Institution: University of Nottingham

Unit of Assessment: UoA8 (Chemistry)

a. Context: Since 2008, research from the School has had demonstrable impact in the areas of the Environment, Healthcare, Culture and Society, the Economy, Business and Commerce, Public Policy, Public Engagement and International Development. Research across our five overlapping thematic areas (see **REF 5**) has impacted on a wide audience from members of the general public (*e.g.* teachers, students and healthcare patients) to companies and businesses from global corporations and drug companies (*e.g.* Pfizer, BP, Rolls-Royce) to regional SMEs within the Chemistry Using Industries. Many of these impacts have arisen as a consequence of close collaboration with other disciplines and through strong links with industry that recognise the business and environmental challenges in developing new processes, technologies and materials. A robust business engagement strategy has been established by understanding the needs of both business and the market, and by appreciating and addressing demands surrounding demonstration, scale-up and skills training.

Impact has been delivered in the following ways:
(i) improvements to processes and technologies have led to increased business competitiveness;
(ii) more energy- and resource-efficient methodologies and greener technologies have had an environmental and economic impact;
(iii) spin-out companies have delivered marketable products, have contributed to the economy, have created new jobs, and have delivered healthcare benefits to the general public;
(iv) research in collaboration with the pharmaceutical industry has contributed to societal benefits by delivering processes and pipelines to current and future healthcare products, drug discovery programmes and drug delivery systems;
(v) a pioneering programme to engage the public interest and understanding of science has resulted in cultural and societal benefits;
(vi) an innovative international development programme has resulted in policy changes, economic, educational and environment impacts on emerging economies in Africa.

b. Approach to impact

***b1. Supporting staff to identify and achieve impact*:** The School's Business Partnership Unit (BPU), first established in 2000, has fostered an entrepreneurial culture among researchers. The BPU has underpinned research impact by acting as an effective point of contact with industry, by resourcing feasibility studies, by building relationships with industry, by facilitating technology commercialisation and by securing knowledge-exchange (KE) funding. The BPU has facilitated the opportunity for impact from the School's research through access to chemistry and commercial specialists who can undertake early-stage market studies, prepare and assess business cases and patent drafts, source funding and investment, and engage with industry partners. For example, the BPU was able to co-ordinate access to research expertise in solid state NMR analysis (Titman) to resolve manufacturing difficulties with air-sensitive materials by Nissan Motor Manufacturing UK, demonstrating an expeditious and agile response to industry needs.

The BPU is led by a Business Development Manager (BDM) and has employed 11 postdoctoral Business Science Fellows (BSFs) and three Industry Fellows (IFs) since 2008 in, typically, 1-year portfolio of projects funded through competitively-won awards from a range of knowledge exchange (KE) initiatives, including HEIF, the EU, NIHR, EPSRC, TSB and from industry (>£750k since 2008). The BPU employs a full-time administrator to co-ordinate financial and contractual matters and a technician to co-ordinate analytical work for industry. The School pioneered the BSF scheme with funding (£243k) from the Gatsby Trust to enable early-career scientists to work on knowledge-exchange and commercialisation projects, typically with industry, while receiving mentoring from academic entrepreneurs, industrialists and KE professionals. School RCUK applications now include a funding component to support KE related activities. The BPU Alumni Network of 20 former BSFs includes two company CEOs and four patent agents who still assist in BSF training and in identifying commercial opportunities from the School's research. Dr Sandy Gordon (former BSF) helped form the spin-out Promethean Particles and is now its CEO (**CS2**).

The UoN KE Framework (2013) recognises KE as a core activity underpinning research and teaching through external engagement, income generation and impact and is implemented through the University's Knowledge Exchange Board and Faculty Directors of Research and Teaching.

***b2. Motivating and rewarding successful engagement*:** A significant proportion (ca. 70%) of the

School's academic staff have collaborated with industry, generating £3.66M in research awards since 2008. 25% of staff have been used as consultants to companies (*e.g.* Unilever, Solvay, Pfizer, GSK and Astra Zeneca (AZ)) to accelerate product development and process innovation across the CUIs. For example, *Moses'* consultancy with Actavis, administered through Nottingham University Consultants Ltd, and supported by a BSF, led to the collection of experimental and analytical data that were pivotal to legal arguments in a pharmaceutical patent litigation case involving a widely-prescribed multimillion dollar anti-depressant.

Together with the University's Institute for Enterprise and Innovation, the School has developed training programmes to enhance researchers' entrepreneurial skills and awareness so that potential impacts from research can be more readily identified and realised. Since 2008 the '*Bench to the Bank*' programme, in collaboration with the Society of the Chemical Industry (SCI), has delivered a series of interactive lectures, seminars and workshops with leading entrepreneurs, business figures and scientists to explore the mechanisms for commercialisation of innovative ideas and technologies, including case studies. More than a dozen academic staff and 250 different postdoctoral and postgraduate researchers have participated.

Staff and their research groups are rewarded by receiving the financial benefits from any income generated from commercialisation, consultancy or the provision of professional services. Knowledge exchange activities form part of the staff Personal Development and Performance Review (PDPR) process and have a positive impact on promotion and salary progression.

***b3. Working with industry*:**

• Since 2008 the School has worked with 36 companies on more than 100 R&D projects ranging from studentship/postdoctoral funding to feasibility projects of only a few months' duration. This engagement has included longstanding relationships led by senior academics and new partnerships facilitated by the BPU. As a result, companies as diverse as *e.g.* Syngenta, GSK, Invista, Lucite, AZ, Unilever, Sasol, Sanofi, Rolls-Royce and the National Grid have developed either new products, innovative new processes, or made strategic investments in greener technologies (**CS3**). For example, since 2008 collaboration with GSK has resulted in £1.8M of funding to six research groups involving 10 projects, leading to knowledge exchange through the secondment of nine researchers and 12 co-authored publications on new synthetic routes and reagents, and the development of flow chemistry methodologies linked to drug discovery.

• Staff and researchers proactively engage with companies through *'Industry Challenge Days'* with major companies (*e.g.* BP, Unilever, Novartis, AZ, Argenta and Boots) to share expertise and seek partners to deliver IP. BPU funding and BSF support have enabled the pump-priming of industry collaborations through feasibility studies (*e.g*. Croda, BP). Recent work with Synthomer has developed into a larger collaboration involving PhD funding and pilot-scale work.

• Industry recognises the quality of the research programmes in Nottingham and is engaged with us in Europe-wide collaborations to generate critical mass in research and training, including: the largest European Innovative Medicines Initiative (€196M) in drug discovery so far funded in collaboration with major pharmaceutical companies across the EU; industry engagement in Marie Curie training sites; partners in COST initiatives; Erasmus Mundus joint doctoral training centres; and FP7 collaborative projects particularly in sustainable chemistry (see detail in **REF5 e1**).

• Recognising the increasing importance of SMEs in the sector for driving innovation, in 2010 the School was successful in winning £800k of ERDF funding to establish a *'Chemistry Innovation Laboratory'* (CIL), which in 2013 has been expanded as part of the £755k University-wide *'Ingenuity Plus'* project to engage with SMEs. This has helped chemistry-using SMEs to innovate and grow through access to the School's facilities and expertise. CIL has allowed more than 30 SMEs to engage with the research activities of 50% of the School's academic staff, seeding new partnerships, improving business performance and creating jobs. A CIL-funded project with European Thermodynamics, based on research into the synthesis of organic semiconductor materials (*Woodward*), initiated an on-going relationship that resulted in a new product opportunity being taken forward through a consortium of industry and academia with a wide knowledge base and supported by EU funding (£1.27m), including a PhD studentship. CIL has also enabled 13 graduates on short-term placements to transfer research knowledge to SMEs (*e.g*. Upperton, Nemaura, Nottingham Zinc Group, Critical Pharmaceuticals).

***b4. Technology commercialisation*:** The School has a portfolio of 30 patents. Nine are subject to licence/assignment agreements, and the remainder are the subject of current commercialisation

projects (seeking licensees) or tactical filings to secure background technologies as a basis for industrial collaborative projects. Since 2008 the School has filed 10 patent applications, successfully negotiated two licence deals and leveraged £733k to realise commercial potential:

• DABAL-Me_3 is an air-stable organo-aluminium reagent developed by *Woodward*. Discussions with BPU staff identified DABAL-Me_3's potential to replace hazardous pyrophoric materials for applications in the pharmaceutical and fine chemicals industries. Following a BSF commercial assessment, a patent was filed (with legal support from the University Technology Transfer Office) and the technology licensed to Sigma-Aldrich. Since 2008, there have been >900 sales to pharma/biotech and academic customers in 20 countries; a BSF has initiated a partnership with Aesica to identify and develop large-scale applications in the pharmaceutical industry.

• QGenta was spun out from collaborative research between the Universities of Nottingham (*Moody*) and Colorado (*Ross* and *Siegel*) and specialises in the testing of novel compounds, developed at Nottingham, as potential therapies for solid tumours (particularly pancreatic cancers). The BPU worked with Colorado on business planning and raising initial investment.

• The School's spin-out portfolio, which includes Critical Pharmaceuticals (*Howdle*) **(CS1)**, Cellaura Technologies (*George*) and, with the Faculty of Engineering, Promethean Particles (*Poliakoff*) **(CS2)**, has benefited from on-going consultation from the BPU, board directorships (*Howdle, Farren*), access to analytical services and joint projects supporting PhD studentships. The companies have secured £4.5m in investment since 2008 and employed a total of 26 staff.

***b5. Maximising knowledge-exchange funding*:** Since 2008 the School has secured >£750k from a range of internal and external knowledge-transfer schemes to fund impact-driven projects:

• Awards have included £393k from HEIF (£265k for the Periodic Table of Videos and £100k to support year-long KE sabbaticals for *Howdle* and *Moody*); €143k of ERC Proof of Concept funding to commercialise metal organic framework (MOF) technology (*Schröder*); a £96k NIHR SBRI feasibility grant to explore patented lysostaphin-based technology's potential to reduce pathogenic bacteria levels within hospital environments (with PAL International and two local hospitals, *Thomas*); £86k from the EPSRC's Impact Acceleration Account and Knowledge Transfer Secondment Programme for deriving high-value chemicals from food waste (with Sustein, *Poliakoff*), developing new commercial high pressure instrumentation for supercritical fluids (with Lacerta Technologies, *Howdle*) and building on a previous regional innovation grant involving four SMEs; £25k in seed-corn investment from the Lachesis Fund to progress the commercialisation of cellulose aerogels (with Engineering); and £5k from the TSB Innovation Vouchers scheme for the supercritical extraction of oils (with Arvia Technology, *Poliakoff*).

• KTP associate Dr Paul Whiteside was awarded the inaugural RSC Duncan Bryant Memorial Prize after a £99k KTP with Molecular Profiles (*George*) developed a new analytical method, giving the company an important competitive advantage. Whiteside is now employed by Molecular Profiles, which also uses a range of state-of-the-art research and equipment within the School to undertake analysis and manufacture for the pharmaceutical industry.

• The BPU has also leveraged TSB funding to develop a new technology to convert lignin into a useful chemical feedstock (*Poliakoff* with Invista – **CS3**) and to undertake a project on novel formulation technology for drug-delivery (*Howdle* with Critical Pharmaceuticals – **CS1**). The School has reinvested £110k of funds from commercial activities to support further knowledge exchange.

b6. Public engagement with science: The School has established a track record in pioneering outreach and science communication which we have used as a platform for creating impact by stimulating public interest in the nanosciences and uranium-driven energy research (**CS5**).

• The School's full-time Public Awareness Scientist (*Tang*) has contributed to four RS Summer Exhibitions since 2008, to local science events in the East Midlands (*NanoWhat? Totally Tiny Technology* (**CS5**)) and School Science Fairs (*e.g.* Salter's Festivals), and has been recognised by the *UoN Vice Chancellor's Award* (2009), and the *RSC President's Award* (2011). Since 2008, >230 outreach events have been organised, engaging >63,000 participants with the research of >60% of the School's academic staff. The School also hosts one of only 6 UK RSC Regional Outreach Co-ordinators.

• Our pioneering YouTube channel *"The Periodic Table of Videos"* (www.periodicvideos.com) (2008), co-funded through philanthropic donations, HEIF, the Aldrich Chemical Company and RSC, is one of the most popular science sites on the internet with more than 298,000 global subscribers and 45.5 million views. It has been recognised by the IChemE Petronas award (2008),

the SPORE Award (*Science*, **2011**, *332*, 1046) and a US Webby Award (2012). New videos are posted weekly on topical chemistry items and research highlights (see **CS4**) which have had a significant impact in persuading students to study Chemistry at University (*Nature Chem.*, **2011**, *3*, 180). *Poliakoff* was the recipient of the *RSC Nyholm Prize for Education* (2011).

c. Strategy and plans

• ***Strategic alignment with government and stakeholder priorities*:** The School's strategy for achieving impact is to engage in dialogue with external stakeholders and industry to inform the School's research strategy and the training needs of students. The School's Strategic Advisory Board, formed in 2009 and made up of industry leaders, academics and members of professional bodies and government advisory groups, is integral to that process. In this respect, the School has strong interdisciplinary links and will increase the impact of its research through key strategic partnerships with industry in new collaborations that will be in place from early 2015 (see below).

• ***Supporting staff to identify and achieve impact*:** The School will continue to build on the success of its existing support mechanisms with the BPU providing the vehicle for maximising the impact of our strategic priorities. A senior academic will be identified as an 'Impact Champion' to develop a deeper staff engagement with the impact agenda. In 2014, a full-time 'Alumni Development Officer' will be recruited to engage alumni contacts in industries and other professions worldwide with our research agenda and broaden the opportunities for impact. A new Media Science Fellowship scheme will enable recently qualified postdoctoral scientists to develop skills in public engagement and communicate research impact as a science journalist.

• ***International collaborations:*** The School has been at the forefront in promoting sustainable technology initiatives and chemistry education in Ethiopia (**CS4**), working with policy makers in both the UK (RSC and the British Council) and Africa. We are further developing an international dimension to our green technologies agenda through the new Shanghai-Nottingham Advanced Academy (a joint venture with the East China University of Science and Technology - ECUST) which has already established a joint PhD research programme and will forge new relationships with companies in China, including current partners such as GSK and AkzoNobel. In 2014 the School will appoint a Mandarin-speaking BSF to work closely with the University's China Business Unit to help identify appropriate companies and develop links, which will also align with our successful undergraduate 'Chemistry with a Year in Industry' programme.

• ***Working with industry*:** The School has developed a unique collaboration with GSK, as part of a £30M project co-funded by the HEFCE Research Partnership Investment Fund to build an iconic carbon-neutral laboratory as part of a new *Centre for Sustainable Chemistry* (completion 2015). The project is supported by a range of industry stakeholders (Invista, EoN, RioTinto, Lucite, AZ and Syngenta) who recognise the impact of developing energy- and resource-efficient processes and technologies as vital in delivering increased global competitiveness. The CNL represents a step change in how research is conducted within a carbon-neutral environment and will provide a 'hub' to strengthen our industry collaborations and to work in partnership to train industry-ready graduates with research, knowledge exchange and business engagement skills to deliver future impacts. Our vision has now been underpinned by the EPSRC announcement to fund a CDT in Sustainable Chemistry in Nottingham in 2014. Technology demonstrator space will be used to showcase research to businesses and, in collaboration with the CIA and SCI, we will establish a regional network of businesses to increase research engagement, building upon our CIL project.

• ***Technology commercialisation*:** The School will identify and commercialise its pipeline of innovative new research and technologies. The growing patent portfolio and proof of concept work, *e.g.* on MOF technology, has generated significant interest from industry, with potential for future spin-out companies or licence deals. Generating impact from current drug-development projects, such as the European IMI (*Stockman*, *Moody*), and funding from Sanofi and the Bill and Melinda Gates Foundation to develop anti-malarial drugs for Africa (*George, Poliakoff*), are two examples.

d. Relationship to case studies

Support mechanisms have played a significant role in delivering the impacts described in the case studies. The BPU and BSFs were integral to the formation of, and continued support for, the spin-out companies that are the focus of **CS1** and **CS2**, and in developing greener technologies for the chemical industries (**CS3**). The School has built strong international relationships that are empowering chemists in Africa (**CS4**) and is committed to informing public understanding of scientific research through innovative outreach activities (**CS5**).