulster-led projects relating to research funding and infrastructural investment during the period are overviewed below.

New Large Projects

- **CHIC: (Invest NI 2013-ongoing)** (extended phase 2 funding obtained in 2019); Total project value £9.3m
- **ECME (INTERREG 2017-ongoing)**; Total Project value €8.4m
- **NWCAM (INTERREG 2017-2022)**; Total project value €8.7m
- **CACR - Centre for Cardiovascular Research** – (Philanthropic Investment 2006-2022); Total project value £900,000
- **Randox Engineering-Centre of Excellence**: Total Project Value £1.04m
- **NIAECC-NI Advanced Engineering Competence Centre**: Total Project Value £5m

New Infrastructure

- **Biodevices Rapid Proto-Typing Lab**; Total Project Value £7.3m
- **XPS-UPS system within situ sample processing (EPSRC (EP/R008841/1) 2018-2020)**; Total Project value £1.09m. An enhancement of our existing, purpose-built laboratories (3000sq.m) that house state-of-the-art materials and nano-device fabrication facilities, characterisation materials equipment (e.g. HR-TEM-EELS, TOF-SIMS, FESEM, XPS etc.)
- **SAFEWATER (EP/P032427/1); - Low-cost technologies for safe drinking water in developing regions (EPSRC 2017-on-going)**; Total Project Value: £4.9m
- **Kelvin-2 (EP/T022175/1) - (EPSRC 2019-on-going)**; Total Project Value: £2.1m (joint with QUB)

In addition to the large scale/strategic grants (c. £1m+ in value) described above further funding awarded for a range of projects is shown in Table 3:

Project	Funder	Value of award to Ulster
All Inorganic Bulk Heterojunction Solar Cell Devices	EPSRC (EP/K022237/1)2014-2016	£692,713
An investigation into engineered thermoplastic polymer composite filament for through thickness reinforcement of laminated carbon fibre composites.	EPSRC (EP/L02697X/1) 2014-2016	£82,793
Advanced Nanotube Application and Manufacturing (ANAM) Initiative	EPSRC EP/M015211/1 2015-2021	£516,056
PATHway: Technology enabled behavioral change as a pathway towards better self-management of CVD	EU H.2020 Id: 643491 2015-2018	£369,974
Plasma-based synthesis of low-cost and environmentally friendly quantum dots with tailored energy band structure	EPSRC (EP/M024938/1) 2015-2019	£419,837
CHESS - Connected Health Early Stage Researcher Support System"	EU H.2020 ID: 676201 2015-2019	£373,937
IC-HEALTH - Improving digital health literacy in Europe", 2017-2018, Awarded (to Ulster): Role: Ulster-PI.	EU H.2020 ID: 727474 2016-2018	£139,502
US-Ireland (SFI/DfENSF/HiH) 2 off Centre-to-Centre's Biomaterials (NUI-Galway, NCSU) & Photovoltaics (MIT-Tyndall-Cork, Arizona University)	USI111 US146	£299,000 £299,000

Novel high performance polymeric composite materials for additive manufacturing of multifunctional components	EPSRC EP/N034783/1 2016-2020	£325,687
Emergent Nanomaterials (Critical Mass Proposal)	EPSRC (EP/R023638/1)2018-2022	£491,525
SHAPES: Smart and Healthy Ageing through People Engaging in Supportive Systems	EU H2020 id 857159 2019-2023	£352,706
Multi-User X-ray Diffraction (XRD) Core Equipment	EP/T024437/1 2020-2021	£100,000
EPSRC-SFI: An ocean microlab for autonomous dissolved inorganic carbon depth profile-measurement	EP/T016000/1 2020-2023	£602,640

Table 3. Range of funded projects

3.4. Focus on Infrastructure and facilities

Significant investment in capital/infrastructure projects has been secured from a **wide range of funders** in the reporting period. As indicated earlier the unit is central to key projects in the ongoing **BRCD and DCSDCD** initiatives (£850m and £250m total investment packages respectively). This most recent success builds on the nearly **£6m key capital and infrastructure** over the period including EPSRC and HERC funded resources (**EPSRC Core-Capital Award, £100k; FE-SEM DfE-HERC £270k**).

NIBEC houses fully integrated surface-science/fabrication, rapid-proto-typing, cell-biology, microbiology and water research laboratories that directly enhance our interdisciplinary activities. In the area of advanced manufacturing, our novel composites fibre loom/resin injection NIACE facilities have recently been upgraded. All facilities are **managed openly and fairly at unit level with maintenance and access** by dedicated technical and administrative support staff with **online systems helping manage access** to accommodate all **R&I priorities and needs regardless of researcher status**.

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

Engineering Research at Ulster prides itself on a long track record of research and innovation based on extensive collaboration.

As indicated throughout this statement, **research collaboration** is fundamental to the unit's operation and staff in the unit receive **extensive support to develop and maintain collaborations, networks and partnerships**. This support is in place both at a unit level and at broader Institutional level.

4.1 Support for Effective Research collaborations

At unit level, all staff are encouraged to appreciate the **value of a collaborative approach to research** as reflected in the probation, DAR and Annual Professorial Progression review processes. This is supplemented by the dissemination of opportunities for research collaboration that are circulated in updates to staff and communicated during staff briefings. In order to reinforce and further encourage this outlook, staff are also frequently updated on examples of where collaborative research has brought benefit to the unit and University. This includes the **dissemination of relevant research metrics** that monitor the extent of research collaborations (e.g. SciVal). An example of such a metric output is provided in Figure 2. These data highlight the extent of the unit's collaborative efforts in developing collaborative research outputs during the

reporting period. As indicated, Engineering has a **strong collaborative profile** where the majority of our published articles (>50%) have international collaborators.

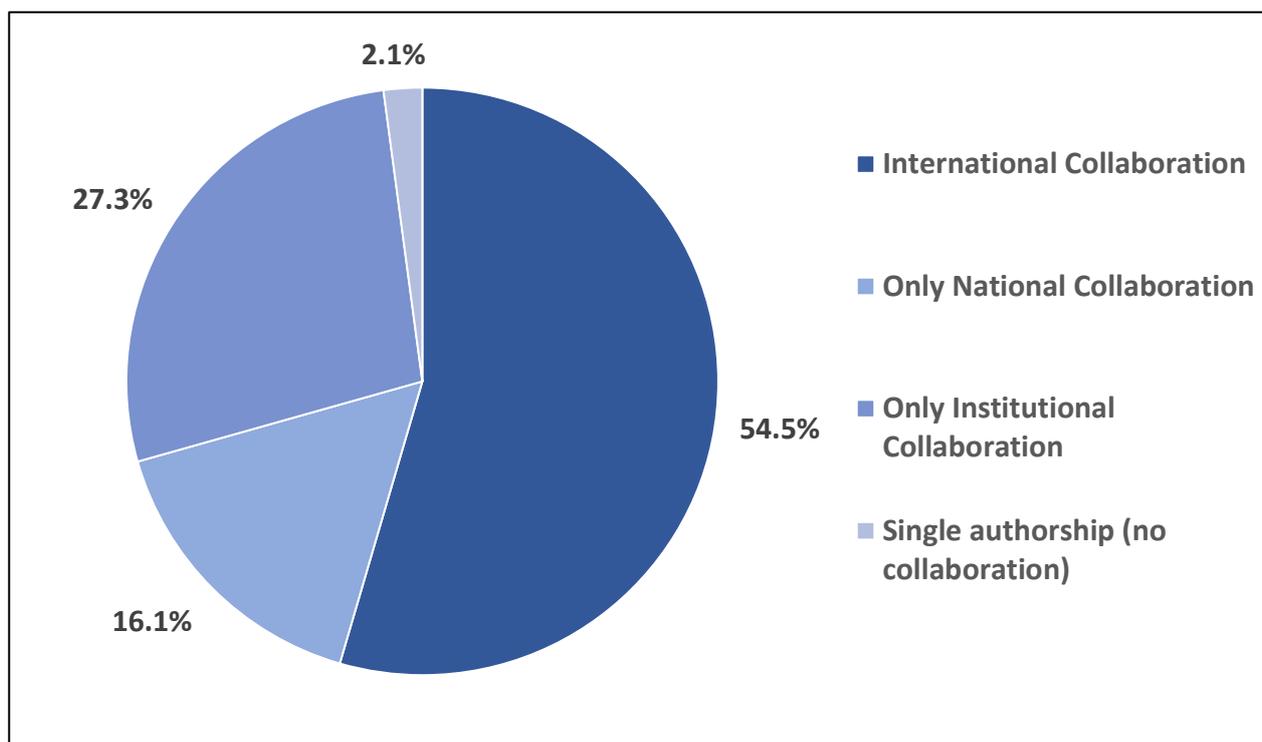


Figure 2. Profile of outputs from the Unit based on levels of collaboration.

4.2 Collaboration and Engagement with Stakeholders

Engineering at Ulster is underpinned by a significant compliment of collaborative engagements. These range from key collaborations with **the local industry and the NI healthcare sector** through to **international collaborations with academic and clinical institutions, global industry and regulators via our affiliated centres, advisory-boards, panel representation, visiting-roles or outreach programmes** as illustrated below with **selected examples**.

Clinical Collaboration:

At a regional level collaboration (MOU) with NI Healthcare and Social Care (HSC) Trusts is underpinned with funded initiatives such as the ECME project (Southern HSC Trust) and the Living-Lab Space at the Royal Victoria Hospital (Belfast HSC Trust). In regard to the latter interaction, the unit's own Living-Lab Space currently co-produces improved solutions and accelerates access to therapies and treatment by bringing together academic, clinical experience and business (e.g. the AI assessment of cardiac risk via blood flow parameters in the eye project). Academic researchers are based both at the University and in the Hospital, thus adopting an enhanced co-ideation approach by almost daily collaboration with leading clinicians. Further **International Collaborations** include Beacon Hospital (Dublin) Craigavon Hospital, Massachusetts General Hospital-Partners (via CIMIT-USA) and with numerous other International clinicians.

Academic Collaboration:

Belgium-KU Lueven; **Finland**-University of Oulu; **Estonia**-Tallinn University; **France**-ESEM & Joseph Fourier, Jean Lamour Institute- CNRS, ENSA; **Germany**-Bochum Ausburg; **Greece**-Aristotle University of Thessaloniki; **Ireland**-University College Dublin, Dublin City University, National University of Ireland Galway & Maynooth, Tyndall Institute, RCS; **Italy**-University of Palermo; **Netherlands**-Groningen; **Norway**-NTNU-SINTEF; **Romania**-Cluj Napoca; **Serbia**-Inst. Physics; **Spain**-Universidad De La Laguna, Plataforma Solar de Almeria, Universidad Rey Juan Carlos, University of Almeria **Switzerland**-EAWAG **Slovenia**-Joseph Stefan Institute; **Turkey**-Ege University; **UK** Cambridge, Manchester, St Andrews, QUB, Surrey, UCL.

International universities including **Australia**-CISRO, Sydney & Wollongong; **Brazil**-Santa Catarina, Univ of Sao Paulo; **Canada**-Waterloo and Alberta; **China** Chinese Academy of Sciences, Nanjing University, China Academy of Engineering Physics, **Columbia**-Univ of Medellin; **Cuba**-Havana; **Ethiopia**-Pontificia Univ of Mekelle; **India**-IIT Mumbai, Shiv Nadar University; **Israel**-Ben Gurion, Technion Institute; **Japan**- AIST, TIT, Zhejiang University; **Kenya**-NGOs; **Morocco**-Rabat University **Singapore**-Nanyang; **S Africa**-Univ of Pretoria (S Africa), **S Korea**- Yong Hee; **Taiwan**-Nat. U. of Taiwan; **USA**- Scripps Oceanography UCSD, Stanford, Connecticut; Pennsylvania, MIT, Massachusetts (Lowell & Dartmouth), Case Western Reserve, Texas, Illinois, Northeastern, NCSU, Arizona State; **Venezuela**-University Javer.

Industrial Collaboration:

2D-Tech/Varsarian, Abington Healthcare, Applicat (Spain), Armstrong Medical, Artemis Technologies, Avellino, AVX, Axial3D, Axis Composites, Boeing, Bombardier (now Spirit), BOSCH, Boston Scientific, BT, Caterpillar, Ciga Healthcare, Cirdan, Dell, Denroy, Dupont, Energia Group, GE Healthcare, Imp-Delft (Netherlands), Innov8 Ltd, Intel, Intelesens, Kainos, LPE, Medtronic, Microsoft, NVIDIA, Philips Healthcare, ProAxis, Radox Laboratories, RHI Ltd, Seagate-Irl/USA, SiSaF, Stryker, Thales, Turpas (Turkey) plus numerous others.

4.3 Contribution to the external research environment

4.3.1 Unit's staff activities in relation to research output activity

Guest editor roles: Applied Sciences (Bhalla), Sensors (Finlay, Ng, Davis), Catalysis Today (Fernandez-Ibanez), Journal of Chemistry Technology and Biotechnology (Fernandez-Ibanez), MDPI Micromachines (Mancuso, Soin), JOM- Minerals, Metals & Materials Society (McFadden), MDPI Water (Dunlop), MDPI - Materials (Soin), MDPI Chemical Engineering (Davis), Journal of Carbon Research (Soin), Chemosensors Special Issue (Maguire).

Editorial Board Memberships: Journal of Electrocardiology (Finlay), Process Safety and Environmental Protection (PSEP) Journal (Fernandez-Ibanez), MDPI-Materials (McFadden), MDPI-Clean Technologies (Dunlop), Acta Materialia Turcica (Papakonstantinou), Journal of Materials Science and Research (Papakonstantinou), Journal of Nanomaterials & Molecular Nanotechnology (JNMN) (Papakonstantinou), Journal of Carbon Research (Papakonstantinou) Nano-Materials Science (Papakonstantinou), MDPI Clean Technologies (Dunlop); IOP Plasma Sources in Nanoscience (Special Issue) (Mariotti).

Editorial and Associate Editorial roles: Frontiers in Environmental science (Fernandez-Ibanez), Journal of Photochemistry & Photobiology, A: Chemistry (Fernandez-Ibanez), IEEE TechRxiv (Ng), IEEE Access (Ng), Frontiers in Physics – Interdisciplinary Physics (Mariotti), Frontiers in Energy Research – Nanoenergy Technologies and Materials (Mariotti); Plasma Processes & Polymers (Mariotti).

4.3.2. Representation on external panels relating to funding and scientific leadership

National funding review and panel activity: **EPRSC** (McFadden, McLaughlin, Maguire, Mariotti, McIlhagger, Soin, Papakonstantinou), **BBSRC** (Boyd, Mancuso), **MRC** (Dunlop, Mancuso, McFadden), **ESRC** (Dunlop), **BARD** (Dunlop), **GCRF-UKRI** (Fernandez-Ibanez), **TSB** (Papakonstantinou), **Royal Society** (Boyd, Soin, Papakonstantinou, McLaughlin), **Orthopaedic Research UK** (Boyd), **Academy of Medical Science** (Mancuso), **Newton Fund** (Ng, McLaughlin).

International funding review and panel activity: **Fernandez-Ibanez**, EU-e.g. h2020, ERC, MSCA etc., Spanish Research Funding (MINECO) Czech Science Foundation; Israeli Ministry of Science and Technology; **Maguire** Inst Physics Belgrade; **McFadden** Helmholtz Institute, Germany; **McLaughlin** DRG (Germany), NSF (USA) and Singapore RC; **Papakonstantinou**, NRF- South Africa, NCSTE- Kazakhstan, Qatar National Research Fund (QNRF), The Dutch Technology Foundation, The French National Research Agency, Foundation for Polish Science, NSFC China; Czech Science Foundation, EU-e.g. H2020, ERC, MSCA etc.; **Rahimian** Icelandic Research Fund; **Soin** NRF SA, NCSTE Kazakhstan.

Representation on research and scientific forums: **Archer**-British composites society, EPSRC future composite manufacturing hub; **Acheson**- Northern Ireland Biomedical Engineering Society; **Boyd**-UK Society for Biomaterials Committee, Northern Ireland Biomedical Engineering Society; **Byrne**-NI Science Festival, Professional Bodies Forum in Support of the All Party Group on STEM; External Advisory Board GCRF SUNRISE AND recirculate; **Dunlop**-Royal Society of Biology NI Committee, NESTA Longitude Prize judging panel; **Fernandez-Ibanez**- Royal Irish Academy – Climate Change and Environmental Sciences Committee, European Committee on Energy Strategic Working Group, Member of MINECO (Spain) **Finlay**- Computing in Cardiology Inc-Board member, Int Society for Computerised Electrocardiology-Board of Directors; **Golbang**-EPSRC future composite manufacturing hub; **Harkin-Jones**-Royal Academy of Engineering Materials & Mining Membership committee (Chair), Royal Academy of Engineering Education & Skills Committee, Council of Mechanical Engineering Professors Ireland, Irish Academy of Engineering Standing Committee on Enterprise, Innovation & Education, Royal Irish Academy Working Group on Brexit and Northern Ireland Higher Education System; **Maguire**- UK COST Action CA19110, UK Technological Plasmas Committee, IOP UK Plasma Physics Committee, RS Newton Fellowship Review Panel, Royal Irish Academy Physical Chemical Sciences Committee; **McIlhagger**- National Aerospace Exploitation Programme Regional Panel, **Mariotti**- RS Dorothy Hodgkin Fellowships Selection Committee, Group Leader, COST Action TD1208 “Applications in nanoscience and surface treatment”, EPSRC SUPERGEN SuperSolar Hub; **McLaughlin**-European Connected Health Alliance (Director), Connected Health Advisory Panel (CHAP), EPSRC Physical Sciences Materials Board Member, KTN Advisory Health Board, NI MATRIX Panel, HIRANI, Trustee of Heart-Trust fund NI – Pantridge Fund, **Ralph**-Technical Textiles Group, Natural Fibre Group, EPSRC future composite manufacturing hub.