Institution: University of Southampton

Unit of Assessment: 15 General Engineering

a. Context: As a large multidisciplinary unit carrying out practically oriented engineering research based on sound fundamental science, we engage directly with a wide range and number of users, beneficiaries and audiences. Direct beneficiaries as funders and collaborators include (superscripts refer to the impact case studies):

- **large industrial corporations** e.g. Airbus[16,18,40], Arup[02,06,32] , ANSYS[02], B&Q[31], BAe Systems[08,24], Boeing[18], Bombardier[01,18], BMW[16], British Nuclear Fuels Ltd.[16], Buro Happold[06], CD-adapco[02,06] , CEMIG (one of Brazil's largest energy companies)[36], Chevron[16], DePuy[12,16,20], Diado[16], CMS Cameron McKenna LLP[22], E.ON Vattenkraft (Swedish Hydropower Company)[36], Etihad Rail[32], GE Aviation[16], Hitachi[24], HS2 Ltd., Inmarsat[22], Intelligent Fluid Solutions[31], Jaguar Land Rover[33], John Crane Ltd.[16], LUL[32], Microsoft[02], Mott Macdonald[32], MSc-Nastran[02], National Grid[41], Network Rail and their equivalents in >12 countries[01,32] , NS Railinfratrust[32], Philips[08], PowerGen[16], ProRail[32], Rolls Royce[16,18,40], Rotork[16], Saipem-Dodsal-Tecnimont JV[32], Schlumberger[16], Sellafield Ltd.[08,16] , Shell[16], Siemens[33] , South-Eastern Trains[32], Statoil[08,] Tata Steel[01], Tribotex[16], Vestas[16], Vossloh Cogifer[32], Windsave[31], Zogenix[08].
- **small and medium enterprises** e.g. Atos Health Care[21], Finsbury Orthopaedics[20], GeoAcoustics Ltd.[08], GeoObservations[32], Ingenieurbüro Lohmeyer GmbH[06], Luxfer Gas Cylinders, Ultrawave Ltd.[08], Weston Medical[08], WJ Groundwater, University-based manufacturing units[21] & spinouts[02].
- **local authorities and third sector organisations** e.g. Eastleigh, Hampshire and Southampton City Councils, Partnership for Urban South Hampshire , Lloyds Register Foundation, Sustrans.
- **national government departments and national and international organisations,** e.g. Carbon Trust[31], Chinese Ministry of Water Resources[36], Confederated Tribes of the Umatilla Indian Reservation[36], Defra[31,36], Environment Agency[36], Fisheries and Wildlife Service in California[36], Health and Safety Executive[16,18] , International Union for Conservation of Nature[36], National Center for Atmospheric Research[06], National Institute for Health and Clinical Excellence (NICE)[03], National Health Service (and health services in many other countries)[03,04,08,12,20], National Deaf Children's Society[04], Parliamentary Office of Science and Technology[08,36], Scottish Natural Heritage[36], Scotland and Northern Ireland Forum for Environmental Research[36], Scottish Executive[36], US Naval Research Laboratory[06], Transport for London[33], UK National Traffic Control Centre[33], UK Dept of Energy and Climate Change[31], UK Dept of Health[04], UK Dept of Transport[33], UK Highways Agency[33], UK Met Office[06], UK Ministry of Defence[08,18], UK Sport[15] (with a verified massive contribution to Tour de France and Olympic gold), UNESCO[32], US Army Corp of Engineers[36], US Dept of Energy[08], US National Oceanic and Atmospheric Administration[36], US Navy[18], World Health Organisation[04,08].
- **industry bodies**, e.g. Association of Air Traffic Controllers, British Wind Energy Association[31], Motor Industry Research Association[33].
- **international and national standard and guidance setting authorities**, e.g. British Standards Institution (BSI)[18], Building Research Establishment[31], European Space Agency[22], Construction Industry Research and Information Association, Inter-Agency Space Debris Coordination Committee[22], EU Directives[18,36] , International Electrotechnical Commission[31], International Organization for Standardization (ISO)[21], Rail Safety and Standards Board[32], UK Space Agency[22], UK and EU legal judgements[18], World Health Organization[08].

In addition, the benefits of our research are spread more widely to:

- classes of users such as **engineering consultants**, **government** and **standards-setting bodies** through the dissemination of results in papers, professional magazines and journals, and their incorporation into design codes;
- **the general public** through the professional services we provide[03,04], outreach via public exhibitions, TV and radio, generating worldwide feedback[02,08,16,22] , enhanced UK competitiveness in the provision of goods and services, increased efficiency and reduced prices.

Types of impact encompass contributions to policy; knowledge underpinning the development of design methods; incorporation of research results into standards, codes and guidance; invention of devices and procedures; and improvement of products and services utilizing the know-how we have

created. Our UoA has:

- given industry the tools to deliver huge cost savings, e.g. providing Arup with software that, in one project alone, saved a six-figure sum in the design of a sports stadium[02]; enabling Intelligent Fluid Solutions[31] to increase lifetime return by over €55M through an improved wind farm layout, and contributing to a £65M saving in earthworks remedial costs for LUL alone[32].
- made business safer, e.g. developing BNFL/Sellafield Ltd's design guidance for the prevention of radioactive slurry leakage[16]; providing an informed legal framework for Hand-Arm Vibration Syndrome (of which 1.2M workers are at risk in the UK alone)[21]; giving space satellite operators the confidence to invest £1Bn since 2008 in worldwide protection against satellite debris damage (which could disrupt telecoms, GPS etc.)[22]; providing rail operators with guidance relating to wheel profile and preventing ballast instability for safer operation at high speeds[32]; and contributing to the design for a 400 km railway in the Arabian Desert to mitigate hazards due to sand ingress[32].
- provided UK business with a competitive edge, e.g. GE Aviation's sensor systems, to be installed in 6000 fighter jet engines[16] by 2025; contributing substantially to increased profits for Rotork Controls[16] and Actuator Worm Gears[16], and to £16M sales by Tata Steel[01]; helping John Crane UK Ltd to win a major contract[16]; providing Jaguar with better dashboard displays for drivers (valued by Jaguar at ~£1M)[33]; and underpinning the biggest design programme in DePuy's history for its new artificial knee[12], seen by DuPuy as their "flagship brand for the future".
- prevented wasteful expenditure, e.g. we were directly responsible for B&Q's policy to refund all sales of micro-wind turbines to UK customers[31], and helped set government subsidy levels for micro-wind power[31]. Our UoA identified critical flaws and solutions for the £532M programme of screens and fish passes required to meet international environmental legislation to protect fish at industrial water intakes[36], and advised on the £34Bn Severn Estuary barrage[36].
- improved quality of life in the UK through our contributions in medical engineering, transport systems and performance sports engineering. While this is beyond financial quantification, highlights include co-authoring the safety guidelines used for every foetal ultrasound scan worldwide (~700M births) since 2008[08]; providing the NHS with the current hearing impairment screening system, used on 4M babies in the REF period and identifying 6000 requiring help at an earlier age than was previously possible, thereby benefitting their language development[04]; underpinning a migraine treatment technology (over 1M sold)[08]; pioneering the work that directly underpins 9000 recipients worldwide of bilateral cochlear implants[03]; and developing a kidney treatment monitoring device used in hospitals on over 200 patients[08] since 2008. Some quality of life improvements do also bring quantifiable business benefits: our revolutionary hip-resurfacing implant used in 9800 patients has benefitted the UK economy through an additional £18.4M turnover (70% from outside the UK)[20]. Both Rolls Royce and Airbus directly credit our UoA with technology addressing the €12Bn/year cost to the EU of health problems resulting from aircraft noise[40]. Our traffic control algorithms and improved methods of forecasting motorway traffic flows[33] not only improve the quality of life for travellers, but also reduced costs for Transport for London by ~£29M/ year, and the UK National Traffic Control Centre by £50M/year[33].

Our UoA is credited by UK Sport[15] as having contributed to 34 British Olympic Gold medal triumphs in Beijing (2008), Vancouver (2010) and London (2012), and the first British victors of the Tour de France in 2012 and 2013. We are independently cited as contributing to the competitiveness of the UK's sailing and motorsport industries worldwide[15].

b. Approach to impact

Interaction of the UoA with the University. The UoA benefits from the University's overarching framework for supporting impact generation. A key University initiative led to the setting up of ***Southampton Asset Management Ltd*** (**SAM**); SAM sets the policy for how the University handles spin-outs and licensing, and is now embedded in the UoS's strategy for impact and enterprise. The University's Research and Innovation Service (**RIS**), a specialist department with >60 staff, provides dedicated expertise to facilitate interaction with our business partners and incubation of new businesses. A specialist legal team in RIS supports commercial contracts and IP management, and provides advice and training to staff on developing IP. Six dedicated Collaboration Managers with relevant industry/sector experience guide exploitation and negotiate licences. UoS operates an 'easy to do business with' framework that includes 'fast-track' templates for commercial contracts and IP sharing developed in partnership with individual companies, based on the Lambert toolkit for universities. Three full time RIS staff are assigned to the UoA, plus a

Collaboration Manager and a Business Development Manager. The result is a flexible but robust approach to impact – as required by the diverse nature of our stakeholder communities – which encompasses a comprehensive integration of strategic, project-related, and opportunistic aspects.

Over the period 2007/08 to 2011/12, the University was ranked by HEBCIS in the top 5 for income from SMEs, and in the top 10 for consultancy (*increase in 2009/10 due largely to the NHS Evaluation, Trials and Studies Co-ordinating Centre (NETSCC), based at the University).

Income source	2007/08	2008/09	2009/10	2010/11	2011/12
SMEs	**1st** (£7.8M)	**2nd** (£8.6M)	**2nd** (£10.5M)	**2nd** (£8.7M)	**4th** (£9.3M)
Consultancy*	**8th** (£10.1M)	**7th** (£11.2M)	**1st** (£27.4M)	**1st** (£26.4M)	**1st** (£27.6M)

UoS has spun-out 15 companies since 2000, of which 4 have floated on London's Alternative Investment Market (AIM) with a combined market value of £180M. Over 40% of our research projects involve one or more commercial partners. More than 150 international businesses have chosen the University of Southampton as a key research and development partner. UoS has a rolling portfolio of some 300 active patent families giving an annual income of ~£1M. At any one time, the University is working with over 1000 external organisations.

Our UoA engages closely with two wider University initiatives that demonstrate its commitment to innovation in emerging areas through strategic investment in major cross-cutting facilities, and bringing together a wide variety of skills to address multi- and interdisciplinary topics of societal importance and foster user and industry engagement. These are the Institute for Life Sciences (IfLS) and the Southampton Marine and Maritime Institute (SMMI), to which the University contributes a budget of ~£1M p.a. Our UoA provides the Director of SMMI, which fosters industry and societal links with Lloyds Register and the wider marine and maritime community. IfLS and SMMI are recent developments with only nascent influences on impact, but huge potential for the future. They have already led to at least nine collaborative and industrially co-funded PhD projects within the UoA, and increased exchange between academics and industry/user parties on joint research and research exploitation. SMMI were involved in 10 bids (out of 62 nationally) for a recent TSB Maritime call; of which 3 (out of 8 nationally) have been funded. SMMI has catalysed the development of the new Boldrewood Engineering Campus (see **Section c**).

Interaction with users. Our core philosophy in research is the discovery of new scientific knowledge and its application to solve practical engineering problems. Thus, much of our research is defined and carried out in collaboration with users across industry, government, the professions and policymakers. Modes of engagement range from strategic partnerships to individual project collaborations. We recognize that publication in academic journals and conferences, though important, is largely passive, and requires considerable insight and drive from users to follow through to impact. Our UoA therefore complements this with active and targeted engagement with wider user groups through publication in professional journals and magazines, seminars and short courses, contributions to professional practice, and formal strategic and project level industry engagement as outlined below.

Strategic level agreements with key industry funders are particularly important, as they give industry both a vested interest in and a direct conduit for implementing the research they support. They also provide continuity of purpose, staff and expertise. Current strategic partners include:

- Airbus: University Technology Centre (UTC) in aircraft noise since 2008; 5 research fellows and 20 research students, ~£1.34M p.a.
- BAe Systems: research into the mitigation of noise and vibration in the maritime sector; £250k p.a. over the REF period, rising to £1.1M in 2013/14.
- De Puy: International University Technology Partnership (UTP) in bioengineering science, with Hamburg and Leeds universities, £100k p.a.
- Lloyds Register: UTC in ship design for enhanced environmental performance, £400k p.a.
- Luxfer Gas Cylinders: UTP in gas containment technologies. £35k p.a., one Industrial Research Fellow and 3 PhD/EngD students.
- Microsoft: Institute for high performance computing, £100k p.a.
- Network Rail: Strategic University Partnership in future infrastructure systems, £1M, 2012-17.
- RNLI: Advanced Technology Partnership on maritime engineering and safety, £50k p.a.
- Rolls Royce: UTCs in gas turbine noise (7 academic staff, 4 postdoctoral researchers, 12

PhD/EngD students, ~£1.3M p.a.) and computational engineering (£450k p.a.). Outputs associated with some of these partnerships are detailed in the impact case studies[08,40].

In addition, there is substantial industry and user involvement with specific research programmes and projects (including KTPs) through *participation in industry steering groups* including TRACK21 (Railway track for the 21st Century, EPSRC Programme Grant), our EngD in Transport and the Environment, our UTPs and the national Centre for Advanced Tribology at Southampton (nCATS). The value placed by companies on these engagements is illustrated by the seniority of their representatives, which include the Head of Noise Research, Airbus; Director of Global Research, Arup; Head of Infrastructure Systems Integration, Deutsch Bahn; Chief Scientific Advisor, DfT; Chief Research Scientist, ESR Technology Ltd; Chief Engineer, HS2 Ltd; Chief Metallurgist, Lloyds Register; Director of Systems Engineering, Network Rail; Chief Engineer (Technology), Ricardo UK Ltd; Directeur Innovation, Systra; and the Director of the Transport KTN.

A key feature of the steering groups and other mechanisms of industry involvement (including KTPs) is that they are engaged in both the definition and direction of the research; active user engagement as the research progresses ensures that key results are rapidly taken up. Examples of impact resulting directly from this policy include the application of:

- track monitoring techniques developed for research purposes to investigate ballast migration and points flicker, for Network Rail and HS1[32]
- new understandings of climate / vegetation / earthworks interactions in vegetation management guidance, by Network Rail and LUL[32]
- our research on electricity tower foundations to underpin National Grid's strategy for mitigating the effects on their network of increased storminess resulting from climate change[32]
- analytical methods to estimate rail capacity by Arup, in capacity charge recalibration for the Office of Rail Regulation (ORR)
- transducer technology and computational and experimental fluid dynamics to help improve the performance of UK athletes (notably in cycling and swimming) in the 2012 Olympics[15]
- computer simulation codes to predict the noise emitted from contra-rotating open rotor engines in given operating conditions, and from radical landing gear designs, by Airbus[40]
- new noise prediction techniques to acoustic liner, open rotor and bleed valve design by Rolls-Royce, together accounting for more than 50% of RR R&T noise deliverables since 2010[40]
- improved design tools and impact damage assessment techniques to reduce materials costs of composite pressure vessels (Luxfer Gas Cylinders)
- computational engineering techniques to the invention and design of a coronary stent platform for Arterius Ltd for its fully biodegradable scaffold, the only one of its kind being developed in the UK.

Users also *engage with individual students and researchers* through KTPs and sponsorship of PhD and Eng D research projects. UoA policy requires all staff (other than new appointees) to obtain a substantial element (usually 67%) of external funding for competitively-awarded Faculty PhD studentships. Industry is by far the major source of this funding, and over the REF period has contributed a total of £4.1M spread across 62 students. Our EngD in Transport and the Environment trains 12 research engineers p.a., most of whom go on to work in industry. The UoA also participates in cross-disciplinary institutional DTCs in Complexity and Web Science, with a total of 66 students in these two centres, and three bids (two led from Southampton) through to final consideration for EPSRC funding from 2014.

Representation on bodies associated with the development of policy and practice guidance. The UoA encourages outward-facing activities aimed at generating impact as part of the annual Personal Performance and Development review (PPDR) of every member of staff. As at 1/6/13, these include **26 company directorships; 13 joint or sponsored appointments/secondments with industry, government and the charity sector** including with Airbus, Arup, BP, Korean Expressway Corporation and Rolls Royce; **49 significant contributions to industry advisory bodies** including British Energy, CBI, CEMIG, ELFORSK, E-ON, Hampshire Economic Forum, Institution of Civil Engineers, Institution of Mechanical Engineers, International Civil Aviation Organisation, International Waste Working Group (four committees), Microsoft, National Grid, Philips Oral Healthcare and Rolls Royce; **130 contributions to government and charity advisory, review or standard-setting bodies** at regional, national and international level, including British Standards Institution (10 committees), Defra (4 committees and chair of the Waste

Implementation Programme Technologies Advisory Committee), Department of Health, EDSU (3 committees), European Commission, Hampshire County Council, Infrastructure UK, International Committee of Sports for the Deaf, Large Hadron Collider, Ministry of Defence, National Audit Office, National Measurement Office, PRC Ministry of Water Resources, Rail Technical Strategy Steering Group, US National Oceanic and Atmospheric Administration (NOAA), and WRAP.

We have a long-established tradition of using **consultancy units within the UoA** (Wolfson Unit for Marine Technology and Industrial Aerodynamics, WUMTIA; Research Institute for Industry, RIfI; ISVR consulting; USAIS; and Engineering and Environment Partners, EEP) to interact with industry and users of our research in an agile and outward facing way, both helping to develop and specify research and pushing the results through into engineering practice. Examples include:

- developing an initial strategy to investigate the potential for ballast flight and critical velocity effects at train speeds approaching 400 km/hour, for HS2 Ltd. [32];
- working with Etihad Rail to understand the potential for ballast fouling by windblown sand, and then specifying and carrying out advanced testing to investigate the problem[32];
- working with landfill operators to identify and specify research needs tor the large scale accelerated stabilization of landfills[41];
- using signal processing methods developed in ISVR to improve the performance of cochlear implants for profoundly deaf people, through SOECIC[03];
- applying understandings developed through research in fluid dynamics, especially turbulence (the UoA leads in the UK Turbulence Consortium), to recreational and industrial applications including the America Cup and Formula 1 motor racing[15];
- using measurement and analysis techniques developed in ISVR to understand and mitigate railway noise in countries all around the world[01].

In addition to employing directly 26 design engineers whose day-to-day job is to promote impact and industry/user engagement, the consultancy units provide the back-up facilities and support needed to enable individual academic members of staff to carry out consultancy based on their research knowledge. A further benefit is that the financial viability of major infrastructure and experimental facilities (e.g. the R.J.Mitchell wind tunnel and various hydraulics flumes) is assured by the income generated from the combination of research, teaching and enterprise in a way that would be difficult without any one of these three income streams.
The benefits of engaging with industry through the consultancy units are illustrated in the HEBCIS data given in Section a. In 2012, WUMTIA was awarded the Royal Institution of Naval Architects (RINA) Small Craft Group Medal in recognition of >45 years of high-level advisory and consultancy work, and the UoA was awarded a Queen's Prize for Higher and Further Education “for innovation and world leading expertise in the field of performance sports over four decades”[15]. Seven licenses have been awarded (to Vicon, Dyson[08], Ultrawave Ltd.[08], Philips[08], Sellafield Ltd.[08], Astrium[08], Planetarium, and TSL Technology Ltd) for the exploitation of technology based on our research.

c. Strategy and plans: We will continue to develop and grow the elements of our structure and organisation that support impact, viz. strategic level partnerships with industry; industry engagement with individual research projects; advisory boards for major programmes and research areas; increasingly professional support for our dealings with users. Above all, through a culture and ethos that emphasises the importance of user links and public engagement, PPDR and mentoring of new staff, we encourage all academics to engage with potential users in specifying, obtaining funding for, carrying out and then disseminating the results of their research through membership of formal and informal research teams, groups and centres, attending and giving industry seminars and obtaining industry co-funding for PhD studentships and research projects.

We will develop our mature industry advisory groups (e.g. nCATS) into more formal industry clubs, and seed the next generation by examining all new EPSRC proposals to ensure that steering groups are established where appropriate. We are aiming to increase the number of strategic partnerships, and are currently looking at six companies who have distributed contacts with us that it would be mutually advantageous to aggregate into a research framework or UTP type agreement. We will exploit the synergies offered by the establishment of the Faculty as a single unit covering the traditional disciplines of acoustical, aeronautical, civil, environmental, maritime and mechanical engineering to form teams better able to address the needs of industry in facing the grand research challenges of tomorrow. To this end we have identified a number of our current corporate strategic

relationships whose focus could be widened.

The central and most ambitious element of our plans is the development of the new Boldrewood Engineering Campus. Opening in 2014 and funded by a £129M investment by Lloyds Register (LR) with £85M from other sources, this is the largest business-focused endeavour of its type in a UK university. The vision for the Campus is that it will bring University researchers and industry users into close proximity to work together on the same site. LR is moving its engineering function to the campus from London. While LR will probably remain the largest single user presence on the site, they will be the first of a number who will have some staff co-located with the UoA. We will use this co-location to facilitate direct interactions between academic staff and key users of our education and research, involving them closely in the design, delivery and uptake of our research and our educational programmes, people and knowledge based outputs. This will pave the way for a redefinition of engineering education and research in the UK with the emphasis very much on the high value, high technology end of the market.

Structural support within the UoA: The Associate Deans for Research (ADR) and Enterprise (ADE) are responsible to the Dean for the generation of impact from research. Both sit on the UoA's *Research and Impact Support Committee (RISC)*, which meets monthly and also includes two other academics (the chair of the graduate school, and a representative of the major industry-facing centres) and support staff dedicated to the UoA covering communications and marketing, outreach, RIS and finance. Two dedicated and experienced Impact and Research Support Officers provide a 'conception to delivery' service for research projects, ensuring continuity from early research proposal negotiations through to the promulgation of outputs and impact both in the UK and overseas. Senior academic staff are asked twice a year to identify colleagues needing particular help in achieving impact for their research results, such that at any time 20-30 staff are receiving individual personalized help from support staff from the RISC and senior colleagues (overseen by the ADR) to increase momentum in specific projects. The ADR and the senior member of RIS meet senior academics monthly in the UoA *Research Policy Committee* to ensure policy is coordinated and implementation is smooth.

The UoA supports individuals to carry out consultancy based on their research through *Engineering and the Environment partners* (chaired by the ADE) supported by RIfI. This opens the full range of expertise of our academic staff to SMEs and large companies alike, and generates not only impact from our research but also further industrial links and collaborative research programmes.

The UoA has a *patents panel* comprising colleagues experienced in IP and chaired by the ADE, which filters and prioritises patent proposals and makes recommendations on filings. It also advises staff on the relative merits of patenting, publishing, or keeping know-how confidential. The UoA has a patents budget of £100k p.a. Once IP has been formally protected, licensing is managed through RIS on either an exclusive or a non-exclusive basis.

d. Relationship to case studies: Our philosophy of developing and applying new scientific knowledge to the solution of practical problems in our research is long-standing, as are many of our industrial units which provide an ideal interface with users in both the specification and application of research. Our case studies exemplify this approach, and illustrate the benefits of developing steady and sustained relationships with key users over a period of time while retaining the agility to form and develop new partnerships, particularly with emerging players. Much of our research has a people dimension so in addition to industry users, engagement with local authorities, government organisations and policymakers is vitally important.

- Case studies [1, 4, 9] arose from the UoA's policy of forming strategic level agreements.
- Case study [17] resulted from the UoA's embedded consultancy and enterprise units, which also generated the Formula 1 motor racing and Americas Cup yacht impacts of Case Study [19].
- Case studies [10, 11] came about because of the UoA's policy of promoting an outward-looking culture that uses RIS to pair world-leading research teams with SMEs that appreciate the opportunity for impact. This also generated the StarStream impact of case study [7].
- Impact in Case Studies [1, 4, 7, 12, 15, 16, 18] resulted from encouraging staff to engage with policy makers and standards-setting bodies.
- Impact in Case studies [7, 10, 11] resulted from the UoA's engagement in IfLS and SMMI.
- Case study [3] is based on a University spin out company.