Institution: University of Leeds

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

Title of case study: *UltraCane* and *UltraBike*: ultrasonic aids for visually-impaired people (Impact Case Study 3)

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

Research at the University of Leeds led to the development of *UltraCane* – an ultrasonic cane for people who are visually-impaired that gives tactile feedback to the user's hand with progressive non-contact warning of obstacles (ground-to-head) up to 4 m. [text removed for publication]. Testimonials from users describe its transformative nature on their quality of life, giving '*a true feeling of independence*', whilst healthcare professionals commend '*the simplicity of operation and ease of use'*. Furthermore, with a technology mimicking bat echolocation, the *UltraCane* has informed and engaged the wider public in science and engineering through, for example, the BBC '*Miracles of Nature'* series. The technology has also been developed to allow people who are visually-impaired to cycle independently and safely around a cycle track – the '*UltraBike*'.

2. Underpinning research (indicative maximum 500 words)

In the 1990s, the University of Leeds commenced a programme of research led by Professor Brian **Hoyle** on the development of tomographic techniques for industrial process monitoring. In particular, this research focussed on the combination of data from multiple sensors to establish spatial distributions in a range of applications, initially stimulated by industrial interest in monitoring material flow in inaccessible processes, e.g. oilfield flows.

This research gained industrial and research council support, e.g. through the dti-LINK-IMS project '*Industrial 3-component flow measurement using novel tomographic techniques*' (GR/H55741) with UMIST (1993–1996), and EPSRC funding '*Intelligent measurement of velocity profiles in turbulent gas flows using ultrasonic tomographic imaging*' (GR/J49686, 1995). This led to the development of tomographic systems based on ultrasonic sensors in 1996 [1].

Major industrial applications were then targeted through investment from a Foresight Challenge project: '*Process tomography – a new dimension in advanced sensor technology*' (GR/L22591) with thirteen partners, including *AstraZeneca*, *Schlumberger*, *Unilever*, and *Du Pont* (1997–2000), and Hoyle's co-ordination of an EU Thematic Network (BRRT-CT97-5039) on '*Advanced Tomographic Sensors for Industrial Multiphase Imaging*' with 30 partners (1997–2000). This led to the optimization of real-time performance using multiple active sensors in ultrasonic process tomography [2], and the subsequent optimization for two-phase flow imaging [3].

Based on this research, Hoyle assembled, and led, a multi-disciplinary university consortium – the Leeds Ultrasound Research Interest Group (LURIG) – to explore new application concepts (1996–2002). This group included, from Biology, Dr Dean **Waters** who specialized in bat echolocation, and Dr Deborah **Withington**, who specialized in neuroscience, including the perception of sound. Drawing inspiration from their combined backgrounds, it became apparent that there was an opportunity to develop a new medical device based on Hoyle's work on ultrasonic sensors and data fusion techniques [1–3] – a multi-sensor ultrasonic aid to provide range and safety data for people who are visually impaired (VI). (We use the accepted phrase 'visually impaired' throughout this case study to refer to people who have a significant limitation of their visual capability, including those who are completely blind). This innovation became known as *UltraCane*. *UltraCane* (Fig. 1) works through use of two high-quality-factor, ultrasonic sensors, integrated within a cane – these give range data to the nearest obstacle, and provide feedback through two tactile vibrators of hazards in the forward (e.g. people and buildings) and elevated (e.g. overhanging branches) paths.

Through the University's Research and Innovation Services, LURIG filed a patent in 1997 on the *UltraCane* concept, which was later extended to give worldwide coverage [4]. Arising from this, a University spin-out company, *Sound Foresight Ltd*, was formed in 1998, and the patent (which is still maintained) was transferred to the company. *Sound Foresight* gained feasibility and usability trial support from a DTI 'Smart' Award (2000–2002) with *Cambridge Consultants Ltd*. Trials of an early pilot device (four ultrasonic transducers) with VI volunteers confirmed the expected gains in safety and mobility. Leeds then participated in the EU *Euro-Assist* programme supporting innovations for VI people (2005–2008); additional trials emphasized *UltraCane*'s capabilities [5].

Key researchers:
Brian Hoyle (Senior Lecturer, 01/01/1981–31/07/1998; Professor, 01/08/1998–31/07/2012; Research Professor; 01/08/2012–present) – specialized in multi-sensor ultrasound sensing.

Dean Waters (Lecturer, 01/05/1995–31/07/2002; Senior Lecturer, 01/08/2002–30/06/2010, when he left the University) – specialized in bat echolocation.

Deborah Withington (Senior Research Fellow, 23/03/1991–31/07/1998; Principal Research Fellow, 01/08/1998–31/07/1999; Professor, 01/08/1999–31/03/2010, when she left the University) – specialized in neurophysiology and spatial perception.

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

[1] B S **Hoyle**, 'Process tomography using ultrasonic sensors', *Measurement Science and Technology* 7(3), 272–280 (1996). DOI: 10.1088/0957-0233/7/3/007.

[2] W **Li** and B S **Hoyle**, 'Ultrasonic process tomography using multiple active sensors for maximum real-time performance', *Chemical Engineering Science* 52(13), 2161–2170 (1997). DOI: 10.1016/S0009-2509(97)00042-0.

[3] M Yang M, H I **Schlaberg**, B S **Hoyle**, M S Beck, and C Lenn, 'Real-time ultrasound process tomography for two-phase flow imaging using a reduced number of transducers', *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control* 46(3), 492–501 (1999). DOI: http://dx.doi.org/10.1109/58.764834.

[4] B S **Hoyle**, M J W **Povey**, D A **Waters**, and D J **Withington**, *Spatial Awareness Device*, UK Patent Application 9726014.5, filed 9 December 1997; PCT/GB98/03589, filed 1 December 1998; subsequent filings and grant dates: Japan JP2003523775T (2003); US US6710706 (2004); Australia AU757503B and Canada CA2313761 (2005); European EP1 037 583 2004 (followed by all major European state filings).

[5] B S **Hoyle** and D A **Waters**, 14pp, 'Mobility Assistive Technology: The Batcane (UltraCane)', in M A Hersh and M A Johnson (eds), *Assistive Technology for Vision-impaired and Blind People*, Springer-Verlag, London, 2007. ISBN: 978-1-84628-866-1.

Leeds researchers in bold. Outputs 1–3 are all published in internationally leading peer-reviewed archival journals, are recognized internationally in terms of originality, significance and rigour, and are particularly highlighted to underpin the impact described in this case study. Outputs 4 and 5 relate to application of the *UltraCane* technology.

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

Safe mobility is essential for people who are visually impaired (VI). The universal 'long cane' is used worldwide but has major shortfalls, and in particular does not detect elevated obstacles such as tree branches, signage, and ladders. Users must discover obstacles by progressive tapping their cane into them. The alternative is the use of guide dogs, but these are expensive (typically £35k for a 5 year working life), mainly resulting from extensive initial training costs. The *UltraCane* innovation uses ultrasonic sensors and a tactile feedback to the user's hand to provide a ground-to-head safety envelope. Importantly, it gives progressive non-contact warning of obstacles (switchable between 2 m and 4 m away in the direction of travel, and 1.6 m vertically), offering the level of safety, ease of progress and dignity that sighted people have in walking freely.

Following patenting (1997) and early trials of the technology through a DTI 'Smart' award, Hoyle/Waters/Withington received the 2002 award for best 'Healthcare Innovation' at the BBC's Tomorrow's World presentation ceremony, and the Mark 1 product was certified as a medical device. In 2003, *Ultracane* received the Sony sponsored '*Design Application of the Year Award*', and in 2005, it was selected by the Foreign Office as one of eight '*Innovations inspired by nature*' and featured centrally in the UK Pavilion at Japan World Expo, being seen by ~5 million people. In 2006, it received Horner's Award for Innovation from the Worshipful Company of Horners.

[text removed for publication]

Hoyle proceeded to obtain further investment capital from Dr Paul Clark (a former member of the School of Electronic and Electrical Engineering at Leeds). *Comms Design Ltd*, a company founded by Dr Clark in 2004, then provided development support to improve the product [B], including introducing auto-tuning of the transducers, eliminating previous problems with manufacturing reproducibility of high-Q electronic circuitry. This led to the relaunch of *UltraCane* through a new

company, *Sound Foresight Technology Ltd*, founded in February 2010, and based in Harrogate.

In the period 2008 to date, *UltraCane* has led to the following types of impact:

- **Economic impact**, through the sales of product, and the creation of jobs;
- **Health impact**, through the take up and use of a new product that prevents injury and improves the quality of life;
- **Public Policy and Services impact**, through adoption of the product and improving patient care practice for people with VI disabilities;
- **Societal impact**, through the drive for inclusion and equality of people who have a VI disability, by educating the general public, and by engaging the general public in science and engineering.

Economic impact

[text removed for publication]. Each *UltraCane* retails (30 June 2013) at £635 per unit [C]. These have been supplied to 28 countries worldwide, with highest sales in the UK, USA, Australia, Israel and Germany. This has provided both direct and indirect employment and commercial activity in the UK and worldwide. Manufacturing is sub-contracted to *Quality Precision Engineers Ltd*, an electronic systems manufacturing company in Scotland, with sensor technology optimization at *Comms Design Ltd* (commsdesign.ltd.uk); [text removed for publication] [A].

There are approximately 50 organisations worldwide that sell/loan *UltraCane*s for use with their mobility and orientation specialists who, in turn, give training to individual VI people. The product is distributed through a number of channels; directly through the VI accessible web-site (www.ultracane.com), and through its global network of 23 distributors in *Africa*, *South America*, *Central America*, *North America*, *Arabia and Middle-East*, *Australasia*, *China and Far East*, *Europe (North)*, *Europe (West and South)*, *Europe (East)*, *Greece and Cyprus* [A].

Strong growth in sales is now occurring despite the challenges in changing healthcare practice. [text removed for publication].

Figure 1 The *UltraCane* handle showing ultrasonic sensors and feedback buttons.

Figure 2 Dan Smith, completely blind, rides an *UltraBike* through woodland [H,I].

Figure 3 *UltraBike* exhibition in the Science Museum, showing the ultrasonic sensors [I].

Health impact

User testimonials endorse the product, and provide evidence of its significance in improving their quality of life, independence, and ability to avoid accidents and injury. Testimonials include [D]:

"*I got used to using the UltraCane and felt strange when it wasn't there and I couldn't rely on the cues it provided.... By being able to literally feel the environment around me...*" [Ms C Crespin]

"*When using the UltraCane, people thought I was faking being blind, because I would tell them where things were and go around them and navigate well...*" [Ms A Bradstreet]

"*The UltraCane's capacity to detect obstacles … and provide the feedback needed to avoid them, helps to give me the information I need...*" [Mr J McAfferty]

"*The area I visited is highly congested. There is much foot traffic, the footways are crowded and one needs to progress slowly even if fully sighted... I found the UltraCane to be most excellent in this situation. It was constantly keeping me updated about people and obstacles*." [Mr B Campbell]

Public Policy and Services impact

UltraCane was developed in close association with VI organisations, with practitioners praising the product in advancing mobility, safety, and independence for VI people. For example [D]:

"*The developers have taken time to ask blind people, and involve them in trials. I'm convinced it's going to be a real benefit to its blind and partially sighted users*" [Mr A Brooks, New Initiatives

Manager, The Guide Dogs for the Blind Association]

"*What I like about the 'UltraCane' is you have everything right there in one hand – enhanced safety and environmental information...*" [Mr M Corbett, Orientation and Mobility Specialist, USA]

UltraCane has influenced the policies and practice of professionals in the field of mobility and orientation. For example, *Guide Dogs Queensland* run training courses, together with 'Graduation Ceremonies' for new cohorts trained in using the *UltraCane* [E]. Furthermore, *UltraCane* allows employers to support VI staff: "*I'm delighted that one of our own valued employees has been supported in receiving such revolutionary equipment, thanks to the Access to Work scheme*." [Mr P Martin, Leader of Essex County Council] [F]. The technology also provides an alternative to help people, especially teenagers, who consider there to be a stigma in using a conventional cane [D].

Societal impact / Public Dissemination of Science and Technology

UltraCane has featured extensively on national/regional television and radio in the UK and overseas, helping promote science and engineering to the general public, demonstrating how technology can address public health challenges, and illustrating to the general public how VI people can be included through provision of appropriate technology [G]. The connection with bat echolocation has, in particular, proved attractive to the general public, and in Autumn 2012, the *UltraCane* featured in the BBC 1 primetime '*Miracles of Nature*' series presented by Richard Hammond [H]. For this programme, the '*UltraBike*' was developed, in which the *UltraCane* ultrasonic sensors were redesigned by Hoyle and Clark, and adapted by *Sound Foresight Technology Ltd* and *Comms Design Ltd* for use on a bicycle. The *UltraCane's* vertical sensor was replaced by a second sensor facing forward, but offset, allowing the user to determine the direction for steering, and the sensing range was increased (switchably) to 10 m. Mr Dan Smith, who is completely blind, rode an *UltraBike* through a woodland pathway on the programme (Fig. 2) [H,I].

This exposure directly led to *Life Cycle UK* and *Sound Foresight Technology* organizing the world's first cycle event for VI people in Bristol on 22 June 2013 [text removed for publication] [A]. This also led to the current exhibition of the *UltraBike* in the London Science Museum [A] (Fig. 3, [I]), with the public providing on-line feedback [text removed for publication] [A].

Further examples of the international public reach of this technology include an exhibition of the *UltraCane* in the State Museum of Natural History (Munster, Germany) in 2012 [I], and *UltraCane* featuring in a textbook (ISBN 978-3-507-42126-4, published 2012) used in German schools [I].

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

[A] Testimonial from the Head of Sales and Marketing, Sound Foresight Technology Ltd, North Yorkshire, 8 October 2013.

[B] 'Sound Foresight Technology relaunch mobility aid', York Press, 11 October 2011, www.yorkpress.co.uk/news/business/news/9298784.print/, accessed 13 June 2012.

[C] 'Our range of *UltraCane* products', www.ultracane.com/ultracanecat, accessed 11 Nov 2013.

[D] *UltraCane* 'User Testimonials' Brochure, Sound Foresight Technology Limited (most also available on www.ultracane.com, accessed 16 August 2012).

[E] 'Blind woman regains independence', Bundaberg News Mail, 17 October 2011, www.news-mail.com.au/news/blind-woman-regains-independence/1139156/, accessed 4 Nov 2013.

[F] 'Techo boost for blind Geoff', Chelmsford Weekly News, 21 October 2012, www.chelmsfordweeklynews.co.uk/news/9993306.print/, accessed 29 January 2013.

[G] BBC footage: 19 October 2011 (www.bbc.co.uk/news/health-15363976); 16 July 2013 (www.youtube.com/watch?v=59okFDRY1pk). BBC Radio 4: 9 July 2013 (transcript available).

[H] BBC 'Miracles of Nature', DVD, Acorn Media, UK, 2012.

[I] www.ultracane.com/news, accessed 31 October 2013.