Institution: University of Southampton

Unit of Assessment: 09 Physics

Title of case study: 09-02 Advances in Gamma-Ray Detection and Imaging

1. Summary of the impact

The University of Southampton's distinguished body of work on the design of technology for gamma-ray detection and imaging has informed new counter-terrorism practices. Technological advances arising from the research have been crucial to delivering significant benefits in the fields of homeland security and nuclear safety – the latter particularly in the wake of the 2011 Fukushima disaster. A spin-out company, Symetrica, currently employs 26 people in the UK and the USA, has a forecast turnover of more than £10 million for 2013-14 and has been recognised as an example of best practice. It is a technological leader in the field of radioactive isotope identification.

2. Underpinning research

Research into designing technology for gamma-ray detection and imaging began in the University of Southampton's Astronomy Group in the 1980s and continued throughout the next two decades, underpinning the formation of spin-out company Symetrica Ltd in 2002. Symetrica's core technologies resulted from a combination of the research activities carried out within the group and specifically within the teams working in instrument design and construction.

Dr Tony Bird, Reader in the School of Physics and Astronomy (1987-present), led the advancement of small low-power scintillator-photodiode radiation detectors for the development programme of the European Space Agency's (ESA) INTEGRAL space telescope [3.1, G1, G2]. The International Gamma-Ray Astrophysics Laboratory is the most sensitive gamma-ray observatory to date and, through the analysis of gamma-ray bursts in space, aims to solve some of astronomy's biggest mysteries.

As a postdoctoral researcher, Bird optimised the design of gamma-ray detectors, creating a technology (paper published in 1993) that was more cost-effective and robust than existing detectors (standard NaI(Tl)/PMT combinations) and, crucially, did not require a high-voltage supply that might cause equipment failure in space. These sensitive radiation detectors paved the way for highly segmented 2D gamma-ray detector arrays, which can provide high-resolution spectroscopy as well as imaging capability.

Essential gamma-ray imaging technologies were developed [G1, G2] by teams led by Professor A Dean, now a Professor Emeritus within the Astronomy Group following his retirement in 2009, and Dr D Ramsden, who retired in 1996 and founded Symetrica in 2002, where he is now chief technical officer and head of research. The resulting imaging systems relied on the temporal or spatial modulation of the incident gamma-ray flux using high-Z materials and produced images of far higher quality than previously possible. These systems are now ubiquitous in high-energy imaging systems for space astronomy and also form the basis for 'stand-off imaging' (i.e. from distance) in homeland security and nuclear industry applications [3.2, 3.3, G3].

Led by Dr Fan Lei, a postdoctoral researcher at the time (left Southampton in 2000), research into instrument modelling guided the INTEGRAL Mass Model project [3.4, G5] an independent and uniform instrument and spacecraft modelling program for ESA. Using data on mass distribution and chemical composition of material in the instruments, Dr Lei formed a Monte Carlo model of the whole payload to assess the performance of each instrument and identify any flaws. It was the first time simulations had provided detailed and useful satellite design input. Simulations were used to optimise the response of the detectors to gamma rays, inform the calibration strategy and support data analysis after launch. Simulations were also used in designing the detector geometry to ensure high and uniform light collection from the scintillation counters, producing the best possible spectral resolution.

Research into spectral response modelling through signal processing and mathematical modelling led to some of Symetrica's core technology for isotope identification [3.5, 3.6]. These methods allow a detector spectrum to be deconvolved into the component isotope signatures, enabling accurate identification and quantification of radioactive materials.

The combination of these technologies provided Symetrica with an initial portfolio of radiation detection products and continues to inform the company's development of innovative radiation detection solutions.

3. References to the research

Outputs (the best 3 illustrating quality of work are starred)

*3.1 Bird, A. J.; Carter, T.; Dean, A. J.; Ramsden, D.; Swinyard, B. M., *The optimisation of small CsI(Tl) gamma-ray detectors*, IEEE Transactions on Nuclear Science, vol. 40, issue 4, pp. 395-399, 1993.

*3.2 Durrant, PT; Dallimore, M; Jupp, ID; Ramsden, D., 1999. The application of pinhole and coded aperture imaging in the nuclear environment, NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A, Vol 422, p667-671

3.3 Ramsden, D; Bird, AJ; Palmer, MJ; Durrant, PJ, 1996, Gamma-ray imaging systems for the nuclear environment, NUCLEAR ENERGY-JOURNAL OF THE BRITISH NUCLEAR ENERGY SOCIETY, Vol 35, p353-359.

3.4 Lei, F.; Ferguson, C.; Bird, A. J.; Lockley, J. J.; Dean, A. J., *The Integral Mass Model – Timm*, Astrophysical Letters and Communications, Vol. 39, p.373, 1999

*3.5 Meng, LJ; Ramsden, D, *An inter-comparison of three spectral-deconvolution algorithms for gamma-ray spectroscopy*, 2000, IEEE Transactions on Nuclear Science, Vol 47, Part 1, p1329-1336

3.6 Meng, LJ; Ramsden, D; Chirkin, VM; Potapov, VN; Ivanov, OP; Ignatov, SM, 2002, The design and performance of a large-volume spherical CsI(Tl) scintillation counter for gamma-ray spectroscopy, NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A, Vol 485, p 468-476.

Grants supporting the underpinning research:

G1. SERC; GR/H93729; £56,328; 01/04/1993-31/03/1994; "Gamma-ray astrophysics"; PI: A J Dean

G2. SERC; GR/J63040; £277,290; 01/01/1994-30/06/1995; "Gamma-ray astronomy with INTEGRAL"; PIs: A J Dean, D Ramsden

G3. PPARC; GR/K41960; £47,838; 01/11/1994-31/10/1995; "Gamma-ray imager for the disordered nuclear environment"; PI: A J Dean

G4. PPARC; GR/K94867; £701,493; 01/11/1995-31/12/2002; "Southampton participation in INTEGRAL imager software"; PI: A J Dean

G5. PPARC; PPA/G/R/2002/00466; £454,158; 01/01/2003-31/03/2005; "UK in INTEGRAL: calibration, mass modelling and core science"; PI: A J Dean

4. Details of the impact

Research by the University of Southampton's Astronomy Group has gone beyond solving galactic riddles, radically improving the capability of security agencies to detect dirty bomb threats and contributing to tighter safety procedures in the nuclear industry.

Responding to US government calls for technology that could be used at ports to detect suspect radioactive materials, spin-out company Symetrica [5.1] set out to adapt the Southampton team's original gamma-ray detector, which had performed successfully in space exploration. Existing

detection systems, housed in 'portals', were unable to discriminate between different threat and natural radiation sources. Symetrica developed its original gamma-ray detector – its spectroscopic capabilities enable it to distinguish different radiation sources and accurately identify threat materials hidden in heavily shielded containers – to make a system that could be used in a portal and in a handheld detector as a second layer of surveillance.

In 2006 Symetrica partnered with Smiths Detection, a world-leading provider of detection systems for X-rays, explosives and traces of radioactive materials, which led to a $222m contract from the US Department of Homeland Security's (DHS) Domestic Nuclear Detection Office (DNDO) to develop next-generation radiation detection and identification systems. This move was crucial in giving Symetrica access to the key US government market. In September 2008 Smiths Detection announced the launch of the partnership's High Performance Radioisotope Identifier (HPRID), a next-generation handheld device for detecting and identifying highly enriched uranium, plutonium and other radioactive materials. A choice of either a NaI or $LaBr_3$ crystal and a neutron detector identify and analyse the specific potential threat. The HPRID was based on Symetrica's original Discovery™ technology for isotope detection and identification.

The collaboration between Symetrica and Smiths led to further success in 2011 when their RadSeeker handheld radioisotope identifier, which superseded the HPRID, was approved by the DHS's DNDO as its primary radiological handheld detector device [5.2, 5.3] to help port and border personnel evaluate cargo, containers and vehicles as part of the US government's counter-terrorism efforts.

Smiths received an initial production order for $4.5m in May 2011, built around Symetrica's key isotope identification and spectrum stabilisation technologies employed in this device. In 2012, the DHS announced the purchase of RadSeeker DL instruments for $8.3m. As a result of this decision, Symetrica's technology was deployed by the Honolulu Emergency Services Department, through US Government grant funding, to screen tsunami debris as it reached Hawaii in the aftermath of the Fukushima disaster [5.4].

Symetrica has grown into an international company with 26 employees in the UK and the USA – a number that is expected to grow by 30% in 2013-2014 with RadSeeker entering full production. Its forecast turnover is £10m. Symetrica Inc, a wholly-owned subsidiary of Symetrica Ltd, was founded in the USA, with a manufacturing and testing facility in Maynard, MA. Symetrica has a strong R&D programme in the UK itself, and has funded PhD studentships at the Universities of Southampton and Surrey. It has also successfully bid for more than £100k of DTI/EPSRC funding on the basis of collaborative research with the University of Southampton [5.5, 5.6].

Symetrica's shift in market focus from space to security is the key to its current success and is attributable to a decision taken by commercial advisers at SETsquared, an organisation that supports spin-outs from the five universities of Southampton, Exeter, Bristol, Bath and Surrey. SETsquared matched the Southampton astronomy team with a mentor, Heddwyn Davies, now the chief executive of Symetrica, who targeted the security sector as Symetrica's primary market.

Symetrica's Homeland Security portfolio now includes scalable, ^{3}He-free neutron detectors, inexpensive Radiation Portal Monitors (RPMs) that can reduce nuisance alarms alarm rates during cargo screening and RPMs equipped with crystal spectrometers that provide a greatly enhanced isotope-identification capability. With all three of these technologies entered into the European Illicit Trafficking Radiation Assessment Program (ITRAP+10), Symetrica's footprint on the Homeland Security Market has significantly increased. A prototype portal monitor, trialled at the Port of Felixstowe, demonstrated its effectiveness in distinguishing naturally occurring radioactive materials from potential threat materials. The trial system reduced the number of manual secondary inspections of cargo by customs personnel at the port by ~80%.

Already partnered with Smith's detection, Symetrica is now in discussions with two other market-leading prime contractors who wish to use their technology.

The story behind the Symetrica spin-out was highlighted as an example of best practice by *The Engineer* magazine in 2011 [5.7], and in February 2012 the Duke of York visited Symetrica's headquarters at the University's Science Park, to learn how its technology is winning export sales for the UK [5.8].

Symetrica continues to be research-active and has filed 15 patents since its launch. There is a programme of continued collaboration between the School of Physics and Astronomy and Symetrica in the field of detector development. Funded studentships, supervised by Bird, were completed in 2009 and 2011 and the findings fed into products now offered by Symetrica. The first student (Dr C Burt) carried out the initial development for large area PVT detectors to act as low-cost replacements for traditional scintillation counters. The second student (Dr M Foster) worked on extending these detectors in the search for a replacement for Helium-3 neutron detectors and is now a Symetrica employee in their research department. Both these developments are now marketed as components within the Symetrica Radiation Portal Monitor (RPM) range, which offer a >75% nuisance alarm reduction and improved isotope identification capability compared to other available systems.

5. Sources to corroborate the impact

5.1 www.symetrica.com (general information on company and products)

5.2 http://uk.reuters.com/article/2011/08/10/idUS175245+10-Aug-2011+BW20110810 (DNDO approve RadSeeker as its primary radiological handheld device)

5.3 http://www.smithsdetection.com/RadSeeker.php (Smiths Detection deploy Symetrica Discovery™ technology in their latest RadSeeker handheld isotope identifier, Aug 2011)

5.4 http://www.kitv.com/news/hawaii/Advanced-radiation-detector-to-scan-debris-from-Japan/-/8905354/16711292/-/149om70/-/index.html (Media coverage of RadSeeker screening tsunami debris)

5.5 http://thebln.com/2011/05/how-the-technology-strategy-board-spent-635-million-company-by-company/ (reports TSB grant of £106,319 to Symetrica)

5.6 Grant - PI: A J Bird, "New photo-detection technology for possible use in sensors for Homeland Security", EPSRC (DTI/EPSRC joint funding), 10/7/2007 – 10/1/2009, £10500 *(this was supported by DTI/TSB funding direct to Symetrica for the joint project)*

5.7 http://www.theengineer.co.uk/in-depth/analysis/spin-doctors/1009205.article/ (identifies Symetrica as a successful spin-out)

5.8 http://www.symetrica.com/news/2012/2012_02_07_1.php (Duke of York meets Dr Ramsden of Symetrica). For verification of Symetrica sales figures, contact: Chief Technical Officer, Symetrica Ltd