| **Institution:** University of York |
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| **Unit of Assessment:** 11,  Computer Science and Informatics |

### a. Context

Procurers, regulators, developers and users of software and systems, particularly critical systems, have been major long-term end-users and commissioners of our software and systems research, such as the Ministry of Defence and high-tech engineering companies such as Rolls Royce. This is mainly based on the research of our High Integrity Systems Engineering, Real-time Systems and Enterprise Systems groups. Commercialised diagnostics and prognostics research of the Advanced Architectures group is used by the transport and medical sectors. Digital inclusivity and cultural heritage applications have emerged over the REF period as areas of impact from our Human Computer Interaction group. Our research has informed standards, influenced products of major engineering organisations and their supply chain (e.g. tool providers), improved maintenance of transportation fleets, enhanced web experience for the visually impaired, and facilitated access to culture and heritage. Our extensive knowledge exchange activities and training of over 100 PhD students have also contributed to the UK and international advanced skills base.

### b. Approach to impact

The major strands of our approach to impact are:

**1)      Developing an impact culture.**  We demonstrate to staff and external collaborators that impact is valued and that it is a priority. Impact has been a major strand in successful promotions (most recently to personal chair and senior research fellow) and is an annual staff appraisal criterion. The Departmental Research Committee (DRC) discusses it as a standing agenda item, ensuring continuing senior management consideration. Our recently developed proposal writing programmes also cover knowledge exchange and impact. Overall, we seek to inform, encourage and support our staff to achieve impact.

**2)      Researching problems of real-world high-tech engineering.** Regular contact with our high-tech engineering collaborators enables us to identify research challenges of clear end-user importance and high impact potential. Often, these challenges are international: the safety issues of leading carmakers in Japan, the United States and Europe, for example, are much the same. Research breakthroughs, consequently, have significant <u>global</u> impact potential. Real-world problems motivate us, and we engage in applied <u>and</u> theoretical research to solve them. For instance, three of our four case studies are exploitations of *fundamental theoretical research*.

**3)      Researching generic technologies and techniques.** We also research improvements on *existing* technologies *known* to have wide (and potentially wider) application, e.g. fundamental fast pattern matching research by our Advanced Architectures group. Similarly, web accessibility, a major focus of our Human Computer Interaction group, is an impactful topic with clear and diverse global relevance.

**4)      Maintaining profile by end-user community engagement.** We contribute to community events of end-users, maintaining a profile that ensures potential collaborators are aware of our capabilities. We attend and contribute to relevant domain fora (e.g. the Safety Critical Systems Club), giving tutorials and master-classes (such as at games-related and web conferences), and organise colloquia via professional bodies (e.g. IET). We seek to be part of the fabric of the communities who need our research. Speaking at industry and sector events (e.g. Kiosk London, for the self-service industry) provides opportunities to reach wider audiences, leading to further invitations. We also fund potential consortia-building visits involving end-users (e.g. we funded visits for two of our five successful EU bids in early 2013).

**5)      Developing relationships with direct and sustained interaction**. Over the REF period we have sought to establish or participate in research consortia or structures with significant external stakeholder engagement. Two mechanisms are outlined below.

Firstly, we use our EPSRC Engineering Doctoral Training Centre in Large Scale Complex IT Systems, which features external sponsors who contribute to costs for students. Thirty-six York students have started their programmes. They are often based at sponsoring organisations, spending much of their four years there, and must demonstrate a portfolio of impactful research. Industrial co-supervision ensures end-user relevance, builds mutual trust and understanding, and facilitates further research collaboration. Collaborators include major software/systems developers (e.g. IBM, Airbus, BAE Systems, ETAS, and Jaguar), SMEs (e.g. YorkMetrics and Stainless Games), and National or sector bodies (e.g. The National Archives, Ordnance Survey, and the

Royal National Institute for Blind People). Our first cohort (who will graduate in 2014) is already delivering initial impact, e.g. one student submitting two collaborative patents in cloud security.

Secondly, we seek projects where collaboration and contact is "built in" and target funding structures with end-user involvement in commissioning work, e.g. successful bids to DSTL's Centre for Defence Enterprise (CDE) scheme. EU collaborations (16 live projects as of July 2013) provide regular industrial contacts and we also collaborate with end-users/academia/industry to craft and execute research programmes, e.g. the US Army/MoD sponsored International Technology Alliance (managed by IBM) and the MoD's Software and Systems Research Institute (managed by BAE Systems). Research funding to York from these two projects was over £3.6m.

**6)     Developing relationships with diverse and multiple benefits.** We seek to develop relationships with multiple and diverse benefits. Partners may concurrently be, for example, researchers (e.g. part-time PhD students), consortium bid partners, industrial co-supervisors, research sponsors, Industrial Advisory Board members, guest lecturers, sponsors of student placements, project proposers and prize sponsors. BAE Systems, for example, have engaged in all the above. Our collaborators are natural career destinations for taught and research graduates and are major CPD commissioners and consumers. Staff dedicated to external engagement (e.g. our full-time UG student placements officer) help maintain the broader departmental relationship.

**7)     Flexible and agile response**. Research is carried out by research students, research associates and academics according to technical needs and timescales. We provide direct research capability and/or consultancy (the latter being particularly useful for short-term opportunities). Significant academic staff deployment is possible, usually for critical engagement with end-users and where very deep expertise is essential. We are normally able to respond to media requests for expert commentary (which are often news-driven and consequently urgent).

**8)     Developing infrastructure for impact**. We provide infrastructure that eases the path to take-up for potential users. For example, Kelly - the lead developer of Goal Structuring Notation (GSN) - organises the Assurance Case Forum (previously "GSN User Club"). This gives opportunities for practitioners and other interested parties to network and to exchange experiences of using GSN. It also provides York with direct user feedback, driving further research. In the REF period there have been 10 meetings with representatives from 52 organisations. Open Source is also a major avenue for impact. Our Enterprise Systems Group have grown their "Epsilon" model management tools suite (an Eclipse Foundation project) from 100KLoCs to over 600KLoCs over the REF period. They engage actively in the user forum (4,000+ entries) and provide tutorials at Model Driven Engineering conferences. (The suite now gets over 9,000 downloads per year.) Even when York technology is free to the consumer we invest effort to ensure take-up. Open Source is also a *promotional device*: Epsilon gives rise to many proposals for collaboration. A list of open source projects using Epsilon is available at: http://eclipse.org/epsilon/users/

**9)     Follow-through to Impact.** Much of our research informs standards and guidance, and we support staff to engage with relevant organisations. Support is typically in the form of staff time and travel and subsistence, but work may also be funded from external sources. Example contributions are: Ada 2012 LRM (Burns), Real Time Java Specification (Wellings), and Object Management Group's Argumentation (2010) and Structured Assurance Case Metamodels (2013) standards (Kelly); lead author on UK Interim Defence Standard 00-56 issue 5 and a member of the Defence Scientific Advisory Committee (McDermid); and expert witnesses at the Haddon-Cave enquiry (McDermid/Kelly). Petrie and Power have evaluated Accessibility Content Guidelines 2.0 (establishing a need for further work to ensure inclusivity) and provided evaluation and advice to UK museums (e.g. Ashmolean and Pitt Rivers) and US museums (with visits funded by NSF).

Since the 1980s we have supported part-time contracts, buyouts and use of sabbaticals to give time for impact and external engagement activities. Austin, Bernat and Davis had such arrangements in the REF period to support commercialisation activities. Our fast pattern matching research led to a series of commercial diagnostics and prognostics products by spin-off company Cybula (with the Advanced Architectures Group winning the THES Engineering Research Team of the Year in 2011). Cybula currently employs 12 staff in York. High-level academic consultancy has also had significant external effect, e.g. advice on hard shoulder usage led to a significant reduction in deaths on a major motorway.

Our safety critical systems oriented Continuing Professional Development operation employs around 7 FTE and has delivered over 1500 student weeks of off-site module activity in the REF period (supplemented by one-off module attendances on our MScs). Modules have been

delivered in Australia, in the USA, in Europe, and in the UK. Our biannual Roundhouse Public Lectures typically attract full (225 seats) audiences, with topics such as breaking Enigma and autonomous robots. We contributed to local radio on topics such as computing at the time of the first moon landing and the National Security Strategy, sharing our expertise and raising the local profile of computer science. We are enthusiastic participants in the Computing at Schools initiative.

**Exploiting Central Resources.** Our Research and Innovation Office (RIO) and Business Development Manager (BDM, funded centrally) help us build relationships with collaborators whose interests span several Departments (e.g. IBM), but also help build consortia where we are the major York Partner (e.g. building a base of 50+ organisations to support a successful 2013 games-related proposal). The RIO also fund a further post within CS specifically tasked with widening our impact, particularly with local organisations. Funding and assistance for commercialisation is also available via the RIO. The University's Communications Office is a frequent media point of call requesting expert commentary (both by new and existing media contacts).

## c. Strategy and plans

Our plans will continue to be helpfully influenced by our Industrial Advisory Board whom we meet every six months and by on-going interactions with end-users and our RIO. We will continue as above but aim to broaden both the impact research base and potential avenues for impact by:

1. **Establishing relationships via small-scale research projects**. We have recently created a post to build up relationships with local organisations. A significant aim is to seek external (problem-based) sponsorship of our advanced masters MSc research projects. This will allow us to build relationships with local organisations (SMEs in particular) at low risk/cost to them and bring external collaborators into the research process via joint supervision and publication.

2. **Exploiting Basic Science.** A great deal of our current impact follows from the work of our software and systems engineering research groups. We now seek impact from our groups who research core scientific aspects of our discipline, e.g. Artificial Intelligence (with very significant exploitation possibilities in 'fun' and 'serious' games and gaming), and Non-standard Computation (with leading edge work, for example, on quantum information processing (QIP), and quantum cryptography in particular). Timescales for exploitation will vary, but the aim is to establish suitable paths for eventual exploitation. We will seek direct exploitation by collaborating with the games industry and longer-term development of QIP, e.g. via EU collaborative projects.

3. **Exploiting Deep Embedding.** We aim to establish and develop deep relationships via funded industrial-academic fellowships from leading engineering and scientific societies, e.g. Royal Academy of Engineering and the Royal Society, with secondments in both directions.

4. **Sustain Existing Relationships.** We will monitor impact achieved by our LSCITS EngD Centre and build on established relationships, seeking further funded research collaborations from appropriate sources (e.g. the Technology Strategy Board for projects with SMEs). We will build on other existing close relationships. IBM now has 16+ staff within the Computer Science Building specialising in data analytics. This topic has widespread interest across the University. We will seek collaborative projects to take technologies forward and research new applications.

5. **Expand Part-time Taught MSc Course Attendances and CPD**. Attendance by industrial part-timers on our CPD modules is often the beginning of long-standing and fruitful relationships. We have contracts for CPD module delivery extending over the next five years (with an estimated value of over £1.5m) and expect CPD to grow in the period. Our safety-oriented CPD training will be augmented by intensive one-week modules from our other advanced MScs (e.g. the MSc in Cybersecurity).

## d. Relationship to case studies

RTA-OSEK/RTA-OS, CANBus, RapiTime, and Goal Structuring Notation (GSN) are all examples of exploiting research driven by real-world problems. The first three are also examples of exploiting fundamental theoretical research. Bernat (Rapitime) was released to become founding director of Rapita, relinquishing his lectureship to pursue a full-time commercial career in 2009. Davis has had flexible contractual arrangements since his return to the Department in 2004. Three case studies are underpinned by different aspects of real-time systems research: scheduling theory, network analysis, and worst-case execution time analysis. They were developed and exploited by three different companies who maintain rights and IPR over the products marketed: ETAS (RTA-OSEK/RTA-OS); Mentor Graphics (CANBus), and Rapita (RapiTime).