Institution: University of Bath

Unit of Assessment:12: Aeronautical, Mechanical, Chemical and Manufacturing Engineering

a. Context

The Departments of Mechanical and Chemical Engineering (MECE), constituting this UoA, foster a dynamic environment that strongly encourages and develops end-user engagement of its internationally excellent research. Our main non-academic user groups are industry, which covers large national and multinational corporations through to SMEs, national laboratories (e.g. NPL), NGOs (e.g. standards organisations), charities (e.g. British Heart Foundation), government agencies (Dstl, DEFRA), non-profit organisations (e.g. Earthwatch Institute), professional practitioners, including clinicians, and other stakeholder groups. Our range of users is extensive and they are key beneficiaries of our research as are society, groups and individuals.

Our research is structured around focused groups that cover 6 research themes: (1) Machine Systems; (2) Design and Manufacturing; (3) Structures and Materials; (4) Aero, Thermo and Energy Engineering; (5) Healthcare Engineering; and (6) Process Engineering. Our principal route to impact is via industry with focus in the automotive, aerospace, power/energy, chemical/biotech, healthcare and manufacturing sectors. Throughout this document, we provide evidence where our agile approach has allowed us to respond to opportunities to nurture and develop impact.

Our economic impact includes new business activity, e.g. through a new product that reduces fuel use, something which also benefits the environment and society. New and improved designs of products and processes have led to more efficient system performance, particularly in the automotive, aerospace and power/energy sectors. Manufacturing research has improved processes for the production of batch products, including aerospace components, through to large and bespoke systems. Health impacts for device manufacturers and patients have been achieved through the implementation of prosthesis fixation procedures. Impacts on practitioners and professional services have resulted in new guidelines, standards and training in engineering and clinical treatments. Impacts on the environment have been achieved through the introduction of new processes, improvements of existing products and new monitoring techniques, which have led to reductions in CO_2 emissions.

b. Approach to impact

Our approach to impact is strongly based on our collaboration with industry. This has led to involvement and influence with the International Organization for Standardization (ISO) as well as delivering continuing professional development (CPD) through practitioner training. We have engaged with industry in a number of ways and here we set out our approach.

Industrial engagement

(a) ***Research council funded projects involving industrial collaborators*****:** Typically, such projects within MECE are linked with industrial collaborators. Hence key users are engaged from the outset and are able to exploit results and findings for technology gain. For example, the Innovative Design and Manufacturing Research Centre, funded by the EPSRC (EP/E00184X/1) had 99 non-academic project partners. In contrast, EPSRC funded gas turbine research (EP/G069107/1), had Siemens as the sole industrial collaborator, and led to a Knowledge Transfer Partnership (KTP). Siemens has since adopted new seal designs that increase the power efficiency of its gas turbine products. This relationship continues to expand and deepen.

(b) ***Collaborative industry led projects and partnerships*****:** Researchers in MECE engage with industry and industry-led consortia through a number of mechanisms. For example, 10 TSB collaborative R&D projects totalling £3.7M have been funded over the assessment period. The Powertrain and Vehicle Research Centre has been involved in six of these under the Low Carbon Vehicles: Integrated Delivery Programme. Two of these undertaken with Ford are the subject of one of our impact cases. In fact, we have 25 years of continuous collaborative working with Ford on fuel efficient cars, which has nurtured and delivered this impact. We are a research partner of choice with Airbus under a Research and Technology Framework Agreement. We also have a joint R&D exploitation MoU with NPL, and in 2014 we will sign a framework level agreement with Jaguar Land Rover. These examples describe some of our approaches in establishing and deepening

partnerships with key end-users.

(c) ***Knowledge exchange (KE)*****:** This is a significant aspect of our engagement with end-users, especially SMEs. In addition to the prominence of KE in (a) and (b), since 2008, 25 KTP projects involving 21 external partners and 30 academics, valued at £3.18M, have led to an overall increase in company turnover of £9.7M and £3.8M in further investment. These data are derived from the final reports from partner companies and compiled by our Enterprise and Knowledge Exploitation (EKE) team. Successful delivery led to a number of follow-on KTPs with, for example, Pall Europe.

The £3.39M EPSRC Knowledge Transfer Account (KTA) at Bath, awarded in 2008, led to £1.34M of funding to MECE for 15 partnership development awards involving 22 academics with £1.14M of matched funding from industry. These projects embedded MECE research knowledge in external organisations to deliver impact and the KTA typifies our agile approach to opportunities. One example involved Parker Domnick Hunter to exploit novel gas separation technologies in the healthcare sector. Other projects have been undertaken with Ashwoods Automotive (for a commercial automotive hybrid system), MAST Carbon International (for pharmaceutical manufacture), and also with Airbus, Rolls-Royce/AEC, Babcock, Renishaw, Ford, Jaguar Land Rover, Cummins, Schenck Process, and DePuy International. Many of these partnerships have delivered impact as a result of the KTA engagement.

(d) ***Secondments*****:** The impact case studies show a number of examples of secondments, inward and outward. Outward secondments of MECE researchers were supported by University KE funds and the RAEng (for Butler). The mobility of key researchers is critical to the successful delivery of effective and agile KE to facilitate impact. Our support for this type of activity has been developed with our key end-users. Inward secondments have proven to be effective for companies to expose and train their professional staff in the use of our specialist facilities.

(e) ***Standards*****:** Members of MECE are convenors of ISO committees that generate international standards from established research to enable equipment manufacturers and their end-users to benefit from more reliable products. For example, Keogh is the convenor of ISO/TC108/SC2/WG7, which is the committee that has developed the standard ISO 14839, to ensure that rotating machinery equipped with magnetic bearings is designed to operate robustly in a range of environments. Beneficiaries include Calnetix (USA), Waukesha (USA), MECOS (Switzerland), S2M (France), GE (Germany), Siemens (USA), Solar Turbines (USA) and end-users such as Shell. Other convenors include Johnston, for ISO/TC131/SC8/WG1 relating to fluid power systems, and Newman, for ISO/TC183/SC4 relating to STEP-NC manufacturing. Since 2009, Gill has been a member of ISO/TC 150/SC 04/WG 01 in the development of a standard for Roentgen stereophotogrammetry for assessment of micromotion of orthopaedic implants.

(f) ***Doctoral and practitioner training*****:** Over the assessment period, MECE has been a partner in the industrial EngD in Systems, run jointly with the University of Bristol. EngD research engineers are based in businesses and this provides another mechanism of engagement for the industrial and academic supervisors. The EPSRC Doctoral Training Centre for Sustainable Chemical Technologies (joint with Chemistry) offers an Integrated PhD involving industrial partners and ensures that doctoral students and supervisors have exposure of industrially-relevant research. There have been 15 EPSRC Industrial Case awards for PhD students/projects in MECE over 2008-2013. EADS/Airbus sponsored five of these, an example of how end-users engage with MECE.

Aspects of MECE research are delivered through CPD activities. The Centre for Orthopaedic Biomechanics currently contributes to accredited training for around 300 orthopaedic trainees and consultants per year. In 2013 it launched the PG Certificate in Orthopaedic Engineering for surgical trainees, engineers and professionals working with the orthopaedic device industry. The Centre for Power Transmission and Motion Control has also provided CPD courses over the assessment period to over 500 engineers from Airbus, Moog, Instron, JCB, Parker, BAE Systems, Alstom Power, Schlumberger, GE, Rolls-Royce, Babcock, Ricardo, Messier-Dowty, and NRG Dynamix.

(g) ***Specialist facilities*****:** Our specialist facilities continue to attract and develop industry collaborations, enhancing our impact agenda. Three exemplars include: (1) Our unique vehicle facility has been used in collaborative research via TSB, KE and direct industry funding, with Ashwoods Automotive for product verification, with Jaguar Land Rover for product development,

and with Ford for early adoption of precise CO_2 measurement tools; (2) Our research partnership with GKN via EPSRC, KE and RAEng funding utilises the ultrasonic C-Scan tank in the development of a laminar flow wing; (3) A current TSB project with Renishaw and Moog is using our state-of-the-art microCT scanner to detect flaws/porosity in future aerospace servovalves.

Mentoring, training and professional support for staff
We specifically support staff to achieve impact through a number of routes and mechanisms. All early career staff are mentored by more experienced colleagues who themselves are integral to the developing impact agenda within MECE. Two KE Champions (Mays and Plummer) support activities that encourage all researchers to make new collaborations, through workshops, visits to external organisations, and secondments. The KE Champions are able to seed-fund impact activities, for example, development of a CPD module in cost estimation for industry by Newnes. The impact activities of staff are recognised through our workload model, which ensures a balance across all activities. Financial reward is realised through a share of revenue being returned to the licencing IP holders, including academic staff. Engagement with end-users on KE, impact and commercial activities is recognised within our promotion criteria.

Engagement with the University's Research Development and Support Office (RDSO) through its specialist services and structured training events assists in developing the skills of staff to enable them to identify, assess and engage in an agile manner with collaborative research opportunities.

Enterprise, innovation and commercial activity
The University of Bath's Enterprise and Knowledge Exploitation (EKE) team facilitates and supports commercial exploitation, especially in the areas of Intellectual Property (IP) and patent applications. During this assessment period, staff have been associated with (a) 17 granted patents; (b) 2 patents applied for and 2 patent sales; and (c) 6 licencing and royalty agreements. A spin-out company, nano-porous solutions limited (n-psl), established in 2007 (by Perera) was sold in October 2013. Funds of £177k from HEIF were awarded to staff for feasibility studies, proof of concept and contributions to collaborative projects with industry to nurture future impact.

c. Strategy and plans
The impact strategy of MECE is subject to ongoing review and development informed by our research, our impact case studies, our plans to further develop and deepen our existing relationships with end-users, and to explore and foster engagement with new beneficiaries. There are four elements (**IFS1**-**IFS4**) to support our strategy.

IFS1: ***Industrial engagement.*** Building industrial partnerships and collaborations with potential users of our research has proved to be a successful mechanism leading to exceptional and mutually beneficial impact. We will continue to develop partnerships and relationships with end-users, which will be achieved in a number of ways:

(a) Provide incentives to increase the number of outgoing researcher secondments and develop opportunities to host industrial secondments aligned to our key research themes.
(b) Continue to engage and extend our portfolio of KE activities. This will involve more researchers becoming engaged as a result of our expansion of academic positions.
(c) Engage in more industrially led activities, e.g. the Business, Innovation & Skills (BIS) Advanced Propulsion Centre, to expand our opportunities for impact achievement.
(d) Develop wider dissemination of our research through the Faculty's marketing strategy to end-users and beneficiaries, including the use of showcase events and exhibitions, trade journals having significant audience reach, webinars and other online workshops.
(e) Continue to invest in specialist facilities to strengthen and deepen our existing industry partnerships and to forge new ones. For example, a successful EPSRC equipment bid will accommodate new research on future fuels, hybrid electric and electric vehicles. This will be launched in 2015 as the Centre for Low Emission Vehicle Research (CLEVeR).

IFS2: ***Impact pipeline.*** We recognise the need to nurture and invest in exciting research activities that have significant potential to deliver future impact. These future activities are embedded in our Faculty Research Strategy and include plans for capacity building in nanotechnology, healthcare engineering, electro-mechanical systems, and water engineering and science. We are already recruiting new academics to support these activities and detailing business plans to provide investment in specialist equipment.

IFS3: *Impact culture*. Over the assessment period we have gained experience, which has allowed us to embark on a process to develop an Impact Toolkit for all our researchers to enable them to link their research to impact potential. Within this toolkit we will, for example:

(a) Explain the impact value chain and how fundamental research can be channelled through to KE, leading ultimately to measurable impact achievement.
(b) Stage workshops on creativity and innovation to help researchers identify where and when their research may create impact, without compromising the quality of their research.
(c) Demonstrate how to identify and capitalise on impact opportunities in an agile manner.

This toolkit will effect a change of culture embedding impact in all of our research.

IFS4: *Management of impact*. The management of our approach to impact has a defined structure. We will create a pool of Impact Mentors, drawn from the existing KE Champions and academics who have demonstrated impact through the submitted case studies. This Impact Delivery Group (IDG) will be led by the Associate Dean for Research, who also chairs the Faculty Research Committee (FRC), and has a place on the Faculty Executive and the University Research Committee. The IDG in MECE will also work with the University-wide Impact Sub-Group of the Research Committee. This approach will ensure that our impact strategy, plans and goals have prominence throughout our academic management structure. It will also ensure that there is two-way exchange of communication and dissemination of our ideas, developments and successful good practice, which will benefit all our researchers.

d. Relationship to the case studies

Our case studies exemplify many of the mechanisms described in **section b.** to achieve impact. They have also been used to inform the development of our approach in **section c.** We now describe how the case studies relate to our impact strategy and its development.

1. *'Reducing CO_2 emissions'*: The MECE research output from two sequential TSB collaborative R&D projects, resulted in the adoption of prototype lubrication systems in Ford vehicles. A KTA project seconded MECE researchers to Ford to implement expertise for precision measurement of vehicle CO_2, developed on our **specialist facilities**. This exemplifies how we engage with long-term **industrial partnerships** using **KE mechanisms** and agile **researcher secondments**.

2. *'Ashwoods Lightfoot'*: Research (1999-2000) did not achieve immediate impact. Ten years later, during collaboration with Ashwoods Automotive, via a KTA project, this research was seen as being of major interest to its business plans. An agile response captured the impact through the use of MECE **specialist facilities** by Ashwoods engineers, exemplifying how we engage in **KE mechanisms** to develop **industry partnerships** and accommodate inward **secondments**.

3. *'Composite wing'*: Impact emerged through links with GKN and its participation on an EPSRC research project, a one-year RAEng sponsored secondment by Butler, and EPSRC funding to deliver pathways to impact through a KT Fellow. This is an excellent example of **industry partnership** fostered through the EPSRC and the RAEng, with **researcher secondment**.

4. *'Gas adsorption and separation'*: The underpinning research was carried out over 1998-2004. The approach included a spin-out company, with patented technology, 2 KTPs and a KTA project took a number of different routes to realise impact through our **commercialisation** and **KE activities**.

5. *'Enhancing clinical materials'*: Early promising research undertaken with Summit Medical and Stryker over 2000-2006 took time to emerge commercially, due to the clinical nature. The impact achievement arose from our perseverance through **long-term collaboration** where research and KE need time to evolve.

6. *'Efficient rotating machines'*: EPSRC funded research with industrial collaborators led to key members of staff serving on ISO committees, and others engaging with Siemens to change current practice and introduce design innovations for rim seals. This case demonstrates our approach to engage with industry and people to influence **practitioners and professional services**.

7. *'Packaging machine design'*: The impact achievement arose from industry collaboration associated with research council funding over 10 years, which is now benefitting 3 businesses. This approach illustrates the strong emphasis that we place on **partnerships** with industry.