Institution: Coventry University

Unit of Assessment: 34

Title of case study: Microcab: realising a hydrogen economy

1. Summary of the impact

Professor **Jostins**' research has produced dual electric/hydrogen-powered vehicles to address urban pollution. The research has delivered impact by pushing the boundaries of alternative fuels design and technology, by supporting the economic prosperity of the automotive industry and its supply chain and by influencing policy makers to invest in hydrogen. From a quarter scale model in 1998, it and subsequent iterations have had significant impact. Highlights include deployment of the UK's first hydrogen vehicle fleet in 2009, nomination for the Condé Nast Award: Innovation & Design in 2012 and the invitation to join the SWARM project (a demonstration of small four-wheeled fuel cell vehicles, http://swarm-project.eu/home.html) as a pan-European hybrid vehicle demonstrator, 2012. **Beneficiaries** include Horizon Fuel Cell, Westfield and Lotus (new products developed), and the South African and Scottish Governments (hydrogen economy developed).

2. **Underpinning research**.

Coventry's transport design research and production expertise was a strength highlighted in RAE2008. **Jostins** has been at the heart of Coventry's niche vehicle design and production research since he joined in 1990. During this time Microcab has progressed from an initial quarter scale concept design in 1998, through a small fleet of prototype test vehicles (Microcab Series 1), to a fleet of commercially operated lightweight vehicles with a range of 180 miles in 2013 (Microcab Series 2). A major feature of Series 2 is a hybrid dual fuel electric/hydrogen powertrain, in contrast to the single fuel hydrogen Series 1 powertrain. The trajectory from Series 1 to Series 2 required a complete redesign of the entire vehicle, as well as its powertrain. The research has included the development of production infrastructure, culminating in the international distribution of 10 vehicles with a 3kW Proton Exchange Membrane Fuel Cell (PEMFC) and Lotus-sourced chassis.

The scale of the research which led to the Series 1 Microcab was such that it warranted a single magnum opus return in the RAE 2008. Positive economic and social impacts from the research evidenced the feasibility of incorporating hydrogen vehicles into the global transport mix, and the potential for a new market opportunity for the platinum, fuel cell and wind energy sectors. Microcab series 2 has been specifically designed within the current census period as a small, lightweight urban and peri-urban vehicle. It's design has incorporated a brand new powertrain, and the ability to cover average urban journey ranges.

To take the research from initial design to full EU-type approval in 2010 required a Research and Development (R&D) grant-funded budget of less than £3m. This compares very favourably with larger Original Equipment Manufacturers (OEM), who have R&D spends typically in excess of hundreds of millions of pounds *and* are a long way behind Microcab: they are planning at present release dates between 2015 and 2018 for production versions of hydrogen fuel cell cars. The R&D focused on usable design and ergonomics, availability, practicality, robustness, affordability, and avoidance of the risk associated with emerging 'exotic' technologies. Government, energy, automotive, and academic experts were engaged at international levels to leverage world class skills and expertise. These collaborations improved the speed of delivery and reduced the budget.

The research has been developed over a number of phases:

- 1999: Early designs with light 3-wheel electric format led to hydrogen fuel cell-powered model called H3, sponsored by DTI SMART funding in 2002. Research challenge: urban air pollution
- 2004: First prototype of the H4 fuel cell vehicle and University spin-out company, Microcab Ltd. Research challenge: production potential of hydrogen vehicles.
- 2008: Installation of the UK's first Hydrogen filling station at the University of Birmingham and closed campus trial of 5 Series 1 Microcab, sponsored by DTI & DECC. Research challenge: key energy priorities of cost competitive carbon emission reductions and the security of supply.
- 2011: Complete Vehicle re-design resulting in Series 2 Microcab, to address challenges highlighted in earlier trials, sponsored by the Niche Vehicle Network. Eight vehicles trialled with full EU Type approval and Hydrogen filling station installation: Coventry 2009/12, sponsored by DECC and TSB, representing the first large scale trial of H2 urban vehicles in the UK. Microcab collaborated with Westfield, Potenza and Lotus to develop their own R&D for 'green' vehicles and received technical support from TATA. Research challenge: improving consumer

acceptance and earlier design issues.
- 2012: European trial of Series 2, sponsored by the European Commission. Horizon fuel cell engineering research is the company's first transport venture (current business is fuel cells for small devices). Research challenge: extending the hydrogen highway infrastructure.
- 2012: Microcab Scotland Ltd set up to provide vehicles, using green hydrogen. Research challenge: Microcab as an efficient storage solution for wind energy.
- 2012: **Jostins** adviser to the South African Hydrogen Economy steering group. Research challenge: to develop a hydrogen economy, adding value to the country's platinum resources.

3. References to the research

1. **Tovey**, M. (2002), Concept design CAD for the automotive industry, *Journal of Engineering Design*, 13 (1), pp. 5-18, ISSN: 0954-4828. Doi: http://dx.doi.org/10.1080/09544820110090287 IF = 0.912 (SJR) IF = 1.807 (SNIP).
2. Kendall, K, Pollett, B and **Jostins,** J. (2008). 'Hydrogen Hybrid Vehicles for University of Birmingham Campus' in Hybrid and Eco-Friendly Vehicle Conference, 2008. IET HEVC - IET Conference Publications (546 CP) ISBN: 978-1-84919-008-4 Citations = 0
3. **Tovey**, M., (6 October 2009), "Design support for Niche Vehicles taking Microcab as an example". Design as an Expression of Creativity and Innovation, Brussels.
4. **Tovey**, M, (2010) 'The Design and Development of Microcab' In Proceedings of 'Design and Complexity', The Design Research Society Biennial Conference, Montreal (www.drs2010.umontreal.ca). http://www.drs2010.umontreal.ca/data/PDF/117.pdf
5. **Tovey** M, **Jostins** J (2010) 'The Design Development and Trial Testing of Microcab', Proceedings of 'TMCE 2010 Tools and Methods of Competitive Engineering International Symposium', Delft University of Technology: Netherlands. Vol.2, pp. 1189-1197. ISBN: 978-90-5155-060-3
6. Kendall, K., Pollet B.G., Dhir, A., Staffell, I., Millington, B and **Jostins,** J. (2011) Hydrogen Fuel Cell Hybrid Vehicles (HFCHV) for Birmingham Campus. *Journal of Power Sources* 196 (1), Pp. 325–330, ISSN: 0378-7753, Doi: http://dx.doi.org/10.1016/j.jpowsour.2009.12.012 IF = 1.975 (SJR) IF = 1.879 (SNIP). Citations = 3
7. **Tovey**, M. (2012) 'The Design and Development of Microcab: A Case Study', in **Tovey**, M (ed), *'Design for Transport: A User Centred Approach to Vehicle Design and Travel' in the Design for Social Responsibility Series*, Farnham: Gower Publishing, pp. 253-270, ISBN: 978-1-4094-3325-5
8. Fisher, P, **Jostins**, J, Hilmansen, S, Kendall, K. (2012) 'Electronic integration of fuel cell and battery system in novel hybrid vehicle', *Journal of Power Sources*, 220, pp.114-121, ISSN: 0378-7753, Doi: http://dx.doi.org/10.1016/j.jpowsour.2012.07.071 IF = 1.975 (SJR) IF = 1.879 (SNIP). Citations = 2

Selected Key Research Grants and Reports

PI: **Jostins** with Co-applicants University of Birmingham, Westfield Potenza, RDM automotive and others. Title: The Hydrogen, Fuel Cells and Carbon Abatement Technologies (HFCCAT) Demonstration Scheme. Period: 1/4/08-30/6/10. Sponsor: DTI. Total funding of £1.3m

PI: **Jostins**. Title: Niche Vehicles Partnership and R&D Programme. Period: 2009 Sponsor: ERDF: Advantage West Midlands. Total funding of £200,000

PI: **Jostins**. Title: Coventry and Birmingham Low Emissions Vehicle Demonstrator programme (CABLED). Period: 2009 – 2011. Sponsor: ERDF: Advantage West Midlands and the Technology Strategy Board. Total funding of £1.1m

Co-I: **Jostins**. Title: SWARM: Demonstration of Small 4-Wheel fuel cell passenger vehicle Applications in Regional and Municipal transport in the UK, the Brussels area and Wallonia, and the Weser-Ems region in North West Germany. Period: 01/10/12 – 30/09/15. Sponsor: European Commission Joint Technology Institute. Total funding of £374,474 to Coventry

Co-I: **Jostins** as Microcab Ltd. Title: Mu-Tool. Period: 1/12/2011 – 30/11/2013. Sponsor: European Commission. Total funding of €1,160,500

3. **Details of the impact**

Impact on Alternative Fuels Car Design and Technology: Microcab research has influenced policy decisions related to hybrid hydrogen and electric vehicles in the UK, Europe and South Africa. In the UK, the government allocated £400 million to deliver programmes intended to place the UK at the global forefront of ultra low carbon vehicle development, demonstration, manufacture and use, under the DfT's 'Transport Carbon Reduction Delivery Plan' March 2010. Microcab was

chosen as a key delivery partner in this programme, with an allocation of £2.4m. This supported the design, development, trialling and evaluation of Microcab vehicles in real world environments. Research findings have had significant impact on transport policy in terms of realising the potential of hydrogen and electric vehicles as a viable element of the transport mix; and this has happened earlier than predicted by the Office for Low Emissions Vehicles (OLEV) in its technology roadmap 2010, where H2 vehicle deployment was initially planned for 2020. Microcab released ten Series 2 vehicles to the general public for hire purchase in July 2013, two years ahead of the major companies and seven years ahead of the initial technology roadmap. The collaborations mentioned above have helped to progress the project to a point where Microcabs are being built and sold to end-users; however, new partnerships with Lotus, which constructs the chassis, will make future mass production options for Microcabs more realistic. The next phase will thus see a shift to a focus on production methods, tools and manufacturing techniques required for low cost mass production, rather than low volume production by OEMs.

Environmental Impact: Microcab addresses the need to increase the uptake of low carbon vehicles and to improve urban air quality. To achieve this result Microcab has collaborated with a wide range of industrial partners. Transport represents 23% of global CO2 emissions (OECD, International Transport Forum, 2010). Microcab makes a substantial contribution to road transport design in that it is the only example in the UK of hydrogen vehicle production with full EU Type approval. Worldwide it is the only example of a hydrogen vehicle that has been developed on a budget under £3 million and has been designed for urban use only (to benefit from reduced size, weight and range); it is the first to use a 3 kW Fuel Cell – compared to a 90 kw fuel cell on the Mercedes B class. To date 16 vehicles have been produced and evaluated. It is particularly timely in the European context where the prediction emphasises, first, a transport ecology favouring electric vehicles, and subsequently a hydrogen based ecology where fuel cell vehicles become crucial to improving urban air quality.

Economic Impacts: Microcab has two UK-based spin-out companies (Coventry, Aberdeen) which employ four people. It has also collaborated with Lotus and Westfield to develop new electric vehicle products. The research enabled Horizon to enter the transport market, by testing its fuel cells in vehicles for the first time. Horizon is a global company with operations in 65 countries; providing fuel cells for small devices such as laptops. Ben Todd, from Horizon Fuel Cell, stated that "... the collaboration with Microcab was a unique opportunity, as the company represent the only small fuel cell vehicle in the world. The work with Microcab enabled Horizon to package a product which is now being sold internationally, representing impact through new product development...". The work with Microcab resulted in job creation whereby Horizon was able to double its workforce from five to ten, which Todd stated could not have been achieved without Microcab. The Microcab research team also helped to facilitate on-going work and secure further funding of £150,000 for Horizon to develop a new project which will be aimed at the American market. The impacts resulting from this relationship include new product development contributing to economic prosperity through job creation, and contribution to an improved business model for Horizon Fuel Cell through the creation of new networks and markets.

Other economic impacts include benefits to RDM Ltd, which developed real time data loggers for the Microcab and other Electric Vehicles in the CABLED project, which enabled RDM to develop this technology for the mass market. Further, Air Products' fuel station at Coventry strategically links three cities in the Midlands with hydrogen infrastructure. Ian Williamson, President of the European Hydrogen Association, said of the Microcab infrastructure project "this will prove to be a

vital step towards the creation of a low carbon hydrogen transport infrastructure for the UK".

Jostins is now researching the development of a supply chain for hydrogen transport under the European 'Mu Tool' project. This includes using microwave composites for low energy body systems, to provide a low cost solution to the manufacture of fuel cell vehicles. This work is being undertaken in collaboration with: TWI Ltd (UK), Neosid Pemetzrieder GmbH & Co KG (Germany), Sampaş Nanoteknoloji Araştrima Geliştime Ve Pazarlama Limited (Turkey), Johnson Controls GmbH (Germany), Loiretech SAS (France).

Impact on Policy: The presence of Microcabs on the streets in Coventry, Birmingham, Brussels and other cities has helped to change perceptions, so that governments are now seriously considering the viability of a hydrogen economy. For example, in Scotland the government has taken a decision, based on evidence of the Microcab Trials in Coventry and Birmingham in 2012, to deploy hydrogen vehicles in Scotland as a means of optimising storage of wind generated energy. **Jostins** has also been invited onto the Hydrogen South Africa Board (HySA) which has purchased a MicroCab to act as a demonstrator platform for the development of hydrogen fuel cells in South Africa. The Microcab research has been recognised at the European policy level in visits of ministers, including the Director General of DG Enterprise and Industry, Daniel Calleja and Malcolm Harbour, West Midlands Conservative MEP. Locally the Microcab project overcame initial speculation and concern about having a hydrogen fuel station and vehicles within a populated residential area. Coventry and Birmingham City Council have used the research to assess the social, environmental and economic impacts of deploying low carbon vehicles and infrastructure. The EU directive for cities to improve air quality or face fines makes this particularly important [a-k].

Recognition and Awards: Through the period of the design and development Microcab has been nominated for a number of awards which recognise the design innovation and contribution to alternative fuels research and development. These include:

2002: DTI Smart Award
2004: EAST (Environmental And Sustainable Technology) magazine, Industry Green Investment Award runner-up
2005: EAST Vehicle innovation award
2006: Microcab was runner-up in Lloyds TSB EAST Green Investment Awards
2006: Shell Springboard finalist
2008: Runner-up in the International Oxygen Award, category: "Technology and Innovation: Sustainable Transport" competing against Volvo, Primagaz, Hondo and Scania.
2010: City of London Guild, Microcab winner of the environment award
2010: Worshipful Company of Carmen, City of London Environmental Award
2012: Microcab is nominated for the Condé Nast Traveller Award for Innovation & Design

Conclusion

Jostins' research on Microcab has delivered design, technological, economic and policy benefits within the UK, Europe and internationally. The unique approach has delivered production versions of small economical hydrogen-fuelled cars several years ahead of larger competitors. In doing so it has delivered economic benefits to a number of organisations by enabling them to diversify into this new market. In addition, the research has had an impact on local, national and international policy, with respect to the adoption of hydrogen-fuelled cars and supporting infrastructure.

5. Sources to corroborate the impact

a. http://www.theguardian.com/education/2011/nov/14/eco-friendly-transport-research?newsfeed=true
b. http://www.earthtechling.com/2011/10/hydrogen-fuel-cell-car-for-uk-is-um-cute/
c. http://tinyurl.com/oq27xfa
d. http://www.thebirminghampress.com/2011/09/26/waving-goodbye-to-oil/
e. http://www.autocar.co.uk/News/NewsArticle/AllCars/259301/
f. http://www.imeche.org/news/engineering/west-midlands-firm-unveils-hydrogen-fuel-cell-car
g. 2012, All energy show Aberdeen – Jostins http://www.shfca.org.uk/event/247/
h. April 30th 2012, South Africa International Partnership on Hydrogen Economy – http://www.iphe.net/events/meetings/SC_17.html
i. Nov 2012, Jostins's keynote: London Hydrogen Partnership http://tinyurl.com/nwy8ebr
j. Hydrogen – Untapped Energy? The Institution of Gas Engineers and Managers (IGEM), 2012
k. Interviews conducted by RAND Europe, see report available from Coventry University