Institution: University of Oxford

Unit of Assessment: Physics - 9

a. Context

Research in the Physics Department delivers benefits to the public and schools, to industry, and to policymakers and professionals. The impacts include public engagement in and understanding of science, the enhancement of science education, economic impacts to both new and established businesses and the informing of public debate and policy. These arise both directly from the results of our research and through the state-of-the-art technology that we develop in the process. Our impact therefore draws on research across the whole department, ranging from curiosity-driven fundamental physics through to work aimed directly at applications. We foster activities leading to impact by providing tailored support within the Department in addition to using expertise and services from the Mathematical, Physical and Life Sciences (MPLS) Division, and specialist units across the University. References given are to our impact case studies **[X]**.

b. Approach to impact

1. Framework and coordination

To support and coordinate our wide range of impact activity, the Department has two committees that report directly to the Physics Management Committee. The **Access and Outreach Committee** is responsible for the provision of a high-quality programme of outreach activities, effective use of the web and media to communicate our research, and access to public engagement training. The Department's Access and Outreach Officer (AOO) undertakes many of its actions and is responsible for providing support for the whole department. The **Industrial Liaison Committee** (ILC), established in 2010, has a strategic remit to develop, promote and bring coherence to interactions between the Department and industry. It is chaired by the Head of Department, has membership drawn from academics and relevant specialist units, and is served by our Knowledge Exchange Officer (KEO) and one of our Research Facilitators (RFs). The AOO, KEO and RFs are dedicated, full-time support posts; all current post holders have a physics degree. This framework allows us to provide effective practical and financial support to all members of the department.

2. Members of the public: stimulating engagement with science

Enabling engagement with research by members of the public is an essential part of our mission and culture. We have a deep commitment to excellent public engagement by our academics, researchers and students. Activity levels are high: since 2008, 63% of our academic staff, 45% of our postdoctoral researchers and 55% of our graduate students have been involved in public engagement activities, resulting in an average of 183 events per year and reaching a total of **140,000 people in person and over one million people online**. Our many excellent communicators and enthusiastic advocates for public engagement help to maintain our culture by demonstrating, sharing and inspiring innovative outreach.

The major platforms for our public engagement since 2008 have included the Royal Society Summer Science Exhibition (RSSSE; 7 exhibits to an estimated total audience of 73,500), the Oxford Science Blog (26 articles, readership 150,000 in 2012/13) and the University's iTunesU channel (22,000 downloads) and examples below show the diversity of mechanisms we employ.

2.1 Awareness of how we do science

We integrate public engagement in our research through a number of innovative **citizen science** projects, in which progress inherently depends on the participation and judgement of non-expert volunteers. The *Zooniverse* **[1]**, led by Chris Lintott, grew from a need for image analysis in astrophysics research to a platform for the internet's largest and most successful citizen science projects. Members of the public are involved with climate simulations through *Climateprediction* **[2]** and Katherine Blundell's astrophysics project, *Global Jet Watch*, relies on the active participation of four girls' schools in India, Australia, South Africa and Chile.

We use public interest in amateur astronomy to **communicate our astrophysics research**. The Department's observatory hosts regular telescope evenings over the winter, typically 3 school visits and one public evening every month, with out-of-hours support from our researchers and support staff. We incorporate talks on our research into these events to demonstrate how astrophysics research uses observations at the newest telescopes. Since 2012, we have also run the

Stargazing Oxford annual event (1,200 visitors in 2012 and 2013) as part of the BBC's annual *Stargazing Live* festival. Lintott has also co-presented the BBC's *Sky at Night* since 2008 and writes the monthly *Night Sky* column for *The Times*.

Public interest in the Large Hadron Collider (LHC) and other 'mega-machines' acts as a catalyst to **communicate our techniques and methods**. Alan Barr presented the LHC on the *National Geographic Channel*; an animation around our research at the LHC (created with internal funding) inaugurated the *Oxford Sparks* series and has received 69,000 views on YouTube; and analysis of collisions in the ATLAS experiment has been made accessible via our smartphone app *LHSee* and its update *Collider* **[4]**. The Oxford Science Blog has featured the LHC switch-on, neutrino physics experiments and giant telescopes. We **introduce our physicists and their work** through videos that are made available on the Department's website, iTunesU and YouTube. Three science shows for schools, *Accelerate!* **[5]**, *Levitate!* and *Fantastic Fields* have all been developed in Oxford to introduce the principles of physics and their applications.

2.2 Understanding the new physics we discover

We endeavour to communicate first-hand the excitement and significance of our research. Our **public lecture programme** has approximately one lecture by an Oxford physicist per month (750 attendees per year). Our Speakers for Schools programme offers more than 20 different lectures from academics and researchers in the Department, which are advertised through local schools networks and on our website: 24 of our staff have given a total of 50 lectures at schools. Phil Burrows has given over 20 lectures that include our current research on particle accelerators to audiences in the department and at schools and public venues. New audiences have been engaged through their existing interests e.g. the *Einstein's Universe* lectures **[3]** are accompanied by violin and have attracted concertgoers to 90 performances. We exhibit at **science festivals** to enable hands-on discovery and discussion with visitors about our work. Topics at the RSSSE have included superhydrophobic surfaces and nanoscale motors. We also exhibit annually at the Oxford Science Festival and presented three stands at the Cheltenham Science Festival (2012, 2013).

Many of our researchers regularly **communicate through the media** including newspaper, radio and TV coverage: for example, John Magorrian's research on black holes featured on *Horizon* in 2013. Presenting our climate physics research in the media stimulates active public debate **[7]**. Current members have written nine **popular science books** since 2008, including *Antimatter* by Frank Close (22,000 books sold), which act as a pathway to wider public understanding of science.

2.3 Enhancing science education

We continue to **develop teaching resources** more widely. We have run a popular Particle Physics Masterclass for A-level students annually since 1998 (~100 pupils per year), as part of a national programme, using a team of more than 30 staff, PDRAs and students giving talks and classes. The AOO is on the organising committee for the Institute of Physics Update Courses; we presented highlights of our research to 140 teachers at sessions held in Oxford (2010, 2012). Our annual APPEAL summer school (2010-13, 51 teachers) **[5]** presents current topics in accelerator and particle physics. Members teach on Continuing Education courses at Oxford, including New Perspectives in Astronomy (Davies, 2012) and Quantum Infinities (Close, 2013). Many of the 19 textbooks by our members published since 2008, while primarily for higher education, incorporate current physics research and thus create a route to impact (e.g. *An Introduction to Atmospheric Physics* by David Andrews has sold 1,500 copies and been adopted as a coursebook by 31 HEIs).

2.4 Developing our public engagement activity

Our **strong culture of public engagement** at all career stages is maintained especially through the deliberate involvement of our students and postdoctoral researchers, whose participation also decreases any perceived barriers between audiences and presenters. We actively promote opportunities and offer a wide range of roles so that each can participate according to his or her confidence and interests. The Department has a budget line to support public engagement activities and, for example, has a policy of always funding RSSSE exhibits. Involvement in public engagement activities is recorded and recognised in staff development and promotion processes.

The AOO and RFs identify opportunities and help prepare **funding applications** for outreach activities. We receive funding for public engagement through pathways to impact on EPSRC, BBSRC and NERC grants and we have won £86k from STFC public engagement funding calls.

The AOO supports and coordinates lectures and visits given by academics, researchers and students as well as undertaking her own public engagement activities. We also work with **external networks** including the South East Physics Network (SEPnet, Associate Member), Science Oxford (STEMNET) and local museums, to publicise our events, host talks by our researchers and share resources for events. We draw on **public engagement training** from a variety of sources: tailored advice is available from the university Press Office; Science Oxford delivers training for STEM Ambassadors; and the Royal Society has provided media training to some of our academics.

We celebrate the **external recognition** of our excellent public engagement, which highlights the role models who propagate our culture. Lintott was awarded the Royal Society Kohn Award in 2011 in recognition of excellence in engagement with society, Katherine Blundell won the IoP's Bragg Medal in 2012 for promoting engagement in and learning of physics, and Frank Close was awarded the Royal Society Michael Faraday Prize in 2013 for his excellent work in science communication. The *Zooniverse* **[1]** has also been recognised internally, winning an award from MPLS in 2013 for excellence in generating broad user interactions that achieved impact.

3. Industrial and commercial users of our research

Benefits to industry and commerce arise both from our advances in instrumentation and analytical methods and from our discovery of new phenomena. In many cases our technology is applied in sectors that are very far from the original objective in our research. We therefore employ a variety of mechanisms for dissemination and exploitation across a broad range of beneficiaries.

3.1 Identifying and commercialising our technology

The commercialisation of our IP is managed and supported by Isis Innovation, the University's technology transfer office. We benefit particularly from their three designated physics specialists, one previously a researcher in the Department, enabling accurate judgement of the opportunities and challenges involved in commercialisation. During the REF period, Oxford Photovoltaics was spun out of the Department; with support from Isis, it has raised £3.5m of capital **[6]**.

On average, **10 patents are filed per year**. This cost is borne by Isis (£167k), as are patent upkeep costs (£673k) while licensees are sought. Isis technology-transfer managers work in collaboration with academics to find suitable licensees, including through conferences and trade shows, marketing materials, and advertising in trade journals **[13]**. During the REF period, **11 technology licence agreements** (capturing 26 disclosures) have been executed with 9 different licensees, enabling our technologies to be rapidly brought to market **[8]**. In addition to patents, we also license fabrication processes and analytical software **[11]** to external users. Where we wish to enable the widest adoption, open-source licences have been used for software.

The KEO, RFs and Isis all assist researchers in securing funding for **development towards commercialisation**, e.g. to enable prototyping, demonstrating and testing. Since 2008 we have been awarded £435k in external grants and 6 early-stage projects have been funded by £146k from the university's EPSRC Pathways to Impact block grant. Our commercialisation ventures have received investment from Oxford's University Challenge Seed Fund (UCSF) **[6]**.

Academics are encouraged to **exploit expertise arising from research [11]** by being allowed to retain the fees from 30 days' consultancy per year within their standard contracts. These provide a means for us to start to engage with a broad range of companies and organisations. In the REF period, academics in the Department undertook 34 personal consultancies, for which Isis provides considerable support, including advice, brokering, negotiation, contracts and indemnity.

3.2 Collaborative research and industrial partners

Since 2008 we have commenced 39 **industrially-sponsored** and **collaborative research projects** of total value £2.8m. Sponsors have included AWE, BP, Pfizer, and HP as well as governmental organisations including CERN, ESA and the Met Office. For each of our key partners, responsibility for developing the relationship is held by a senior member of the department, e.g. the Head of Department for AWE. With multinational companies we increasingly take advantage of new multidisciplinary frameworks, supported by the MPLS business development team: e.g. Oxford was awarded Partner University status by Siemens in 2012. Henry Snaith leads the SANS Solar €5m EU project which has three industrial partners. We have trained 22 graduate students with CASE co-sponsorship, including with Siemens, Merck and Selex Galileo and with SMEs including TMD Technologies. In collaborative research projects, the Department is

assisted by the University's Research Services team to ensure that appropriate IP terms are agreed, both to support continuing R&D and to enable subsequent licensing and commercialisation.

Knowledge transfer takes various forms through which we can develop deeper interactions. Since 2008, 102 Confidentiality Agreements have been signed with companies to facilitate a variety of discussions. Knowledge Transfer Secondments have been undertaken with Chelsea Instruments and Oxford Photovoltaics. Knowledge and expertise are also naturally transferred when our graduate students and postdocs take up positions in industry: e.g. a recent doctoral student now working in oil exploration uses data-mining skills from his particle physics research. Results from our planetary climate research are now used directly in spacecraft engineering **[10]**.

3.3 Extending our reach

We disseminate news about our research and our specialist capabilities through a dedicated Enterprise section of our website, social media, and our newsletter, which reaches recipients including alumni worldwide in a wide range of sectors. We held an Open Day for the accelerator science industry, which has already resulted in new contracts for our design engineers, and the John Adams Institute for Accelerator Science has an industrialist on its Advisory Board. A Continuing Professional Development course on nanotechnology at the University's Begbroke Science Park engaged professionals, as did the 'Scenarios' programme for policy and business leaders at the Saïd Business School. Since 2012 we have engaged companies including Astrium, Tata Steel and Oxford Instruments with undergraduate group projects to solve industrial problems.

We reach professionals in many spheres through routes including the Oxford Innovation Society (OIS), university events for industry, and the entrepreneurship networks of the University's Said Business School. Grainger hosted an industry event for the Space sector in 2013 and Burrows spoke at the regional 'Venturefest' in 2012. One of our RFs actively builds contacts with the Harwell and Daresbury campuses to enable companies based there to engage more readily with us, while links with STFC and CERN tap into wider technology-transfer networks and opportunities.

3.4 Support and training to grow activity

Our KEO and RFs provide **advice and support for new projects** by finding funding and collaborative opportunities, developing proposals and pathways to impact, and liaising with Isis and other University services. We have integrated early-stage support from Isis into the department during the REF period: Isis staff are members of the Industrial Liaison Committee, run a weekly drop-in session in the common room, and attend the annual academic away-day.

We draw on expertise across the university to offer **training in commercial issues and opportunities**. A consultancy workshop for the Department, run by Isis in 2011, attracted 25 attendees and led to two consulting projects. Thirty six of our doctoral students attended a business awareness course run by the Said Business School and five academics joined the first MPLS Division workshop on research projects with industry.

4. Policymakers and professionals

The generous consultancy arrangements at Oxford enable members of the department to draw on their research to **influence policy.** Several have appeared before Select Committees and similar (Palmer, Seryi, Davies, Rawlings, Bell Burnell). Our students and PDRAs have presented their research to MPs at 'SET for Britain', where six won prizes. Other examples of influence on policymakers and professionals are speaking at a Chatham House conference (K. Blundell); participation enabled by the university in the 'Ideas Lab' at the World Economic Forum (Antoranz-Contera and Trigueros); and input to EU policy on nanotoxicity (Trigueros). **Climate physics** is a major research theme in the Department; we have contributed data, analysis, and expert opinion to key policy groups; e.g. through Palmer's roles in the Committee on Climate Change, the Intergovernmental Panel on Climate Change, and the Governmental Office for Science.

c. Strategy and plans

We aim to create a culture in the department where generating impact is the norm so that every researcher is not only free to undertake such activities but is actively supported in doing so with specialist training, advice and services, and with directed funding. We know of at least one recent professorial hiring in which this freedom to pursue research impact is cited as one of the reasons for joining the Department.

Our **public engagement** activity is long established, has been systematically supported for many years, and involves a substantial proportion of the department. Our plans for improvement include:

- a more coherent and structured approach to online content for public engagement, including better integration of our exposure in the broadcast and printed media.
- identifying communities that we *do not* currently reach, and developing routes to doing so
- working in partnership with other organisations where it will extend our reach, e.g. we are currently discussing with AWE how we could contribute to their regional schools network.
- refining our activities by learning from the feedback we now routinely collect, through monitoring-systems developed by the AOO during the REF period.

Although our technology development activities are long-standing, the proportion of academic staff with formalised relationships with **industry** (20%) is much lower than for public engagement. Since establishing the ILC in 2010, we have created the role of KEO (with 40% STFC funding) and recruited to the new post in 2012 to provide, for the first time, dedicated and systematic support within the department. With this support now fully established, over the next REF period we aim to double the 20% proportion to 40%. We plan to:

Develop stronger relationships with people and organisations we know, to enable proactive identification of opportunities and a focused and agile response by:

- building overarching relationships with large businesses that we know are likely developers of our technology or users of our expertise. Priorities include extending our collaboration with AWE beyond plasma physics; developing our partnership with [text removed for publication]; and deeper interactions with [text removed for publication], the UK Met Office, and [text removed for publication].
- exploiting our proximity to the Harwell science and innovation campus and existing collaborations with scientists there, to pursue opportunities with recent arrivals such as Element 6 (particularly in quantum devices) and ESA.
- facilitating greater collaboration with other parts of the university, such as medical sciences, to leverage their knowledge and expertise in engaging with particular sectors.
- inviting leading individuals from outside academia to present industry challenges: Oliver Heid (Siemens), John O'Malley (AWE) and Ellen Williams (BP) gave Physics Colloquia in 2012-13.

Reach those we do not know by:

- improving the Enterprise section of our website to market our technical facilities and scientific capabilities as effectively as possible.
- establishing a regular departmental Industry Day run by the KEO, from a first event in October 2013, and tasking the ILC to refine its format and frequency for maximum effectiveness.
- exploiting our database of 8500 physics alumni to reach organisations with which we currently have no involvement.

Recognise better the potential of the technology we produce by:

- improving identification of potential impacts, and pathways to achieve them, by involving the KEO and RFs from the inception of research proposals.
- working with Isis and divisional support to embed training in consultancy, technology transfer and business awareness into staff induction at all career stages.

d. Relationship to case studies

Throughout §b, cross-references indicated where case studies arose, at least in part, through the mechanisms we have described.

For example, *Zooniverse's* **[1]** impacts are underpinned by all aspects of our approach described in §b.2. Lintott is enabled to give time to specific public engagement activity, and the AOO provides support for *Zooniverse* events and evaluation. *Absolute Distance Measurement* **[11]** used a combination of collaborative R&D funding (both internal and external), consultancy, patents and licensing to find a market for our technology. Our successful spin-out *Oxford PV* **[6]** benefited from UCFS funding and support from Isis Innovation; this included seeking investors, use of the OIS to obtain contacts and funding, and licensing of further patents from Snaith's research.