Institution: Coventry University		
Unit of Assessment: UoA12		
Title of case study: Influencing Single Pilot Aircraft Research Strategy		
Period when the underpinning research was undertaken: 2014 – 31 December 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
Don Harris	Professor	Sept 2012 – date
John Huddlestone	Associate Professor	April 2013 – date
Dale Richards	Senior Lecturer	August 2012 – June 2019
Alex Stedmon	Professor	August 2013 – October 2019
James Blundell	Assistant Professor	Sept 2017 – date
Steve Scott	Assistant Professor	Sept 2015 – date
Period when the claimed impact occurred: 2014 – 31 December 2020		
Is this case study continued from a case study submitted in 2014? No		

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

Coventry University has been involved in the development of design concepts and flight deck technologies in three major research programmes with a number of industrial partners (General Electric; BAE Systems; Rolls-Royce; Airbus). The emphasis has been on the Human Factors aspects of the design of a single pilot commercial aircraft concept and identifying the underpinning technologies required for its development. This work has had a direct effect on influencing national research policy. Work to develop single pilot flight deck concepts has been identified as a key technology for UK strategic funding by the Aerospace Technology Institute (ATI)/Department for Business, Energy & Industrial Strategy (BEIS)/InnovateUK.

2. Underpinning research (indicative maximum 500 words)

This case study is based upon work undertaken in three major multi-partner projects:

- Future Flight Deck (FFD): an InnovateUK funded project on advanced flight deck technologies undertaken in conjunction with General Electric; BAE Systems and University of Southampton with a total value of *circa* £11 million (across the consortium). Coventry University was responsible for the development of configurations for single pilot aircraft and the development and evaluation of head-up display information formats.
- REducing WorkloAd Through EffiCient TechnOlogy and ProceduRes (REACTOR): another multi partner project with General Electric; BAE Systems and DLR - Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre), part of the Large Passenger Aircraft program, led by Airbus DS (Spain). REACTOR is funded by the European Union as part of the CleanSky 2 Joint Undertaking with a total project value of circa €5 million. Coventry University provided Human Factors support for the development of voice command, pilot visor, pilot monitoring and ground control support station technologies, all of which have potential applications for single pilot operations. In addition, Coventry developed a predictive model of

pilot workload for the prospective estimation of cognitive demand for use in the early design stages of flight deck equipment.

- Open Flight Deck (OFD): is a follow-on project from FFD, also funded by InnovateUK, with a total value of *circa* £26 million. Project undertaken in conjunction with General Electric; BAE Systems; Rolls Royce and University of Southampton. In this programme, Coventry University continues to develop further the single pilot airliner concept (commenced during FFD) and is involved in the Human-Centred testing of supporting technologies, such as the use of colour on HUDs and the role of haptic feedback for flight control design (Figure 1).

Work resulting from the conceptual studies for the design of novel flight deck configurations for single pilot operations is described in refs 1, 2, 4 & 5. Flight deck design and the wider operating concepts for a single crew airliner are described in refs 1, 2, 4 & 5 (FFD; OFD projects); aspects of the specification and operation of a ground-based pilot support station (from FFD and REACTOR) can be found in refs 2 & 5. The ground station provides a range of pilot support activities to reduce the pre-flight and in-flight workload of the single pilot with emphasis on enhancing operational capability in high intensity/short haul operations.

Figure 1
Simulator Trials at BAE Systems, Rochester during the Open Flight Deck programme managed by Coventry University

The development of the displays and display formats to support reduced crewing operation, particularly for low visibility (landings, taxi guidance, etc.) is described in refs 3, 4 & 6. These have been implemented both using novel Head Up Display technology (the WaveGuide™ system developed by BAE Systems: FFD and OFD projects) and on a head mounted version, the Enhanced Light Weight Eye Visor (ELWEV – REACTOR project). Display formats have been developed using pilot-centric, task-based methodologies initially as a fast prototype and then implemented in an engineering simulator for testing [refs 3 & 6]. Novel display technologies and display formats will form a key building block

for flight decks supporting single pilot operations. Novel haptic control interfaces currently being developed as part of the OFD programme will provide further assistance to the single pilot.

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

[R1] Harris, D., Stanton, N.A. & Starr, A. (2015) 'Spot the Difference: Operational Event Sequence Diagrams as a Formal Method for Work Allocation in the Development of Single Pilot Operations for Commercial Aircraft'. *Ergonomics 58 (11)*, 1773–1791 https://doi.org/10.1080/00140139.2015.1044574

[R2] Stanton, N.A., Harris, D. & Starr, A. (2016) 'The Future Flight Deck: Modelling dual, single and distributed crewing options'. *Applied Ergonomics 53*, 331-342 https://doi.org/10.1016/j.apergo.2015.06.019

[R3] Richards, D., Scott, S., Furness, J., Lamb, P., Jordan, D., & Moore, D. (2016) 'Functional Symbology - Evaluation of task-specific Head-Up Display information for use on a commercial flight deck'. Paper no. AIAA 2016-3374. *Aviation 2016,* Washington D.C.: USA, Gregg, R. D, AIAA https://doi.org/10.2514/6.2016-3374

[R4] Huddlestone, J.A., Sears, R. & Harris, D. (2017) 'The Use of Operational Event Sequence Diagrams and Work Domain Analysis techniques for the Specification of the Crewing Configuration of a Single Pilot Commercial Aircraft'. *Cognition, Technology and Work, 19 (2-3)*, 289-302 https://doi.org/10.1007/s10111-017-0423-5

[R5] Harris, D. (2018) 'Network Re-analysis of Boeing 737 Accident at Kegworth Using Different Potential Crewing Configurations for a Single Pilot Commercial Aircraft. In, Harris D. (Ed.) *Engineering Psychology and Cognitive Ergonomics. EPCE 2018. Lecture Notes in Computer Science (LNCS 10906).* Springer, Cham. https://doi.org/10.1007/978-3-319-91122-9_46

[R6] Blundell, J., Scott, S., Harris, D., Huddlestone, J. & Richards, D. (2020) 'Workload Benefits of Colour Coded Head-Up Flight Symbology during High Workload Flight'. *Displays (65)* https://doi.org/10.1016/j.displa.2020.101973

Grants:

[G1] Future Flight Deck (October 2013-December 2016), with participants GE Aviation Systems Ltd (Lead), BAE systems, University of Southampton and Coventry University. Total project valued at £10 949 688, of which £416, 757 was allocated to Coventry University. Funded by Innovate UK.

[G2] Open Flight Deck (March 2017- November 2020), with participants GE Aviation Systems (Lead), BAE Systems, Rolls Royce, University of Southampton and Coventry University. Total project valued at £26.5m, of which £600,000 was allocated to Coventry University. Funded by Innovate UK.

[G3] REACTOR (Reducing Workload through EffiCient TechnOlogies and ProceduRes) (2016-2020), with participants GE Aviation Systems (Lead), Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Centre and Coventry University. Total project valued at £3,911,930.00, with £250,954 allocated to Coventry University. Funded by Horizon 2020/ Clean Sky 2.

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

The work on developing operational concepts and technology for single pilot airliners has contributed to informing the UK strategy for commissioning aeronautical research and development in the area of novel flight deck design. The Chief Technology Officer from the Aerospace Technology Institute has stated:

> *I am writing to you to commend the high impact that Coventry University's capabilities in human factors is having on the UK's national aerospace technology strategy and technology programme. Coventry University is recognised as one of the UK's and world's leading academic centres for human factors research…*
>
> *The UK national aerospace technology strategy recognises the importance of technologies to support the development of single pilot aircraft for commercial air transport. Coventry University's inputs on human factors have been instrumental in shaping the thinking and technology roadmaps in this area."* (Supporting Document 1)

Harris initially started the development of a novel, distributed systems concept for single crew airliners, which was further developed in conjunction with GE Aviation Systems and formed a key component of the successful InnovateUK bid for the Future Flight Deck (FFD) programme. The outputs of the FFD program (including the new single pilot concept) were promulgated directly to industry and international aerospace research laboratories in an International Roadshow during 2016. This included visits to Boeing, Airbus, Gulfsteam, NASA, DLR and FAA (https://www.ati.org.uk/wp-content/uploads/2017/10/113004_GE-FFD-Full-Final.pdf) and formed one of the major work streams in the Open Flight Deck (OFD) program (Ref 1, 2 & 4: Supporting Document 2). Over 200 people from industry and aerospace research laboratories attended the road shows. The FFD program safeguarded 71 jobs in UK industry and helped to create eight new posts (Supporting Document 2). Furthermore, all InnovateUK grants require matching funding to be provided by the industrial partners for at least 50% of the grant value, hence this development work has attracted significant financial support from industrial partners across the FFD and OFD programs (in the region of £18 million in matched funding).

The ATI (acting in conjunction with BEIS and InnovateUK) selected the development of single pilot aircraft as a technology requiring strategic national funding to enhance the competitiveness of the UK Aerospace Industry. A Green Paper (ATI Insight), based around the work undertaken, was commissioned from Harris on the single crew aircraft (https://www.ati.org.uk/wp-content/uploads/2017/02/ATI-INSIGHT_12-Single-Pilot-Commercial-Aircraft.pdf: Supporting Document 3). The single pilot aircraft was identified as a prioritised technology theme for a collaborative longer-term research and development competition announced at the Farnborough International Air show in 2018 (https://www.ati.org.uk/wp-content/uploads/2017/02/ATI-CR-and-D.pdf: Supporting Document 4). The ATI Insight paper on single pilot operations was formally launched by the ATI to the UK aerospace sector at the Discover-Discuss-Disrupt event on 16 May 2019.

Single pilot aircraft technology has been explicitly incorporated into the 2019 ATI Technology Strategy as part of the strategic aim for the UK to '*be a key player in the delivery of future sustainable commercial aircraft*' https://www.ati.org.uk/strategy/vehicles/ (ATI 2019 Strategy Document – Supporting Document 5). Initially this will be for shorter-range cargo aircraft (2025-2030) with single pilot passenger operations expected by 2035. A letter of support from the Chief Technology Officer verifying the contribution to ATI strategy and UK national strategy is available in Supporting Document 1. Development of single pilot aircraft technology has also been included in the Institute for Ergonomics and

Human Factors (IEHF) strategic aviation white paper 'The Human Dimension in Tomorrow's Safe Aviation System: A Vision and Roadmap', formally launched on 23 September 2020 (https://www.ergonomics.org.uk/common/Uploaded%20files/Publications/CIEHF-Future-of-Aviation-White-Paper.pdf) Supporting Document 6). Harris was the principal author of this aspect of the document and was the presenter at the webinar launching the IEHF White Paper.

> *'The ideas from these projects* [OFD and FFD] *that propose development of single pilot aircraft, initially for cargo operations and subsequently for passenger transport have been directly incorporated into the latest ATI UK national aerospace technology strategy, entitled Accelerating Ambition'.* (Supporting Document 1)

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

[S1] Testimonial letter of support from Chief Technology Officer, Aerospace Technology Institute, Martell House, University Way, Cranfield, Beds, MK43 0TR

[S2] Aerospace Technology Institute Report (2016): Future Flight Deck (FFD) Technologies

[S3] ATI Insight paper (2019) 'The Single Pilot Commercial Aircraft' (online) available from https://www.ati.org.uk/wp-content/uploads/2017/02/ATI-INSIGHT_12-Single-Pilot-Commercial-Aircraft.pdf [13/01/21]

[S4] ATI/Innovate UK (2018): Collaborative R&D Technical Topics call

[S5] ATI Strategy Document (2019) (online) available from https://www.ati.org.uk/strategy/vehicles/ [13/01/21]

[S6] CIEHF (2020) *The Human Dimension in Tomorrow's Safe Aviation System: A Vision and Roadmap* [white paper] Wootton Wawen, Warwickshire, Chartered Institute of Ergonomics and Human Factors (online) available from https://www.ergonomics.org.uk/common/Uploaded%20files/Publications/CIEHF-Future-of-Aviation-White-Paper.pdf [13/01/21]