Institution: UNIVERSITY OF BIRMINGHAM

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

a. Overview

The School of Mechanical Engineering is one of nine schools in the College of Engineering and Physical Sciences at the University of Birmingham. Research in the School is focused through three Centres (with the Head of Centre's name emboldened below):

- **Advanced Manufacturing Technology** (**AMT**) for advanced machining, autonomous and intelligent systems, computer-aided engineering (CAE), laser processing and micro manufacturing (*Castellani, Cripps, **Dimov**, Essa, Hood, Kong, Pham, Saadat, Soo, Stolkin*)
- **Biomedical & Micro/Nano Engineering** (**BMN**) for tissue mechanics, implant and surgical devices, micro sensors, power generators and nanofabrication (*Al-Dadah, Anthony, Butt, Espino, **Jiang**, Shepherd*)
- **Vehicle and Engine Technology** (**VET**) for future power systems, novel fuels in engines and non-carbon energy carriers for transportation, and vehicle dynamics (*Dearn, Olatunbosun, Tsolakis, Wyszynski, **Xu***)

A distinctive feature of the School is the extensive scope of our research portfolio which stretches well beyond traditional mechanical engineering into non-conventional and micro machining, healthcare, micro electro-mechanical systems (MEMS), intelligent systems, nanotechnology, green energy and power generation**.** Our Centres align well with two of the College's three priority areas, these being "Advanced Manufacturing" and "Resilience, Energy and Sustainability". The ethos of the School is also in line with the University's strategy to promote interdisciplinary work across all specialisms. More widely there is a close fit between our technologies and both EPSRC and national government priorities for research as a route to re-invigorating the economy.

b. Research Strategy

Major achievements since 2008 have included:

- enhanced quality and volume of our research outputs: our established academic staff (16 of the submitted staff) have produced 670 publications in peer reviewed journals and conferences over the REF period (averaging 5.2 per academic per year).
- growth in research funding: we have won an increased number of EPSRC, Technology Strategy Board (TSB), Industry, and European grants. The average annual income per established academic from all sources has risen by 45% compared with the RAE 2008.
- increase in the number of doctoral degrees awarded: since 2008, we have increased awards by 15% and grown PGR numbers by 20% whilst maintaining intake quality.
- attracting and retaining high quality staff: we have recruited experienced academics (3) and early career researchers (8) whilst promoting key people (7) for sustained research performance.
- securing new and substantive strategic partnerships with major collaborators including Jaguar Land Rover (JLR) and the Manufacturing Technology Centre (MTC) in Coventry.

Evaluation of the current position with reference to RAE 2008 plans

(numbers in brackets denote respective staff outputs)

AMT: Our RAE 2008 plans were focused on *"developing techniques and applications for machining new alloys"* and carrying out *"innovative work in the very specialised field of CAD/CAM".* These have now made an impact in industrial applications as can be seen in the "*Advanced Machining*" and "*Process Modelling*" Impact Cases (REF 3b). In line with UK priorities, we have also considerably strengthened AMT with appointments in non-conventional machining, micro manufacturing and intelligent systems. Examples of significant outputs include:

- Efficient processes for machining advanced composites (Soo 3) and novel machining processes for hard aerospace materials (Soo 4; Hood 1)
- An efficient technique for triangulating trimmed parametric surfaces (Cripps 2) and a novel approach to enhance the quality of geometric data for CAE (Cripps 4)
- A novel master-making process chain for organic and large area electronics (Dimov 2)
- A fundamental understanding of micro injection moulding (Dimov 1, 4)
- Innovative agent-based methods/ architectures for task allocation in manufacturing (Saadat 1)
- First use of abrasive waterjet cutting to machine titanium aluminide alloys (Kong 1)
- A novel and efficient algorithm for complex engineering optimisation problems (Pham 4)

- New intelligent systems tools for manufacturing informatics (Pham 1-3; Castellani 1-4)

BMN: An essential part of our RAE 2008 research strategy was to "*develop new spinal implants".* This has led to a new industrial collaboration with S14 Implants in France in a large FP7 project coordinated by our School (Shepherd). Outputs include:

- New surgical implants (Shepherd 2,3)
- New fundamental knowledge to aid implant surgery (Espino 1)
- Novel method for analysing fluid-structure interaction for heart valve modelling (Espino 4)
- Novel processes for fabricating MEMS (Jiang 4; Anthony 3) and BioMEMS (Anthony 2)
- Novel use of carbon nanotubes to produce holograms (Butt 1)

VET: In RAE 2008, we planned to research "*the interaction of fuel and engine*". This work has important implications for engine development including control of emissions, which are of considerable value to our industrial partners. Our collaborative research on biofuels with JLR, Ford, Shell, Johnson Matthey (JM) and various SMEs has created wide impact within the automotive industry, as described in the "*Automotive Technology*" Impact Case (REF 3b). Outputs include:

- Unique Flex-fuel diesel engine (Xu, TSB SERVE project)
- Unique heat recovery technology with proven fuel economy and CO_2 emissions benefits (Tsolakis 1).
- First study on new biofuel for transportation derived from biomass at low energy cost (Xu 1, Dearn 4)
- Advanced analytical techniques for the speciation of harmful Poly-cyclic aromatic hydrocarbons (Wyszynski 1).
- First study on the recycled soot part of the EGR in the engine out soot (Tsolakis 2)
- Novel after-treatment systems for pollutant reduction (Tsolakis 3)

Vision and Strategic Plan for the Future

Our vision is to develop innovative engineering science to solve problems important to industry and society. This involves research to answer challenges in the design and manufacture of products ranging from the very small (MEMS) to the very large (e.g. Airbus wing panels) across different sectors including aerospace, automotive, electronics, manufacturing, healthcare and transport.

Our new strategic plan was devised by our Research Committee (Chair: Jiang) with input from the Industrial Advisory Committee (Chair: Mr D Waide, Director JLR). The Research Committee promotes research at the interface of our groups and engages in 'horizon-watching' to ensure that research plans benefit from emerging trends and disruptive technologies. It encourages interdisciplinary research, co-opting academics from across the globe [e.g. Prof Hu, China, Prof Kalghatgi, KSA, Prof Zhou, China, Prof Jamshidi, USA, Prof Jovane, Italy]. Specifically, we plan to:

1) Build core strengths in areas where we have specialist expertise and facilities and where we can influence and guide both national and international agendas for commerce, industry and policy (e.*g.* new ISO standard Ref. no.: ISO/TC 44 N 1770, Kong 3).
2) Develop areas at the interface of current strengths. The interface areas receiving particular attention include those between technology and management (e.g. supply chain management) and between mechanical and electronic engineering (e.g. MEMS, intelligent automation, and mechatronics). We shall also continue to focus on the interfaces between biomedical and micro engineering and between micro and nano engineering and other areas of mechanical engineering such as automotive. We shall also develop activities across the University.
3) Maintain flexibility to take advantage of disruptive technologies (e.g. new energy carriers) and changing national priorities (e.g. emphasis on high-value manufacturing and alternative energy vectors) by targeted recruitment and the focussed application of University investment.
4) Forge alliances with key industrial and academic partners to leverage human and financial resources and deliver impact nationally and internationally. Our key partners will include JLR, the MTC and the recently announced High Temperature Research Centre (HTRC). Academic partners will include the University of Illinois, Beijing Institute of Technology, Beijing Jiaotong, Tsinghua, Xian Jiaotong and Wuhan. We are one of the few centres now working in a formal strategic partnership with JLR signed in February 2013. We have new appointments linked to the MTC and HTRC. The MTC relationship will provide a vital two-way conduit to industry exposing us to industrial problems which will benefit from the low TRL research being pursued in the School. The MTC Core Research Programme (CRP), co-funded by industrial members

and the High Value Manufacturing (HVM) Catapult, will be used to feed and build upon our research outputs in the context of the specific needs of the MTC industrial members (currently in excess of 60 companies) and thus to initiate joint industry-focused research.

5) Shape our capability, particularly in areas such as high-value manufacturing, healthcare and sustainable energy. We plan to direct efforts at maximising our potential in these areas to generate impact. We will do this through our staffing strategy and through strategic alliances with organisations such as the MTC, JLR, BP and DePuy.
6) Develop academic and industry leaders. We train future leaders for industry and academia. Through them, and in our own right, we plan to continue influencing UK and international research strategies and priorities, building on successes such as the progression to senior industrial roles made by Burton (Mazak), Minards (Aston Martin) and Mughal (Rolls-Royce) and to top academic roles by Simmons (Edinburgh) and Sharma (Delhi).

Plans for each Centre

AMT: We shall focus on (i) processing of new materials including advanced composites particularly for aerospace applications; (ii) micro-manufacturing platforms, e.g. reconfigurable micromachining platforms and laser surface structuring and texturing systems; (iii) computational techniques including computational geometry and intelligent systems.

BMN: We shall exploit the expertise and facilities in biomedical, micro and nano-engineering to develop novel solutions to health problems including research at the interface between (i) function and failure of natural tissues; (ii) design of mechanical implants and surgical devices; (iii) design of micro power generators and sensors and the application of nanofabrication technology.

VET: We shall focus on research in (i) combustion and advanced in-cylinder analytical techniques; (ii) fuels, environmental catalysts and engine interaction using a combination of chemistry and physics; (iii) alternative energy carriers for transportation, building on the capabilities we have in the Centre for Cryogenic Energy Storage and waste to energy conversion; iv) low carbon energy, by developing long-term mutually-beneficial partnerships specifically with new Brazilian and Indian partners - all capitalising on state-of-the-art facilities for engine R&D not replicated in any other UK HEI.

c. People: Staffing Strategy and Staff Development

Staffing strategy and relationship to School vision

The School has invested strategically in new research areas through the recruitment of experienced internationally leading professors and early-stage lecturers with the profile and trajectory to become professors. These gains have been balanced by seven retirements and the departure of three staff to professorships elsewhere. Appointments have been made in all research centres, but the main investment has been in AMT, reflecting the importance of manufacturing to the UK and the collaborative opportunities with the MTC. The medium-term strategy is to maintain approximately equal strengths in the three Research Centres reflecting their equal importance to wider national and international research agendas. Details of all 11 individual appointments and their specific research contributions are given below:

Centre	Name (date of appointment to teaching staff)	Role / contribution
AMT	Pham OBE FREng (2011)	Chance Chair of Engineering and Head of School (HoS), leading Intelligent Manufacturing
AMT	Dimov FIMechE (2011)	Professor of Micro-Manufacturing, leading Micro Manufacturing & Laser Processing
AMT	Stolkin (2013)	Senior Birmingham Fellow, Robotics & Intelligent Systems
AMT	Hood (2013)	Lecturer, Advanced Machining
AMT	Essa (2013)	Lecturer, Process Modelling
AMT	Castellani (2013)	Lecturer, Robotics and Intelligent Systems
AMT	Kong (2013)	Lecturer, Water Jet Machining and Laser Processing
BMN	Anthony (2008)	Lecturer, Micro Engineering
BMN	Espino (2013)	Lecturer, Biomedical Engineering
BMN	Butt (2013)	Lecturer, Nanotechnology
VET	Dearn (2008)	Lecturer, Tribology for Engine & Biomedical Research

Staff development and support

The University operates an annual Performance Development Review for academic staff conducted by the HoS, which is fully implemented in the School. Staff attend courses provided by the University's Centre for Learning and Academic Development (CLAD). The School has a flexible sabbatical policy to enable staff to develop their research profile (e.g. Al-Dadah spent 6 months at Meggitt supported by the Royal Academy of Engineering). Since 2008, promotions based upon research excellence have been made to Chairs (Jiang and Xu), Readerships (Shepherd; Tsolakis) and SL (Cripps; Saadat; Soo).

Early-career staff have low teaching and administrative loads and are formally mentored through their probation by senior colleagues. They can preferentially access School funds for PhD scholarships and development courses to build research and supervision expertise. Two staff members recently completed probation, and a further six are being mentored to ensure successful completion of probation.

We place importance on active personal development of both our permanent academic and contract research staff. The School readily embraces the Research Concordat. All staff also benefit from the many schemes offered by the University designed to enhance transferable skills and employability. We encourage research staff to gain experience in teaching, research supervision and writing grant applications. Prior to their academic appointments, a number of our research staff (Espino, Essa, Hood and Stolkin) gave tutorials and co-supervised PhD students. They participated in the preparation of grant proposals, wrote their own bids as PIs and executed research as co-investigators.

The School also runs seminars with leading international speakers (e.g. T Hu, China; X Hu, China; Sutkowski, Finland; Jamshidi, USA; Jasiuk, USA; Mayor, USA) as well as organising an annual conference for and regular technical presentations by PhD researchers.

International and honorary staff appointments and emeritus staff

Honorary staff provide a vibrant background to the research with appointments from across the globe. Appointments have been made aligned to our strategic aims and include 9 Honorary Professors [D Aspinwall, F Bakhtar, R Cracknel (Shell UK), M Jamshidi (Univ Texas), F Jovane (Poly Milan), D Pratt (NHS), S Richardson (JLR), C Whitehouse (formerly RAL) and A York (JM)], 7 Honorary Lecturers/Senior Lecturers/Readers, and 21 Honorary Researchers. The School also has 9 Emeritus Professors [inc. A Ball, T Dean, D Hukins, P Prewett, C Sturgess and D Walton], many of whom actively contribute to our work through their own research or advice to colleagues.

Equality and diversity

The School is culturally diverse. More than 50% of our staff are from overseas contributing to our international presence and influence. They originate from Bulgaria, China, Egypt, Greece, Iran, Italy, Malaysia, Nigeria, Pakistan, Palestine, Poland, Spain, and Vietnam. As part of a University-wide initiative, all staff in the School must attend and pass training in Equality and Diversity. Al-Dadah is leading our application for an Athena Swan award. We participate in University outreach activities such as '*Girls don't just want to have fun … with STEM'* and *'Discovery Day'* to encourage a more diverse student population. We pro-actively support staff returning from career breaks such as maternity/health/ paternity leave (e.g. buying out teaching, allowing staff to focus on re-establishing research).

ii. Research Students

PGR recruitment

We recruit only high quality PG students from around the world. Our multi-disciplinarity has led to students being admitted from a range of engineering and science disciplines (e.g. electrical, chemical and materials engineering, mathematics, chemistry and physics). Students are supported by industry, TSB/KTP, EPSRC, EU and other overseas funding agencies. Ten school scholarships are also competitively available each year and are awarded to the most outstanding of our first-class students. They are also encouraged and supported to apply for competitive national scholarships such as IMechE (e.g. Green was successful with her PGR Research Scholarship in 2013)

Training, support and progress monitoring

Our PGR training, support and progress monitoring processes are designed to drive up quality. Each student has an individually tailored training programme which includes courses on generic skills, specialist topics or supervised reading. Each student has two supervisors sharing the

supervision responsibilities appropriately when the research requires multidisciplinary expertise. In many cases, a third industrial supervisor is also involved. The School Welfare Tutor provides pastoral help and refers students to other University services for additional support if needed. Students are encouraged to present their work at national and international meetings (with financial support from the School or with external funding), and at the School's annual research conferences financed by the University's Graduate School and organised by the students themselves. They are also supported in applying for grants to conduct research overseas in schemes such as Universitas 21 (e.g. Leung to travel to Japan, and Green to Ireland).

In addition to the normal day to day supervisory contact, each student has a formal monthly meeting with supervisors to document progress on a Supervision Record. This record also lists issues that the student may want to discuss with the supervisors, the research planned for the following month and any work to be submitted. From those meetings, the student's performance is regularly evaluated and potential problems detected. At 9, 18 and 30 months, students give a presentation to and are orally assessed by independent academic staff to provide an impartial review of progress and enabling a fair decision on how or whether to proceed.

Our track record in this area is demonstrated by the success of our former students in their chosen employment path. Past students have already achieved senior roles with Ford, JLR, Mazak, JCB, BP, Perkins, Shell, Aston Martin and Rolls-Royce as well as securing senior academic positions. The range of employers also highlights our success in developing researchers able to work at senior levels in world leading companies.

d. Income, Infrastructure and Facilities

Specialist infrastructure and facilities

The School's extensive research facilities are organised and managed through the three Centres.

The AMT Centre has comprehensive facilities in advanced machining with an equipment base originally costing approximately £2.5M built through Joint Infrastructure Funding, Advantage West Midlands investment in micro machining and SRIF funding to consolidate the facilities (in 2006). Since 2008 we have secured three significant long term loans or donations of equipment to cement industrial relationships. These are the latest minimum-damage electrical discharge machining tool on long-term loan from Agie-Charmilles for collaborative research (worth £180k) and one vertical and one turning computer numerical control (CNC) machining centre donated by Mazak to strengthen joint research in advanced machining (worth £215k). Specific investments secured since 2008 are a reconfigurable multi-axis laser micro machining platform integrating a nanosecond laser and a femtosecond laser (£400k, University investment), an InfiniteFocus surface metrology and inspection system (£100k, University investment), and a robotics and advanced manufacturing laboratory (£200k, University investment)

The BMN Centre has state-of-the-art facilities for undertaking a wide range of research in the application of engineering to medicine. The Biomedical Eng Lab has a class II containment area and a biological class II safety cabinet for handling and dissecting human tissue. The lab also houses two Bose materials testing machines funded in 2004 by Arthritis Research UK and the University. Three single-station Bose spine simulators for testing spinal devices were installed in March 2009 (£286k, EPSRC). The Micro/Nano Eng Lab consists of two Class 1000 clean rooms equipped with 100keV electron beam nanowriter, an inductively coupled plasma etcher, a dual-beam focused ion beam/SEM nanofabrication system, alongside equipment for optical lithography following a £3M investment.

The VET Centre consists of the Future Fuels and Engines Laboratory (FFEL) and the Vehicle Dynamics Laboratory (VDL). FFEL provides modern facilities (e.g. engine test cells, fuels and lubricants analysis, emissions speciation) to support engine R&D. A £1.5M University investment to build FFEL was matched by £2.75M in investment (2009 – 2011) by Advantage West Midlands (AWM)/ European Regional Development Fund (ERDF). Our VDL provides key facilities(inc. 4-post vehicle dynamics rig, 3-axis tyre dynamics rig, quarter-car rig, universal suspension 6-axis test rig) to support research in tyre dynamics, vehicle ride/handling, and vehicle structural dynamics.

Recent and planned investments

Since 2008, we have been successful with major infrastructure grant applications to EPSRC, TSB and AWM/ERDF and have received further support from industry for specialist facilities. Investment highlights since 2008:

- Advanced Manufacturing to develop MTC collaboration (£2.75M, University)

- EPSRC Pre-clinical Mechanical Testing of Medical Devices - (£581k, EPSRC)
- Science City Energy Theme – co-lead Birmingham/ Warwick (£20M, £2.5M for School, AWM)
- EPSRC Centre for Cryogenic Energy Storage (£6M, £750k for School, EPSRC)
- Infrastructure and revenue for the MTC – co-lead Birmingham, Loughborough, Nottingham and TWI (£40.5M, AWM and TSB)

Research funding portfolio, including future plans

We work with a broad spectrum of research funders including research councils, industry, TSB, UK charities and European Commission (EC). Our research is supported by large companies including Airbus, BAe, Corus, DePuy, Delcam, Doncasters, Ford, GKN, JLR, JM, Mitsubishi Carbide, Rolls-Royce, Shell, Mazak and various SMEs, e.g. Agie-Charmilles, Brandenburg, Element Six, Erodex, Hardinge, Iscar, John Pointon & Sons, Mapal, Matsuura (UK), Saint-Gobain Abrasives, Seco Tools, Unimerco, TruFlow and Winbro Group. The arrival of new senior staff with extensive links to other EU countries is expected to increase substantially our funding from Europe in the future as Horizon 2020 opportunities emerge. Collaboration with the MTC and its partners will also raise industrial income.

The AMT portfolio includes research into specific micro manufacturing platforms with EC funded projects (HYPROLINE and HINMICO), the study of laser material interactions and development of laser surface texturing solutions with funding from the EC (projects ECO-LASERFACTS and STEEP), the Korea Institute of Machinery & Materials (KIMM) and the UK MoD. Also in this portfolio is research on sustainable and resource efficient cutting of titanium, automation and intelligent manufacturing, and computer-aided engineering (all TSB/EPSRC funded).

In the BMN portfolio, there is EC-funded research into the improved design and mechanical testing of spinal implants and studies of improved investment casting methods for medical devices. Our work to understand the mechanical properties of natural tissues including articular cartilage has been funded by the EC and Arthritis Research UK. EPSRC and EC funding has been secured to investigate novel micro/nano fabrication techniques for industrial applications. Various funders are supporting R&D of microengines, fuel cells and alternative energy sources.

Within the VET portfolio, there is research into alternative energy carriers to provide fuel security and deliver emissions reduction funded by the TSB, EPSRC, JLR and JM. Engine R&D includes work on combustion systems and control funded by EPSRC, JLR, and the EC. In the wheels and brakes area, the causes of brake noise and system design to avoid squeal are being studied with funding from JLR, and TSB is supporting the development of a low-carbon variable rolling resistance wheel.

Our future plans are to develop research income, with Catapults (such as the MTC) where appropriate, in the following areas.

In the mainstream of our Centres into:

- non-conventional processes including laser ablation and water jet cutting for micro machining and surface texturing
- the use of carbon-free energy carriers in transportation (e.g. Cryogenic)
- new catalytic technologies and alternative fuels for pollutants reduction, fuel treatment, and improved fuel economy

At the interfaces with other disciplines between:

- mechanical and manufacturing engineering and information science, e.g. in intelligent machines and autonomous systems with optimisation and learning capabilities
- engineering and medical specialities such as cancer research and neurology, building upon our expertise in the traditional areas of orthopaedics and cardiovascular science
- biomedical and micro engineering, particularly for minimally invasive surgery
- the BMN and AMT Centres for improved manufacture of medical devices

In support of these aims, we will continue to develop and exploit our patent portfolio, which currently stands at around 12 main patent families. For the next generation of patents, we will draw on the 33 records of invention submitted by our staff during the REF window to the University's commercialisation company, Alta Innovations.

Consultancies

Staff in the School are in demand from a wide variety of industries and organisations. These range from major international companies such as JLR, Shell, and Tata through to smaller businesses needing very specific advice on particular topics. As an example from the VET area, we have

provided consultancy to CNG Ltd, Gas Data Ltd, CCD Ltd, and A P Cox Ltd. We have also supplied expertise to help with the development of engineering and science teaching curricula in both the UK and the US, and have provided expert witness testimony in a US patent case.

e. Collaboration and Contribution to the Discipline or Research Base

Support for and exemplars of research collaborations

Within the University, we collaborate widely including with Chemical Engineering on fuels from waste; Computer Science on engine control (EPSRC funded); Electrical Engineering on Ka band filter design and assembly, human factors in tele-operation (MoD) and scale-up manufacture of microwave circuits for communications systems (FP7, HINMICO); Metallurgy & Materials on manufacturing process and valve design (TSB-KTPs); and Physics and Astronomy on invisibility cloaks and robotic nuclear decommissioning (National Nuclear Lab).

We also have wide ranging collaborations with other UK Universities. These include joint projects with: Mechanical Engineering at Loughborough, Queen's Belfast, Brunel and Bradford; Chemistry at Oxford and Cardiff; Electrical Engineering at Warwick and Liverpool on areas such as environmental catalysts, fuels treatment, hydrogen for engines, control of engine management and cryogenic engine R&D; Biomedical Engineering at Nottingham and Imperial on spines; Biomedical Engineering at Loughborough, on tissue mechanics; and Engineering at Loughborough, Nottingham, Manchester, Liverpool and Cambridge on manufacturing technology.

Our numerous collaborations with industry extend from large international companies (Airbus, Ford, JLR, JM, Rolls-Royce, Tata), through to smaller companies such as Cambustion, Dearman Engine, Green Fuels, Innospec Inc, John Pointon & Sons, MG Motors, Revolve, UPM and Whiston Industries). We also have joint projects with RTOs and Government Labs such as NPL.

In EU projects, we work with universities such as Vrije Universiteit, Brussels, Kungliga Tekniska Högskolan, Sweden, and Karlsruhe Inst Tech, Germany. Our EU industrial partners include DePuy (Ireland), S14 Implants (France), Alicona and Wittmann Battenfeld (Austria), FIAT (Italy), Philips (Netherlands). In our wider research collaborations, we work with Univ. Castilla La-Mancha (an on-going collaboration since 2003 following a Marie Curie fellowship and 5 Spanish government funded projects), Madrid University and the University of Cordoba and with Tsinghua University, Xian Jiaotong University, Beijing Inst of Technology and Hefei and Wuhan Universities of Technology (China). Staff in the School also hold visiting chairs, for example, Pham (KSU and Univ de Metz); Jiang (Tian Jin Univ, Inst Automation, Chinese Acad of Science and Xian Jiaotong Univ); Olatunbosun (Carlos III Univ, Spain and Univ Lagos, Nigeria); Xu (Tsinghua Univ, Beijing Inst of Technology and Hefei Univ Technology); Dearn (Alexander Univ Erlangen). Our wider industry engagement includes Wartsila (Finland) and Han Kook Machine Tools (Korea).

Interdisciplinary Research

There are numerous examples of truly interdisciplinary research both within the University and beyond. For example, there is collaboration with the School of Geography, Earth and Environmental Science on emissions speciation (EPSRC and EC project FASTER); with the Medical School on patch clamp manufacture; and with the Medical School, the Royal Orthopaedic Hospital, and the Children's Hospital on implant design. Almost all of the activities in the BMN area are interdisciplinary given the focus on biomedical applications and the wide applicability of microsystems technology. For example, through the latter capability, we are working in the alternative energy field. Core to our vehicle and engines activity is the physics and chemistry of combustion and materials which underpin all of our research in this area. Interdisciplinarity is at the heart of our strategic vision, and is evident in our plans, our partnerships, and the culture of our people. More details in each of these areas can be found in sections b, c and d of this submission.

Impact of Research Collaborations on School Strategy

Staff have been actively involved in discussions on the funding priorities for EU projects including the definition of EC FP7 Programme in New Materials and Processes (Pham and Dimov). Staff have also been involved in the co-ordination and integration of European research in Innovative Production Machines and Systems and Multi-Material Micro Manufacture through leadership of multinational EU-funded Networks of Excellence (Pham and Dimov). These activities have improved our understanding of the academic and industrial landscape in our research fields and helped define research strategy.

Academic Leadership

Examples of national and international roles: Pham: Tech Res Centre of Finland Scientific

Council member (2008-2010); Strategic Scientist, Wuhan Univ Tech China (2013-2018); MTC Prog Board member; Chair Intelligent Automation Tech Committee, IMechE; member RAEng Distinguished Visiting Fellow Scheme Panel (2007-2012); member Programme Committee for 20+ international conferences; Xu: Alternate Member Exec Committee International Energy Agency; Vice Chair Chinese Soc Automotive Eng UK; Advisor, North America Chinese SAE, SAE Int Combustion and Fuels Committee and SAE Int Adv Power Source Committee; Dimov: Member MTC Tech Advisory Board; KIMM Tech Advisory Board in Korea; Member Exec Boards 4M Int Assoc and European Infrastructure in Micro and Nano Fab; Tsolakis: Member SAE Int Exhaust & Emissions Committee and IMechE Professional Review Committee; Dearn: Chair IMechE Whitworth Awards Panel; Olatunbosun: Scientific Liaison Officer NSERC Canada (2008 –11); Scientific evaluator Swiss NSF (2011); Member Int Experts Group, Centre for Quality Assessment in HE Lithuania (2012); President Eng Forum of Nigerians (UK) (2008 – 2010) and Member Tire Tech Int Annual Awards (2008 -); Shepherd: Board member IMechE Eng in Medicine and Health Division. We also have a strong representation in research council activities (e.g. EPSRC College).

International conference programmes chaired: these include Pham - Innovative Production Machines and Systems 2008-10; Control 2012; Tsolakis - 4 inc. Session SFL402 (I) and (II), SAE Int Powertrains, Fuels and Lubricants Meeting, Italy, 2009; Anthony - 12th IEEE Conf Nanotechnology, IEEE-Nano 2012; Dimov - 5 inc. 4M/ICOMM 2009 Karlsruhe, 4M2010 Oyonnax, 4M2011 Stuttgart, 4M2012 Vienna; Jiang - 6 inc. IEEE Int Conf Nanotechnology; Xu - 3 inc. SAE World Congress (annually); Saadat - Int Conf Manuf with Applications, World Automation Congress, USA; Cripps - Int Conf Maths of Surfaces, UK; Espino - 3 inc. 2nd Workshop on 3D Physio Human 2009, Switzerland; Stolkin - IEEE Int Conf Multi-sensor Fusion and Info Integ and IEEE Int Conf Robotics and Automation.

Invited keynote/plenary lectures: these have included lectures in Bulgaria, China, Finland, France, Germany, Korea, Romania, Spain, Thailand, UK, and USA. Examples since 2008: Pham – 7 invitations inc. Manuf Summit, Finland, 2009; 10th Int Conf Industrial Tech Innovation, Taipei, 2009; 5th IEEE Int Conf System of Systems Eng, Loughborough, 2010; Int Conf Ind Eng and Systems Management, Metz, France, 2011; Int . Conf Comp, Control and Ind Eng, Wuhan, 2013; Dimov - 8 inc. ICALEO 2011, Florida; EU Forum Micro-Manuf, Finland, 2010; Tsolakis - 1st Int Conf Multi-Discipline of Eng on Adv Tech and Env Design, Thailand 2012; Espino – 5 inc. 3rd European Conf Mech Eng, Paris, 2012; Jiang – 6 inc. Nanoscale 3D Visualization - Nanotopography and NanoCT, Nano Trends 2011, Hefei; Stolkin - 100th Anniversary Indian Science Congress, 2013; Indian Statistical Institute, Platinum Jubilee lecture series, 2008; Xu – 13 inc. UK-China Science Festival, Symp Clean Energy and Nanotechnology, 2010; Al-Dadah - Institute of Refrigeration, UK, 2012; Shepherd - 3 inc. World Congress on Eng, London, 2012; Saadat - 3 inc. 5th Int Conf Integ Systems Design and Tech, Madrid, 2012. 4th Int Joint Conf Integ Systems Design and Tech, Siegen, 2010.

Journal editorship: Pham - Proc IMechE J. Mech Eng Sci; Proc IMechE J. Syst and Control Eng; Int J. Syst Sci; Adv. in Mech Eng; Int J. Automat and Comp; Micromachines; Virtual and Phys Prototyping; Int J Prod and Manuf Res; Dimov – Proc IMechE J. Eng Manuf; Bentham Science J. Micro and Nanosyst; ASME J. of Micro- and Nano-Manuf; Dearn - Int J. Applied Mech Eng; Soo - Comm Micro-Manuf; Int J. Machine Tools and Manuf; Int J. Manuf Eng; Espino - 5 inc. Open J. Orthopedics; Cripps - J. Mathematics; Xu – Int J. Eng Studies; J. Automotive Safety and Energy; Olatunbosun – Int J. Eng Simulation; J. Veh Structures Anal and Optimisation; Jiang – 5 inc. Int J. Nanoparticles; J. Ceramics; J. Appl. Mech Eng; Saadat - Int J. Intelligent Automation and Soft Comp (Autosoft). Shepherd – 5 incl European Spine Journal and BMC Musculoskeletal disorders.

Memberships of professional bodies and awards/prizes: Prestigious Fellowships held include Pham, FREng, FSME, FLSW, FIMechE, FIET; 6 other staff are FIMechE, FInstR, FRSS. Memberships include IMechE, SAE, SIMR, IET, BCS and InstP. Xu is a Fellow of the SAE (one of only 5 in the UK). Other Fellowships include Dearn (IMechE Visionary, 2009; Whitworth Senior Scholar, 2009); Espino Intra-European Fellow (EU FP7; 2-year fellowship); Butt Henslow Res Fellowship (Wolfson College Cambridge; 3-year fellowship). Prizes include best poster award at the Johnson Matthey Academic Conference 2010 (Tsolakis); Ted Perry Award for research of a practical nature related to refrigeration from the Institute of Refrigeration (Al-Dadah); ABTA Doctoral Researcher Award 2013 (Association of British Turkish Academics recognising scientific excellence of young researchers) (Butt); Best Paper (2009) in the J. of Eng. Manuf, IMechE (Kong); Philip Leverhulme Prize (Butt).