

Impact template (REF3a)

Institution: University of Cambridge
Unit of Assessment: 15. General Engineering
<p>a. Context</p> <p>Research outputs from the Department of Engineering (DoEng) principally achieve impact in society in two ways: (1) through products and services, which offer new functionality, higher performance, greater efficiency, lower costs and/or other clear-cut benefits; and (2) through information, analysis and tools, which improve the quality of decision making. Companies and government organisations are the primary audience, as they generally deliver the relevant products and services or play a significant role in making relevant decisions. The DoEng also strives to reach a wider audience of stakeholders, which includes the public with a special focus on schools, to engender informed debate about the role of engineering in society.</p>
<p>b. Approach to impact</p> <p>Interactions, engagements and relationships between staff and key users, beneficiaries or audiences are essential for engineering academics and research staff, who are, by definition, focussed on the <i>application</i> of science and technology. DoEng researchers need to stay in contact with engineers, engineering companies, entrepreneurs, investors, standards bodies and policy makers in order to: shape their research to address relevant challenges; gain access to relevant data, facilities and operations; and translate research outputs into real impact by creating new products/services and influencing decisions. The DoEng's approach to impact is, therefore, centred on fostering and supporting networks of these stakeholders.</p> <p>DoEng academics develop personal networks with companies, practitioners and policy makers that can span their whole careers: inviting their contacts to talks and seminars; partnering with them in research grants; spending sabbaticals with them; seconding research staff and students; inviting them for extended visits; embedding their staff in the DoEng; licencing intellectual property to them; setting up new companies to sell products and services to them; engaging in consulting to them; open sourcing results to them; teaching their staff on executive and masters courses; encouraging recruitment of DoEng students and research staff; and running specific events for them. DoEng academics also hold over 100 elected fellowships of learned societies and professional institutions, which help build a wide range of connections. Researchers use their networks to identify research questions of importance to an external audience, use the same network to gain the support for funding research, and use it once more to achieve impact. They also publicise outputs to a wider audience, including outreach to schools.</p> <p>All of these networking activities are encouraged and enhanced by support activities and services provided by the DoEng, the University of Cambridge (UoC) and Cambridge Enterprise (CE), the UoC's vehicle for commercialisation. The following subsections present evidence of activities, follow through to impact, agility, DoEng support, UoC support, and other mechanisms.</p> <p>Evidence of interactions, engagements and relationships is clearly provided by a breakdown of research grant income, which totals approximately GBP30M per year. 30% of research in the DoEng is funded directly by industry, demonstrating strong direct links. Approximately half is funded by the EPSRC, whose application process requires an impact plan in which the DoEng nearly always names companies, which provide letters of support defining in kind and direct contributions. Over 11% is funded by the EC in consortiums that nearly always include industrial partners. TSB projects are always led by companies and the DoEng has won 20 projects during the REF period with a total contract value to the DoEng of over GBP5.6M.</p> <p>The DoEng has maintained a strategic focus on winning funding from industry throughout the period. The Director of Research (DoR) maintains a directory of 90 company relationships, which are fostered for the DoEng by academics assigned as lead contacts. There are many times more relationships between individual academics and companies in their specialist domains. Specific examples show the diversity of activity engendered by collaborative research grants.</p> <p>Some of the relationships are close partnerships with a single company, for example:</p> <ul style="list-style-type: none"> • Rolls-Royce (R-R) has provided half of the GBP3.4M annual funding on a rolling 5-year basis for a research collaboration that started before 2008 in which DoEng and R-R strategies are aligned with academics serving on 2 of R-R's Technology Advisory Boards and chairing a third • Laing O'Rourke committed over GBP8M (including a GBP5M donation) during the REF period to create a new centre in the DoEng having developed a shared vision of transforming the construction sector with the innovative application of emerging technologies and manufacturing processes.

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Other relationships are centred on consortia. Examples founded on EPSRC grants include:

- The Cambridge Integrated Knowledge Centre in Advanced Manufacturing Technologies for Photonics and Electronics Exploiting Molecular and Macromolecular Materials (GBP6.7M, 2007-13), from 2008, created 42 commercially-focussed projects with 81 industry partners, leveraging GBP19M of funding, and facilitated the formation of 4 start-up companies
- The Centre for Smart Infrastructure and Construction (GBP9.5M, 2011-16) gained additional contributions of GBP7M from over 40 industry partners including all levels of the construction industry supply chain: (a) consultants and contractors (e.g. Arup, Atkins, Mott MacDonald, Halcrow); (b) infrastructure owners and operators (e.g. Crossrail, Transport for London, Humber Bridge); and (c) technology providers (e.g. Toshiba, IBM, Thales).

Examples of consortia funded purely by industry include:

- The Centre for Advanced Photonics and Electronics was established in 2004 as a partnership in which non-competing companies work with the DoEng to set the industry agenda and collaborate on research (over GBP3.8M funded during the REF period). The current partners are Dow Corning, Jaguar Land Rover and Disney with Carl Zeiss as an associate partner
- The Cambridge Vehicle Dynamics Consortium is a partnership of 14 companies, including Volvo Trucks, Firestone, Haldex, and Goodyear, in which company subscriptions are enhanced by EPSRC and Isaac Newton Trust funding to support research (yielding a total of GBP200-300k annually throughout the REF period). The consortium provided a springboard to win the GBP4.4M Centre for Sustainable Road Freight plus GBP1.4M from an industrial consortium that includes new partners John Lewis, Tesco and DHL.

EPSRC-funded Centres for Doctoral Training (CDT) aim to produce new generations of PhD students with a rounded set of skills and expertise to create impact in selected industrial sectors.

The DoEng leads 1 CDT and is a partner in 2 others (with more awarded in 2013 - see section c):

- Ultraprecision in partnership with Cranfield with 9 industrial partners including Aixtron, Applied Laser Engineering, Base4 Innovation, Oxford Instruments and Xradia
- Photonic Systems Development in partnership with UoC Materials and UCL with 29 industrial partners including BT, Cisco, Highways Agency, HP, Selex, Thales and Toshiba
- Nano Science and Technology in partnership with UoC Physics, Materials and Chemistry with 13 industrial partners including Hitachi, Merck, Microsoft, Nokia, Toshiba and Unilever.

Evidence of interactions is not limited to collaborative research grants, but includes the policy work described in the section on institutional support, and the marketing and schools outreach work described in the section on other mechanisms.

Evidence of follow through to impact is shown by DoEng research resulting in external investment in: IP disclosures, protection and transactions; knowledge transfer projects and awards; consulting; spin-out companies; the Cambridge high-tech cluster; and DoEng researcher careers. Statistics and examples are presented below.

CE invested its resources to progress over 160 intellectual property (IP) disclosures by DoEng inventors to CE arising from their research during the REF period, which resulted in over 60 priority patent applications and over 40 IP transactions (using the AUTM definition) during the REF period. These figures underestimate the totals as not all commercialisation is routed through CE. For instance, in many industrial relationships, the DoEng agrees that the sponsor will patent research outputs themselves and these do not count in the CE total.

An element of technology transfer is often built into the research plan, but specific funding is regularly sought to enhance knowledge transfer, for instance:

- 10 proof of concept projects funded via CE during the REF period
- 2 Knowledge Transfer Partnership projects (JCB and Romax) came to an end during the REF period and 2 new ones started (Crossrail and Computational Modelling Cambridge Ltd)
- 1 EPSRC Follow On Fund project ended during the REF period and 2 new ones started
- EPSRC funds also supported 4 Knowledge Transfer Secondments (Aquaterra Energy, ECS, PragmatIC Printing and Rolatube) during the REF period
- the Royal Academy of Engineering (RAEng) awarded the ERA Foundation Entrepreneurs Award to Sabesan and Crisp in 2011 and an Enterprise Fellowship to Gardner in 2013.

The DoEng also wins awards for knowledge transfer:

- Royal Society Brian Mercer Awards for Ferrari and his team (Innovation Award, 2008), Seshia (Feasibility Award, 2010) and Kelly (Feasibility Award, 2013)

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- RAEng Silver Medals for Travis (2008) for his commercialisation of his research through his company Cambridge FPD Ltd and Udrea (2012) for CamSemi Ltd and CCMOS Ltd.

Consulting income is another strong indicator of knowledge transfer, for example:

- CE reported an average of approximately 40 consulting assignments per year by DoEng staff during the REF period with a contract value of approximately GBP750k per year
- ECS Ltd, the DoEng's wholly owned subsidiary for disseminating DoEng research results, saw its annual revenue rise from approximately GBP2.25M to over GBP3.5M during the REF period, with wins such as the European Regional Development Fund PrISMS programme (2012-2015). PrISMS aims to use the latest research findings to help companies in the region improve revenues, profitability and sustainability. ECS has already engaged with 47 companies in the REF period through this project alone.

Note: many academics do not use either CE or ECS for their private consulting, so the figures above significantly underestimate total activity.

Seven major new DoEng spin-out companies benefitted from the UoC's generous IP policy and CE's support and went on to raise over GBP15M of external funding. In 6 of these, DoEng academics were among the founders: Cambridge CMOS Sensors, Gas Recovery and Recycle, Input Dynamics, Pneumacare, Amantys, and Zappar; and, in one, Cambridge Transport Solutions, DoEng graduates were founders. In total, in July 2013, there were twelve companies in the CE portfolio led by DoEng academics and two graduate companies. At least four other companies have grown under academics without being in the CE portfolio. Spin-outs are examples of impact in their own right, but they also grow to enhance DoEng industrial relationships and knowledge transfer, for instance:

- Cambustion Ltd manufactures high-speed gas and particulate sensors based on DoEng research, which it has supplied to virtually every internal combustion engine manufacturer in the world. Many of its closest customers are DoEng industrial research collaborators, such as, Ford, JLR, Caterpillar, Continental, BP and Johnson Matthey
- Cambridge Flow Solutions (CFS) Ltd was created to commercialise computational fluid dynamics modelling services and products based on DoEng research, which it currently provides to DoEng partners, Rolls Royce and MHI (CFS has an office in Kobe).

The DoEng makes an impact locally by providing expertise, research capacity, spin outs and graduates for Cambridge's thriving community of high-technology engineering firms consisting of both mature companies and start-ups. UoC is a founder member of the Cambridge Network; the Vice Chancellor (VC) is the President and its PVC Research sits on its board. The DoEng DoR is a member of the Technology and Innovation Leaders Peer-learning Group. The Network lists over 200 science and engineering firms and nearly 150 healthcare and bioscience firms. The University of Cambridge is also a founder member of Cambridge Cleantech, which lists over 100 firms as members in Cambridge and over 100 outside. The interplay between the Cambridge high-tech cluster and the DoEng is complex and intense. The DoEng together with this lively cluster of companies encourages other engineering firms to locate in Cambridge and stay in Cambridge:

- *Microsoft Research Cambridge took out a 20 year lease on new larger premises in Cambridge in 2012* – Microsoft Research Cambridge recognised the contribution of DoEng research to its development of Xbox 360 Kinect, which spawned multi-billion dollars of new business for Microsoft from 2010, having hired DoEng PhD student, Dr Jamie Shotton, who exploited seminal DoEng research published in 2008 with Cipolla, his DoEng supervisor
- *Nokia Research Centre (NRC) in Cambridge did not suffer cuts as the company restructured in 2011 and committed to a larger footprint in the UoC's Broers Building* - During the REF period, Nokia rented space in the DoEng as an embedded company, funded four projects (over GBP1M total contract value) and became a major industrial partner in the new EC Graphene Flagship project
- *Carl Zeiss increased its footprint in Cambridge with five new applications laboratories in 2013* – Carl Zeiss is an Associate in the DoEng CAPE consortium, it has donated two fully serviced SEMs to the DoEng, and it sponsors the annual DoEng Photography Competition.

The impact that the DoEng makes on these companies is indicated by the number that commit to placing staff in the DoEng, for example:

- Dow Corning embedded a full-time member of its staff in the DoEng throughout the period
- Dyson rented an office in the DoEng from 2012 for the use of its senior research manager to

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establish strong relationships with research contacts

- PragmatlC Printing embedded 3-4 staff between 2011 and 2012 for technology transfer from the DoEng Innovation and Knowledge Centre in photonics and electronics.

Impact is also achieved when researchers move into industry. The DoEng awards over 100 research doctoral degrees every year. 96-97% of leavers each year during the REF period reported being in employment or study in the Destination of Leavers from Higher Education annual survey conducted by the University of Cambridge Careers Office. The last three available annual reports have shown that 50-58% of those employed found work in research and manufacturing.

Evidence of an agile approach is provided by the examples above that show the DoEng using a wide variety of mechanisms to build relationships, address challenges and achieve impact. In addition, the following examples demonstrate the ability to give a rapid response to emergencies.

- Late at night on 22 December 2011, Transport for London contacted DoEng Reader, Dr Chris Burgoyne, for a second opinion on whether to close the Hammersmith Flyover after identification of structural defects. Dr Burgoyne provided his advice the next morning. He was on site on 2 January 2012 during inspections and helped field press enquiries. Works were carried out and this vital route reopened in May 2012 in time for the London Games.
- Following the Haiti earthquake of 2010, the World Bank commissioned remote damage assessment of building stock in Port-au-Prince in February 2010 for rapid evaluation of the extent of loss and to plan temporary housing needs. This was carried out by the DoEng, in collaboration with Architecture, with funding granted from the EPSRC in March 2010. They analysed pictographic and satellite imagery to classify damaged building stock. In April 2010, the DoEng team went visited Haiti to validate its analysis, reporting shortly afterwards.
- In October 2008, Rolls-Royce needed the DoEng to run a proof of concept experiment for a novel stator shroud design without delay. The experiment was set up in just 4 weeks using a research compressor at the DoEng. The results showed that the new design had promise. After further development, the concept is being integrated into the XWB engine.

Support for staff is provided by the DoR, who is a full-time senior administrator with industrial R&D, technology management and business consulting experience. DoR duties include: developing research and engagement strategies with researchers; building and maintaining links with companies and other sponsors; marketing; managing grant applications/proposals; making arrangements for visitors and embedded companies; and advising on all related contractual and IP matters. The DoR is supported in these activities by four members of staff. The Head of Department is closely involved in all major visits and events, lending the resources of her office. The DoR not only provides a service in response to requests by DoEng researchers and external companies/sponsors, but also actively cultivates relationships, for instance: Laing O'Rourke, Dyson and JLR. The DoR makes arrangements for companies to be embedded in the DoEng i.e. gain a physical footprint on DoEng premises. This can be an excellent means of deepening relationships with external firms and transferring knowledge as described earlier. The same mechanism is used to help staff incubate their spin-off companies. Examples from the REF period include: Cambridge Flow Solutions; Wind Technologies; and RedBite.

The DoEng's subsidiary, ECS Ltd, was mentioned earlier as a means for staff to disseminate their results outputs through consulting services. It also helps academics to plan their research and its future impact with industrial partners through techniques such as roadmapping.

The DoEng strongly supports staff applying for prizes and awards for achieving impact, which have been described earlier with examples. It also supports staff with training under one of its research themes (described in section c). Well over 100 researchers have attended the monthly workshops. Coaching support has been provided to multidisciplinary teams of researchers engaging with industry in pursuit of bids which total more than GBP20M.

Institutional facilities, expertise and resources are centred on three offices: CE (mentioned earlier), the Research Strategy Office (RSO), and the Centre for Science and Policy (CSaP). CE provides a service for handling invention disclosures by staff and students, patenting, licensing, creating spin-offs, consulting and other issues of commercialisation. CE operates a network of Enterprise Champions, who are regularly briefed and well supported to provide local advice, including the DoR and two DoEng academics. CE can provide seed and pre-seed funding. Cambridge is the first university to launch its own Seed Enterprise Investment Scheme (SEIS) fund, and the first to combine the SEIS with the more established Enterprise Investment Scheme. CE manages one of the most successful seed funds in the university sector, with GBP75 of

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investment following each GBP1 the CE invests, on average. It also manages introductions to a variety of Cambridge and London-based angel investor networks, venture capitalists and other investors. Cambridge Innovation Capital was launched in October 2013 with a GBP50M fund to extend future support to bridge the critical middle-stage of company growth, the “valley of death”. The PVC Research and the RSO provide coordination across the University for: strategic initiatives and networks; interactions with companies or other sponsors that involve multiple departments; and the HEIF Pathways to Impact and Impact Acceleration Awards (discussed in section c). This central team has coordinated relations with, for example, EPSRC, TSB, BP, Siemens and Shell. CSaP was founded in 2009. The DoEng DoR has been CSaP’s Special Advisor throughout. CSaP helps promote engagement of its network members: policy professionals, experts in the sciences and engineering, business leaders, and early career researchers. 64 DoEng researchers were engaged with CSaP in 2012, meeting 38 visiting fellows from government and business, out of a total of 43. CSaP arranged a 3-month placement of Pelenur, a DoEng PhD student, in the UK Government Behavioural Insights Team (BIT) in 2012. It also arranged for the DoR to design and apply a systems approach: to help the Heseltine Review in 2012; and to stimulate new thinking on ageing policy for a multi-department team.

The DoEng and UoC have been flexible in encouraging academics to take Chief Scientific Advisor positions in government, allowing a reduction to 20% full-time: Kelly (DCLG, 2006-09), Welland (MoD, 2008-12), and MacKay (DECC, 2009-).

Training courses relevant to achieving impact are available within the UoC’s: Personal and Professional Development Programme for all staff; Researcher Development Programme for research staff and research students; and vast array of events run by CE, Cambridge University Entrepreneurs, Cambridge University Technical and Enterprise Club, Centre for Entrepreneurial Learning and Silicon Valley Comes to Cambridge.

Researchers can also get support for commercialising research outputs by: providing business planning projects for MBA students at the Judge Business School; and similar projects for postgraduates under the iTeams initiative run by CUTEC. There were 14 iTeams projects in the DoEng during the period involving 42 DoEng students.

Innovators can use space and resources at ideaSpace, the University’s hub for early stage innovation, which is managed by DoEng ECS. It gained its 100th member in 2012 having been launched in 2010. Its director was a finalist in the Cambridge Business Excellence Awards 2013.

Other mechanisms for building external relationships include using undergraduate student placements, final year projects, design projects and UROPs (Undergraduate Research Opportunities Programme), which help companies explore the DoEng, while enhancing the students’ educational experience. The DoEng also has an industry partnership for supporting student-led projects, such as Cambridge University Spaceflight and Eco Racing, which includes Boeing, BP, JLR, Marshalls, National Instruments and Shell. Many sponsors use these mechanisms every year, which can enable technology transfer and lead to further research.

Taught masters courses give companies the chance to: collaborate on dissertation projects; recruit graduates; and develop their staff. These courses include: Energy Technologies; Engineering for Sustainable Development; Industrial Systems, Manufacturing and Management; Nuclear Energy; Construction Engineering; and Interdisciplinary Design for the Built Environment. The DoEng provided resources to build industry groups around these courses. The industrial group for Nuclear Energy, for example, now includes EDF Energy, Atkins, Nuclear Decommissioning Authority, Amec, Areva, Frazer Nash Consultancy and Serco.

In addition to approximately 300 talks and seminars per year that are run in the DoEng and that are open to non-academics, the researchers in DoEng also run events specifically to share the latest research results with their target sector with the aim of prompting both impact and further research. For instance, events are regularly run on glass facades and on vehicle dynamics.

Wider engagement is achieved through public dissemination of research, school outreach and engagement with the media, for instance:

- 40 Engineering for Sustainable Development Distinguished Lectures have been held during the period attracting audiences of up to 400 people with two-thirds from outside the DoEng
- every year, the DoEng Schools Outreach Officer engages approximately 100 engineering students, staff and alumni as volunteers to give over 1000 hours as volunteers to run events for approximately 3500 school pupils, parents and teachers (Warde won the Inspiring Ambassador Award from STEMNET in 2008)

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- Prager won GBP1M from the Underwood Trust to create an online learning resource for students aiming to study engineering at university (www.i-want-to-study-engineering.org)
- the DoEng outreach team and academics feature strongly in the annual Cambridge Science Festival which attracts over 30,000 visitors and extensive media coverage
- Hunt has been the featured expert in many television programmes explaining engineering concepts (Engineering Connections, Fifth Gear Stunt Special and others) and was the lead presenter for “Escape from Colditz” and “Dambusters: building the bouncing bomb”, which won the Royal Television Society Award for Best History Programme in 2012
- the DoEng marketing team released over 400 stories during the REF period on the DoEng news web pages (over 2 million hits in 2012) and in the DoEng newsletter (circulation of 17,000) with automatic news alerts for journalists sent to over 100 subscribers and content further distributed across DoEng Flickr, Youtube, Twitter, Facebook and a LinkedIn group.

c. Strategy and plans

The DoEng’s approach to impact is centred on fostering and supporting networks that connect DoEng researchers with working engineers, engineering companies, entrepreneurs, investors, standards bodies and policy makers in order to: shape their research to address relevant challenges; gain access to relevant data, facilities and operations; and translate research outputs into real impact by creating new products/services and influencing decisions. This approach fits with the overall DoEng strategic aim, which is *“to benefit society by creating world-leading engineering knowledge that fosters sustainability, prosperity and resilience”* and *“share this knowledge and transfer it to industry through publication, teaching, collaboration, licensing and entrepreneurship”*. It also fits with DoEng research income strategy to diversify its sources of income by maintaining and developing its partnerships with industry.

One of the DoEng’s four research themes is *“Inspiring Research through Industrial Collaboration”*. This theme aims to significantly reduce the time from research to large-scale implementation through improved design and management of research collaborations and knowledge transfer, building on the DoEng’s world-leading research on the innovation process, open innovation, knowledge transfer, emerging industries and related topics. It was launched in 2011 with funding from EPSRC Pathways to Impact (GBP150k), HEIF5 (GBP220k) and EPSRC Impact Acceleration Award (GBP220k) funding will support its further development. The goal in the next 5 years will be to give every researcher and sponsor access to best practice in research management and the opportunity to collaborate in the latest research in this field.

In addition, the DoEng will establish new CDTs, creating communities of PhD students who have the training and experience to make an immediate impact in industry. In 2013, 4 out of 5 full applications to the EPSRC led by the DoEng were successful together with 3 in which the DoEng was a partner. The DoEng will also continue to commit resources to build stronger links with industry throughout the period with the aim of increasing the proportion of industry funding in the research grant portfolio to exceed one third. Furthermore, the DoEng will invest in its website to make DoEng research and teaching transparent to potential partners. This will include developing its online communities, especially LinkedIn, to create forums for discussion between professional practising engineers and DoEng researchers. Finally, the DoEng will use its new website, social media sites such as Facebook and Twitter, and involvement in television and films to build public understanding of the role of engineers in society.

d. Relationship to case studies

DRed, 3D blades, S-ducts and **Sandwich Structures** show how research in collaboration with a long-term corporate sponsor can be translated to create impact in capital intensive industries. **Vibration Modelling** shows how cycles of consulting, collaborative research and knowledge transfer with a company over many years can yield progressive impact. **CamSemi, Enecsys, Granta, Metail, NanoInstruments, Zappar** and **Zinwave** show how intellectual property and knowhow can transfer to start-up companies, which often growing to sponsor further research. **3D Ultrasound** and **Inerter** show how research can be stimulated by close working relationships with end users, consulting and collaborative research to generate intellectual property that can be licenced to more than one company to create impact. **Distributed Fibre Optic Sensing, Inclusive Design, Manufacturing Networks, Roadmapping** and **Speech Technology** show how a mixture of collaborative research, open publishing and consulting can yield impact for many companies.