Institution: University of Surrey

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

Title of case study: GIOVE-A: Europe's Pathfinder Satellite to the Galileo Constellation

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

The GIOVE-A satellite, built by Surrey Satellite Technology Limited (SSTL) based upon the University of Surrey's Space Centre research, was the first satellite launched to provide navigation and timing signals for Europe's Galileo constellation (a 'European GPS').

Built in just 30 months against a hard deadline and at a fraction of the competing industry cost, GIOVE-A enabled Europe in 2008 to secure the rights to the key frequency bands critical to the operation of Galileo over the coming decades. GIOVE-A also provided the first precise timing transmissions from its 22,000 km Earth orbit with widespread impact through enabling European industry to build and test commercial consumer products for this market estimated at £90B from 2008 onwards.

2. Underpinning research (indicative maximum 500 words)

Europe's first satellite (GIOVE-A) in the new Galileo constellation providing precise timing and navigation could not have been built without the research into a wide range of spacecraft technologies and techniques undertaken at the Surrey Space Centre (SSC). The 600kg GIOVE-A satellite was designed and built by Surrey Satellite Technology Limited (SSTL) the University's spin-out company, working closely with Surrey researchers. As a direct result of Surrey's underpinning research, it has operated successfully in a hostile radiation orbit providing test and calibration timing signals for over 7 years, greatly exceeding its 27-month design lifetime. In 2010, the European Space Agency declared 'complete mission success' for GIOVE-A.

SSTL relied on the research carried out at Surrey's Space Centre to design, build and operate the GIOVE-A satellite, specifically research covering the modular mechanical structure, thermal models, power system, on-board data handling system, S-band communications system, three-axis attitude control system using reaction wheels and cold-gas propulsion, electric-resistojet propulsion system for orbit manoeuvring, dynamic control algorithms, and orbital astrodynamics models. Many of these techniques and associated technologies using 'commercial off-the-shelf technologies (COTS) were first developed and then demonstrated successfully in-orbit by Surrey on the UoSAT-12 minisatellite, built at Surrey and launched in 2000, prior to being developed further by SSTL specifically for the GIOVE-A mission.

The research at Surrey into GPS/Galileo signal and timing structures, codes, algorithms and associated receiver/decoder circuits enabled SSTL to design and build a second, independent, UK navigation payload providing increased signal formation flexibility that was flown on GIOVE-A alongside the primary payload supplied by the European Space Agency (ESA). This research has also been exploited by SSTL to provide robust GNSS receivers for use on-board satellites that enable autonomous orbit manoeuvres, significantly increasing the efficiency of use of the limited on-board fuel resources and reducing the cost of orbital operations. Prior to GIOVE-A, a series of space GPS receivers were designed at Surrey and flown in orbit on microsatellite and minisatellite missions to demonstrate and evaluate their performance.

The GIOVE-A mission also could not have been successful without the detailed knowledge gained from the long-term sustained programme of research undertaken at Surrey's Space Centre 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 the European Space Agency (ESA), Surrey's research in radiation effects modelling, 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 Surrey satellites between 1993 and 2006, specified the design and manufacturing requirements for GIOVE-A to survive the extreme radiation environment in its 22,000 km orbit and convince ESA that SSTL's approach largely using commercially-manufactured components was sound.

Research Team: Professor Sir M.N.Sweeting, Professor C.Underwood, Dr S. Hodgart, Dr MJ Unwin, Dr P.Jales

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

1. "Cost Effective Propulsion Systems For Small Satellites Using Butane Propellant." Gibbon D, Underwood C, Sweeting M.N, Amri R. (2002) Acta Astronautica, Vol. 51, No. 1-9, pp. 145-152, 2002.
2. "Intelligent Optimisation of Microsatellite On-Board Power."Baillester-Gurpide I, da Silva Curiel R.A, Sweeting M.N. (2000) Acta Astronautical, Vol. 47, No. 2-9, pp. 275-280, 2000.
3. "Low- cost orbit manoeuvres for minisatellites using novel resistojet thrusters"Sweeting M.N. Lawerence T., Leduc J. (1999), Proc. Insitution of Mechanical Engineers. Journal of Aerospace Engineering Proceedings – partG, Vol 213 pp. 223-231, Jan 1999
4. "Orbital Experiment with the UoSAT-12 SGR Space GPS Receiver." UnwinM, Purivigraipong S, Sweeting M.N. Presented at the 51st International Atronautical Congress. 2-6th October 2000 / Rio de Janerio, Brazil.
5. "Low- cost orbit manoeuvres for minisatellites using novel resistojet thrusters " M.N Sweeting. T Lawerence J.Leduc. PROCEEDINGS OF THE Insitution of Mechanical Engineers. Journal of Aerospace Engineering PROCEEDING PART G. Vol 213 pages 223-231, Jan 1999
6. "Results from the PoSAT GPS Experiment." Unwin M.J, Sweeting M.N. IEEE Position Location & Navigation Symposium 1994, Las Vegas, USA, Apl, 1994, Proc. pp. 598-604.

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

Research carried out by Surrey Space Centre (SSC) based at the University of Surrey and later exploited by SSTL has had a dramatic impact on Europe's (€2B) indigenous timing and navigation satellite system, Galileo (a 'European GPS'). The GIOVE-A satellite, built at Surrey, was the first satellite launched to provide navigation and timing signals for Galileo.

As a result of an innovative unsolicited proposal by SSTL to The European Space Agenct (ESA), GIOVE-A was built in just 30 months against a hard deadline and at a fraction of the competing industry cost, enabling Europe to secure the rights to the key frequency bands critical to the operation of Galileo over the coming decades. GIOVE-A provided the first representative precise timing transmissions from its 22,000 km Earth orbit, enabling European industry to start building and testing commercial consumer products for this market estimated at £90B.

By creating a credible and competitive alternative to a single European consortium, SSTL both

provided resilience and achieved dramatic cost savings for the European tax-payer.

Europe's economy and security is now completely dependent upon space-derived timing signals that are used to control our utilities, rail networks, financial transactions, mobile phone networks and co-ordinate complex manufacturing and distribution logistics, commercial and domestic navigation services – and the ability to support military operations. These signals are currently provided by the USAF military Global Positioning System (GPS) and the loss or degradation of GPS signals would have colossal economic and military impact on Europe. To provide adequate independence and robustness of this critical infrastructure, Europe committed to building its own timing constellation through the European Commission (EC) and ESA. Galileo, intended for operation in 2008, was beset by spiralling cost estimates and extended delays in implementation that allowed competing systems (from China & India) to argue for rights to the frequency bands allocated to Europe for this service alongside the GPS signals. If Europe could not launch and demonstrate navigation signals from orbit by the regulatory deadline of June 2006, their reservation of these critical frequency bands would expire and China could lay claim to them for their competing system. This would have been catastrophic for Europe's commercial and military independence.

In January 2004, ESA signed two contracts for the first Galileo demonstration satellites – one with a consortium of European industries and a second with SSTL – with a deadline of June 2006. Surrey's 600kg GIOVE-A minisatellites was designed and built within a budget of just €30M, making extensive use of the latest 'COTS' electronic components to achieve the very rapid manufacture time and high performance necessary – and at a fraction of the cost. GIOVE-A was launched in December 2005 and successfully generated the first European timing signals in January 2006, five months ahead of the regulatory deadline, thus securing the frequencies for Europe. GIOVE-A performed exceptionally well, providing >95% service availability and all of the mission goals had been fully met by March 2008 when ESA declared GIOVE-A "a full mission success". Despite its intended 27-month design lifetime, the satellite operated for over 7 years, continuing to provide a useful test-bed to the European GNSS and space environment communities. (NB. The competing industrial consortium eventually launched their first satellite 'GIOVE-B' in 2009, over two years later and with a budget of ~€170M).

The real impact of the above was realised when a decision was taken by the European Commission to procure the operational Galileo system (2008). SSTL teamed with the German satellite builder OHB –System to offer the EC a fully operational satellite constellation design based on an enhancement of the GIOVE-A payload. Due to the success of the GIOVE-A mission and the experience gained by Surrey, the SSTL-OHB team was awarded a contract for 14 operational satellites in January 2010 for €560M and, in a second competition in February 2012, the EC awarded the SSTL-OHB team a further €255M contract for 8 additional satellites – in both cases winning against competitive bids by major European space companies. SSTL's work share is valued at ~€320M for the design and manufacture of the 22 complex navigation payloads, based upon GIOVE-A.

SSTL was formed by the University specifically to exploit the research in the Surrey Space Centre. It has since built and launched 40 satellites, earned export revenues of £500M for the UK and created over 620 highly skilled jobs – some 100 staff from the University were transferred to the Company in 2000/2001. The University's shareholding in SSTL was acquired by EADS-ASTRIUM in 2009 for around £50M – believed to be the largest UK University cash spin-out to that date. The synergy of academic research with commercial exploitation achieved by SSC & SSTL has radically changed the economics of space and pioneered a modern small satellite industry worldwide.

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

C1. CEO of SSTL. Contact details provided.

C2. Galileo Project Manager at European Space Agency. Contact details provided.

C3. DG Energy&Transport EU at European Commission. Contact details provided.

C4. BIS Economics Paper No. 3, The Space Economy in the UK: An economic analysis of the sector and the role of policy, February 2010 http://www.bis.gov.uk/assets/biscore/economics-and-statistics/docs/10-624-bis-economics-paper-03 (Specific reference to Surrey: box 2.2 on page-11 and box 5.2 page-67)

C5. http://www.bis.gov.uk/ukspaceagency/missions/galileo-europes-new-satellite-navigation-system

C6. Selection of Media Articles;

http://www.news.bbc.co.uk/2/hi/science/nature/4555298.stm

www.gpsdaily.com/reports/Galileo_pathfinder_GIOVE_A_retires_999.html

http://www.bis.gov.uk/ukspaceagency/news-and-events/2012/Jan/esa-director-general-praises-uk-space-innovation-during-sstl-kepler-building-unveiling

http://www.bbc.co.uk/news/science-environment-17755205

http://ec.europa.eu/unitedkingdom/press/press_releases/2010/pr1001_en.htm