Institution: University of Surrey

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

Title of case study: An International Disaster Monitoring Satellite Constellation

Spin Out - DMCii

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

The University of Surrey created the first international satellite constellation dedicated to monitoring natural and man-made disasters worldwide. The Disaster Monitoring Constellation (DMC) comprises 6 advanced small Earth Observation satellites built at Surrey Satellite Technology Limited (SSTL) for China, Algeria, Nigeria, Turkey, Spain and the UK that can image worldwide within 24 hours to provide critical and timely information to international disaster assessment and relief agencies. The DMC has responded to over 200 major disasters and, the UN estimates, aided over 250,000 disaster victims. SSTL's subsidiary company, DMCii, has created commercial applications and services generating sales of over £130M and ~100 high-technology jobs.

2. Underpinning research (indicative maximum 500 words)

The key to a practical Earth Observation constellation providing not just high spatial and spectral resolution but also high temporal resolution has been the development of low cost yet highly capable small satellites and imaging sensors using the latest 'commercial-off-the-shelf' (COTS) technologies and devices. Research at the Surrey Space Centre (SSC) based at the University of Surrey into small satellite platforms and payloads provided the foundation for the six Earth observation (EO) micro/mini-satellites that have been designed and built by Surrey Satellite Technology Limited (SSTL), the Surrey spin-out company, between 2003 and 2010 to create the international Disaster Monitoring Constellation (DMC).

SSTL relied on Surrey's research for its design, construction and operation of the DMC – specifically the research into satellite platforms covering the modular mechanical structure, thermal models and designs, power systems, on-board data handling systems and mass data storage, S-band/X-band communications systems, agile yet precise three-axis attitude control systems using reaction wheels and cold-gas propulsion, imager micro-vibration stabilisation techniques, electric-resistojet butane propulsion system for orbit manoeuvring, on-board GNSS for autonomous orbit determination and precise positioning, astrodynamics analysis for optimal orbital constellation control and maintenance .

Essential to the DMC was the development of very wide (600km) swath, multispectral and high resolution panchromatic imaging cameras taking innovative advantage of the latest 'COTS' sensors, processing and mass storage components adapted for space to achieve high quality imaging from a small and relatively inexpensive satellite, all based on research conducted at the University of Surrey's SSC. Accurate radiometric and geometric calibration techniques were developed by SSTL from research at SSC through over 50 camera systems built & launched on Surrey satellites since the earliest demonstrations of COTS imaging sensors on UoSAT-1 in 1981 through to 2010.

SSTL launched the world's most advanced and capable EO minisatellite (NigeriaSAT-2) in 2010 providing 2.5-metres GSD high resolution (previously the preserve of spy satellites a decade ago) at about 1/20th of the cost of conventional such satellites andour research is now supporting SSTL in building the world's highest resolution (civil) small satellite constellation providing 1-metre

imaging.

Surrey's research into cloud feature extraction, vegetation stress signatures, radiometric and geometric calibrations, flood and forest fire burn scar delineation has enabled SSTL's subsidiary company, DMCii, to offer highly competitive space-derived data and information services to the agricultural and environmental communities. SSC and DMCii are now recognised as world-class experts in satellite imager calibration.

The DMC could not have been successful without the detailed knowledge gained from the long-term sustained programme of Surrey's research into the effects of the harsh space radiation environment on the design of both satellite platforms and payloads - especially when using COTS devices originally designed for terrestrial use. Commencing in 1993 and sponsored by EPSRC, UK MoD, and ESA, SSC's research in radiation effects modelling, the design of instruments and in-orbit testing onboard over 30 SSTL-built satellites in a wide range or orbits has created at Surrey the UK's centre-of-excellence in the understanding and reliable use of COTS components in orbit. This expertise, based on previous flight heritage and data from 10 cosmic particle and trapped radiation effects monitoring instruments built by SSC and flown in orbit on 23 Surrey satellites to date, specified the SSTL's design and manufacturing requirements for the DMC satellites to survive the orbital radiation environment.

Research Team: M.N.Sweeting, C.I.Underwood; S.Mackin; T.Vladimirova; A.Pechev; M.Fouquet; J.W.Ward; H.Steyn

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

1. "Second generation disaster-monitoring microsatellite platform." da. Silva Curiel R.A, Wicks A, Meerman M, Boland L, Sweeting M.N. Acta Astronautica, Vol. 51, No. 1-9, pp. 191-197, 2002.
2. "FPGA-based On-board Multi/Hyperspectral Image Compression System" Guoxia Yu, Tanya Vladimirova, Martin Sweeting: Proceedings of IEEE International Geoscience and Remote Sensing Symposium (IGARSS'09), Cape Town, South Africa, 7-11 July 2009, Vol. 5, pp. V-212 - V-215
3. "Image compression systems on board satellites" Yu, G.; Vladimirova, T.; Sweeting, M.N Acta Astronautica, Volume 64, Issue 9-10, May 2009, Pages 988-1005
4. "Earth Observation using low cost micro/minisatellites." M N Sweeting, M Fouquet. Acta Astronautica, Vol. 39, No. 9-12, pp. 823-826, 1996.
5. "Uosat-12 Minisatellite for High Performance Earth Observation at Low Cost." Fouquet.M, Sweeting M.N, October 1996. Acta Astronautica Vol 41 No3 pp 173-182 1997.
6. "An Efficient On-Board Lossless Compression Design for Remote Sensing Image Data" Guoxia Yu, Tanya Vladimirova, Martin Sweeting Proceedings of 2008 IEEE International Geoscience & Remote Sensing Symposium, IGARSS'2008, 7-11 July 2008, Vol. 2, pp. II-970 - II-973, Boston, Massachusetts, U.S.A.

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

Surrey, through the DMC, has fundamentally changed the economics and capabilities of imaging the Earth from space by pioneering capable, low cost Earth Observation (EO) small satellites with innovative on-board cameras to provide a rapid-response, global imaging service - a trend that has since been increasingly adopted worldwide.

The DMC enabled the UK to join the UN International Charter on Space and Major Disasters with global impact on hundreds of thousands of lives. Approximately 200 major disasters occur globally each year and the DMC responds to approximately 20 such disasters annually worldwide – the UN estimates that the DMC has aided over 250,000 disaster victims. For example, the DMC provided the first comprehensive coverage of the Asian Tsunami disaster in 2004 on which the UN based their early recovery plans and provided the first images of the Katrina hurricane disaster to US authorities.

The DMC satellites are also used to provide scientific information on land and water resources, agriculture, pollution, urban development and especially deforestation - the DMC, for example, was used extensively in the preparations for the Beijing Olympics and in providing annual assessments of deforestation and illegal logging in the Amazon basin rain forest.

By dramatically lowering the cost of sophisticated EO satellites, Surrey has enabled 15 nations to develop their own space activities and form space agencies (Surrey has trained the nucleus of 6 new space agencies) and achieve their own independent ability to image from space, better to manage their national resources and security and to be able participate more fully in international affairs. The DMC concept pioneered by Surrey has been recognised internationally and the concept has since been emulated by China, Japan and France.

The DMC satellites provide more data than is needed purely for disaster monitoring and national use, and so DMCii has supplied data to the commercial EO data marketplace generating revenues of over £10M that has been used to build and launch replacement satellites in the constellation. DMCii is the vehicle that has created impact post 2008.

The imagery generated from the DMC satellites is a significant commercial and economic success. Over £5 million of DMC imagery is sold in over 30 countries for governmental and commercial use in agriculture, National Spatial Data Infrastructure (SDI), forest monitoring, disaster planning/management, and land cover mapping. This commercial success enabled DMCii to commission a new satellite (UK-DMC2) from SSTL in 2010 that was financed wholly within the SSTL group: a world 1st for a commercial EO satellite. In 2012, by creating a novel 'DMC-3 leased imaging capacity service', DMCii won a £115M, 7-year contract to provide high resolution EO image data to China. In 2013, based upon the latest developments from SSC research into small satellite platforms and imaging techniques, SSTL is building a new high capacity EO microsatellite (funded from DMCii revenues) that will form a constellation that will image the whole of the Earth's land surface every 24 hours to provide a unique database for a wide range of change detection applications.

For the last 7 years farmers in the US and Europe have relied on DMC imagery to generate precision farming services to determine the best time and place to apply fertilizer on their fields. Before the DMC it was impossible for these services to achieve the scale and frequency of national observations required to mitigate cloud visibility for successful commercial operations. The US Department of Agriculture began replacing previous supply sources with DMC imagery in 2011 for Agriculture Land Cover Classification in the US Cropland Data Layer. Recent analysis of the UK DMC-2 satellite image data by NOAA (USA) gave it a quality rating of 81% compared to LANDSAT's 69% in the same bands.

DMCii, using data from the DMC satellites, is heavily engaged in monitoring deforestation and illegal logging activities. The Brazilian government has relied heavily on DMC satellite imagery to provide the annual Amazon basin deforestation assessment. In 2012 a £2.1M contract was signed with DMCii enabling Brazil to access imagery directly from UK-DMC2 satellite from its ground station to image the entire Amazon basin every two weeks, enhancing the ability to identify deforestation at an early stage and alert the authorities when logging is detected. The Brazilian

Space Agency is providing DMC-derived data on their website so the general public can follow progress against deforestation – described by the Director General as;

"an innovation which has enhanced public monitoring of forest management in Brazil."

DMCii is now a key supplier of satellite imagery for the annual survey of opium poppy cultivation. The UK FCO and the UN office of drugs and crime (UNODC) has required full-country imagery coverage of Afghanistan programmed to coincide with forecast harvest and crop cycle events to reveal areas of cultivation, crop yields and annual change.

DMCii is a subsidiary of SSTL specifically formed to coordinate the DMC, exploit its data and stimulate EO applications. It has achieved £18M annual turnover (2011) and has created ~30 highly-skilled jobs in the UK and ~60 jobs in the international supply chain.

By exploiting the research carried out by SSC, DMCii is currently the first and currently only EO company worldwide that is able to fund its own EO satellites in orbit on a fully commercial basis without government subsidy or support - this has only been possible due to the SSC research and SSTL developments of small satellite techniques.

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

C1. Use of the data can be viewed in the UNODC Reports:

http://www.unodc.org/documents/crop-monitoring/Afghanistan/Afghanistan_OS_2012_FINAL_web.pdf

http://www.unodc.org/documents/crop-monitoring/sea/SouthEastAsia_Report_2012_low.pdf

C2. Head/Spatial Analysis Research at US Department of Agriculture. Contact details provided.

C3. S. N. JONKMAN, Global Perspectives on Loss of Human Life Caused by Floods, Natural Hazards (2005) 34: 151–175, Springer 2005

C4. Afghanisthan Opium Survey 2011, December 2011, UN Office of Drugs and Crime

C5. Monitoring Deforestation in the Amazon Rainforest; DMC Imaging Campaigns since 2005 in Support Of Brazil; P Stephens, S Mackin, J Soares, D Valeriano; IAC-08-B1.5.14

C6. D.J. Barnhart, T. Vladimirova and M.N. Sweeting. "Satellite Miniaturization Techniques for Space Sensor Networks" – AIAA Journal of Spacecraft and Rockets, Vol. 46, No. 2, March – April 2009, pp. 469-472.

C7. Cawthorne A, Gomes L, Sweeting MN "SSTL's Ongoing Programme for high resolution imaging from small satellites" IAA-B7-0211P, Digest 7th International Symposium of the International Academy of Astronautics, Berlin May 2009, pp.57-60 ISBN: 978-3-89685-572-5