Institution: University College London

Unit of Assessment: 13 - Electrical and Electronic Engineering, Metallurgy and Materials

a. Context

UCL's submission to Unit of Assessment 13 comprises staff from its Department of Electronic and Electrical Engineering (EEE), some of whom hold joint appointments with the London Centre of Nanotechnology (LCN). The end-users of our research activities include some of the world's leading technology companies, SMEs, non-profit organisations, governments and other policy-making bodies. We engage with our partners particularly through collaborative research, but also through joint training and education programmes. These collaborative relationships with research and industry partners facilitate major impacts on a diverse range of applications. Some key applications and industrial collaborators include: wireless and optical communications (ARM, HP, Huawei, IBM, NEC, Nokia, Xyratex), networks (BT, Deutsche Telekom, France Telecom, Aeroflex, Ericsson, Ciena, Cisco), antennas (EADS, ESA, Thales), medical and biomedical diagnostics (CERN, The NHS), nanoscale devices (Philips, Toshiba, BAE Systems), microwave photonics (Agilent, Zinwave), sensors (Lockheed-Martin, Selex, Senceive), renewables and energy efficiency (NSG/Pilkington, Sharp, Total) and others. We also work closely with more than ten SMEs, to whose competitiveness we contribute through our provision of world-class research facilities to enhance their research and development practices and capabilities, and by helping improve their design and fabrication processes. In addition, the provision by many of our academics of expert advice through consultancy and their membership of various advisory boards and committees has helped shape industrial strategy, professional standards, and public policy in areas including telecommunications, the internet and future networks.

b. Approach to impact

We have long recognised and promoted the mutual benefits of engagement with the end-users of our research, particularly in terms of transferring complementary skills, expertise and facilities; generating new research income; facilitating research commercialization and product development; and improving commercial competitiveness. The Unit has particularly promoted the following approaches to helping ensure that such positive outcomes result from our research activities.

Bringing Industry into the Unit: Since 2008, a number of projects have been designed and created at both institutional and Unit-level to foster existing and new industry collaborations. These include formal initiatives such as KTPs, as well as more localised projects providing our partners with an opportunity to use the equipment in the Unit at competitive rates and to receive advice and assistance from our staff in drafting joint research proposals. One key approach to instituting and maintaining industry links has been our development of co-funded PhD and Engineering Doctoral programmes such as UCL Impact Awards, wherein 50% of the costs of a PhD studentship is covered by an industrial partner and the rest by the Unit. Since 2008, Impact Awards have been awarded to 15 PhD students supervised by 11 Unit academics. The Unit has worked hard to attain a substantial increase in the number of research studentships fully sponsored by industry: since 2008, 35 industrially funded PhDs have been supervised by 19 of the Unit's academics and EngD students have been sponsored by 23 companies, an increase of 59% since the RAE2008 period. In 2009, UCL and the University of Cambridge set up the EPSRC-funded Centre for Doctoral Training (CDT) in Photonic Systems Development, now a leading UK centre for Photonics research. The Centre is explicitly tasked with connecting science and engineering research with business and developing real-world solutions by building strategic partnerships between our research communities and a range of leading optics and photonics companies. It currently works with more than 30 companies and organisations, including BT, Ericsson, Hamamatsu, Oclaro, Sharp, Thales, Toshiba and Zinwave. The CDT in Photonic Systems Development has run its own annual Industry Day since 2011, providing students with an opportunity to present their research accomplishments and to network with industry representatives; the 2012 event attracted more than one hundred delegates. In addition, the Unit offers taught components to all its PhD students designed to encourage entrepreneurial thinking and commercial awareness. We have also worked with our partners to forge and strengthen our mutually beneficial links with them via industrial internships. A key achievement in this area was the introduction in December 2011 of an International Internship Programme, set up in collaboration with global technology giant Cisco and

allowing up to 12 students in their penultimate year of study to undertake a year's paid internship at Cisco's Headquarters in San Francisco.

KTPs have constituted a further key facet of our approach. The Unit has been involved in two such schemes since 2008, one with Dr Kenneth Tong in power electronics and another with Professor Paul Brennan in microwave electronics. In 2011 we appointed Mr Tim Bodley-Scott to a new, full-time, non-academic post of Business Development and Marketing officer, in which role he draws upon his business experience to facilitate knowledge exchange between the Unit and end-users. Finally, within the REF period, we made Knowledge Transfer one of the four criteria for academic recruitment, appraisal and promotion (alongside teaching, research and administration), ensuring that contributions in this area are reviewed and rewarded. The success of this targeted strategy is evident in the fact that we have signed 84 new contracts with industrial partners since 2008, generating £5,010,348 of new income for the Unit (a 28% increase in industrial funding compared with RAE2008).

Knowledge Transfer via Consultancy: The Unit is also heavily engaged in consultancy activities, in which it is supported by UCL's policy of allowing academic staff to undertake up to 40 days of remunerated consultancy per annum. Since 2008 we have signed 28 new contracts with a total value to the Unit of £609,123. One notable example of such activity is the provision since 2009 of consultancy services by our Optical Networks Group (ONG) to the leading Chinese telecommunications equipment vendor, Huawei Technologies. Following the initial consultancy work, Huawei has funded 4 further projects within the Unit and agreed to act as one of the leading industrial partners in the recently-awarded £4.7 million EPSRC-funded Programme Grant UNLOC – Unlocking the capacity of optical communications – which will run between 2012 and 2017.

Commercialising our Research: The Unit has strongly encouraged its academics to engage in commercialization activities, the financial return from which will support research leading to further discoveries and innovations in the future. Since 2008 it has submitted 38 formal invention disclosures to our technology transfer office UCL Business (UCLB), with 14 patents being granted in the period. To facilitate spin-out activities, we make space and facilities available on fair-market terms to our early stage companies. Successful spin-out companies nurtured within the Unit and generating commercial impact since 2008 include Senceive Ltd, founded in 2005 and Zinwave founded in 2003 by the Unit in collaboration with the University of Cambridge. Zinwave has raised £16 million investment funding since 2008 and employs some 25 staff, whilst Senceive has had ~£0.5 million of equity investment during this REF period. Our strong support for commercialisation activities included offering space and access to equipment at competitive prices to Senceive, facilitating the development of its initial technology. Case studies UCL13-SCH and UCL13-SEE provide further detail. We also run regular in-house events promoting and providing information and advice about the commercialization of research, which are well attended by members of the Unit and industry colleagues. Recent examples include the October 2012 Advanced Technology Showcase, organised at UCL by the Unit's Business Development and Marketing officer in collaboration with the ESP KTN, UCLB, and Cambridge Enterprise, which was attended by more than 60 industry representatives. The event provided a forum for the development of productive collaborative relationships between business representatives and academics seeking joint venture opportunities or access to expertise and technology licensing opportunities. A straightforward IP ownership scheme has been enacted since 2008 to encourage industrial investment, under which the rights of an industrial partner to the generated IP are proportional to their committed funds. An industrial partner can own the IP when they fully fund a project; alternatively, we offer them a first right to the exploitation of products developed in projects only partially funded by them, with the Unit retaining IP ownership. We have also simplified the procedure by which our faculty members file for a patent. Initially, only a brief summary of the proposed idea and its commercial potential is required for evaluation. If the proposal passes the evaluation phase, a full disclosure is submitted to UCLB, which then completes the legal procedures on behalf of the inventors. In addition, a number of Best Practice sessions are regularly organized in the Unit in areas like drafting patents, and negotiating with businesses and others, and we will continue to offer this support. Since 2008, the Unit has been running an internal mentoring scheme through which senior members of staff provide guidance, advice and support to less experienced academics engaged in commercialisation activities.

Provision of expert advice to policy-makers/ advisory board, committees: The Unit's transfer of expert knowledge and advice to governmental and other policy-making bodies, particularly those whose remit it is to enhance the UK's economic competitiveness, is an integral part both of its approach to impact specifically and of its research mission more broadly. Since 2008, many of our academics have served on committees and advisory boards that input to policy-making processes. Professorial Research Fellow Alex Galis, for example, became a Vice-Chair of the ITU-T Focus Group on Future Networks in 2009, a position awarded partly on the basis of his previous contributions to four future standards and internet and energy efficiency networks. Between 2009 and 2011 Galis was also part of a group coordinated by the Digital Communications Knowledge Transfer Network and endorsed by the UK Department of Business, Innovation and Skills, which advised the UK Government about UK Future Internet Strategy. Professor Polina Bayvel's Foresight state-of-science review "Switching to light: all optical data handling", published in 2004, has influenced the development of the government's Digital Britain Programme and the TSB programmes on optical access systems in 2009. Dr David Selviah has served on the board of the International Electrotechnical Commission and Optical Telecommunication standards committees since 2010, representing the UK in defining new optical standards.

Public engagement: During the period of assessment the Unit has run regular events open to interested members of the public as well as to representatives of industry and intended to engage both audiences with key aspects of our research. One example of such activity is the annual Barlow/Mildner Lecture and Research Poster Open Day, which routinely attracts some 100+ industry representatives, but is also open to the public. Wherever appropriate and feasible, we undertake media engagement activities as a further means of connecting a wide non-academic audience with our research. Recent examples include the appearance of researchers from our newly founded UCL-Aeroflex lab on the BBC's *Fast-Track* programme (03/11/2012), for which they tested the effects of tablet devices on the safety of aeroplane flights. Dr Tony Kenyon's work on memristors appeared in the Science section of the BBC's website, as did Professor Andreas Demosthenous' work on spinal implants. The flagship publication of the IET, Engineering & Technology, featured an article on the TINA research project on intelligent airports involving Professors Alwyn Seeds and Paul Brennan.

c. Strategy and plans

The Unit is committed to developing a highly effective structure of support for enterprise activities such as the commercialization of its research through directly spinning-off companies or licensing its technologies, and to ensuring that impact is embedded across the breadth of its academic activities. It is also determined to maximize the societal impact of these activities, both by maintaining and building on its current public engagement activities and by making full use of social media and other online technologies to ensure awareness of our research expertise and findings among the widest possible non-academic audience. To achieve its aims, the Unit will maximise the efficacy of its use of local resources, as well as drawing fully on central resources available at UCL. To that end, we will continue to work closely with UCL Advances, UCLB and UCL Consultants, which provide, respectively, training in entrepreneurship, intellectual property protection and exploitation and consultancy services.

A key priority is to increase the availability and take-up of training for our staff in entrepreneurship and other business-related skills, partly as a means to maintain, expand, and improve the efficacy of our existing business relationships. That training will be provided in collaboration with UCL Advances, which currently offers a number of programmes including communicating science to business, and courses in small company management, as well as the opportunity for UCL staff to attend entrepreneurial electives at London Business School, the leading Business School in Europe. To support the commercialisation of research and innovations arising from the Unit, we will coordinate our actions with UCLB, which manages the commercialisation process of technologies from the laboratory to the market, and which has recently assigned a full time member of its staff, Dr Vassilios Albanis, to develop the Unit's inventions portfolio. This portfolio will be evaluated annually by members of UCLB with the relevant inventors and Heads of Departments to assess its value and opportunities for commercialization. Our objective is to maximise, not the number of patents or other IP protections filed, but exploitation of the technologies we develop. IP in our area of research usually requires substantial development effort before it is fully ready for commercial

exploitation; to facilitate this we will work with UCLB to invest directly in proof-of-concept and development projects to unlock the potential of our research and to ensure that good ideas make it to the market. We will continue to support spin-out activities by making space and research facilities available, and will also maintain our internal mentoring scheme. Finally, we will make use of a range of schemes available at UCL, including the Enterprise Secondment scheme; proof-of-concept funding; and pre-seed and seed funding through the Combined London Colleges University Challenge seed-fund.

The Unit also intends to maximise the new opportunities to deliver extra-academic impact, which will be provided by UCL's new £300,000 EPSRC-funded 'Breakthrough Information Technology Exchange' (BITE) impact acceleration hub. Opened in April 2013 and directed by the Unit's Professor Izzat Darwazeh, the hub will build on UCL's key areas of research strength in ICT, particularly within the Electronic and Electrical Engineering and Computer Science Departments, to strengthen our knowledge exchange activities. The Unit will deliver impact using the following mechanisms within the hub, which have been designed to promote public engagement, encourage academic and student entrepreneurship and to enhance industry-academia links: 1. The Unit's technologies and research will be showcased through its organisation of conference and networking events and use of a dedicated web/social-media presence, whose aim will be to foster industry-academic interaction. 2. Direct knowledge transfer and links with companies will be strengthened through the hub's programme for early researchers, which will facilitate and fund placements for our students in industry. 3. A 'Dragon's Den' style competition will be open to our undergraduate and research students, to promote innovative knowledge exchange ideas and small projects around the theme 'The Internet of Things'. The winner will receive £5,000 of funding and an opportunity to work in partnership with FTSE 100 company ARM Holdings.

We will develop further our programme with UCL Consultants to simplify the process by which our academics can engage in consultancy activities, and will continue supporting and making use of Bio Nano Consulting, a joint venture between UCL and Imperial College that acts as a vehicle for consultancy and contract research work based on technologies developed within the Unit. We aim to provide comprehensive contractual, tendering and administrative support that assists staff in providing consultancy and technology development services. We will also strengthen the role of our Business Development and Marketing officer in promoting knowledge transfer and enterprise in areas specific to the Unit, promoting our research and education activities in public and social media, and organising and representing the Unit in outreach and networking events. In addition, we plan to develop links and work with the Future Cities Catapult. Finally, we will maintain Knowledge Transfer as a key criterion for recruitment and promotion of our staff.

d. Relationship to case studies

The impacts described in all five submitted case studies have resulted, at least in part, from key facets of the Unit's current strategy and approach and from our policy of engaging fully with, and maximising the benefits of, the centralized resources available at UCL. UCLB was used, for example, in all cases to draft and file patents in order to protect the intellectual property stemming from the research prior to commercialization stages. Our capacity to deliver impact through the **commercialisation of our work** is evident in the Senceive case study (UCL13-SCH), which describes the use of sensor technology to help owners of rail, utility and industrial infrastructure monitor the state of their assets in a more efficient and robust manner. It is likewise demonstrated in the study of the impacts of Zinwave's work on wideband signal distribution, which provides wideband wireless coverage in public spaces and office buildings in the US, Europe, the Middle East and the Far East (UCL13-SEE), and in the Diamond Devices case study (UCL13-JAC), which describes the use of radiotherapy dosimetry products to improve patient treatment through the directed use of lower levels of radiation. Our approach to realising research impact by **bringing industry into the Unit** and by effecting **knowledge transfer through consultancy** is demonstrated in the Advanced Optical Fibre Transmission System and Network Technologies case study (UCL13-BAY) This outlines the impact of the provision of new technologies that have been commercialised by companies including Huawei and Intel. The same approach has underpinned impacts described in our Marine Navigation case (UCL13-BRE), wherein the active target design proposed by UCL's Professor Paul Brennan was adopted across the entire Guidance Microwave product range, due to its cost effectiveness and better performance.