Institution: Loughborough University

Unit of Assessment: B9 Physics

a. Context

a1. Loughborough University's Physics Department (the Unit) is wholly contained within the multi-disciplinary School of Science. Since its formation the Unit's research has impacted on the ***economy*** through the formation of companies and the generation of IP and ***industry*** through the development of technologies which, in their turn, have had ***broad reach***.

a2. Our first example of the links between Departmental research and impact is the laser and optics research carried out until the early 2000's leading to developments in laser cleaning which have translated to major advances in the field of ***cultural heritage*** (Emmony, see section d2) impacting not only on ***conservation practitioners*** but also the ***general public*** through ***improved public services*** as well as ***promoting public understanding and appreciation of the conservation process***. The work also impacted on ***health and environment*** benefitting ***conservation workers*** by reducing their exposure to harmful substances.

a3. Holography work within the Unit (Phillips) led to a spin out company Advanced Holographics (currently API Holographics) who are a leading producer of ***security*** holograms widely used on bank cards and bank notes benefiting ***The Treasury***, ***banking industry*** and the ***public***.

a4. Loughborough Surface Analysis Ltd was formed by three former Departmental staff. During their time in the Unit, collaborative grants with industry had enabled them to realise that industry had a ***genuine need*** for a commercial ***surface analysis service***, particularly those businesses involved in semiconductor manufacture. To this end they set up an independent surface analysis company that has been in continuous operation to this day. It is one of a very few UK surface analysis providers and it benefits directly from expertise in and research developed within the Unit. Work in a related area by Howson provided the coating process to ***Applied Vision***, pioneers of *'in shop'* lens coating systems as used by ***major high street opticians*** (see d3).

a5. The unit has also engaged in Knowledge Transfer Partnerships such as physical vapour deposition applications (with *Cryogenics and Vacuum Technology Ltd* and *Scientific Vacuum Systems Ltd*) and other collaborative grants with partners such as Applied Vision and WA Technology. This resulted in ***improved performance and processes*** as well as ***implanting skilled research workers*** and a ***research culture*** into ***industry*** (Scientific Vacuum Systems).

a6. Most recently research work on metamaterials and acoustics has led to the development of novel sound barriers (Kusmartsev, Swallowe) and a ***spin out***, ***Sonobex***, whose barriers are receiving wide interest from users and investors which has recently ***established its viability*** (see section d1).

b. Approach to impact

b1. Our approach to impact rests on our open and interdisciplinary research ethos within the Unit. While research is strategically focused through themes we avoid constraints enabling staff to pursue interests in diverse areas which results in collaborations across the subject divide with consequent ***wide ranging impact***. As such we are always ***open to new potential applications*** of our research and can ***respond in an agile*** way to opportunities from spinning out companies (e.g. d1) through to the provision of consultancy (e.g. b5ii). The broad portfolio of the Unit's activities that has delivered significant reach (e.g. d2) evidences the fact that the Unit's approach is ***highly effective***.

b2. Example evidence of follow through from the Unit's research strategy is: (i) development of the application of laser cleaning - presented in detail as a case study, (ii) recent impact to pedagogy extending significantly beyond the University through the Institute of Physics (IoP) New Quantum Curriculum project. The latter provides freely available online learning and teaching materials for a contemporary approach to university quantum physics (Everitt based on research on foundations of quantum mechanics) and, demonstrating our long term commitment to this approach, (iii) the development of the now almost universally used Torbeck valves (silent hydraulic valves to eliminate cistern noise) invented by former staff member (Jones).

b3. In the case of potentially patentable developments staff are encouraged to consult with the Enterprise Office who will fund patent applications and provide advice on business planning and

funding including provision of direct seed funding through the University's Knowledge Transfer Account to develop research to a stage where it may be commercialised. In addition the Enterprise Office employs consultants with knowledge of the appropriate business area to provide introductions and arrange meetings with key users and beneficiaries and potential funders. This agile approach enables inventors to concentrate on enterprise. Incentives and rewards for achieving impact through commercial activity are usually in the form of shares and executive roles within spun out companies. For examples see a6 and d1.

b4. The Unit's approach to developing impact in early stages of commercialisation is to protect intellectual property and retain key personnel and know-how. This is exemplified by work in THz radiation sources and detectors (Gulevich, Kusmartsev). Here the Enterprise office has funded patent applications. Another example is nanoblade technology (nanodiscs that spin in applied magnetic fields to kill cancer cells) where an Innovation Fellowship was awarded to Forrester who has subsequently been appointed to a temporary lectureship within the Unit in order to further develop his research and establish his career. See also a6 and d1.

b5. The department encourages generating impact on UK industry by engaging in collaborative grants - illustrating an alternative route that we have used to achieve impact and respond to opportunities. A recent example is a EPSRC/Defence Science and Technology Laboratory (DSTL) grant on *Polymer Nanocomposites for Light Armour Applications* (Swallowe). More examples can be found in a4, a5, d2 and d3.

b6. The Unit's approach is supported by close collaboration between the School's Associate Deans of Research (ADR) and Enterprise (ADE) and ensures that the UoA's research can deliver significant and wide-ranging impact, innovation and enterprise. Patent, legal, funding and business advice provided by the University's Enterprise Office facilitates the process from research to beneficiary. For examples, see a6 and d1. The Unit also develops impact with the wider community through public engagement though organising events such as observatory open days and participating in outreach activities such as the Big Bang Fair.

b7. Looking to the future, the Department has identified key potential research strands that should lead to high impact outcomes. Examples include: fractal and meta-material antennas (the novel-materials sub-Unit, where we have already secured funding – Kusmartsev) through to quantum meta-materials and engineered quantum devices (quantum electronics and quantum engineering sub-Units) and nano-composite armours (novel-materials and physics of extreme conditions sub-Units). An example of the Unit's reach that has developed through its open interdisciplinary approach to its activities is that the ***Bank of England*** recently funded research into econophysics (Kusmartsev) which has the potential for global impact. A recent grant from the Leverhulme Foundation leverages interdisciplinary research to enhance rapid decision making which targets impact on key decision makers such as business leaders, policy makers and military personnel (Savel'ev in collaboration with the Salk Institute, USA).

b8. Our approach to impact in terms of staffing is evidenced by the Unit's recent appointment of Morrison. A significant consideration in the appointment process was her research related to increased efficiency in thermoelectric generation (including waste head harvesting) which has significant potential future impact in an increasingly energy focused society.

c. Strategy and plans

c1. The Unit's current strategy takes advantage of the small and intimate nature of the Department to quickly identify potential applications and commercialisation of research outcomes. The Unit then works closely with the University's Enterprise Office to formulate business plans, engage external consultants to help identify potential partners and/or investors, secure intellectual property and, if appropriate, seek Knowledge Transfer Account funding to develop an idea. The Unit's commitment to the academic freedom needed to pursue curiosity driven, and interdisciplinary, research has resulted in a broad portfolio of impact with wide reach and significance (as evidenced by our case studies). Our strategy has been effective and we will continue with this as our mechanism for realising impact over the next five years. We will however seek to improve the reward procedures for staff to encourage staff to reflect on, extract and capitalise on impact from their research.

c2. The Unit's goals for supporting and enabling impact over the next five years are:

i. To have put in place additional reward mechanisms for staff to pursue and to begin

measuring the effectiveness of these mechanisms.

ii. To put in place a formal mechanism for short-term bridging funding to facilitate the commercialisation of IP.

iii. Having established the viability of the Unit's spin out company, Sonobex, we now seek to leverage our on-going relationship to establish a strong, broad-based, research-focused industrial advisory board.

c3. The University is currently putting in place reward mechanisms for commercial and non-commercial research-generated impact. These include taking account of such activity in promotion cases and recognising the effort needed to realise such impact in the workload model. Specifically academics now have enterprise terms and conditions within their employment contract and as part of their annual Performance Development Review. They may cite such activity as evidence towards promotion or salary enhancement [Enterprise is defined as "academic engagement with business, public and voluntary organisations to create social, cultural and economic impact through knowledge exchange"]. Support includes training in Enterprise and provision of time for such activities. This effort supports and aligns with our broad strategic aims and should help us achieve our goals.

c4. A restructuring in 2011 gave the School a senior management structure which contains, amongst others, three Associate Deans (ADs), one for each area of Research (R), Teaching (T), and Enterprise (E). Each area of activity is led in the University by a Pro-Vice-Chancellor; PVC; ensuring that each area, at both University and School level, is afforded equal visibility. Our strategy is to embed impact more strongly into our activities and will develop through working closely with the ADE and ADR to proactively identify potentially exploitable IP from our research portfolio. This will maximise the impact and benefit of our research for all of our stakeholders.

d. Relationship to case studies

d1. Practical Sound Attenuation Devices: This is our most recent case study and therefore most clearly evidences our current approach as follows: **b1:** The project arose from an interdisciplinary, curiosity driven, idea of applying the theory of electromagnetic metamaterials to acoustic systems. It was recognised that the applications of sound barrier technology could have significant impact on improving external built and industrial environments (from reducing rail traffic noise through to industrial machinery). As curiosity driven research that started with undergraduate projects and later PhD studies this is a excellent exemplar of our open approach to impact and research. **b2:** the Enterprise Office provided funds for patents and initial business planning and consultancy. The consultant provided links to British Gypsum, Alkake Energy (a methane recovery company), Lindhurst (a major East Midlands bespoke engineering company), East Midlands Trains etc. which proved key to the success of the early stages of commercialisation. Further Knowledge Transfer Account funding was then awarded, via the Enterprise office, to support the work until formation of the spin out in May 2013. **b3:** PhD students (Elford and Chalmers) were supported by the Unit with bridging funds (see **c2.ii**) while an Innovation Fellowship and an EPSRC follow-on Fund grant were obtained to investigate commercialisation of their project. **b6:** The University's integrated approach to the exploitation of IP was made use of extensively in the formation of the spin out company Sonobex.

d2. Laser cleaning leads to the preservation and restoration of world heritage and art: The original research was funded by the US Office of Naval Research to investigate laser damage which was application-driven but the flexibility and interdisciplinary nature of the department's approach (**b1**) allowed alternative curiosity-driven extensions to the research. This led to interest and activity in the laser cleaning process with support from CASE studentships and Liverpool Museums (**b4**).

d3. Control of Reactive Sputter Deposition: This is an example of how consulting activity within the department leads to impact with reach. The case emerged from research within the department in parallel with consultancy where coatings were developed for many and varied applications. This established a broad and strong knowledge base that enabled the unit to take advantage of the opportunity to develop lens coatings for glasses through a joint grant with industry (**b4** and see reference [7] of the case study).