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AIRWORTHINESS AND SUSTAINMENT OF OLDER AIRCRAFT: AA&S_Mon_001/11

Introduction

The average age of the Australian Low Capacity Regular Public Transport and charter civilian aircraft fleets is increasing: old aircraft are not being retired and newer models are not entering the mix. Defence fixed and rotary wing fleets operate examples of old aircraft which will exhibit similar usage degradation. The purpose of modification and maintenance is to return an aircraft to an airworthy standard and is effective only if those actions identify all unknown degradation issues and then address them. Identifying and correcting all of the potential issues requires the application of known and emerging technologies to targeted structure and systems. The United States of America began addressing this issue in 1988 and there is a pressing urgency to address age related degradation in Australian aircraft fleets. This paper will first present the problem and then canvas solutions

Aim

To quantify industry and Government support to address the degradation in Australia's civilian and Defence fleets of ageing aircraft.

Ageing Problems in the Australian Civil and Defence Fleets

In a paper entitled "How Old is Too Old? The impact of ageing aircraft on aviation safety" released in Feb 2007, the Australian Transport Safety Bureau[ATSB] reviewed the age, and its effect, on the safe operation of the then Australian aircraft fleets.[1] The paper concluded that the average age of the low capacity Regular Public Transport fleet reflected few retirements and even fewer new additions. In defining aircraft age, "There is no single criteria that defines an aircraft as 'old' (Kizer, 1989)."[2] The age depends on deterioration through use including flight cycles and flight hours, wear from mechanical abrasion such as the removal of electrical cable insulation and environmental degradation including corrosion and

[1] How old is too old? The impact of ageing aircraft on aviation safety. B2005/0205 February 2007
ISBN 1 921164 39 5

[2] Ibid

electrical cable conductor oxidisation. The cause of aircraft accidents has been traced to these ageing mechanisms.

Accidents which have a structural age-related cause can have catastrophic effects with significant loss of life: B737 Aloha flight 243 on 28 Apr 1988 suffered an explosive decompression, the rudder of a BA Concorde failed and separated in flight on 12 Apr 1989 and a B747 TWA Flight 800 on 17 Jul 1996 was lost from a fuel tank explosion traced to deteriorated electrical wire insulation.[3] On 2nd April 2011, a one metre by one metre hole appeared in the fuselage roof of a SouthWest B737 aircraft dispite recent non destructive testing inspections of the fuselage following a previous fuselage roof rupture. The failure was identified as fatigue cracking.[4]

In the Australian fleets, the average age of the High Capacity Regular Public Transport Fleet in 2007was 11 years in 2007?. The smaller multi-engined turboprop fleet had an average age of 18 years whilst the even smaller multi-engined piston fixed wing fleet that services the Low Capacity Regular Public Transport and charter markets had an average age of 31years[5]. These aircraft service remote communities whose needs are of a charter nature, spasmodic, whose operators have high overheads and are operated on small profit margins. This limits the available capital to buy replacement aircraft.

In Dec 2009, The Australian Government released an Aviation White Paper[6] which addressed Ageing Aircraft and an ageing workforce. That paper acknowledged the effect degrading structure and systems had in the safety record of old aircraft and required CASA to focus on this matter from a regulatory perspective. As well, the White Paper noted the ageing Australian work force and suggested a redirection of study and an increased throughput in both education and training. These actions would anticipate an age related decline in the pool of qualified and experienced people. The White Paper moved away from direct economic subsidies to purchase new aircraft as a similar initiative had been tried and failed. Without other initiatives, Australian fleets are expected to age further.

Under the Australian Constitution, Australia can raise Defence Forces and the Technical Airworthiness of Defence airborne fleets is a Defence Responsibility. The Directorate General of Technical Airworthiness [DGTA] is responsible for this role. Along with the Defence Science and Technology Organisation, Monash University hosts a Centre of Structural Expertise to provide specialist research advice to DGTA and the questions posed relate to life assurance in the face of ageing structures. Monash University has the background and the structure to address research into a wide range of airworthiness topics.

Accident statistics and the number of age related aircraft defects are the basis for Government concern and a solution to the problem must be found to keep the loss of Australian lives and Australian aircraft to a minimum. By examining a selection of in-service defect and accident reports, the problem can be sub-divided into themes.

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3 Ibid p3.
4 ABC World News 3rd April 2011
5 How old is too old? The impact of ageing aircraft on aviation safety. B2005/0205 February 2007 ISBN 1 921164 39 5
6 National Aviation Policy White Paper: Flight Path to the Future, Commonwealth of Australia 2009, ISBN 978-1921095-96-2

Structural Integrity and Corrosion. Durability and Damage Tolerance Analysis [DADTA] design philosophy is central to the continuing airworthiness of both civilian and military aircraft fleets. The design and through life certification standards require structural members to be tolerant of inherent flaws, manufacturing defects and defined damage that arise from in-service operations. The average age of the Australian Low Capacity Regular Public Transport fleet placed their certification standards pre-DADTA and therefore the Australian fleets are not subject to airworthiness strategies to detect and rectify debilitating failures. Corrosion can erode structure below its load carrying limit and can precipitate serious fatigue damage. As a direct result of US Congress Public Law 107-314 Sec: 1067: "Prevention and mitigation of corrosion of military equipment and infrastructure", all USAF, US Army and US Navy aircraft must be now managed in a damage tolerance fashion. In 2009, the Federal Aviation Administration regulated that all civilian aircraft structural requirements be designed to Durability and Damage Tolerance rules.

Obsolete Avionics including Ageing Wiring. Ageing wiring insulation can deteriorate and subsequent sparking can lead to fire or explosion. Oxygenation of copper conductors and silver sulphide deposits can cause terminations to fail, limit power to electrical and avionic equipments and can cause arcing. Following the TWA B747 accident which was traced to wiring faults, the FAA recognised that "current maintenance practices may not be adequate or proactively address aging non-structural systems". Other wiring faults found during the investigation included "stiff and cracked cables, contamination of wire bundles with metal shavings, dust and fluids, cracked insulation, corrosion on connector pins and improper wire installation and repairs."[7] Methods to identify and replace deteriorated cable looms will be required. Digital avionics are smaller, lighter and smarter than their predecessors and integrating these devices into "analogue" aircraft requires complex interfaces. Whilst the technical problems can be engineering, the human interface with smart equipments and their failure modes must not be neglected.

Gearboxes, propellers, internal combustion engines and rotating assemblies. Whereas helicopter rotor blades have received significant design and maintenance attention, the same regulatory attention has not been applied to gearboxes, propellers and other rotating assemblies to ensure safe operation.

Certification Rules. Current design policy enables new aircraft to be designed to historical design standards where the aircraft is a superseding model. This process enshrines outdated safety rules whilst requiring maintainers to apply old and new philosophies at the same time to ensure adequate standards of airworthiness. The policy of permitting the use of "grand-fathered" design standards must be qualified quantified? and examined.

Maintenance. Continued airworthiness is achieved through appropriate and timely maintenance. Appropriate is defined by where to look and what to do whilst timeliness ensures items do not deteriorate below a performance limit. Maintenance to manufacturers' schedules and Approved Systems of Maintenance have few discrepancies but there is another option selectable by the Registered Aircraft Owner of Class B Australian aircraft: CAR[1988] Schedule Five. "Schedule Five" is open to interpretation and is not updated by in-service experience. CASA is concerned that "Schedule Five", when used on "fare paying" passenger

[7] NTSB Safety Recommendation A-00-105 through -108 19th September 2000, p8

aircraft, can provide a lesser standard of continuing airworthiness. A Maintenance theme, in particular the use of Schedule Five, must be included in any study of Australian Ageing aircraft.

Education and Training. Tertiary training of design engineers includes familiarisation with current design rules but ignores the rules used in most of the equipments on which those engineers will work. At trade level, the lack of numbers and a focus on ageing aircraft problems ill-prepares the student for work on the Australian aircraft fleet. The accreditation of design engineer courses and trade training courses must include the philosophy and practice of ageing aircraft support.

The US Experience

Tear Downs. With a larger aeroplane population than Australia, the US aircraft maintenance experience is valuable to examine and where pertinent, imitate. The FAA commissioned and funded a research programme to tear down a Cessna 402A[8], a Cessna 402C[9], a Piper Chieftain[10], and one Beech 1900D[11] as examples of old aeroplanes. The examinations used both visual and non-destructive testing methods and an extract of the significant details in the extensive reports raised forms Table One.

Type	Flying Hours/cycles	Date of birth	Structural anomalies	Electrical anomalies
Cessna 402A	20,000	1969	25	362
Cessna 402C	25,000	1979	37	187
Piper Chieftan	17,000	1975	1035	199
Beech 1900D	15,000/23,000	1993	266	Not inspected

Figure 1: Overview of Four Aircraft Teardowns

These aircraft were classified “serviceable” and fit to carry fare paying passengers immediately before being removed from service for the teardown. Some items were minor but two, 2.5” [63mm] cracks in a Cessna 402A tailplane leading edge is not insignificant.

The Piper Chieftan had been employed in tourist sight-seeing flights over the US Grand Canyon. The desire to expose tourists to a “close look” at this unique geography exposes the airframe to a severe gust spectrum and the large number of results is expected. Australia does not have a “Grand Canyon” but low level pipeline and power line inspections over distances comparable with the US along with bush fire spotting where aircraft are circled in the strong

[8] DOT/FAA/AR-07/35 Air Traffic Organization Operations Planning Office of Aviation Research and Development Washington, DC 20591
[9] Ibid
[10] DOT/FAA/AR-07/64 Air Traffic Organization Operations Planning Office of Aviation Research and Development Washington, DC 20591
[11] DOT/FAA/AR-08/28 Air Traffic Organization Operations Planning Office of Aviation Research and Development Washington, DC 20591

vertical gusts associated with bush fires [US wild fires] added to hot and strong climatic winds characterise Australian operations and can be just a severe as US experience.

There is no database of structural or electrical faults for aircraft operated in Australian conditions. There are defect reports for significant issues and anecdotal evidence of what aircraft maintenance engineers have found and rectified during routine inspections. Whilst the former can be used to alert all owners of similar types of where to inspect, the later is relegated to folk lore and is therefore implemented in a haphazard manner. To have confidence that a maintenance regime will ensure safe operations cannot be left to haphazard procedures.

The BEECH Boys. The engaging music of the sixties singing group were at odds to the FAA severe rectification regime imposed on Beech owners when defect reports indicated wing centre section deterioration. The US aviation regulatory authority required significant wing centre section repair on a no-crack-allowed-basis. The "one solution fits all" result was pitched at the most deteriorated aircraft and ignored conscientious operators who had maintained their aircraft in an airworthy by inspection condition. The solution was simple for the regulator but a major impost for the operator. The Beechcraft Owners Association rebelled and sought the services of a respected US university to investigate the damage due to fatigue and propose an alternative inspection and rectification regime. The FAA accepted the scientific proposal and legislated it as an alternative. Scientific solutions will be sought in increasing numbers and diversity as alternatives to expensive and draconian regulation.

Solutions

Having identified a latent or at least looming problem with the continuing airworthiness of Australia's Low Capacity Regular Public Transport fleet, a range of solutions to correct the problem can be suggested, viz:

Aircraft Replacement. Replacing ageing aircraft with newer models is expensive. A new eight seat Cessna Caravan aircraft used in Low Capacity Regular Public Transport service has a retail price starting at US$2m. Cessna Caravans are powered by gas turbine engines, significantly lighter than equivalent piston types, are designed to Durability and Damage Tolerance FAA standards and are manufactured with the latest corrosion resistant technologies. Conversely, a second hand Piper Navajo ten seat piston engine aircraft, which ceased production in 1984 and was designed and manufactured under the "grand-fathering rule" to superseded standards and practices, is available in the price range of US$82,000 to US$260,000[12].

[12] Aircraft Dealer On-Line

Maintain the Status Quo. The least expensive option in dollar terms is to do nothing. Limited structural and system degradation, which is found from implementing the existing maintenance schedule and in-service defect reports, will be corrected. As the bath-tub curve rises exponentially with time, degradation which is not found and repaired will eventually incapacitate the aircraft and loss of aircraft and people will ensue. The owner, the manufacturer and the airworthiness regulator will be called into public question and be unable to answer what they did to address an identified problem. Insurance losses will rise making liability capping more expensive and complex. The political fallout in a hung parliament tilted toward regional Australia where the Low Capacity Regular Public Transport fleet are primarily used could be debilitating. The Status Quo is not a recommended option.

Piece-meal. The "piece-meal" approach relies on structural and system deterioration being identified as an unintended consequence of inspections or investigations in adjacent areas. This is a process of luck and chance. Qualified, experienced and conscientious engineers and tradesmen working in adjacent areas and with a thoroughness beyond that of a reasonable person have found degradation, corrected it and alerted others. Like the Status Quo approach, this philosophy relies on luck and chance and the consequences are similar. The "piece-meal" approach is not recommended.

Creation of a CRC for Aircraft Airworthiness and Sustainment

With increasing age, the number of rectifications to an aircraft and its systems has followed an exponentially path[13]. However, a management and research structure addressing the problems of aircraft airworthiness and sustainment would encompass a systematic review of all of the structure and all of the systems in ageing aircraft addressing those areas most likely to degrade and commission correcting action. The research element would match the most appropriate repair technique to the rectification of degraded structure and systems whilst identifying cutting edge repair techniques to reduce repair costs and time. This review must begin with the derivation of simple and effective tools then commission the application of those tools across the fleet.

As an example of one possible opportunity to create Australian business and export potential, the cost of rectifying corrosion in US military equipment is estimated to be US$20b per annum. Australian industries participating in a CRC for AAS would be well placed to capture a "slice" of this work as well as related work in the Asian and Pacific region.

Research across the six themes identified in "The Problem" segment of this Paper needs to be managed across some six universities and all of the industry partners. An existing Australian

[13] Bath-tub

Federal Government structure is available to manage this activity and to commercialise[14] the outcomes viz: a Cooperative Research Centre[CRC].

A CRC for Aircraft Airworthiness and Sustainment would manage the tasking of a suite of Australian and New Zealand Universities having world recognised expertise and achievement records in solving problems proposed by the host of industry partners. These problems would have to be collected and collated then allocated to competent research teams. Research progress would be monitored and reported with outcomes commercialised in favour of the industry partners. A finance system which supports the research would be raised and used as a reporting and management tool. The CRC initiative is explained on the World Wide Web at URL www.crc.gov.au

Urgency

In 1988, the US federal Government passed the Aviation Research Act, in 1991 the Ageing Aircraft Safety Act and subsequently, the FAA authored the National Ageing Aircraft Research Programme. In the USA, research activity into the airworthiness and sustainability of ageing aircraft has been underway for over 20 years. Through tertiary and other research bodies, Australian researchers became involved with the USA Federal Aviation Authority [FAA] who recognised Australia's unique capabilities and funded Australian based research in the first tranche of ageing aircraft solutions.

As outlined in this paper, Australian aircraft lives are increasing because of the prohibitive expense of new aircraft and there is no sign of this changing. Australia is well behind the USA initiatives increasing the urgency to act and ensure the airworthiness of older aircraft before accidents claim their toll.

Support for the Initiative

Support for the initiative to raise a Cooperative Research Centre for Aircraft Airworthiness and Sustainment is being sought from Monash University as a host and on behalf of other universities in support, from Australian Government airworthiness regulators, the Victorian State Government, Aviation Industry representative bodies and commercial aviation industries.

[14] The cost of corrosion within the US military has been estimated as $20 billion per year. Ausralian industries participating in the CRC AAS will be well placed to capture a significant slice of this work as well as related work within the Asian and the local region. This has the potential to create new export industries and opportunities.

Crystal Balling

As Australian aircraft age, routine inspections to approved schedules will detect deterioration; astute maintainers will discover debilitating deterioration beyond the routine inspection areas because those individuals are thorough and the regulatory authority will alert the industry and the public. Projecting ahead for two or three years can help prepare for the most probable outcomes.

CASA, as the Australian Civil Aviation Regulating Authority, has expressed concern about its declining confidence in the airworthiness of ageing aircraft. The Stage One Ageing Aircraft Management Plan included recommendations for gathering accurate data about the Australian fleets, educating Registered Owners and Operators in their responsibilities for the airworthiness of their aircraft, more stringent and prescriptive maintenance requirements for all and consequential audits to provide confidence in the recovery actions. These actions meet the intent of the CASA motto of "Safe Skies for All". The cost of completing these activities will be borne by the aviation community.

In regulating for more in-depth maintenance but in the absence of type specific instructions, a "regulation-only" approach would result in a "one-size-fits-all". Without individual model teardowns, inspections and supplementary inspection documents, where to look and approved repair action will be commissioned by requirements for a greater in-depth inspection for all aircraft. Notwithstanding comprehensive manufacturer's maintenance schedules or thorough inspection to the existing CAR [1988] Schedule Five, all registered Owners will incur a deeper inspection regime. This additional work will, most likely, be costly, incur longer aircraft time-on-the-ground culminating in reduced aircraft availability. In order to gain confidence in the effectiveness of this approach, regulatory requirements for prescriptive audits and reports will be included whilst any degradation found will precipitate an engineering design task and consequential repair activity.

Approval of engineering designs requires a statement that the design "has no unsatisfactory features". Such a requirement on aircraft maintainers could result in maintenance judged acceptable at the time it was completed but some time later, in the subsequent accident investigation, may be re-judged to be unsatisfactory: technology advances, processes, tools and knowledge are expected to improve with time. Maintenance must be prescriptive and this requires an intellectual process to define where to look using the most advanced and reliable technology and what to do when degradation has been found.

Universities and technical colleges are best placed to develop and prove emerging technologies for aircraft testing and repair. To reduce aircraft down time and to accurately find structural and systems deterioration, non-destructive testing, neural networks for finding intermittent wiring faults and advanced repair techniques must be developed, evaluated, adopted and proven reliable and easy to use. A structured and funded programme to complete this work will assist operators, maintainers and the airworthiness regulator.

In the mean time and under a more demanding and costly maintenance regime, Australian airline businesses running on slim margins will go out of business. This may or may not reduce the aircraft accident rate but it will deny sparsely populated areas of fast and efficient transport. Without air travel, development in these areas will slow until a new airline with new aircraft attempts to satisfy the market. The outcome will be higher ticket prices. As for Government support, The National Aviation Policy White Paper ruled out financial support for new aircraft in that funds had been provided previously for exactly this purpose and they had not delivered the "new" aircraft outcomes.[15]

The Next Step

The Australian Aviation Transport Bureau, through their reporting into ageing aircraft and the Civil Aviation Safety Authority through the Aviation Ageing Management Plan are identifying the looming consequences of operating ageing aircraft in Australia. Fixing the problem will need direction, management, research and application from research institutions and the wider aviation industry. A demonstrable need is the precipitant for funding contributions from all parties to resolve this problem.

Extensive overseas experience with ageing aircraft has resulted in accidents and loss of life precipitating state and federal laws to ensure that old aircraft are safe to fly. Ignoring the not-invented-here syndrome will surely result in one or more fatal Australian accidents and adverse reflection on regulating authorities and aviation industries. Learning from overseas experience and complimenting it with unique Australian factors will save Australian lives, reduce insurance payouts and associated financial waste. Sources of funding need overwhelming evidence that investment into research and recovery is cost effective.

A mechanism to define where to look in an ageing structure is to select a high time and high cycle airframe with accurate operational history and disassemble it. During the disassembly, every part is closely examined for cracks and deterioration. The results of the inspection are compiled and revised maintenance schedules can be raised for all of the other aircraft of this type which are still flying. Their operation will be safer for the additional inspections and ensuing repairs resulting from this process.

A wealth of relevant maintenance information is held by CASA in the form of Major Defect Reports. These documents are required by law and raised by operators to record defects not flagged by the original manufactures inspection and repair documents. These reports can precipitate advice to all users of the same type for correcting action whilst the manufacturer can amend the maintenance schedule to include this new item. Trawling through this bank of data may well precipitate recurring items initially considered isolated occurrences as well as directing engineering investigations into associated structural and system areas on the same or similar aircraft types.

The embryo CRC took advantage of a most generous initiative by the Australian Aviation Industry Forum and Airshows Downunder to raise an exhibition at the Avalon Airshow 2011. An attractive logo was displayed along with corroded and cracked aircraft structure which had been found by existing investigative means. The presence attracted many aviation practitioners who supported the initiative but being individually small, their individual contributions would not support an initiative acting in isolation. They universally supported an aircraft "teardown" to add weight to the argument for Government and other large

[15] National Avaition White Paper: Flight Path to the Future, December 2009, p64

enterprise funding. A focus on compliance by all aviation practitioners was emphasised and if compliance was perfect then the need for additional work could be focused on emerging structural failure sites and emerging repair technologies. Compliance is not perfect and therefore more diligence is required to complete existing processes through training and functional/physical hardware audits.

As a bid to raise a Cooperative Research Centre [CRC AAS] to manage and research ageing aircraft issues, the next step is to canvas industry support through the auspices of the Australian Aviation Industry Forum, the Australian Association of Aerospace Industries, Defence Technical Airworthiness and Government support at State and Federal level through a direct approach. To date, that support has been most encouraging and the preparation of a CRC AAS bid which meets Government guidance and has significant industry and Defence input will follow. Bid preparation will include problem definition, risk management analysis, CRC management and a budget. This bid will require funding to be complete and to be pitched at the appropriate level. Round 15 of the CRC programme has yet to be announced but is estimated to have a mid 2012 submission date.

Conclusions

The average age of the Australian Low Capacity Regular Public Transport civilian aircraft fleets is increasing: old aircraft are not being retired whilst at the same time newer models are not entering the mix. Defence fleets have similar examples. Rectification and maintenance is effective only if all known and unknown degradation is fixed.

Purchasing new aircraft types would reduce the problem; however, the return on investment is not currently viable. Not addressing the increased risk would leave industry, insurers and regulatory authorities open to public criticism as aircraft accident rates most probably would increase with consequential loss of life. Whilst a “piece-meal” effect addressing issues as they occur would be least disruptive, the risk is similar to that of the Status Quo. Anything but a properly structured vehicle to address all of the issues could attract public ire.

The most appropriate vehicle to corral ageing aircraft problems and focus appropriate research onto correcting those problems is a Cooperative Research Centre for Ageing Aircraft and Sustainment

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