Institution: University of Portsmouth

Unit of Assessment: 19 Business and Management Studies

Title of case study: A World First in Flight Safety: University of Portsmouth Academics Bring Avionic Data Analysis into the 21st Century

1. Summary of the impact

A Portsmouth team has helped revolutionise how flight data from aircraft flight recorders is being analysed. This has improved the corporate performance of a leading UK company in a globally competitive market by helping it expand its business in the UK and to subsequently compete in the dynamic North American market. Historically, data was manually evaluated on a flight by flight basis. Research by the Portsmouth team means such data can now be analysed automatically by artificial intelligence (AI), saving significant man-hours, and allowing the company to diversify domestically into a related market and to expand internationally. The techniques developed were subsequently applied in a new market, enabling the new corporate partner to realise savings estimated at £100,000 p.a.

2. Underpinning research

In 2012, there were 31 million commercial flights involving 15,000 aircraft and about 239 major airlines worldwide. Annex 6 of the International Civil Aviation Organization's (ICAO) Convention on International Civil Aviation for aircraft over 27 tonnes stipulates that all such aircraft should undertake flight data monitoring (FDM). Each of the 189 countries belonging to the ICAO is therefore obliged to introduce this requirement into national law, or provide a disclaimer stating why they feel this is unnecessary in their country[1]. In the UK it is a legal requirement for each plane to carry a flight data recorder (FDR). The FDR collects raw data from plane sensors for later analysis. These analyses are not only of critical importance in the event of an accident, but can also play a crucial role in their prevention. In the UK, for example, the law stipulates that these flight recorders must be analysed at least once a year in order to detect flight errors occurring outside accepted safety parameters. Historically, this task was undertaken manually, a process that was time-consuming, expensive, and required complex technical skills. The process was also prone to human error. Furthermore, there were concerns that existing flight data analysis approaches were ignoring some of the abnormalities (events) that could potentially affect aircraft safety on time/cost grounds.

The complex challenges of detecting errors through the processing of extremely large amounts of data formed the basis for the underpinning research which was carried out by the Portsmouth team in conjunction with Flight Data Services Ltd via two KTPs (Knowledge Transfer Partnerships) and an EPSRC grant over the period from 2006 to 2013. The implicit objective was a desire to enhance flight safety by introducing improved data processing techniques.

Historically, approaches towards flight data analyses employed Operations Research (OR) techniques and a user chosen threshold for certain parameters to identify a specific abnormality. The key contribution of the Portsmouth OR team in the first research phase (KTP1) was to create an intelligent search engine that could extract pertinent flight safety data from an FDR. This research employed pattern recognition techniques to highlight relationships between key parameters [Sma09, Jes08] which suggested that the current event based analysis system, which depended [usually] on one parameter, was inefficient. Subsequent EPRSC and KTP2 funded research enabled the team to develop and demonstrate a 2-phase method [Sma12a, Sma12b]

[1] Aside from the US which has made the provision of FDM voluntary, all other ICAO members have either introduced a legal requirement for FDM, or are working towards this.

using one-class classifiers that were able to detect 3 times more abnormalities (faults) than the existing industry standard. This method also provides more information to flight data analysts because it quantifies the impact of an abnormality. The research focused on identifying the impact of an abnormality in aircrafts' descent, the most dangerous phase of flight.

The key research outcomes were: (i) the discovery that fusing multiple parameters at once is more useful in identifying abnormalities than considering individual parameters in isolation (KTP 1), (ii) the development of an automatic system to check the flight data recorder system for errors – including the sensors and their connections (KTP 2) and (iii) the development of a method to quantitatively detect and rank the impact of abnormalities during the descent and landing phases of aircraft flight (Sma 12a and Sma 12b). The published research (Sma12a and Sma12b) also proposed a new scoring system – the 'Smart Score' - that investigates levels of fault in flights and integrates and ranks their accumulative effect on safety.

University of Portsmouth staff involved:
Professor David Brown (Director of the Institute of Industrial Research),
Professor Honghai Liu (Intelligence Systems Research Group),
Dr Farshad Fahimi (Lecturer, School of Computing),
Dr Edward Smart (Research Fellow, Institute of Industrial Research).
All have been involved in the underpinning research over the 2006-2013 period.

3. References to the research

Peer Reviewed Publications:

1. [Sma12a] Smart, E., Brown, David J. and Denman J. (2012). Combining Multiple Classifiers to Quantitatively Rank the Impact of Abnormalities on Flight Data, *Applied Soft Computing Journal*, 12 (8), pp. 2583-2592. **Journal Impact Factor = 2.14.** Ref2 output: 19-ES-002
2. [Sma12b] Smart, E., Brown, D., Denman J. (2012). A Two-Phase Method of Detecting Abnormalities in Aircraft Flight Data and Ranking Their Impact on Individual Flights, *IEEE Transactions on Intelligent Transportation*, 13 (3), pp. 1253-1265. **Journal Impact Factor = 3.064** Ref2 output: 19-ES-001
3. [Sma09] Smart, E., Liu, H., Jesse, C., Brown, David J. (2009). Quantitative Classification of Descent Phases in Commercial Flight Data, *International Journal of Computational Intelligence Studies*, 1 (1), pp. 37-49. DOI: 10.1504/IJCISTUDIES.2009.025337
4. [Jes08] Jesse, C., Liu, H., Smart, E., Brown, David J. (2008). Analysing Flight Data Using Clustering Methods, *Lecture Notes in Artificial Intelligence* (Journal now renamed as *Knowledge-Based Intelligent Information and Engineering Systems)*, 5177, pp. 733-740. DOI: 10.1007/978-3-540-85563-7_92

Details of grants that supported this work:

1. Knowledge Transfer Partnership (1)

- **Awarded to: Professor David Brown (PI)**
- **Title –** 'Creation of an Intelligent Search Engine to Extract Flight Safety Information from Aircraft Data'
- **KTP Number –** 001136
- **Amount -** £156,000
- **Dates:** 27/02/2006 – 26/02/2009

2. Knowledge Transfer Partnership (2)

- **Awarded to: Professor David Brown (PI)**
- **Title –** 'Semi-Automatic Testing of a Digital Flight Data Recorder System (DFDRS) in Accordance to a Method of Compliance for Airworthiness and Operational Approval'
- **KTP Number –** 001511

- **Amount -** £217,000
- **Dates:** 28/06/2010- 25/09/2013

3. <u>Knowledge Transfer Partnership (3)</u>

- **Awarded to: Professor David Brown (PI)**
- **Title:** 'Condition Monitoring for Dairy Filters'
- **KTP Number –** 007935
- **Amount** – £229,000
- **Dates:** 01/09/2011-01/08/2013

<u>EPSRC</u>

- **Awarded to: Professor David Brown and Edward Smart (PIs)**
- **Title –** 'Detecting Abnormalities in Aircraft Flight Data and Ranking their Impact on the Flight'
- **EPSRC Grant Number –** GR/T18868/01 Voucher Number: VN06001600
- **Amount -** £84,000
- **Dates –** 01/10/2007 – 01/04/2011

4. Details of the impact

In 2006 the University was approached by Flight Data Services Ltd (FDS Ltd), a UK SME involved in analysing data captured by airline FDR with a view to further enhancing airline safety. At the time FDS Ltd had contracts with 8 airline companies covering more than 300,000 flights annually, and was required to review daily around 10 gigabytes of data provided by its clients. Concerned at the '*time consuming and costly manual methods of analysing*' this data, the company approached the University of Portsmouth to request support in more effectively exploiting this data (Collaborating Person 1 – CP1).

This collaboration was formalised in February 2006 when a KTP agreement was signed between the company and the University (led by David Brown) with the brief to "Create an Intelligent Search Engine to Extract Flight Safety Information". Successful completion of the project in early 2009 brought immediate commercial benefits to the company as it took on board the recommendations of the Portsmouth team and automated its analytical systems in Summer 2009, allowing:

- a saving of '*as much as 4,000 man-hours per year*', and;
- the freeing up of skilled staff who were then re-assigned to help the company enter the new (for the company) FDR readout market.

The company estimated that this one collaboration alone enabled it to save over £50,000 p.a. (CP1).

As the advantage of artificial intelligence (AI) over manual techniques in examining large flight data-sets had become evident early on in KTP1, the partners successfully bid for an EPSRC award to develop and use advanced AI algorithms in detecting and ranking abnormalities in aircraft flight data. This research also highlighted a number of abnormalities which could potentially cause aircraft failure, but which were not captured by analytic procedures within the sector. As a consequence, the company responded following completion of the project in April 2013 by developing a series of informative case-studies for potential customers, allowing them to take action to improve their airline's safety record (http://www.flightdataservices.com/fdm-foqa-products-services/casestudies/). These insights, allied to the '*technology base and the published papers have given FDS Ltd a reputation for innovation which has helped us to win significant new contracts including the SAS (140 aircraft) and another major European operator. These have an approximate value of £750,000 p.a.*' (CP1).

Moreover, this research enabled FDS Ltd to secure two prestigious contracts with the North American Space Agency (NASA) in the United States. The first contract was based on the

development of artificially intelligent algorithms using data gathered by Hewlett Packard and the techniques developed by the Portsmouth team. The second NASA contract saw FDS Ltd use the findings from this first KTP project to provide an informed view on the development of Next Generation air traffic control systems for the North American market. These contracts generated £100,000 profit for FDS Ltd, and, more critically, enabled a small company to establish a presence within the highly competitive and lucrative US market.

Building on these collaborative successes, a new KTP (KTP2) was signed which focused on validating the sensing system within the flight recorder(s) and with the plane sensors. Preliminary results derived from this project enabled FDS Ltd to offer a complete service to their clients in early 2013, from checking their planes' sensing and recording systems through to an evaluation of pilot performance, giving it first-mover advantage in the global market. Realising the commercial potential of this service, the company swiftly responded by:

- expanding its operations at their HQ in Fareham, increasing their staff from 6 to 36;
- setting up an American subsidiary in Phoenix, Arizona; and
- seeking to protect its intellectual property rights by investing £250,000 to take out a series of patents in the UK and the US in 2012/13 (Flight Data Monitoring Method and System US Application No: 2013205845// Flight Data Validation Apparatus and Method, UK Patent: GB2494487A// Flight Data Monitoring Method and System, UK Patent: GB2494553A // Flight Data Validation Apparatus and Method, UK Patent: GB2494569A // Flight Data Monitoring and Validation, US Patent: P044407US [Applied for])

The Portsmouth team's development of abnormality detection methods within the aerospace industry were subsequently applied by Brown and Smart to the food and packaging process in 2011. Stork (part of Unilever) is one of the largest dairy machine manufacturers in the world, and provides 75% of the dairy machines used within the EU. Machine failure costs Stork approximately £50,000 per day as supermarkets (such as Tesco) impose penalty clauses for lost production. Brown and Smart used their OR expertise to predict faults occurring within Stork's dairy machines that could lead to failure (KTP 3). This £250,000 KTP applied similar techniques to those employed in the FDS Ltd KTP, generating savings to the order of £100,000 for the company (CP2). This success in turn led to a new £1.2m Technology Strategy Board award to a consortium headed by Brown and Smart (PI) to integrate the company's operational management systems with the data analysis system developed from the KTP (September 2013).

This Impact case study demonstrates how applied OR research can be employed to help a company grow its income stream and establish an international presence. It further illustrates how intellectual advances in one production domain (flight data analysis) can be modified to produce commercial benefits in a related production domain (dairy machines).

5. Sources to corroborate the impact

Corroborating Person

CP1: **Letter dated 11th October 2013 from Managing Director, Flight Data Services Ltd**. *REPORTER.* Author of the letter was a *participant* in the sense that the KTP and EPSRC grants involved FDS Ltd as a partner in the research.

CP2: **Letter dated 23rd October 2013 from Sales Director, Stork UK**. *REPORTER.* Author of the letter was a *participant* in the sense that the KTP and TSB grants involve Stork UK as a partner in the research.