Institution: University of Southampton		
Unit of Assessment: 09 Physics		
Title of case study: 09-01 Symetrica: Gamma-ray detection and imaging for security applications		
Period when the underpinning research was undertaken: 2000 – 2019		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Antony (Tony) Bird	PDRA; Lecturer; Professor	1999 – present
Matthew Dallimore	Enterprise Fellow	2000 – 2001
Grant Crossingham	Enterprise Fellow	2001 – 2002
David Clark	Research Fellow	2008 – 2010
Period when the claimed impact occurred: August 2013 – July 2020		
Is this case study continued from a case study submitted in 2014? Y		

1. Summary of the impact

The spin-out company **Symetrica** was created in 2002 to translate novel methods of high-energy radiation detection developed at the University of Southampton (UoS), originally for the ESA's INTEGRAL Space Telescope, to applications in the homeland security market. Symetrica products drive security standards and result in benefits to both the economy and public safety/wellbeing.

Now an established world-leader in its field, the company has shown strong growth over the impact period: Between 2014 and 2019, employee numbers increased from 26 to 75 (50 UK and 25 US). Between 2016 and 2019, Symetrica experienced a 74% rise in annual sales to GBP11m, earning it 60th place in the Sunday Times list of 100 fastest growing technology companies. Symetrica's UK market has grown rapidly, and the company exports to more than 10 countries, including the USA, Hong Kong and the Netherlands.

2. Underpinning research

Symetrica's formation and current product lines derive directly from past and ongoing research streams in astronomy at UoS. Symetrica's speciality is the use of both novel detector readout and spectral deconvolution to provide world-leading identification of radioisotopes in a wealth of compact and (relatively) low-cost systems.

The underpinning research may broadly be grouped into **detection**, **imaging** and **data analysis** techniques, much of which is based on research performed as development for the European Space Agency's INTEGRAL space telescope – essentially a very large radiation detector capable of both imaging and high-resolution spectrum measurement.

Research undertaken in 2000-2002 by Dr Matthew Dallimore and Dr Grant Crossingham, while PPARC enterprise fellows within the UoS Astronomy group, made fundamental improvements to the spectral performance of small scintillation counters, which enabled the design of the detectors underpinning the formation of Symetrica. The research, in collaboration with Dr David Ramsden who had previously worked at UoS until his retirement in 1996, included the use of spectral deconvolution to reconstruct spectra from low-resolution and lower-performance detectors [**3.1**], and the design of optimised detector geometries to improve spectral performance [**3.2**]. These enabled the detector to accurately identify threat materials hidden in heavily shielded containers, using a compact system that could be operated in a portal and in a handheld detector as a second layer of surveillance. Dallimore, Crossingham and Ramsden went on to found Symetrica in December 2002.

At the same time Professor Tony Bird led improvements to the operations of ESA's INTEGRAL telescope post-launch. These included the use of complex simulation and computer response modelling to mitigate the effect of complicated and imperfect detectors [**3.3**] and the use of tagged calibration sources to provide real-time continuous gain stabilisation without increasing detector background [**3.4**]. Both are crucial in operating detectors in real-world scenarios, and

were a fundamental component of Symetrica's early *Discovery Technology*® for spectral deconvolution and radiation isotope identification.

Post-INTEGRAL detector research

Following the INTEGRAL launch, there was a need for radiation detectors for space applications to develop in terms of size, robustness and efficiency. On the other hand, commercial drivers – scalability of production, stability of supply and low cost – were becoming more relevant in space where the emphasis was moving towards faster and cheaper deployment. In this context, Bird led research on novel detector techniques between 2004 and 2011, starting with an investigation into spectroscopy using plastic scintillators as a low-cost alternative for large area detectors. Plastic scintillators produce a small signal, and were previously considered impractical for spectroscopic measurements of radiation energy. New readout methods and deconvolution algorithms were developed to overcome these problems. Bird then led a DTI/EPSRC grant [**G2**] which studied the use of Silicon photomultipliers (SiPMs) in radiation sensors. These were shown to provide a more robust replacement for the traditional photomultiplier (PMTs), and required lower power and voltage to operate.

Post-INTEGRAL imaging research

A strong research effort has been towards directional and imaging radiation detectors for the gamma-ray waveband. Coded apertures allow imaging of high-energy radiation that cannot be imaged by conventional lens- or mirror-based systems. They employ mathematical image reconstruction methods to estimate the radiation source distribution from a shadow of a complex pattern of radiation-opaque elements (the 'mask'). The techniques for analysing coded mask data have matured considerably thanks to the in-flight experience gained with ESA's INTEGRAL and NASA's Swift telescopes, and research has continued into the design and application of coded apertures in a number of areas of value to terrestrial applications. This programme of research was funded initially by STFC as INTEGRAL Post-Launch Support (PLS), which ended in 2010, and then more recently by responses to more applied funding streams.

Collaborations between UoS and Symetrica on bespoke applications such as the Stonehenge imager [**G3**] demonstrated the theoretical advantages of stand-off imaging systems over proximity ones [**3.5**].

Data analysis, image reconstruction and processing

Two key techniques were developed as part of a KTP collaboration between University of Southampton and Symetrica (2016-2018) [**G5**]. Firstly, methods for co-aligning optical and gamma-ray images were shown allowing a user to quickly identify the source of radiation in an image. In addition, Bird extended a method used in INTEGRAL for cleaning of coded mask images to remove imaging artefacts in the case where no a-priori knowledge of the source position was available. This method has been successfully demonstrated with the spectral analysis and Symetrica Discovery algorithms to allow location and isotope identification of multiple sources in an imager field of view.

Advanced coded mask image reconstruction

Development of image reconstruction algorithm for a moving imaging system (2018-). This is being applied to an INTEGRAL slew survey for astronomy [**3.6**] and is essential for scanning or hand-held imaging systems.

The most recent development is of near-field 3-D imaging systems based on pixellated detector plane technologies (2018-), which will be essential for future medical applications of the coded aperture methods.

3. References to the research

3.1 Crossingham, G., **Dallimore, M.**, Ramsden, D., "The effect of counting statistics on the integrity of deconvolved gamma-ray spectra", IEEE NS25-56, 696, 2003. https://doi.org/10.1109/NSSMIC.2003.1352136

3.2 Ramsden, D., **Dallimore, M.**, **Crossingham, G.J.**, Herbert, D., "Toward both larger and smaller scintispheres", 2003, IEEE TNS, 50(4), 782. https://doi.org/10.1109/TNS.2003.815352

3.3 Bird, A.J. et al., "IBIS Ground Calibration", 2003, A&A, 411, L159. https://doi.org/10.1051/0004-6361:20031439

3.4 Bird, A.J. et al., "In-flight performance of the IBIS calibration unit", 2003, A&A, 411, L197. https://doi.org/10.1051/0004-6361:20031210

3.5 Clark, D.J., Ramsden, D., **Bird, A.J,** Engdahl, J.,"A stand-off imager for the location and identification of nuclear threat materials", IEEE Conf on Technologies for Homeland Security, 2009. https://doi.org/10.1109/THS.2009.5168024

3.6 Costantino, A. and **Bird, A.J.**, "Constructing an IBIS/ISGRI Slew Survey", 2019, In Mem. d. Soc. Astron, Italiana, 90, 1-2, 107 http://sait.oats.inaf.it/MSAIt9001-0219/PDF/2019MmSAI..90..107C.pdf

Grants:

G1 2006-2008 - PPARC/STFC - INTEGRAL Post-launch Support (PP/C000714/1, PI: Dean, Bird was recognised researcher; value GBP435k)

G2 2007-2008 - DTI/EPSRC grant (DT/F003080/1; PI: Bird; value GBP26k)

G3 2007-2008 - STFC - MiniPIPSS grant for study of 'Stonehenge' imager combining spatial and temporal modulation (ST/F006772/1, PI: Bird, value GBP107k)

G4 2008-2010 - STFC - INTEGRAL Post-launch Support (ST/G004196/1, PI: Bird, value GBP117k)

G5 2016-2018 - InnovateUK - KTP grant to transfer knowledge of imaging techniques to Symetrica (KTP010399, PI: Bird, value GBP101k)

G6 2019 – SPRINT/Research England – 3D gamma-ray camera using coded-aperture imaging for tumour detection (SPRINT OW131379P4V11; PI: Symetrica; value GBP85k)

4. Details of the impact

4.1 Background to *Symetrica* and commercial success since 2014

Symetrica Ltd (now Symetrica Security Ltd) was spun out from the School of Physics and Astronomy at UoS in December 2002 to commercialise proprietary, high-performance gamma-ray spectroscopy capabilities, originally developed for the ESA's INTEGRAL Space Telescope and redesigned in 2000-2002 for real-world scenarios. Its US sister company, Symetrica Inc., was founded in Maynard, Massachusetts in 2005.

The company has shown strong growth since 2014 and is now an established world-leader in its field of homeland security, marketing handheld radioisotope identifiers (RIIDs), cargo scanning portals, and bespoke radiation detection solutions. Customers include the Home Office's Office for Security and Counter-terrorism (OSCT) and private companies such as Tata steel. Its technology is now in use in many countries including UK, US, Holland, Belgium, Finland, South America, Middle East, Hong Kong, Israel and Italy. Between 2014 and 2019, overall Symetrica employee numbers increased from 26 to 75 (50 in the UK and 25 in the US). [**5.1**]

Between 2016 and 2019, Symetrica experienced a 74% rise in annual sales to £11m, earning it 60th place in the Sunday Times Hiscox Tech Track 100 list of fastest growing technology companies [**5.2**].

4.2 US Department of Homeland Security and *Radseeker*

In 2006 Symetrica partnered with Smiths Detection Inc., a world-leading provider of detection systems for X-rays, explosives and traces of radioactive materials, and won a contract to develop next-generation radiation detection and identification systems for the US Department of Homeland Security's Domestic Nuclear Detection Office (DNDO). A flagship product was the **RadSeeker**, approved by the DNDO in 2011 as its primary radiological handheld detector device. These devices are based on *Discovery Technology* developed by Crossingham and Dallimore, working on the principle of proximity to the radioactive material using a combination of sensors to determine nature of the radioisotope.

In January 2016 the DNDO renewed its commitment to RadSeeker with a five-year indefinite delivery/indefinite quantity (IDIQ) contract. A GBP10,000,000 order followed in September 2018 [**5.3**], with Symetrica completing shipment of their 3000th RadSeeker that year [**5.1**] In 2020 Symetrica received a USD7m 3yr contract to update and enhance the devices deployed in the field .

4.3 Product lines based on SiPMs and plastic scintillator: *Verifinder*

SiPM and large-area plastic scintillator technologies developed under [**G2**] continue to underpin many Symetrica products including the Radiation Portal Monitors (plastic) and He3-free neutron detector in Verifinder RIID (SiPM). Verifinder was released in 2016 as the successor to Radseeker, and is sold in several variants including Verifinder handheld, Verifinder backpack and Verifinder Drone. [**5.1, 5.4**].

Since its launch in 2016, the Verifinder system and its variants have been sold across European (Finland, Belgium, Holland, Italy) and US (National Nuclear Security Administration (NNSA)) markets. The US military use Verifinder backpacks, currently being supplied via a multi-year contract,

In May 2016, Symetrica launched Neutron Vest, a wearable system that has a partial direction-finding capability using SiPMs for neutron detection [**5.5**].

A new mobile system currently in production by Symetrica uses both tagged radiation sources for gain stabilisation [**3.4**, **3.5**] and large-area plastic-based neutron detectors.

4.4 Deployment of enhanced portal systems

Symetrica's Radiation Portal Monitors deploy large area detectors and Discovery Technology to provide class-leading performance. They have benefited from continual improvements on the original gamma-ray detector to offer a >75% nuisance alarm reduction and improved isotope identification capability compared to other available systems.

Portals are now deployed at ports and airports around the world. Since 2017, four Symetrica portals have been deployed at the Tata steel site in Port Talbot in order to screen incoming radioactive material for signs of accidental melting, which has been a major problem for the metals reprocessing industry [**5.1**]. Apart from improved worker safety, the main benefit has been the substantial financial savings due to the prevention of temporary shutdown of the mill, which would incur costs relating to decontamination, waste disposal and lost revenue. US steel mills have incurred costs averaging USD8 to 10 million as a result of these events and, in one case, the cost was USD23 million [**5.6**].

The high performance of Symetrica systems in the identification of illicit radioactive materials compared to Naturally Occurring Radioactive Materials (NORM) has led to **changes in international standards and expectations** stated in procurement specifications. In particular, nuisance alarm rates (alerts on NORM) have been dramatically reduced from 3% to 0.1% in the latest specification released in 2017 which explicitly states the expected technology is large-area plastic scintillator spectrometers.

Deployment of improved security portals at UK ports has a dual impact. Firstly, it leads to **improved transit rate at ports** with obvious benefits to UK economy. The reduction to 0.1% of nuisance alarms should be seen in the context of the global use of containers: 616.7 million containers passed through ports in 2018 so a 2.9% reduction means 18 million fewer unnecessary container inspections. Better selectivity leads to lower detection thresholds, improved sensitivity to detection (without additional nuisance/false alerts) and provides **improved national security** via improved detection rates for genuine contraband.

4.5 Embedding new company capability for imaging systems

The development of imaging systems was enabled through a Knowledge Transfer Partnership (2016-2018, Innovate UK KTP010399) aimed at embedding the design skills within the industry, and hence creating a long-term capability for the industrial partner, providing long-term impact far beyond the benefits of the initial product designs. Bird provided a series of seminars and workshops to the development teams at Symetrica. The KTP was rated outstanding by Innovate UK [**5.7**]. The KTP Associate, Dr Callum Shand, was seconded to Symetrica to act as the focus of the knowledge transfer, and was subsequently employed by Symetrica at the end of the KTP and leads development of the new imaging product lines. At the end of the KTP, Symetrica had an embedded capability, through the use of computer simulation methods, to design imaging systems for specific roles, quantify their performance and develop data analysis software for tasks. Validated modelling techniques for use in imager design allow for faster instrument design with much reduce prototyping costs [**5.8**].

Dallimore, now CTO at Symetrica, stated: “The KTP is an excellent opportunity to reinforce the links between ourselves and the excellent faculty members at the Department of Physics and Astronomy. Symetrica’s strategy is to push the boundaries of detection and identification of radioactive threats for Homeland Security applications. It is imperative that we remain at the cutting edge in our field; this KTP provides Symetrica with the opportunity to do just that, as well as move into the Nuclear Medicine market.” [**5.8**]

4.6 Informing company strategy - medical imaging

In July 2020, a SPRINT collaboration between Symetrica, the University of Southampton and Southampton General Hospital was set up to translate the imaging technology for medical imaging applications [**5.9**]. Symetrica expects to achieve a 5% market penetration within 3 years rising to 15% within 5 years. Assuming the gamma-ray camera accounts for 25% of the system price, this would lead to a turnover of the order of GBP30,000,000 per year. [**5.1**]

5. Sources to corroborate the impact

5.1 Letter from Chief Executive Officer, Symetrica.

5.2 Sunday Times Hiscox Tech Track 100 (2019) https://www.fasttrack.co.uk/league-tables/tech-track-100/league-table/?leagueyear=2019

5.3 https://www.smithsdetection.com/press-releases/smiths-detection-inc-receives-10m-order-from-dndo-for-hand-held-radseeker-radiation-detectors

5.4 https://symetrica.com/products

5.5 https://www.hstoday.us/channels/federal-state-local/symetrica-presents-compact-and-ultra-light-wearable-neutron-detector-system-for-first-responders-and-security-staff

5.6 International Atomic Energy Agency bulletin, *Safety & Security of Radioactive Sources* https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull41-3/41302692227.pdf

5.7 KTP final assessment.

5.8 The joint development was highlighted at: https://www.phys.soton.ac.uk/news/5543

5.9 SPRINT project: https://www.sprint.ac.uk/news-stories/symetrica-to-bring-innovative-gamma-ray-astronomy-technology-to-medical-imaging-sector