Institution: University College London

Unit of Assessment: 11 – Computer Science and Informatics

a. Context

UCL's CS (Computer Science) has for many years, had effective and efficient procedures and mechanisms in place to maximise impact. Staff in this unit have made seminal contributions across the full range of its core strengths and associated 11 research groups and 8 centres listed in REF5. As a result, the unit's research has produced deep, lasting and sustained impact, particularly in Internet technologies, security, finance, media, healthcare and the economy generally. As this document demonstrates, the lives of everyone in the developed world are positively affected in multiple ways by this impact. Many in the developing world are also increasingly impacted by the unit's research, particularly in healthcare and in extending Internet penetration.

a1 Direct impact on the UK economy: The unit has made critical and foundational contributions to the recovery and success of the UK economy. The unit's work has significantly benefited its many public and private sector partners. It also impacts UK GDP directly through its spinouts and consultancy services, underpinned by the unit's research specialisms and expertise.

a2 Transforming Internet communication and security: UK and international governments, as well as the UK general public, have greatly benefited from work relating to Internet technology and standards. The unit has led research into Internet congestion, Internet telephony, the Future Internet and the Internet of Things. The unit's cryptographic ciphers and federated identity work have both had major impacts on national and international standards of Internet security, enabling security professionals and government policy-makers to improve online safety.

a3 Safer, more effective and reliable healthcare: In healthcare, the unit has developed interactive medical devices and enhanced diagnostic tools through new analytical methods and algorithms. This work has provided, and will continue to provide, tangible benefits to medical device developers, healthcare decision makers and medical practitioners. The unit's work on Electronic Health Records forms the basis of National and International Standards with far-reaching impact on worldwide healthcare.

a4 Underpinning financial sector trading systems: Partners and beneficiaries in the finance sector include companies ranging from SMEs to multinational corporations, the UK government and general populace. The unit's work established the reliable mechanism for Over-The-Counter derivatives trading and has impacted high frequency trading and systemic risk, significantly improving commercial banking systems; a sector critical to the UK and international economy.

a5 Setting the agenda for new media developments: The unit has worked at the forefront of media research and practice in close partnership with the BBC and others. It has brought together the best minds from both academia and industry to accelerate and expand research and practice in exciting new digital media services such as content creation and user experience.

b. Approach to impact

The department has put in place a range of structures and initiatives that maximise the impact of its research. Some of its impact mechanisms were well established before 2008, while others have more recently augmented core practices to ensure continual improvement; all of the unit's impact processes and structures have evolved during the period of assessment. Indeed, the unit is committed to continual opportunity-led enhancement of impact mechanisms and it has the processes in place to guarantee agile response:

b1 External Advisory Board (EAB): Established in 2003 to formalise pre-existing advisory mechanisms that facilitate dialogue with potential research beneficiaries. The Board's members include highly experienced industry partners, leading technologists and entrepreneurs (see REF5 Section b5.2 for more details). It meets bi-annually with senior academics, advising on the development of current and future plans to maximise research relevance and impact.

b2 Director for Industrial Liaison: After initially assigning this post to an academic, in 2012 the department responded to the continual growth in activity and opportunities by establishing a full-time commercially experienced Director, Jane Butler. She has 25 years of senior commercial experience in industry, most recently as Technology Leader and the advisor to Cisco's CTO. In this role Jane spearheaded multiple new technology ventures. This appointment has been consolidated by the addition of two further members of staff to ensure research relevance, responsiveness and knowledge transfer activities continue to scale up effectively. The team manages the department's relationships with over 50 key partner companies each year. It co-ordinates KTPs, internships,

prizes, industry-led research, industrial funding and industry-placed projects. Companies such as Cisco, Microsoft, Google, Facebook, Intel, Amazon, IBM, BBC, Morgan Stanley, Goldman Sachs and many more undertake research projects with departmental academics, give guest lectures and present academic prizes.

b3 Departmental Strategic Research Fund: The entrepreneurial activities of the unit's staff are an important part of its approach to fostering sustainable and productive relationships that deliver economic benefits to the UK economy. To this end a formal Departmental Strategic Research Fund was established in 2011 for pump priming support. The Fund provides departmental starter grants that support nascent entrepreneurial activities. It supports early pilots of new ideas and proof of concept demonstrations. These stimulate the development of projects to the point where they will attract commercial interest from industry partners. It has proved exceptionally successful, for instance in: Anthony Steed's spinout Animal Systems (described later); Philip Treleaven's Sports Analytics platform (which analyses the performance of world-class athletes and professional players in golf and football); and Kyle Jamieson's ground breaking work on location sensing of mobile devices (which will help transform the retail and entertainment industries).

b4 Entrepreneur in Residence: In 2003 the unit recruited Dan Brown as its Entrepreneur in Residence. Dan's responsibilities include the identification of promising technologies and opportunities for the unit to develop new businesses with appropriate early stage management and financial infrastructure. Achievements within the REF period include the development of several companies, such as MegaNexus, which employs 45 staff with a turnover of £3.5M. He developed significant relationships with the Department of Health, leading to investment of over £500K in the unit's research, and with Microsoft already generating research income of £400K.

b5 Impact delivery through specific initiatives

b5.1 Joint appointments: These include Wolfgang Emmerich (with Zuehlke Engineering GmbH, 2009), Byron Cook (with Microsoft, 2012) and Thore Graepel (with Microsoft, 2013).

b5.2 Staff secondments to industry: At least 5 staff members have undertaken external placements and training since 2008, for example, Juha Heiskala undertook a placement in a Helsinki hospital from July to September 2011 taking his research into a real world environment.

b5.3 Transfer of specialist knowledge: Technology transfer occurs through KTPs supported by UCL's KTP office and other knowledge transfer schemes. Since 2008 UCL CS has contributed to 6 formal KTPs, producing benefits to external partners in a range of industries, including Anna Cox's work between 2008 and 2010 with Paperstone Limited, for which she developed methods that increased Paperstone's weekly website-generated revenue by 50% (£8K per week).

Mark Harman's test optimisation work is used by Visa Europe and deployed in Microsoft's Pex tool. John Shawe-Taylor and David Silver transferred to Causata inc., reinforcement learning IP valued at $7.3M when Causata sold for $23M in 2013, this work constituted one third of its intellectual assets.

Peter Kirstein, who set up the first non-US ARPANET node (pre-cursor to the Internet) at UCL in 1973, continues to consult through the NATO supported Silk project. This recent work helped to establish the Internet in Central Asia, Caucasia and Afghanistan.

During the REF period, Anthony Steed was a London Technology Network (LTN) Business Fellow, while Chris Clack founded the Financial Services KTN, both helping research staff understand routes to market for the unit's research output.

b5.4 Consultancy work: Consultancy is supported financially and legally by UCL Consultants, part of UCL Enterprise. Academics in the unit are encouraged to undertake up to 40 days per year of remunerated consultancy work. Since 2008 they have delivered 35 significant consultancy projects with a value of more than £800K to clients ranging from local start-ups to high-tech multinationals including Proctor and Gamble, LogicaCMG, Merck, NTT and BAe Systems; legal companies including Allen and Overy LLP, Tilly Bailey Irvine LLP and Powell Gilbert LLP; other HEIs including Queen Mary, University of London and Dartmouth College; and governmental bodies including the Cabinet Office, the London Probation Service and NATO.

b5.5 Impact of research on policy-makers: The unit transfers knowledge to governmental departments, agencies and policy-making bodies through expert advice and joint projects. Recent examples include Angela Sasse's provision of advice between 2009 and 2012 to the DWP/Directgov on usable/acceptable online registration and login procedures. She also advised the Cabinet Office on its planned Federated Identity Scheme, and co-authored the 2009 Database State report on data privacy, commissioned by the Joseph Rowntree Trust.

b5.6 Expert witness expertise and advice: This has involved gathering and presentation of evidence on patent litigation by Mark Handley for Cox v Verizon (2008), Brad Karp for Research in Motion (RIM) between 2006 and 2010 and Anthony Steed for HTC in 2011. The unit's expertise enables governmental patent systems to support fair and open competition globally. It ensures companies make popular products successful and it stimulates entrepreneurship. Such initiatives provide global benefit and greatly contribute to the UK's outstanding reputation for IP law.
b5.7 Commercialisation of research: Some of the companies formed and successfully grown out of the unit's research are (1) Animal Systems, led by Anthony Steed, which launched Chirp in 2012. Chirp is an award-winning new mobile phone service that facilitates audio-based data sharing. It was funded by the technology transfer arm of the university, UCL Business, as well as by Imperial Innovations. (2) Satalia, led by Daniel Hulme and Anthony Finkelstein, which provides Optimisation-as-a-Service. It has successfully applied its technology to a wide variety of business problems including those posed by NTT in semantic web (1000x speedup of RDF querying) and network design optimisation for fibre deployment (100x speedup plus a 10% reduction of costs).
b5.8 Industrially funded centres: The unit founds large industrially funded centres to ensure that its research reflects the changing needs of industry and society. These have responded to the Tech City agenda and the Cabinet Office's desire to stimulate the growth of Computer Science related innovation. The Intel Collaborative Research Institute on Sustainable Connected Cities was established in 2012 under the directorship of Yvonne Rogers. It builds on the research excellence of UCL's Interaction Centre (UCLIC). The Cisco Future Cities Centre includes Internet of Things (IOT) research led by Steve Hailes, and Future Smart Buildings research led by David Shipworth of the UCL Energy Institute. The unit has also established a major Future of Media research collaboration with the BBC, founded by Anthony Steed and led by Sebastian Riedel. The initiative combines world-beating expertise from UCL and the BBC to set the international agenda for Content Capture and Production, Distribution Technologies and User Experience. The unit also co-founded Fintech**,** a technology accelerator in the city of London, funded by the Canary Wharf Group, dramatically enhancing Computer Science relevance to the future of UK financial services.
b5.9 Shared collaborative workspaces: To stimulate research with industry the unit supports multiple shared collaborative workspaces. Ecosystems in place include: the 80-desk office space at No. 1 Euston Square, split equally between UCL and the BBC; shared space at Fintech in Canary Wharf; desks for Intel co-workers within UCLIC; workspaces shared with Cisco and DC Thomson at IDEALondon in Tech City.
b5.10 Public engagement activities: Key research insights are communicated to a broad cross-section of the population in order to promote public understanding of the beneficial impacts of Computer Science in society. Two members of staff, Peter Bentley and Sue Black, are dedicated to this activity. Through this outreach the department's research has reached international audiences measured in the hundreds of millions; examples are given in REF5 Section CII.6 on Public Engagement. An imaginative addition to the unit's public engagement is the appointment of Gordana Novakovic as departmental artist in residence. Gordana has more than 20 years' experience in developing and exhibiting large-scale time-based media projects. She promotes the public's understanding and perception of Computer Science, through engaging, innovative and technologically inspired and informed art installations and activities.

c. Strategy and plans

The impact strategy supporting research activities within the department is now well developed and forms a strong foundation for the future. Community building is fundamental to this strategy. We believe that impact is best created and delivered through mutually beneficial partnerships and trusted relationships with government, with industry and within the unit. This philosophy is laced through all six strands of the strategy. The Impact Team will continue to expand and enhance mechanisms, processes and policies for impact as follows:
c1 Raising internal awareness of the importance of achieving research impact. Mechanisms will include regular face-to-face meetings with unit researchers and measures to ensure impact contributions in all project funding applications.
c2 Raising external awareness of the departmental impact initiatives and opportunities via social media, including active Facebook, Twitter and LinkedIn accounts. A dedicated departmental impact portal will be launched in 2014. Additionally the team will bolster its outreach work with organisations such as The Big Innovation Centre and the UK Innovation Forum, and the unit will focus on engaging with the TSB Connected Digital Economies Catapult and the TSB Future Cities

Catapult. We plan many exciting and tangible high-impact collaborations based on the established research centres already in place with Intel and Cisco.
c3 Continuing to leverage institution-wide initiatives by maintaining and growing our already successful collaborations with UCL Enterprise; this comprises Advances (UCL's centre for entrepreneurship), Business and Consultants. Together we will continue pioneering impact through spin-outs, consultancy, patents and licensing, KTPs and large industry collaborations. We will extend joint outreach activities with the Alumni, Careers, and Public Engagement Offices to optimise research collaborations for impact.
c4 Streamlining relationship management by launching a customer relationship management (CRM) system to manage the plethora of relationships with the public and private sectors. The CRM will be used to disseminate impact, manage legal agreements, ensure relationships are correctly owned and maintained, as well as generating analytics to aid decision-making. This will ensure that the unit is always seen as a reliable and professional contributor by our current and future industry partners.
c5 Cultivating collaborative physical environments; the department will continue to invest in developing shared workspaces, break out areas and hot-desks for staff and industrial partners thereby enabling very active ongoing collaborative discussions, increasing the successful outcomes and impacts of research.
c6 Increasing student-industry engagements will be an invaluable component to our impact strategy for introducing companies to our research offer; these include hackdays, joint projects and internships across almost every industry sector. The unit celebrates extensive collaborations with Microsoft, Google, Cisco, IBM, Intel and Facebook as well as with almost every major UK financial and governmental institution. The engagement of these partners in impact events will continue to grow to at least 20 events per year. As part of the faculty-wide Integrated Engineering Programme, our researchers will continue to benefit from the many industry guest lecturers, course contributors and designers such as Hugh Varilly, Visiting Professor of Innovation, and IBM Distinguished Engineer.

d. Relationship to case studies
The primary mode of realising impact in Computer Science at UCL has been through direct engagement with industry. This approach is exemplified by UCL-HAN '*SIP/SDP as an Enabler of Real-Time Internet Communication'* which has had a seminal effect on the global telephony industry; and UCL-KAU '*Enhanced photo and special effects processing for professional and amateur photographers'* which has had lasting effects on the photography and media industries by transforming the quality of photographic images**.** Our policy of embedding knowledge transfer in the unit is exemplified in UCL-SAS *'Human-centred security in government and commercial applications'* from which knowledge has flowed into private industry and government agencies with lasting and widespread improvements in online safety and security. Our strategy of encouraging and facilitating interdisciplinary research has led to three significant case studies in the area of medical research. Computer Science plays an increasingly crucial role in the development of new analytical and algorithmic tools for use in medicine as exemplified by UCL-BAR *'Improving Prostate Cancer Diagnosis and Care using Computer Simulation'* and UCL-ALE *'Camino diffusion MRI toolkit'*. In these two Case Studies, it is very clear that Computer Science is transforming the efficiency and efficacy of diagnostic tools by leveraging collaborations between medical practitioners and computer scientists. Work on electronic health record (EHR) systems demonstrates the clear link between computer science and medical practice as exemplified UCL-KAL *'A Clinical Management Service for Stroke Prevention'.*
The unit's successful stimulation of entrepreneurial work and commercialisation of research is witnessed significantly in UCL-TRE *'3D body scanning in clothing manufacturing and retail, and healthcare'* which describes the creation of three successful companies - Sizemic, Bodymetrics and ShapeDynamics. Impact on the clothing industry was successfully extended to tackle obesity and associated diseases such as diabetes. Entrepreneurship and commercialisation of research also underpins UCL-EMM *'xlinkit for fast, cheap, reliable banking with automated verification of Over The Counter Derivatives trading'* which had a profound and lasting impact on the financial industry, increasing efficiency and reducing derivative trading operational risks. This Case Study drew on support from UCL Enterprise and Business for both finance and software licensing support.