Institution: University of Oxford

Unit of Assessment: 15, General Engineering

a. Context

Oxford Engineering has an impact strategy built around delivering societal and economic benefit through rigorous research. This ethos pervades our scientific discoveries, the development of new technology, the reduction or elimination of risk of harm, gains in system efficiency, and the support of wealth creation through commercialisation. A vital element is the forging of strong relationships with collaborators and end-users in order to understand their needs. Active engagement with industry and commerce is especially critical to ensuring that our research is relevant, timely and positive in its practical applications.

Key stakeholders, including collaborators, beneficiaries and audiences comprise:

- Major engineering and manufacturing companies in the UK and overseas, including Rolls-Royce, Nissan, Invensys, BAE, Mitsubishi Heavy Industries, Alstom and Ferrari.
- The healthcare sector, where we have many direct links (*e.g.* with the NHS, companies, the Oxford Biomedical Research Centre, the Oxford Academic Health Sciences Network, Oxfordshire Biosciences Network).
- Small companies, including University spin-outs (*e.g.* YASA Motors, Oxyntix) with whom we maintain close and productive working relationships.
- Companies beyond the engineering sector (*e.g.* the Man Group, RBS) that value our solutions.
- The wider community, engaged through lectures, open days and other public engagement activities.

The impact we achieve is characterised by its variety as well as value, and includes:

- 'Game-changing' and 'disruptive' implementation of innovative concepts (*e.g.* in nuclear fusion and autonomous vehicle navigation).
- Direct medical benefits (*e.g.* through the development of imaging techniques that enable improved early diagnosis of diseases).
- Implementation of improved designs of high-value systems (*e.g.* for the aerospace industry).
- Risk avoidance as a result of input into British and international standards and codes of practice.

b. Approach to impact

The freedom we give individual academics to pursue their research interests is fundamental to their ability to deliver impact, *e.g.* through collaborations with industry to identify challenges, and develop ideas and solutions. We enable impact by a range of proven mechanisms at a variety of scales. At the largest these involve carefully managed long-term programmes (*e.g.* through UTCs) and at a small scale we encourage individual enterprise and entrepreneurship. In between are a host of mechanisms that ensure timeliness and relevance in research.

Long-term collaborative agreements and University Technology Centres

UTCs constitute the most profound mechanism by which companies undertake long-term engagement with our Department. Rolls-Royce supports 30 UTCs worldwide and we host two of the longest established (Heat Transfer and Aerodynamics, and Solid Mechanics, both established in 1989). Both play a pivotal role in Rolls-Royce's technology roadmap, ensuring a short pipeline between research and its implementation in the company's aero-engines. During the REF period, the University invested in the Southwell Building, leveraging substantial funds from SEEDA and Rolls-Royce to commission new strategic test facilities for turbomachinery, led by Ireland (ex-Rolls Royce). A result is that our UTC is the only one worldwide that is ISO9001 compliant, allowing us to win key contracts.

We also created extensive new laboratories at Begbroke to house state-of-the-art facilities for impact and high strain-rate testing of materials and components to enhance the capacity of our UTC in solid mechanics (Petrinic, Reed). We apply the UTC model in other areas: for example, our Invensys UTC in Advanced Instrumentation (established in 1998, now led by Henry) develops world-leading Coriolis meters for multiphase flows, primarily for the oil and gas industry.

Research and service contracts with industry

Research contracts form the backbone of our industrial links. Outside the UTC mechanism we have significant contracts from companies such as Nissan, BAE, Mitsubishi Heavy Industries,

Alstom and Ferrari. These sponsor or co-sponsor projects, directly accessing research through formal and informal mechanisms such as project steering committees and direct person-to-person links between academics and industrial collaborators.

We also undertake a significant volume of services-for-industry contracts that exploit our specialised knowledge and facilities for immediate practical application (*e.g.* work by Gillespie on Trent 900 HP/IP seals for Rolls-Royce). Professional advice on contract negotiation and terms is provided by the University's Research Services Office (with a member of staff embedded part time in the Department), and to remain competitive we maintain a flexible approach to costs and overheads. Average annual income from these services is £667k over the past five years.

Direct support for research students through industrial sponsorship is an efficient means of engaging with industry, as well as fulfilling an important training role for the graduates involved. Industrial funding supports 59 of our current doctoral students (fully or partially). Increasingly, to share risk and leverage funding, we underwrite doctoral funding in cases where companies are only able to make a partial commitment.

Co-location of research with industrial partners; formal knowledge exchange programmes

We co-locate research with commercial organisations, such as research at the Oxford-Man Institute and at the new Ferrari facility sited at Begbroke Science Park. The Mobile Robotics Group hosts engineers employed by both Nissan and Guidance. Dr Marko Bacic of Rolls-Royce has been seconded to our Osney Thermo-fluids Laboratory for a period of 5 years.

Since 2010, our Department has secured 30 awards totalling around £0.45M that draw on EPSRC and HEFCE funds won by the University for knowledge exchange, with a further £0.6M allocated during the REF period for awards due to start after 2013. These include 5 secondments to industry, funds for targeted meetings, and a broad range of grants aimed at accelerating the take-up of new ideas. We have hosted Knowledge Transfer Partnerships with WRc (instrumentation for the water industry), Teledyne (subsea pipelines) and Guidance (robotics).

There were 15 TSB projects in the REF period, with a total value of £5.7M, involving partners such as Rolls-Royce, EADS and Johnson Matthey.

Consultancy

We encourage every academic to undertake up to 30 days of consultancy per year. Oxford University Consulting (OUC), the University's consulting arm, identifies opportunities, negotiates and manages consultancies and provides Professional Indemnity cover. This is a highly effective model that has delivered strong growth of this activity. Engineering undertakes through OUC more than half the University's consulting activity, providing expert advice in, for example, the aerospace, energy, offshore engineering, motor sport and medical devices sectors (see also Environment Template, Section e).

As an example, a significant amount of the Department's work is safety-related, and in the offshore oil and gas sector we have a long pedigree in research that enhances understanding of mobile offshore drilling rigs, typically working through Joint Industry Projects (JIPs) to improve safety in the oil and gas industry (*e.g.* the InSafeJIP, resulting in a guideline for industry). Impact is also delivered through academics' service on ISO and BSI committees (*e.g.* Houlsby, Martin).

IP and spin-out activity

The University and its technology transfer arm, Isis Innovation, support IP generation, complementing the Department's own strong culture of patent activity. During the REF period, Isis Innovation recorded 233 disclosures of IP from the Department, with 124 of these leading to formal protection via patenting or other means. As a result, 14 spin-out companies have been formed since 2008, a success based on the priority that we give this activity. This proactive culture, reinforced by Isis Innovation, angel investor networks and others, is supported by the flexible access to labs and facilities that we provide, and the fostering of on-going research contracts between spin-outs and originating groups in the Department (*e.g.* continuing research in the Department supported by Oxyntix).

As an exemplar of spin-out activity, through Isis Innovation we patented new technology, invented by Dr McCulloch for electric motors for vehicles, that allows very high torque and power to be achieved within a low volume. This led to the spin-out YASA Motors in 2010. Take-up has already been achieved in the nascent market for hybrid and electric vehicles, where the potential for future impact is substantial.

Other spin-outs delivered by our existing strategy (excluding biomedical spin-outs, which are listed in the following Section) include:

- Navetas Energy Management (2008 - smart metering)
- Kepler Energy (2010 - novel turbine for tidal power extraction).
- OXEMS (2010 - detection of buried infrastructure via RF signals)
- Run3D (2012 - measurement of athletes' gait for improved performance and injury prevention)
- Farmware (2013 – multi-sensor technology for livestock welfare)

Commercial Partnership with Technikos

In 2006, Technikos LLP invested £13M in the Department to establish the Institute for Biomedical Engineering (IBME); in return, the company receives a share of University equity in any spin-out company established in this field. A steering committee – with representatives from Technikos, Isis Innovation and the Department – meets three times a year. Early-stage disclosures are assessed and progress is monitored on patenting and spin-out formation. Because of its close working relationship with the Department and individual academics at the IBME, Technikos plays an active role in securing first-round investment in spin-outs. This has helped the IBME to establish an excellent record in technology transfer that moves research breakthroughs from the laboratory to industry via the clinic, with seven firms spinning out as a result:

- OrganOx (2008 – normothermic liver preservation, first in-human trials in February 2012)
- Zyoxel (2009 – cell culture platforms)
- Eykona Technologies (2010 – 3D wound imaging and measurement)
- Oxstent (2011 – curved stent grafts)
- Intelligent Ultrasound (2012 – medical imaging software)
- OxeHealth (2012 - non-contact sensing of vital signs)
- OxSonics (2013 – non-invasive therapy and drug delivery by ultrasound)

The Technikos partnership has also been central to the spin-out Oxyntix (2011), exploiting bubble collapse for ultra-high temperatures and pressures for industrial applications, and ultimately perhaps for nuclear fusion.

Support for Interdisciplinary Research

Much of our high-impact research lies at interdisciplinary boundaries. Where appropriate, we therefore employ specialists from beyond the field of engineering: for instance, Prof. Ian Thompson is a microbiologist whose work harnesses engineered solutions (in the form of nanotechnology) to design innovative treatment processes for industrial effluents, providing environmental and economic benefits for the aviation and automobile industries.

CDT, Industrial Doctorate Training and Student Engagement with Entrepreneurship

As a direct contribution to the training of the next generation of industry leaders in the growing field of biomedical engineering, we host the RCUK CDT in Healthcare Innovation. Our programme of training for students incorporates a public engagement dimension delivered via school visits, STEM advice and other activities, CDT students also undertake industrial placements, carry out market research and interact closely with industry. We also provide teaching and doctoral student supervision on the Systems Approaches in Biomedical Sciences Industrial Doctorate Centre SABS-IDC which engages with the pharmaceutical, biomedical imaging, biotechnology and health related sectors.

In 2010, PlinkArt, set up by two doctoral students from the Department in 2009, became the first UK company acquired by Google. Emerging from work designed to enable web searches for information in images, this provides a clear demonstration of how we foster entrepreneurship at every level – with undergraduate and graduate students enthusiastically embracing our philosophy.

CPD Training

We organise and deliver courses designed to meet the needs of industry. For instance, responding directly to requests from companies, we have developed 'Foundation Design for Offshore Renewables' for Atkins Ltd and 'Bayesian Non-Parametrics' for BAE, finite element and contact mechanics courses for Rolls-Royce, John Deere, and Wilde FEA, and electrical engineering courses as part of a programme in collaboration with Oxford's Dept. of Continuing Education.

Public Engagement

The University and its colleges organise numerous talks for schools and host many school visits,

often highlighting engineering. We organise annual Headstart and Dragonfly courses for the Engineering Development Trust (aimed at school age students to inform them about engineering), and participate in the Uniq summer schools (http://www.uniq.ox.ac.uk). We host the prestigious annual Lubbock Lecture, inviting a wide audience (from local schools to industrialists), and the Medtronic Lecture in biomedical engineering. Recent public engagement activities include Prof. Paul Newman's Oxford London Lecture "Where are the Robots?" (2013) and Dr Eleanor Stride's BBC TV and radio contributions on the use of microbubbles in medical imaging (2012/13).

c. Strategy and plans

We will continue to strengthen the mechanisms described in Section b. Ongoing and planned activities designed to expand our impact portfolio include:

- ***New UTCs:*** In February 2011, the University signed an MoU with BP. Within this framework we are pursuing initiatives in environmental and offshore engineering. Recently established, our Laing O'Rourke Centre for Construction Engineering is based on the UTC model but has a wider remit that includes planned engagement with the Oxford e-Research Centre, the Department of Materials and the Said Business School.
- ***IP and Spin-outs:*** With the support of a financial group that plans to raise investment funds for Department's spin-outs, we plan to extend the successful Technikos support model to the whole Department. We shall appoint a facilitator who will gather information on research developments, disclosures and patents. They will work closely with academics to identify opportunities, formulate business plans and present information to potential investors through mechanisms such as the Oxford Innovation Society. Formal quarterly reporting will be provided to an Innovation Steering Group, which will also address strategy in this area.
- ***Relationships with major engineering companies and research organisations:*** Working in collaboration with MPLS Division's new Impact and Innovation Team, we are actively seeking opportunities to develop longer-term relationships with major engineering companies, with engineering providing the hub for many of these interactions.

  For example, facilitated by Prof. Jong-Min Kim, we are pursuing several initiatives with Korean companies and research organisations, with the promise of substantial for future impact. We have concluded formal collaboration agreements with the Korean Institute for Energy Technology, Evaluation and Planning (KETEP) and Korean Institute for Energy Research (KIER), both of whom have started sponsorship of our research. We have a major inter-Departmental initiative on "Future Materials" currently under consideration with Samsung, who already support several projects through their GRO programme.
- ***Future national and international collaborations:*** During the current REF period, healthcare technologies have been a major focus for our Department, while new initiatives in engineering for sustainability and energy are expanding rapidly. Almost without exception, these inter-disciplinary issues demand national and international alliances to achieve global impact. We are therefore exploring new links with India (in 2011, an MoU was signed with the Indian Institute of Science in Bangalore), while research collaborations in place include the Bristol-Oxford Nuclear Research Centre and those in affordable healthcare in South Africa, India, Kenya and China.

  We are in the early stages of planning a major strategic development in China. In collaboration with adjacent Departments we have identified Suzhou Industrial Park as a partner organisation for a research facility, entirely managed from Oxford, which will be focussed on translational work clustered around three themes of Biomedical Engineering, the Environment and Nanotechnology (see http://www.sipac.gov.cn/english/news/201304/t20130407_207000.htm).
- We will play a full role in the implementation of recommendations of the report "The Oxfordshire Innovation Engine: Realising the growth potential", recently launched by the University and Science Oxford, which identifies the need for expansion of engineering and the sites at Begbroke and Harwell (see http://www.sqw.co.uk/file_download/411).

To aid delivery of our strategy, we will make comprehensive use of University-wide expertise, including the Research Services Office (RSO) and Isis Innovation. At our invitation, Isis Innovation holds regular awareness-raising events and 'clinics' in the Department to provide guidance and support for those interested in protecting IP, patenting inventions and developing spin-outs.

During the REF period, we have appointed a Research Administrator who, with her team,

facilitates much of this activity. In another initiative, an RSO representative is now embedded in our Department to provide fast, efficient support for contract negotiation and set up. Similarly, a member of MPLS Division's Impact and Innovation Team – established to develop links with major companies - has been embedded in the Department. They played a key role, for example, in building our strategic alliance with Scuderia Ferrari.

Looking towards the future, the spectacular growth of biomedical engineering research is not yet fully reflected in our impact portfolio. Building on our ground-breaking work on autonomous vehicles, recent funding will underpin a new robotics centre at Oxford which will provide the environment needed to maximise impact on transport, security and other sectors.

d. Relationship to case studies

Our ten case studies demonstrate the breadth and reach of our impact. Naturally, these illustrate the underpinning approach set out in Section b. Four focus on research embedded in our UTCs (1, 2, 3, 4). Two relate to biomedical engineering (5, 6). Two underline the strength of our research in imaging, but for very different applications: biomedical imaging (5) and the film industry (10). Four concern the aerospace industry (1, 2, 3, 7). Two reflect spin-out activity (5, 10) – another sphere where we anticipate and are actively pursuing significant growth. Three relate to risk mitigation, in healthcare (5, 6) and aerospace (7). Three address issues where improved industrial design has triggered substantial economic benefits (4, 8, 9). Key themes are outlined in more detail below.

Economic Benefits for the Aerospace Sector

- **Case studies 1** and **2**: our research has had a major impact in reducing the fuel burn of jet engines used on civil aircraft, resulting in not only economic but also environmental benefits.
- **Case study 3**: research into fatigue and impact has generated improved understanding of fatigue in aero-engine components and has allowed accurate prediction of "blade-off" events, thus significantly reducing the testing that needs to be done to certify an aero-engine.
- **Case study 7**: non-UTC research sponsored by Rolls-Royce has produced advanced techniques for processing statistical data that have been used to develop ground-breaking systems for monitoring aero-engine health.

Economic Benefits through Improved Industrial Design

- **Case study 4**: research on novel instrumentation for measuring the flow of oil/gas mixtures is delivering important economic benefits for the oil and gas industry, with a suite of protected IP successfully exploited by Invensys.
- **Case study 8**: research into advanced membrane technologies has resulted in industry securing valuable cost reductions as well as environmental benefits.
- **Case study 9**: cooling systems developed for use in space have resulted in efficiency gains, an excellent example of the benefits of retaining a team of experienced, industrially funded, designers capable of exploiting our research in practical applications.

Improved Safety and Avoidance of Harm

- **Case studies 5** and **6**: these two examples demonstrate how enhanced healthcare enabled by our research has led to a significant improvement in patient outcomes.
- **Case study 7**: more effective monitoring of jet engine health made possible by our research has translated directly into improved aircraft safety.

Improved Healthcare

- **Case study 5**: our research has a tried and tested track record of enabling the more effective monitoring of hospital patients considered to be at high risk.
- **Case study 6**: our oncology-related medical imaging analysis breakthroughs have generated better patient care, primarily through the work of spin-outs Mirada and Matakina.

Environmental Benefits

- **Case study 8**: in the water sector, we have helped companies to reduce the environmental impact of their activities, as well as their costs, through novel designs for membrane processes.

Benefits to Society, Culture and Creativity

- **Case study 10**: the 'Boujou' visual effects system has had a huge impact on the film industry, including use on the Harry Potter series and many other high-profile films in the last five years.

In summary, we are confident that our policy of actively supporting engagement with external organisations, as exemplified by our case studies, has been instrumental in ensuring that our research successfully reaches out to the 'real world' and achieves genuine, lasting impact.