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GUEST EDITORIAL

From research to engagement to translation: words are cheap. Part 2 – a case study

Timothy G. Leighton

Institute of Sound and Vibration Research, University of Southampton, Southampton, UK

Introduction

The first of these paired editorials[1] introduced 'the virtuous circle', where taxpayer funded research, including that in the surface finishing field, can produce benefits to society, which in turn not only benefits the health of society as a whole and its individual members, but also generates tax income that can be re-invested into the research and development base to continue this onward progress. It argued that a risk-averse approach hindered this, but was what the current drivers in the system produced, rewarding sponsors and researchers alike for avoiding accumulating a record of 'failed' high-risk projects. This approach leads to an underestimation of the cost to society of proper translation of research across the 'valley of death' between academia and society. It will also lead to investment in the appearance of societal benefit (vanity spin-outs, valueless patents, and the substitution of high-impact-factor publications in place of real societal change). The challenges in the journey, from fundamental research to societal benefit and contributions to the 'virtuous circle', will be illustrated through one case study.

Case study: Sloan Water Technology Limited (SWT)

Just as with publication and public engagement, on the road to translation there are changelings that should not stand proxy in place of a genuine push for societal and Treasury benefit. These include patent applications that are never granted, patents granted that sit idle until they expire, and vanity spin-outs that will never expand to become genuine employers or producers. Even the extravagant sums claimed for the sale of spin-outs can hide zero societal gain: sales can simply be made to larger competitors that wish to bury a rival technology. Before selecting a funder for SWT, I turned down dozens of short term investors whose proposed model was to form a company (shared 50–50 between us) with a nominal value of £1 M, then (after I had done a year of advertising) declare that the company had grown in value, and we were looking for an investor to buy half of it for £10 M. That sale would reduce my share to 25%, but now of a real £10 M. After two rounds of this, the investor and I could sell and be rich, but no jobs or products would have been created. If we rely on short term investors we will be driven by short term profit. Even in large companies, too much emphasis on short-term profit can be detrimental to society – this has led us to the state where there are hundreds of new cancer drugs in development, but those concerned with antimicrobial resistance still ask 'where are the new antibiotics?', despite the fact that many successful treatments for cancer depend on successful control of infections.[2]

If not by short term investment, what was the route from fundamental research to company, that was undertaken for the technology in the paper by Malakoutikhah *et al.*[3] It was a long journey: I began to wonder about the interaction of sound with bubbles in 1984 on hearing a countryside babbling brook[4] (Figure 1a), which led to an interest in using sound in the oceans to estimate the exchange of atmospheric gases (particularly CO_2) between air and sea (for applications in climate change and ocean acidification),[5–7] leading to at-sea measurements 20 years later (Figure 1b,c) that revealed substantially higher dissolution of CO_2 from atmosphere to oceans than is assumed by current climate change models,[8] and produced sensors to support its mitigation.[9–11]

However, early in the course of developing sensors[5–7,12] for these ocean studies, in the late 1980s I discovered the new acoustic signal[13] that led directly to the invention described by Malakoutikhah *et al.*[3] That signal was at a frequency $\omega_i \pm \omega_p/2$ and was scattered off a bubble when it was driven by two acoustic frequencies, a 'pump' frequency ω_p close to the bubble resonance for its pulsation mode of oscillation, and an 'imaging' signal ω_i having a frequency two or three orders of magnitude higher than ω_p. The ability to stimulate $\omega_i \pm \omega_p/2$ allowed me to deduce that the pump field was generating cyclostationary scattering of the imaging field by exciting surface waves[14,15] on the walls of a bubble (see Figure 4 of Malakoutikhah *et al.*[3]). Such waves generate[16] local circulatory liquid currents, pressure and shear, which act as three 'agents of change' that could affect liquids and solids close to the bubble (example changes being cleaning and healing the solid). The clear implication was that, whilst the basic science relating to these 'agents of change' could be published without jeopardising the ability to later mass produce technology to deliver these benefits on a societal scale, what could not be published (until patents were secured) were the inventive steps to deliver these 'agents' to the target that required changing (i.e. the 'vectors of change', that is, the ultrasound and bubbles). The tension between the two (publishing and patenting) is at the heart of my strategy to produce societal benefit from the scientific discovery,[1] and required publication of some elements to be withheld for many years.

Elements of new knowledge on the 'agents of change' that could be published from the fundamental research undertaken to underpin this technology, covered:

CONTACT Timothy Leighton tgl@soton.ac.uk

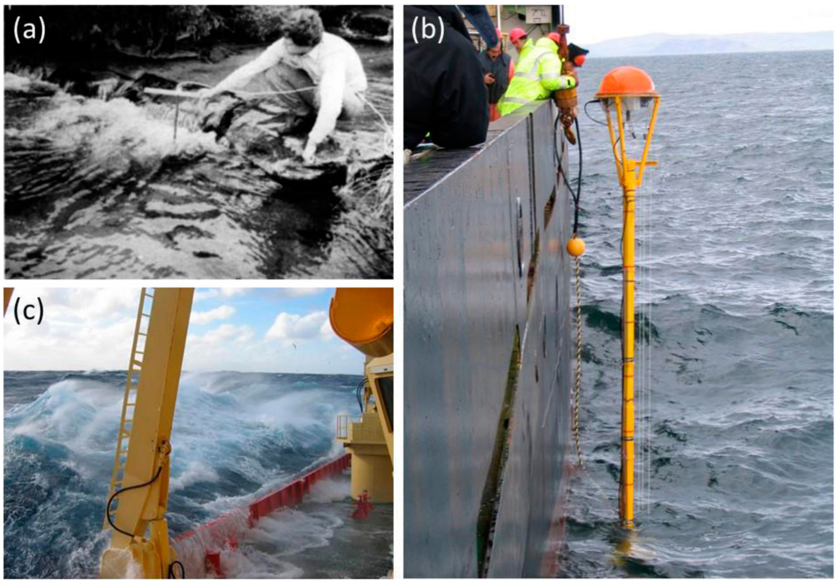

Figure 1. (a) The author in 1985 holding a hydrophone (the submerged tip at the end of the vertical dark rod bisecting the white horizontal handle) in a brook running from Kinder Scout in the Peak District (Derbyshire. UK) to detect bubbles (from Leighton and Walton[4]). (b) A more sophisticated version of substantially the same experiment being launched from the side of *RRS Discovery* in 2007, in a trial deployment in calm seas off Scotland, before this equipment was deployed to monitor storms in the Atlantic (panel (c)), a deployment that discovered a far larger asymmetry in the amount of atmospheric CO_2 that dissolves into the ocean as opposed to the amount that leaves it and returns to the atmosphere, than had previously been believed (after Leighton *et al.*[8]).

- the conditions required to stimulate the surface waves on the bubble wall;[16–18]
- the shear and microstreaming that the surface waves can induce;[16,19–22]
- the use of acoustic radiation forces to drive the bubbles towards targets, and into cracks and crevices in that target that are normally resistant to traditional ways of cleaning (by wipes and brushes),[16,22–25] requiring foundational research in the propagation of ultrasound through porous materials (that in turn led to the first theory to show why passing ultrasound through different directions in the human ankle could monitor bone health, e.g. for osteoporosis[26]);
- the way the ultrasound could be pulsed to enhance the effects it had on targets and cells;[16,27]
- the use of ultrasound to manipulate, relocate, and affect the viability of, living cells.[16,28–30]

Furthermore, whilst they could not be published directly without jeopardising the ability to use them to bring about societal benefit, advances in delivering the 'vectors of change' led to outcomes that could be published for the benefit they produced in other topic areas. Examples include the way the underpinning knowledge discovered for this technology could be applied to extra-terrestrial and oceanic environments, such as on the topics of:

- the propagation of sound down a curved fluid column, and how horns and cones could facilitate this (discoveries that are used in the device,[3] but published for their ability to allow the sounds of voices and musical instruments on other planets to be simulated, a capability that has since been distributed to planetaria for their Outreach);[31–34]
- the acoustic losses in water surrounded by a pressure-release interface (used in the device,[3] but also used to improve maritime safety);[35]
- the propagation of sound in bubbly water contained in a vessel that supports coupled modes (used in the device,[3] but also for example, to support safety of the liquid mercury coolant containment system at the world's largest pulsed spallation neutron source, costing US$1.4 billion).[34,36–40]

Premature publication of other aspects of the 'vector' discoveries would have prevented patenting, which was required if the technology was to benefit society: without the protection of a patent, a manufacturer cannot sell the first products at a price that recoups the decade of research and development they paid for before ever any sales income came in, because a competitor (who is not pricing to recoup those R&D costs) can reverse-engineer a product and sell for a lower price.[1] Premature publication therefore can dissuade any industry from making the necessary investment in R&D.

The low cost (under £300) to process the filing of a patent is often touted as an attractive feature, but this is another misleading factor. If a few thousand pounds are not also spent on hiring professionals to help draft the patent, it may be too weak to be granted. Depending on the route taken 1 year after filing (UK only filing, or Patent Cooperation Treaty etc. costing up to a few thousand pounds), ~12–30 months after the initial filing, a separate filing must be made in each country, which will cost thousands, perhaps tens of thousands, of pounds. The patent application is then examined in each of those countries, and each defence costs the fees of lawyers and patent fees. After this, the application for that country might be rejected or granted, and only if it is granted does it have real worth. The criterion for 'should I file a patent' should not be 'is this novel' but rather 'do I have a strategy to earn tens of thousands of pounds from this in a few years, to pay the costs to get it granted, and is it likely to be granted?'. A patent that is not granted has little worth, and in assessing the translation of a technology it is vital to distinguish whether a patent is granted and live, applied for and being examined, or applied for and dropped (because it was rejected at examination, or because funds were inadequate to pursue it). The phrase 'I have patented' is frequently used for all these scenarios, but only one has real value.

As regards the technology described by Malakoutikhah *et al.*,[3] once the patents had been published (which occurs ~18 months after filing), publications on the first device could be made, although extra delay can be useful to accrue funds and evidence to bolster the inventor against the almost inevitable attacks from large threatened companies. That first publication[41] on the device included proof-of-concept validation for cleaning baby equipment[41] and kitchens,[41] followed by validation for cleaning hands,[21] food packaging[21] and pipework,[21] tools,[21] grease,[21] and rail components.[21]

Collaboration with electrochemists allowed exploration of the option of electrolytic bubble generation. Expansion of the multidisciplinary team to include microbiologists, biomedical researchers and surface engineers allowed proof-of-concept testing for reducing the railway hazard from 'leaves on the line',[42] removing marine biofouling,[43] and for cleaning salad[44] and other foodstuffs.[45]

Patenting also allowed the technology to be advertised, and a small number of demonstrator units to be made under licence by Ultrawave Ltd. By using these to demonstrate the potential of the technology, commercial funds were secured for the long-term vision. In 2018, Sloan Water Technology Ltd, a new UK company, was formed, the author's patents being purchased from the University of Southampton. In the 1984–2019 period of research after the original discovery towards direct development of this device, whilst funds were obtained for offshoots of the work (in climate change,[8] nuclear technology[34,37–40] etc.), no RCUK or EU application for funding to support development of the technology[3,21] was ever successful, despite applications in 2018 and 2019 specifically warning of a future pandemic and outlining the need to invest in such technology[3] to make the washing of hands, doorhandles, keypads, Personal Protective Equipment and wounds etc. more effective against all microbes (viruses, bacteria, fungi, parasites etc.) and so reduce person-to-person transmission. Such lack of success cannot be laid at the door of the funding bodies, since the proposals were made untenable by poor peer reviews from the academic community. We as a community must embrace the concept that supporting some research that provides income to the Treasury in the 8–20 year timeframe, supports academia as a whole, by introducing new tax revenue into the virtuous circle.

Conclusions

A proportion of taxpayer-funded research must produce societal benefit and commercial returns to ensure sustainability of the source of that funding. The generation of such benefits is assisted by a well-rounded approach to ensure that the research questions are drawn up using appropriate engagement with end users, and that the results are translated. It should be realised that to take a promising research breakthrough to the point where it can be delivered cost-effectively to millions of people, usually takes tens of millions of pounds (for development work, trials, the provision of suitable manufacturing and distribution facilities, with commensurate years of staff costs), all of which must be spent before any income is generated from the sales themselves.[1] The initial product price will include an element to pay back that investment, and therefore a manufacturer must be protected (e.g. through patenting) from a competitor who did not make such an investment, but who might purchase and copy the product and sell it more cheaply. Failure to protect intellectual property would therefore kill off the early stage investment necessary to take research breakthroughs to millions of people.

We should not fool ourselves that we have solved societal needs with a spin-out that simply raises money without generating the promised products. We should not be satisfied with a journal paper that purports to offer a solution to a societal problem but whose authors expect someone else to discover the paper and make that solution when no handover has been made and no intellectual property has been protected (or, indeed, when it has been compromised through publication). When future impact is discussed, a good dose of pessimism (to discuss budgets, timescales and the local problems with eventual deployment in terms of training, infrastructure, warlords, culture, security of water and electricity, behaviour etc.) is needed to balance the optimism that was necessary to embark on the research. Above all, a good dose of realism and sound judgement, on what research can produce societal benefit and new tax revenues, and what is needed to achieve these, is vital amongst the academic community, because these things fuel the virtuous circle for research.

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Disclosure statement

No financial interest or benefit has arisen from the direct applications of this article, although it does provide opinion on attitude when funding research, and in this context I hold a University position. It also advocates supporting the conduct of ground-breaking research and then translating it through on a societal scale, and in this context I am a Director and Inventor-in-Chief of Sloan Water Technology Ltd. (from which to date I have taken no salary).

ORCID

Timothy G. Leighton http://orcid.org/0000-0002-1649-8750

References

1. T. G. Leighton: *Trans. IMF*, 2020, **98**, (4), 161–164.
2. L. J. V. Piddock: *Lancet Infect. Dis*, 2012, **12**, 249–253, doi:10.1016/51473-3099(11)70316-4.
3. M. Malakoutikhah, C. N. Dolder, T. J. Secker, M. Zhu, C. C. Harling and T. G. Leighton: *Trans. IMF*, 2020, **98**, (5), 259–271.
4. T. G. Leighton and A. J. Walton: *Eur. J. Phys*, 1987, **8**, 98–104.
5. A. D. Phelps and T. G. Leighton: *J. Acoust. Soc. Am.*, 1996, **99**, 1985–1992, doi:10.1121/1.415385.
6. A. D. Phelps, D. G. Ramble and T. G. Leighton: *J. Acoust. Soc. Am.*, 1997, **101**, (4), 1981–1989, doi:10.1121/1.418199.
7. A. D. Phelps and T. G. Leighton: *IEEE J. Oceanic Eng.*, 1998, **23**, (4), 400–410, doi:10.1109/48.725234.
8. T. G. Leighton, D. G. H. Coles, M. Srokosz, P. R. White and D. K. Woolf: *Scientific Reports*, (*Nature Publishing Group)*, 2018, **8**, article 8301, doi:10.1038/s41598-018-25818-6.
9. 7G Leighton and P. R. White: *Proc. Roy. Soc. A*, 2012, **468**, 485–510, doi:10.1098/rspa.2011.0221.
10. J. Blackford, H. Stahl, J. Bull, B. Berges, M. Cevatoglu, A. Lichtschlag, D. Connelly, R. James, J. Kita, D. Long, M. Naylor, K. Shitashima, D. Smith, P. Taylor, I. Wright, M. Akhurst, B. Chen, T. Gernon, C. Hauton, M. Hayashi, H. Kaieda, T. Leighton, T. Sato, M. Sayer, M. Suzumura, K. Tait, M. Vardy, P. White, and S. Widdicombe: *Nature Climate Change*, 2014, **4**, (11), 1011–1016, doi:10.1038/nclimate2381.
11. B. J. P. Berges, T. G. Leighton and P. R. White: *Int. J. Greenhouse Gas Control*, 2015, **38**, 64–79, doi:10.1016/j.ijggc.2015.02.008.
12. T. G. Leighton, D. G. Ramble and A. D. Phelps: *J. Acoust. Soc. Am.*, 1997, **101**, (5), 2626–2635, doi:10.1121/1.418503.
13. T. G. Leighton, R. J. Lingard, A. J. Walto and J. E. Field: *Ultrasonics*, 1991, **29**, 319–323.
14. A. D. Phelps and T. G. Leighton: *Acta Acustica*, 1997, **83**, 59–66.
15. D. G. Ramble, A. D. Phelps and T. G. Leighton: *Acustica with Acta Acustica*, 1998, **84**, (5), 986–988.
16. T. G. Leighton: The acoustic bubble, Academic Press, San Diego, 640 pages. 1994. ISBN 0124419208.

17. A. O. Maksimov and T. G. Leighton: *Acta Acustica*, 2001, **87**, (3), 322–332.
18. A. O. Maksimov and T. G. Leighton: *Proc. Roy. Soc. A*, 2012, **468**, 57–75, doi:10.1098/rspa.2011.0366.
19. T. G. Leighton: *Internat. J. Modern Phys. B*, 2004, **18**, (25), 3267–3314 (Invited Review Article), doi:10.1142/S0217979204026494
20. T. G. Leighton: *Progr. Biophys. Mol. Biol.*, 2007, **93**, (1–3), 3–83, doi:10.1016/j.pbiomolbio.2006.07.026
21. T. G. Leighton: *Acoustical Soc. Amer.*, 2015, **24**, (070006), doi:10.1121/2.0000121
22. T. G. Leighton: *J. Phys: Conf. Ser.*, 2017, **797**, (2017), 012001 (23 pages), doi:10.1088/1742-6596/797/1/012001
23. T. G. Leighton, A. J. Walton and M. J. W. Pickworth: *Eur. J. Phys.*, 1990, **11**, 47–50.
24. T. G. Leighton, M. J. W. Pickworth, A. J. Walton and P. P. Dendy: *Phys. Med. Biol.*, 1988, **33**, (11), 1239–1248, doi:10.1088/0031-9155/33/11/002.
25. A. O. Maksimov and T. G. Leighton: *J. Acoust. Soc. Am.*, 2018, **143**, 296–305, doi:10.1121/1.5020786.
26. E. R. Hughes, T. G. Leighton, G. W. Petley and P. R. White: *Ultrasound Med. Biol.*, 1999, **25**, (5), 811–821.
27. M. J. W. Pickworth, P. P. Dendy, T. G. Leighton and A. J. Walton: *Phys. Med. Biol.*, 1988, **33**, (11), 1249–1260.
28. M. J. W. Pickworth, P. P. Dendy, P.R. Twentyman and T. G. Leighton: *Phys. Med. Biol.*, 1989, **34**, (11), 1553–1560.
29. T. G. Leighton, M. J. W. Pickworth, J. Tudor and P. P. Dendy: *Ultrasonics*, 1990, **28**, 181–184.
30. R. O'Leary, A. M. Sved, E. H. Davies, T. G. Leighton, T.G. Wilson and J. B. Kieser: *J. Clinical Periodontol.*, 1997, **24**, 432–439.
31. T. G. Leighton and A. Petculescu: *Acoustics Today*, 2009, **5**, (3), 17–29.
32. T. G. Leighton: *J. Acoust. Soc. Am.*, 2009, **125**, (5), EL214–EL219 (*JASA Express Letters*), doi:10.1121/1.3104628.
33. T. G. Leighton, N. Banda, B. Berges, P. F. Joseph and P. R. White: *J. Acoust. Soc. Am.*, 2016, **140**, (2), 1469–1480, doi:10.1121/1.4960785.
34. J. Jiang, K. Baik and T. G. Leighton: *J. Acoust. Soc. Am.*, 2011, **130**, (2), 695–706, doi:10.1121/1.3598463.
35. S. D. Richards, T. G. Leighton and N. R. Brown: *Proc. Roy. Soc. A*, 2003, **459**, (2038), 2153–2167.
36. T. G. Leighton, D. G. Ramble, A. D. Phelps, C. L. Morfey and P. P. Harris: *Acustica with Acta Acustica*, 1998, **84**, (5), 801–814.
37. T. G. Leighton, K. Baik and J. Jiang: *Proc. Roy. Soc. A*, 2012, **468**, 2461–2484, doi:10.1098/rspa.2012.0053.
38. K. Baik, J. Jiang and T. G. Leighton: *J. Acoust. Soc. Am.*, 2010, **128**, (5), 2610–2624, doi:10.1121/1.3495943.
39. K. Baik, J. Jiang and T. G. Leighton: *J. Acoust. Soc. Am.*, 2013, **133**, (3), 1225–1236, doi:10.1121/1.4773863.
40. K. Baik, T. G. Leighton and J. Jiang: *J. Acoust. Soc. Am.*, 2014, **136**, (2), 502–513, doi:10.1121/1.4881922.
41. T. G. Leighton: *Proc. Inst. Acoust.*, 2014, **36**, (3), 58–86.
42. L. Goodes, T. Harvey, N. Symonds and T. G. Leighton: *Surf. Topogr.: Metrol. Prop.*, 2016, **4**, (3), 034003, doi:10.1088/2051-672X/4/3/034003.
43. M. Salta, L. Goodes, B. Mass, S. Dennington, T. Secker and T. G. Leighton: *Surf. Topogr.: Metrol. Prop.*, 2016, **4**, (3), 034009, doi:10.1088/2051-672X/4/3/034009.
44. T. G. Leighton: Climate change, dolphins, spaceships and antimicrobial resistance – the impact of bubble acoustics. *Proceedings of the 24th international congress on sound and vibration*, 2017, ICSV24 (23–27 July 2017. London; Editor, B. Gibbs) ISSN 2329-3675; ISBN 978-1-906913-27-4; paper no. 6.
45. T. G. Leighton: *Baking Europe*, Summer 2018, 24–28. http://www.bakingeurope.eu/OnlinePublication/Summer2018/mobile/index.html