

<b>Institution:</b> University of Huddersfield
<b>Unit of Assessment:</b> UOA12 Engineering
<p><b>1. Unit context and structure, research and impact strategy</b></p> <p><b>Overview</b></p> <p>The University has long-established links with engineering and manufacturing industries, dating back to the precursor Huddersfield Mechanics Institution formed in 1843. These links remain strong and Engineering is, by some margin, the largest area of research activity within the University. Having grown significantly in the previous REF period (37 staff submitted to General Engineering in 2013 compared to 10 in 2008), the UoA has continued to grow strongly with <b>88 staff (84.7 FTE)</b> now being submitted to UoA 12, Engineering, for this assessment. In parallel, research-related income has grown considerably from <b>£7,323,689</b> during the previous assessment period to <b>£37,311,669</b> in the current assessment period, including large and prestigious awards across a range of funding streams. This rapidly expanding portfolio remains grounded in the institution's principles of undertaking user-inspired research that delivers real and lasting impact, maintaining an ethos created over 175 years ago.</p> <p>Particular highlights during the period include <b>The EPSRC Future Metrology Hub (£10.3m of EPSRC funding)</b>, The UK Rail Research Innovation Network, <b>UKRRIN (£9.5m of Research England funding)</b> and the <b>'MIAMI-2' microscope and ion accelerator facility (£3.5m of EPSRC funding)</b>. These complement many other research, collaborative R&amp;D and knowledge transfer projects across many areas of application and industry sectors.</p> <p>The UoA is based wholly within the University's School of Computing and Engineering, which itself is divided into <b>two</b> Departments; Engineering and Technology (in which the vast majority of the UoA activity resides) and Computer Science. Research institutes/centres/groups within Engineering and Technology submitting staff and outputs are summarised below:</p> <ul style="list-style-type: none"> <li>• The <b><u>Centre for Precision Technologies (CPT)</u></b> is a large and well-established research team focused on aspects of engineering associated with precision manufacturing and, specifically, manufacturing metrology. Activity is broadly organised into four groups: Surface Metrology, Engineering Control and Machine Performance, Bio-metrology, and Optics Manufacturing, with extensive collaboration across these groups. <b>CPT is host to the EPSRC Future Metrology Hub</b> and additionally has a wide portfolio of programmes with EPSRC, EU, Innovate UK, RAEng, and direct industry funding. The group is submitting <b>25 staff (24.8 FTE)</b> to the UoA. These include internationally respected senior academics (Jiang, Blunt, Scott, Longstaff and Walker) plus a large group of established and early career researchers (Bills, Martin, Fletcher, Gao, Zeng, Yu, Tong, Qi, Lou, Williamson, Pan, Addinall et al.). CPT also maintains a large community (c.40) of Post-Graduate Research students. CPT has a strong network of academic and industry partnerships, nationally and internationally, and has excellent links to national measurement institutions (NPL, NIST, LNE) and to the UK's High Value Manufacturing Catapult Centres.</li> <li>• The <b><u>Institute for Railway Research (IRR)</u></b> is another large and well-established research team, submitting <b>17 staff (16 FTE)</b> to the UoA. With a focus on railway vehicle interaction with track and infrastructure, research topics include various aspects of suspension, wheel-rail contact, traction and braking, and track. As part of the current <b>Research England funded UKRRIN project</b>, IRR is also extending its portfolio to include pantograph/overhead-line interaction. The IRR has grown rapidly over the assessment period and has a very strong reputation within the rail industry, working closely with a wide group of industry partners to improve rail safety, performance and efficiency. This was recognised in 2020 with the <b>award of the Queen's Anniversary Prize, for research and development that has brought significant improvements to the railway industry</b>. This network of industry and academic contacts also extends internationally, and IRR is actively involved in European rail collaborations and networks. IRR has a senior academic team</li> </ul>

(Iwnicki, Allen, Bevan, Bezin, Pombo) supported by a large team of researchers (Crosbee, Shackleton, Tucker, Antunes, Wang, et al.) and PhD students.

- The **Centre for Efficiency and Performance Engineering (CEPE)** is a large and diverse group conducting research across subject areas including diagnostics, thermo-fluids, signal processing, and power engineering. This group has a strong international reputation and long track-record in the condition and performance monitoring of industrial assets such as rotating equipment (motors, pumps, compressors, turbines, etc.). The group has strong international networks with other research groups in the field and a long track-record of industrial collaboration, with an active portfolio of Innovate UK and direct industry funded research programmes. During the period, the group has developed new interests in thermoacoustic technologies, electrical power, green energy and powertrain applications, and also works increasingly across engineering and computer science disciplines. CEPE has recently begun a **strategic partnership with TWI** (£0.5M TWI and £0.5M UoH) for 12 PhD joint scholarships. CEPE is submitting **22 staff (21.3 FTE)** to the UoA, including senior staff (Ball, Jaworski, Gelman, Gu, Schofield, Allport) and a large group of both established and early career researchers (Lazaridis, Mather, Smith, Tahera, Hafeez, et al.).
- The **Ion Beam Centre (IBC)**, made up of two core groups in the fields of Accelerators and Electron Microscopy and Materials Analysis, is submitting **9 staff (8.1 FTE)** to the UoA, including senior staff (Donnelly, Edgecock, Seviour, Van den Berg, Vishnyakov) and both established and early career researchers (Hinks, Greaves, Rossal, and Mir). Much of this group's work is a multi-disciplinary combination of engineering, physics and materials, and a several staff were submitted to non-engineering UoAs in the last REF assessment. The group has a strong international reputation around innovative particle accelerator development and the use of particle accelerators for probing the properties of materials. This work is conducted using the group's extensive research infrastructure and these facilities ('MEIS' and 'MIAMI') are **part of the EPSRC UK National Ion Beam Centre**.
- The **Centre for Audio and Psychoacoustic Engineering (CAPE)** specialises in the study of auditory perception and its application in audio engineering and music technology. In particular, CAPE is active in researching the perception, recording and reproduction of audio for immersive 3D and VR formats, and has specialist facilities (see section 3), including a 3D audio reproduction room, to support this work. The group is submitting **5 staff (5 FTE)** to the UoA (Lee, Bourbon, Moore, Fenton and Mynett), all of whom are established academic staff. The Centre has strong international research relationships and active interdisciplinary collaboration with staff within UoA 33 (Music).
- The **Centre for Engineering Materials (CEM)** is a multidisciplinary centre with members of staff from across several schools and UoAs. Staff associated with the Centre are undertaking research in new material synthesis, characterisation of materials, and the development of material applications across wide-ranging sectors such as healthcare, energy, transport, textiles and food processing. The group is submitting **4 (3.5 FTE) staff** to this UoA (Mishra, Barrans, Lambrinou, Aliyu), though many of its associated academics and researchers are linked to other groups (CEPE, IBC, IRR) or being submitted to different UoAs more closely aligned to their main research focus.

A small number of staff submitting in this UoA are from research centres that sit within the Department of Computer Science:

- The **Centre for Planning, Autonomy and Representation of Knowledge (PARK)** is a cross-school, multi-disciplinary group primarily engaged in the computer science domain, and most of its staff will be submitted to UoA 11. However, as a result of active research programmes in engineering control and high-performance computing, the group is submitting **4 staff (4 FTE)** to this UoA (Holmes, Pandey, Dhimish and Johnson).
- The **Centre for Mathematics and Data Science (MDS)** is a recently formed group submitting **2 (2 FTE) staff** to the UoA (Lee and Coman). The group focuses on applications of mathematics and data science to problems of industrial and societal relevance.

It is worth noting that the UoA's research structure represents a **significant diversification and expansion from 2014**, when all staff came from only four research groups within the Engineering and Technology Department (CPT, IRR, CEPE and Systems Engineering), and this is reflected in how the UoA has developed and performed against its objectives, as well as influencing its strategy for the next assessment period.

### Research strategy and objectives

During the assessment period the University targeted **three-fold growth** and uplift in the 'level' at which academics and researchers were contributing to and influencing their subject area through **increased production of high-quality peer-reviewed publications, securing of competitively applied for funding, and impact generation** activities. Cascading from this is a School research strategy with local targets and priorities which influences where and how investment and support decisions are made but does not seek to influence the specific nature/subject of research being conducted. Broadly following the **Industrial Strategy Grand Challenges**, the School strategy, which is closely aligned with the UoA, is led by the School's Associate Dean for Research, with support from the School's senior management team, and regularly reviewed by the School's Research and Enterprise Committee, which has members from all of the UoA's research groups.

The UoA strategy and objectives expressed at the start of the assessment period (2014) were focused on the then four key research groups (CPT, IRR, CEPE and Systems Engineering), how they could respond to priorities within the UK's Industrial Strategy, and with an emphasis on **growth and the achievement of high-quality applied research and impact with industry partners**. The UoA was also guided by the University's overall research strategy and key performance indicators, which emphasised the same priorities. To achieve this a number of initiatives were described:

#### a) Consolidation and further investment of time, resource and capital equipment in the four primary research areas.

With the diversification of the UoA (described earlier) and inclusion for this submission of staff from Physics/Materials backgrounds, investment has been wider than the four groups described in the last REF statement. CPT, IRR and CEPE have still benefitted from support through capital investment/co-investment, new staff appointments, re-investment of project surpluses, and significant support from University and School-based business development, technology transfer, and research administration staff. This support has, however, also been extended to the IBC, CAPE, and CEM groups. **All groups have grown (in terms of staff and income levels)** during the assessment period, as evidenced by the overall growth already outlined and described in more detail in **Section 3**. The UoA has also benefitted from central and school-based investments in support staff, including, for example, the creation of centrally funded '**Research Development Manager**' posts, the creation of a school-based '**Impact Officer**' role, and growth of pre- and post-award teams to support academics/researchers in securing and delivering research projects. Investments have also been made in capital equipment, detailed further in section 3.

#### b) Identification of fundamental gaps in research capability, supported by recruitment of additional staff/teams to address these gaps.

CPT, IRR, CEPE and IBC have grown significantly, with new research programmes driving recruitment of staff to complement existing expertise, primarily in closely aligned areas of expertise. In the case of CEPE, with the previous group head (Ball) having senior management responsibilities (Pro Vice Chancellor for Research and Enterprise) a new senior academic lead was headhunted and appointed during the current period (Gelman). In terms of a specific gap in research capability (and in an area identified as an institutional priority) Materials Science was an area targeted for investment and a senior academic to lead CEM was recently appointed (Lambrinou). More details of relevant activities supporting this priority are described in **Section 2** of this document.

**c) Recruitment and development/mentoring of staff with the potential to become research leaders in their chosen field.**

As described above, research groups have grown over the period and there is a significantly larger community of academics and post-doctoral researchers in the UoA compared to 2014, including many early and mid-career staff. Development and mentoring of these staff is a priority for continued growth and achievement of objectives, both now and in the future, and is described in detail in **Section 2** of this document.

**d) Formation of partnerships with research intensive academic/research institutions, and key industry partners.**

With a research strategy focused on growth of research income and research quality/impact, the development of a broader portfolio of research collaborations with high calibre researchers in other academic institutions (nationally and internationally) has been hugely important, as has been a focus on increasing R&D collaboration with industry partners. Actively supporting researchers in the UoA to bid more into UKRI funding streams (e.g. EPSRC and Innovate UK), and to pro-actively develop research relationships with high-quality international research groups, has seen significant growth in both of these types of collaboration, and this is described in more detail in **Section 4** of this document.

**e) Creation of clear and mobile career paths for progression of researchers.**

With the significant growth that the UoA has achieved over the past two REF periods, research now represents a large proportion of the activity and income of the School (c. 50% in 2019/20), and there is a large community of research active academic staff and post-doctoral researchers employed within the area. Having clear career paths that take into account successful research activity has become increasingly important as this community grows, and a number of steps have been taken to ensure that these exist, both in terms of postdoctoral researchers securing permanent academic posts (successful examples include Martin, Bills, Mian), and for established academic staff seeking promotion within their career paths (e.g. Longstaff, Gu, Allen, Lee, Bills, Hinks). These are described in more detail in **Section 2** of this document.

In addition, some specific emerging challenges were identified in the strategy as priority targets, in particular technologies associated with future manufacturing and engineering challenges around real-time and in-situ measurement, imaging/visualisation and remote sensing. These areas of research feature highly in many of the research activities of the UoA's large research centres (CPT, IRR and CEPE) and are key themes/work packages in a large number of research projects and collaborations, as evidenced by the body of outputs being submitted by the UoA.

Looking ahead to the **future research strategy**, the initiatives and priorities described above remain relevant as the UoA strives to continue on a path of growth in research quality, income and impact. In particular, the significant work and investment supporting academics and researchers (particularly early career staff) to achieve these aims remains a strategic priority for the UoA.

In terms of specific research areas, the Department of Business Energy and Industrial Strategy (BEIS) first issued a policy document in 2013 outlining their envisioned future **Grand Challenges**. In September 2019 and July 2020 (Research and Development Roadmap) the strategy was updated, however the primary four grand challenges in the post-Covid era remain; Artificial Intelligence and Data, Clean Growth, Future Mobility, and Ageing Society.

The BEIS industrial strategy grand challenges can be mapped onto UKRI strategy in terms of their themes of **Digital Economy, Energy, Manufacturing the Future and Engineering**, and these themes are the basis of our UoA research priorities, with each of these themes having significant activity undertaken within the UoA. Consequently, the UoA has a clear guiding strategy for its key Research Institutes and Centres. Additionally, the UoA's Institutes and Centres align with **University ASRI's (Areas of Strategic Research Importance)** namely; Digital Manufacturing and Industry 4.0, Productivity, Energy and Materials, Infrastructure and Sustainable Environment,



and Creativity. Hence, there is a holistic research strategy cascading down from industrial grand challenges, through University research priorities, down to UoA Institutes and Centres.

Furthermore, the University's Strategy Map (2018–2025) includes several objectives and KPIs associated with research and these have been subsumed into School/UoA objectives. For UoA 12 this means that performance will be monitored against the following 2025 KPIs:

- 100% of academic/research staff publishing at a quality that is at least recognised internationally in terms of originality, significance and rigour.
- 75% of academic/research staff publishing at a quality that is at least internationally excellent in terms of originality, significance and rigour.
- 15% of research outputs co-created with research end-users (primarily industry).
- Annual research-related income of £13m

These KPIs will be used as part of annual planning cycles to steer progression over the next REF period.

An additional priority for the UoA in the next period will be to build upon and expand multi-disciplinary research collaborations. The CEM research group was established as a multidisciplinary centre (including engineering, applied sciences and health) and focused investment of the University's EPSRC Doctoral Training Programme (DTP) has helped drive collaboration in this area. There is already a rapidly growing portfolio of work across engineering/computer science/mathematics disciplines as AI and data analytics are an increasingly critical aspect of engineering/manufacturing solutions, evidenced by much of the work of CPT, IRR and CEPE research groups and by a number of staff from PARK and MDS research groups being submitted within this UoA. Established links also exist between music technology (in engineering) and music (UoA33) and are developing between engineering and biology (UoA5) in response to grand challenges in both the ageing population (e.g. medical sensors, devices and applications) and clean growth. New opportunities for cross-institution collaboration are also being created via Industrial Strategy and Global Challenges sandpit events organised by the University's central Research & Enterprise function, with which UoA researchers have actively engaged.

### Research Impact

As described above, the University's links with engineering and manufacturing industries are strong and the UoA impact strategy is one of close collaboration with industry partners to accelerate knowledge exchange and the adoption of new technologies to deliver impact. This includes extensive use of funded mechanisms such as **24 KTPs** (Knowledge Transfer Partnerships) and **c.25 Innovate UK Collaborative R&D** programmes during the period, and a growing portfolio of **research contracts** and **IP licenses/assignments** funded directly by industry partners. To help researchers engage in these activities the School has invested in its own Business Development team (two full-time staff) and created a new full-time Impact Officer role during the current REF period to support staff in achieving successful impact outcomes from their research. This (and other) investments in supporting infrastructure, and the benefits they have delivered to research income, are described in more detail in **Section 3** of this document.

The UoA (primarily through the School's Business Development team) also draws heavily on the University central resources to support technology transfer activities, as well as the growing legal and contracts teams that help facilitate contractual/collaboration arrangements with industry partners. During the period, the UoA's research programme has created new technologies which are the subject of numerous **new patent applications** and several new **IP licenses/assignments** with industry partners (which will generate future revenue through royalty-based mechanisms) and is currently in the process of creating a new **spin-out company** (Cubit Precision Measurement Ltd) to exploit new metrology instrument technologies from the CPT research team.

The UoA is submitting 7 (seven) Impact Case Studies for this assessment period, and these have been selected from a 'long-list' (c.15) of case studies that were initially proposed by research group leaders and discussed/evaluated by the School's Research & Enterprise Committee. Given the

extended period it typically takes for underpinning research to deliver industry-based impact, it is not surprising that the bulk of the selected case studies (five of the seven) are from the large and well-established research centres of CPT and IRR, where long-term research programmes and multiple industry partnerships are delivering significant economic and societal impacts, in some cases as much as 10-15 years after the original research began. In line with the UoA's strategy of strong engagement with industry partners, all of these case studies rely heavily on evidence and testimonials from industry partners to demonstrate their impact, these being from a diverse group of industry sectors including aerospace, automotive, rail, metrology equipment/software/services, flow handling (e.g. industrial valves), and audio engineering (e.g. microphones and speakers). A number of the more recently established/growing research groups in the UoA (CEPE, IBC, CAPE) are also developing excellent impact pathways and these are expected to deliver strong new Impact Case Studies over the next REF period.

### Open Research

The UoA is committed to ensuring publicly funded research is openly accessible, transparent, collaborative and efficient. The UoA actively uses systems which the University has invested in to promote open research and open access to research outputs, and research data management (e.g. Elsevier's PURE information system). Where conflicts may occur (e.g. industry funded research, new IP requiring protection prior to publication) support is provided to researchers from Business Development and Research Development staff to proactively manage issues within the context of the Institution's policies. Whilst much of the UoA's applied research and knowledge transfer activity is driven by industry partners (and therefore commercially sensitive), some researchers are active in developing/contributing to **open-source software**. For example, significant work has been contributed to the OpenFOAM® open source CFD toolbox by researchers within the UoA, and which is being applied to support industry partners. Similarly, where appropriate researchers are **publishing data sets** accessible to the wider research community. For example, researchers in CPT have contributed research data to the NIST Ballistic Toolmark Research Database (<https://tsapps.nist.gov/NRBTD>).

### Research integrity

The UoA is committed to having a culture that promotes research integrity, in line with the University's commitment to the Concordat to Support Research Integrity. An institutional Code of Practice for Research provides the framework under which researchers operate, and all new projects and proposals are subject to ethical review and approval as part of a standard sign-off process prior to project approval. Where specific ethical concerns may exist, the School Research Ethics Committee provides guidance and support to researchers, as well as a link to the Institution's University Research Committee which has overall governance of research integrity.

## 2. People

### Staffing strategy

The UoA's staffing strategy underpins the growth ambitions of the area. A successful research track-record is a pre-requisite for all new academic and researcher staff appointments, with all expected to have a PhD (or equivalent qualification). In the case of senior appointments there is an expectation that track-record will include significant high-quality research outputs and evidence of securing competitively awarded research funding, and of successful collaboration with industry partners. In the case of early career appointments, evidence of the potential to develop these outputs is a key element of the recruitment process. These criteria have been applied to all new academic/researcher appointments in the UoA, with **46 new academics/ researchers appointed** to the UoA during the current REF period, all either having a PhD or actively undertaking PhDs.

Growth (and retention) of staff within the UoA is primarily achieved through successfully securing external funding from sources including EPSRC, H2020, Research England, RAEng, and Innovate UK, with this funding supporting (or at least partially supporting) Post-Doctoral Research Assistants (PDRAs). The UoA's impressive track-record in recent years has enabled growth in staff numbers, and this has been further enhanced by significant investment from the School in which the UoA is based. Throughout the current REF period, the School has had a research

income distribution model in which a large proportion of overheads (indirect and estates costs) received from grant-funded programmes are returned directly to the research groups for reinvestment. This has enabled groups to recruit additional staff, cover funding gaps for PDRAs between grant-supported projects (i.e. retaining experienced PDRAs), to develop and maintain research facilities, to invest in network building, and to develop new research and impact opportunities. This funding model (particularly for the larger groups with broad portfolios) has enabled significant growth in the PDRA community, and has also enabled the vast majority of staff **(80.2 FTE, 95% of total) to be employed on permanent contracts** (i.e. not fixed-term linked to a specific grant/project), providing a much more stable environment in which early career researchers (ECRs) can develop. This has enabled staff to successfully progress their careers, either as research-focussed staff (Hinks, Allen, Bezin, Gao, Fletcher, Zeng, et al.) or through transition to academic staff positions within the School (Martin, Bills, Mian et al.) where they can continue to develop their research interests. Some of these staff have also taken on significant management/administrative duties to support the ongoing development of research. For example, Hinks is current Director of Graduate Education with the School. The overall success of the UoA's staffing strategy can clearly be seen in the growth of the UoA, with 88 staff (84.7 FTE) submitted compared to 37 in 2013. Of the total submission, **43 staff gained their PhD qualification during the current REF assessment period** (i.e. since 2014), meaning the UoA now has a significant and active ECR community, which will be vital to its continued success and succession planning.

The UoA has further grown through access to the University's Research Excellence Staffing Scheme (RESS) which was established in 2016 to support (fund) opportunities for high-calibre senior research staff from other institutions to join the University. **Six new senior staff have joined the UoA during the period using this scheme**, Professors Walker (CPT), Gelman (CEPE), Lambrinou (CEM), Jaworski (CEPE), Schofield (CEPE) and Lee (MDS).

### Staff Development and Progression

In terms of staff development and advancement, the University is an 'HR Excellence in Research Award' recipient and the UoA adheres to the national Concordat to Support the Career Development of Researchers, which sets out the seven key principles for funders and employers of researchers in the UK. The UoA aims to support staff according to these principles whatever their career stage and believes a supportive culture enhances researcher performance, improves staff retention, and aids recruitment of both staff and post-graduate students. All staff undergo an annual personal development review/appraisal which includes consideration of research performance and planning, including identification of specific training and development needs/opportunities. Research performance is an important metric for successful career progression for both academic and research staff, with indicators such as research outputs, income, and successful Post Graduate Researcher (PGR) supervision essential for progression to senior academic/researcher positions.

During the current REF period, **seven existing ECRs have secured academic positions** within the School, and a total of **39 staff within the UoA have had some form of promotion/career progression**, either within their existing roles or to new roles within the School.

In terms of development and training, the UoA has access to a large institutional staff development portfolio which is mapped against the Vitae Researcher Development Framework and has actively engaged with the University's initiative (with the Chartered Management Institute) for senior and mid-level staff to achieve Level 7 management qualifications and obtain Chartered Manager status (21 senior academics in the UoA have so far achieved this goal).

The School's Research and Business Development team has also established a Researchers' Network (aimed primarily towards early career staff but open to all) and are running regular seminars and workshops on topics of interest and value to the community (e.g. the funding landscape, IP protection and exploitation, how to build industry partnerships, maximising impact from research, etc.). These are designed to supplement centrally provided training and are practical/operationally focussed, encouraging researchers to share their own experiences and challenges with colleagues.

ECRs benefit from mentoring within their respective research groups, all of which hold regular (typically weekly) seminars where researchers can present and discuss their work with peers and senior group members. Through these fora ECRs benefit from advice and support in, for example, how to get published and how to identify funding opportunities. ECRs (and PGRs) are actively encouraged and supported in gaining experience of supporting teaching activities. The embedding of research culture into undergraduate programmes (every UG student is linked and interacts with a research group as part of their study programme) has helped to broaden researcher engagement with teaching activities. This is helping to develop skills in researchers that make them better prepared for securing academic roles in the future.

All staff can take advantage of research, impact leave/sabbatical leave, regardless of their career stage. The UoA operates a policy/process where staff can apply for this type of leave as either paid or unpaid (depending on what is most appropriate in their case) and applications are reviewed by the Dean of School and the individual's line manager.

Exchanges between academia and industry are also supported, often benefitting from external funding streams. A particularly successful example over the current period has been the use of the HVM Catapult 'Researcher in Residence' scheme supported by EPSRC, with staff within the UoA (Longstaff, Gao, Lou, Fletcher and Muhamedsalih) having benefitted from this mechanism. A number of staff have very close links with industry partners and provide formal input and advice through mechanisms including non-executive Directorship (e.g. Seviour with Alceli), split part-time employment (e.g. Scott with Taylor Hobson), sponsored chairs (e.g. Jiang with Renishaw) or strategic research partnerships/collaborations that include specific time commitments to industry partners (e.g. Longstaff with MTT, Gelman with TWI). All of these mechanisms benefit both parties, help to steer the UoA's research, and accelerate technology adoption and impact.

### **PGR Student Recruitment, Development and Progression**

The UoA currently has a community of c.170 PGR students, of which 55% are international students, and during the current REF period has had **175 successful PhD completions** (compared to 48 in the previous REF period). Recruitment of PGRs follows a robust recruitment process with all projects/potential projects advertised through a variety of channels, including the University's main application platform 'Coursefinder'. Improving research visibility amongst the Undergraduate community (as previously described) is helping with recruitment of home students and the building of stronger networks, both across disciplines within the University and with other research institutions also supports the recruitment process. The UoA follows the University-wide recruitment process for all of its doctoral research students, which includes a review of the proposals by the research group/supervisor, interviews, completion of a Pre-Enrolment Form and ensuring all the relevant checks are completed before the applicant is offered a place at the University. For some projects (industry sponsored studentships, DTP scholarships, iCASE awards) there may also be additional steps to satisfy the needs of funders or in recognition of the prestigious nature of the scholarship.

The UoA has been successful in developing many different sources of funding to support PGR studentships, which help in attracting and retaining high-calibre candidates. Due to the significant (over £20 million) portfolio of EPSRC funding within the UoA, the University is the recipient of an EPSRC Doctoral Training Programme (DTP) which fully funds a number (currently 12) of PhD studentships each year. The UoA has also been awarded EPSRC iCASE studentships (industry co-funded), has benefitted from EPSRC Doctoral Training Centre in 'Application of next generation Accelerators' support, and receives some direct industry sponsorship for PhDs (recent examples of partners fully funding PhDs include TWI, TEKNEK, NPL and Renishaw). The UoA has also benefitted from significant University and School investment in funding for PhD studentships through several different mechanisms including **£1 million to support c. 21 studentships** working on projects related to the EPSRC Future Metrology Hub, **£500k of co-investment for PhD funding** (alongside the same investment from TWI Ltd) for creation of a joint research centre, and large numbers of fee waivers (and small scholarships) via several initiatives and aimed, primarily, at Huddersfield alumni from Undergraduate and Taught Masters programmes, and also to support good Research Masters students progressing to PhD. The UoA has also been successful in attracting significant numbers of international students in receipt of scholarships from



their own country of origin. These are typically secured through the development of international collaborative partnerships and in recent years have been successfully established with China, Iraq, Libya, Pakistan and Thailand.

All PGRs have both a main and a second supervisor and receive the equivalent of one formal hour of supervision per fortnight. Research group seminars and meetings provide additional opportunities for PGRs to benefit from support and peer mentoring. Records of supervisions are kept by both students and supervisors in the University's 'SkillsForge' platform. Robust progression vivas are held after 9 and 21 months, for which students are required to submit an annual report detailing their progress, and then give a short presentation to a panel consisting of two academics from the subject area who are not involved in the student's supervision (this allows also for frank discussion of the student's level of satisfaction with the supervision provided). For progression to be approved, the examiners must be satisfied that the student has made sufficient progress both intellectually and in terms of timescale for completion. Research training needs form part of the discussion in these vivas. PGRs are also able to access specialist support for academic writing via the In-Sessional Academic English Support Programme provided by the University's Research and Enterprise department. PGRs also have access to an extensive suite of training and development materials made available by the University. This includes, for example, materials on Research Methods, Research Ethics, Entrepreneurship (in the research context), Research with Impact, etc. The UoA's strong partnership with NPL also means that those PGRs working in relevant areas (primarily in CPT) are also able to benefit from access to NPL's Post Graduate Institute for Measurement Science which offers a portfolio of training and development opportunities.

The UoA actively supports students to develop their research careers by attending and presenting at conferences, and students can bid for funding from the UoA's QR allocation or University Research Fund (URF) for costs associated with presenting at conferences. PGRs are strongly encouraged to publish research outputs prior to their viva and UoA staff support this, often co-authoring with students to help introduce them to the publishing process. PGRs are also eligible to apply to the University's Postgraduate Researcher Environment Development Fund (up to £2k) to support the development of public engagement or impact-focused projects designed to be of benefit to other PGRs. PGRs are also encouraged to see research and teaching as symbiotic and of mutual benefit and the UoA provides opportunities to gain teaching experience to those students who wish to do so. This experience encompasses seminar tuition, workshop provision, lecturing (supported by staff), and co-teaching of small groups (in collaboration with staff). Students are also encouraged to take the University's Teaching Assistant Preparation Programme run by the central Research & Enterprise team. Consequently, PGRs emerge from our PhD programmes well prepared for careers in research and/or teaching. Based on the 2019 Postgraduate Research Experience Survey, overall satisfaction in the UoA was comparable to the national average in the subject area (78.6% versus 79%). Areas identified for further development were primarily around professional development opportunities and, in particular, more training and support for PGRs delivering teaching-related activities.

### **Promoting EDI (Equality, Diversity and Inclusivity)**

The UoA is committed to creating and maintaining a culture of research diversity and recognises that a positive and supportive environment where researchers from all backgrounds can flourish will significantly support the UoA's future ambitions.

Similarly, the University is committed to EDI and has robust policies and codes of practice to guide and support staff and PGRs. In 2020, the University signed up to the Race Equality Charter (REC) and completed the Investing in Ethnicity Maturity Matrix to inform the REC action plan. In 2018, UoH was accredited as a Disability Confident Employer and was a signatory to the Mindful Employer Charter, it is also a Stonewall Champion and participated in the Stonewall Equality Index in 2019. The University has four staff networks (LGBTQI+, BAME, Women and Disability) run by members with support from the University EDI Officer. The University has **Athena Swan Bronze** accreditation and the School in which the UoA sits is also working towards an Athena Swan Bronze award.

EDI is also a priority within the University's **REF2021 Code of Practice**, and a detailed **Equality and Impact Assessment (EIA)** has been completed as part of the process of selecting staff and outputs for inclusion within the REF assessment process. This provides an assessment of protected characteristics (gender, ethnicity, disability, sexual orientation, religion, age, marital status, maternity) within the total baseline population versus the population selected as having Significant Research Responsibility (SRR) and Independent Researchers (IR). For UoA12, the assessment shows that the only protected characteristic impacted upon by the SRR/IR and outputs selection process is gender, in which there was actually **a more favourable outcome for the minority female population** (13.6% of staff and 12.2% of outputs selected from a population of only 11.4%).

The most significant factor in UoA12 affecting SRR/IR selection was postgraduate qualification, for example 62% of staff who were identified as not-SRR are currently still studying for a doctorate degree. 25% were also identified as not publishing international quality research. These figures provide a good indication of areas of prioritisation for supporting staff within the UoA to enable further development of the research environment.

Whilst the EIA suggests that those with protected characteristics have not been adversely disadvantaged by the SRR/IR selection process, and even given a significant existing diversity of ethnicity, religion, age, etc, the UoA does recognise that positive actions can be taken. For example, as is typical nationally within the engineering discipline, the proportion of female staff is low (11.4% of baseline and 13.6% of SRR/IR selection) and efforts are being made to try and address this imbalance. In particular, with a push to grow interdisciplinary research, there is more opportunity to recruit from across a broader range of subjects, and emerging themes such as bioengineering and forensic analytics are bringing greater female representation into the UoA's PGR student and researcher communities. Encouraging and supporting staff to engage proactively with EDI issues (for example Qi is an EPSRC sponsored member of the Women's Engineering Society) is also important. It is also worth noting that UoA staff have to undertake training in EDI and Unconscious Bias prior to being involved in any recruitment activities.

### 3. Income, infrastructure and facilities

#### Income

As previously highlighted, the UoA's research income growth has been very strong, rising from **£7,323,689** during the previous (five year) assessment period to **£37,311,669** in the current (seven year) assessment period. In terms of annual income this represents an increase from a **£1.46 million pa** average to a **£5.33 million pa** average, representing **c. 365% growth**.

A significant proportion of the UoA's income (**43.3% or £16,170,421**) has been in the **'BEIS Research Councils, The Royal Society, British Academy and The Royal Society of Edinburgh'** category, primarily through a focus on successfully securing a growing portfolio of high-quality, peer-reviewed, Research Council funded programmes. This has included:

- Leadership of large and highly prestigious **critical-mass national centres of excellence**, the 'EPSRC Centre for Innovative Manufacturing in Advanced Metrology' (Grant reference: EP/I033424/1) and the EPSRC Future Metrology Hub (EP/P006930/1)
- **Equipment grants**, 'World Class Materials Facilities at the University of Huddersfield' (EP/M028283/1), 'Advanced Freeform Generator' (EP/S033300/1), 'Multidisciplinary Research Equipment Investment: Coherence Scanning Interferometer (CSI) and Vector Network Analyser (VNA)' (EP/T02433X/1), and 'Multidisciplinary Underpinning Instrumentation investment' (EP/V035940/1)
- **Fellowships**, 'EPSRC Fellowship in Manufacturing: Controlling Geometrical Variability of Products for Manufacturing' (EP/K037374/1 and EP/R024162/1), 'EPSRC UKRI CL Innovation Fellowship: A semantic infrastructure for advanced manufacturing' (EP/S001328/1), and 'EPSRC Engineering Fellowship: Addressing self-irradiation

damage and its impact on the long-term behaviour of nuclear waste matrices' (EP/T012811/1)

- RCUK **Catapult Researcher in Residence fellowships**, '(HVM MTC) - Surface measurement methods for manufacturing, functioning & metrology of additively manufactured products' (EP/R513520/1), '(HVM CPI) - Ultra fast in-line surface metrology for roll-to-roll process' (EP/T517732/1) and '(HVM NAMRC) - Reducing uncertainty of in-process measurement of large component with embedded metrology for traceable on-machine inspection' (EP/S515784/1)
- Leadership of **responsive mode projects**, 'Atomistic Scale Study of Radiation Effects in ABO<sub>3</sub> Perovskites' (EP/K03684X/1), 'A Study of the Combined Effects of Displacement Damage and Helium Accumulation in Model Nuclear Materials' (EP/M011135/1), 'Radiation Damage in Nanoporous Nuclear Materials' (EP/M01858X/1), 'Combined Effects of Light Gas and Damage Accumulation in Beryllium' (EP/T027193/1), and '(H)olistic (A)pproach to the Design of Efficient Heat (R)ecover Systems for Electrical (P)ower (P)roduction (HARP<sup>2</sup>)' (EP/R023328/1 and EP/R023689/1)
- Supporting (Co-investigator) roles in a number of call-based and/or **responsive mode projects**, 'Ceramic Coatings for Clad (The C<sup>3</sup> Project): Advanced Accident-Tolerant Ceramic Coatings for Zr-alloy Cladding' (EP/K039237/1), 'A Multiscale Digital Twin-Driven Smart Manufacturing System for High Value-Added Products' (EP/T024844/1), 'Miniature Flexible & Reconfigurable Manufacturing System for 3D Micro-products' (EP/K018345/1), and 'The science and analytical tools to design long life, low noise railway track systems' (EP/M025276/1)
- **New investigator awards/first grants**, 'Perceptual Rendering of Vertical Image Width for 3D Multichannel Audio' (EP/L019906/1) and 'Measurement and characterisation of additively manufactured surface texture' (EP/S000453/1)

The UoA has also benefitted from access to funding for doctoral training through the University's **Doctoral Training Programmes** (EP/R513234/1 and EP/N50967X/1) as well as through **iCASE and NPIF** studentship awards.

In total, the UoA has a current portfolio of EPSRC funded projects totalling c. £20m in value, and this includes two recently secured awards, a **standard research award** 'Combined Effects of Light Gas and Damage Accumulation in Beryllium' (EP/T027193/1) and an **EPSRC Programme Grant**, 'Next Generation Metrology Driven by Nanophotonics' (EP/T02643X/1).

There have also been some other successes during the REF period in this funding category, for example, Royal Academy of Engineering funding in the form of the **Renishaw/Royal Academy Chair in Precision Metrology**, and **Innovation, Enterprise and Industrial Fellowships**.

Many of the UoA's research outputs, in particular those by the CPT and IBC groups, are closely related to these funded projects, as are the two Impact Case Studies associated with CPT that are being submitted by the UoA.

The category '**UK central government bodies/local authorities, health and hospital authorities**' has accounted for a further 19.9% (£7,436,283) of the UoA's income and grown significantly over the period. Within this category are two large and prestigious IRR group projects, the Regional Growth Fund supported '**Centre for Innovation in Rail**' and the Research England RPIF '**UK Rail Research and Innovation Network**', plus a large portfolio of funded collaborative research and knowledge transfer projects, spread across all of the UoA's research centres. The UoA has been an active user of IUK's **Knowledge Transfer Partnerships (KTP)** scheme for many years and has had 24 different KTP projects running during the REF period, typically having a portfolio of 6-8 running at any one time. These are an excellent way of building and maintaining long-term relationships with industry partners and projects have significantly supported two of the UoA's impact case studies. Other IUK funding streams (in particular the **SMART collaborative R&D** scheme) were specifically identified as having the potential to support income growth and enhanced impact, and the UoA has significantly increased activity in these over the current REF

period, with over 25 projects running during the period. As with KTPs, these projects help build strong and lasting industrial collaborations and accelerate impact from research, as well as generating some high-quality research outputs, usually co-created with the industry partners. Several of the UoA's Impact Case Studies (primarily in CPT, IRR, CEPE and CAPE) have been supported and enhanced by these projects.

'UK industry, commerce and public corporations' accounts for **18.7% (£6,979,002)** of income and has also grown significantly. The IRR research group in particular have a very diverse research portfolio, with large and numerous collaborations and contracts with key partners in the rail sector, most notably the Rail Safety and Standards Board (RSSB), Network Rail, Alstom and Siemens. These collaborations have helped facilitate numerous research outputs and directly supported the three Impact Case Studies IRR have contributed to the UoA submission. A large long-term research collaboration with Borg Warner (on turbocharger design and manufacture) was also a major contributor in this category, along with many smaller collaborations across a wide variety of activities including sponsored PhDs, collaborative research, knowledge transfer, consultancy, and industrial training.

The category '**EU government bodies**' accounts for **10.3% (£3,839,082)** of income but has remained fairly static over the period, with uncertainty over post-Brexit access to EU funding streams a major factor in the recent development of this portfolio. The UoA has had projects from across a variety of EU funding mechanisms. This has included **European Research Council** research/innovation projects (e.g. 'SURFUND', 'EMinstr'). There have been c.20 collaborative **FP7/H2020 R&D** projects, more than half of these rail-industry focused and within IRR (e.g. In2Rail, Run2Rail, SustRail, Capacity4Rail, Shift2Rail) plus several CPT-based metrology projects (e.g. NanoMend, Prosurf, Ease R3), and a CEPE based 5G project (Motor5G). The UoA has also engaged with **Erasmus+/Leonardo** grants on lifelong learning/training projects (e.g. WINGS+).

The balance of UoA income (**£2,886,881**) has come from a mix of sources but primarily from projects with UK charities/not-for profit organisations and through international research and industrial collaboration. Examples include a large strategic partnership with RSSB, a research collaboration with CERN (related to upgrade of the Large Hadron Collider facility), and a number of research contracts with international industrial partners.

As has been described above, all research groups are active (and have been successful) in bidding for external research funding. All academics and researchers are encouraged to bid and are supported by their peers and by the School's Research and Business Development teams, who have extensive experience of supporting colleagues in the development of bids to all of the main UoA funding bodies, and of supporting engagement with industry partners. This support is available to all staff, and particular efforts are now being made to support ECRs in developing this knowledge and capability in the early stages of their career.

Looking forward, the UoA will continue to pursue a strategy of **research income growth**, aiming to at least **double in size by 2025** (this coincides with the University's current strategy period and KPIs). Successful delivery of this growth will rely on the continued success of existing senior researchers, use of the University RESS scheme to attract established researchers to the University, plus a cohort of ECRs establishing themselves and accessing significant funding streams (hence the existing focus on supporting ECRs). Additional investments in research infrastructure (see below) will support this growth.

### Infrastructure

Groups within the UoA maintain a number of specialist facilities to support their research and impact activities. In some cases, this is highly specialist, UK-leading infrastructure, for example:

- CPT's combination of high accuracy optics, metrology and precision engineering instrumentation (both fixed and portable), including clean room with nanoscale capability, totalling over 2,000m<sup>2</sup> of laboratory space.
- IRR's full-scale bogie rolling contact rig and advanced dynamic test cell, and recently constructed full-scale pantograph test cell (over 1,000m<sup>2</sup> of laboratories).



- IBC's suite of accelerators and microscopes, including the MIAMI-2 system which is part of the EPSRC UK National Ion Beam Centre facility (in conjunction with universities of Surrey and Manchester).
- CAPE's 3-D audio capability, including ITU-R BS.1116-compliant listening room.

In all cases, research groups in the UoA have access to a core set of facilities (hardware and software) that enable them to undertake their research effectively.

Over the REF period, the University has invested c.£7.9 million institutionally in supporting delivery of its Research Strategy via the "University Research Fund" (URF), and **£1.7 million** of that investment has been to support initiatives in UoA12. This investment has included, for example, funding of six senior staff (and associated costs) joining the University under the previously described RESS initiative, funding to help establish the new Centre for Engineering Materials, development/improvement of research facilities within the CPT and CAPE research groups, support for delivery of international conferences, and staff exchange and/or travel grants.

In addition to the URF investment, the University has also provided match funding and/or co-investment (from central and/or school reserves) to some of the UoA's prestigious research awards and strategic industrial partnerships. This has included, for example, **£1.25 million cash** investment to fund PhD students and 50% of equipment costs associated with the EPSRC Future Metrology Hub, **£2.5 million cash** match-funding commitment to IRR's strategic partnership with RSSB, a **£500k** cash match funding investment to CEPE's strategic partnership with TWI Ltd, and a **£250k cash** match funding investment to CPT's Renishaw/RAEng Chair in Precision Metrology. These investments are in addition to the ongoing commitment within the School of Computing and Engineering to return a significant proportion of estates and overheads surpluses from funded projects directly back into research groups. Over the REF period this has amounted to **over £5.25 million reinvested by the School** to support the UoA.

The University has recently (Nov 2020) committed to over **£5 million investment** in upgrading and expanding engineering research laboratories, in particular to support multidiscipline Digital Manufacturing and Industry 4.0, Productivity, and Energy and Materials ASRI's, all of which fall primarily within UoA12. This will support further growth of CPT, CEPE, CEM, PARK and MDS research groups, and will be completed in 2021.

The School has invested heavily in its administrative/management infrastructure to support research and impact over this REF period. This includes a new **Business Development Manager**, a **Research Finance Support Team (2.5 FTE)**, a part-time **Research Development Manager** and an **Impact Officer**. A new **Technical Services Manager** has also been appointed bringing all the technical and IT technicians under one management structure resulting in more joined-up support for UoA researchers.

The School has also invested in a dedicated state-of-the-art space (c.500m<sup>2</sup>) for PGR students including hot-desking facilities, lockers, meeting rooms, kitchen facilities, and communal/social space. This is co-located with the research support and business development teams and is a focal point for the school's research administration and support activities.

### Use/exploitation of Infrastructure

Given the ethos of delivering research with impact through collaboration with industry, many of the UoA's research facilities/specialist resources are used to support impact generation activities, as evidenced by the significant amount of industry-led/commercial funding the UoA has received over the REF period. For example, CPT's metrology research infrastructure (surface measurement, co-ordinate measurement, X-ray CT, portable measurement lasers) is used to deliver specialist design and measurement support to industry. This includes long-term development programmes, typically with metrology solutions providers and/or large OEMs, rapid turnaround measurement services with regional and national manufacturing end-users, and hands-on industrial training programmes. Similarly, IRR's full-scale test cells (bogie rolling contact rig, advanced dynamic test cell) and scaled laboratory test rigs are used extensively with rail-industry partners to support their R&D programmes, delivered through both research contracts and specialist test services. In the case of CEPE, this large and diverse group is using a variety of facilities (engine test cells,

dynamometers, motor/compressor/pump test cells, specialist design and simulation software) to support industrial development and consultancy projects. Whilst impact activities are typically delivered by academics and researchers, with support from core technician teams, in the case of both CPT and IRR, specialist technicians/applications engineers have been recruited by the research groups specifically to support delivery of industry-facing services.

The UoA also benefits from having access to equipment in the University's 3M Buckley Innovation Centre (3MBIC), notably plastic and metal additive manufacturing machines and a selection of microscopes and materials analysis instruments. These are in regular use by UoA researchers to support a number of EPSRC, Innovate UK and direct industry funded projects.

Cross-HEI shared use of infrastructure has been growing with the UoA's increase in multi-disciplinary research programmes. In particular, closer collaboration with computer/data scientists is seeing engineering infrastructure (mostly in CPT, IRR and CEPE) being used to create large data sets for subsequent analysis and manipulation. This is particularly relevant for researchers in the PARK/MDC groups, some of whom are submitting within this UoA, but who are mostly submitted in UoA11. There is also a long history of shared use of microscope facilities across campus, in particular CPT, IBC and CEM working with colleagues in the School of Applied Sciences. CPT's X-ray CT capability in particular is used regularly by research groups outside of the UoA with particular focus on the School of Applied Science.

Some of the more specialist infrastructures already described (primarily those in CPT and IBC) are also accessible to researchers from other institutions. CPT's 'Nanolab' facility for example has been used in this way by academic and industry-based researchers, including long-term hiring of work bench space within the laboratory. Another example is IBC's MIAMI (Microscope and Ion Accelerator) facility which is accessible to UK academics through the EPSRC supported UK National Ion Beam Centre.

The UoA has also benefitted from some in-kind donation and/or long-term loans of specialist equipment that supports research activities, notably focus variation microscopes donated by Bruker Alicona and the long-term loan of a Romer portable metrology arm donated by Hexagon, plus the University benefitted from a significant discount from CPT's industry partner Renishaw when purchasing the two metal additive manufacturing machines that are based in the 3MBIC.

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

##### Support for research collaborations, networks and partnerships

Research collaborations, networks and partnerships are fundamental at both UoA and institutional level to support the raising of research profile, nationally and internationally. The philosophy across the UoA is aimed at facilitating growth of these collaborations with both academic and industry stakeholders. To support this a range of software and services are available as a first port of call for researchers seeking information and guidance. Information repositories (notably the PURE system and research group web pages) ensure information that supports collaboration building is in the public domain, and the University's Microsoft Dynamics CRM system enables active tracking of relationships with external partners.

University-wide mechanisms and funding are under the umbrella of the University Research Fund (URF), which includes a **Researcher Development Fund** (primarily aimed at ECRs), **Conference Presentation Fund** (for papers and posters at conferences of national and international standing), **Intellectual Climate Fund** (for student-led initiatives to enhance opportunities for learning and research practice), **Research Networking Fund** (for PGR visits to national/international centres of excellence), and **Public Engagement Fund** (for formal training in public engagement). In addition, the UoA has been investing c. £280k per annum of QR funding into mechanisms that directly support the development and maintenance of national and international collaborations. This includes funding for **National and International Consortium Building** with the aim of bidding to international projects such as H2020, British Council and Global Challenges Research Fund, **Visiting Academic Programmes** (to and from the University), **Conference Travel** funding for ECRs (including PGRs), **Strategic Equipment Purchase/Maintenance** (to support specific collaboration opportunities) and funding to support short-term **Bridging of Staff** between funded

contracts. These QR funds are allocated through a formal, transparent application and assessment process, with proposals reviewed by senior UoA academics.

To further support researchers, the University and School have significant infrastructure and support staff for whom a significant part of their role is supporting the creation and maintenance of research collaborations. Centrally this includes a **Business Development team** focused on engagement with industry partners, Pre- and Post-Award teams that support financial management of funded relationships, and legal and contracts teams that support the creation of robust agreements for collaboration. The University's **3MBIC** is based alongside the main campus and, as well as being home to a number of innovation businesses, contains a range of advanced engineering equipment and a team of business advisors which enable researchers to better engage with regional and national industry. Of particular relevance to the UoA are X-Ray Computed Tomography, Microscopy and Metrology facilities, plus the Renishaw Metal Additive Manufacturing Facility. The School in which UoA12 sits (alongside UoA11) has made significant investments to create research support infrastructure locally, including a **Research and Business Development Team** (2.5 FTEs) and a **Research Finance Team** (2.5 FTEs) that provide more intensive and focused support as well as seamless connection to central teams. Hence, researchers have easy access within the school to hands-on help with costing/pricing, partnership/consortium building, identification and bidding for appropriate grants, contract development/negotiation, management and exploitation of intellectual property, budgeting and financial management. The School also has an active **Industry Advisory Panel** which meets three-times per annum. This provides an opportunity for senior UoA staff to engage with, and get feedback from, a broad industrial group to understand how research can be better directed by, and connected to, industry needs.

#### **Research collaborations, networks and partnerships highlights**

All research groups across the UoA are actively developing and engaged with partnerships and networks in their respective disciplines. Whilst it is not possible to list all activities within the constraints of this document, some examples highlighting the breadth and significance of the activity across the UoA follow:

- **CPT** researchers are active contributors to networks in metrology and precision engineering, including **CIRP**, **euspen**, **CERN HL-LHC** and **COLUSM** network, and the **HVM Catapult Metrology Forum**. Also, highly significant is the group's contribution to national and international standards (**BSI/ISO/ANSI/ASTM**) committees in the creation of new standards, which are hugely important in the metrology discipline. The group has strong links, primarily through UKRI funded activities, with leading universities and research organisations in the field in both the UK (e.g. universities of Strathclyde, Heriot-Watt, Newcastle, York, Leeds, Bradford, Manchester, Nottingham, Birmingham, Cranfield, Cambridge, UCL, Southampton, South Wales and Cardiff, plus NPL, TWI and all seven of the HVM Catapult Centres) and internationally (e.g. universities of North-Western, ENS-Paris-Saclay, RWTH Aachen, Kaiserslautern and Shanghai Jiaotong, plus PTB, NIST and Lawrence Livermore National Lab). Through the **EPSRC Future Metrology Hub** programme, CPT is also actively leading the development of a UK metrology research network. This group of c. 20 universities and research organisations has collaborated to produce the recently published 'UK Metrology Research Roadmap'.
- **IRR** researchers are actively engaged with networks including **UKRRIN**, **RSSB** and the **Centre for Innovation in Rail** (hosted by IRR) and are influential in both academic and industry led networks across the rail sector. The group has strong links with UK universities (e.g. Birmingham, Newcastle, Heriot Watt, Leeds, Lancaster, Loughborough, Bristol, Cambridge, Sheffield, Nottingham and Southampton) as well as active collaboration through a portfolio of FP7/H2020 programmes (e.g. In2Rail, Run2Rail, SustRail, Capacity4Rail, Shift2Rail) with European academic partners including Milan, Lisbon, Delft, Cantabria and Rome.
- **CEPE** is a large and diverse group and has strong international research networks across its portfolio. These include a **CEPE China network** (with Beijing Institute of Technology in Zhuhai, Shanghai Jiao Tong, Xi'an Jiao Tong, Tsinghua, Chongqing, Nanjing, Tianjin

and Zhejiang universities), an international **Turbocharger network** (with Shanghai Jiao Tong, KTH Royal Institute of Technology, Monash, ANU, Victoria, and Technical University of Kenya), and a developing network linked to the **H2020 Motor5G** project (with Bucharest, Aarhus, Thessalonika and Sofia universities). In addition, there are a large number of collaborations (linked to specific projects) with organisations including universities of Southampton, Sunderland, KAIST, Arizona, Delhi, Hong Kong, Valencia, Opole, Poznan, Oulu, Alberta, Genoa, Grenoble and Modena.

- **IBC** is a key partner of the **UK National Ion Beam Centre** (with Surrey and Manchester universities) as well as part of the **H2020/Euratom II Trovatore network** (with 29 other partners including Cambridge, Oxford, Imperial, Manchester, KU Leuven, Karlsruhe, Dresden, Poitiers, Torino and Kyoto universities). UK collaborations (primarily EPSRC-funded) with leading universities in the field are particularly strong (notably Surrey, Manchester, Sheffield and Liverpool) and the group also collaborate extensively with the UK Atomic Energy Authority, e.g. via their Culham Centre for Fusion Energy.
- **CAPE** researchers are active in several specialist related networks including the **Abbey Road Spatial Audio Forum**, **UK Acoustics Network**, and **Immersive Audio Network**. The group collaborate widely with international universities (New York, Institute of Acoustics China, Bialystock, Graz) as well as having active collaborations in the UK with, for example, York University. Of particular note is the collaboration with New York on the development of the “City Tones” soundscape database.
- **CEM**, which is submitting only a small number of researchers to this UoA, is very active in the **H2020/Euratom II Trovatore network** (co-ordinated by Lambrinou) as well as having a strong portfolio of international collaborations with research institutes including Uppsala, KU Leuven, Baku, Kiev, Leoben and Madrid universities.
- As previously highlighted, a small number of researchers from **PARK** and **MDS** are submitting to this UoA. These research groups are primarily submitting to UoA11 and have research networks and collaborations described in detail within that submission.

#### Links with key research users and wider society

The UoA’s most impactful collaborations with research users are described in seven Impact Case Studies being submitted by the UoA for this REF period, but these are only a small representation of many hundreds of collaborations taking place between UoA researchers and industrial partners.

As highlighted earlier, the UoA has a very strong culture and track-record of applied research in close collaboration with industrial partners. This has grown during the current period, evidenced by significant increases in business-led research grants and contracts, notably **24 KTP projects**, c. **25 IUK collaborative R&D projects**, c. **20 EU FP7/H2020 R&D projects** and numerous industry-funded **research contracts**. There has also been an active **consultancy** portfolio, and several **licenses/assignments of new IP**. Even for more fundamental research funded by EPSRC, engagement with industry is critical to maximise opportunities for impact acceleration. For example, the EPSRC Future Metrology Hub had **29 co-creating industry partners** and has collaborated with **over 150 different companies** at its project mid-point (Aug 2020).

The UoA’s research user base is very diverse, being from a wide range of industry sectors, with particularly strong representation from amongst the **Rail** (RSSB, Network Rail, London Underground, Alstom, Hitachi, et al.), **Aerospace** (Rolls Royce, BAe Systems, Airbus, GKN, et al.), and **Metrology** (Renishaw, Taylor Hobson, Hexagon, Zeiss, Faro, et al.) sectors which are closely aligned with major research strengths within the UoA. There are numerous collaborations with **specialist and precision engineering** product and service companies locally, nationally and internationally. These include local/regional clusters in **automotive** (e.g. Cummins Turbo Technologies, BorgWarner), **flow handling equipment** (e.g. Trillium, Koso Kent Introl, HR Blowers) and **advanced machinery and automation** (e.g. Holroyd, Reliance Precision, Wayland Additive, MTT, CR Solutions) as well as wider national/international collaborations. All UoA research groups actively collaborate in their fields, even where these are highly specialist. For example, CAPE collaborates with world-leading audio companies such as Schoeps Mikrofone,



Genelec and DPA Microphone, as well as with music production and broadcasting companies such as Abbey Road Studios and the Austrian Broadcasting Corporation.

In addition to assessing industry engagement through income streams and project collaborations, the UoA is seeking to increase the proportion of research outputs co-created with research users. Co-created outputs are clear evidence of close collaboration and are being used as a KPI within the University's current strategy map. At Jul 2020 c. 7.5% of the UoA's outputs were co-created with end users and the UoA has a target to grow this to 15% by 2025.

Outside of industrial collaborations, the UoA is committed to the Concordat for Engaging the Public with Research. Wider public engagement by researchers has primarily been through formally organised events such as University European Researcher Nights in 2016 and 2017 (where **over 3,000 members of the public** attended the University for open events showcasing our research) delivering presentations and, more importantly, hands on activities. Researchers have also developed a public lectures showcasing research in off-campus locations. These "Café Scientifique" events have proven popular and have been running since 2015 in conjunction with researchers from the School of Applied School Sciences.

### Contributing to Sustainability of the Discipline

As described in Section 1, the UoA's main research focus is aligned to the **UK's Industrial Strategy**, including elements of all four Grand Challenges (Artificial Intelligence and data, Ageing society, Clean Growth, and Future of mobility), and to the UKRI priorities of **Digital Economy, Energy, Manufacturing the Future and Engineering**. In addition, some researchers are focussing on opportunities to address priorities of the **Global Challenges Research Fund** to support sustainable development goals for the developing world. In each case, broad themes and objectives naturally promote interdisciplinary research and the UoA has been building interdisciplinary specialisms over the REF period.

One example is the development of bio-medical engineering and bio-metrology capabilities, with researchers from CPT collaborating with medical engineering partners (University of Leeds, UCL, London Implant Retrieval Centre, DePuy Synthes, Zimmer Biomet, Renishaw) to improve the design and use of medical bioimplants. This work, which crosses engineering metrology, materials science, medicine and biological sciences disciplines, will help improve quality of life for many thousands of patients each year receiving joint replacements (hips, knees, etc.).

Another example is the application of AI and data science to engineering challenges. The increasing use of sensor networks to collect real-time manufacturing process and/or engineering assets data generates massive, complex data sets that cannot be exploited by conventional methods. Collaboration with computer scientists, within the University and at other partners, is becoming common for researchers in CPT, IRR and CEPE, and will be essential to address future challenges in autonomous manufacturing, remote asset monitoring/management, the increasing servitization of engineering products, and other Industrial Internet of Things applications.

### Contribution to the discipline, nationally and internationally

In addition to the actual undertaking of research activities, researchers across the UoA are actively contributing to the discipline through a wide variety of mechanisms.

A number of UoA staff are making significant contributions via **journal editorial boards**, for example, Editor in Chief; Journal of Rail and Rapid Transit (**Iwnicki**), Editor in Chief; International Journal of Railway Technology (**Pombo**), Editorial Board; IOP Journal Surface Topography Metrology and Properties (**Blunt**), Editorial Board; Journal of Multibody System Dynamics (**Pombo**), Editorial Board; CIRP (International Academy for Production Engineering) Annals (**Jiang**), Honorary Technical Editor, the International Journal of Condition Monitoring (**Gelman**), Editor-in-Chief, the International Journal of Engineering Sciences (**Gelman**), Associate Editor, International Journal of Condition Monitoring and Diagnostic Engineering Management (**Mishra**), and Editorial Board, Journal of Advanced Transportation (**Mishra**).

In addition, UoA staff act as **referees for over 100 peer-review journals**, with highlights including Acta Materialia (**Hinks**), Nature Communications (**Hinks, Jiang and Tong**), Carbon (**Hinks**),

Optics and Photonics (**Jiang**), Proceedings of the Royal Society A (**Blunt and Jiang**), Optics Express (**Jiang and Martin**), Precision Engineering (**Longstaff**), IEE Transactions on Audio Speech & Language Processing (**Lee**), IMechE Journal of Engines (**Allport**), International Journal of Railway Technology (**Pombo**), and the International Journal of Condition Monitoring (**Gelman**).

Researchers across the UoA have participated widely in **funding and awards committees** nationally and internationally. Examples include: member of EPSRC Manufacturing Prioritisation Panel 2018 (**Walker**), EPSRC panel member for Engineering Fellowships 2015- (**Hinks and Seviour**), Member of DoE (USA) INCITE 2016 review panel (**Seviour**), Polish Roadmap for Research Infrastructures, Ministry of Science and Higher Education 2018 & 2019 (**Blunt**), member of Technology and Accelerator Advisory Board of STFC, 2019 (**Jiang**), Rail Safety Strategy Board V-V SIC, consultation on authorising RSSB R&D project funding (**Allen**), member of the evaluation panel assessing applications for R&D funding R&D projects National Innovation Agency – ANI (Portugal) 2011- (**Pombo**), member of the evaluation panel assessing applications for R&D projects Agencia Nacional de Evaluación y Prospectiva – ANEP 2013-(Spain) (**Pombo**), Funding Evaluation Executive Government Agency of National Science Centre – NCN 2015- (Poland) (**Pombo**), member of Grant Committee for Industrial Research Fund (IOF), 2017 Belgium, (**Gelman**), Grant Committee, Agency for Innovation by Science and Technology (IWT), Belgium, 2015 (**Gelman**), member of Royal Academy of Engineering Manufacturing Panel (**Jiang**), member of Royal Academy of Engineering, Newton Fund Panel (**Jiang**), member of Royal Academy of Engineering, Member, Chair and Senior Fellow appointments committee (**Jiang**). Also, 12 UoA staff are members of the **ESPRC Peer Review College**.

The UoA also contributes to significant UK discussions via Membership of **EPSRC Science, Engineering and Technology Board**, Membership of the **Wales Science & Innovation Advisory Council**, and Advisor to the **National Measurement Program** (all **Jiang**).

Researchers across the UoA engage with other Boards and Committees including as **Elected Learned Council Members**, International Discipline representatives, **ISO Committees Chairs** and **Professional Institutional Chairs**, and such activities are clear evidence of active engagement with their discipline. Highlights include: Representation on the Northern Powerhouse Mission to China International Industry Fair, 2017 panel discussion member (**Jiang**), UK Chair of International Academy of Production Research (CIRP) 2015 (**Jiang**), Deputy Chairman of the Railway Division of the I Mech. E (**Iwnicki**), Elected Council Member of European Society for Precision Engineering EUSPEN 2015- (**Blunt**), Election to Senior Membership of Optical Society of America 2018 (**Walker**), Chairman of Manufacturing Technologies Association Technical Committee 2019- (**Longstaff**), Member of Technology and Accelerator Advisory Board of STFC, (**Jiang**), Participation on Parliamentary Select Committee on Small Module Reactors 2014 (**Seviour**), Chair of the Condition Monitoring Technical Committee, British Institute of NDT (**Gelman**), Principle Member of, ISO TC39 Machine Tools SC2 (**Longstaff**), Chair of British Standards Institute (BSI) MTE/1/2, Machine Tool Standards (**Longstaff**), BSI 004/04/10 Technical realisation of X-ray Computed Tomography (**Bills**), ISO TC213 Dimensional and Geometrical Product Specifications and Verification, strategic board (**Scott**), Advisory Group 12 ISO TC 213 Convener Mathematics for Metrology (**Scott**), ISO TC213, Principle member WG15 Data Analytics and Filtering WG16 Surface texture principle member (**Scott & Jiang**), American Society for Testing and Materials ASTM: E07 Non-destructive Testing E11 Quality & Statistics (including E11.50 Metrology) E57 3D Imaging Systems F04 Medical and Surgical Systems & Devices (including F04.22 Arthroplasty) F42 Additive Manufacturing Technologies (including F42.07.03 Medical/Biological) ASTM Smart Manufacturing Advisory Committee (all **Bills**), BSI: CH/150/04 Bone & Joint Replacements (**Bills**), and Principle Member of ISO/TC108 Technical Committee, Condition Monitoring (**Gelman**)

UoA researchers recognise the importance of networking and forming connections within their discipline and have been active in **chairing and hosting key conferences** during the period (as well as many conference attendances as delegates/presenters). Some of the more significant highlights are: **Conference Chair** for Laser Metrology, Coordinate Measuring Machine and Machine Tool Performance (LAM DAMAP) 2017 and 2019 (**Blunt**), **Conference Chair** for International Metrology and Properties of Engineering Surfaces, 2017 Gothenburg, 2019 Lyon

(**Blunt**), **Organization Committee** of "International Conference on Railway Technology" 2014, 2016 (**Pombo**), **Local Chair** International Conference On TEM With In-Situ Irradiation (WOTWISI) Huddersfield 2018 (**Hinks**), **Conference Chair** International Conference Condition Monitoring and Diagnostic Engineering Management (COMADEM) Huddersfield 2019 (**Gelman**), **Local Chair** 4th Workshop on Intelligent Music Production (WIMP2018) 2018 (**Lee**), **Local Chair**, Audio Engineering Society Workshop on the capture and rendering of audio for VR, 2017(**Lee**).

UoA Researchers are also regularly invited to give keynote addresses and invited lectures, often as part of large international conferences and workshops. Over the REF period there have been many examples, but highlights include: **Plenary Speaker**, 3rd CIRP Conference on Bio-Manufacturing, Northwestern Uni, Chicago, USA 11-14 July 2017, (**Jiang**), "Metrology for Bio Systems" **Keynote address** Proc Int. Conference on Metrology and Properties of Engineering Surfaces, UNC Charlotte USA 2015 (**Blunt**), **Invited speaker** at the UK and Swedish Aerospace Cluster International Exchange Event at the AFRC 2019 (**Longstaff**), **Invited keynote and session chair**, "Ultra-precision machining of functional surfaces with embedded metrology", the 6th Asia Pacific Conference on Optics Manufacture, 2019 (**Tong**), **Distinguished Plenary Keynote**, 25th International Congress on Sound and Vibration, Japan, 2018 (**Ball and Gelman**), **Plenary Keynote** lecture, European Conference on Materials, Mechatronics and Manufacturing, Amsterdam, 2019 (**Barrans**), **Invited Speaker**: "Multibody/finite element co-simulation method for multidisciplinary applications in railway dynamics", The Sixteenth International Conference on Civil, Structural and Environmental Engineering Computing, Riva del Garda, Italy, March 17-19, 2019. (**Antunes**), **Invited talk** in Microscopy and Microanalysis of Nuclear and Irradiated Materials session at Microscopy and Microanalysis 2019 (Portland, OR) (**Hinks**), **Invited Keynote** Congress Francais de Mechanique, "Digital Twins " Brest, France, 2019 (**Mishra**), **Invited paper** and Virtual Encore Series, Audio Engineering Society AES International Conference, Vienna, June 2020. "Goodbye Stereo" Virtual Encore Series (**Lee**).

#### Recognition in the discipline, nationally and internationally

Many of the researchers/research groups across the UoA have seen recognition during the REF period for their work and contribution to the discipline, typically in the form of prizes (group and/or individual) and awards. Some notable highlights include:

- The award of **Dame Commander of the Order of the British Empire** for services to Engineering and Manufacturing was bestowed upon **Prof X Jiang** in the Queen's Birthday Honours, 2017.
- **IRR** were awarded the **Queens Anniversary Prize for Higher and Further Education**, 2020, for R&D that has brought significant improvements to the railway industry.
- **CPT** (via their EPSRC Centre for Innovative Manufacturing) were recipients of the **IET Innovation Award for Manufacturing Technology**, Nov 2014, for their breakthrough surface measurement technology.
- The **COMADIT Prize** "For significant contribution through research/development in condition monitoring to benefit of industry or society" was awarded to **Prof L Gelman** by the British Institute of Non-Destructive Testing, UK, 2017.

UoA researchers have also been awarded fellowships with learned societies during the REF period. These include Fellows of the **Royal Academic of Engineering** (Jiang and Iwnicki), Fellows of the **IMechE** (Allport and Mishra), Fellow of the **Royal Society for Statistics** (Scott), Fellow of The **British Institute of Non-Destructive Testing** (Gelman), Fellow of **CIRP** (Jiang), Fellow of The **Audio Engineering Society** (Lee), Fellow of The **Society of Diagnostic Engineers** (Gelman), and Fellow of the **International Association of Engineering** (Gelman).