Institution: THE UNIVERSITY OF LEEDS

Unit of Assessment: 34B Design

Title of case study:

Designing new nonwoven fabrics: The creation of NIRI Ltd and the commercialisation of products for the industrial, healthcare and consumer sectors.

1. Summary of the impact

Professor Stephen Russell's fundamental and applied research on the formation, structure and properties of nonwoven fabrics has directly led to the creation and continued success of the Nonwovens Innovation and Research Institute (NIRI) Ltd a University of Leeds spin-out company. Formed in 2005 to exploit Russell's research, NIRI has grown annual sales revenue to ~£1 million supplying products and services that have enabled many medium-sized enterprises (SMEs) and global public limited companies (PLCs) to launch improved or new products, growing their market share and positively impacting consumers. Additionally, the research has enabled NIRI to independently establish and co-fund new commercial joint ventures that have resulted in the development of new IP (intellectual property)-protected products for improving global health and security. NIRI has grown its workforce to twenty (mainly University graduates) and has been profitable from the first year of trading.

2. Underpinning research

Research by Professor Russell (Professor of Textile Materials & Technology, University of Leeds) between 2003 to 2012 has focused on the manufacturing and process-structure-property relationships of engineered technical textiles and nonwoven assemblies. Four areas of Russell's research are summarised below as key underpinning research:

(i) A University of Leeds research team directed by Russell with PDRAs (Dr Mao, Dr Ahmed and Dr Pourmohammadi) and technician (Mr Rathod) found that high velocity water jets could be used to simultaneously mechanically bond, displace and interconnect fibres in two adjacent webs around tubular templates such that well-defined cavities could be introduced in the cross-section. These cavities within the material, formed into a predefined shape and size can be filled with solids, waxes or gels to functionalise the fabric. Hydrospace™ technology was subsequently patented in 2010 (Nonwoven spacer fabrics, US Patent 7,814,625). In research led by Russell with Elaine Durham (PhD student) [completed 2009] and Professor Eileen Ingham, Institute of Molecular and Biological Engineering (iMBE) it has also been shown that the cavities in the fabric improve cell penetration and distribution in scaffolds for tissue engineering **[1]**.

(ii) From 2003, research by Russell and Dr Ningtao Mao (senior lecturer in School of Design, University of Leeds) examined the relationship between fabric structure and directional permeability, capillarity and absorption. It revealed how fibre arrangement, fibre dimensions and porosity can be manipulated to control fabric properties **[2,3]**. This was important in the context of controlling liquid transport characteristics, which affects the way in which many nonwoven products behave in use. In 2006 such understanding was further developed by Russell in collaboration with engineers in Zelo Creative Ltd and NIRI Ltd to manufacture new fabric composites capable of retaining and internally distributing large volumes of antibacterial fluids for the development of SurfaceSkins [Surface Mountable Delivery Device, World Patent Application 2007135424(A1), 29 Nov 2007], a range of patent-pending disposable hygiene devices that delivers clinical disinfectant/solution on contact, such as the EN1500 alcohol gel currently used in hospitals.

(iii) A Leeds research team led by Russell involving Dr Pourmohammadi (PDRA) and Mr I Ezra (UG dissertation student) using Dyneema fibre supplied by industry (Dr Jacobs, DSM), [*2003 –*

2005] determined the impact resistance properties of hydroentangled fabrics containing high modulus polyethylene fibres, leading to the development of flexible fabrics with good protection characteristics when tested under ballistic and lower velocity conditions **[4]**. Such understanding was further refined and developed by Russell in 2008 for the design of Rollastop™ [Reinforced Material, World Patent Application, WO2009104003(A1), 27 Aug 2009]. The protective fabric met stringent independent slash resistance test standards, and different performance qualities also enabled ultra violet light resistance, flame retardancy and anti-microbial variations.

(iv) Securing funding in 2006 from the Bill & Melinda Gates' Foundation [Grant Number *38519*] **[5]**, and working in collaboration with Dr Bruce Alexander (MD of Xeroshield Ltd at the Roslin BioCentre) and Dr Mao (PDRA), Russell led research at the University of Leeds into new insecticidal fabric constructions enabling development of a revolutionary mosquito net, the world's first to have a non-neurotoxic chemical insecticidal surface **[6]**. The new technology involving mechanical disruption of the insect cuticle using non-toxic materials was showcased by invitation at the Bill & Melinda Gates Malaria Forum, Seattle, USA (October 16-18, 2007). Using the material's structure to induce mosquito mortality, the net avoids the problems posed by insecticide-resistant insects and the need for chemical re-treatment, whilst still maintaining inherent breathability, strength and durability.

3. References to the research

[1] Durham ER, Ingham E., Russell S.J., (2012) Technique for internal channelling of hydroentangled nonwoven scaffolds to enhance cell penetration, *Journal of Biomaterials Applications*, 28(2), 214-249. http://dx.doi.org/10.1177/0885328212445077
The *Journal of Biomaterials Applications* is a peer-reviewed journal devoted to new and emerging biomaterials technologies. The Journal emphasizes the development, manufacture and clinical applications of biomaterials and new developments in biomaterials R&D.

[2] Mao N., Russell S.J., (2003) Anisotropic Liquid Absorption in Homogeneous Two-Dimensional Nonwoven Structures, *Journal of Applied Physics*, 94(6), 4135-4138. http://dx.doi.org/10.1063/1.1598627 The *Journal of Applied Physics* is the American Institute of Physics' journal that publishes significant new experimental and theoretical results of applied physics research. It is subject to normal academic peer review protocols.

[3] Mao N.; Russell S.J. (2003) Modeling Permeability in Homogeneous Three-Dimensional Nonwoven Fabrics, *Textile Research Journal,* 73, 11: 939-944. http://dx.doi.org/10.1177/004051750307301101 *The Textile Research Journal* publishes peer-reviewed papers on new concepts, innovative technologies, and improved understanding of textile materials, processes, chemistry and systems.

[4] Russell S.J., Pourmohammadi A., Ezra I., Jacobs M. (2005), Formation and Properties of Fluid Jet Entangled HMPE Impact Resistant Fabrics, *Journal of Composites Science and Technology*, 65 (6), 899-907 http://dx.doi.org/10.1016/j.compscitech.2004.10.015 *Composites Science and Technology* publishes refereed original articles on the fundamental and applied science of engineering composites.

[5] Development of a New Insecticidal Textile for use in the Control of Malaria Transmission by Mosquitoes**,** *Bill & Melinda Gates' Foundation Global Health Programme Grant*, Number 38519, 2006-2008. http://www.gatesfoundation.org/How-We-Work/Quick-Links/Grants-Database/Grants/2006/05/OPP38519

[6] Alexander B. and Russell S.J. Pest Control Materials, *US Patent Application US20090288334* (A1), www.google.com/patents/US20090288334 Priority date: 28 June 2006 and Pest Control Materials, World Patent Application *WO2012095533* (A1), Priority date: 14, Jan 2011. http://www.google.com/patents/WO2012095533A1

4. Details of the impact

Economic and commercial impact – creation of a new business

NIRI Ltd was set up as a University of Leeds spin-out company in 2005 to directly exploit the research by Russell and develop nonwoven materials that were found to have major applications in industrial, healthcare and consumer markets. NIRI's external impact is reflected by the rapid growth in its global client base and following initial business angel investment of £80K annual sales revenue has increased to ~ £1 million (2013) **[A]** with an operating profit of around 10% of turnover. The company has grown its workforce to 20 staff (mainly textile graduates). NIRI's economic impact has been achieved via three modes of operation: commercial product development for SMEs and international PLCs; licensing of NIRI's proprietary technology developed from Russell's research; and co-funding product development joint ventures. From the outset, Russell has been retained by NIRI Ltd as Technical Director and is seconded 50% FTE by the University to drive the Company's innovation portfolio.

NIRI's work is conducted under strict confidentiality and the international client base (>100) that directly benefits from the company's products and services include the defence industry, major healthcare, food and beverage, hygiene and industrial manufacturing companies **[B]**. Examples of improved commercial products developed by NIRI working with industry clients include a more efficacious blood filter, low adherent wound dressings and tea bags with enhanced permeability. For reasons of commercial confidentiality a full list of companies is not included, but involves large organisations (public limited companies) as well as small-medium size enterprises operating nationally and internationally.

Further evidence of impact – new and improved commercialised products for the industrial, healthcare and consumer sectors

In addition to establishing NIRI Ltd as a successful business, with Russell's research informing product development, proprietary technology and process improvements, NIRI has co-funded joint ventures with other companies to initiate new commercial technologies, all of which have been developed from Russell's underpinning research. These commercial developments can be used as further evidence of impact, through identifying the new and improved nonwoven and textile products in the market and their contribution to improved global health and security.

Below, new products are directly linked to Russell's underpinning research (i), (ii), (iii) and (iv), as referenced in Section 2.

(i) The trialled method of injecting high performance materials within the fabric cross-section to functionalise the structure is evidence of research adding value and functionality to a fabric at the point of manufacture. Hydrospace™ technology has led to the development of a unique nonwoven material that has multiple commercial uses enabling the storage, release or controlled delivery of the contents of the cavities **[C],[D].** It is being commercialised in blood filtration **[E]** and in absorbent hygiene products as part of license and development agreements that have been established with market leading European product manufacturers.

(ii) SurfaceSkins technology was commercialised in partnership with industrial design consultants, Zelo Creative Ltd. Underpinned by Russell's research on nonwoven composites capable of retaining and internally distributing large volumes of fluid such as antibacterial formulations, a range of innovative hygiene devices have been developed to reduce the transmission of Healthcare Associated Infections (HAIs) in critical areas such as hospitals. The products are compression-activated hygiene devices that clip-fit directly to existing door handles and push plates, delivering either antibacterial or viricidal liquids immediately on contact. According to the Health Protection Agency (HPA) over four million people in the EU acquire a healthcare-associated infection (HAI) every year, of whom approximately 37 000 die as a direct result of the infection. About 20-30% of these cases are preventable by better infection and

control procedures **[F]**. Trials by the NHS have successfully demonstrated the effectiveness of SurfaceSkins in killing pathogens found in hospitals and a commercial development and license agreement is under negotiation with a major global healthcare company for launch in 2013/14. The clinical significance of SurfaceSkins has been highlighted by The Clinical Director of Microbiology/Pathology at The Leeds Teaching Hospitals NHS Trust **[G]**.

(iii) Rollastop Secure was developed and commercialised in partnership with Rollatherm International Group based upon the hydroentangled metal-polymer fibrous composite technology developed by Russell. Rollastop Secure provided the first lightweight cut-resistant security roller blind, offering a similar performance to heavy metal shutter protection systems. A supple material that offers greater flexibility, the protective fabric also provided a printable surface leading to wider marketing capabilities, benefitting retailers in particular. Also aimed at protecting domestic properties, the product "is undergoing commercial trials in three major supermarkets and other retailers" **[H]** [text removed for publication].

(iv) Developed with a medical entomologist from Xeroshield Ltd at the Roslin Biocentre, the revolutionary mosquito net is effective against resistant mosquitoes offering a longer-term solution to preventing transmission of malaria. With about 219 million cases of malaria and 660,000 deaths annually (2010), the reach and significance was summarised by the Director of the Bill & Melinda Gates Foundation's Infectious Diseases program before the product was developed: "Entrenched global health problems, such as malaria, require innovative solutions…if successful, this research could produce an important new tool to fight malaria in the world's poorest countries" **[I]**. Professor Russell's expertise on insecticidal net properties has been acknowledged by his appointment as a World Health Organisation (WHO) advisor **[J]**.

5. Sources to corroborate the impact

[A] Annual Accounts of the Nonwovens Innovation and Research Institute Ltd. available from the Managing Director and Finance Director.
[B] Letter from the Managing Director of the Nonwovens Innovation and Research Institute Ltd.
[C] "An introduction to Hydrospace fabrics", product video can be viewed at: http://www.youtube.com/watch?feature=player_embedded&v=ywRg0sSnTbA (accessed 15-08-2013)
[D] "New Hydrospace fabric to open the door for new markets", article about expansion of Hydrospace product range: http://www.fibre2fashion.com/news/fabrics-news/newsdetails.aspx?news_id=61138 (accessed 12-09-2013)
[E] "Taking it to the Blood Bank", article published prior to the world's largest nonwovens exhibition in Geneva (INDEX): http://www.index14.ch/en/news/taking-it-to-the-blood-bank-0-2624 (accessed 25-10-2013)
[F] English National Point Prevalence Survey on Healthcare-associated Infections and Antimicrobial Use, 2011: preliminary data. Health Protection Agency, May 23 2012 the full report can be viewed at http://www.hpa.org.uk/webc/HPAwebFile/HPAweb_C/1317134305239 (accessed 25-10-2013)
[G] Supporting statement from The Head of Microbiology & Clinical Director of Pathology, Leeds Teaching Hospitals NHS Trust.
[H] Letter from The Managing Director of the Rollatherm International Group, UK and product sales website: http://www.rollatherm.com/services (accessed 20-09-2013)
[I] "Leeds receives Gates Foundation grant for material approach to malaria prevention", Reporter Article: http://reporter.leeds.ac.uk/press_releases/current/gates_foundation.htm (accessed 28-09-2013)
[J] World Health Organisation (WHO) letter regarding invitation to act as temporary advisor in a consultation to determine and compare fabric strength and flammability of 10 brands of WHOPES recommended long-lasting insecticidal nets.