Institution: Swansea University
Unit of Assessment: 9 - Physics
a. Context

The UoA's two research groups – **Particle Physics Theory (PPT)** and **Atomic, Molecular and Quantum Physics (AMQP)** – undertake **fundamental** rather than applied physics but nevertheless deliver impact through collaborative relationships with commercial partners that provide significant and quantifiable benefits. The UoA's research yields **industrial and societal benefit nationally and internationally**, complemented by a **public engagement** programme with a global footprint.

Our case studies exemplify these two strands of impact: both the *Laser Spectroscopy* and *BSMBench* studies illustrate **economic** impact via industrial collaborators; the *Antimatter* case demonstrates **public engagement** impact. These two types of impact illustrate the UoA's strategy, with non-academic beneficiaries corresponding naturally to the two themes.

Economic impacts are evidenced by the UoA's laser spectroscopy work with three companies whose customers include the **nuclear power industry** and **military** in both the UK and USA, and the global **aerospace industry** demonstrating the Department's **reach** and **significance**. Numerical simulations of particle physics performed by the PPT group has spun-off a computer benchmarking tool, *BSMBench*, used by **IBM, Fujitsu** and others, and has **led to the establishment of a start-up company**. The AMQP group's antimatter research in the trapping and spectrographic measurements of **antihydrogen**, generated **worldwide media interest** and was awarded the 2010 "**Physics breakthrough of the Year**" by Physics World. Building on this public interest, a significant programme of public engagement has been developed that enhances science-related education in schools and amongst the general public. Activities include the development of bespoke software simulators of the antimatter experiment for school students.

b. Approach to impact

While the UoA's research is fundamental in nature, it has **responded with agility to embrace opportunities** to develop and commercialise research with industrial partners. Some of these interactions are deliberate, such as our **PPT** group's development of a high performance computer benchmarking tool with **IBM**, and some are indirect, such as the **AMQP** group's laser spectroscopy work in measuring isotopic concentrations which is attracting the attention of the **ITER fusion** facility. The approach is to seek impact through **three complementary mechanisms** that encourage and support the early engagement of researchers with beneficiaries, fostering closer collaboration with industry and maximising the impact of research in term of its reach and significance: strategic collaborations, spin-out companies, and public engagement.

1) **Strategic collaborations** with industrial partners harness the UoA's research strength to a shared research vision driven by user needs. For example, the ability to detect and identify trace concentrations of particles ranging from nuclear isotopes to bacteria has a wide variety of industrial and medical users. Research on laser-induced breakdown spectroscopy (LIBS) was funded and used by **Nuclear Electric** (now Magnox Ltd, part of EDF) and **BNFL**. The methodology and instrumentation, also developed under contract, is used for element analysis by **Nippon Steel** and **Tata Steel**. Tunable diode laser spectroscopy (TDLAS) is used under contract with **AWE Aldermaston** to provide instrumentation for trace analysis of gases from chemical explosives.

Within the PPT group, the UoA uses intensive computer simulations of the Standard Model of Particle Physics and its extensions, often performed on the fastest systems on the planet. In-house code simulates "Beyond the Standard Model" (BSM) theories and is particularly mature in terms of its efficiency and portability and provides a perfect benchmark suite to test the performance of computer systems well beyond the often discredited *Linpack* benchmark. Work with the **IBM Watson Research Laboratory** enabled our researchers to apply the tool to IBM's BlueGene supercomputers, and to benefit from early access to the BlueGene/Q supercomputer before its official release. The UoA funded a PhD student to hold an internship at IBM Cambridge MA and

Swansea University provided leave to a staff member to pursue commercialisation of the product. The PPT group also utilised our links with a Linux magazine (to which we contribute) to distribute the code on DVD in order to gain as wide a circulation as possible.

2) The UoA supports the commercialisation of research through the **establishment of spin-out companies**. For example, **Applied Photonics Ltd**, which was established to commercialise technology developed in the UoA, has grown into a manufacturer of state-of-the-art LIBS equipment and has a strategic agreement with Energy Research Company (ERCo) in the US; **BSMbench Ltd** has invested in the benchmarking software described above to roll out test suites for a variety of computer platforms. **Institutional support** is provided by the Department of Research and Innovation, which manages programmes that bring together businesses, academics and research groups, such as Knowledge Exchange Wales and Enterprise Europe Network, **supports IP protection**, launches spin-out companies and facilitates consultancy services through a subsidiary company, Swansea Innovations Ltd.

3) The Department undertakes **significant public engagement** activity to raise awareness of physics research in society. Activities are underpinned by the UoA's research, with impact arising particularly through antimatter research focussed in CERN's ALPHA experiment. The recent major success in trapping and performing spectroscopy on antihydrogen led to **global media interest** with reports appearing in world-wide TV news bulletins and over 100 newspapers in 25 countries. The UoA's outreach programme has capitalised on this media prominence with the development of a programme of activities and hands-on materials for schools based on this research. Each year, the Department runs highly successful Particle Physics Masterclasses for A-level students, and schools lectures for younger pupils. Using **EPSRC outreach funding** to employ a dedicated RA, the UoA developed a 'Hands-On Antihydrogen' software package that allows students to run a virtual ALPHA experiment.

Other activities include **presentations at major events** such as the Cheltenham Science Festival 2013, the CERN Open Days 2013, Welsh language presentations at the National Eisteddfod (which attracts over 10,000 visitors each year), as well as local groups such as the Swansea Science Café (average monthly audience >100), and astronomical societies. Members of the UoA also contributed to local and regional radio broadcasts related to the discovery of the Higgs boson and black holes. A recent issue of "UK News from CERN" (edition 23) featured CERN's (Swansea dominated) Welsh connection, and it also appeared in a Welsh language version.

The UoA **supports staff** to achieve impact through initiatives designed to encourage and promote impact-led research. A **staff loading model** recognises participation in knowledge transfer activities and industrial projects and leads to reductions in teaching load. The College grants **sabbatical periods** to enable staff to concentrate on enhancing impact and encourages applications to the STFC/RSE Enterprise Fellowship scheme. Conducting research with impact is recognised in the *University Performance Enabling* and academic career pathways schemes which include **innovation and engagement**, rewarding staff who can demonstrate their impact.

Staff have access to a range of **institutional facilities that attract commercial collaboration**, including the EPSRC National Mass Spectrometry Service Centre in the College of Medicine; the £22m Centre for Nanohealth (a collaboration between the Colleges of Engineering, Science and Medicine, delivering impact in the field of nanotechnology applied to novel healthcare innovations); the £40m HPC Wales supercomputing facility, and other supercomputing facilities on campus that enable the further exploitation of strong numerical simulation activity within the Department. The University also holds an **EPSRC Impact Acceleration Account** (2013-2016: £638k), which funds an institution-wide impact award scheme to recognise and celebrate research impact.

c. Strategy and plans

We will continue to explore all avenues to enhance our approach to impact, recognising that future impact will be delivered by further developing **industrial collaboration** and **public engagement** activities. The strategy is a natural extension of the programme developed over the last five years.

The impact agenda will be developed in parallel with new research directions heavily influenced by the Welsh government's strategy for economic renewal. Expansion of the UoA is anticipated via

new appointments in medical physics, enhancing links with both the College of Medicine and the adjacent Singleton Hospital, and accelerator physics, in partnership with the nuclear industry. Current research in analytical laser spectroscopy and high performance computing has played an important part in catalysing two major Swansea University-led initiatives — the Centre for NanoHealth and HPC Wales**.**

The UoA is **evolving partnerships** with Renishaw (a world-leading manufacturer of Raman instrumentation) and JPK Instruments (a leading innovator in nano-analytics) in medical imaging based on its research in Raman spectroscopy and Scanning Near-field Optical Microscopy, in collaboration with the College of Medicine. This will **develop and commercialise new technologies**, eg. rapid clinical diagnosis of bacterial infections crucial for early detection of hospital-acquired illnesses, nano-scale imaging of bio-markers in normal and cancerous cells, and enhanced MRI imaging via quantum control optimization of pulse-shapes. The Department also carries out important research at the **KATRIN neutrino mass experiment** at Karlsruhe, where it has developed a method to determine isotopic abundances in real time via Raman spectroscopy. The **ITER fusion facility** has entered into contract negotiations to implement this technique for the crucial task of measuring hydrogen isotopic concentrations in their injector. The potential impact of this work, both in terms of reach and significance, is clearly enormous.

The existing collaboration between BSMBench and **IBM** will continue and several new and exciting commercial opportunities developed. BSMBench will be rolled out to monitor the STFC **Hartree Centre**'s IBM supercomputers, discussions regarding the **INTEL** Phi processor have commenced and work on porting the software to **GPU**'s has begun. The next-generation of BSMBench will incorporate the benchmarking of financial market systems.

The UoA will continue to develop its antimatter outreach and engagement programme. The ***Hands-On Antihydrogen*** **virtual experiment** will be rolled out into an open source package available as an educational resource for schools, colleges and other Physics Departments in their **MasterClasses**. An important and developing element of our outreach work is **Welsh language** provision. We plan to continue our major presence at Eisteddfodau utilising our staff and students fluent in Welsh to provide media interviews, public lectures and one-to-one discussions with the public. We have received funding from the STFC Science in Society grants to create bilingual material and will embrace any opportunity of further funding.

The UoA will continue to **support academic staff** in their pursuit of impact by enhancing all the good practice that has been developed in our approach to impact. This includes financial support to maximise dissemination of good knowledge exchange practice, ensuring that performance in this area is included in job descriptions and personal development reviews, and utilising the expertise of our University's Department of Research and Innovation to bring spin-out companies to fruition. The Department will continue to support staff in their **exploitation and technology transfer activities** by adjusting other academic duties accordingly, including funding sabbatical leave. Funds available through the University's strategic partnership with EPSRC will continue to be awarded competitively to impact and outreach projects via the College of Science Research Committee. Industrial partnerships funding graduate students through individual contact and national schemes such as the Knowledge Economy Skill Scholarships will be championed. The University has approved **new promotion routes to Chair level** for outstanding technology transfer, exploitation, public engagement or similar impact activities. These routes formally equate achievements in the area of impact with those in blue sky research. The UoA will **continue to seek the appointment of world-leading researchers** and to invest in its strengths by expanding activity in successful areas.

d. Relationship to case studies

The three impact case studies provide strong evidence of the UoA's commitment to collaborating with non-academic users, and of our approach to industrial liaison, creation of spin-out companies and public engagement which will guide the future impact strategy. Both the *BSMBench* and *Laser Spectroscopy* studies illustrate **economic** impact via industrial collaborators; the *Antimatter* case demonstrates **public engagement** impact.