Taylor & Francis
Taylor & Francis Group

AVIATION
ISSN 1648-7788 / eISSN 1822-4180
2015 Volume 19(4): 165–170
doi:10.3846/16487788.2015.1126909

CONTINUING AIRWORTHINESS: MAJOR DRIVERS AND CHALLENGES IN CIVIL AND MILITARY AVIATION

Huong LE[1], Ilias LAPPAS[2]

[1]School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Melbourne, Australia;
[2]School of Engineering, University of South Wales, Treforest Campus, Cardiff, United Kingdom
E-mails: [1]s3385006@student.rmit.edu.au (corresponding author); [2]ilias.lappas@southwales.ac.uk

Received 9 December 2013; accepted 13 November 2015

Huong LE
Education: BSc (Aviation, Management) in 2011, Edith Cowan University. Master of Aviation Industry Management in 2014, RMIT University.
Employment: 1988–1990 Australian Airlines; 1990–1993 United Airlines; 1993–1994 Cathay Pacific; since 1994 – Qantas Airways.
Research interest: human factors and safety management systems.

Ilias LAPPAS
Education: MEng (Aeronautical Engineering) in 2000, Hellenic Air Force Academy. MSc (Aerospace Dynamics/Aerodynamics) in 2006, Cranfield University.
Employment: 2000–2014, Hellenic Air Force; since 2014 – University of South Wales.
Research interest: aircraft airworthiness, aviation consulting, aviation education and training, strategic decision making, multi-disciplinary problem solving, transformation and knowledge management.

Abstract. A wide regulatory reform is taking place world-wide in the continuing airworthiness domain. The major influences for promoting changes in how continuing airworthiness is managed are civil and military aircraft accidents to which fatigue, corrosion, wear, deterioration in ageing aircraft and the need for regulatory harmonisation of the International Civil Aviation Organisation (ICAO) signatory states and the military were the contributing factors. Another emerging factor is the conversion of older passenger aircraft to freighters, which brings forth the concern that aircraft are being used in a capacity for which they were not designed. The challenges of the regulatory reform are acceptance, certification of maintenance organizations and personnel, education and training, as well as information sharing and administration. This paper presents both the drivers and challenges in these areas and proposes a related change management framework.

Keywords: airworthiness, aviation safety, ageing aircraft, regulation.

1. Introduction

In the early use of the concept of 'continuing airworthiness', it was clearly recognised at the time that there was a need for communication among the manufacturer, who identifies and enumerates the safety-significant items, the operator's maintenance engineers, who in service would become more familiar with the aircraft, the operator, who is mostly concerned with the business model, and the generation of profit and the airworthiness authorities, who were concerned that yesterday-certified aircraft would not exactly meet the current safety standards. The most influential event for continuing airworthiness in the commercial aviation domain was the Aloha Airlines B737-200 accident that happened in April 1988. The safety issues raised in the accident investigation report were the quality of the operator's maintenance program and the Federal Aviation Administration (FAA) surveillance of the programs. Shortfalls in the engineering design, certification and continuing airworthiness of the aircraft were revealed, particularly regarding wide spread fatigue cracking, maintenance human factors, inspection of airframe continuing airworthiness and training and certification of aircraft technicians and inspectors (NTSB 1989).

On the other end of the spectrum there is General Aviation (GA). The Australian Civil Aviation Safety Authority (CASA 2012) echoed this sentiment and has grouped the factors influencing the ageing of GA aircraft into three main groups: pre-manufacturing, manufacturing and post-manufacturing. In Australia's general aviation (GA) area, many aircraft designed for a 20-year notional life are still operating well into their 40 years and later (CASA 2012). Major concerns have been raised in terms of the airworthiness condition of the General Aviation aircraft fleet, particularly with regard to their structural integrity and best practices to mitigate the associated issues (Kourousis 2013).

On the military front, the accident that sparked controversy was the loss of the Nimrod XV230 over Afghanistan in 2006. Sir Haddon-Cave QC (2009) has identified the factors that have contributed to the loss of the Nimrod, highlighting the inadequate appreciation of the needs of aged aircraft and the military airworthiness system that was not considered to be fit for the purpose.

The spectrum of civil aviation ranges from very large commercial aircraft used for regular public transport to small aircraft used for general aviation. CASA has modelled its continuing airworthiness frameworks on the frameworks of European Aviation Safety Agency (EASA) for large commercial aircraft and the US Federal Aviation Administration (FAA) for small general aviation aircraft.

2. Civil aviation

2.1. Sustainment of ageing aircraft

There is no universal definition of an ageing aircraft since the ageing process starts from the day of manufacturing and the rate of ageing of an individual aircraft depends on its usage, on how it is maintained, and how it is stored during its life (CASA 2012). Ageing aircraft and the associated maintenance challenges are not typical to any country or type of aircraft or type of operation, i.e. the number of flight cycles, flight hours or the actual age of aircraft. Friend (1992) has illustrated the increase of the average age of civil jet transport: while in 1981 it was thought that the average age of an aircraft was 15 years and 50,000 flight hours were high, ten years later the average age increased to 20 years and the flying hours crept up to 60,000 (Ramsden 1981).

As of today, almost 40% of the global civil fleet operates within airlines based in North America (Fig. 1). A closer look at the aircraft aging data for this particular region reveals that approximately 30% of the fleet have been operating for more than 15 years (Table 1).

The case of passenger to freight conversion of aircraft is very interesting, as it illustrates the issues associated with the sustainment of continuing airworthiness of ageing aircraft. The forecast for the demand for air cargo services will double in the next twenty years (Boeing 2012), where two thirds of the projected airfreight deliveries will be freighter conversions, 60% of which will be from standard-body passenger aircraft. The implications of the increase in conversions of passenger aircraft to freighter are related to the ageing effects including: fatigue, corrosion, wear and deterioration, coupled with the modifications in the design that would be extremely different to the intended purpose of the aircraft.

Recently, the European Aviation Safety Agency (EASA) has published a Notice of Proposed Amendment (NPA) specifically addressing ageing aircraft structures

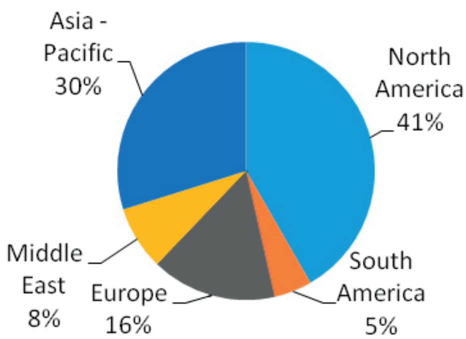

Fig. 1. Geographical distribution of civil aircraft fleets in service (Africa was omitted due to the lack of representative data) (primary data obtained from Airsafe 2015).

Table 1. Civil aircraft age range and distribution per geographical region (Africa was omitted due to the lack of representative data) (primary data obtained from Airsafe 2015).

Region	% of Regional Aircraft with at least X Years of Weighted Average Age (WAE)		
	X > 15	X > 20	X > 25
North America	29.9%	14.6%	1.1%
South America	0.9%	0.9%	0.0%
Europe	9.7%	3.8%	0.0%
Middle East	4.4%	2.2%	2.1%
Asia – Pacific	6.0%	0.8%	5.3%

of large aeroplanes (EASA 2013). The five changes proposed are summarised as the amendments of:

- Part 21 'Certification of aircraft and related products, parts an appliances, and of design and production organisations';
- Part 26 'Additional airworthiness requirements for operations' and the corresponding 'Certification Specifications (CS) 26';
- Certification Specifications (CS) 25 'Certification Specifications and the corresponding AMC for large aeroplanes';
- Acceptable Means of Compliance (AMC) 20-20 'Continuing Structural Integrity Programme';
- Acceptable Means of Compliance (AMC) to Part-M 'Continuing Airworthiness Requirements'.

The amendments proposed by EASA are significant for converted aircraft because these affect mostly used aircraft (12–16 years old) that have outlived their intended purpose as passenger aircraft for a variety of reasons (e.g. development of new generation technology, high fuel prices that would render the operating costs for passenger service to be too high, etc.). These converted aircraft would be subjected to heavy modifications, such as: new fuselage cut outs to install new cargo doors, strengthening of the floors, modifications to increase the gross weight, zero fuel weight, and others. These modifications may adversely affect the structural integrity of the aircraft. The vigilance needed to maintain airworthiness of the modified aircraft would need to be more stringent (EASA 2013). Another challenge for continuing airworthiness of the converted aircraft would be to obtain the historical maintenance data of the aircraft and to apply discipline in the continued maintenance, in order to mitigate the increase of any ageing effects due to modifications.

General Aviation (GA) is a part of the industry that cannot be overlooked, due to its significant magnitude and the issues that it is currently facing. CASA was one of the major regulators that took action in an attempt to proactively tackle these issues. One of the main challenges identified by CASA is the gathering and sharing of information for the GA fleet to determine the issues affecting aircraft the average age of which is 40 years. CASA has admitted the impossible task to oversee the management of the ageing issues of individual GA aircraft; therefore it has put the onus back onto individual registered operators. The challenges for GA in the management of continuing airworthiness are the accurate determination of the rate of aging due to their different uses and the location of their storage. Continued airworthiness, thus, very much depends on the organization of operators and maintenance (de Florio 2006). In this framework, CASA has developed a series of solutions, including:

- The deployment and utilisation of a Matrix tool to assist the operator to assess the aircraft's likelihood of suffering from negative impacts of ageing better.
- The introduction of an Ageing Aircraft E-learning course, which is intended to improve the operators' knowledge to be equipped better in the management of ageing aircraft issues.
- Promotion of better use of the type club, where information of the particular type of aircraft can be shared and support may be gained from other members (CASA 2012).

2.2. Evolution and harmonisation of regulations

The aim of the Chicago Convention in 1944 was to ensure the safe, orderly and economic development of air transport. The majority of the world's nations became signatories to the convention, hence each signatory must adhere to the rules, regulations and requirements set out by the International Civil Aviation Organisation (ICAO). EASA, the European Aviation Safety Agency is an independent body accountable to the European Union member states, it is not an ICAO signatory, because it is not itself a state but works closely with ICAO and FAA to harmonise standards and promote the best aviation practices worldwide (CAA 2015).

CASA offers a very good example of how harmonisation can be effectively implemented in the continuing airworthiness regime. In this frame, the Civil Aviation Regulations (CARs) on Continuing Airworthiness have been revised to reflect the world's best practice. A timeline presented in the sequel demonstrates the drawn out journey that CASA has taken to harmonise Australia's regulations with international standards:

- 1996: CASA initiated the Regulatory Framework Program to review and rewrite the Civil Aviation Regulations and Civil Aviation Orders. The new regulations would be renamed Civil Aviation Safety Regulations (CASRs). The aim is to establish a closer compliance with ICAO's standards and recommended practices and to harmonise with other National Airworthiness Authorities by removing maintenance requirements and terminology which is unique to Australia;
- 1996–2004: initiated and conducted the consultation process, revision and further consultation with Notice of Final Rule Making published in 1999, 2001, 2002 and 2004;
- 2005: the Chief Executive Officer of CASA directed a joint CASA/Industry team to develop a suite of maintenance regulations modelled on the EASA structure;
- 2006: the NFRM 060MS was published – a proposal to modernise and harmonise rules for the maintenance of Australian aircraft and licensing of aircraft maintenance personnel; a proposed policy for Parts 42, 66, 145 and 147 of CASRs;
- 2006–2009: it was evident, based on public comments and feedback, that Australian legislative

format protocols could not accommodate some aspects of the European regulatory style. In order to reconcile the two styles, CASA restructured the draft CASRs to empower the use of Manuals of Standards (MOS);
- 2009: CASA published consultation drafts of CASR parts 42, 66, 145, 147 and MOS for further comments and consultations;
- 2011: the NFRM was published on 25 February 2011. The complete documents and their comments are accessible on the CASA website;
- 2011–2013: further consultation and revision leading to amendments to the CASR Part 42-Continuing Airworthiness Acceptable Means of Compliance and Guidance Material has finally ended on 14 October 2013;
- since 2013: the implementation of the regulations, certification and licensing of continuing airworthiness maintenance organisations (CAMO) and engineers as well as education for the operators are carried out.

The challenges that CASA faced during this large scale harmonisation exercise were the accommodation of Australian legislative format protocols to those of EASA and the long drawn out consultation, revision and further consultation with the public and the various agencies. Nevertheless, the impendence from the old system was overcome and today CASA has largely re-structured the continuing airworthiness regulatory set.

3. Military aviation – harmonisation of airworthiness frameworks

The loss of the Nimrod XV230 over Afghanistan in 2006 saw the adaptation of civil aviation best practices that were configured and refined to provide greater management of continuing airworthiness within the UK Military Air Environment. Sir Charles Haddon-Cave QC (2009) in his investigation of the accident found that there was inadequate appreciation of the needs of aged aircraft and a military airworthiness system that was not fit for the purpose amongst other findings. One of the key recommendations for the military was to establish its own Continuing Airworthiness Management Organization (CAMO). The concept of the CAMO is a key part of EASA Part M regulation. The first CAMO approval was presented in 2013 to Captain Mark Garrett of the Royal Navy (Haddon-Cave QC 2009; MAA 2014).

The challenges for the harmonising process in the military are those of sovereignty, recognising the environment and the application purpose of a heavily modified airliner before certification and the sheer amount of time it takes to integrate a civilian best practice into the military regime. In Europe, a decreasing defence expenditure, which also affected the defence Research and Technology expenditure over the last years, has led to a series of cost saving initiatives, among which the harmonization of military airworthiness requirements stands out (Figs 2 and 3).

The European Defence Agency (EDA) is driving a Europe-wide initiative in harmonising airworthiness to enable closer armament cooperation and pooling and sharing within Europe. The roadmap towards harmonised European Military Airworthiness Regulations (EMARs) starts with the agreement on common military airworthiness requirements, followed by national implementation and finally mutual recognition amongst member states (Purton, Kourousis 2014; Purton *et al.* 2014a; Purton *et al.* 2014b). The challenge of the process is very much a sovereignty issue at every stage from the implementation to recognition (Stegmeir 2012; Purton *et al.* 2014c).

In Australia, the Australian Defence Force (ADF) is the owner, operator, maintainer, regulator and designer of modifications of its own aircraft; therefore the ADF is responsible for the airworthiness management and self-regulation of "state aircraft". These aircraft are used and commanded by the defence force, customs and police services of Australia (Davies 2014). However, there

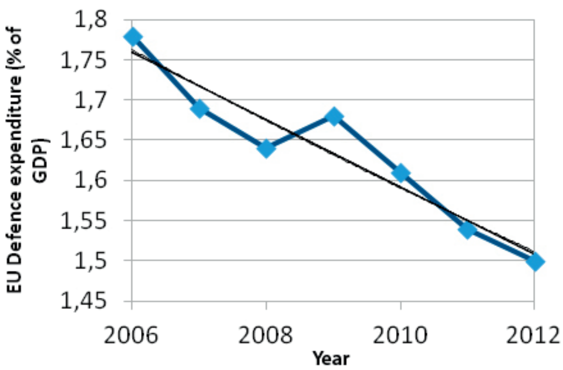

Fig. 2. The European Union (EU) annual defence expenditure in percentage of the GDP (data adapted from EDA 2015).

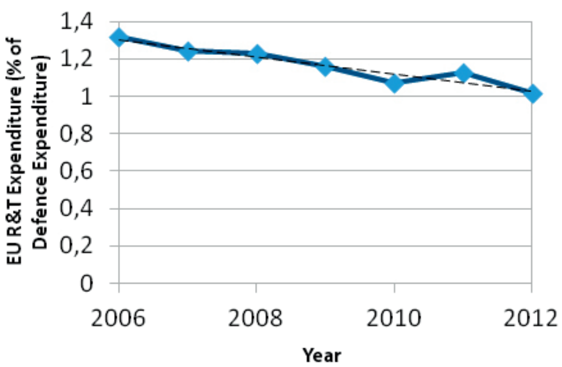

Fig. 3. The European Union (EU) annual research and technology (R&T) expenditure in percentage % of the defence expenditure (data adapted from EDA 2015).

is a process for Recognition of Prior Acceptance (RPA) applicable where there exists an extant aircraft design and systems design. An example is the KC-30 Multi Role Tanker Transports (MRTT), which is a modified Airbus A330 airliner used for air-to air refuelling. EASA is accepted as the National Airworthiness Authority for original type certification of A330-200 but there needs to be recognition of the incompatibilities of the environment and the purpose of the modified aircraft, as well as risk assessment before granting full certification. The RPA extends to all three branches of the defence forces of the USA, FAA, EASA, CASA and the UK Ministry of Defence (Saunders 2011).

4. Proposed change management framework

It is anticipated that in both civil and military environments, a key success factor for the evolution and harmonization of the airworthiness requirements will be a carefully designed change management process. The following change management framework is proposed, based on the Lewin's change management model (Fig. 4) (Lewin 1951).

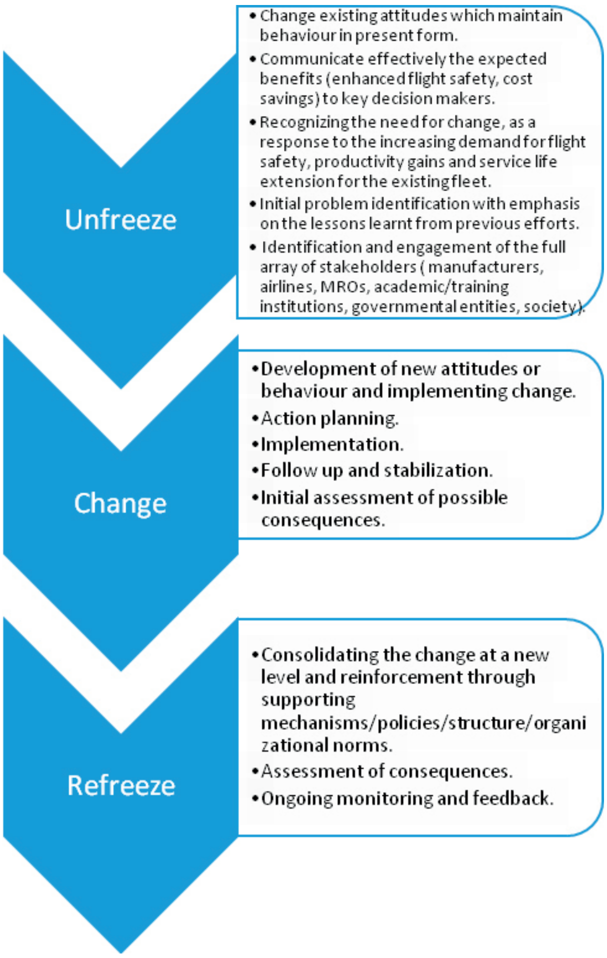

Fig. 4. Lewin's change management model (Lewin 1951) for the evolution and harmonization of the airworthiness requirements.

The model, schematically shown in Figure 4, consists of three stages: Unfreeze, Change and Refreeze. The Unfreeze stage is the most crucial part of the process, as it is about getting ready to change. It is the stage in which a high degree of consensus is required amongst the various stakeholders, concerning the need which drives the change. As long as this consensus is reached, the Change stage can be launched and the agreed change can be implemented. The final, Refreeze stage of this process involves the establishment of stability over the changes that have been made. However, it is very crucial not to consider this final stage as an inelastic one. Aviation is a fast changing industry, thus, ongoing monitoring and feedback need to get incorporated in the implementation of the airworthiness framework to reassure that it is always in line with the operational requirements.

Conclusion

The major driving forces for regulatory reform taking place in the continuing airworthiness domain for civil and military areas are ageing effects that have contributed to aircraft losses and accidents. Although there is no definitive definition for ageing, the effects are too evident in fatigue cracking, corrosion, wear and deterioration. The rate of ageing depends on the operation, maintenance and storing of the aircraft. Statistics have shown that aircraft are being used beyond their notional (design) age, flight hours and some have been modified for purposes far different from their original design. The increasing trend of converting used passenger aircraft to freighters has also resulted in challenges to continuing airworthiness. The used aircraft are usually converted at the average age of 12–16 years, they are heavily modified, which includes total reconfiguration of their fuselage and weight tolerances. These modifications may have an adverse effect on the aircraft's structural integrity and long term airworthiness sustainment. Hence, EASA has published a Notice of Proposed Amendment of Regulations to address the safety issues related to ageing large aircraft.

The formation of EASA was a catalyst in the harmonisation of worldwide continuing airworthiness. In Australia, CASA has accepted EASA's best practice as a model for its own regulations for commercial aircraft and FAA's model for general aviation aircraft. The military in the UK and in Australia have adapted and refined parts of EASA's model into their regulations by recognising the certification of A330 and awarding approvals for Continuing Airworthiness Maintenance Organisations.

The challenges of the harmonisation process have been the integration of foreign laws into the national laws, in the case of military aviation the question has been sovereignty. Time has been the main issue since comments, feedback, revisions and further revisions have to be gathered and written, as evident in the timeline for the development of CASR Part 42-Continuing Airworthiness. Education is also another challenge that CASA faces when dealing with the implementation of continuing airworthiness for GA. The variety of usage and storage possibilities coupled with geographical challenges and the sheer volume of GA aircraft has seen CASA put the onus of airworthiness back onto the owner-operator. CASA has developed prototype tools to assist the owner-operators of GA in gaining better knowledge of the ageing effects of their aircraft, provided an avenue for learning as well as encouraged owner-operators to support and share information with each other.

Since the implementation of these regulations have just begun in Australia and the adaptation of the best practices is still continuing, it has been proven that the process of continuing airworthiness is a dynamic one, so there are sure to be more changes to come.

Acknowledgments

The authors would like to thank Dr Kyriakos I. Kourousis, of the University of Limerick, for his critical evaluation of the paper and expert advice on airworthiness management contemporary issues.

References

Airsafe. 2015. *Average fleet age for selected airlines* [online], [cited 15 February 2015]. Available from Internet: http://www.airsafe.com/events/airlines/fleetage.htm

Boeing. 2012. *World Air Cargo Forecast 2012–2013. The Boeing Company* [online], [cited 24 February 2015]. Available from Internet: www.aia-aerospace.org/assets/Boeing_World_Air_Cargo_Forecast_2012-2013.pdf

Civil Aviation Authority (CAA). 2015. *Regulations, operations & airworthiness* [online], [cited 02 December 2015]. Available from Internet: http://www.caa.co.uk/default.aspx?catid=1407&pagetype=90

Civil Aviation Safety Authority (CASA). 2012. Ageing aircraft management plan in *Discussion Paper DP1205CS-September 2012* [online], [cited 02 December 2015]. Available from Internet https://www.casa.gov.au/sites/g/files/net351/f/_assets/main/lib100097/dp1205cs.pdf

Davies, G. 2014. *Airpower: maintaining the capability* [online], [cited 24 February 2015]. Available from Internet: https://www.aspi.org.au/__data/assets/pdf_file/0010/19972/Air-Power-in-Australias-future-strategy-Mar2014.pdf

de Florio, F. 2006. *Airworthiness – an introduction to aircraft certification*. Oxford: Butterworth-Heinemann. 194 p.

European Aviation Safety Agency (EASA). 2013. *EASA NPA 2013-07* [online], [cited 4 December 2015]. Available from Internet: https://easa.europa.eu/system/files/dfu/NPA%20 2013-07.pdf

European Defence Agency (EDA). 2015. *Defence Data Portal* [online], [cited 25 February 2015]. Available from Internet: http://www.eda.europa.eu/info-hub/defence-data-portal

Friend, C. H. 1992. *Aircraft maintenance management*. Harlow: Longman Group UK, 65–71.

HaddonCave QC, C. 2009. *The Nimrod review*. London: House of Commons.

Kourousis, K. I. 2013. A holistic approach to general aviation aircraft structural failure prevention in Australia, *Aviation* 17(3): 98–103. http://dx.doi.org/10.3846/16487788.2013.840055

Lewin, K. 1951. *Field theory in social science*. New York: Harper and Row.

Military Aviation Authority (MAA). 2014. Roles and responsibilities, continuing airworthiness management organizations (CAMO), *Regulatory Article (RA) 1016* [online], [cited 02 December 2015]. Available from Internet: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/460627/RA1016_Issue_2.pdf

National Transportation Safety Board (NTSB). 1989. Aloha Airline, Flight 243, Boeing 737-200, N73711, *Aircraft Accident Report, NTSB number: AAR-89-03* [online], [cited 24 February 2015]. Available from Internet: http://www.ntsb.gov/investigations/accidentreports/pages/aar8903.aspx

Purton, L.; Kourousis, K. I. 2014. Military airworthiness management frameworks: a critical review, *Procedia Engineering* 80: 545–564. http://dx.doi.org/10.1016/j.proeng.2014.09.111

Purton, L.; Clothier R.; Kourousis K. I. 2014a. Assessment of technical airworthiness in military aviation: implementation and further advancement of the Bow-Tie Model, *Procedia Engineering* 80: 529–544. http://dx.doi.org/10.1016/j.proeng.2014.09.110

Purton, L.; Clothier, R.; Kourousis K. I., *et al.* 2014b. Mutual recognition of national military airworthiness authorities: a streamlined assessment process, *International Journal of Aeronautical Sciences* 15(1): 54–62. http://dx.doi.org/10.5139/IJASS.2014.15.1.54

Purton, L.; Clothier, R.; Kourousis K. I., *et al.* 2014c. The PBP framework for the systematic representation and comparison of military aviation regulatory frameworks, *The Aeronautical Journal* 118(1210): 1433–1452.

Ramsden, J. M. 1981. Continuing airworthiness, *Flight International* 119(3748) [online], [cited 02 December 2015]. Available from Internet: http:// https://www.flightglobal.com/FlightPDFArchive/1981/1981%20-%200567.PDF

Saunders, T. 2011. Lessons learnt from the military certification of an existing EASA type certified aircraft into a military role (MRTT), in *Military Airworthiness (MAWA) Conference*, 07 July 2011, Warsaw, Poland.

Stegmeir, J. 2012. Harmonised airworthiness as a key enabler towards closer armaments cooperation and pooling and sharing within Europe, Europe Defence Agency (EDA), *Military Airworthiness Authorities (MAWA) Forum* [online], [cited 25 February 2015]. Available from Internet: http://www.eda.europa.eu/docs/documents/2---harmonised-airworthiness-as-a-key-enabler-towards-closer-armaments-cooperation-and-pooling-and-sharing-within-europe-j%C3%BCrgen-stegmeir-%28eda-assistant-armaments-director-policy%29.pdf