Institution: University of Hertfordshire

Unit of Assessment: Panel B (9): Physics

a. Context

Physics research at the university is organised within the **Centre for Astrophysics Research (CAR)** and the **Centre for Atmospheric and Instrumentation Research (CAIR)**.

Both centres have roots reaching back to the early 1970s when the then Hatfield Polytechnic was recently established. In the following two decades, they continued to develop successfully, achieving sustainability through external research sponsorship and building both national and international profiles. Most importantly, the absence of 'core support' (provided by QR today) meant that our research was heavily influenced by support from commercial and governmental organisations, such as the MoD, as well as national funding agencies. Achieving research impact and outreach was therefore a natural and necessary outcome of our continued research success.

Today, this broad research portfolio contains a significant proportion of basic research, not only in astrophysics but also in areas of theoretical light scattering that underpin our work in, for example, atmospheric cloud radiative properties or hazardous particle identification. However, the end-user influence prevalent in those earlier years has remained part of our research ethos and is manifest most clearly through the responsiveness of our research to national and international priorities, through the widespread uptake of our research outcomes by commercial and public bodies, and through its dissemination to the public. The Physics impact case studies give examples of these.

Our non-academic research beneficiaries/audiences are diverse and numerous. **CAIR**'s include:

1. **The Met Office**, which has adopted our fundamental Ray Tracing and Diffraction on Facets (RTDF) theoretical formalism in their Global Circulation Model (a world-leading tool for climate prediction) to verify light scattering parameterisations of ice clouds.
2. **Governmental atmospheric research organisations** in the UK, Europe and USA who use our wing-mounted 'SID' particle probes for cloud microphysics research.
3. **Occupational and workplace health officials**, atmospheric and environmental scientists, and the military, all of whom benefit from our 'WIBS' bioaerosol detection technology licensed for commercial production to a USA company.
4. **European airlines** and their passengers (including military flights to Afghanistan) whose safety was ensured in part by our unique 'aerosol sondes' that provided the first *in situ* measurements of volcanic ash over northern Europe in 2010.
5. **UK Instrumentation SMEs** and their customers in fields of stack emissions monitoring and air quality, which benefited from our particle light scattering expertise in new product designs.
6. **Many of the 5 million plumbers, electricians, and other tradespeople** across Europe who will be protected from inadvertent airborne asbestos inhalation by our real-time 'ALERT' laser-based asbestos detector, now entering commercial production.
7. **Policy makers at DEFRA and the EC**, who have used our dynamical modelling of air quality trends for regional scale policy/regulation analysis and response.

For **CAR**:

1. **The general public, schools, societies and community groups**, totalling ~4,000 per year, who have been informed and enthused by **CAR** researchers at our Bayfordbury Observatory. Regular open evenings featuring themed talks based on our research strengths from exoplanets to high-redshift galaxies accompany hands-on interactions exploiting the Observatory's 7 domed optical telescopes, radio telescope and interferometer, planetarium and celeostat for solar observations.
2. **Teachers and other professionals** who, through the East of England Science Learning Centre based at the Observatory, exploit **CAR**'s expertise and the Observatory's facilities in their CPD courses. One example, **CAR**'s 'From Hydrogen to Humans' ('H2H', now 'Astrophysics'), is delivered regularly to teachers to enable them to inspire their students and pupils. It is a key course supported by a £60,000 RCUK grant for 'Cutting Edge' science courses.

3. **The public, schools, astronomy clubs, etc**, who benefit from **CAR**'s other public engagement events, some supported with small external grants. For example, the **CAR**-produced film *Starry Messenger*, based loosely on a 'meeting with Galileo Galilei', has been distributed to several hundred schools and is available online. Designed for GCSE Physics and Astronomy students, the film was written, produced, directed and acted by **CAR** researchers, and supported by an £8,500 PPARC grant.
4. **Industry**, with close collaboration between **CAR** researchers and commercial bodies, most notably Astrium (Stevenage) which supported our bid for the Science Learning Centre and was an industrial partner on the **CAR**-led EU Initial Training Network (ITN: RoPACS-Rocky Planets Around Cool Stars, with €3.2M of funding for a four-year project, starting Dec. 2008). Although science-based space missions for companies like Astrium remain a relatively small-scale activity, **CAR** expertise has given the company a competitive edge in international projects such as EChO, an ESA medium-class mission proposal to study exoplanet atmospheres.

b. Approach to impact

A strong academic research reputation greatly assists the achievement of effective and far-reaching impact. This is true for both **CAR**'s outreach programmes and **CAIR**'s commercial and societal impact delivered through exploitation of their research outputs and direct commissions for new research instruments. Our approach to impact therefore begins by striving to ensure we achieve and sustain the highest possible levels of research integrity and output quality. From this, experience has shown that benefits will naturally flow to commercial and government organisations, teachers and pupils, and the wider public.

Major public outreach events, such as a three-day 'research showcase' at the university, involved both **CAR and CAIR** researchers in staffing exhibits and giving public lectures to audiences of 300 plus. This is just one among a range of strategies that **CAR** and **CAIR** adopt to maximise impact. In **CAR**, our astronomers have always capitalised on their expertise, their sometimes eye-catching science data, and the facilities of the university's Observatory to strengthen engagement with the general public, schools and other interest groups. Their primary reward comes from the enthusiastic audience response (via live feedback, letters, the Observatory's website, etc). Senior management makes every effort in terms of time allowances expenses, and recognition of its importance in annual appraisal to encourage and foster this outreach. A number of our staff have become prolific authors/broadcasters in the subject (e.g. Stuart Clark, Chris Kitchin, Iain Nicolson).

The increasing importance of astronomy in the schools curriculum has also provided the opportunity for us to deliver **CAR**'s 'Astrophysics' course as part of the RCUK-supported CPD course for teachers. Wherever possible, **CAR** also exploits industry links to enhance outreach. For example, Astrium supported the UK and European Astronomy Society's 'Astronomy & Space Science' conference, held at the university in 2009, and underwrote a special 'Schools' Day' that allowed some 250 school children to interact with exhibits including the Astrium Mars Rover. Finally, each year, research students and other young researchers undertake a two-hour course on engaging the public with their research. Several students have also participated in the national 'Researchers in Residence' programme.

CAIR's approach to impact is built upon both short-term (responsive) and long-term (strategic) objectives. In the former case, **CAIR** has always sought to be highly responsive to external challenges where we can offer solutions. The eruption of the Eyjafjallajökull volcano and our role in rapidly identifying the resulting dust layers was a case in point. On a longer timescale, our theoretical light scattering research, whilst itself groundbreaking, never loses sight of the larger objectives, such as providing the climate modelling community with more accurate cloud microphysical data with which to reduce model uncertainties or providing tradespeople with a means of detecting deadly airborne asbestos. Through **CAIR**'s international profile and the widespread adoption of its instruments, more than 50% of its research project portfolio now arises from requests from external research organisations for custom instrumentation or through invitations to join research project consortia to which our specialist skills can contribute. In both cases, end-user requirements are paramount and the subsequent route to impact is identifiable.

c. Strategy and plans

The preceding sections outline the key elements of our underlying strategy for maximising impact, i.e., (i) to achieve and sustain the highest possible levels of research integrity and output quality; (ii) to capitalise on the inherent enthusiasm for their subject of our researchers in the conception and delivery of outreach activities and wide public engagement; and (iii) to focus on national and international scientific priorities but remain ready to respond rapidly to short-term or emergency challenges where our research expertise can offer solutions.

Specific plans to deliver this strategy:

1. The extensive collaborative portfolio will be further built upon through long-term national and international collaborations, and particularly partnerships with industry (e.g: via ICASE, Knowledge Transfer Partnerships, and direct industrial funding).
2. The role of consortia in tackling major scientific challenges is increasing, and already a third of **CAR**'s and half of **CAIR**'s research income is derived from their involvement, frequently as an invited partner, in national and international consortia. The benefits of such consortia include far wider and more rapid realisation of impact, and both research centres will actively pursue such platforms to contribute to and further enhance their expertise.
3. The extensive schools outreach programmes will be enhanced not only through continuing visits to the Observatory but also via online access to the remote observing facilities and queue scheduling, now offered on five of the telescopes. Training courses will be offered to teachers that, importantly, will include how to extract science from their observations. For example, some of our Galactic Plane survey leads have initiated or are in the process of initiating the re-use of survey data in school STEM club and curriculum support, or for outreach.
4. The university has invested £125,000, matched by universities of Leeds and Oxford, in a partnership with the Goonhilly regeneration project (Goonhilly Earth Station (GES) Ltd). This will result in a fully operational satellite communications centre and radio astronomy facility complemented by a large visitor centre for education and outreach. It aims to inspire the next generation of scientists and showcase the best of the UK's space sector. **CAR** will be fully involved in this development, using its experience in education and outreach.
5. Increasingly, interaction with schools will be through collaborative programmes with the University of Hertfordshire Science Learning Centre (SLC), which now has responsibility for 46% of English schools following the government's restructuring of the regional SLCs. For example, we will be increasing support for their Subject Knowledge Enhancement (SKE) courses offered to those for whom Physics is not their primary discipline.
6. The university became a member of the South East Physics Network (SEPnet) in 2013. SEPnet outreach goals include 'promoting physics, providing support for physics teaching through strategic partnerships (e.g. SLCs, Institute of Physics) and engaging the public with the research activities of its members', all consistent with our own goals. As part of SEPnet, we are formally committing a further 0.5fte of effort to outreach.

d. Relationship to the case studies

We have selected case studies that best reflect the breadth of impacts our Physics research has achieved. The case studies on **airborne bio-organisms** and on the exploitation of **spatial light scattering** are examples of how fundamental research in areas of spatial light scattering and particle fluorescence spectroscopy respectively have led to practical research instruments subsequently widely adopted by national and international research communities, often beyond the field of physics. In both cases, technologies developed have been ultimately licensed to industrial organisations for commercial production. The case study on the **measurements of ash spread** is an illustration of the opportunistic generation of impact arising from joint **CAR–CAIR** research and the unforeseen eruption of the Icelandic volcano. The final case study describes the **public engagement activities centred upon our Bayfordbury Observatory** and their impact on school students, teachers and the wider public.