Institution: Loughborough University

Unit of Assessment: B12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering

Title of case study: Engineering elite footballs through high quality research

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

Research by Loughborough University academics has influenced the development of elite footballs used in numerous global tournaments including FIFA World Cups, UEFA European Championships and Olympic Games. Research findings have led to increased design freedoms that have allowed adidas to produce balls with improved commercial appeal resulting in a tenfold increase in sales whilst maintaining product performance in line with the highest certifiable level of FIFA standards.

2. Underpinning research (indicative maximum 500 words)

Loughborough University, (LU), began applying engineering research to sports products in 1985, but it was the award of the SESAME grant (1999-2001) **[G3.1]** that provided the platform from which a multifaceted portfolio of expertise grew.

Analysis and mathematical modelling of hollow sports balls and their performance emerged as a key research theme through the PhDs completed by Cordingley (2002) and Neilson (2003), both supervised by Prof Roy Jones (LU, 1985-2011). Cordingley successfully demonstrated the potential for commercially available finite element analysis software to model thin walled pressurised spheres with homogenous material properties and simulate their impact with rigid surfaces. Concurrently, Neilson reported detail of the kicking capabilities of elite footballers and subsequently derived the in-service requirements for elite match balls in a manner previously unreported.

The EPSRC award of the Innovative Manufacturing and Construction Research Centre to Loughborough (2001-2006) **[G3.2]** supported further research by Price (2005) **[G3.2a]**, supervised by Dr Andy Harland (LU, Lecturer 2001-2007, Senior lecturer 2007-present). The work demonstrated the influence of localised material anisotropy on ball performance and proposed methods to model its effects **[3.1]**, thus avoiding the need for expensive and lengthy prototyping, as well as proposing strategies for alignment of the constituent woven material panel layers that overcome unwanted bounce irregularity.

With the increase in complexity of designs and the enhanced scrutiny of players and the media, substantive research questions were identified within the field of ball aerodynamics. Expertise developed through the aerodynamic study of bluff bodies **[3.2]** and the design and build of a £2M wind tunnel at Loughborough, brought Dr Martin Passmore (LU, Research Associate 1984-1991, Lecturer 1991-2001, Senior lecturer 2001-present) into the team and resulted in a detailed study of spinning and non-spinning ball performance **[G3.2b] [3.3]** (2004-2005).

As this research began to be applied to ball design through collaboration with leading manufacturers, including adidas, the exposure of academic staff to more advanced applied research questions led to further studies. The first of these related to the interactions between the outer layers of the ball and the various other surfaces involved in the game. Cotton (2008) was awarded an LU PhD for his thesis concerned with experimental and mathematical modelling of the role of surface texture on these deformable outer layers on the grip, stick and roll of the ball in a range of environmental conditions (2004-2007) **[G3.2c]**, which proposed designs to overcome the inconsistencies found in previous balls.

Rogers (2011) was awarded an LU PhD for research relating surface panel and seam geometry to aerodynamic ball performance following a four year programme of research supervised by Drs Harland and Passmore **[G3.3] [3.4]**. Concurrently, Dr Simon Tuplin (LU, Research Associate 2002

– present) **[G3.4, G3.5, G3.6]** developed fast and effective experimental and flight simulation analysis tools to support the performance characterisation of real and rapid prototyped ball designs during product development stages, published in response to an invitation from the editor of a special edition of the Journal of Sports Engineering and Technology **[3.5]**. Dr Passmore was also invited to present this work as a keynote address at the World Congress on Science & Football (WCSF), Japan 2011.

In recognition of expertise in ball design, construction and performance analysis, Dr Harland was engaged as a consultant during the conceptual design stage of the ball to be used for the World Cup in 2010. This resulted in a patent **[3.6]** that covered the inclusion of grooves within panels to mimic the role of panel seams in providing aerodynamic stability which were included throughout the range of footballs produced for the 2010 FIFA World Cup.

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

3.1 Price, D.S., Jones, R. and Harland, A.R., "Soccer Ball Anisotropy Modelling", *Materials Science and Engineering A, Structural Materials: Properties, Microstructure and Processing*, 420(1-2), March 2006, 100-108, ISSN 0921-5093. DOI: 10.1016/j.msea.2006.01.079. Impact factor: 2.11

3.2 Passmore, M, Richardson, S., Imam, A. "An experimental study of unsteady vehicle aerodynamics", 2001, *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering* 215(7), 779-788, DOI: 10.1243/0954407011528365. Impact factor: 0.58

3.3 Passmore MA, Tuplin S, Spencer A, Jones R, Experimental studies of the aerodynamics of spinning and stationary footballs. *Proceedings of the Institution of Mechanical Engineers. Part C: Journal of Mechanical Engineering Science, IMechE* ISSN 0954-4062, Vol 222 2008. DOI: 10.1243/09544062JMES655. Impact factor: 0.63

3.4 Passmore, M, Rogers, D, Tuplin, S, Harland, A, Lucas, T, Holmes, C (2012) The aerodynamic performance of a range of FIFA-approved footballs, *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, 226(1), 61-70, ISSN: 1754-3371. DOI: 10.1177/1754337111415768. Impact factor: 0.62

3.5 Tuplin, S, Passmore, M, Rogers, D, Harland, AR, Lucas, T, Holmes, C (2012) The application of simulation to the understanding of football flight, *Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology*, 226, 134-142, DOI: 10.1177/1754337112444402. Impact factor: 0.62

3.6 World Cup Ball Patent: Nuernberg, H. -. P., Gordon, J. R., Lucas, T. D., van Oorschot, J., Geyer, H., & Harland, A. R. (2009). Ball with pseudo seams. Application number EP20100155323 (03/04/2009).

Research grants:

G3.1 R Jones, S Mitchell, D Kerwin, S Rothberg, The SESAME laboratory: The key to unlocking the UK's future sport engineering excellence, EPSRC (GR/M54407/01) September 1999 – September 2001, £512,151

G3.2 IMCRC GRANT: C Backhouse, S Newman, S Rahimifard, P Palmer, M Jackson, P Dickens, P Conway, R Harrison, Dr D Hutt, S Mitchell, K Case, A West, R Young, R Parkin, S Rothberg, R Jones, M Caine, K Walsh, N Burns, A Thorpe, A centre for innovative manufacturing and construction research Total IMCRC grant, EPSRC (GR/R64483/01), £11,350,001, October 2001 - September 2006, *from which specific allocations:*

G3.2a A Harland, R Jones, Advanced modelling of soccer balls, EPSRC (IMCRC) £104,424,and adidas £45,890, July 2002 – June 2005

G3.2b R Jones, M Passmore, A Spencer, Aerodynamics of Sports Balls, EPSRC (IMCRC) £49,703, March 2004 – February 2005

G3.2c A Harland, R Jones, Soccer Ball Surface Interactions, EPSRC (IMCRC) £3,790 and adidas £30,000, October 2004 – September 2007

G3.3 A Harland, M Passmore, R Jones, Analysis of surface features influencing aerodynamics of ball flight, adidas £45,000, April 2007 – March 2011
G3.4 A Harland, M Passmore, Experimental Aerodynamics of Footballs 1, adidas £36,000, March 2009 – February 2010
G3.5 A Harland, M Passmore, Experimental Aerodynamics of Footballs 2, adidas £16,500, March 2010 – August 2010
G3.6 A Harland, M Passmore, Experimental Aerodynamics of Footballs 3, adidas £16,500, September 2010 – February 2011

- Evidence for the quality of the research undertaken may be found from the outputs in which the work was published, which are the leading journals for researchers publishing in this field, and the number of invited and Keynote lectures presented by the investigators, the latter including: Prof Jones Keynote Lecture, World Congress on Science & Football (WCSF), Turkey, January 2007
- Dr Harland Invited Lecture, BA Festival of Science, York, September 2007
- Dr Harland Invited Lecture, VUB Crosstalks, Vrije Universiteit Brussel (VUB), Université Libre de Bruxelles (ULB) and the Belgian Sports Technology Club (BSTC), Sep 2011
- Dr Passmore Keynote Lecture, World Congress on Science & Football (WCSF), Japan 2011.

Dr Harland and Dr Passmore were also invited to form the inaugural FIFA flight dynamics technical committee, together with colleagues from MIT, NASA and Technical University of Munich, November 2013.

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

The balls used in elite professional football have been required to satisfy performance standards laid down by the FIFA Quality Concept since 1995. Therefore, in order for football brands and manufacturers to improve the commercial success of their products, they must enhance areas other than performance, since this is constrained. Until 2002, the potential for brands to fundamentally improve the consumer appeal of footballs was inherently limited by the manufacturing process. The research carried out at Loughborough has realised a greater understanding of the relationship between ball design and performance, which has allowed adidas to overcome these restrictions.

Given the restrictions on changing ball performance, the research was instead used to identify and inform those aspects of design and construction where modifications could enhance the aesthetic and tactile beauty of the ball for commercial advantage without compromising performance.

The impact of the research carried out at Loughborough has been to ensure that the new manufacturing method achieved the following:

- Ensured that the inner carcass of the ball provided the appropriate uniform structural rigidity removing the need for outer panels to provide this function.
- Removed constraints of outer panel shapes such that they could be designed around the desired graphical imagery. This means that patterns are now able to extend across panel edges, where previously the imperfect alignment of conventional flat panel assembly led to misalignment that undermined the quality of appearance.
- Allowed outer panels to be manufactured from new materials that can be assembled without unevenly straining during inflation, meaning the ball is more spherical and has improved tactile feel.
- Maintained ball flight performance through the conception and implementation of aero-grooves, where increased outer panels sizes introduced for commercial advantage had potential to detrimentally affect ball aerodynamics

These advantages have been realised sequentially by adidas in major tournament footballs. The *Teamgeist* ball used in the 2006 World Cup was the first to include the new carcass and curved panels whilst satisfying all FIFA Quality standards to the highest certifiable level. It was commercially successful, returning sales of 15 million units compared to 2 million sold in 2002 **[5.1]**.

In 2008, the research reported in Cotton's PhD thesis (2008) led directly to the inclusion of a surface texture on the *Europass* ball used in the UEFA Euro 2008 tournament.

For the 2010 *Jabulani* ball, Loughborough research **[3.3,3.4,3.5]** led directly to the inclusion of aero-grooves on the surface that were designed to maintain flight stability; they are protected by a patent **[3.6]** on which Dr Harland is named as co-author. In addition to the tournaments mentioned, derivatives of these balls have also been used for Olympics, Champions League and various national leagues around the world.

The success of this approach has led to ball patterns influencing design themes across clothing, stadia and media throughout each tournament. Therefore the consequential impact of this research is likely to be greater than that claimed, but is difficult to substantiate.

Sales figures of major tournament footballs are highly sensitive and not made public due to the nature of the sponsorship agreements between brands and tournament organisers, with adidas reported to be paying $351 million to FIFA for the 2010 and 2014 World Cup tournaments alone. As a result sales figures are collated from media reports and press releases but indicate that during the period of Loughborough's research, sales of the adidas match balls and their replicas have increased tenfold - from two million in 2002 to an estimated 20 million in 2010 **[5.1,5.2]**. The 2010 World Cup made a significant contribution to adidas revenues, with the relevant financial quarter in 2010 generating $3.47B, more than $0.58B higher than the $2.89B generated in the equivalent quarter in 2009 **[5.3]**. These gains have been supported by the raised awareness of engineering innovation achieved via media coverage of the tournament – more than 2.2 billion people watched more than 20 continuous minutes of TV coverage during the 2010 tournament **[5.4]** – and specific coverage of the research. Dr Harland completed more than 60 interviews with international broadcasters, including ESPN, BBC and CNN, resulting in coverage totalling more than £1M in AVE (Advertising Value Equivalent). This engagement extended across hard to reach demographics, such as the ~5 million young people who consciously chose to engage with technical films and information on the adidas Facebook site **[5.5]**.

In summary, the research cited in this case study has resulted in a step change in the commercial success of a significant product in a global sport leading to huge economic benefits for a multinational company.

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

The following sources of corroboration can be made available at request.

Research Users

5.1 Letter of Support from the Engineering Director, adidas AG covering the impact of the research and key ball sales figures.

Press Releases

5.2 adidas-Group Press Release: 2010 FIFA World CupTM already sales success for adidas, June 21, 2010 *[Ball sales volumes]*

5.3 adidas-Group Press Release: Nine Months 2010 Results, Herzogenaurach, November 4, 2010 *[financial performance data]*

5.4 2010 FIFA World Cup South Africa, Television Audience Report, Produced for FIFA TV by KantarSport *[TV audience data]*

Social Media

5.5 adidas-football facebook page, accessed various dates from 2010 *[social media reach]*