

Institution: The University of Manchester
Unit of Assessment: UoA9
<p>a. Context:</p> <p>Main non-academic user groups and beneficiaries: Our main user groups arise from: industry, national & international agencies (including hospitals) and the general public. Industrial interaction has included health & personal-care companies (e.g. Unilever, Astra Zeneca, Merck, Baxter Healthcare Corp, Ultravision, Strauman, Farfield Group) and electronics & defence companies (e.g. Samsung, Thales Underwater Systems, Thales France, AWE, Galileo Avionics SpA, Thales Optronics, Newport Spectra-Physics, Thomas Keating, QinetiQ, NanoCo). The public is a major beneficiary of our decades-long commitment to showcase research from across our portfolio, with a wide range of audiences from viewers of national TV programmes to school children.</p> <p>Range of research and main types of impact: The UoA is involved in a wide range of research across the entire discipline from large international projects to bench-top science. Big science is often a primary source of public interest drawing in audiences that can then be exposed to the full breadth of our research in outreach and public-engagement (PE) activities that educate and inspire. Industrial applications have arisen from our research, particularly in novel materials where graphene has been a highlight that is now finding a huge range of uses. In response to emerging grand challenges, we have encouraged collaborative research with industry in energy (e.g. low-energy lighting, solar cells, new fission reactor concepts) and health arenas (e.g. radiation dosimetry & therapeutics; heart modelling, cell culture; lasers in biological systems; tuneable contact lenses). Our research is generically at Technology Readiness Levels 1 to 3 and therefore requires external partnerships to carry the work through the development stages to market.</p> <p>b. Approach to impact: Our approach arises from the appreciation that non-academic impact can arise either directly from research focussed on a particular real-world problem, or may spring out of addressing some otherwise fundamental physics issue. Impact may be gained both by direct application of the research findings, or from hardware or software tools developed to undertake research. We view <i>all</i> successful research as potential subjects for PE. Our approach can therefore be classified under 3 headings: outreach and public engagement; collaborative projects with industry; and impact opportunities following from successful research. Moreover, we have introduced structures and initiatives to identify and realise impact opportunities. These 4 areas are discussed below.</p> <p>1: Outreach and public engagement: We have a long-standing active PE policy. While our graphene, astronomy, particle and nuclear physics research are often subjects of particular public curiosity, our outreach activities have spanned the entire UoA research portfolio. Our approach has several elements: permanent visitor facilities, regular annual events, one-off projects, and on-going interaction with the media. A major element of this portfolio is the Jodrell Bank Discovery Centre (JBDC). Where possible, we have a strategy to produce legacy material (e.g. websites, posters, installations) for sustainable impact. We also aim to encourage young scientists, using PhD students, postdocs and early career staff in our events, to give PE experience to the next generation. Training courses are available through the Faculty development programme on various aspects of PE from getting started in outreach to dealing with the press and using social media. Examples from our PE programme include:</p> <ul style="list-style-type: none"> • Visitor attractions: year-round exhibitions and activities at JBDC; <i>Jodrell Bank Live</i> summer events; and <i>Stargazing Live</i> TV programmes. • Regular annual events include: <i>One-Day Schools in Physics</i> talks on hot research topics selected from across the UoA research activity, run each Easter since 1980s, regularly attract more than 1000 sixth-form students; <i>Particle-Physics Master Classes</i> have been run for students and teachers for 15 years; regular involvement in prestigious Royal Society Summer Exhibitions and Manchester Science Festival Science Spectaculars. • One-off projects included: a public exhibition in collaboration with Manchester Museum of Science and Industry, estimated to have been viewed by more than 100,000 visitors, and a <i>Rutherford Day</i> in 2012 for Year-10 students, both marking the 100th anniversary of the discovery of the atomic nucleus. UoA staff are responsive to a large number of individual invitations for talks and lectures in schools, colleges and other institutions. • Regular media interactions included: TV programmes by Brian Cox; popular books by Cox and

Forshaw; Observer articles by Forshaw; *Jodcast* astronomy fortnightly web-based videos; and many other contributions on subjects from graphene to the Higgs Boson, which illustrate a strong web-, broadcast- and print-media responsiveness.

2: Collaborative projects with industry: The UoA's engagement with industry has grown throughout the period, albeit from a low base. Over the RAE period, the relevant *direct* income totalled £247k, while this has risen to £906k over 08-13, with expectations of further increases due to known projects in the coming year (see below). This growth is a result of encouraging staff to develop collaborative research programmes with companies and recognising success of such projects (see below). Substantial indirect benefits arise from collaborative post-graduate training and associated in-kind contributions. The critical mass provided by UoA expertise, and active participation with research institutes has encouraged approaches by potential external partners; for example, from ESA in a contract to identify isotopic replacements for ^{238}Pu in batteries, attracted by physics/chemistry expertise in the Dalton Institute. Similarly an approach from AWE led to collaborative work (supported by £400k) on muon tomography that uses UoA expertise in large wire chambers. Our approaches to collaborative projects are exemplified the following cases:

(i) Relationships with external partners have been developed from work in liquid crystals; with half of our PG students in this area having significant fractions of their funding from industry. Particular partnerships that been developed in the period include: (a) Syngenta, a University of Manchester (UoM) strategic partner, who, along with TSB and other companies supported development of a ferroelectric liquid-crystal smart sensor system for the perishable goods industries using RFID-readable printable plastic electronics. Rights to 2 patents from the UoA were assigned to Syngenta; (b) Ultra Vision CLPL with development of liquid crystals for contact lenses with switchable focal lengths. The work started from an MRC-funded CASE award, and developed via UMI³ Proof of Principle support (see below) of 2 PDRAs and business development to take designs to clinical trial stage. A patent has since been filed. Other significant partnerships have involved Sharp, via an EngD project, and Merck, with 2 iCASE awards.

(ii) Wet bio-interfaces have been studied with neutron scattering and a range of laser-based techniques, such as the effect of synthetic materials at protein and tissue interfaces. Such systems arise with implants, biosensors and in skin care, so efforts have been made to translate results to practical problems. Physics expertise illuminates basic mechanisms in simplified laboratory conditions that mimic important aspects of real-world situations. About 30% of the work is directly linked with industry. Partners include: (a) Unilever R&D Port Sunlight Labs to develop personal-care products; this partnership has been successful in securing support for 3 separate KT projects including 2 KTPs; (b) Thermo-Fisher Scientific also within a KTP, involving thermo-responsive bio-interfaces for benign cell harvesting for drugs screening and stem cell research. An industrial license has arisen from this work.

(iii) The UoA has begun a strategic shift emphasising applied nuclear physics since RAE, facilitated by staff membership of the Dalton Nuclear Institute (DNI). It is recognised that ~75% of subject-matter experts and technical leaders in the UK nuclear industry will retire over the next 10 years. In response, UoA and DNI play a lead role in the Nuclear Technology Education Consortium (NTEC) taught MSc course and run a Nuclear EngD programme with a research core. These link UoA staff with industry on masters projects with commercial value and recent examples include: improving radiation monitoring on the Sellafield site (with Sellafield Ltd); and development of an unmanned aerial vehicle for environmental monitoring (with the IAEA). A second facet is the measurement of nuclear data within an international consortium. After evaluation, these data underpin the safety and economics of industrial nuclear operations. The UoA is producing high-accuracy measurements of neutron cross sections and other nuclear properties. These address industry-identified deficiencies in existing databases that are important for the design of future generations of reactors and in waste management.

(iv) Selex-Galileo (SG) approached the UoA to help win a contract with Lockheed Martin, the prime contractors for the 2011 NASA JUNO mission. SG make star trackers, based on CCDs from e2v plc, which are critical for navigational guidance. The UoA was awarded £333k to evaluate a special design that could operate in the intense radiation field around Jupiter. The successful evaluation involved experimental work and GEANT4 modelling, which led to SG winning a multi-million-€ contract to supply the star trackers. Lockheed Martin has retained the UoA, as the spacecraft will not reach Jupiter until 2016.

3: Impact opportunities following from successful research: Our approach to realising the potential impact that arises from a fundamental science discovery can be exemplified by the graphene strategy developed over the period. Graphene research, initiated within the UoA, has drawn upon the wide range of capabilities in UoM, attracting complementary expertise and growing into an interdisciplinary and highly collaborative effort across a broad range of disciplines. While there is freedom for basic science to develop its best directions, with external partners there has been concentration on application sectors where capability can be matched with application potential and a competitive position in relation to other international centres. The National Graphene Institute (NGI), in which UoA staff play key roles, acts as a hub for UK research in order to build sustained partnerships with other leading universities in the UK and internationally. A £61M capital investment for new buildings and laboratories has been made by Government through EPSRC and the European Regional Development Fund. The NGI aims to exploit our leading research position to create sustainable economic value and competitive advantage by bringing together academia and commerce in a high-tech environment. A number of core partnerships are being established to cover key sectors; a strategic link was recently announced with Bluestone Global Tech, a major graphene manufacturer, leading to significant research contracts with UoM (£5M) involving the UoA and starting in Aug 13. Wider opportunities are also being developed to encourage interactions across the range of business activity, including SME's. The NGI's Project Manager has already handled >300 interactions with external companies in the past 18 months.

4: Structures and Initiatives: The UoA's approach to impact was supported by a series of more general initiatives, including embedding impact issues into the UoA management structure. A senior academic has the role of Director of External Affairs, with a broad knowledge transfer and social responsibility remit. In 2012 this remit was divided into two specific roles, Enterprise and PE & Communications, to allow more focus on our two main strands of impact. The current Director of PE & Communications is also Faculty Associate Dean for Social Responsibility and is supported in part of his remit by the UoA's Schools and Colleges Liaison Officer, a post that has existed in the School for more than two decades, reflecting one of our main PE audiences.

Recognition and reward for impact is another important aspect of our approach that takes advantage of UoM promotions policy. Significant contributions to community engagement and/or enterprise and knowledge transfer into the wider economy form one of four main promotion criteria, along with research, teaching and administration. Over the period several successful promotions cases have been enhanced by significant impact activity.

The UoA has made regular use of UoM support for impact. The UoM Contracts Team provides professional services in checking and negotiation of research contracts and disclosure agreements. UMI³, the UoM agent for intellectual property (IP) commercialisation, manages UoM IP; identifies, protects and evaluates commercial potential; and commercialises IP via an appropriate route (sale, licence or spin-out). UMI³ holds UoM patent budgets, manages a Proof of Principle scheme and provides access to spinout investment funds, such as the £32M UMIP Premier Fund, the largest in the UK HE sector. UMI³ received 78 IP disclosures from the UoA leading to 10 distinct patent families and 1 license agreement over 08-13. The Business Engagement Support Team provides external partners with services covering research, KT, consultancy and commercialisation. KT resources managed by them (KTA, KTP, IAA) have supported 5 projects in 08-13.

In a new initiative, the UoA has engaged with UMI³ in piloting an Entrepreneur in Transit (EiT) initiative. The aim is to embrace "market pull" by giving experienced people access to innovative technology. The Manchester EiT initiative is independent of the STFC Entrepreneurs in Residence scheme, but STFC is supporting the programme. In early 2013, the first set of interactions between business people and UoA staff with potentially transferable technology took place resulting in 4 of our projects selected for more detailed assessment of their viability by an EiT board.

We encourage KT and business awareness in young scientists, with enterprise courses at UG level, and for PG and post-doctoral researchers as part of the Faculty training programmes covering a range of subjects from IP to "how to start a business". Visibility of graphene research led to the initiation in 2013 of the £50k Eli and Britt Harari Graphene Enterprise Award, supported by a UoA alumnus, to encourage the development of an entrepreneurial culture across UoM doctoral and postdoctoral research base. Many final-year UG student projects are hosted by external partners and have been employed as a useful method of catalysing or cementing new

Impact template (REF3a)

collaborative relationships. For example, a co-supervised MPhys project, hosted by the Christie Hospital, for improving the resolution of single-photon emission CT using nuclear physics techniques has generated new projects that have been successful in the STFC Innovation Partnership Scheme.

c. Strategy and plans: Over the next five years we will continue to form new external partnerships and enhance the impact of our research programme by a combination of strategies:

- By recruiting top-quality research staff with direct industrial experience. For example, a Professor (FREng) to work on innovative manufacturing at the interface between academia and applications for soft photonic materials will join the School in late 2013. Beyond the new partnerships generated by this specific appointment, the increase in industrial expertise and experience within the UoA will be invaluable in forging other new external interactions.
- By promoting a cultural change in attitudes to impact generation: encouraging existing staff to contribute in the impact arena by emphasising that promotion routes via contributions to the social responsibility and economic impact agendas are highly valued; consolidating the successful start of the EiT scheme; raising the profile of successful impact activity within the UoA and externally, for example, as news stories and with dedicated web pages.
- By targeting novel materials to build on a world-leading position in graphene research, by supporting application development and business opportunities through partnership with firms and commercialisation of IP, and by providing highly trained people with scientific and entrepreneurial skills. This will involve full realization of the unique opportunities provided by the National Graphene Institute to incubate collaboration with industry.
- By growth in applied nuclear physics within the Dalton Institute and by developing accelerator physics (proton therapy) for therapeutic intervention in collaboration with the Christie Hospital.
- By building on the investment in research staff associated with the Square Kilometre Array (SKA), described in REF5, we will continue to attach strategic importance to technical development associated with SKA construction in collaboration with industry and the SKA Organisation, now sited at Jodrell Bank. For example, in association with government investments in “Big Data”, engineers will be seconded from industry for SKA development.
- By fully exploiting the External Advisory Board drawn from people in a wide range of companies and in education sectors. This commenced in 2013 and is expected to bring outside expertise and viewpoints to many areas of the UoA, including impact. Terms of reference include:
 - Developing links that may result in industry-related research projects and collaboration, student project work, student scholarships and sponsorships.
 - Providing advice on the possibilities created for the UoA’s research programmes by longer-term national needs or trends and by particular international or national initiatives often driven by the requirements of society, for example, in energy, climate, health and security.
- By appointing a *Fellow in Technology Translation* with responsibility for business engagement. Experience of a similar post within the School of Mathematics, indicates that the appointee is likely to become a self-financing resource within two years.
- By undertaking and developing a high-profile outreach and public understanding programme, following on from our long-standing and successful approach:
 - Via a science education programme in a new building for the JBDC planned for 2014.
 - Via a new *Ogden Trust Fellow* who will enhance and extend the existing PE programme, particularly to audiences that we have not targeted previously, for example, students below Year 10, at ages where many basic attitudes to science are formed.
 - Via a new RCUK School-University Partnership award; a £150k grant led by the UoA has been secured to maximise engagements with research activity across UoM.

d. Relationship to case studies: There are 3 cases based on PE; the UoA ethos of communicating our research is showcased in the continued growth of the Jodrell Bank tradition; in the extraordinary success of Prof. Cox founded on his particle physics research; in on-going contributions to Royal Society Summer Exhibitions. There are 4 cases that seized impact opportunities arising from successful research: graphene; applications of laser research; software for charged-particle optics; the SKA’s international impact.