Institution: Manchester Metropolitan University

Unit of Assessment: B15 General Engineering

Title of case study: Novel Methods For Detecting Concealed Weapons And Explosives In Stand-Off Security Screening

1. Summary of the impact

The Sensing & Imaging Group at Manchester Metropolitan has developed novel, effective non-imaging radar methods for the stand-off screening of people for concealed threat items. Some of this technology is at a high Technology Readiness Level (TRL) and has undergone rigorous independent trials. The results of these trials and of other published work by the group has informed UK Government strategy in effective methods of people screening at standoff distances, created a product which is entering production, and data which are used in the design of effective simulants for testing threat scenarios. This will save lives, deter and stop gun crime and prevent damage to key infrastructure when deployed in sensitive areas likely to be targeted by terrorist action.

2. Underpinning research

Crime is generally reducing in the UK, however, the threat of attacks from Person Borne Improvised Explosive Devices (PBIED) and other bag carried weapons of mass destruction is increasing, so the need for the type of technology that can detect concealed threats, preferably from a safe distance, increases also.

Currently, screening of persons for concealed threat items at stand-off ranges of greater than a few metres is carried out with millimetre or sub-millimetre wave imaging cameras. Such cameras are very expensive, bulky (hence non-portable) and have limited range and generally do not work outdoors. Other techniques, such as metal detection portals are inflexible as they are installed in a fixed position and have a limited range and ability to detect threats. In the current global climate where terrorist groups seek to target, not only military assets and personnel, but civilians and state infrastructure, enhanced security screening is a key strand in protecting people and buildings.

A technique for remotely detecting handguns and layers of plastic explosives, which can operate at useable standoff ranges (e.g. 10 metres) , is inexpensive, handheld, safe and effective was proposed to the EPSRC by Professor Nicholas Bowring in 2005, with research commencing around that time. Prof Bowring, who joined MMU in 2004 and was awarded a Chair in Electrical Engineering in 2007, established a sizeable group to undertake the research, consisting of post-doctoral fellows, research associates and PhD students. In the last decade they have undertaken the following investigations:

- The development of an entirely novel, W-band frequency millimetre wave polarimetric radar system to illuminate and remotely screen for threats on a person or people covertly, at a safe distance. The researchers found that by ultra wide band (UWB) illumination very effective threat detection was possible using inexpensive direct detection receivers, thus enabling high resolution time domain reflectometry to be performed and greatly enhancing the screening capability of the radar system **[1]**. The techniques invented and developed are now the subject of world-wide patents.
- An investigation into the transmission at millimetre wavelengths through commonly worn fabrics for clothing and bags **[2]**. The group devised an inventive free space method of measuring the transmission and reflection of microwaves/millimetre waves through/off clothing. The research informed the choice of millimetre wavelengths at which detection technologies can realistically be based for concealed threat detection at a distance.
- Detecting layers of plastic explosives strapped to the body that do not contain fragmentation, at a distance. An investigation into the millimetre wave dielectric properties of explosives and their simulants found that layers of dielectric type plastic explosives concealed on the body could be detected by ultra wide band radar and an original paper was published on this work **[3]**. A free space method was developed to determine their properties, together with that of simulants that could be used in the extensive trials that take place when testing out security screening

equipment.
- The bulk of this initial work was funded by an EPSRC/Home Office/MPS partnership, with MMU as the PI, with 4 other UK Universities (Manchester, QMUL, Newcastle, Leeds Metropolitan).

At this stage, the performance of the devices warranted patent protection being sought and patents were applied for covering a variety of related techniques and over a wide range of territories. This has so far resulted in patents being granted in the UK, USA and other territories **[4]**.
The system has attracted the interest of the Metropolitan Police Service (MPS) for security screening operations as it met their requirement for a compact, portable and effective screening solution.
The research group secured funding by the MPS, CPNI and other government bodies of over £1M under restricted contracts to improve the device with end user requirements being clearly established. The device has been developed to a high Technology Readiness Level (TRL) and tested in two variants, one for handheld shorter range screening and the other for longer range, checkpoint screening. The techniques and results have been published in a variety of conferences and journals **[5]**.
A further technique for classifying the nature of concealed objects, relying on the late time response of concealed objects at microwave frequencies, for a walk through portal scenario was also developed **[6]**.

Two variants of the technology are now entering production via a UK company (Anglo Scientific) with first sales expected Q2, 2014, and are being evaluated by the US Navy.

3. References to the research

[1] A Review of Nonimaging Stand-Off Concealed Threat Detection with Millimeter-wave Radar, Stuart William Harmer, Nicholas Bowring, David Andrews and Nacer Rezgui, Jan/Feb - 2012, IEEE Microwave Magazine. **DOI**: 10.1109/MMM.2011.2174125

[2] Determination of the complex permittivity of textiles and leather in the 14-40 mm wave band using a free-wave transmittance only method. Harmer, S.; Rezgui, N.; Bowring, N.; Luklinska, XZ.; Ren, G. IET Microwaves, Antennas and Propagation, Vol. 2, No. 6, 2008, p. 606-614.
DOI: 10.1049/iet-map:20070235

[3] A sensor for the detection and measurement of thin dielectric layers using reflection of frequency scanned millimetric waves, Nicholas J. Bowring, John G. Baker, Nacer D. Rezgui and John F. Alder Meas. Sci. Technol. 19 (2008) 024004 (7pp). **DOI:** 10.1088/0957-0233/19/2/024004

[4] Nicholas Bowring, David Andrews, Nacer Ddine Rezgui and Stuart Harmer. Remote Detection and Measurement of Objects. Filed March 18 2008 and granted January 24 2012. US patent number: US 8,103,604. Available online at Google Patents - http://www.google.com/patents

[5] On body concealed weapon detection using a phased antenna array, Stuart William Harmer, S. E. Cole, Nick Bowring, N. D. Rezgui, D. Andrews, Progress In Electromagnetics Research, Vol. 124, 187-210, 2012, Available online at http://www.jpier.org/PIER/ **DOI**: 10.2528/PIER11112105

[6] Detection of Handguns by their Complex Natural Resonant Frequencies, Stuart Harmer, David Andrews, Nacer Rezgui and Nicholas Bowring, IET Microwaves, Antennas & Propagation 2010. Available online at http://ieeexplore.ieee.org **DOI:** 10.1049/iet-map.2009.0382

Indicators of Research Quality: The work at MMU was funded under grant EP/D079195/1 (Deployable sensors for concealed gun detection at a standoff distances; £130k), with Bowring as PI, running from 2006 to 2008. Thereafter, the work was funded under a restricted series of grants from the Home Office, Metropolitan Police, CPNI with a value of £1m (approximately) running from 2008 to 2013. The latest of these is a Home Office grant of value £60,000 code named SPUR which finishes in December 2013.

4. Details of the impact

The research conducted by The Sensing & Imaging Group has had impact in categories including 'prevention of harm', 'economic' and 'commercial', with the chief beneficiaries being the Home Office, Metropolitan Police Service and our industrial partners, Anglo Scientific. Specifically, our impact has been in:

- The invention and development of new techniques for screening at a distance that are both portable and which can be rapidly deployed.
- The selection of suitable "bands" or wavelengths and operating modalities of sensors operating in the electromagnetic spectrum where concealed threats can be effectively detected at standoff distances.
- The measurement and calibration of materials that can form threats or simulate hazardous threat items.

The Sensing and Imaging Group are regularly consulted by Senior Scientists from the Home Office Applied Science Division. For example, in 2013 alone they have had several visits from the Home Office Chief Scientist, have undertaken four weeks of joint trials and tests with the same scientists, given at least 5 demonstrations in MMU labs to visiting senior scientists and capability advisors, been invited to successfully tender for closed bids. In 2012, a live demonstration of the technology was given to the Commissioner of the Metropolitan Police, Sir Bernard Hogan-Howe and two of his deputies.

In addition to supplying vital data and know-how to the Home Office, through its extensive research programme with the Metropolitan Police Service and other government bodies, the group has developed a range of deployable sensor technology for the screening of threats that are effective at significant distances. The Metropolitan Police Service have corroborated the impact of this work with them in the following statement received in June 2013 **[A]**:

"*The group at MMU have developed the concept of using polarimetric active radar to detect threats at a standoff distance, rather than imaging, because these systems are more portable and effective at a distance and therefore informed UK Government thinking on its approach to the detection of concealed threats at standoff distances"*

In an example of impact from this earlier work, the Home Office has commissioned a research programme (in March 2013, the details of this work are confidential) to characterise a range of materials that are of interest to them. The results of this research will further inform the Home Office Centre for Applied Science and Technology of the way forward for its comprehensive programme of testing and validating technology for people and baggage screening technology. The following statement by the Home Office in July 2013 **[B]** corroborates this impact:

"*The group at MMU have undertaken work with CAST that directly informs Government thinking in gaining enhanced capability in the important area of standoff threat detection. The work undertaken by Prof Bowring's group will provide higher performing, lower cost alternatives for law enforcement agencies. The programme of work into materials characterisation also informs the important aviation security area, which is vitally important to the UK economy. "*

Currently the threat detection technology and associated IPR are in the process of being licensed to a UK company and prototype devices exist and have been demonstrated commercially. Commercially produced devices are expected to be taken up by police forces, security forces and other law enforcement bodies. The first production versions are now being built (October 2013). The impact of the technology is expected to increase and provide improved security products which are relatively inexpensive when compared to currently available products. The Chairman of Anglo Scientific Ltd who has licensed the technology from the university is able to corroborate this impact. Below is an extract from a statement he has provided (October 2013);

"The Sensing and Imaging Group at Manchester Metropolitan University has invented and developed novel techniques for the remote detection of threat items and contraband that are

portable, effective, unique, and which are well covered by protective patents. We are in the process of investing into the group and also are producing these devices for manufacture, with company having expended £100,000 on productisation in 2013, with an expected £500,000 committed for 2014" **[C]**

The group has had expressions of interest from the US Department of Defence, having given a live demonstration in London in 2011, and has had a recent (October 2013) enquiry from US Army Laboratories, where the technology will be demonstrated early in 2014, and from the US Navy (November 2013)

There has been considerable interest from the media (BBC 2006, 2009, 2013, ITV 2013). Because of the sensitive nature of the technology, most of these approaches have been refused, but these articles were produced by the BBC: http://www.bbc.co.uk/news/science-environment-24941084 and http://news.bbc.co.uk/1/hi/8089959.stm. Also, professor Bowring was interviewed by Radio Manchester in 2006.

5. Sources to corroborate the impact

Statements that corroborate the impact of the research described here have been received from the following individuals on behalf of their organisations in support of the research, development and commercialisation work undertaken by the Sensing and Imaging group:

[A] By the Metropolitan Police Service (MPS) Project Manager, Detective Inspector SC&O25 (Serious and Organised Crime) on behalf of a Deputy Assistant Commissioner. The technology has recently been given a live demonstration to the Commissioner of the Metropolitan Police Service.

[B] By the Home Office Chief Scientist and Senior Scientist at the Home office Centre for Applied Science and Technology (CAST). The Home Office Chief Scientist and several of his senior scientists are regular visitors to the Sensing and Imaging Group at Manchester Metropolitan University.

[C] By the Chairman and founder of Anglo Scientific ltd, who have licensed the Intellectual Property surrounding this technology and who are investing commercially in the production of the devices described in this impact statement, and who are funding further research and development work for the group.