Institution: University of Sheffield

Unit of Assessment: 12A - Aeronautical, Mechanical, Chemical and Manufacturing Engineering: **Mechanical Engineering and Advanced Manufacturing**

a. Context

Our vision is to address the key challenges facing society using our research excellence in mechanical engineering science. As such, stimulation of impact is an integral, valued, and rewarding aspect of our research activity. Much of this impact has had a significant **economic** and **practitioner** benefit on leading engineering businesses such as Rolls-Royce, Tata, Siemens, Ford, BAE Systems, Messier-Dowty, Airbus, and Boeing.

In particular, our Advanced Manufacturing Research Centre (AMRC) has had an international impact on the economics of major aerospace companies creating or safeguarding 100s of jobs in the UK and abroad. Our pioneering partnership approach has been emulated in 14 other centres worldwide. This success has led us to cultivate similar achievements in other sectors, through the Low Carbon Combustion Centre (LCCC) (alternative aviation fuels – policy and practices) and the INSIGNEO centre for in-silico medicine which is translating bioengineering into clinical practice.

b. Approach to impact

Our strategic approach to impact involves key partnerships, complemented by a portfolio of mechanisms that seek to build new relationships with end users. In this way we aim to maximise the serendipitous and planned impact from all of our research.

Flagship Partnerships

Advanced Manufacturing Research Centre (AMRC): This is our flagship centre that delivers unprecedented impact in the global manufacturing sector. This assessment period has seen the development of the Nuclear AMRC (2011), an extension to the Rolls-Royce Factory of the Future for composites activity (2012), the decision by Rolls-Royce to site their new turbine blade production facility adjacent to the AMRC site (2013), and the HEFCE-sponsored £43M Factory 2050 supported by Boeing, Airbus, Rolls-Royce, and BAE Systems (2013).

Our approach is based on a combination of strong industrial focus, targeted industrial membership and collective industrial funding, addressing the difficult transition from low technology readiness levels to market application. The AMRC includes over 70 member companies, who pay up to £200k per year to steer, participate, and benefit from shared research programmes. This pioneering approach to impact has been emulated in five other UK centres and has informed government policy regarding Technology Innovation Centres (now known as Catapult Centres). Boeing has used this approach as the model for its centres in Canada, Australia, Germany, the Netherlands, Singapore, the USA, Denmark, South Africa and India.

Two case studies exemplify the impact arising from this approach, and the AMRC's 'Boeing Supplier of the Year' award (2010) further demonstrates the value to industrial stakeholders. In addition, societal impact is achieved through the AMRC's partnership with the Bloodhound land speed record project, and the £500k MANTRA outreach initiative. MANTRA is a unique road show providing a showcase for advanced engineering which has visited over 450 schools, colleges and company premises and in doing so, has reached over 18,000 adults and children to date.

The AMRC approach provides inherent agility, as industrial partners can directly fund their own projects in the Centre with little administrative burden and the collective industrial funding is allocated annually to research projects that benefit the whole consortium. In addition, the EPSRC Industrial Doctorate Centre in Machining Science provides a platform for specific high-impact research. Here, industrial collaborators pay ~£70k towards the cost of a four year EngD project that is closely aligned with their current business and technology needs. Current beneficiaries of these EngD projects include Rolls-Royce, Sandvik Coromant, Technicut, and Messier Dowty.

Low Carbon Combustion Centre (LCCC): Our second flagship partnership is the LCCC, whose industrial partners include Rolls-Royce, BP, Shell, E.ON and Npower. The LCCC is at the forefront of technology transfer for the development of environmentally friendly aviation, process and power generation fuels and combustion systems. The spinout company EPTeC (Energy & Power Technology Centre) ensures industrial access to the unique pilot scale facilities, enabling the commercialisation of experimental fuels at very low risk to the end-user, accelerating final approval

for use and bringing their beneficial impact on the environment forward. Work with the US Government's Federal Aviation Administration is helping to develop their aviation fuel policy, LCCC staff have been seconded to Shell to train researchers in experimental techniques, and the LCCC is the only academic partner contributing to the European Commission's Aviation Alternative Fuel Policy. The LCCC plays a key role in the development of new engine heat and fuel management designs for existing and future aircraft engines. The Centre is also the home of the UK's Pilot Scale Advanced Carbon Capture Technology (PACT) core facilities, jointly funded by DECC and the EPSRC (£1.9M) and operated as part of the UK Carbon Capture and Sequestration Research Centre. These specialist national facilities aim to accelerate the development and commercialisation of novel technologies in this emerging field, and are also being used by Carbon Clean Solution (India), an international energy company researching carbon capture technologies.

Longstanding partnerships

We have an excellent record of nurturing longstanding relationships with organisations to maximise the impact of our research. Examples of long-standing relationships include:

- Dynamics have worked closely with Rolls-Royce design teams for over 15 years. Current activity is transferring technology by providing bespoke in-house software for friction modelling, and developing new ideas through funded PhD students.
- Bioengineering have been heavily focussed on translational research. A current example uses CFD models to predict the pressure gradient of diseased arteries, now being trialled on 100 patients with funding from the Department of Health and the British Heart Foundation.
- In Solid-Mechanics, we have worked with Tata Steel who adopted and further developed our cellular automata and finite element (CAFE) damage model.
- EPSRC funded research in collaboration with the International Tennis Federation led to a new technique for monitoring the performance of tennis court surfaces which will be used at international events such as the Davis Cup.

Three case studies epitomise other longstanding relationships, as explained in Section 4. Whilst these mature relationships involve direct industry funding, the relationship is often developed through collaborative research and knowledge transfer, such as **Knowledge Transfer Partnerships** (KTPs). KTP bids are supported by a dedicated Faculty post, and once programmes are underway we have a dedicated administrator to support the project. As a result we have been awarded 21 KTPs during this assessment period; examples of follow-through include:

- Development of a landing gear event monitoring system for Messier-Dowty led to follow-on direct industry funding and creation of a new Technical Specialist role at the company.
- An optimised design of hot water cylinders (patent pending) for [*text removed for publication*] is anticipated to save the company [*text removed for publication*] per year in cost of materials.
- Development of a 'quick coupler' to enhance a waste compaction system has led to a new product for [*text removed for publication*] that is expected to increase sales by [*text removed for publication*].

Building and exploiting relationships

In order to generate larger scale partnerships, to support opportunities for staff to build new relationships, and to provide an agile approach for enabling impact, various processes are used:

Consultancy and gateways: The Faculty's Engineering Gateway employs three staff and is a focal point for external enquiries. For example, this approach enabled the initial contact with EDF Energy, which subsequently led to EDF's involvement in steering committees, funding of a PhD student, and direct knowledge transfer via consultancy activities. All academic staff are encouraged to undertake consultancy, as this allows easy and flexible access to our expertise. Examples of impact arising from consultancy are:

- Work with the Centre for Protection of National Infrastructure has informed UK Government policy and has had a direct impact on design for security and counter-terrorism.
- [*text removed for publication*] has reduced the vibration of power generation turbine blades.
- [*text removed for publication*] have worked with us to develop and embed technology for the next generation of off-shore oil riser systems.
- [*text removed for publication*] directly used our work on soccer balls to develop a new product.

- Expertise in residual stress measurement in glass has helped the Manchester Royal Exchange Theatre use glass safely in their productions.
- Expertise in automotive valve wear has been transferred to [*text removed for publication*].

Innovation vouchers provide another opportunity for industry to engage with our expertise and build confidence in working with us. For example, underpinning research on radiator thermodynamics led to an innovation voucher with [*text removed for publication*], resulting in a patented (EP 1164600 B1) new product, [*text removed for publication*].

Knowledge Transfer Account (KTA): The University's EPSRC KTA provided a means to build relationships through work on specific projects. An example is the provision of a 'development hot-house scientist' to assist with the development of a novel machinability test methodology for Tata.

Industrial secondments: Academic staff can be relieved of their teaching and administrative duties to allow a contiguous period of time to be spent working in a third party organisation. In this assessment period we have enabled secondments that have embedded robust on-track measurement methodologies for [*text removed for publication*], developed recyclable composites suitable for use in hot climates for the Qatar Science & Technology Park, and transferred expertise in the finite element modelling of composites to [*text removed for publication*].

Advisory boards: Many of our staff are engaged in end-user advisory boards, where their own research expertise has led to greater practitioner impact. Examples are the AMRC/Nuclear AMRC membership of the High Value Manufacturing Catapult, and Lawford's membership of British Standards Committees for cardiovascular implants and valves.

Stakeholder involvement: All of our major research activities involve external stakeholders in a steering, advisory, or collaborative role. For example, Wagg & Worden's programme grant includes EDF Energy, Airbus UK, and AgustaWestland. The INSIGNEO institute has 15 clinicians within its membership. We also have a number of Visiting Professors and Fellows from companies such as Philips, Rolls-Royce, and EDF Energy, who have been selected for their ability to actively engage with our research staff and offer strategic advice from their sectors' point of view.

Licensing and commercialisation. The University has a streamlined mechanism to enable economic impact that is well suited to both planned commercial opportunity and more serendipitous research findings. A partnership between Fusion IP and the University enables investment to be made in intellectual property with commercial potential. The AMRC has a separate agreement with their industrial members. A commercialisation manager supports academics at Faculty level, by helping to identify potential opportunities, locate seedcorn funding, and presenting a case so that the commercial potential can be assessed. This provides an agile mechanism for serendipitous impact: for example, Hose's research concerning biomedical imaging led to an £800k license sale to a global orthopaedic company.

Staffing strategy

A key part of our approach has been to recruit the best scientists and engineers who appreciate the value of high-impact research, which we routinely assess in appointment interviews. In Professorial interviews we explore how strategic stakeholder partnerships are managed by the candidate (e.g. Horoshenkov had previously founded a company to commercialise his research). For new Lectureships we assess understanding of the pathways to impact for their research. We also identify opportunities to recruit staff who can work in new strategic areas. For example, the INSIGNEO concept was strategically identified as an area with great potential for impact. The initiative led to the recruitment of a number of prestigious academics, and the formation of a new collaborative centre to translate the latest biomedical modelling into clinical applications.

Existing staff are also rewarded for delivering impact: examples include Marshall's promotion to Senior Lecturer and Lewis' promotion to Professor. The level of impact achieved by each academic is explicitly recorded on their promotion application and we hold impact-focused sessions at Research Away Days. Our Workload Allocation Model sets aside 20% of the working week for activities that are not directly related to a particular research project or to teaching with knowledge transfer and impact activities forming a significant portion of this time.

Our structure is specifically organised to ensure that our fundamental engineering science research can be brought to bear on real problems. Each member of staff belongs to one Core Area of Excellence (e.g. Dynamics or Thermo-Fluids), but works in any number of application-focused

expert teams and research centres (e.g. Computational Fluid Dynamics and the Rail Innovation Technology Centre). Entrepreneurship is embedded in our research culture: two of our postdoctoral researchers have been awarded Royal Academy of Engineering ERA Foundation Entrepreneurs Awards and have become Fellows of the Foundation. Public Engagement is also a valued activity: many of our staff contribute to University-wide events (e.g. Festival of the Mind, National Science Week and Global Manufacturing Festival) and to public events promoted by engineering professional institutions (IMechE, RAoE), the Royal Society and other organisations.

c. Strategy and plans

We aim to emulate the AMRC's successful approach to impact with our new initiatives in healthcare. By engaging with clinicians and the medical technology sector we will translate research into clinical practice, in the same way as the AMRC interacts with its industrial stakeholders. We will build stronger links between Dynamics and its industrial partners, focusing on our expertise concerning health monitoring of ageing systems and infrastructure. The formation of the Leonardo Centre aims to maximise the impact of leading research in tribology from colleagues across the University. We will also continue expanding the high-impact activities in combustion, with a focus on the new PACT facility. We have funded three dedicated Business Development Managers to support these strategic plans.

Meanwhile, we aim to continue building upon the global success of the AMRC, whilst recognising that its unique approach necessitates a separate structure that focuses entirely on high impact industry driven research. At the AMRC, the latest £43M infrastructure funding (2013) will enable the building of Factory 2050. Our vision is to build the UK's first fully reconfigurable assembly and component manufacturing facility for collaborative research, capable of rapidly switching production between different high-value components and one-off parts. Around 50 researchers and engineers will work in the new facility. The AMRC's pioneering approach will continue with flagship activities such as joint road-mapping with industrial partners, industry-facing conferences and interaction with the High Value Manufacturing Catapult, all providing a flexible and sustainable strategy for the Centre.

These detailed plans are synonymous with the Faculty's vision: to ensure that its research has an impact beyond the traditional academic disciplines; to solve the problems that matter to society; and to focus investment in the four strategic areas of manufacturing, infrastructure, energy, and health. Our ability to impact on these societal areas will be supported by the Faculty's 'Research and Innovation Hub' (5 staff), along with our three dedicated Business Development Managers, and the Engineering Gateway. As a result, we expect to significantly improve our capacity to conduct consultancy and applied research, maximise synergy from working with key external partners such as NHS trusts, and create new partnerships with end users that are developed and managed at a senior level.

These aims are in turn supported by the University's Impact, Innovation, and Knowledge Exchange (IIKE) strategy. For example, central funds are set aside to provide staff development courses, and the desire to foster deeper partnerships with external organisations has resulted in framework agreements that streamline contract administration. For EPSRC-funded research the £2.4M Impact Acceleration Account provides support for industrial collaboration, application of research, and development of staff skills.

d. Relationship to case studies

'Transforming the manufacturing of aero-engine casing components for Rolls-Royce and its supply chain', and 'Reduced production costs for aero-engine discs leads to new manufacturing facilities' exemplify our **flagship** AMRC approach to impact. AMRC industrial partners, collaborating with us on core EPSRC-sponsored underpinning research, worked in parallel with Rolls-Royce initiated research projects developing the technologies required to solve their specific production problems.

'New vibration damping technology which extends the life of aircraft engine components' describes the **longstanding** relationship between Dynamics and vibration engineers at Rolls-Royce.

'Engineering companies benefit from improved sensor design for tribological machine elements' exemplifies how smaller scale **consultancy** activity has led to longstanding relationships within the discipline of tribology and demonstrates practitioner impact on a wide range of companies.

'New computational aerodynamics design tools for the aerospace industry' is an example of

industry-funded research, from **longstanding** relationships with DSTL, Rolls-Royce, and Airbus.