Institution: Durham University

Unit of Assessment: Computer Science and Informatics

a. Context

Durham's Computer Science research is, essentially, partitioned into "theory" and "practice". The *Algorithms and Complexity* research group (*ACiD*) works at the interface between (pure) Mathematics and (theoretical) Computer Science; and the *Innovative Computing* research group (*IC*) works on more practical aspects of Computer Science, namely computer methodologies and systems, and, in particular (and to an increasing degree), on inter-disciplinary research. The main non-academic beneficiaries of our research are society in general (cultural enrichment) and industry and the economy (knowledge transfer and the commercialisation of basic research), with this impact derived almost exclusively from the activities of Innovative Computing. However, recent research developments within Durham University, namely the merger of Computer Science and Engineering in 2009 and the creation of the *Institute for Advanced Research Computing iARC* in 2012, will better enable all of Durham's Computer Scientists to contribute to impact-related activities in future.

b. Approach to impact

Our approach to **developing impact** is common to both Computer Science and Engineering within the School (this synergy between Computer Science and Engineering is mutually beneficial and leads to collaborative impact-related opportunities). It is organised and managed by the Head of School in collaboration with the Director of Research (Stewart), with the School's Research Committee providing invaluable input and guidance. Major industrial partners join other representatives from industry (local, national and international) on our *Industrial Partnership Committee* (there is representation from Sage and BAe Systems along with a larger number of engineering-oriented companies) whose remit is to advise us on industrially-related directions in research and teaching, and to facilitate the impact of the School's research.

We interact with different non-academic users in a variety of ways. We are developing relationships with **key industrial partners** such as RealD Inc. (USA), Proctor and Gamble, IBM, Nokia Research and Icona Solutions Ltd. (a local SME) so as to facilitate the development of our research into impact. For example, (and in combination with *Durham Business Innovation Services*, DBIS) we regularly run "show-and-tell" sessions in the *Durham Visualisation Laboratory* (DVL, for which the University provides infrastructure funding) for such partners and this has led to funded projects, e.g., Proctor and Gamble have provided PhD funding (for a student to work on measuring binocular shine) and RealD (then Colorlink) after visits to the DVL licensed a patent from Durham University and are now working closely with IC on (stereoscopic) visualisation (IC staff have been employed in consultancy roles by RealD and RealD have provided 3D display prototypes to the DVL for use in our research). We have also visited companies to present our research to them, e.g., Dreamworks Animation (USA) and Imagination Technologies Ltd.; and Google Zurich are involved in the research of a current PhD student.

A **memorandum of understanding** (MoU) was signed with IBM in May 2013. The MoU will enable ongoing, broad engagement between the University and IBM, characterised by links at different levels across both organisations and multi-disciplinary interaction across research, teaching and learning, student experience and employability, and public engagement. The areas of specialised research will include high-performance computing, smarter cities (the innovative use of city data to deliver a sustainable, high-quality life), digital humanities (computing with humanities topics) and big data analytics (extracting knowledge from the analysis of large complex datasets). IC and iARC will be heavily involved with collaborations with IBM (with ACiD also involved in big data analytics).

We contribute to a number of Durham's **inter-disciplinary research institutes** such as Durham's *Institute for Computational Cosmology*, *Wolfson Research Institute for Health and Wellbeing*, *Institute of Advanced Studies*, *Biophysical Sciences Institute*, *Centre for Biological Imaging* and *Centre for Vision and Visual Cognition* (in future it will be primarily through iARC that our inter-disciplinary research will be focussed). Our involvement in these institutes has led not only to inter-disciplinary research opportunities but to impact-related activities. For example: the content for our award-winning movie "Cosmic Origins" came from the Institute for Computational Cosmology; PhD funding from Proctor and Gamble came through the Biophysical Sciences Institute; a new funding link with Nikon has arisen through the Centre for Biological Imaging; and the strong links with RealD arose through research undertaken through the Centre for Vision and Visual Cognition.

Sony Computer Entertainment Europe provided us with a **public domain list of research challenges**. Our students have tackled these challenges at both undergraduate and postgraduate level. A recent conference paper has been used by Sony in their internal global training programmes and another conference paper on one of the Sony challenges has resulted in a student being invited to Dolby Laboratories, San Francisco.

We have acted as **consultants** to a number of companies, e.g., RealD Inc., Mercedes GP and Visual Acuity Ltd. This has resulted in Durham having access to leading-edge industrial research, e.g., to advanced 3D displays at RealD and Kodak prior to their general release, and future industrially-oriented research directions, e.g., Sony's interest in the influence of sound on 3D depth perception.

We actively contribute to **science festivals** such as the Royal Society Summer Science Exhibitions (2009, 2010, 2011, 2013), Durham Science Festival (2010, 2011), Newcastle Science Festival (2011) and the British Science Festival (2013). These exhibits include our 3D movie "Cosmic Origins" and a 3D "spot the weapon" game demonstrating how threat detection at airports can be improved by using 3D displays.

Our **impacts** are currently primarily in knowledge transfer, through IP generation and on society, although we have created spin-out companies in the past (see a case study).

As regards **knowledge transfer**, our consultancy activities with companies such as RealD Inc., Mercedes GP and Visual Acuity Ltd. have led to knowledge transfer in the area of stereoscopic imaging. In addition, we have held knowledge transfer awards in combination with, for example, Codeworks Ltd., Wildcat Films Ltd. and the NHS that have led to researchers working with these companies and organisations so to transfer knowledge.

As regards **IP generation**, we have generated patents (in the UK and the US). For example, US patent 7983477, whose production was originally supported by Codeworks Ltd., was subsequently supported by and licensed to RealD Inc., a leading developer and supplier of 3D technology, the US patent being issued in July 2011.

As regards **societal impact**, our work has produced a number of 3D films (including "Cosmic Cookery" and "Cosmic Origins") that have been shown to schoolchildren throughout the UK and overseas in museums, planetariums and other public exhibitions (see a case study).

As can be seen from one of our impact case studies, a **spin-out company** from Durham that was set up in the 1990s and underpinned through Durham research throughout the 90s, is still extremely active and has, over the years, become increasingly successful.

Institutional support for impact activities from the University is strong. The Durham University strategy 2010-2020 embeds impact as a key component of academic activity across the institution. The headline research strategy seeks to ensure that the university is "*recognised internationally for creative thought and transformative research of the highest calibre across a broad subject base of sciences, social sciences and the humanities*". This is developed in a specific objective "*To deliver research in every discipline that addresses questions and issues with the potential to make significant impact on knowledge, people or the economy, or to enhance or change society for the better*". The University initially implemented the strategy through the creation in 2010 of a new professional support department, Durham Business Innovation Services, which seeks to establish collaborative links with external organisations, as well as being responsible for consultancy, research commercialisation and analytical services. The unit, which has 17 staff members, won the Times Higher award for Outstanding Contribution to Innovation and Technology in 2012, whilst the Dean of Technology Transfer was awarded The Queen's Award for Enterprise Promotion, also in 2012.

Over the period 2011-2012 the University developed a specific Impact Strategy, with associated actions, which was approved by Senate and Council in 2012. To implement this strategy, the University created a new role of Dean of Knowledge Exchange and Impact. The strategy seeks to maximise Impact by embedding it through the academic culture of the University. Thus, Impact now forms a part of the recruitment, probation, appraisal and promotion processes, and it is being embedded within the academic staff training programme. In addition to DBIS, the University provides dedicated support for Impact activities through an Impact Coordinator, located in the Research Office, who assists in the development and recording of Impact-generating activities, and it has recruited three Impact Officers, one to support the University research institutes, one in Arts and Culture and one in Policy.

Other Professional Support Departments have also realigned their priorities to maximise Impact.

Thus, for example, in 2011 the University created a new team within Marketing and Communications to support the development of Impact case studies. The support department Impact teams work through the Impact Support Group, which meets monthly to coordinate support for Impact generating activities. The University has made an annual sum of £250,000 available for an Impact Seedcorn fund, allowing individuals, project teams or departments to bid for sums of up to £20,000 to support new Impact-generating activities.

The implementation of the Impact Strategy by the Dean of Knowledge Exchange and Impact is supported by an Impact Advisory Committee, consisting of external representatives from local and national government, industry, commerce, NGOs and cultural organisations.

c. Strategy and plans

As we have mentioned, iARC will provide the primary focus to our impact-related activities in future. One of the impact-oriented aims of iARC is:

- "*to undertake long-term relationship building with external partners in academia, government and industry to enhance impact outcomes*".

Our strategic aims relating to impact include:

- "*to use our expertise in systems and computer methodologies to enable impact via collaborations with key industry players such as IBM*'
- "*for iARC will be at the fulcrum of all computationally-relevant impact activities across Durham University and for Computer Science to lie at the heart of all iARC activities*"
- "*for ACiD to influence the impact of Durham Computer Science research through collaborative activities with IC and other departments*"
- "*to increase the engagement of Computer Science researchers with committees and organisations having impact upon public policy*".

Recent appointments (since 2012) have facilitated the fulfilment of our impact-oriented strategy and have all been in strategic areas related to computational methodologies (their development and application), especially where there is a synergy with computational methods, high-performance computing and engineering. For example, Theodoropoulos brings with him inter-disciplinary and industrial expertise and links with IBM; McGough with Northumbrian Water and the Department of Health; and Breckon with Selex Galileo, Marshall, QinetiQ, TRW Conekt, Jaguar Landrover, GE Imaging, HOSDB/CAST, DfT and DSTL. As regards impact upon public policy, Stewart has always been involved in the activities of learned societies, such as the BCS and the LMS, and other organisations that have the capacity to influence policy, and he is currently a member of the BCS Academy Research Committee and the Executive Committee of UKCRC.

d. Relationship to case studies

The case study "Stereoscopic imaging" is a prime example of how our on-going and concerted efforts to engage with stakeholders and bring Durham research to the attention of the general public so as to increase their understanding of science has resulted in a significant public outreach impact. Moreover, the commercial impact of this case study demonstrates how our process of developing and nurturing relationships with industry has resulted in impact for our research and also future opportunities of both engaging in industrially-relevant research and bringing this research to impact.

The case study "From Formal Methods to Software Migration" is a real success story in the conversion of as blue-skies, theoretical (almost mathematical) research and became massively applicable so as to create considerable economic impact. This case study did not arise from the pursuance of our nurturing processes described above; nevertheless, its development has enabled us to better understand and appreciate the route to impact through an SME, to reaffirm our relationship with Software Migrations Ltd. and to potentially realise the impact of our more theoretical research.