Institution: University of Sheffield

Unit of Assessment: 15 - General Engineering

a. Context

The Department of Automatic Control & Systems Engineering's (ACSE) main research users are engineering and manufacturing companies, systems integrators, utilities, pharmaceutical companies, clinicians, government and space agencies. The main types of impact relevant to our research are: *economic impacts* (new processes, technical standards and protocols, transition of experts into industry roles); *health related impacts* (enhanced quality of life of patients, individualised care pathways); impacts on *public policy* (findings to inform public health interventions); and *society* (public engagement in STEM subjects). Our three Research Groups have the potential to deliver impact in each of these categories but employ different approaches: *Complex Systems, Signal Processing and Control* has an applied engineering focus involving multi-disciplinary collaboration, while *Intelligent Systems, Decision and Control* and *Autonomous Systems and Robotics* have a strong industrial focus and deliver impact through strategic partnerships with world-class engineering companies and via industrial research institutes.

b. Approach to impact

Strategic partnerships

Our Rolls-Royce University Technology Centre in Control and Systems Engineering (RR-UTC) provides the company with the necessary technology to support the efficient production of world-class engine control and monitoring systems [text removed for publication]. The Centre achieved economic impact by developing a new design methodology for tuning gas turbine engine control laws, enabling a unified approach to design across the company's products. The Centre has also developed highly skilled people who have taken up specialist roles drawing on their research e.g. [text removed for publication] is now Engineering Manager at Rolls-Royce; [text removed for publication] is Chief of Component Engineering.

The success of RR-UTC has motivated us to incubate new partnerships which replicate this model. In 2009 Harrison was founding director of the Rail Innovation and Technology Centre (RITC) funded by Network Rail [text removed for publication], established as a cross-faculty entity, of which the directorship rotated into another part of the Faculty as planned in 2012. One RITC project to-date has been central to ACSE: in partnership with Network Rail we secured EPSRC Knowledge Transfer Account (KTA) funding to develop a solar-powered data logger – technology now being taken forward to commercialisation [text removed for publication]. In 2012 we also established an embryonic partnership with [text removed for publication]. In the early stages of this collaboration, we embedded a researcher within the company and ran a suite of four MSc projects involving different staff in ACSE. The research to develop a multivariable robust controller for individual blade pitch control on wind turbines is currently being benchmarked [text removed for publication] to establish the business case for taking the design forward to production.

Industrial research institutes

ACSE is a member of the Institute of Microstructural and Mechanical Process Engineering: The University of Sheffield (IMMPETUS), which aims at early implementation of advances in thermomechanical metal processing in collaboration with 28 industrial companies. IMMPETUS features an annual colloquium in which industrialists present requirements and researchers present capabilities and track record. Through IMMPETUS, ACSE has worked with TATA Steels, Airbus and The Welding Institute (TWI). ACSE initially engaged with TWI at the colloquium in 2008 and, through a series of projects, developed a model-based framework for optimising friction stir welding (FSW). The framework was adopted and used by TWI in work for a number of clients [text removed for publication]. EPSRC funding and a METRC Innovation Award then enabled ACSE and TWI to create a real-time monitoring tool that has helped to define a new ISO professional standard for the certification of FSW applications.

Recruitment of Professor Zhong in 2012 enabled ACSE to establish a new Control and Power Systems Laboratory (CAPS). CAPS has a number of partners – Rolls-Royce, Alstom, National Grid, Yokogawa, National Instruments, Texas Instruments, add2, Turbo Power Systems and Power Systems Warehouse – who have provided capital to the laboratory and provide research direction via an industrial advisory board. Knowledge transfer of inverter technologies to Power

Systems Warehouse was facilitated by the KTP scheme, with further developments to synchronverter technology funded by two KTA projects.

Multi-disciplinary collaborations

Multi-disciplinary research is a hallmark of our approach and we have sought to extend our research user base laterally by participating in research centres and by providing our staff with sufficient autonomy to develop specific collaborations at practitioner-level.

Centre-led model: We lead the Centre for Signal Processing and Complex Systems (CSPCS), the Rolls-Royce UTC in Control and Systems Engineering and are active in seven other research centres. The Centres enable us to create impact from our research through multi-disciplinary collaboration. *Examples of impact:* Through CSPCS we are developing condition monitoring systems for wind turbines in collaboration with the Northern Wind Innovation Programme; developed a prototype FPGA solution for protein identification, now at the licensing stage; and developed, in collaboration with NHS neurologists, the first reliable method to detect the onset of an epileptic seizure several seconds before the seizure occurs. Within the Centre for Signal Processing in Neuroimaging and Systems Neuroscience (SPiNSN), we are progressing two promising impact pathways: fast diffuse tomography algorithms that make it possible to routinely monitor in real-time patients/neonates at bedside using existing instruments and in the future on mobile devices; and a new method to measure endothelial function, which is progressing to clinical trials. We are also members of the Institute for *in-silico* Medicine (INSIGNEO) which formed in May 2013. Through the Sheffield Alcohol Research Group (SARG) our modelling has informed alcohol policy development by the UK and Scottish Governments, supported the National Institute for Health and Care Excellence's public health guidance on preventing harmful drinking, and contributed to the public debate (Today Programme, BBC News 24, Sky News). Through the Sheffield Centre for Robotics (SCENTRO) we engaged with the Civil Aviation Authority and Unmanned Air Vehicles (UAV) developers by leading IET sponsored UAV events in 2012 and 2013; we participated in the development of several new standards for robotics (e.g. ISO/TC/184/SC2, BSI AMT/00-/02) and stimulated public engagement with STEM subjects through the showcasing of our swarm robotics research (Reuters, The Gadget Show, Time Magazine) and secured KTA funding to prototype a novel robot manipulator for the food industry in collaboration with DEFRA and Bradgate Bakeries. Our involvement in the Solar Physics and Space Plasma Research Centre (SP^2RC) produced the most accurate forecasting tool for electron fluxes at Geostationary Orbit which was made available on request to Los Alamos National Laboratory and NASA to mitigate operational risks for spacecraft.

Individual-led model: Complementary to our institutional models, we have an impact culture that encourages our staff to seek out collaborations independently and to respond flexibly to emerging opportunities. This agility has enabled us to initiate and sustain a healthy volume of research users across a diverse range of sectors. *Examples of impact:* To benefit scientists working with ESA and NASA, Balikhin and Pope developed algorithms to clean magnetic field observations from the Venus Express spacecraft that were previously unusable owing to the lack of shielding on the spacecraft; Kadirkamanathan informed array design for lead optimisation for GlaxoSmithKline; Mahfouf collaborated with a Consultant in Anaesthesia and Intensive Care Medicine in Sheffield NHS Trust to prototype a decision support system for critically ill patients in intensive care, winning Medipex's 2010 NHS Innovation Award for Software and ICT. Fleming is working with Ford Motor Company on a KTA project to develop a general engine optimisation framework for reduced vehicle emissions [text removed for publication].

Impact culture

Through ACSE's Industrial Liaison Committee we arrange networking events for industrialists and staff, to understand research user requirements and promote our research capabilities. We embed industrial perspectives in the daily life of the Department through the appointment of visiting staff (Dr Griffin, Rolls-Royce, and Professor Jackson, Meggitt) and regular visits from alumni and other company representatives to contribute to our taught programmes (e.g. BAE Systems, Ford Motor Company, HMK Automation, Inspec Solutions, McLaren F1, Outo Kumpu, Rolls-Royce, Thales). We support our early career researchers in effective planning for impact by co-opting them into our existing partnerships [text removed for publication], group peer review of Pathways to Impact statements on EPSRC First Grant applications, and by encouraging new members to join the New-ACE network for new academics in control engineering (Zhong and Coca lead/co-proposer), which

aims to develop and strengthen long-term collaboration activities with industry (participants included add2, Ricardo, Rolls-Royce, Texas Instruments, Vestas).

c. Strategy and plans

ACSE's strategy is to develop technology platforms which deliver tangible benefits to new and existing users within aerospace and transport, life sciences and health, energy and environment, and manufacturing and robotics. The strategy was developed in consultation with research staff through our Departmental Away Days in 2011 and 2013. Our plans are based on four objectives:

1. To sustain and extend our existing Pathway to Impact models

Strategic partnerships will remain a centrepiece. We will seek to strengthen our relationship with Rolls-Royce, continue to grow our research programme [text removed for publication] and seek to establish further **partnerships** with major companies. We are nurturing an early relationship with Thales, with whom we have submitted proposals to TSB and the Centre for Defence Enterprise, and have secured one funded PhD on autonomous vehicles for sea mine discovery and disposal. We are pursuing the establishment of a joint research centre with the China Electrical Power Research Institute (CEPRI), a subsidiary of the State Grid Corporation of China, and we have submitted two collaborative proposals with CEPRI to EPSRC for next-generation smart grid research. We are developing new collaborations with the Advanced Manufacturing Research Centre (AMRC) with Boeing, initially through joint ACSE-AMRC PhDs to develop concepts to full proposal stage. We are recruiting a **Business Development Manager** (BDM) to facilitate engagement with end-users and to lead follow-through activities (e.g. via the Faculty Research & Innovation Hub, who have 4 staff with expertise in the industrial-funding landscape and external partnerships, and the Sheffield Engineering Gateway, which is dedicated to knowledge transfer activities).

2. To identify and exploit opportunities for impact in our existing research portfolio

We recently formed an **Impact Review Panel**, chaired by our Director of Research, to identify unrealised potential impact in completed research contracts. The panel will meet annually from January 2014 to compare achievements against project impact plans and to identify, in collaboration with PIs, both lateral and downstream opportunities for impact. The BDM will work with PIs to realise these impacts, including help in drawing on the appropriate institutional support such as a proposal to the HEIF Proof of Concept Fund or IP exploitation in collaboration with the University's commercialisation partner, Fusion IP.

3. To ensure that all our staff identify and implement realistic pathways to impact for their research

We will be explicit in **recognising and rewarding** impact work by assessing impact achievement as part of the annual staff review and development process and exploiting existing University incentive schemes. The BDM will offer an **Impact Planning** service to staff during proposal development to help with brainstorming and reviewing impact plans. To inspire researchers and enable reflection, one third of our existing programme of **research seminars** will focus on research with impact and a new workshop on impact will be included in our PhD cohort-training programme.

4. To assess the effectiveness of our impact activities undertaken between 2014 and 2018

Our Impact Review Panel will investigate the progress being made against project impact plans in order to identify the enablers of and barriers to achieving impact, and to identify examples of good practice. The Panel will report to the Research and Innovation Committee, enabling findings and recommended actions to feed into our existing management structures. The RIC will have a new permanent "impact" agenda item and progress against actions will be monitored.

d. Relationship to case studies

A new design methodology for civil aero-engine control: arose through the RR-UTC strategic partnership with Rolls-Royce.

The impact of the Sheffield Alcohol Policy Model on alcohol policy: arose through staffing investment in our growing social systems research area and participation in the Sheffield Alcohol Research Group multi-disciplinary centre.

Right-first-time production in aerospace manufacturing: arose through a research collaboration established at the 2008 annual colloquium, organised by the IMMPETUS industrial research institute, and was supported by specific impact funds from EPSRC and METRC.