Institution: Plymouth University

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

Title of case study: Ensuring Banknote Security

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

This case study highlights the research at Plymouth University into the development of a specialist security thread in banknotes which has been commissioned and adopted by De La Rue, the world's largest commercial currency printer and papermaker. The system has provided quality assurance for over five billion banknotes, including the Euro, and improved the performance of a worldwide business through the introduction of new technology. Potential future losses through counterfeit have been mitigated by the improved quality assurance systems.

2. Underpinning research (indicative maximum 500 words)

Developing anti-counterfeit measures is a key challenge in the sector. The Bank of England estimate that of the 2.6billon notes in circulation in the UK, there were 566,000 counterfeit notes in 2009. As counterfeiting gets more sophisticated, more technological approaches are being adopted to combat fraud. Research undertaken at Plymouth University from 1993 onwards has developed new, cost effective measures to enhance bank note security. This case study demonstrates the way that this issue has been addressed and has led to the practical solutions now employed in the security printing of currency.

Over the past three decades a great deal of research on the development of novel magnetic sensors, new magnetic material, and advanced signal processing & coding techniques has been undertaken at Plymouth University by Prof. Des Mapps (Professor 1973-2009, Emeritus Professor 2012-to date), Dr. Paul Davey (Research Fellow 1997-2000, Lecturer 2000- 2012, Associate Professor 2012-to date) and Nick Fry (Research Officer 1983-2012, Technical Specialist 2012-2013). This work has focused on improving areal density in magnetic storage devices, such as hard disk drive and tape backup systems. During this time approximately 25 PhD's have been successfully completed in this area and approximately 150 papers have been published in recognised international research journals.

The research underpinning this case study and referenced in the papers below concerns state-of-the-art techniques initially developed, for high-speed, high-density, data processing and storage application that the team have also applied to improve banknote security. The specific tailoring of the technology required for this unique application has not been published due to the high security nature of the product.

This Plymouth University team translated their work on the development of magneto-resistive sensors and associated signal processing into methods of reliably detecting and decoding new security and anti-counterfeit measures in collaboration with De La Rue. This has involved the use of advanced data storage and recognition systems, advanced micro-fabricated sensors involving magneto-resistance and magneto-impedance technologies. This phase of the research began in 1993 in collaboration with the Bank of England. De La Rue purchased the Bank Of England printing operation in 2003 and the Plymouth University research has continued with the new owners. Nine research contracts relating to security measures on banknotes have been commissioned between 2004 and 2009. De La Rue Currency provides market-leading banknote paper, printed banknotes and a substantial portfolio of banknote security features, including cylinder mould watermarks, security threads, a wide range of printed features and sophisticated optically-variable devices.

The research team fabricate and recalibrate the detection and recognition systems regularly as part of their on-going relationship with De La Rue.

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

Davey P.J., Donnelly T., Mapps D.J., "Two-dimensional coding for a multi-track, maximum likelihood digital magnetic storage system". *IEEE Transactions on Magnetics*, Vol. 30, No. 6, Nov 1994, pp 4212-4214. The IEEE Transactions on Magnetics publishes research in science and technology related to the basic physics and engineering of magnetism, magnetic materials, applied magnetics, magnetic devices, and magnetic data storage. It is the leading journal in the field.

Smith D.F., Donnelly T., Mapps D.J., "Fixed sample rate Bayesian detector in a variable speed magnetic channel." *IEEE Transactions on Magnetics*, Vol. 33, No. 5, Sept 1997, pp 2797-2799.

He L.N., Wang Z.G., Mapps D.J., Wilton D.T., Clegg W.W., Robinson P., "Keepered perpendicular media reproduction with dual MR heads". *Journal of the Magnetics Society of Japan*, Vol. 21, Supp. 52, October 1997, pp 273-276. Official publication of MSJ with international circulation.

Shute H.A., **Mapps D.J**., Wilton D.T., "Eddy-current assisted digital video read/write head". *IEEE Trans. Magn*., Vol. 37, 2001, pp 3043-3052.

Shute H A., Wilton D T., McKirdy D M., **Mapps D J**., "Analysis of two-dimensional shielded pole heads using singular expansion functions". *IEEE Trans. Mag*. Vol. 40, No. 5, Sept 2004, pp 3402-3406

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

The research team in Plymouth worked as part of a Knowledge Exchange project with De La Rue to design a quality assurance system for specialist security features used in their banknotes. The team designed, developed and constructed a complete system to reliably detect and identify security measures with a tolerance better than 5%. Such precision is currently impossible to recreate in counterfeiting. The patented technology used in the sensors was invented by Plymouth University academics and has also been used to provide applied solutions for a number of other companies.

The University team worked to tight deadlines to meet De La Rue's production start date for the manufacture of their new technology feature. The project involved a combination of mechanical design, sophisticated magnetic sensor design, electronic circuit design, and working in partnership with another De La Rue subcontractor. The team have successfully installed and commissioned working detection systems at the De La Rue, Bolton & Loughton sites.

This technology is highly confidential and subject to non-disclosure contacts for much of the detail. The precise details of the implementation cannot be described for these reasons. In outline, invisible encrypted features are identified by specialist magnetic detectors precisely designed to optimise the recovered signal from the security thread. These heads are micro-fabricated in the Clean Room facility at Plymouth to ensure maximum security. The recovered signal is decrypted using novel information processing algorithms, also developed at Plymouth, to allow the tiny signal to be reliably recognized with very low signal-to-noise ratios. The latest evolution, included in all Euro and other banknotes, allows innovative optical effects linked to more complex structures which do not increase the production cost of the banknotes.

Specifically, the development with Plymouth has resulted in two technologies, Magtext® and MagForm™ which are found on banknotes. The University technology was applied specifically to the De La Rue requirement and has resulted in a completely bespoke system which has now provided quality assurance for over 5 billion banknotes. MagForm™ can only be identified on the expert level. Magtext® is part of De La Rue's Mask™ technology which is used on many currencies including the EURO and GB Pound.

The research has improved the performance of a worldwide business through the introduction of new technology. Potential future losses through counterfeit have been mitigated by the improved

quality assurance systems. The new technology has been adopted by De La Rue, the world's largest commercial currency printer and papermaker. This research has considerable reach in that De la Rue is involved in the production of more than 150 currencies worldwide including the EURO. Almost half of all banknotes issued into circulation in the past two years across the world were created by De La Rue.

The technology is now used on all issued UK Bank of England notes. The Bank of England has confirmed that *"Plymouth have developed a sensor technology based around a novel structured magnetic read head to monitor the quality in banknote production and fraud detection. This has had an outstanding benefit enabling all UK bank notes to be monitored using this technology."*

De La Rue is delighted with the system and the partnership continues with Plymouth University providing technical support and periodic calibration of the magnetic sensors. The company has benefited greatly from the application of the novel technology and the rare academic skills employed to support their mission critical project. The new technology is a step-change in security thread technology.

Dr. Jim Snelling, Research Manager at Overton Technology Centre (De La Rue International) has said: "*We have enjoyed an excellent working relationship with the University of Plymouth team whose expertise and technology have produced a tailored and robust solution for our on-line QA process*"

The innovative methods to deter forgery help De La Rue remain market leaders. Contracts in this sector are large, for example the contract to produce new banknotes for the Board of Commissioners of Currency of Singapore is worth £30 million.

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

Factual Statement from Research Manager, Overton Technology Centre, De La Rue International. States the impact of the work of Plymouth University.

Factual Statement from Senior Technical Expert, Notes Division, Quality and Research, Bank of England, London.

Case study of Knowledge Exchange between Plymouth University and De La Rue, produced by De La Rue.

De La Rue is awarded the Queen's Award for Enterprise for the new material (Optiks) that incorporates the technology developed at Plymouth University.
http://www.guardian-series.co.uk/news/10371728.Bank_note_printers_awarded_for_anti_fraud_design/

The 13th International Currency Conference in Buenos Aires where De La Rue presented on the new security with their bank notes.
http://icpress.ru/en/information/articles/?ID=8530&sphrase_id=7994