Institution: Plymouth University

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

Title of case study: Coded Track Systems for Train Detection

1. Summary of the impact (indicative maximum 100 words)

This case study highlights the research carried out by Plymouth researchers in developing a new product in coded railway signalling, the EBI Track 400. Through this patented product, Bombardier Transportation UK Ltd has become the world leader in coded track systems, currently making profits in excess of $6 Million per annum through worldwide sales. The innovative coding algorithms and enhanced system performance has improved railway reliability, eliminated 'false positive' danger alerts, and achieved savings for train operators while improving the travelling experience. It has also secured existing jobs and increased investment at their Plymouth site.

2. Underpinning research (indicative maximum 500 words)

This case study highlights the commercial application of research undertaken by The Centre for Security, Communications and Networks Research (CSCAN) at Plymouth University. CSCAN, comprising staff from the School of Computing and Mathematics at Plymouth University, have expertise in IT security, communication and network technology and are specialists in the design of efficient linear error correcting codes. The team is led by Prof. Martin Tomlinson (Professor 1982-to date) and includes Dr. Marcel Adrian Ambroze (Lecturer 2003-to date), Dr. Mohammed Zaki Ahmed (Lecturer 2001-2008, Senior Lecturer 2008-2010, Associate Professor 2010-to date) and Dr. Cen Jung Tjhai (Lecturer 2007-2010).

The research published its first results in 2005 and commercial translation began with through a Knowledge Transfer Partnership (KTP) with Bombardier Transportation UK, Ltd. that ran for two years between 2006-2008. The company started in Plymouth in 1959 as ML Engineering, and manufactures signalling systems for trains. Bombardier Transportation designs, manufacturers, and delivers rail control and signalling solutions at its Plymouth site. The research continues with a direct synergy between the development of the research and its commercial application.

The research undertaken focused on the development of the latest generation track circuit unit for rail control safety systems. Error correcting codes are specified by the number of information symbols and the number of codeword symbols. An efficient code is one that has the largest distance between codewords for a given number of information symbols and codeword symbols, with the best known codes normally published [R5]. The research carried out at Plymouth has developed new codes that were proven to be better for communications systems than previously used codes.

The research created a coded track system that was substantially more advanced than existing coded railway signalling. The Plymouth team designed a very specific new error correcting code that was suitable for the unique noise and interference challenges of the railway signalling channel. This new error correcting code provided a very robust solution that was subsequently the basis of the EBI Track 400 product. Part of the on-going challenge after the KTP was to prove the safety case for the new train detection system. This is a highly complex and important process before a new system such as this is adopted for use, since it is safety critical and lives depend upon its effective and constant operation in the field. Dr Ahmed provided subsequent support in verifying the safety case for the EBI Track 400 that was highly acclaimed by Network Rail [I9].

3. References to the research (indicative maximum of six references)

R1 Tjhai, C.; Tomlinson, M.; Ambroze, M.; Ahmed, M. (2005) Cyclotomic idempotent-based binary cyclic codes Electronics Letters Volume: 41 , Issue: 6 DOI 10.1049/el:20057266 Electronics Letters embraces the entire field of modern electronics, including electronic science and engineering, telecommunications, optoelectronics and optical communication. It is widely

recognised as being the leading journal in its field for the rapid publication of short international research papers at the cutting edge of electronics technology and is highly cited. All articles are peer reviewed.

R2 Tjhai, C.; Tomlinson, M.; Grassl, M.; Horan, R.; Ahmed, M.; Ambroze, M. (2006) New linear codes derived from binary cyclic codes of length 151 Communications, IEE Proceedings- Volume: 153 , Issue: 5 Page(s): 581 – 585
This journal covers the fundamental and generic research for a better understanding of communication technologies to harness the signals for better performing communication systems using various wired and/or wireless media. All articles are per reviewed.

R3 Horan, R.; Tjhai, C.; Tomlinson, M.; Ambroze, M.; Ahmed, M.Idempotents (2006) Mattson-Solomon polynomials and binary LDPC codes Communications, IEE Proceedings- Volume: 153 , Issue: Page(s): 256 - 262 DOI 10.1049/ip-com:20050415

R4 Tjhai, C.; Tomlinson, M (2007) Results on binary cyclic codes, Electronics Letters Volume: 43 , Issue: 4 DOI 10.1049/el:20073898 Page(s): 234 – 235

R5 CJ Tjhai, Martin Tomlinson, Markus Grassl (2011) There is No Binary [35,10,13] Code, 6094 - 6096. In IEEE Transactions on Information Theory 57 (9)

M. Tomlinson, M. Jibril, C. Tjhai, S.V. Bezzateev, M. Grassl and M.Z. Ahmed (2013) A generalised construction and improvements on nonbinary codes from Goppa codes. IEEE Transactions on Information Theory. 59(11):7299-7304

4. Details of the impact (indicative maximum 750 words)

The research undertaken has impacted on the performance of Bombardier by opening up new international markets. This has led to an investment in their Plymouth site which exports some of the products. The innovative coding algorithms and enhanced system performance has improved railway reliability, eliminated 'false positive' danger alerts, and so achieved savings for train operators while improving the travelling experience.

The research has led to the EBITrack 400 being launched by Bombardier. Officially launched at the InfraRail exhibition at the NEC in March 2008, the system has enabled Bombardier to reinforce their market presence and increase their market share. It has resulted in increased worldwide sales of the system in international markets including European and Asian markets, Australia and the USA. It has led to projected worldwide sales in excess of $6m per annum (2,000 systems per annum) in international markets including; the UK, Spain, The Netherlands, Russia, Latvia, India, Australia and the USA, and has also triggered an increase in sales enquiries for the product family of over 200% with a further 30% gained due to recovery of markets recently lost to competitors. The KTP project was awarded the 'KTP Business Impact Award 2011', presented at Innovate 2011 [I4,I5,I6,I7]. This award, funded by the Technology Strategy Board, is awarded to the business that has benefited most from its KTP project.

As Bombardier state:

"As a result of our successful collaboration with the University of Plymouth through KTP, the joint team developed a cutting-edge product that is innovative and marketable and has already secured a market lead over its world-wide competitors" (Bombardier Transportation).

The EBITrack 400 offers significant reliability advantages over other products on the market
After seeing a presentation of the new EBITrack 400 coded track circuit system, Network Rail approached Bombardier to adopt the system for use in the UK, which is unprecedented within the industry and makes Bombardier the only UK company to have coded track circuit technology being trialled by Network Rail.

"The EBI Track range embodies several significant design enhancements over its predecessors, principally: A unique, exceptionally safe, coding system and communication technique - a particular feature of EBI Track 400; and extremely high immunity against traction current interference. The EBI Track 400 coded track circuit offers a significant improvement in track circuit performance since: Dangerous failures caused by traction current interference are practically impossible. The incidence of nuisance failures is significantly reduced because of improved ability to tolerate excessive traction current interference;" (The Institution of Railway Signal Engineers)[I8].

At a more local level, the research has had a significant impact on the Bombardier site in Plymouth. The new product and increased orders has ensured the long term survival of the site, securing the jobs of 60 people and retaining vital skills by ensuring that Bombardiers research, design, development and manufacturing functions remain in the UK [I1,I2,I3]. The knowledge embedded through this Partnership has also been vital to the company's long term strategic direction and has enabled it to compete for a larger range of future work and projects. The research has ensured that Bombardier are now far ahead of their competitors and they have continued to use this market advantage to grow and develop. All Research and Development funding for the Plymouth site is generated from its product sales, so it is vital to demonstrate long term viable product development opportunities within the UK business to the multinational business. This will have a significant impact upon future innovation and on-going job security at the site.

In markets where export from the UK is not possible the technology is manufactured under license in those countries, thus returning the funding to the UK. It has created jobs in other countries including Russia and Sweden. The intellectual property and codes that makes the system unique are so critical and confidential that they are kept securely at the Plymouth Bombardier site.

5. Sources to corroborate the impact (indicative maximum of 10 references)

I1 Letter with the following facts, figures and information from Bombardier Transportation UK, Ltd.

- New markets
- Number of units sold per annum
- Existing markets
- Statement or quote from industry

I2 Local News story
http://www.thisisdevon.co.uk/University-partnership-leads-innovation/story-13553931-detail/story.html

I3 Local News story
http://www.thisisplymouth.co.uk/Safety-wins-award-saves-jobs/story-13540259-detail/story.html

I4 INNOVATE Business Impact.
http://www.innovateuk.org/content/news/outstanding-business-partnerships-and-future-busin.ashx

I5 National Rail News
http://www.rtmjobs.com/rail-news/article/2053-bombardier-wins-business-impact-award/

I6 KTP Online
http://www.ktponline.org.uk/assets/2011/special/2011AwardsBestOfBest.pdf, page 11.

I7 Railway Industry Association News
http://www.riagb.org.uk/images/news_documents/1318598658.pdf

I8 Institution of Railway Signal Engineers IRSE NEWS ISSUE 147, Pages 2-7, JULY/AUGUST

2009
http://www.irse.org/knowledge/publicirsenews/IRSE%20NEWS%20147%20Jul%2009.pdf

I9 Rail Safety Case Report
Ahmed MZ (2009) Report on EBI Track 400 Safety