Institution: Queen's University, Belfast

Unit of Assessment: 8

a. Context

Staff in UOA8 are organised into 4 research groups (Centre for the Theory and Application of Catalysis, Innovative Molecular Materials, Synthesis and Biological Organic Chemistry and Atomistic Simulation Centre). In addition, staff are involved with two Industry-University Research Centres in Ionic Liquids (QUILL) and Environmental Chemistry (QUESTOR). The high quality fundamental research undertaken in these groups benefits industry, government and society and these provide impact in the areas of the economy, the environment, health and society.

The main impact from the research is *economic,* both for the industries involved and the country's GDP. We have strong collaborative links with SMEs, national and multinational companies associated with the design of new products and processes. This is exemplified by work with Roche which led to the development of a critical care blood sensor (OPTI), with Petronas (Malaysian oil company) who developed a process for the removal of mercury from natural gas together with QUB and Almac Sciences Ltd. (privately owned UK/US pharmaceutical company) who instigated their business in biocatalysis based on the work undertaken by staff in the UOA.

The research also has strong *environmental* impact in terms of benefiting the ecosystem as well as the health of the population. The removal of Hg from natural gas streams is vital for the environment as well as the overall health of the general public. We have had significant impact in the area of emission control catalysis working with Johnson Matthey, General Electric and Toyota including the development of a new prototype lean burn exhaust gas after-treatment system.

Societal impact from the research is also clear. New analysis techniques have been developed to counter the waves of synthetic drugs that threaten to overwhelm the existing Forensic laboratory analysis system. These have led to changes in the methods used to examine evidence in criminal casework. The OPTI blood sensor has had a major impact in healthcare with the rapid analysis of blood composition enabling efficient treatment of patients even in remote locations.

b. Approach to impact

We encourage and develop our interactions with non-academic users as follows:

Industry: With industry and other funding groups, we have used low overhead rates, supported by the University, to encourage initial, pump-priming industry-based projects. We have an Industrial Advisory Board which provides advice on the curriculum for UG and PG programmes including how entrepreneurship, commercialisation and intellectual property can be embedded into the educational and research activities. The board consists of representatives from local government agencies, SMEs, national and multinational companies to provide a broad perspective (Stitt (JM), McMordie (Almac Sciences), Walker (Lab. Government Chemist), Wray (Invista) Coulter (Warner Chilcott), Durnin (Seagate)). These contacts provide incubator projects to be developed through UG and PGT research projects. These projects are presented in the form of posters which the industrialists and academics are able to discuss widely and provide a forum where all researchers can interact directly with industry. In addition, the School has appointed a number of senior industrialists as honorary professors (Speers (Forensic Science Agency in Northern Ireland (FSNI) then United Nations), Stitt (Johnson Matthey), Harrison (Almac Scienes), Davey (Givaudan), Shariff (Petronas)) who regularly visit the School and discuss technology transfer opportunities with staff. In addition, Atkins (BP then Petronas) has been appointed as a member of academic staff providing advice, contacts and IP support for technology transfer. For example, by acting as a conduit between the academics and the industrial engineers, Stitt enabled the scale up from the laboratory to large scale for the dehydrogenation of 2-hydoxytetrahydrocarbazole with Robinson Bros. Ltd. Atkins has expedited the Hg system with Petronas and is currently facilitating the pilot scale testing of a new separation process for the removal of acids from crude oil. Speers worked with academics in the Schools to achieve the approval of novel drugs analysis methods. A significant amount of the research undertaken is associated with industry whether this is directly funded research or where industry participates in directing the research. QUILL and QUESTOR carry out directly funded research but also host biannual industrial advisory board meetings which provide an open forum where current projects are presented and plans for future research are

explored. QUILL was instrumental in developing the Hg removal project with Petronas by providing the initial base on which to build the industrial relationship. In addition, strong links are maintained with industrialists through RCUK, industrial and KTP/KTS grants. In these projects, typically formal meetings between the university and industrial partners occur quarterly with more frequent informal teleconferences. Importantly, these take place both in the industrial and university settings.

Commercial: Staff are encouraged to act as consultants and Queen's has clear arrangements which enable staff, the University and Schools to benefit from these activities and currently staff consult with many industries including Unilever, Warner Chilcott, Johnson Matthey, GlaxoSmithKline, Tata Steel. Through consultancy, commercialisation of research can be enabled, for example, consultancy with Insignia Technologies has led to smart plastic film technology developed by Mills to be spun out of the University and is now being commercialized. Spin outs are further encouraged by utilisation of reduced initial overheads; for example, MOF Technologies (a company specializing in the synthesis of metal organic frameworks using mechanochemistry and recent winner of 2012 NISP CONNECT 25K Award) and InkIntelligent (a company specializing in photocatalyst film detection) as well as the proof-of-concept stages of research interactions with companies, for example, in the development of superhydrophobic coatings for sportswear with Adidas. Laboratory space has been assigned to allow the creation of an International Photocatalyst Standards Test Centre which is currently being spun out. Extensive support is given through the support infrastructure in the University through the Enterprise Development Unit which gives significant levels of advice and practical help for exploitation/knowledge transfer. It offers an integrated package which aids patent filing, contract negotiation, brokerage between companies and investigators. In addition, QUBIS Ltd supports spin out companies by direct investment as well as by providing business services and mentoring. They also assist with negotiations with the larger external investors and have been extremely proactive in setting up spin out companies. This includes Avalon Instruments which became a multimillion pound business before being sold to an international instrument manufacturer in 2006 as well as the recent spinout of MOF Technologies.

Outreach: We engage in significant out-reach activities with the general public and schools, through demonstrations, lectures and open days, in order to provide a better understanding of our research and educational activities and the value it affords society. We also aim to have a significant impact on local government through discussions with local politicians and the local regional development agency, Invest Northern Ireland. This has been facilitated via the launch of the QUB's DNA of Innovation document and a series of public lectures to demonstrate the impact of the research both locally and internationally. In addition, researchers are regular attenders at events such as SET for Britain in order to showcase the research undertaken.

c. Strategy and plans

Our current direct involvement with industry is strong, particularly through our Industrial Consortia, e.g. within QUILL and QUESTOR, and we will expand these links particularly through the links with the UK Catalysis Hub and our Programme grants. This will involve building new partnerships with industry, central facilities and other academic centres with complementary expertise in order to develop critical mass. The examples of the catalysis and ionic liquids research show what can be achieved by concentrating resources but it is also necessary to retain a broad research base to be able to respond to a range of research challenges. This is currently being done in the area of medicinal chemistry through the links with Almac Sciences and the Cancer centre in QUB. In addition, the new £5M Centre for Advanced Sustainable Energy provides a forum for research and development between our staff and local and multinational companies in energy research funded by Invest Northern Ireland. A significant development is the appointment in 2013 of a new Chair in Innovation (Atkins) which is a senior position within QUB. His role is to provide expertise in transferring fundamental research ideas into industrial processes. The post is based in the School of Chemistry and Chemical Engineering but his remit is to work across the science and engineering schools. This post will identify areas which may be exploited in the chemical and related industries, as well as opportunities for research that would be of interest to local, national and multinational companies. The School's Industrial Advisory Board was established in 2011 and will be expanded in order to provide greater direct interaction for academics, undergraduate and postgraduate students. This will include the continued development of degree programmes which include entrepreneurial skills and intellectual property at all levels to facilitate the translation of

research into tangible impact.

To develop impact for the theoretical research within the UOA, we encourage collaboration with experimentalists. This arrangement has been developed over the last 10 years between QUILL/CenTACat with the ASC and we plan to reinforce this strategy by expanding the interactions between the ASC with IMM, SynBIOC and QUESTOR.

In order to incentivize academic staff, we prioritize matching funding for PhD allocation where 50% funding is available from industrial sponsors. This has led to PhDs with, for example, Almac Sciences, FSNI, Merck, Johnson Matthey, UOP, Givaudan, Invista and this arrangement will be extended. An international fee waiver scheme also has been extensively used to provide opportunities for international companies to send staff to undertake PhDs in the School. For example, Petronas has benefitted from this scheme which enabled 5 students to obtain their PhDs and return to the company and to act in the area of university liaison. We encourage the hosting of conferences and meetings within QUB to enable us to showcase our facilities to all sectors. For example, we are the centre for the UK and Ireland semiconductor photochemistry network and regularly hosts one of the Network's biannual meetings attended by industry and academia.

To aid the development of research impact of, in particular, our early career researchers, all academic staff use their multiple contact points to promote the research undertaken across the Schools. Senior academic staff also mentor them in research negotiations and management. This is magnified by developing close links across the other Schools in QUB as well as the Directorates including the international office, research and enterprise, the alumni office and the Vice Chancellor's office which enables the research to be disseminated widely and thus both industrial and commercialisation opportunities to be attained. Through these mechanisms, contracts with Petronas, GSK and Jaguar Land Rover, have been obtained in the REF period. UG and PGT research projects are used widely across the research groups as an additional mechanism to support research projects and knowledge transfer activities and are especially useful for early career staff developing initial contacts with industry. Industrially linked projects provide a mechanism to undertake proof of concept research and developing projects with future impact. For example, 10 final year projects in 2012/13 have been directly connected with FSNI, Invista, Almac Sciences, Johnson Matthey. Analogous PGT projects based in industry are being introduced.

d. Relationship to case studies

The Petronas project exemplifies our overall strategy for impact from initiation of the contact to the resultant technology transfer and exploitation. The links with Petronas were initiated in 2007 by the interaction of the Director of Research and Enterprise. This subsequently led to the award of >£9M research contracts covering a range of ionic liquid and catalytic applications and Petronas becoming an industrial member of QUILL. The rapid development of the Hg project has been achieved through strong interactions with the company via visits of academic staff and researchers, secondment of Petronas staff as PhDs and PDRAs, employment of QUB PDRAs to positions in Petronas. The project has been strongly supported by the Vice Chancellor who has made the company a strategic partner with QUB. This link was further strengthened by the appointment of Atkins to Petronas in 2009 from BP. His significant experience of interacting with universities from an industrial perspective has been invaluable in developing the environment for the research to transfer from the academic laboratory to full industrial scale. The success of this model has been widely promoted across QUB. In addition, the appointment of Atkins has enabled this process to be initiated with other industrial partners and to facilitate technology transfer.

Interaction with FSNI was supported from the earliest stages by the School with a PhD allocated to support the initial stages of the work and the subsequent supply of matching funding for PhD studentships jointly funded with FSNI. Subsequently part of the work was funded by an EPSRC responsive mode grant 2008-12 but again the University was able to support the further exploitation of that research in 2012-13 by allocating funds to support a PDRA who was seconded to FSNI to help them validate the methods for screening of novel drugs of abuse. The School's strategy of appointing senior figures to aid in technology transfer/exploitation was highly successful in the case of Speers, who was instrumental in driving adoption of the technology at FSNI and is now in a position to promote the work internationally through his position in the United Nations.