Institution: Liverpool John Moores University

Unit of Assessment: 9 (Physics)

Title of case study: TRANSFORMATION OF A LOCAL ENGINEERING COMPANY THROUGH COLLABORATIVE R&D

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

To survive and grow in a shrinking UK market, the local engineering company SENAR set out to transform itself from a local company into one capable of winning international contracts. This required the company to make quality improvements, update skills and equipment, and develop relationships with international organizations. LJMU brought its programmes of astronomical research and instrumental development at national and international level into a symbiotic relationship with SENAR, collaborating on design and manufacture of advanced instrumentation and developing new capabilities within the company. It thereby:

- entered new markets and won worldwide contracts
- developed the skills and expertise of their workforce
- protected existing high-skilled jobs and created new ones
- won grants to upgrade their manufacturing capabilities
- earned R&D tax credits.

2. Underpinning research (indicative maximum 500 words)

From 1992, Bode has led a research group at LJMU (currently comprising 9 staff) in time-domain astrophysics, that is the study of varying celestial phenomena including Novae, Symbiotic Stars, Supernovae and Gamma Ray Bursts. A key insight made in 1993 was the value of robotically operated telescopes to important research problems in these areas **[Ref 1]**. A fully robotic observatory would address the shortcomings of conventional telescopes in several important areas: (i) rapid response to Targets of Opportunity with subsequent longer-term systematic follow-up; (ii) regular and frequent monitoring of known variable objects, sometimes over long timescales; (iii) multi-frequency campaigns, in particular with spacecraft where the majority of programmes had historically failed to deliver the required complementary ground-based coverage, and (iv) large-scale tasks such as searches for transient sources.

This led to the development of the Liverpool Telescope project (1995 – ongoing), which was conceived as the first multi-instrument robotic telescope that would operate in a completely unmanned fashion **[Ref 2]**. It was funded initially through the EU's European Regional Development Fund with a specific focus on industrial regeneration. Steele and Carter joined the group in 1997 not only to transform the scientific requirements derived from the underpinning research into an engineering specification but also to carry out new research in novel control architectures, scheduling algorithms and instrumentation for a robotic telescope. The ERDF funding led to the formation of a spin out company (Telescope Technologies Ltd – TTL), which at its peak employed over 50 highly skilled staff. ARI staff oversaw the design of a telescope that was scalable in the 2.0-4.0 meter class which incorporated specific technologies that derived from their research into optimising telescope performance and efficiency. These included techniques which achieved stabilised tracking with guaranteed performance (H-infinity control), consistent optical performance (active collimation), consistent operation (self-healing computing), and efficient execution of the highest priority observing programme (adaptive dispatch scheduling with look-ahead).

In parallel with work on telescope design, the ARI has also established a research programme to inspire instrumentation for robotic telescopes, focussing on identifying science problems that can be addressed with novel instrument concepts. As an example of this Mundell (in 2002) and

Kobayashi (in 2005) joined the research group and subsequently developed a leading programme in GRB jet physics **[Ref 3]**. A key research insight obtained in 2006 was the strong diagnostic power of optical polarization in understanding the magnetic field configuration in the burst. This then drove research by Steele into a new instrument concept (the RINGO series of polarimeters) that for the first time allowed the measurement of the polarization of a rapidly fading object by combining a rapidly rotating Polaroid with electron multiplying CCDs and in-house designed fast-trigger electronics **[Refs 4, 6]**.

Capital Investment since project start in 1995 has been ~£9,377,000 (£6,950,000 from LJMU, £887,000 from UK Research Councils, £340,000 from other universities and £1,200,000 from EU/ERDF). In addition project operating costs since 2004 have been ~£5,600,000 (~£3,000,000 STFC, £2,600,000 LJMU)

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

[Ref 1] Bode, M.F. (ed) , "Robotic Observatories", 1995, Wiley Praxis series in Astronomy and Astrophysics, New York (ISBN: 978-0471956907)

[Ref 2] Steele, I.A., Carter, D,. 1997, Proc SPIE **3112**, 223, "Control Software and scheduling of the Liverpool Robotic Telescope"

[Ref 3] * Kobayashi, S, et al., 2007, Astrophysical Journal, **655**, 391, "Inverse Compton X-ray flare from Gamma Ray Burst Reverse Shock" (DOI: 10.1086/510198)

[Ref 4] * Mundell, C.G., et al., 2007, Science, **315**, 1822, "Early optical polarization of a Gamma Ray Burst Afterglow" (DOI: 10.1126/science.1138438)

[Ref 5] * Gaudi, B.S., et al. (including Steele I.A.), 2008, Science, **319**, 927, "Discovery of a Jupiter/Saturn Analog with Gravitational Microlensing", (DOI: 10.11126/science.1151947)

[Ref 6] Steele, I.A. et al., 2010, Proc **SPIE 7735**, 142, "RINGO2: an EMCCD based polarimeter for GRB followup" (DOI: 10.1117/12.856842)

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

SENAR Precision Engineering Ltd (http://www.senar.co.uk/) is a long established (70 years) SME on Merseyside, currently (July 2013) with 33 employees. The need to provide high quality instrumentation to deliver cutting edge research data has driven capability development at the company and has allowed it to (a) enter new markets, (b) upgrade their manufacturing capabilities, (c) safeguard jobs in an area of historically high unemployment and (d) expand and upskill their workforce **[Source 1]**.

Background

The need to develop an agile robotic telescope led to the establishment in 1998 of the university-owned company Telescope Technologies Ltd (TTL) with a specific mandate (through ERDF funding) of industrial engagement and regeneration. SENAR was identified at that time as a potential supplier to the project and through contracts with TTL built the majority of the high value precision mechanical components of the Liverpool Telescope in the period 2001-2004.

Ongoing Impact 2008-2013

This initial work for the Liverpool Telescope provides an ongoing impact for SENAR, still featuring in their advertising as an example of a high-profile/high-technology client. The reputation that SENAR have developed as a result of this has taken them into new international markets in astronomy, particle physics and other advanced opto-mechanical systems. This has led directly to them being awarded contracts in the period 2008-2012 with other international observatories (e.g. work on the new William Herschel Telescope Auxiliary Camera) and CERN (for whom they produced the chain links that carry cooling pipes and electrical cables for the LHC). SENAR are now actively targeting work for STFC on the WEAVE multi-object spectrograph and for ESO on the

E-ELT (European Extremely Large Telescope).

As well as simple reputational impact from their engagement with the LT project, however, we have also made significant efforts to improve their capability. SENAR staff frequently (most weeks) work directly with ARI staff in the design and construction of enhanced instrumentation for the Liverpool Telescope such as the RINGO series of fast readout imaging polarimeters (2008-2012) and the IO:O (2009-2011) and IO:I (2012-2013) Infrared-Optical cameras. As part of this, ARI have worked with SENAR in developing their expertise in machining difficult-to-work specialist materials such as molybdenum and Invar.

A recent (2011) project with SENAR involved the design and manufacture of a large (~1.2m diameter) bearing location ring that had to be stiff yet lightweight. The need for this component arose from a requirement for higher image quality than was being delivered by the LT which was identified in the Robonet research programme to seek out exoplanets through their gravitational lensing effect on background stars (microlensing) **[Ref 5]**. LJMU is a consortium member for this programme. Because microlensing effects are rare events, the project requires that very crowded fields with large numbers of stars must be repeatedly searched for the brief and unpronounced brightening of background stars caused by the chance passage of a low-mass exoplanet across them. This in turn requires the best images. Research through pupil imaging into the image quality delivered by the LT identified a spherical aberration component that could be corrected by offsetting the telescope focal plane. This needed a large locating and spacer ring to be inserted into the telescope structure. ARI and SENAR staff collaborated on the design of this, carrying out Finite Element Analysis on proposed structures while still ensuring the proposed designs were actually feasible to manufacture. This activity allowed the company to earn "R&D tax credits" (value £48,000 in 2011/12). This project also contributed to the success of the company in winning a grant of £20,000 from the local council against a total capital spend of £80,000 to purchase a new, large vertical milling machine. The need for specialist operators of this equipment subsequently directly created two new jobs in the company. In addition, several other posts in the company can be attributed to the work generated by the continuing collaborative relationship between SENAR and ARI. Overall, since 2008 turnover at SENAR has grown by 160% (from £980k in 2008 to £2.6m in 2013) and they now employ 33 staff compared to the 18 they employed in 2008 (delivered against the background of a general engineering recession in the UK) [**Source 1]**.

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

[Source 1] The Managing Director of SENAR Precision Engineering Limited