Institution: University of Birmingham

Unit of Assessment: UOA 12: Aeronautical, Mechanical, Chemical and Manufacturing Engineering – **MECHANICAL ENGINEERING Submission**

a. Context - Our core and interdisciplinary research has produced beneficial impact for our industrial partners and audiences in the aerospace, automotive, electronics, energy, healthcare, manufacturing and transport sectors. Those include world-leaders, such as Rolls-Royce (RR) and Airbus (aerospace, manufacturing); Mazak, GKN and Delcam (manufacturing); Ford, Jaguar-LandRover (JLR) (automotive); GE Druck, Shell (energy); Johnson & Johnson (J&J) (healthcare); Johnson Matthey (JM), Innospec (chemicals). We also work extensively with SMEs. Between 2008 and 2013, we have helped over 100 SMEs to solve problems with their products or develop new ones, including Glassworks Hounsell, Whiston Industries, Loadpoint, UPM (manufacturing), Ranier Technology (healthcare); Green Fuels, John Pointon & Sons, ITM Power, Truflo Marine (energy); Revolve Technologies, Cambustion, Indestructible Paints (automotive). The matrix demonstrates how each of the School's three research centres generate environmental, health and economic impact from their research. The examples chosen for the impact case studies are in bold.

		Advanced Manufacturing Centre	Biomedical & Micro/Nano Centre	Vehicle & Engine Technology Centre
Environmental	**Energy & Sustainability**	• **Reducing energy consumption in casting processes** (J&J, KTP) • Decreasing cutting fluid in machining (Airbus, GKN, Seco)	• Micro sensor for energy harvesting in wheels. (EPSRC) • Micro porous material for low-temperature adsorption cooling (Meggit Control Sys)	• **Alternative fuels for transportation** (JM, JLR,GF, Innospec, TSB, Shell, EPSRC) • New energy carriers (e.g. Cryogenic EPSRC, Dearman)
Health	**Healthcare**	• Robotic rehabilitation (ACE Ltd; W. Mid Rehab.)	• Bio-MEMS for artificial fingers (Unilever; FP7) • New spinal implants (S14 Implants, EU FP7)	• Vehicle emissions characterisation (Ford, JLR, JM, EPSRC, EC-FP7)
Economic	**Knowledge economy**	• Design of multi-point forming tools (MGM, UPM, TSB, EPSRC)	• Tool for bone cutting (Surgicraft)	• Use of tallow as fuels (JPS, KTP)
	Process /Product character.	• **Machining of advanced materials** (RR, Airbus, GKN)	• Friction/wear/lubrication of TDA (Ranier, EPSRC)	• **Environmental catalysts** (JM, Ford, JLR, TSB)
	Systems optimisation & modelling	• **Point-based surface modelling and improved CNC machining** (Delcam, Pilkington, RR, BAE, Wedgewood,EPSRC)	• CFD for heart valves (British Heart Foundation) • Process modelling for improving investment casting (J&J, EPSRC)	• CFD for process optimisation (JLR, Ford, TSB) • **CAD/FE tyre design system** (Airbus, Dunlop)

b. Approach to impact

Engagement with industrial partners and audiences

We actively ensure there is a two-way flow of knowledge, research findings and industrial requirements between our staff and our research users. We have long-standing industrial collaborations providing a sustainable platform for future impact and an environment enabling the development of new links. Our Industrial Advisory Committee makes a major contribution to engagement; it comprises highly placed engineers in the automotive (JLR), healthcare (Corin Medical) and manufacturing (Delcam and Renishaw) sectors. They advise us on issues affecting industry, provide input into our research strategy, comment on the industrial relevance of our research and connect us to their network of contacts and potential users of our results.

This successful engagement has meant that our industrial partners have contributed to investment in our specialist facilities. Since 2008 and with this support, we have built a cold-start engines facility, the world's first laboratory for cryogenic (e.g. air) powered reciprocating engines research, fuels and catalysts laboratories equipped with state-of-the-art analytical facilities, and laboratories

for bio-materials testing, spine simulation, nanotechnology, advanced machining and laser surface structuring and texturing.
Several members of the School (e.g. Al-Dadah, Anthony, Castellani, Cripps, Dearn, Dimov, Jiang, Kong, Pham, Soo, Tsolakis, Wyszynski and Xu) have worked in industry or have direct contact through consultancy and research projects. Close and successful interaction in one industrial project often leads to others. For example, research on Biodiesel fuels with JLR led to TSB-funded project SERVE, and consultancy work with John Pointon and Sons on use of tallow for fuel in engines led to a KTP (6803).
To promote two-way flow of knowledge, we have also made senior honorary appointments from industry and other user groups (Professorship: R Cracknell, Shell; S Richardson, JLR; A York, JM; D Pratt, NHS; Senior Lectureship: J Qiao, Energy Technologies Institute). These connections facilitate regular communication with potential research users. This approach provides us with natural sources of sponsors and has led to long-term partnerships (e.g. JLR, JM and RR) and major investments. For example, long-standing links with RR have contributed to the recent £60M investment for a new HEFCE High Temperature Research Centre (HTRC) with the University.

Agile approach to opportunities to generate impact

We responded speedily and effectively to the opportunity to win investment from Advantage West Midlands, the former regional development agency, in advanced research facilities for conducting impact-creating work with industry. This generated £2.75 million to develop our engine and fuels laboratory. The laboratory has already been used by 18 industrial partners, e.g. Carbon Clean Direct, JM, Shell and Wartsila, assisting them in the design of new fuels and engines.

Follow-through to impact

Engineers from industry and other user groups also come to use our facilities and work on joint projects. These exchanges strengthen links with the user community and create further opportunities for work leading to impact. Examples include Al-Dadah's work with Meggitt Control Systems; Cripps with Delcam; Dearn with Truflo Marine; Olatunbosun with Fusion Innovations; Saadat with ACE Ltd; Shepherd with DePuy; Soo and Hood with Rolls-Royce; Tsolakis with Johnson Matthey; Xu with Jaguar Land-Rover. Detailed information on the follow-through from this to economic and environmental impact is given within our three case studies: (i) impact on modelling techniques for Delcam, DePuy and Dunlop, including use of a knowledge transfer agreement with DePuy; (ii) impact through enabling Johnson Matthey catalysts and Jaguar Land-Rover engines to work with a wider range of cleaner fuels; (iii) impact for Rolls-Royce through the application of advanced machining technology.

Supporting and enabling staff to achieve impact from their research

We encourage staff to take up industrial secondment and a number have spent sabbatical periods working in industry. We reward industrial collaboration to stimulate impact generating research. Recent promotions have included staff with extensive industrial links, e.g. Jiang (Professor, funding/collaboration with JM, Intelligent Energy West Wind Bearings), Shepherd (Reader, funding/collaboration with J&J, Ranier Technology, Scottish Healthcare Innovations Ltd, Surgicraft Ltd), Saadat (SL, funding/collaboration with NHS, Formax Ltd, Applied Computing and Engineering Ltd, GFM in Italy), Soo (SL, funding/collaboration with GKN, RR, Airbus), Tsolakis (Reader, appointed from JM, funding/collaboration with Ford, JLR, JM, Shell), Xu (Professor, appointed from JLR, funding/collaboration with Shell, JLR, Tata Motors, SAIC, Innospec).

Use of the University's business development and engagement teams

We make frequent and proactive use of the University's business development and engagement teams to establish new industrial partnerships including Knowledge Transfer Partnerships and arrange protection for, and exploitation of, the intellectual property we generate. For instance, we have worked with the business development team to establish a new KTP with Brandenburg UK Ltd using combustion products as a novel way of controlling disease-carrying insects.

c. Strategy and plans – Our strategy is guided by **3 key objectives**: (a) develop robust and sustainable organisational frameworks that foster impact in research; (b) cultivate and extend user networks; (c) provide a stimulating creative research environment that fosters development of innovative engineering leaders and also yields publications of the highest possible quality. **The strategy comprises 5 elements designed to further the progress we have made**.
(i) **Conducting research with the potential to create impact**. Our research is tightly linked to impact generation through our focus on issues critically important to manufacturing and the economy (e.g. new, more efficient materials processing methods for RR and J&J; advanced CAD

modelling software for Delcam), health (e.g. new surgical tools for Surgicraft; CFD analysis of heart valves for the British Heart Foundation), and the environment (e.g. new fuels for Shell; new catalysts for JM; reduction of soot emissions for Ford). We shall vigorously pursue this focused approach to ensure that our work continues to benefit society. We will also continue exploiting our patent portfolio, which currently has around 12 main patent families, and draw on the 33 records of invention submitted in 2008-2013 to the University's commercialisation company, Alta Innovations.
(ii) **Leveraging the strengths of the Manufacturing Technology Centre (MTC)**. An integral and distinctive part of our strategy to increase impact for industry is the £40.5 million MTC. The MTC translates our research into industrial processes, to bridge the gap that hinders the introduction of ground-breaking research into UK industry. The MTC's impact during the last 2 years has far exceeded our expectations, with some 60 companies, ranging from multi-nationals to micro SMEs, attracted to the Centre as partners and a £17.5m annual turnover. We have made new academic appointments to capitalise on this unprecedented opportunity and will concentrate further manufacturing research efforts on collaborative industrial projects.
(iii) **Building strategic industrial relationships**. To increase the reach of our research, we shall prioritise long-term productive relationships with large user organisations whose needs for research input can be matched by our expertise. We shall build on the formal collaboration framework recently agreed with JLR and accelerate the development of cleaner and more efficient engines in collaboration with JLR, Shell and JM. We shall strengthen our links with RR, Mazak and Delcam in advanced machining and generate new links in manufacturing informatics with other blue-chip companies some of which will come to us via the MTC. We shall work with the University's Medical School on projects at the interface between our Advanced Manufacturing Technology and Biomedical and Micro/Nano engineering research centres, while developing strategic collaboration with the NHS and the healthcare industry. These major partnerships and the additional resources generated will give us a sustainable platform on which to conduct short-term projects benefitting smaller firms.
(iv) **Building strong links with the High-Temperature Research Centre (HTRC)**. The HTRC is a new £60m strategic investment in partnership with RR and HEFCE. It creates the environment for the University to deliver world-class fundamental and applied research focused on radical manufacturing process improvements and predictive process modelling to enhance product quality and production efficiency. With funding already agreed with the MTC, we shall establish a new Chair in Modelling and Simulation directly linked to HTRC and a world-leading research group combining our strengths in optimisation and intelligent automation to work on the design and manufacture of complex castings for the aerospace industry.
(v) **Growing European partnership.** We will selectively form links with organisations in Europe. This has the advantage of broadening the impact of our work and facilitating access to the large European research funding pool. Two of the companies we plan to cultivate links with are Wärtsilä (Finland), a global leader in diesel power plants, and DePuy J&J (Ireland), a leader in healthcare technologies. Links will also be established with Alicona & Wittmann Battenfeld GmbH (Austria), Ortofon (Denmark), Flann Microwave (UK), Mondragon Assembly & EuroOrtodoncia (Spain), S14 Implants and Flowdit (France), and leading research organisations including KIT (Germany), TNO (Holland), CEA and PEP (France) and Ik4-Tekniker (Spain), as part of our new micro manufacturing research programme which includes four recently awarded EU contracts.
We will also ***enhance our academic excellence*** through continued engagement with RCUK and EC, and the dissemination of results in the best journals.

d. Relationship to case studies - Each of our three selected case studies exemplifies aspects of our successful approach to impact. **'Cleaner fuels, reduced emissions and efficient engines'** illustrates the success of our approach to developing unique expertise and facilities in vehicle and engine research. "**Modelling techniques: cost savings in design and manufacture**" highlights our strategy to achieve impact through developing partnerships with leading industrial companies to create solutions to complex problems. The case study also illustrates our effective use of two-way staff secondments to enhance collaboration and impact. **'Advanced Machining Technology'** describes our approach towards forging successful and long standing collaborative relationships with key aerospace OEM companies and their first-tier suppliers.