Institution: 10007822

Unit of Assessment: 12

Title of case study: Increased capability in missile seeker and countermeasure analysis

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

Cranfield has improved modelling and simulation capability in the infrared and radio frequency regions of the electro-magnetic spectrum. This research has been exploited by Chemring in:

- a product improvement plan for a highly detailed modelling suite that enables the assessment of air, land and maritime missile and target engagements with particular emphasis on the efficacy of the countermeasures deployed by the target.

- insights in specific areas of countermeasure product development such as the desirability and efficacy of release of the countermeasure before the threat has been detected.

Cranfield's research has also contributed to a major new Chemring hardware product called the Centurion launcher, by informing the development of the software algorithms to control the launcher in operation.

2. Underpinning research (indicative maximum 500 words)

Cranfield's research has contributed to the refinement and extension of modelling tools to enable the assessment of air, land and maritime missile and target engagements. The modelling tool increases the capability to faithfully replicate real world activity. In particular we have studied Infrared missile seeker and countermeasure modelling [G1, P1, P2 and P3] to understand the utility of launching infrared countermeasures prior to the detection of the threat missile to enhance aircraft survivability, and the ability to combat the more advanced missile systems that are becoming more widely proliferated in the modern battlespace. This has included looking at countermeasures in the ultraviolet region, a novel region of investigation [P4].

The research carried out by Cranfield has also involved using the model in the naval role to enable missiles with full imaging seeker technology to be studied and hence fully understood. The latest image processing techniques have been evaluated by Cranfield to assess ship survivability under different conditions of ship heading and wind speed to optimise the deployment of the countermeasure in terms of its positioning with respect to the ship and its actual countermeasure characteristics (such as burn temperature, composition, persistence etc), [G2, P5, P6].

Higher fidelity rendering of the real world in the model has been investigated to minimise computational costs. This has been done at both infrared and radio frequencies. In the RF case a novel genetic algorithm approach has been developed and used by Cranfield to generate an efficient technique of representing the radar cross-section of a complex target, [G3, G4].

Key Researchers	Post details and dates	Research
Dr Nabil Aouf [G2]	Lecturer (2006 – 2011); Senior Lecturer (2011 - present)	Missile Seeker and Countermeasure Analysis
Dr Ivor Morrow [G3, 4]	Senior Research Officer (2001 -2002); Lecturer (2002 – 2007); Senior Lecturer (2007 - present)	Missile Seeker and Countermeasure Analysis
Dr Evan Hughes [G3, 4]	Lecturer (1998 – 2004); Senior Lecturer (2004 - 2012); Left Cranfield December 2012.	Missile Seeker and Countermeasure Analysis
Prof. Mark Richardson [G1- 4]	Lecturer (1993 – 2003); Senior Lecturer (2003 – 2010); Reader (2010 – 2012); Professor (2012 – present)	Missile Seeker and Countermeasure Analysis

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

Evidence of quality – Peer reviewed journal papers

P1* Birchenall R P, Richardson M A, Butters B[b] and Walmsley R[a] , Modelling an IR Man Portable Air Defence System, *Infrared Physics & Technology Journal*, **53**, (5), pp. 372-380, 2010.
doi:10.1016/j.infrared.2010.07.001.

P2* Jackman J, Richardson MA, Butters B[b], Walmsley R[a], Millwood N[a], Yuen P W T and James D B "Simulating pre-emptive countermeasures of varying performance against a Man-Portable Air-Defence (MANPAD) system with a track angle bias counter-countermeasure (CCM)", *Infrared Physics & Technology Journal*, **54**, (2), pp. 121-129, 2011.
doi:10.1016/j.infrared.2011.01.006.

P3 Birchenall R P, Richardson M A, Butters B[b] and Walmsley R[a] and Jackman J, "Modelling Infrared ManPAD Track Angle Bias Missile Countermeasures", *Infrared Physics & Technology Journal*, **54**, (5), pp. 412-421, 2011.
doi:10.1016/j.infrared.2011.06.004.

P4* Birchenall R P, Richardson M A, Butters B[b] & Walmsley R[a] and Jackman J, "Modelling an Advanced ManPAD with Dual Band Detectors and a Rosette Scanning Seeker Head", *Infrared Physics & Technology Journal*, **55**, (1), pp. 67-72, 2012.
doi:10.1016/j.infrared.2011.09.004.

P5 Gray G, Aouf N, Richardson MA, Butters B[b], Walmsley R[a] and Nicholls E[a], "Feature-based recognition approaches for infrared anti-ship missile seekers", *Imaging Science Journal*, **60**, (6), pp. 305-320, 2012.
doi: 10.1179/1743131X12Y.0000000012

P6 Gray G, Aouf N, Richardson M A, Butters B[b] and Walmsley R[a], "Countermeasure effectiveness against an intelligent imaging infrared anti-ship missile", *Optical Engineering*, **52**, (2), 2013.
doi: 10.1117/1.OE.52.2.026401

* 3 identified references that best indicate the quality of the research

Key to authors on publications
a, Chemring Countermeasures Ltd.
b, Formerly Technical Manager - Modelling and Simulation and RF CM Design at Chemring Countermeasures Ltd, now Director at Meon Technology Ltd.

Evidence of quality – underpinning research grants
(Note: investigators for research grants indicated in table above)

G1 *Infrared Pre-Emptive Countermeasure Study and Analysis*, Chemring Europe Ltd, £79,000, 09/2008 to 08/2011.

G2 *Infrared Imaging Seeker Techniques Research*, Chemring Europe Ltd, 06/2009 to 05/2012, £91,000.

G3 *Sensor Systems and Countermeasure – Model Fidelity Analysis*, Chemring Europe Ltd, 05/2009 to 10/2011, £150,000.

G4 *Radar Cross Section & Seeker Modelling*, Chemring Europe Ltd, 05/2011 to 05/2012, £114,850.

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

Cranfield's research has enabled Chemring, a world leader in munitions, pyrotechnics, countermeasures and counter-technologies against improvised explosive devices (C-IEDs), to formulate future products across their portfolio helping to ensure a viable future in this important manufacturing and development area of UK business. In particular in the countermeasures area Chemring have succeeded in capturing £184 million of the global £360 million market [C3].

Specific examples of Cranfield's research impact are as follows:

- Contributions to improving the Chemring software "CounterSim" for the modelling of Man-Portable Air-Defence (ManPAD) missile threats while gaining insights into pre-emptive decoys. This has permitted the company to enhance its delivery of training on modelling to overseas customers by enabling seeker launch sequences to be analysed by Chemring customers and enabled comparisons of existing products with potential future products. It has also resulted in a product improvement plan for Chemring's computer modelling software *CounterSim* [C1, C2]. The work on advanced Man-Portable Air-Defence (ManPAD) modelling was able to demonstrate some advanced features that are employed in early generation missile seekers which represent a significant threat to current in-service aircraft and thus enabled Chemring engineers to develop improved models for the licensing of the *CounterSim* model [C1, C2].
- Following successful implementation of the product improvement plan referred to above the enhanced *CounterSim* model delivers much improved support for studying countermeasure applications for UK and overseas customers in both the military and civilian markets [C1,

C2].

- Improvements to *CounterSim* with regard to infrared (IR) imaging has provided the incentive to link *CounterSim* directly to Matlab. This enables rapid testing of new ideas and delivers the capability of running advanced image processing techniques using the Matlab tools. This work has been most useful with regard to the "Centurion" launcher programme and has helped in the development of the algorithms used for protection against IR guided missiles by confirming the need for low launch angles and control of a wide range of azimuth angles [C1, C2].
- The Centurion launcher product is now a commercial success as evidenced by recent international interest and mentions in the press and on the Internet of collaboration between Chemring and Raytheon [C4, C5, C6].

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

C1 Contact: Director, Meon Technology Ltd. (formerly Technical Manager - Modelling and Simulation and RF CM Design at Chemring Countermeasures Ltd).

C2 Contact: Senior Software Engineer, Chemring Countermeasures Ltd.

C3 Chemring Group Website:
http://www.chemring.co.uk/our-business.aspx
last accessed 07/03/13.

C4 Centurion Launcher product description:
http://www.chemringcm.com/Download.aspx?ResourceId=51647
last accessed 17/10/13.

C5 Chemring Group Press release available at:
http://www.chemring.co.uk/media/press-releases/2013/2013-02-19.aspx
last accessed 07/03/13.

C6 Media write-up on web-based specialist newsletter:
http://www.naval-technology.com/news/newsraytheon-chemring-team-develop-anti-surface-naval-weapon-system
last accessed 07/03/13.