Institution: Plymouth University

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

a. Context

Research activities in UoA13 occur in two university-recognised Research Centres: the **Centre for Security, Communications and Networks Research (CSCAN)** and **Centre for Research in Translational Biomedicine (CRTB)**. Staff in both Research Centres actively engaged with both industrial partners and non-academic beneficiaries such as Bombardier Transportation Ltd, De La Rue, and the National Health Service. Staff engage in Knowledge Transfer Partnerships (KTPs), generate patents (supported by *Proof-of-Concept* funding provided by the University or in collaboration with industry) and provide consultancy to international and local industries.

CSCAN focuses on digital security and communications, and includes expertise in error correction code design. The construction and design of many best known error correcting codes was conducted by this Research Centre at Plymouth (over two hundred new best known codes were designed since 2008). The design and application of a unique code to address the noisy environment of railway signalling forms the basis of one of the impact case studies, and was realised with Bombardier Transportation Ltd. Bombardier now has a class-leading and patented coded train detection system called EBITrack 400. Officially launched at the InfraRail exhibition at the NEC in March 2008, the system has enabled Bombardier Transportation Ltd to both reinforce their market presence and increase their market share. They are now world leaders in coded track signalling equipment. Research on the assignment of spreading sequences to reduce interference in mobile communication networks led to a joint patent with Aetheric Engineering. Aetheric Engineering is currently exploiting this development (Patent GB2495709: Filed 17th Oct 2011, Granted 24th April 2013). The work was undertaken as a consultancy for Atheric Engineering, and a joint patent application was made at the end of the consultancy work.

CRTB focuses on sensors and signal processing. Consultancy with the Bank of England Printing Works and De La Rue has resulted in novel magnetic heads and detection techniques employed in banknote paper security production. These are used internationally as banknote anti-counterfeit measures such as in De La Rue's MagForm™ and Magtext® systems. CRTB remains the sole supplier of these magnetic sensors to De La Rue. Work on magnetic security paper with Arjo Wiggins (2006) led to a joint worldwide patent whereby the magnetic read-write head and signal processing were both patented jointly with Arjo Wiggans (WO 2006/046016). Work with Plymouth Hospitals NHS trust led to a new labour management tool, designated as INFANT (INtelligent Foetal AssessmeNT) by Plymouth staff. A new company (K2 Medical Systems) was set up in 1999, where the IP ownership from research in intelligent signal processing was transferred for a small shareholding. The INFANT system is now undergoing the largest maternity trial undertaken by the NHS and will potentially change the way clinicians monitor childbirth throughout the UK.

b. Approach to impact

Our approach to support impact activities involves:

- pursuing commercialisation opportunities with Frontier IP;
- emphasising the inventive aspects of research and protecting advances by filing patents to protect the generated intellectual property (IP);
- working closely with the university's commercial Research and Innovation Directorate, for business exploitation of the IP; and
- seeking UK and EU funding for industry-academia partnerships.

To permit approaches from external groups and individuals, the University maintains an externally oriented online research showcase for all Research Centres and has an online searchable Research Directory that details special interest areas and contact information. Key relationships are identified more pro-actively through networking events hosted by the Schools and Research Centres, in addition to focussed meetings organised by University Research and Innovation Division staff with local and national companies. These identify relevant projects that match with the expertise of the academics. Within the unit, industrial collaborations are also encouraged

through an industrial liaison group that meets regularly and most importantly during the Final Year Technology Project Open Day, which provides an opportunity for employers to exhibit free of charge, meet our final year engineering students, and network over lunch with university experts and like-minded businesses. Each year this event showcases the many innovative ideas and designs for technologies of the future by final year students who are available for employment after graduation in June, or hoping to secure funding and investment to carry their ideas forward into their own business ventures.

Financial support is sought through various Technology Strategy Board funding schemes like Knowledge Transfer Partnerships and Innovation Vouchers. These are managed and actively pursued in partnership with the Research and Innovation Division. Both CSCAN and CRTB actively engage with KTPs, both Research Centres having secured a number of KTPs in the REF period. Plymouth University remains one of the largest providers of KTP in the South West region with national recognition as a UK-leading KTP Office that has a significant reputation for high funding success rates. Our success in this field has been recognised with three 'wins' in the ***National KTP Awards***, with the 'Best Business Impact' win for the Bombardier case study KTP. Once established, on-going contacts with established partners are maintained through regular contact and through involving them in our regular liaison events.

Impact based on the outcomes of previous projects is also pursued. For example, excellent working relationships with the Medical School and with epidemiological statistics is apparent in a 30-partner, €6.4 million, EU Network of Excellence Project (BIOPATTERN) led by **Prof E. Ifeachor** and involving intelligent biomedical data analysis for brain diseases and cancer. Key outcomes of this project included a 20-year Roadmap on the development and creation, as well as the use of bioprofiles for personalised healthcare for brain diseases and cancer. The impact of this will remain significant because of the on-going digital revolution in healthcare, which puts Ifeachor in a unique position to promote and support the impact from this project.

The unit actively pursues the creation of patents and working with partners to exploit inventions. In the period 2008 to 2013, staff filed 28 patents, of which 10 have been granted. This is very significant as it needs to be proved to the patent examiner that there is an invention with a significant, inventive, step and not mere incremental progress. This activity is supported by the University's Research and Innovation Division and its Enterprise Solutions system, which provides support, through Frontier IP, to manage and secure patents. Funding for *Proof-of-Concept* is provided, and management support for academics involved in *Proof-of-Concept* is provided. *Proof-of-Concept* grants have been secured by **Pan** for Graphene based biosensors and **Ahmed** investigating Novel algorithms for Photo Voltaic energy extraction in this REF period. Previous *Proof-of-Concept* funds have resulted in 4 granted patents. A framework for supporting external consultancy and IPR exploitation is also provided through University of Plymouth Enterprise Ltd. (UPEL).

The Centres participate in University-hosted regional groups and meetings of professional organisations such as ***The Institution of Engineering and Technology***, and ***BCS The Chartered Institute for IT***. This facilitates networking opportunities with engineers and staff from a wide range of local companies and other Higher Education Institutions. These occasions also provide a mechanism to facilitate the public understanding of engineering and technology. An annual Science and Technology showcase event for school children and teachers, normally held in National Science and Engineering Week, features some of the best undergraduate projects and industrial success stories. The highly successful and well-attended event is open to the general public in the afternoon and provides an opportunity to disseminate our research and demonstrate research impact.

c. Strategy and plans

Our strategy is to undertake basic and applied research at the frontiers of engineering. We engage through a variety of programmes (e.g., consultation, KTPs and EPSRC funding) to ensure that creative engineering research in academia is utilised by industry and, eventually, the public. The overarching strategic aims of this UoA, as detailed in REF 5, are to undertake cutting-edge research and to work in concert with research end-users. These are pursued through:

- The creation of patents and working with partners to exploit the inventions. In addition to generating IP and filing patents, we plan to increase the number of licences granted to companies based on the IP we generate.
- Collaborating with leading industry players to ensure that our research has the opportunity to reach and benefit the wider community. This includes continuing with existing outreach activities, alongside new activity with national agencies (such as the UK Safer Internet Centre) and international ones (like the Internet Watch Foundation).
- Alongside this, we are actively working with bodies such as the Institute for Information Security Professionals and GCHQ in order to help define and promote standards (for the coverage of cyber security).
- Continued investment in School-funded PhD studentships, with a particular view to further strengthening the synergies between the security and communications research areas.
- The School will continue to support targeted staff recruitment within areas of cybersecurity, and networking/communications, with the aim of adding directly to the base of key frontline researchers. This will enable teaching and administrative relief for existing active researchers, using grant-funded projects as a means of building this capability base.

d. Relationship to case studies

The two Case Studies reflect the strengths and diversity of this UoA's research. They demonstrate the impact on companies and the importance of ensuring we continue to have strong links into industry. While they both are unique, they demonstrate that our research has resulted in considerable economic impact that companies prefer to develop through on-going relationships with our staff. This helps us develop our applied research programme and ensure our research areas benefit company performance. These two case studies exemplify how our collaboration with industrial partners ensures our research benefits the wider international community.

The adoption of a unique technology is presented in the Banknote Security case study. This is in line with our strategy, and demonstrates the filing of a patent and working continuously with industrial partners (strategy 1 above). We originally developed heads for the Bank of England Printing Works for detecting the magnetic thread in banknotes. When De La Rue took over printing of the currency we formed a new relationship. De La Rue moved onto transparent material because the patent on the magnetic barcode was coming to an end and De La Rue needed new technology. They came up with a transparent material, but they could not record any information magnetically onto it, due to the low amount of magnetic material in the transparent media. Because of our success at detecting magnetic signals in the pound currency we were approached to see if we could make a sensor that would work with their new transparent material. The initial investigation yielded positive results within the initial deadlines, and consequently went on to develop the final detection technology (sensors, electronics and signal processing). The commercial relationship was developed over many years and sustained through different companies. Impact was achieved through filing a world-wide patent and working closely with R&I in managing the relationship as the printing of bank notes evolved through different companies.

Direct economic impact has been achieved in a KTP project with Bombardier Transportation, Ltd. The case exemplifies the second strategy above, and was funded by the KTP. The KTP associate on the project had previously completed her MSc at Plymouth, doing her MSc project within CSCAN. Her PhD fees were partially reduced through a funding scheme by the School. Her success in the KTP demonstrates how important it is to recruit the right candidate. Her success in part led to the creation of School funded PhD's (strategy 4), enabling us to support and recruit our best MSc and MEng students. The case demonstrates the utilisation of leading research in industry, and has also led to closer ties between industry and the CSCAN Research Centre. Based on the Bombardier success, the UoA has also built closer ties with the Research and Innovation Division, in particular a better understanding of the expertise of UoA staff has been gained, leading to a quicker and more focussed approach in business meetings with local and national companies. Research which could have significant impact is also flagged to R&I staff by UoA members as a result of this closer tie, and future plans on better IP protection have stemmed from this impact case study, in particular the emphasis on licencing IP.