

**Institution: Lancaster University**

**Unit of Assessment: Engineering, UoA12**

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

### 1a. Unit Context and Structure

Lancaster's Engineering Department is one of the five fastest growing Departments in the UK (source: HESA) and is going through an exciting period of expansion and change as it pursues its vision to become a School of Engineering that is world-leading in terms of research excellence, inclusivity and teaching innovation.

Created in 1969, it is a General Engineering Department with an inherently interdisciplinary ethos exemplified by it employing staff in disciplines that span engineering from applied mathematics to the natural sciences, and demonstrated by >90% of our REF2021 outputs being submitted as interdisciplinary. Exploiting this interdisciplinarity, it has grown in strength by synergistic integration of research, knowledge exchange and teaching across the engineering disciplines.

It is structured into 5 Research Groups (RGs), each led and managed by a member of the professoriate. Group Leads are managed by the Head of Department (HoD). Each RG houses a number of research themes that build on staff core expertise. Intergroup collaborations are the norm and fully encouraged. Each RG is affiliated to one or more of the University's cross-faculty Research Institutes/Centres. Table 1 gives their composition, focus, underpinning disciplines and Institute affiliation. This lists 100% of the Department's 'Category A eligible' academic staff, all being returned in REF2021. Of particular note is Lancaster's leadership of the Cockcroft Institute - a Daresbury-based, STFC-funded international centre for Accelerator Science and Technology joint with Liverpool, Manchester and Strathclyde. Cockcroft collaborates widely with CERN. 4 engineering staff members are Cockcroft co-appointees and work split-site.

Due to the sustained upward trajectory and vitality in research activity evidenced by the Department after RAE2008, Lancaster invested in a strategic expansion of Engineering through two transformative growth plans covering 2011-2015 and 2018-2028. During 2011-2015, staff headcount increased from 14 to 32. In 2015, to accommodate new staff, laboratories and to further enhance the research environment and student experience, Engineering moved into a purpose-built new, £12.25M BREEAM "Outstanding" building (Figure 1).

**Figure 1. Exterior (left) and atrium/foyer (right) of Lancaster's new, 2015-opened Engineering Building.**



**Table 1: Department RG Structure (numbers as headcount)**

<b>Name (Abbreviation)</b>	<b>Lead &amp; Composition</b>	<b>Research Focus</b>	<b>University Institute / Centre Affiliation</b>
Electronic Engineering	<u>Paoloni</u> 12 Academics (3 Professors, 3 ECRs*), 11 PDRAs**, 25 PhDs***	Particle Accelerators; Millimeter Wave/THz Engineering; Sensors, Photonic/Flexible electronics; Wireless networks	Cockcroft Institute; Security Lancaster; Quantum Technology Centre; Materials Science Institute (MSI)
	<b>Underpinning disciplines:</b> electrical & electronic engineering; materials science & engineering; physics; computer science & communications		
Structures, Materials & Manufacturing (SMM)	<u>Kennedy</u> 13 Academics (6 Professors, 4 ECRs*), 3 PDRAs**, 22 PhDs***	Advanced, Additive & Digital Manufacturing; Laser Processing; Composites Functional Materials;	MSI; Centre for Global Eco-Innovation (CGE); Data Science Institute
	<b>Underpinning disciplines:</b> mechanical, civil and chemical engineering; materials science & engineering; physics		
Nuclear Science & Engineering (Nuclear)	<u>Taylor</u> 10 Academics (4 Professors, 1 ECR*), 14 PDRAs**, 43 PhDs***	Nuclear Energy (Fission & Fusion); Decommissioning; Safeguards & Security; Control & Instrumentation; Robotics; Policy	Energy Lancaster; MSI
	<b>Underpinning disciplines:</b> electronic, control and chemical engineering; materials science & engineering; physics; chemistry		
Chemical Engineering	<u>Martin</u> 9 Academics (3 Professors, 2 ECRs*), 5 PDRAs**, 23 PhDs***	Low Carbon Energy Conversion & Storage; Green Chemistry; Biochemical & Bioengineering; Process Intensification	MSI; Energy Lancaster
	<b>Underpinning disciplines:</b> chemical engineering; chemistry; materials science & engineering; environmental science; biological sciences		
Energy	<u>Aggidis</u> 7 Academics (3 Professors, 2 ECRs*), 12 PhDs***	Renewable energy; Condition Monitoring; Economics; Transport and Policy	Energy Lancaster; CGE, MSI
	<b>Underpinning disciplines:</b> mechanical, mechatronic and control engineering; environmental science; physics; economics, policy		

\*ECR: Early Career Researcher

\*\*PDRA: Post-Doctoral Research Assistant/Associate

\*\*\*includes those intercalating and writing up.

Recognising the strategic importance of Engineering, its global ambitions and potential for a step-change in research intensity, the University approved a second substantial investment for a long-term expansion phase over the period 2018-2028 with the aim of creating the UK's newest School of Engineering, including a £17M second new building in 2022 (Figure 2). The considerable and sustained growth in research income (see Chart 2, §3a), student numbers (at census: 580 UG, 22 PGT, 95 PGR) and increase in league table positions provided the financial strength and stability for the implementation of the plan.

This second growth plan underpins our research and impact plans for the next REF period (see §1e). Supported by these two expansion phases, the Department has grown strongly in numbers and income during this REF period, as shown in Table 2, below:

**Table 2: KPIs for REF2021 period compared with REF2014 and pre-expansion RAE2008**

	RAE 2008	REF 2014	REF 2021	Change 2021 vs 2014
Cat A Staff, FTE at census	14	24.99	45.83	+83%
Publications indexed in SciVal	423	618	990	+60.1%
Total research spend, all REF period, all sources	£6.7M	£9.7M	£24.82M	+156%
Total research spend, industry/end-user (co- )funded	£4.6M	£4.7M	£20.43M	+335%
PGR students registered at census	24	39	95	+143%

Significantly, academic staff FTEs have grown by 84% from 25 to 45.83 (including 4 named chairs, 3 Research Fellows (RFs) and 3 Research Officers), increasing by 41% post-2017 alone. The strategy underpinning this growth has been to create disciplinary critical mass by balanced recruitment of senior academics and ECRs. Two new areas have been targeted, Chemical Engineering and Advanced Manufacturing, with substantial investments in the professoriate for leadership (increasing from 8 to 19) and ECRs for vitality (maintaining at 12 FTE, >25% of the Department).

Time-averaged research grant spend p.a. has near-doubled from £1.95M in REF2014 to £3.55M in REF2021, with £4.76M in 2019/20 alone (due to rapid post-2017 growth, metrics which divide time-averaged figures by current FTEs significantly under-estimate our performance (see Chart 2, §3a)). Our grant portfolio has increased by 100% from £7.5M in 2013 to £15M in 2020 equivalent to £321K per FTE. PDRAs have increased from 7 to 32.34 FTE and PGR numbers from 39 to 95 FTE (excluding intercalations), giving an average of 0.7 RAs and 2 PGR students/academic. The Department has 2.2 FTE teaching fellows/associates, 2 FTE business development staff, 3 Emeritus Professors, 13 technicians and 10 professional services staff.

**Figure 2. Illustrations of west (left) and east (right) elevation of second new Engineering Building, planned opening 2022.**



Research management including development of Research and Impact Strategies, and oversight and monitoring of their implementation against sector-benchmarked KPIs, is the responsibility of the Department's Research Framework Committee (DRFC). Chaired by the Director of Research (DoR) it includes, the HoD, Group Leads, the Department's Impact Champion, the Chair of the Department's Equality, Diversity and Disability Committee, an ECR and the Chair of the Department's PGR Studies Committee.

The DRFC organises biannual research away-days in which all staff debate, identify and develop research opportunities and support routes. The Department employs a Research Administrator who services the DRFC and supports grant management (see §3b).

## **1b. Research and Impact Strategy: Development**

**1b.1 The Department's Research Vision** is to be a multidisciplinary centre of excellence able to respond to challenging, world-scale problems with rigour and innovation, and to be an agent of change in partnership with end-users.

**1b.2 Department Strategy Development.** The Research and Impact Strategies are led by the HoD in consultation with the DRFC and the Department Management Team (DMT) chaired by the HoD. The DRFC and DMT drive their implementation and as well as alignment with the Department's vision and University/Faculty priorities.

The strategy is driven by the great research questions of the age, incorporating ongoing engagement with the Research Groups to identify key priorities, informed by analysis of national/international policy aims, industry trends and funders' strategies (inc. UKRI, key charities, HMG Industrial Strategy, the EU and industrial partners).

Addressing grand societal challenges such as clean growth, AI & data and the future of mobility, our strategy aims to enhance and exploit our historical excellences in fields such as nuclear, high frequency electronics, advanced materials, nanotechnology and energy, and introduce new, cutting edge research themes. Advanced and digital manufacturing, Bioengineering and Engineering Catalysis are new areas that are flourishing with new investment; both in staff and equipment.

Progress towards our strategic aims as stated at REF2014 is the focus of §1c and §1d, wherein we also summarise progress in measures to ensure research integrity and an open research environment. §1e addresses the aims for the next decade.

## **1c. Research and Impact Strategy: Progress Against Aims Identified in REF2014 Submission**

**REF2014 Aims** are in ***bold italics***, *KPIs* in *italics*.

### ***1c.1 Aim 1 – To continue to improve our research performance***

***KPI:*** *to raise the proportion of our outputs rated globally excellent by external benchmarks to >80%.*

This was successfully achieved with 85.9% of submitted outputs rated 3\* (internationally excellent) or better. The total number of papers published by members of the Department has been 990, a 60.1% increase compared to REF2014 (source: SciVal). Quality is evidenced by the recording of a significant number of world firsts attracting extensive international coverage. Selected Group highlights follow.

### **Electronic Engineering:**

- The first linear acceleration of relativistic particles with terahertz and the first acceleration of electrons from a proton wake;



- First-ever millimetre wave W-band point-to-multipoint data transmission enabled by traveling wave tubes for 5G for enabling ultra-high capacity backhaul and fixed broadband.

**Nuclear :**

- The first real-time radiation imaging of an operating nuclear reactor;
- Novel solid state beta detectors for near-real time, interference-free measurement of tritium in groundwater down to WHO levels for leak detection on nuclear sites.

**SMM:**

- Development of novel approaches to virtual prototyping of porous structures, including the first 3D printed metal foams; performing the first multiscale modelling of additively manufactured alloys and developing new models of steel ageing resulting in new improved alloy designs.
- The first use of graphene oxide in cements to produce high performance geopolymers (coverage in The Times, Daily Mail, The Economist), leading to the use of novel sugar beet-derived 2D nano-bio materials in greener, stronger composite-based construction materials.

**Chemical Engineering:**

- The first use of cryocharging for the analysis of H<sub>2</sub> storage materials and the first experimental evidence of solid H<sub>2</sub> in a porous material at supra-critical point temperatures;
- The first in operando optical observation of alkaline fuel cell degradation and the successful fabrication/demonstration of the world's first, Li-ion competitive thick film NaNiCl cell.

**Energy:**

- A RAEng report "Living without electricity" on the effects of Lancaster's 2015 Storm Desmond-induced weeklong power loss (covered by *The Guardian* (1.9M reads), the report is now a "standard text" for UK emergency response committees) and reports on how electricity from renewables can be integrated into the UK grid (conclusions discussed with DECC/BEIS, OFGEM and adopted by the National Grid).
- The development of a Hydro Resource Model used by the World Bank for quantifying the feasibility of establishing hydropower projects, especially in the 3<sup>rd</sup> World, and work on triple regulation of turbines that led to its industry-wide adoption, breaking a 100 year status quo.

**1c.2 Aim 2 – To continue growing and diversifying income sources to ensure sustainability.**

**KPIs:** to increase research spend to £3.1M p.a. by 2020; and to increase the industry related component of this to £1.7M p.a. by 2020.

Annual spend has risen to £4.76M in 2020 (see Chart 2, §3a). Evidencing diversification, only 53% of our REF2021-reported spend was from UKRI sources. >82% of all research was conducted in collaboration with industry/end-users, such spend reaching £3.7M in 2019/20.

**1c.3 Aim 3 – To continue growing the size & quality of postgraduate research provision**

**KPI:** to grow our PGR student population by 33% by 2020

PGR numbers have grown dramatically this REF period, more-than doubling from 39 in 2013 to 95 in 2020. Evidencing the Department's reputation for high-quality PGR study, each post attracted an average of 5.2 applicants. Further evidence is provided by doctorates awarded, more-than doubling from 6 p.a. during the REF2014 period to 16 in 2019/2020 and, since 2016/17, a year-on-year decrease in the FT non-completion rate to 3.6%. See §2 for more detail.

**1c.4 Aim 4 – To continue developing an environment for internationally leading research**

**Implemented through:** *interdisciplinary work within Engineering and across Lancaster University; (inter)national leadership and engagement; and through our Distinguished Visitor Programme.*

There have been >75 international Visiting Researchers (formally contracted for insurance) from nearly 50 institutions in 18 countries, totaling 585 Person Months – equivalent to nearly 7 FTE p.a. since 2014. 6 members of the Department hold visiting positions at overseas institutions. Members of the Department have also delivered >200 presentations internationally – in 96 different locations in 29 different countries outside of the UK, including 6 Keynote Presentations, 7 Plenaries and 46 invited talks.

The Department has invested heavily in internationally connected staff; 28 staff obtained a full- or partial- education abroad, and 11 staff have held a previous position in a non-UK academic institute. The professoriate has more than doubled from 8 to 19 since REF2014 – all of whom collaborate internationally and/or provide leadership to UK national bodies. We now collaborate with >150 groups in >30 countries over 5 continents, all evidenced by joint funding or publications. As a result, 62% of our outputs indexed on SciVal involve international co-authors. Exemplars of international partnerships and leadership include:

- Lead partner in the Cockcroft Institute (STFC funded, £20M, post-2004 §1a);
- Leading role in the €4.9M HiLumi LHC FP7 (2011-2015) project preparing for 2021's Large Hadron Collider upgrade, a collaboration with CERN, and 15 EU/US accelerator laboratories.
- Partner in the £5M UK component of the CERN-led 29 country programme to develop a Compact Linear Collider (CLIC-UK).
- Coordinator of H2020 projects TWEETHER (€3.3M, 2015-2018) and ULTRAWAVE (€3M 2017-2020), collaborations between 9 EU partners to realize the first W-band wireless system for distribution of high-speed internet everywhere and to enable 5G cell densification.
- Co-chairing the Management Committee of the BEIS-funded National Nuclear Users Facility (NNUF) and hosting £5M worth of NNUF facilities (§3c).
- Leading the £2M Lloyd's Register Foundation International Research Centre in Nuclear Safety (2014-19), with Tennessee, Harbin (China), Coventry University.
- Key UK member of SACSESS (€5.6M, 2013-2016) and GENIORS (€5M, 2017-2021), EURATOM funded projects on weaponization-proof nuclear reprocessing, 27 partners, 11 countries.
- Membership of UK HMG's Nuclear Innovation and Research Advisory Board.
- Leading the £1.7M ERDF-supported Sustainable Design for Rapid/Additive Manufacturing: Engineering Design Academy (2014-15), assisting 128 SMEs.
- Leading the £1.8M Lancashire Enterprise Partnership Growth Deal-funded ACADEME Project (2016-23), hosting next-generation additive manufacturing equipment to support innovation in local industry (§3c).
- A strategic partnership with The Welding Institute (TWI) through two Innovation Centres (ICs) for digital joining technologies and additive manufacturing.
- Engineering partner in RECIRCULATE, a GCRF-funded collaboration (£5.9M, 2017-2021) between Lancaster and 10 African research centres/institutes, delivering safe, circular water economy in Africa.
- Authorship of RAEng Policy Reports including "The sustainability of liquid biofuels", "Wind Energy", "Transforming the Electricity System" and "Scope for reduction in transport CO<sub>2</sub> emissions by modal shift", the latter finding that the benefits of switching from road to rail are overstated, resulting in HMG changing policy to promote electric vehicles (see §4c below).
- Establishing, via two joint professorial appointments (Aroua, Rahman), a strategic relationship with Sunway University, Malaysia in the areas of renewable energy and CO<sub>2</sub> fixation.

**1c.5 Aim 5 – To maximise the impact of our research and to exploit the benefits that accrue:** *in particular maximising our policy-related impacts.*

We have delivered a wide range of far-reaching impacts significant to public policy, society, the environment, the economy and quality of life, see §4b for detail.

**1c.6 Additional Aim to those at REF2014 - Creating an Open Research Environment**

The University is a signatory to DORA. The Department also subscribes to Research England's policy of making research available electronically – immediately, free of charge and copyright restrictions. Since 2016, all journal accepted manuscripts, most other outputs and associated data are made open access in Lancaster's repository. Access occurs immediately if gold route (spend this REF period = £172k) and within 3 months if green.

**1c.7 Additional Aim to REF2014 – To maintain high standards in research integrity and ethics**

We adhere to research ethics and integrity guidelines and procedures specified by the University, funding bodies and relevant professional organisations, and fully subscribe to the commitments of the Concordat for Research Integrity.

The Department operates a process of internal peer review of grant applications, including ethics and integrity as well as technical content. Projects are referred to the Faculty Research Ethics Committee if they involve human participants or other ethical risk factors. PIs must take the Faculty's research integrity course. PGRs are mentored in research ethics through the supervisory process and *via* Faculty Graduate School-delivered training.

**1d. Research and Impact Strategy: Facilitating Impact**

We are culturally and strategically committed to the highest-quality research that produces impact for end-users. Culturally, the road to impact starts with compulsory UG MEng industrial projects through to new spin-outs and externally-funded chairs. Strategically, Research Group goals include protecting/exploiting their knowledge base, engagement with policy makers and maintaining a grant portfolio with industry partners.

Impact is embedded in the entire research process, starting from project conception/development (e.g. *via* end-user co-design in proposal preparation), throughout the research itself (e.g. *via* secondments to industry and end-user facilities), to wide dissemination to the user community and society. The success of our approach is evidenced by >82% of our research (measured by financial value) being conducted in collaboration with industry/end-users. Our approach is:

- **Supported** by the Department's Industrial Advisory Board, which meets quarterly and constitutes the formal interface between our research and a wide group of regional, national and international businesses/end users, including Oxley Developments, Sellafield, Mott MacDonald, Siemens, BAE Systems.
- **Facilitated** by the Department's in-house technology transfer/knowledge exchange resources such as, the *Lancaster Product Design Unit* (LPDU, typically ~15 FTEs), for additive manufacturing activities and the Faculty's Partnerships and Business Engagement (PBE) Team for other areas. The LPDU provides expert, research-derived design support and access to cutting-edge facilities for a portfolio of >145 SMEs in different sectors (art, leisure, automotive, energy, healthcare, etc.). The LPDU employs graduate engineers, giving them mentored industrial experience. LPDU impact extends into the UG body via mini projects derived from the Department's research activities. This REF period, R&D for >220 SMEs has been conducted by this route.
- **Amplified** by involvement in £27M-worth of ERDF initiatives bringing together departments across Lancaster:
  - The £4.1M Cumbria Innovations Platform (CUSP), helping businesses access technical and management expertise in accelerating innovation in products and services.
  - Next Generation Chemistry (NextGenChem, 2019-23), a £4.92M partnership with Chemistry that will provide research/innovation support to 150 firms in the region around process chemistry and scale-up.

- Greater Innovation for Smart Material Optimisation (GISMO, 2019-2023), £4.92M, collaborating with 125 firms in the fields of hydrogen materials, surfaces and coatings and additive manufacturing.
- The £6M AI Foundry project, with all Manchester HEIs, providing access to 200 Greater Manchester companies.
- The £7.1M Centre for Global Eco-Innovation (CGE), a £7.1M ERDF project with the Lancaster Environment Centre and Liverpool, (RCUK Awards “The Outstanding Knowledge Exchange and Commercialisation Initiative 2015”), supporting 11 PhDs working with SMEs across all Department research areas.
- **Exemplified** by the TWI Centres and CINDe initiatives (§2d), where PGRs are embedded at TWI’s Cambridge/Sheffield and NNL’s Workington sites throughout their PhD, in close-proximity to key end-users.

Infrastructurally, impact is facilitated by measures including an Impact Champion, Manager and Support Officer, a Schools Liaison Officer (§4b), three Faculty-based business incubator facilities and the University’s central Research and Enterprise Services (RES) (see §3a).

Impact is embedded in the Department’s workload model (§2b) and by modifying individual contracts. For example, one Chair has been a director of a spin-out business alongside his academic role for 16 years resulting in a 4\* REF2014 Impact Case Study (ICS) and an ICS for this submission (ICS-[Joyce](#)), and a Senior Lecturer negotiated a contract reduction to 0.2 FTE to concentrate on a spin-out from his research (ICS-[Dawson](#)). Details relating selected ICSs to our approaches to achieving impact, as well as other impact exemplars, are given in §4b.

### 1e. Research and Impact Strategy: The Future

Our Research and Impact Strategy is a key part of Engineering’s 2018-2028 growth plan which aims to create a new, world-leading School of Engineering. The impact of the C-19 pandemic may adjust the timescales of these ambitions but the overall aims remain the same. In addition to the planned new build (Figure 2), our strategy will be achieved through the following.

1. **Creation of three new groups** with a common theme of Advanced Manufacturing – specifically Digital Manufacturing, Robotics & AI and Bioengineering. Our core disciplines (Table 1) will be expanded to include Civil Engineering, permitting a truly comprehensive engineering research offering.
2. **Appointment of 21 new academic staff** to support the above. Appointments will be at all levels, maintaining an ECR population of 25% FTE for sustainability.
3. **Engagement with industry locally, nationally and internationally** and with key funding bodies and initiatives, enhanced by:
  - a. Creation of 10 sector specific, cross-RG clusters to identify new strategic relationships/collaboration opportunities. Each will have an academic and industrial champion, the latter a member of our Industrial Advisory Board (see §1d).
  - b. Building on existing long-standing partnerships (e.g. Lloyds Register, Fisher Foundations, TWI, Fort Vale Foundation).
  - c. Exploiting synergies offered by Lancaster’s Research Institutes (Table 1), and relevant Departments to amplify the new School’s engineering capability.
  - d. Bioengineering engagement with Lancaster’s 2020-opened £41M, 8,000m<sup>2</sup> Health Innovation Campus.
4. **Substantially increasing research income** by pursuit of objectives 1-3 and increasing the success rate and value of grant applications through robust internal support (§3a.1). We will aim to grow income (spend) by 10% p.a. to £7.5M in 2025.



5. **Deliver increased RF/RA/PGR numbers** and improved training as follows:
  - a. **Increasing PDRA numbers** from 0.7 to 1 per academic FTE by increasing RAs on funding applications.
  - b. **Delivering strong growth in PGR registrations and completions**, increasing total PGRs by 33% to 3 per academic FTE by 2028/29, by enhancing international reputation and impact.
6. **Applying EDI best practice for appointing new staff, and PGR students**—We will seek to progress from Athena SWAN bronze to silver, building on our ethos of inclusivity and equality and support of the gender balance already demonstrated by the number of women promoted and innovations in their recruitment (§2a,e for detail).
7. **Ensuring an open research environment** with 100% of outputs being open access compliant.
8. **Setting strategic objectives for the current RGs:**
  - a. **SMM** will focus on materials and composites; a new RG for Advanced and Digital Manufacturing research, will be created with a focus on machine learning.
  - b. **Electronic Engineering** will further enhance its leadership in millimetre wave electronics (by having recently established one of the few laboratories worldwide for fabrication of novel sub-THz vacuum electronic devices) and electronics for particle accelerators (through the Cockcroft Institute and engagement with CERN).
  - c. **Nuclear** will expand its robotics activities and into nuclear fusion, the latter by engagement with the Culham Centre for Fusion Energy.
  - d. **Chemical Engineering** will capitalise on GCRF opportunities in the sustainable energy and environment areas and Faraday Challenge opportunities for fuel cells/batteries. A new RG will focus on Bio-/Biochemical Engineering technologies.
  - e. **Energy**: A new research front in the area of electric vehicles will be opened, complementing existing world-leading policy work on such vehicles and grid architecture and resilience.

## 2. People

### 2a. Staffing Strategy and Recruitment

Staffing strategy is summarised in objectives 1, 2 and 6 in §1e. We seek to achieve diversity in gender, ethnicity, age, disability and nationality and attract the best candidates internationally, appointing on research excellence, and the ability to contribute to our teaching and engagement ethos.

Academic recruitment procedures are underpinned by sector-benchmarked EDI best practice. A 2015–2028 strategic recruitment campaign has been defined by the HoD and DMT to:

- (1) Build strategic strengths in existing and new RG;
- (2) Enhance research and teaching offerings;
- (3) Expand interdisciplinary networks.

Recruitment is by open competition. All person specifications, role descriptors and adverts are EDI compliant. Short-listing takes place following University fair practice guidelines. Sufficient notice of interviews is given to candidates to make arrangements for caring responsibilities if required. Interviews are conducted remotely where it is impractical for candidates to attend in person (e.g. due to COVID). The panel chair has received formal training for this role and all panel members have undertaken training in EDI and unconscious bias. All recruitment panels have at least one woman member.

The Department is a diversity exemplar for internationality. Of **52 permanent and 33 fixed term staff members** 18 and 15 are BAME respectively (including 6 Professors, 3 Senior Lecturers). This compares with REF2014 when 7 of our permanent and 1 of our fixed term staff were BAME. Further, 30 permanent/fixed-term staff obtained a full- or partial- education abroad, and 12 held a previous position in a non-UK academic institute. **34 new permanent staff were appointed in this REF period** (14 BAME) of which 16 were ECRs (6 BAME) and 9 were Professors (6 BAME); 10 new appointees were from overseas institutions.

Women are represented by 3 permanent (1 Lecturer, 1 Senior Lecturer, 1 Professor) and 8 fixed term staff. Engineering is proud of its commitment to innovative recruitment initiatives designed, as per our Athena SWAN Action Plan, to broaden the field of applicants for each position, particularly with respect to gender. An exemplar returnship programme was designed for applicants wishing to return to a permanent FT/PT academic role after a significant career break. We have already appointed one woman Lecturer under this scheme and will appoint more.

**Regarding ECRs**, of the 34 permanent staff appointed post-2014, 19 had not held established academic positions before. The need to maintain a balance of new talent and experienced staff has been met with faculty mean age of 47.7 in December 2020 (c.f. 45.7 in 2014, 47.1 in 2008), 33% under 40 (c.f. 25% in 2014) and 15% over 60 (c.f. 11% in 2014).

This submission includes 12 FTE ECRs, >25% of the FTE returned, illustrating the importance of ECRs to our sustainability strategy and commitment to the 2019 Concordat to Support the Career Development of Researchers (§2c for detail). Underscoring this commitment, particularly regarding recruitment and retention:

- The Department was comprised of an average 29% ECR p.a. throughout the REF period;
- Five Lecturer appointments were ex-Lancaster researchers, providing a career path for our best RAs;
- Three appointments were made under the University's 50<sup>th</sup> Anniversary Lectureship scheme which was designed to support candidates to meet the research pathway criteria for Chair within 5 years, see §2.1.7, REF5a. Successes include >£600K in awarded grants and 35 scholarly outputs.

**At professorial level**, to provide leadership in key research areas, the Department recruited 9 external candidates to Chairs. We have also had four visiting chairs during the period in the following areas:

- **RAEng Visiting Chair** – Lee (NNL), nuclear measurement and analysis
- Taylor (NNL), actinide science
- Garnsey (ex-NDA), nuclear safety and policy;
- McIntosh (STFC), accelerator science and technology.

Of the permanent academic staff in the Department at REF2014, 3 have become Emeritus returning for periods of part-time service. 6 have left, 2 to Chairs at other HEIs (QMUL and a Canada Research Chair in at the University of Waterloo), the others to senior posts at other universities or the private sector.

**Fellowship and Awards;** Applications for externally funded fellowships/awards are strongly supported for enhancing career development. During the REF period, 6 permanent staff have held Fellowships (1 woman, 2 BAME):

- Joyce: Royal Society Wolfson Research Merit Award;
- Rivera: LPW Technology / RAEng Research Chair;
- Carrington: RAEng Research Fellowship;
- Lok: Royal Society Research Fellowship;
- Letizia, Adamopoulos: RAEng/Leverhulme Trust Senior Research Fellowships.

## 2b. Staff Development

All new staff have introductory meetings with the HoD where the ethos of the department, resources and probation objectives are discussed. They receive the Department induction handbook covering governance, administration, research support, and other relevant information. Group Leads then manage and develop staff within their group, supporting them to achieve their full potential. This REF period, 2 BAME staff have been Group Leads.

All new staff must undertake EDI and Health & Safety training, renewed regularly. CEng registered staff (the majority) are required to undertake CPD, which includes professional ethics.

**Probation:** All new Lecturers undertake a probationary period of 3 years supported by an experienced academic mentor. New EC staff must take the Advance HE-accredited Postgraduate Certificate in Academic Practice (PGCAP) teaching qualification. Teaching duties, already low relative to many comparator departments, are further restricted to 50 and 75% of a full load in years 1 and 2 of a new appointment, freeing time for research development. We have a 100% success rate in new staff passing probation.

**Appraisal:** Group Leads conduct annual Performance and Development Reviews (PDRs) for each group member, wherein staff reflect on progress against targets set the previous year and more widely. The PDR is used to set objectives for promotion, addressing KPIs such as publication, grant capture, PGR progression, translational work, and leadership. Group Leads have their PDR with the HoD.

**Workload Model (WLM):** A formal and transparent WLM, managed by the HoD, allows the Department to balance staff contributions in research, teaching and administration, maximising time for research and impact. Monitoring shows that this process is highly effective, indicating that staff spent an average of 67.2% of their time on research and impact in 2019/20 (source: Department WLM, TRAC return).

**Sabbatical Leave:** Staff may apply for sabbatical leave, accumulating 1 term of leave per 7 terms of service (including Family-related, and paid sickness leave). The applicant must produce

a research plan with measurable outputs for HoD and Dean's approval. Since 2014, 3 Lecturers and 4 Professors have been awarded sabbatical leave (2 BAME).

**Promotion** is open to all. All eligible staff are encouraged to apply to the annual promotion call by Group Leads who then, with other senior staff, help candidates prepare cases. The HoD then writes a supporting statement for the case. Processes are DORA compliant at all levels.

This REF period, 20 Staff have been promoted: one to professorial band 2, 7 within professorial band 1 (2 BAME), 5 from SL to professorial band 1 (1 woman) and 7 from Lecturer to SL (2 women, 1 BAME).

## 2c. Research Staff

PDRAs/RFs and PGR students are key Departmental assets, vital for research and technology transfer. We currently employ 32.3 FTE PDRAs, nearly 5 times those in 2014.

We fully support the 2019 Concordat to Support the Career Development of Researchers (CSCDR) as follows.

1. *Researchers are recruited, employed and managed under conditions that recognise and value their contributions.* Most are funded by research grants; thus, this is the responsibility of grant PIs, recruiting and monitoring development in accordance with §2a and §2b above.
2. *Excellent research requires a supportive and inclusive research culture.* PDRAs are active in the Department's research community, in particular through contributing to seminars, and representation on committees (e.g. the DRF and EDI Committees).
3. *Professional and career development are integral to researchers developing their full potential.* New PDRAs have a one year probation and an annual PDR with their PI. They are encouraged to undertake national/international conference attendance and CPD training, enhancing their reputation, experience and prospects for a permanent job. Those wishing to develop their teaching practice, after proper mentoring, may contribute to small group teaching, demonstrating and supervision tasks. They are encouraged to pursue independent research including comprehensive support to develop externally-funded Fellowship proposals.

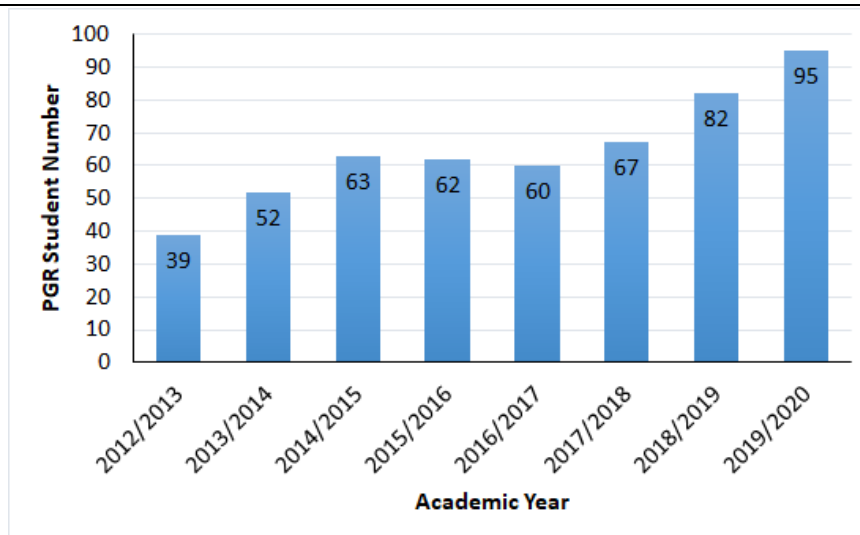
Of the 33 PDRFs/PDRAs currently in post, 8 are women. This period, 87 PDRAs have been appointed. Reflecting the employability of our RAs, of those who have left, 6 have moved into permanent academic posts (2 UK, 4 abroad), 16 obtained a PDRA post elsewhere, 8 moved to positions within national research or funding agencies, 14 entered industry.

## 2d. PGR Students

**PGR Management**, including policies, processes, and monitoring of training, progression and completion rates, is the responsibility of the Department's Postgraduate Studies (PGS) Committee. Chaired by a PGS Director it includes the DoR, the PGR Director, the PGR Admissions Tutor, the Chair of the Department's Equality, Diversity and Disability Committee and one administrator.

**Recruitment and Admissions:** numbers have grown substantially, more-than doubling from 39 in 2014 to 95 in 2020, Chart 1, giving a current average of 2 PGR students/FTE academic. We have recruited 152 research students (89% FT, 11% PT, 40% BAME, 45% UK, 18% EU, 37% non-EU) of which 33% were women, compared to 21% in 2014.





**Chart 1:** PGR numbers p.a. (Source: LU Tableau)

Factors driving growth include:

- Our membership of three Centres for Doctoral Training, see below.
- Winning, year-on-year, of peer-reviewed Nuclear Decommissioning Authority PhD studentships.
- Provision of 16 studentships from ERDF funded technology transfer/innovation projects such as GISMO and the CGE (§1.d).
- Strategic partnership in two TWI Innovation Centres (§1c.4) allowing us to offer fully funded, industry co-sponsored PhD places in advanced manufacturing.
- Provision of University-funded PhD studentships as match-funding for large research projects >£500K.
- Provision of ~5 Department-funded PhD studentships p.a., targeted at ECRs.

In total, 36 FTE PhDs have been funded since 2014 by these latter two routes. We will continue in pursuit of **objective 5** of our future strategy (§1e).

**Recruitment** is buoyant with an average of 5.2 PGR applicants/post this REF period. Typically, advertisement occurs November-March for an October start, although we are flexible towards non-standard application/starting times.

The majority of advertised studentships are for grant-supported pre-defined projects. Applicants are interviewed by a panel of academic staff. We also accept speculative applications from students with self-originated projects, project review then forming part of the selection process. Recruitment is done with due consideration for EDI.

**Admissions** are overseen by the PGR Admissions Tutor who ensures the research will be appropriately resourced and supervised. Supervision, progress monitoring, training and support are overseen by the PGR Director.

**Supervision:** Each student has a primary and a second supervisor. EC staff are supported by a more senior colleague when primary supervising their first PGR.

**Progress monitoring:** Attendance and supervision are documented *via* monthly submissions on-line. Progress is monitored *via* student appraisal that involves biannual reports to the PGR Director. These are reviewed by 2 independent reviewers who then interview the student to discuss their research and identify any additional support necessary, after which they make their progression recommendations. Consideration of MPhil-to-PhD transfer occurs at the end of Year 1 appraisal. As a result of these measures, we have seen a year-on-year decrease in the FT non-completion rate to 3.6%.

**Training and Support:** We fully subscribe to the CSCDR, the QAA Code of Practice for Research Degree Programmes and the 'Roberts' recommendations for PGRs, and map our training against Vitae's Researcher Development Framework. Training and pastoral support is provided *via*:

- **Transferable Skills:** Additional to Department support described above, the Faculty Graduate School Research Development Programme provides training on topics including induction, skills development, project management, thesis preparation, presentation skills (also fostered via the 6 monthly appraisal meetings and an annual, 2 day Engineering PGR Conference) and career planning.
- **Subject specific skills:** >20 PGT modules in Engineering specialisms, underpinned by an IET commended research methods module covering technical writing, statistics, critical thinking, IP, literature search and retrieval. There are dedicated funds to attend specialist external courses.
- **Pastoral support:** provided by the student's second supervisor, PGR Director, Faculty Graduate School and LU's Graduate College (all PGRs are members), providing a social centre for the community. PGR representation is embedded within committee structures, and PGR also have quarterly informal meetings with the HoD.

**Centres for Doctoral Training:** The Department is a member of three CDTs:

- The EPSRC-funded NGN (£5.2M, 2013-2021) and GREEN (£6.3M, 2018-2026) nuclear CDTs, consecutive partnerships with Manchester, Leeds, Liverpool and Sheffield, aiming to train 160 PhDs over 2013-2026, recruiting ~20 students p.a. Both have considerable support from nuclear industry partners who have committed to co-fund 80 studentships over both CDTs.
- The Sellafield/NNL funded CINDe (Centre for Innovative Nuclear Decommissioning), a partnership with Manchester and Liverpool recruiting ~8 nuclear S&T students p.a. CINDe provides doctoral training in an industry setting, basing its students at NNL Workington. CINDe was a finalist for an IChemE Global Award 2019 (Team Category) and highly commended for its training at the same ceremony.
- The £1M Leverhulme Trust-funded Materials Social Futures CDT, a partnership between Lancaster's Institute for Social Futures and MSI (Table 1) focussed on the environmental, sustainability and social impact of new materials. Awarded 2018, it will train 21 PhDs over 7 years.

**Impact:** As well as the PGR-relevant measures outlined in §1d, we use iCASE and iCASE-modelled studentships (offered by, e.g., the ERDF-funded projects and CDTs above) to create end-user benefit. We also use business-facing ERDF/charity-funded MSc PGR students (16 post-2014) to deliver impact to industry, primarily via the LPDU (§1d, 4c).

Our PGR students regularly get involved with various organisations to promote engineering to our wider community e.g. outreach schemes by the Smallpeice Trust, the Engineering Education Scheme and Headstart, using these opportunities to champion especially women engineers and scientists.

## 2e. How We Support and Promote EDI: Additional Evidence

Our most recent staff survey found that 87% agreed that we actively promote a culture of equality and inclusion. 100% of women and 87% of men staff were satisfied with their

awareness of diversity issues and 92% of women and 79% of men would recommend the University as a place to study/carry out research.

The Department has a termly Equality, Diversity and Disability Committee meeting (EDDC, 8 women, 5 men) comprised of 6 academic, 4 professional services staff and 2 students, including our Disability Officer. The Deputy HoD (a woman) also chairs the EDDC and is our AS/EDI lead. She is a member of the DMT and DRFC and sits on the University EDI Committee. The HoD also sits on the EDDC. Thus, EDI is embedded in all the Department's decision-making processes.

Compliance with our Athena SWAN silver action plan is achieved through on-going dialogue between the EDDC chair and other committee chairs, and the EDDC and wider Department. Since 2015, we have been members of the WISE campaign which staff and students can join at no cost.

The Department policy on family-related leave follows the University's. Staff holding one or more funded research projects and supervising one or more RA/PGR may access the University Maternity and Adoption Research Support fund, up to £10k/disbursement and designed to minimise disruption to research during, and after, family-related leave. For staff on such leave, the Departmental Officer provides support as needed (processing HR forms, maintaining communication etc.). For PGRs and PDRAs, arrangements are made case-by-case with their supervisor. On return, staff may submit requests to the HoD to work on a flexible/PT basis. Returning staff receive reduced administration/teaching loads for a period, to allow for a quicker return to research productivity. During the current period 13 staff have taken parental leave (2 maternity, 11 paternity) and 10 members of academic staff have worked part-time (2 women, 8 men). All staff who have made requests for flexible/PT working have had them agreed.

For all PT staff, work-load allocations are made on a pro rata basis. Staff with young children are given teaching that avoids early starts or late finishes and Department meetings are restricted to 10am-4pm. This is beneficial to the good mental health and wellbeing of all staff, which is also cultivated through monitoring of annual leave (ensuring it is taken in full) and prohibiting emails outside of 7am-7pm, Mon-Fri. Staff with caring responsibilities or special needs are encouraged to consider the University's flexible working policy. Further support is provided by the Faculty Wellbeing minisite that provides guidance on the 5 Ways to Wellbeing and multiple support routes. Oversight is provided by our Safety, Health and Wellbeing Committee.

Finally, all the above-described measures related to improving gender diversity are being used to address our Gender Pay Gap, with an additional measure being accelerated increment rewards for women, especially at career stages where such gaps initially appear e.g. for EC staff and those returning from parental leave. Our Athena SWAN Bronze Award has a five year SMART action plan against which these measures are monitored.

**3. Income, infrastructure and facilities****3a.1 Support for Research Funding Applications**

Group Leads, the Director of Research, HoD and Institute Directors support all staff in obtaining funding. The DRFC promotes external calls for proposals through all-staff emails. Workshops on grant applications/research strategy help stimulate grant submissions. An Engineering-dedicated Research Development Officer (RDO) within RES supports proposal development and advises on costings, funders' T&Cs and University procedures. Drawing on broad experience of UKRI College Membership in the Department and Institutes, proposal pre-submission review by successful senior staff is offered, as are practice panels for proposals assessed in-part by interview.

Pump priming/match funding is available as follows:

- A central University fund that algorithmically supports 50% of the cost of all equipment requests of more than £10K on all research grant applications to external funders.
- Centrally funded PhD studentships as match-funding for all grant applications with a FEC value greater than £500K (see §2d).
- Department and Faculty travel grants to attend events, support networking, meet with potential collaborators or provide seed-corn funding for the organization of conferences. ~10 awards were made p.a. for a total of ~£40K
- Availability of a Faculty Impact Fund and the University's Impact Acceleration Accounts (IAA, see below).
- The provision of DTP and department-funded PhD studentships for first grant applications and as pump-priming for ECRs more generally.

Other ECR-specific support measures include:

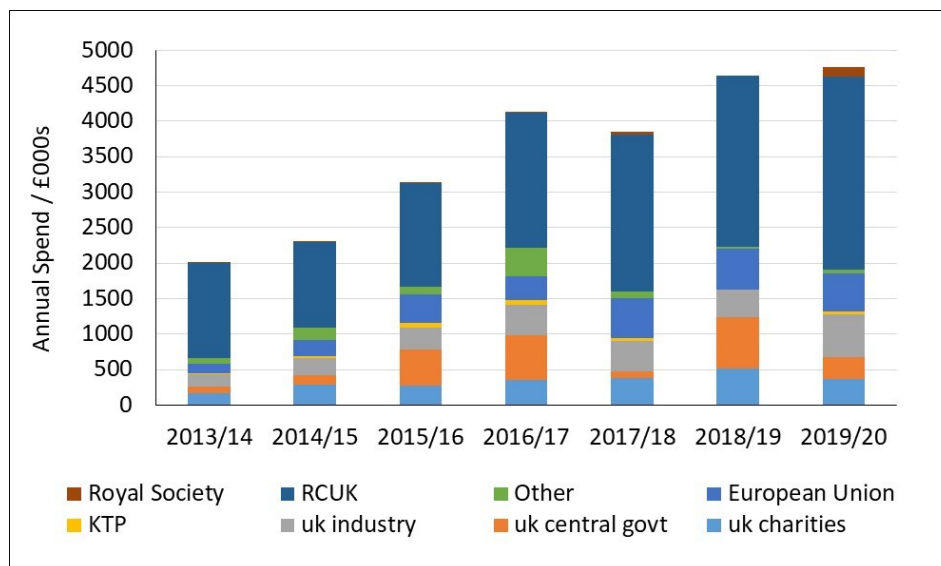
- Rigorous internal review of EPSRC New Investigator Grant applications involving feedback from at least two senior staff and the HoD. For unsuccessful applications, Group Leads and the DoR review feedback and advise on resubmission strategies.
- A minimum Department grant of £4K during probation, with more from the University on submission of an appropriate case by the HoD (3 ECRs recently successful in securing >£25K).
- Providing additional support for involvement in international conferences, national meetings and workshops, funding body panels, blogs and news to increase their visibility and build on the Department's reputation.
- Priority access to CDT studentships.
- Inclusion within extant collaborative networks; involving ECRs in large grant applications as co-investigators to support their development of and exposure to research project delivery and leadership.

**3a.2 Income: Research and Consultancy**

The measures detailed in §3a.1 have been highly successful, leading to a substantial increase in our research income. We have more than tripled our annual external grant capture from £2.3M



in 2013/14 to £8.4M in 2019/20, resulting in a sustained year-on-year growth in research spend, more than doubling from an average of £1.95M p.a. in REF2014 to £4.76M in 2020, see Chart 2. Across the REF period, the portfolio consisted of 364 grants worth an aggregate £36.9M.



**Chart 2:** Dept research spend p.a. (Source: HESA 2020)

As measured by financial value, >82% of our research is conducted in collaboration with industry/end-users. This component of research has nearly quadrupled from £1M p.a. in 2012/13 to £3.7M p.a. in 2019/20. Supplementing this, we are also extensively involved in consultancy for industry. This is managed by the PBE Team (see §1d), generating £425K through 50 contracts with SME, non-SME businesses and non-commercial organisations.

Sustainability of research is evidenced by:

- Having a balance of funders. This REF, 53% of spend was from UKRI/RCUK funds, with 10% coming each from: Central Government, the EU, charities, direct industry funding.
- 84% FEC recovery for research over the REF2021 period. The HE sector as a whole is 72.9%, with only 13 out of 147 UK HEIs achieving >81% at institutional level (Source: OfS FSSG Report on Income Cross Flows, 2019)

We have had particular success in securing larger scale grants, with 11 awards with Departmental components >£0.5M. These have all either been led by Lancaster, involved extended international partnerships (see §1c.4 for detail), supported large cohorts of PhD students (CDTs, see §2d) or funded cutting-edge new facilities (see §3c), so being of direct benefit to our reputation and research environment.

Future research plans are described in §1e, critical success factors including staff growth and expanded engagement with funding bodies and industry especially in the area of advanced manufacturing.

### 3b. Infrastructure

In 2015, the Department moved into a new £12.25M, 4750 m<sup>2</sup> BREEAM 'Outstanding' building (Figure 1), including state-of-the-art laboratories for additive manufacturing, fuel cell, robotics, micro/millimetre wave device, nuclear, chemical and biochemical engineering research. Since then, due to growth in staff and students (Table 2), we have recently retaken possession of 1100 m<sup>2</sup> of refurbished supplemental space in our pre-2015 building and will expand into a planned £17M, 2,700 m<sup>2</sup> second new build (Figure 2). This will give us a total departmental space of ~8,550 m<sup>2</sup> of which research space, including laboratories and two strong-floors, accounts for

half. As part of the Cockcroft Institute, (see §1a, §1c.4, *passim*) we share its £10M, 3250 m<sup>2</sup> building and accelerator research labs at Daresbury.

Research Support Staff includes 2 Research Officers, 11 Technicians, 2 FTE Business Partnership Managers (BPMs) and a Research Administrator who supports the DRFC and grant management. The latter is also supported by an Engineering-dedicated Post-Award Administrator within central RES. The Department has one IT Technician with additional support from the Faculty IT Manager.

Research impact support is offered at:

- **Department level:** Engineering is supported by the LPDU (see §1d, §4c), two BPMs and an Impact Champion who direct strategy and resources for impact enhancement, including a Faculty Research Impact Fund for amounts up to £5K and EPSRC, STFC and HEIF-funded University IAAs for amounts up to £25K. Such funds are used for industry placement; innovative LU/end-user co-created early stage projects and for turning research outputs into commercial propositions. Since 2014, these funds have supported 42 projects with awards totalling £467K. All involved co-funding from industry ranging in size from SMEs (e.g. Tokamak Energy) to multinationals (e.g. Johnson Matthey).
- **Faculty level:** the 45-strong PBE Team helps organisations access expertise across three themes: Engineering and Physical Sciences; Computing and Communications and Environment and Sustainability. Each theme is led by a BPM who supports staff in maximising their impact, KE and user engagement.
- **University level:** RES provides support and resource for IP protection / commercialisation, proof of concept projects, KTP development, contract negotiation and KT/KE publicity.

### 3c. Facilities

Large, externally-won grants and Department growth plan-associated University investments (§1a) have led to substantial expansion in in-Department facilities. For maintenance and support purposes, each is associated with a specific Research Group; in practice, all are shared across all Groups at no-cost.

**The Nuclear Group** won >£5M from HMG/EPSRC to create open access national facilities that are part of the BEIS-funded National Nuclear Users Facility including:

- ADRIANA – one of the UK's few fast neutron sources for radiometric instrument research.
- UTGARD Lab – a cutting-edge comprehensively-equipped materials fabrication (including field-assisted sintering) and analytical facility for the study of nuclear materials and process chemistries.
- Accelerator Mass Spectrometer – unique in the UK, for monitoring and speciation of, *inter alia*, environmental plutonium.

**The SMM Group** won £1.8M of Lancashire Enterprise Partnership Growth Deal Funding to create ACADEME, a state-of-the-art 3D printing and additive manufacturing research and innovation facility. Sited within specially-refurbished laboratory space, this includes fused deposition extrusion systems for materials from polymers to ceramics, selective laser melting machines and full colour, cutting edge 3D printers.

Using Department growth plan investment, the SMM Group have also created a new specialist laboratory for advanced materials research with materials testing and characterisation equipment (including 3D-laser confocal microscopy, white light interferometry, AFM and SEM).

**The Chemical Engineering Group** have, using Department growth plan investments, created six new specialist laboratories since 2014:

- Two wet labs including: porosimetry, electrochemistry, microgravimetry, TGA, particle size analysers, chemical semi-pilot units (batch & flow reactors, extraction, filtration and distillation rigs) and a catalyst test rig (funded by the £4.92M NextGenChem project (§1d)).
- Two state-of-the-art fuel cells and battery testing laboratories, gas safe for 24/7 unattended running of fuel cells and equipped with numerous potentiostats and a chemisorption active surface analyser.
- Two bioengineering laboratories including: a clean room for cell culture and CAM assay work, including Class II biosafety cabinets, incubators, autoclaves, and cryogenic storage systems; and a wet synthesis/fabrication lab with spectroscopy/imaging facilities and tablet testing apparatus.

**The Electronic Engineering Group** has, through a series of grant successes and Department growth funds, invested in world class facilities including:

- A new class-1000 clean room (for optoelectronics, photonic materials research).
- A THz-Time Domain Spectroscopy system.
- A cutting-edge Travelling Wave Tube fabrication and test Lab with UV-LIGA, high-voltage power supplies, precision laser welding and a 0 – 220 GHz network analyser; and
- An advanced manufacturing laboratory with two XYZ CNC milling and two new high precision HAAS CNC lathes.

Through Cockcroft's Daresbury site, facilities also include a state-of-the-art CRAB/microwave measurement clean room lab with a 3-axis bead-pull facility and two 3 MeV X-ray sources for cargo imaging.

**The Energy Group** has a number of well-established large-scale facilities including a 1/50<sup>th</sup> scale wave/tidal flume tank (recently upgraded with adjustable floor), siphon and low-head hydropower facilities and turbine & cavitation laboratories (marine energy research) and a wind tunnel and jet engine (wind energy and combustion research).

**Intra-institutionally**, we are regular users of:

- Lancaster's High End Computing cluster (450 25 Gb/s Compute Nodes, 8,800 cores, 40TB memory) for CFD and multi-scale materials modelling work.
- The Quantum Technology Centre's £4M clean room (including e-beam lithography, plasma deposition CVD, SEM-EDX and numerous scanning probe microscopies) for materials fabrication and characterisation.
- The Materials Science Institute's state-of-the-art, high throughput/resolution Kratos XPS.

**Extra-institutionally**, our extensive collaboration network provides access to world-class facilities including:

- Synchrotron light sources *via* Diamond.
- Particle accelerators *via* our membership of Cockcroft.
- Radiation sources at ISIS, Oak Ridge National Lab, the NPL, Manchester University, the Jožef Stefan Institute Research Reactor and Fukushima's Naraha Remote Technology Centre.
- NNL and EU Joint Research Centre facilities for working with highly radioactive materials including plutonium and spent nuclear fuel.
- Wave tank and fluid machinery testing facilities at the University of Athens and Institute of Ocean Engineering, Zhejiang.
- Advanced electron microscopies at Sheffield's Sorby Centre and Tsinghua University.
- Electron beam welding, friction stir welding and brazing facilities at key strategic partner TWI.

Through membership of the EPSRC High End Computing Materials Chemistry Consortium and UK Applied Aerodynamics Consortium, we have access to the ARCHER Supercomputing Service, using ~£220K of access p.a. and have used 13 million core hours on the Blue Joule IBM BG/Q cluster at STFC's Hartree Centre.



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

##### 4a. Research Collaborations, Networks and Partnerships

Reflecting the success of our strategy to deliver excellence *via* partnerships (§1b.1) collaborations have increased in number and strength to >150 groups in >30 countries over 5 continents. Examples of **international collaborations and networks** are given in §1c.4 whilst exemplars of **nationally based collaborations** and end-user relationships are given below.

**The Nuclear Group** has an extensive network of relationships with all of the UK's major nuclear universities, end-users and implementers. Examples of these are:

- ATLANTIC, an EPSRC-funded, £2.5M 12 university collaboration with NNL, where Lancaster is leading on the disposability of new accident-tolerant fuels.
- TRANSCEND, an EPSRC-funded, £4.5M collaboration in the area of nuclear decommissioning involving 10 universities, 8 industrial partners, where Lancaster is leading on understanding plutonium storage.
- The BEIS-funded Advanced Fuel Cycle Programme, in collaboration with NNL and 5 HEIs that has funded Lancaster's UTGARD Lab (§3c) to a total of >£1.2M to develop a safer and more secure route to mixed oxide fuels.
- Two EPSRC nuclear robotics hubs – RAIN and the National Centre for Nuclear Robotics – total funding of £23.8M, involving 16 universities and 50 end-user/ industrial partners.

**The Electronic Engineering Group**, part of the Cockcroft Institute since its creation in 2005 (§1a, §1c.4), has a deep, on-going relationship with CERN. Its post-2012 expansion into microwave, THz and photonic materials research has led to the following collaborations:

- HyperTerahertz, an EPSRC-funded £6.5M collaboration seeking to develop high precision terahertz spectroscopy and microscopy, involving 5 UK HEIs, the Universities of Jerusalem and New Jersey and 11 end users including NPL, Sandia National Laboratory and Toshiba
- DLINK, an EPSRC-funded £800K collaboration with Glasgow seeking to demonstrate high capacity sub-THz communication systems.
- A £570K RAEng Fellowship in collaboration with Procal, Pilkington and IQE developing mid-infrared semiconductor materials on silicon.

**The SMM Group** has a strategic partnership with TWI (§1c.4, §1d, §2d) with research projects and students located at Lancaster and TWI Cambridge. Other collaborations include:

- Carpenter/LPW Technology Ltd co-funding a RAEng Research Chair (§2a) focused on alloy and microstructure design for additive layer manufacturing.
- 145 businesses and SMEs benefitting from expert, research-derived design support and cutting-edge facilities via the LPDU (§1d).
- A new University Enterprise Zone in Secure Digitalisation (SecureD UEZ), a collaboration with Security Lancaster (Table 1). Funded by £1.5M from the Research England Development Fund will support businesses to digitalise securely.

**The Chemical Engineering Group** have long-standing relationships with key players in the fuel cell space including AFC Energy and Ceres Power (ICS-Dawson, §4b). Alkaline fuel cell work with the former is currently funded by the SuperGen Hydrogen and Fuel Cells Hub, one of two SuperGen Centres to which the Department has been affiliated since 2014.

As well as the GCRF-funded RECIRCULATE (§1c.4), the Group has collaborated with EDF on a £20M proposal to BEIS's Hydrogen Supply programme and with AGM Batteries, Quantum Base, CNC Asset, Delta Motorsport, Altelium and Brill Power on two battery-focused InnovateUK projects with a total value of £1.2M.

**The Energy Group** has worked extensively with the World Bank, HMG, and the RAEng and IET on a number of learned reports, influencing policy (§4b). Other key collaborations include:

- A strategic relationship with Sunway University, Malaysia in renewable energy (§1c.4).
- Membership of SuperGen Marine (14 HEI, 5 industry partners) for its whole 2003-2019 funding period.
- Membership of the £10.2M Faraday Institution-funded Multi-Scale Modelling Fast Start advanced battery project; with industry partners Jaguar-Land Rover, BMW, Delta Motorsport, BBOXX, AGM Batteries.
- Complementing RECIRCULATE above, the Group leads a number of RAEng/GCRF-funded projects in the aligned areas of off-/micro-grid energy (Africa, Myanmar) and energy education (Africa) in collaboration with UjuziKilimo, Ubuntu Power (Kenya), Sunlabob and Energy Action Partners (Laos).

#### 4b. Contributions to the Economy and Society

Since 2014, the Department has made a wide range of contributions to, and delivered impact significant to, *inter alia*, the economy, society, public policy and the environment. These have all been delivered by working in close cooperation with key beneficiaries such as business, policy makers, NGOs, professionals/practitioners and the public. Types of contributions and impact delivered are exemplified by our ICSs and other examples below.

**Economic impacts** across all sectors by growth of spin-outs and provision of knowledge, IP and training to >300 (inter)national businesses and innovation-focussed SMEs. Examples include:

- ICS-Joyce, for which Lancaster, Createc, Costain and OC Robotics have developed new products and businesses for safer nuclear decommissioning;
- ICS-Richardson, the provision of test engineering protocols used by STMicroelectronics to achieve mass market penetration of its MEMS, integrating them into Apple and Nintendo products;
- ICS-Dawson, for novel fuel cell technology, generating >£100M of license and investment income for Ceres Power from 2018 on and leading them to create an £8M UK fuel cell manufacturing facility and 100 new jobs.
- Spin-out LiNa Energy Ltd, exploiting novel sodium batteries developed by Dawson (also a founding director), recently raising >£2.5M via equity release and BEIS funding;
- Spin-out Hybrid Instruments, applying radiation detection technology developed by Joyce (also Technical Director) for nuclear safeguards with instrument sales across the globe;
- The LPDU whose business assistance and employment creation/protection metrics are summarised in §1d. Noteworthy assists include AmDel Medical Ltd that saved the NHS £2M p.a. via optimised ocular speculums and Assured Performance Group Ltd, impacting their UK fleet of 800 vehicles.
- Our ERDF-funded initiatives, CUSP, NextGenChem, GISMO and the AI Foundry (§1d) targeting >500 business interactions to generate economic and societal impact.

**Quality of Life Impacts** via the development of novel high capacity millimetre wave wireless networks for the global roll-out of 5G/6G telecommunications (Paoloni).

**Societal impacts** through increased security derived from the uptake of novel nuclear materials monitoring technology by international security and safeguarding agencies; the use of that technology for the depth profiling of radioactivity to significantly reduce risk during nuclear clean-up, ICS-Joyce; and the regulation of professionals and practitioners, especially in construction by provision of international design guides for glass fibre reinforced polymer structures, ICS-Turvey, regulating safe construction of >800 bridges, walkways and viewing platforms worldwide.

We work with numerous organisations to promote engineering in the wider community, through outreach and schemes such as those run by the Smallpeice Trust, the Engineering Education Scheme, Headstart and the Arkwright Trust (we sponsor an Arkwright scholar). Staff and students regularly get involved in PEI themed events and careers fairs (IMechE Engineering your Future, Big Bang, Cumbria STEM Centre events), using these opportunities to champion women engineers to a wider audience. Activities are supported by the Department's full-time Schools' Liaison Officer (funded by the Sir John Fisher Foundation), focused on engagement with local schools, colleges, teachers and aiming to foster interest in engineering research at primary level. Awarded a Lancaster Staff Prize, 2019, this activity has attracted interest from the RI, via invitations to host their masterclasses, and from the RAEng, via a prestigious Ingenious Award for Public Engagement. Typically, this disseminates our research to >1300 children at >50 schools p.a.

**Policy impacts** in the areas of communications, energy and mobility/transport via evidence to the European Commission and select committees, representation on international delegations and reports to UK HMG. The former is exemplified by the H2020 TWEETHER project, led by Paoloni, resulting in the redaction of ECC Recommendation (18)02, allowing for Point-to-MultiPoint operation in the W-band. The latter is exemplified by a RAEng report on system integration by Kemp, highlighting the key uncertainties involved in the UK electricity network, and influencing DfT policies on plug-in hybrid vehicles and electrification of railways, via presentations to e.g. the Engineering Group in the House of Lords. His RAEng "Living without Electricity" report (§1c.1) has been widely cited by the Ministry of Housing, Communities and Local Government, BEIS and the Cabinet Office and caused Ofgem to develop new guidance about the monetary value for preventing electricity blackouts.

**Cultural Impacts**, exemplified by local interest in the 'Living without Electricity' report, emulated (inter)nationally by media and press, leading to Lancaster's Dukes Theatre producing an original play ('Blackout') based on testimony from residents, community organisations and emergency responders. Following coverage in the national press and broadcast media (Top Gear), Kemp's transportation research was adopted by the NGO Rail Safety and Standards Board, for the calculation of rail emissions, and used in HS2 debates.

**Environmental Impacts** via provision of understanding of fuel cell manufacturing processes to inform new designs to reduce waste in clean energy production, ICS-Dawson. Experimental and computational modelling for new hydropower turbines for renewable energy generation, used by Northern Tidal Power Gateway in their submission to HMG in 2019 of the £10Bn business case for the Morecambe Bay Bridge (Aggidis); and the CAPTAIN Toolbox, time series analysis software, used by >100 researchers worldwide to quantify, *inter alia*, environmental change, and pollution reduction (Taylor).

#### 4c. Contributions to the Research Base

Staff have received numerous awards, prizes & fellowships in recognition of their contributions to the community. Noteworthy are:

- Kemp's MBE for Services to Engineering (2016);
- Joyce's RS Wolfson Merit Award (2016) and ICE's James Watt Medal (2014);
- Clarivate/WoS naming Aroua (2018) and Rahman (2018, 2020) as Highly Cited Researchers;
- Aroua receiving a Gold Medal at the Innovation Invention & Solution Exposition at EUREKA and an IChemE Global Award (Water Category).

**Staff hold fellowships** of the RAEng and Royal Society of Arts (Kemp), IOM3 (3 staff), IMechE (3), IET (2), Women's Engineering Society, Energy Institute, Institute of Marine Engineering, Science & Technology, the Nuclear Institute and ICE.

**Staff hold visiting professorships** at NUDT, Changsha, China, (Joyce, Ma); Bergamo (Deq'Innocenti); University of Malaya, Institute National Polytechnique de Toulouse (Aroua);

Pakistan's University of Health Sciences, King Faisal University, King Saud University ([Rehman](#)).

**Post-2014, 24 staff have sat as members of advisory boards and UKRI/RCUK, learned society & professional body committees** including service as members of UKRI/RCUK, 15 peer review colleges, peer review panels (which [Boxall](#) has chaired), H2020 evaluators and IOM3 accreditors:

- [Kemp](#) sits on the IET Energy Policy Panel, was a member of RAEng working groups investigating the penetration of wind energy and sustainability of biofuels, a member of the Project Delivery Board of a major IET study on the UK's Future Power Systems Architecture and has represented the IET and RAEng to Parliamentary Select Committees.
- [Aggidis](#) has provided advice to BEIS on Tidal Energy (2018-19), he is a board member of the IMechE Emerging Technologies Advisory Committee and Energy & Environment Group and the IET Renewable Energy Advisory Board.
- [Paoloni](#) is Member-at-Large of the IEEE Electron Device Society Board of Governors and Chair of the Vacuum Electronics Technical Committee.
- [Joyce](#) is co-Chair of the National Nuclear Users Facility and sits on HMG's Nuclear Innovation & Research Advisory Board.
- [Ye](#) is on the ASCE Stability Committee.
- [Montazeri](#) is on the IFAC Technical Committees for Adaptive & Learning Systems and Modelling, Identification & Signal Processing.
- [Boxall](#) has been a member of FCO delegations representing the UK to Nuclear Collaboration Workshops (US 2014, Japan 2015, 2019) and has presented to a Parliamentary Briefing on the Future of Nuclear Power (2016).

**Staff and students regularly organise and present at conferences. Since 2014, we have given >300 presentations at major conferences worldwide including 23 keynotes and 13 plenaries**, the latter at events including: International Conference on Heat Treatment and Surface Engineering ([Pinkerton](#), 2016); National Congress on Membrane Technology and International Congress Energy Security & Environment ([Aroua](#), 2016, 2018); Application of Molecular Spectroscopy in Nanomedicine Workshop ([Rehman](#), 2014); CST SIMULIA European User Conference ([Paoloni](#) 2018); The Third International Conference on Water, Energy and Environment ([Aiouache](#), 2015).

**We have organised 60 conferences at 27 locations in 16 countries, serving as programme chairs on 30**, including: Living without electricity workshop (attendees including Cabinet Office, BEIS, Ofgem, DCLG) 2016 ([Kemp](#)); IEEE Nuclear Science Symposium Medical Imaging Conferences 2017, 2018, IEEE International Conference on Nuclear Instrumentation Measurement Methods and their Applications 2017, Physics of Reactors 2020 ([Joyce](#)); LINAC 2016 ([Burt](#)); 7th Multiscale Materials Modelling International Conference 2014 ([Rivera](#)); IUMRS 2014, EMRS 2014, 2015 ([DeGuelldre](#)); Euromat 2017 ([Kennedy](#)); IEEE International Conference on Automation and Computing 2018, 2019 ([Ma](#)); International Vacuum Electronics Conference 2017, European Communication Network Conference 2017, European Conference on Networks and Communications 2018, IEEE Wireless Communications and Networking Conference 2018, 5G World Forum 2019 ([Paoloni](#));, National Vacuum Electronics Conference 2016 ([Letizia](#)).

**Staff are/have been on the editorial boards of 16 major international journals**, including. Editor-in-Chief of Progress in Nuclear Energy ([Joyce](#)) and Editors of IEEE Trans. Electron Devices ([Carter](#), [Letizia](#)); Composite Structures ([Turvey](#)); Adv.Mech.Eng ([Ye](#)).

**Staff have guest edited 5 special issues of journals** including Frontiers in Chemistry ([Aroua](#), 2020), IEEE Trans. Electron Devices ([Paoloni](#), 2014).