

Institution: 10007822

Unit of Assessment: 12

a. Context

Cranfield is a specialist university leading postgraduate education and transformational research in applied science, engineering and management to support business, government and wider society. Research impact is delivered to the aerospace, automotive, defence and security, energy, environment, health, management and manufacturing sectors: the eight themes addressed by Cranfield (www.cranfield.ac.uk). UK based global companies, small-to-medium enterprises (SMEs), government and non-governmental organisations (NGOs) are the main beneficiaries of the research.

Cranfield's research strategy is focused on deep engagement with business. Our knowledge exploitation and transfer is therefore largely through embedded research partnerships which co-create knowledge directly relevant to the strategic research agendas of our partners. Research outcomes from such work can therefore be readily translated directly to partners, along with intellectual property (IP) rights where appropriate.

In delivering impact, the University recovers full direct costs and margin from partners where exploitation and protection of IP becomes their direct responsibility. The scale of our exploitation through this route is distinctive in the UK HE sector, with research income from UK Industry and Commerce (HESA definition) being over four times greater than the sector average (29% of research income compared to a sector average of 6% - HESA Finances of Higher Education Institutions 2011/12).

Examples of the 621 UK companies who have sponsored research include Alstom Power, Anglian Water, Arup, Bentley Motors, Bombardier, Cuadrilla, Doncasters, EADS UK, Elster Metering, General Dynamics, Honda UK, IBM UK, International Paint, Martin-Baker, National Grid, Nissan Motor Manufacturing UK, Samsung Electronics UK and Schlumberger. Companies from Europe that have financed research include ABB, Active Space Technologies SA, Airbus Deutschland GmbH, Alstom Transport SA, Biogas Fuel Cell SA, Cemex AG, Getrag Ford Transmissions GmbH, Kemira Oyj, Keppel Seghers Belgium, MAN Diesel, MBDA France, SAGEM, Statoil Petroleum AS and Suez Environment. United States companies sponsoring research include Alcoa, Boeing, Chevron, Chromalloy, Conoco Philips, Dow Chemicals, Magnesium Elektron, Matthews International, MWH Americas and Praxair. Staff within UoA12 with engage with industry-led networks to influence industrial, government and international policy.

Of the £117.3M research income earned over the Research Excellence Framework (REF) period, over half (£60.5M, 51.5% of the total) has been won directly from UK, European Union (EU) and non EU industry and UK central government bodies, local authorities, health and hospital authorities, i.e. partners that will be directly impacted by the outcomes of that research. Industry has provided £45.6M (39% of the total) of research funding since 2008. Cranfield researchers working with partner organisations have co-created knowledge to their benefit with more than 1,100 different organisations. These include 791 companies from the UK and the rest of the world, of which 22 are FTSE 100 Index listed, including Amec, BP, BSKyB, Centrica, Coca Cola, GKN, Meggitt, Rolls-Royce, Severn Trent, Shell, Unilever and United Utilities. UK central government bodies who have directly funded research include the Department of Energy and Climate Change (DECC), the Ministry of Defence (MoD), the Department for Environment, Food and Rural Affairs (Defra), the Home Office and the Department for Transport (DfT). Government agencies that have directly funded research include the Civil Aviation Authority (CAA), the Defence Science and Technology Laboratory (DSTL), the Environment Agency (EA), the Health and Safety Executive (HSE) and the UK Atomic Energy Authority (UKAEA). Major global corporations who have benefited from Cranfield's research in direct contractual relationships include AVIC, Boeing, COMAC and Tata. Cranfield is 4th in the UK for engineering research income (Higher Education Statistics Agency (HESA), quoted in Times Higher Education, 13 June 2013).

Economic benefit is a major focus of our approach to impact; improving existing businesses through the introduction of new, and improvement of existing, products, processes and services along with enhancement of strategy, operations and management practices. Impacts on public

Impact template (REF3a)

policy and services are also a major focus, led by reduction of the risks to the security of nation states and by informing policy decisions and debates. In manufacturing, an example of policy influence is the National Manufacturing Debate organised annually by Cranfield, the 5th of which will be held in May 2014, which attracts influential opinion formers from industry, government and organisations such as the Royal Academy of Engineering. The Debate has a government minister or equivalent level to deliver the keynote. These have included BIS Ministers Mark Prisk and Michael Fallon.

Delegates from industry on technical and management continuing professional development (CPD) short courses are taught the latest applicable research outcomes by Cranfield academic staff, thereby contributing to the impact of research. We also draw on our pool of research to provide our postgraduate students with a distinctive, mature and 'real world' learning environment, allowing them to develop as professionals, transferring and applying their new knowledge to the global economy (www.cranfield.ac.uk/research/about/cranfield-research/index.html). The Quality Assurance Agency for Higher Education (QAA) in its June 2010 Cranfield University institutional audit noted as a feature of good practice "the integration of all students into the research and industry-linked culture and activities of the University"

(www.qaa.ac.uk/InstitutionReports/Reports/Pages/inst-audit-Cranfield-University-10.aspx).

As a wholly postgraduate institution, Cranfield graduates more students in Engineering and Technology than any other UK University, growing from 965 in 2008/09 to 1,355 in 2011-12 and totalling 4,875 graduates in the REF period up to 2012 (HESA 2012), of which 583 were Doctoral students (REF period). Between 40 and 50% of a Masters' student's time is spent on a research project that is invariably sponsored by industry and often with the student embedded at the company site, able to directly transfer research outputs to that company.

b. Approach to impact

Underpinning our approach to impact is the direct engagement of industrial, government and NGO clients in the majority of research projects. This not only includes projects designed to engage industrial end-users, such as Knowledge Transfer Partnerships (KTPs) and Technology Strategy Board (TSB) sponsored work, but also EU Framework projects and Doctoral studentships. The research and training environment within which academic staff, researchers and Doctoral students operate is typified by this deep industrial or other third party involvement. This is from provision of direct financial support and in-kind funding through to deep engagement by having regular project progress meetings with external bodies to help ensure focus and impact. A number of 'pathways to impact' have evolved of which seven are firmly established:

1. Strategic Research Alliances with Industry and Government: Formal strategic alliances with a range of major organisations have been formed by Cranfield. Those organisations relevant to UoA 12 include Airbus, Astrium, AWE, BAE Systems, Boeing, Chemring, DEFRA, EADS, Jaguar Land-Rover, Johnson Matthey, Lockheed Martin, MBDA, MOD, Nissan, Procter and Gamble, Rolls-Royce, Severn-Trent Water, Unilever, Thales, Yorkshire Water. Typical examples of impact through these strategic alliances include:

- A new Aerostructures and Systems Installation Laboratory established by Cranfield in collaboration with Airbus and the Royal Academy of Engineering. This research has been so successful that it is being introduced into the wing assembly process at Airbus UK.
- One of Cranfield's strategic defence and security partnerships is with the Atomic Weapons Establishment (AWE), with the focus of this activity being primarily on energetics and the synthesis and formulation of explosives. Much of the output from this partnership is necessarily classified but the partnership has also extended to include the professional development of their staff through postgraduate programmes, CPD and vocational training.
- Boeing chose Cranfield to lead a global centre of excellence in Integrated Vehicle Health Management (IVHM). The IVHM Centre was launched in 2008 with other core industry partners; BAE Systems, Meggitt, Rolls-Royce and Thales.
- The UK-based defence, security and safety company, Chemring, outsourced areas of their future R&D by accessing Cranfield's expertise and specialist facilities and staff. This partnership has now extended to include the professional development of their staff through postgraduate programmes, CPD and vocational training.
- Severn-Trent Water fund a wastewater research partnership with Cranfield staff embedded in

the company. WS Atkins, water consultants, are also partners and help to ensure that research impact is delivered to the business.

- A partnership with Yorkshire Water has existed for eight years on water process technologies. Research strategy is determined jointly by Cranfield and Yorkshire Water staff.

2. Industry Support for Research Council Grants: Wherever possible, Research Council grants are leveraged with associated industry projects to ensure impact. Examples include:

- The EPSRC Innovative Manufacturing Research Centre ([IMRC](#)), which received £9.7M of EPSRC Phase 2 funding from 2007 to 2011. Over the ten year lifetime of the IMRC, 264 new companies were engaged, with £11.9M of additional funding from UK private companies.
- The Integrated Knowledge Centre ([IKC](#)) in Ultra Precision and Structured Surfaces received £5.5M from EPSRC from 2007 to 2013. Over £10M of additional funds were won, mostly from over 50 companies, to translate research into commercial processes and products. Companies benefiting included Apple, Bookham Technology, Microsoft, Philips, Pilkington, Swatch and Zeiss.
- The Flapless Air Vehicle Integrated Industrial Research ([FLAVIIR](#)) Project was a five year, £6.5M project led by Cranfield and BAE Systems with nine other universities. The team developed Demon, an unmanned aerial vehicle (UAV), the world's first flying flapless aircraft, winning The Engineer's 2011 Aerospace Technology and Innovation Award (www.theengineer.co.uk/awards-2011).

3. Industry Engaged Research Degrees: Of the 583 Doctoral students graduated in the REF period, the majority had an industrial, government department (non-research) or NGO as a funder or co-funder. Companies and other non-research organisations that have sponsored Engineering Doctorate (EngD) and PhD students include ACO Technologies, Airbus, Alphasense, Anglian Water, BAE Systems, Bluewater Bio, Claas, Corus, Doncasters, Dathan Tool and Gauge, Datum Alloys, Eaton, Halcrows, HR Wallingford, Praxair, Qinetiq, Rockwell Automation, Rolls-Royce, Scottish Water, Thames Water, United Utilities and Viridor Waste Management. Cranfield leads the EPSRC Industrial Doctorate Centre (IDC) for water in partnership with four other universities (www.stream-idc.net) and is a major contributor to EPSRC Centres for Doctoral Training in composites and precision engineering. Cranfield has established its own Doctoral Training Centre to stimulate impact through interaction with industry that maps onto our eight strategic themes.

4. Knowledge Transfer Grants. Impact is achieved through undertaking research with a wide range of external partners through grants with industrial leverage that embed knowledge transfer. The funding is gained principally from sources such as EU Framework consortia grants, KTPs, the TSB and KTNs.

An example of an EU consortium project which has had major impact is Lean Product and Process Development. Research through this consortium has developed a new paradigm that has taken lean manufacturing concepts and applied them to the entire product life cycle, i.e. from design conception through to end-of-life waste elimination. Of the industry partners, Rolls-Royce, Sitech and Visteon have each adopted practices developed by the research.

A total of 17 KTPs have been delivered, valued at £2M and employing 17 Associates. Clients have included SMEs such as Caltec (based on Cranfield University Technology Park), Dathan Tool and Gauge, Geotechnical Instruments and Morgan Cars, and large companies such as Airbus, Rolls-Royce and United Utilities.

Cranfield has received £1.96M of TSB funding to support collaborative projects with industry. Examples of funded projects that have had immediate impact on industry partners include SAMULET with Rolls-Royce (www.rolls-royce.com/about/technology/research_programmes/) to improve the efficiency of manufacturing processes.

The UoA is a strong contributor to, and partners with, a number of KTNs, including the Aerospace and Defence KTN, Environmental KTN, Resource Efficiency KTN, Materials KTN and Nanotechnology KTN. For example, Cranfield's Professor Sir John O'Reilly chaired the

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Aerospace, Aviation & Defence KTN Conference 2011, we are Steering Board members of the Environmental KTN and hosted a Knowledge Transfer Manager helping industry exploitation of Cranfield waste processing research. Perhaps uniquely, a number of EPSRC sponsored networks secured a life beyond the end of their funding due to the strong interaction with and support of the industrial partners, e.g. WATNET has been operating for ten years since the end of its funding and its members include the majority of the UK water utility companies.

5. **Knowledge Transfer via Trade and Other Bodies:** In order to influence policy in key subjects, Cranfield is typically a member of industry-led network organisations which influence industrial, government and international policy. Examples include:
- The Aldersgate Group, an alliance of business, politics and society, drives action to trigger changes in policy required to address environmental challenges effectively and secure the maximum economic benefit (www.aldersgategroup.org.uk/). Cranfield is the only university member out of a total of 58 organisations that includes Aviva, BT, the Environment Agency, Friends of the Earth, Johnson Matthey, Marks & Spencer, National Grid, Sky and the TUC.
 - The European Society for Precision Engineering and Nanotechnology (Euspen) has, since its foundation in 1999, been based at Cranfield (www.euspen.eu). The membership of this network includes over 100 companies throughout Europe and 750+ individuals, linking academia and industry.
 - Cranfield is a member of British Water, the trade association representing almost 200 water supply chain companies that have a combined annual water-related turnover of some £1.2 billion (www.britishwater.co.uk).
 - Cranfield is a member of the Manufacturing Technology Association (MTA), representing the UK's machine tool sector (www.mta.org.uk).
 - Cranfield is the only university that is a shareholder in the Water and Sanitation for the Urban Poor (WSUP) Partnership that brings safe water and sanitation to people in less developed countries (www.wsup.com). It links industry, e.g. Halcrows, Thames, Unilever, with NGOs, e.g. Oxfam, Water Aid, WWF.
6. **Cranfield Companies:** The UoA also ensures the impact of research through a range of company routes that are classified as venture, parallel and spin-out.

Venture companies are managed through a central technology transfer company, Cranfield Ventures Limited (CVL), with 100% of the shareholding owned by the University. The primary example is Cranfield Aerospace Limited. A £6M turnover company based on the Cranfield campus, it provides a range of products and services at the forefront of innovative solutions for manned and unmanned aircraft, motorsport and flight simulation. An example of technology transfer creating impact is the design and manufacture of the NASA / Boeing test unmanned air vehicle (UAV), the X-48B (www.cranfielddaerospace.com/unmanned-air-systems/).

Parallel companies are wholly-owned by Cranfield. They have a remit to commercialise Cranfield developed technologies, techniques and management for the direct benefit of the University by reinvestment in research. Examples include Cranfield Impact Centre (CIC) (www.cranfieldimpactcentre.com), a company that commercialises Cranfield's research to develop crash testing techniques and provides commodity crash testing for motorsport. CIC is one of only three companies in the world that are accredited by the FIA to provide crash testing for Formula One (F1); in the period covered by REF, ten of the twelve F1 teams have been clients of CIC. Cranfield Engineering Innovation Ltd. is a parallel company that has taken the University's research into the psychology of driver behaviour and commercialised it in a risk assessment method, Drivermetrics (www.drivermetrics.com), to provide an on-line service to companies and individuals that tests the safeness of their driving habits.

Spin-out companies are supported where the intellectual property (IP) associated with our research is not vested directly in an industrial partner, such as through our research funded by RCUK. We exploit such licensing or spin out opportunities through a strategic partnership between CVL and Isis Innovation – the knowledge transfer arm of Oxford University. This partnership element of our strategy has been commended by HEFCE in their recent review of the sector's HEIF strategies (<http://www.hefce.ac.uk/whatwedo/kes/heif/heifcommendedstrategies/>).

Impact template (REF3a)

CVL holds equity in spin-outs resulting from our relatively small volumes of unencumbered IP, examples include:

- Halo X-Ray Technologies (www.haloxray.com), a joint venture with Nottingham Trent University, exploits chemical analysis using X- Rays to determine the composition of solids.
- Loxham Precision (www.loxhamprecision.com), formed to exploit new ultra-precision machine tool technologies.
- Water Innovate (www.waterinnovate.com), set up in 2005 to exploit novel water and wastewater measurement and process technologies. Water Innovate was sold to Bluewater Bio Ltd (www.bluewaterbio.com) in 2010.

When appropriate, Cranfield has invested in protecting IP with 19 patents granted in the REF period within the UoA. In a small number of cases, impact is also created via open-innovation approaches, where the use of IP by companies throughout a supply chain is appropriate.

7. **Continuing Professional Development (CPD):** Within the scope of the UoA, Cranfield has delivered CPD courses to approximately 5,000 individuals since 2008. Cranfield differentiates its educational offering by integrating teaching with leading-edge research and innovation activities applied to industrial practice through sponsored research projects, staff exchanges and collaborations. Examples of CPD courses that have been delivered since 2008 and that have used the results of research to inform industry, regulators and policy makers include Aerospace Manufacturing, Aircraft Crash Investigation, Corrosion in the Offshore Environment, Cost Engineering, Fracture Mechanics, Introduction to Integrated Vehicle Health Management, Potable Water Treatment, Precision Engineering, Wastewater Technologies (www.cranfield.ac.uk/study/professional-development/cranfield/).

c. Strategy and plans

The UoA will make full use of the University's overall knowledge transfer strategy to increase the impact of its research. The seven 'pathways to impact' identified above will continue, and be further enhanced as outlined below.

Knowledge Exploitation Partnership: The overarching principle of knowledge exploitation through direct engagement with industry, government departments and agencies and NGOs will continue. However greater assessment of unencumbered IP through our knowledge exploitation partnership will be enhanced. Raising awareness through sessions within departments and 1-2-1 coaching with staff from Isis Innovation has already begun. Cranfield was an exploitation partner of Imperial Innovations Ltd from 2008 to 2011 and Isis Innovation from 2011 to date (www.isis-innovation.com). Isis provides advice on exploitation of IP that ranges from evaluating the commercial potential of an individual's ideas, protection of IP and the best strategy for exploitation. Examples of technologies evaluated through Isis that are at the first stages of commercialisation include sensors for phosphates in the environment, 3-D printing, energy storage and frequency selective polarization surfaces. Isis Innovation will also provide links to funders to complement the annual Cranfield School of Management Venture Day started in 2008 (www.ventureday.co.uk). The Venture Day puts together technologists and business angels to exploit ideas of Cranfield staff and students.

Knowledge Exploitation Facilities: The Cranfield University Business Incubation Centre (CUBIC) on the Cranfield campus provides facilities for individual staff, student entrepreneurs and others to start-up companies (www.cranfield.ac.uk/business/support/setting-up-a-business/cubic/). An innovation habitat for organisations at the next stage of development is available in the Cranfield Innovation Centre on the Cranfield Technology Park, adjacent to the Cranfield campus (www.cranfieldtechnologypark.co.uk/). Other units provide for next stage companies.

Extended Impact Acceleration Account (IAA): A major part of future impact plans are centred on Cranfield's EPSRC IAA, which will be further extended and supported by Cranfield. The IAA has three core elements: funding to support 'proof of concept' work to move our research to a commercial proposition; development of business skills in our academics and researchers; increasing the visibility of our research portfolio to those in the business community. 'Proof of concept' projects have been funded to develop a high energy capacity battery, membrane systems for biogas cleaning, small footprint micromachining tools and 3-D printing for large-scale metallic structures.

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Local Economy: Initiatives to create increased impact from our research in the local economy include:

- Close engagement with the South East Midlands Local Enterprise Partnership.
- Support for South Bedfordshire University Technical College and Kimberley College, a 16-19 STEM College focused on engineering.
- An Operations Excellence Institute to transfer manufacturing engineering knowledge and skills to industry across educational levels from Further Education to Postgraduate.

Carbon Brainprint: The Cranfield-developed ‘Carbon Brainprint’ concept measures the potential and actual impact, of academic research in reducing the carbon footprint of society’s activities (www.carbonbrainprint.org.uk). An initial scoping study funded by HEFCE and Santander, led by Cranfield in partnership with the Universities of Cambridge and Reading, has demonstrated the applicability of the technique to a wide range of research. The *Thermal Barrier* Impact Case Study included in UoA 12 was used to test the technique. It is intended to roll out the Carbon Brainprint to all future major research projects to assess their impact in mitigating climate change.

d. Relationship to case studies

The submitted case studies demonstrate the significance and reach of our economic impact led by improvement of businesses through the introduction of new products, processes and services, as well as enhancement of strategy and operations and impacts on public policy and services. The table below indicates how our submitted cases make use of our seven different ‘pathways to impact’. These pathways are often interdependent and mutually reinforcing: impact may be developed through a primary route, e.g. an industry sponsored doctoral student or Research Council grant, and is then amplified by other routes, e.g. delivery of CPD to others in the relevant sector.

	Strategic Alliance	Industry Doctorates	Research Council Leverage	KT Grants	KT via Trade Bodies	Cranfield Companies	CPD
Short Case Study Title							
A new joining process for deep sea pipelines							
Aerodynamic modelling							
Aircraft anti-icing							
Composite landing gear brace for Boeing 787							
Controlling uncertainty with cost engineering tools							
Extended life of industrial gas turbine blades							
From source to tap							
Improved bioremediation							
Improved shock physics modelling							
Increased capability in missile seeker analysis							
Nano-reinforced composite engine components							
Optical fibre sensors: superconducting magnets							
Osteomics							
Reduced bioaerosol emissions							
Safeguarding air quality							
Thermal barrier coatings							
Ultra precision machining							