Trainer Aircraft ASIP Case Study



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Outline

- 1. Background
- 2. The evolution of the RAAF PC-9/A ASIP
- 3. Unexpected in-service Cracking
- 4. Structural Life Assessment
- 5. Implications for ASIP
- 6. Initial Mitigation





- 7. Planned Withdrawal Date Creep
- 8. Root and Branch Review of the ASIP
- 9. Ageing Aircraft Structural Audit
- 10. Ageing Aircraft System Audit
- 11. ASIP Recovery Fleet Management
- 12. Summary



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1. Background

 Royal Australian Air Force (RAAF) operates a fleet of 62 Pilatus PC-9/A aircraft

in an advanced pilot training role.

- PC-9 introduced into RAAF service in the late 1980s Planned Withdrawal Date (PWD) of 2008.
- Fleet has experienced several extensions to this PWD since, with the current PWD in 2019.
- Organizations involved in ASIP:
 - Defence Aviation Safety Authority (DASA) (PC-9/A ASIP Manager)
 - Defence Science & Technology Group (DSTG)
 - QinetiQ Australia (Engineering, Independent Consultant)



- Trainer Aircraft
 Systems Program Office
 (TASPO)
- Pilatus Switzerland (OEM)
- Pilatus Australia Design Office



2. Evolution of the RAAF PC-9/A ASIP.

- Structural Life of Type (LOT) derived from an in-country Full Scale Fatigue Test (FSFT) performed by DSTG in the mid 1990s accounting for RAAF Configuration, Role and Environment (CRE).
 - No such test performed previously for the FAR-23 aircraft; analysis alone considered insufficient evidence for fatigue performance of aircraft.
 - ADF insisted on test; sensitive to fatigue performance (due to <u>catastrophic failures</u> in 1990s.
- Test Interpretation and subsequent Fatigue Management derived from <u>DEF STAN 00-970</u>
- FSFT resulted in modifications and a Safety by Inspection (SBI) program to manage the fleet to PWD.
- Routine ASIP established

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3. Unexpected in-service Cracking

- Fatigue cracking prior to Safe Life Limit established through FSFT, • especially in aft fuselage structure
 - Aft Fuselage Skin
 - Aft Fuselage Frames
 - Fin Ribs
 - **Fin Attachment**





4. Structural Life Assessment (SLA)



- QinetiQ Structural Life Assessment in 2007 and 2014:
 PWD achievable but ASIP and FSFT deficiencies identified:
 - earlier recommendations by DSTG to verify FSFT spectrum development assumptions for aft fuselage had not been followed up
 - Also various other issues with fatigue meter calibration, quality of condition data, build quality related to Australian built aircraft, environmental degradation, stress corrosion cracking, configuration control and Instruction for Continuing Airworthiness (ICA) for growing number of mods and repairs – especially for aft fuselage!
- Number of recommendations for Environmental Degradation Management System and Fatigue Management System,
 - Most significantly fatigue management of aft fuselage: Safety net through inspections, Operational Loads Monitoring (OLM) Ageing Aircraft Audit (AAA) incl teardown.



5. Most Significant Implications for ASIP

- Cert basis for aft fuselage inadequate for
 - identification and lifing of critical locations
 - repairs and mod designs
 - assessing Life of Type
- Safety net through inspections, but
 - over-maintenance of primary structure
 - inspection regime, maintenance burden
 - maintenance induced damage (torque tube)
 - unknown unknowns





6. Initial Mitigation

Several activities subsequently initiated to address these deficiencies and address ageing aircraft concerns.

- Risk assessment- Retained medium residual risk
- Operational Loads Monitoring Program (DSTG, Pilatus, QinetiQ for TASPO)
 - Strain gauges and accelerometers; ground and flight test program; identify and quantify loads
 - FEM; Local stress; manoeuver loads and high frequency buffet
 - Stress sequence
 - Fatigue life analysis
 - Identify new hotspots
- Adjust Inspection Program for aft fuselage
- Tear down of high life aircraft considered, to supplement OLM





7. Planned Withdrawal Date Creep

- Ongoing Issues
 - further reports on aft fuselage damage
 - ageing risks
 - growing backlog of ASIP recommendations from SLA and other routine ASIP activities
 - progressive extensions to the PWD
- But 'Impending PWD' limited forward investment,
 - What is necessary to get to PWD?
 - Example Ageing Aircraft Structural Audit (AASA): Requirements waived
- However, latest PWD Extension by 2.5y to Dec 2019
 - -> Root and Branch Review of the ASIP





8. Root and Branch Review of the ASIP

- Aim: Ensure that sustainability risks to operations to December 2019 are disclosed and managed
- Steps:
 - Ageing Aircraft Audit:
 - Structural Audit including Tear Down
 - System Audit
 - ASIP Recovery Fleet Management





9. Ageing Aircraft Structural Audit - Background

- ADF Airworthiness Regulations require AASA at mid-life point or 15 years inservice
- Gap Analysis: requirements vs activities in the past
 - Top down: FMS/EDMS desktop review
 - Bottom up: Fleet Condition Review
 - Risk and Gap Assessment
 - Outstanding Requirement: Physical Audit
 - Teardown of an in-service aircraft
 - Data collection of damage within non-inspectable structure.
- Post-2019 PWD extension: Decision to conduct full aircraft teardown to address outstanding requirements.



9. Ageing Aircraft Structural Audit - Teardown

Selection and Process

- One high life/high fatigue accrual fuselage and wing torn down.
- Targeted inspection locations defined through consideration of:
 - Structural classification and part criticality
 - Outcomes from OLM/FEA Program
 - Known susceptibility to Stress Corrosion Cracking (SCC)
 - Part accessibility
 - Usage, configuration and condition data of fleet and selected assets
- Teardown process involved:
 - Disassembly
 - Inspection (visual and targeted NDI)
 - Forensic Engineering & Analysis of Findings





9. Ageing Aircraft Structural Audit - Teardown

Results

- Teardown article in overall reasonable condition.
- Damage found in
 - Safety By Inspection (SBI) locations.
 Deficiencies in the extant SBI practices!
 - Previously uninspected primary structure.
- Examples of findings:
 - Fatigue cracks, extensive corrosion pitting and SCC.
- Action for fleet
 - Fleet inspection, parts replacements, repairs
 - Expand inspection program



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10. Ageing Aircraft System Audit - Background

Aim:

- Identify and assess usage and age-related threats to PC-9/A aircraft systems integrity
- Independent assessment of aircraft management processes
- Identify patterns or trends pointing to future airworthiness, supportability or obsolescence problems.
- ensure ageing risks to systems are captured and managed

PC-9/A Ageing Aircraft System Audit (AASysA) approach based on:

- UK Military Airworthiness Authority Regulations: RA 5723 – Ageing Aircraft Audit.
- QinetiQ UK AASysA knowledge and experience.
- F/A-18 Classic Hornet <u>AASysA</u> by TFSPO, QinetiQ, Jacobs





10. Ageing Aircraft System Audit– System Threat Analysis

HRI	Risk Level	
1-3	HIGH	
4-6	MEDIUM	
7-10	LOW	
11-16	NEGLIGIBLE	

- On-board systems analysed for threats to ongoing operations.
 - Risk based approach using Hazard Risk Index (HRI) methodology as per TASPO System Safety Program Plan.
 - Ageing threat types considered: •

	HAZARD SEVERITY						
PROBABILITY		Minor	Major	Hazardous	Catastrophic		
	Probable	7	4	2	1		
	Remote	11	8	5	3		
	Extremely Remote	14	12	9	6		
	Extremely Improbable	16	15	13	10		

- Wear
- Fatigue
- Environmental Degradation
- Maintenance Management
- Accidental Damage
- Overload
- Configuration Control Management
- Supply/Obsolescence
- Design/Manufacturing Error
- Change of Use
- Change of Policy, Culture or Legislation



Ageing Aircraft System Audit– System Threat Analysis

- Threat analysis largely based on:
 - Maintenance, defect and condition data.
 - OEM service bulletins.
 - RAAF modifications.
 - RAAF Special Technical Instructions (STIs).
 - Hazards reported within Defence Aviation Hazard Reporting and Tracking System.
- Consideration given to:
 - Previous failures.
 - Reliability trends.
 - Item criticality.
 - Existing inspections and replacements.
- Potential for previously unseen threats.





10. Ageing Aircraft System Audit– Zonal Hazard Analysis (ZHA)

- System and sub-system analysis considered systems in isolation. ZHA considered interaction of physically collocated systems.
- ZHA conducted to assess potential for failure propagation and associated implications.
- Conducted similarly to system threat analysis with aircraft split into 6 zones.
- Zonal threats considered:
 - Pressure
 Heat, Temperature and Flammability
 Friction / Mechanical Wear
 Electrical
 Vibration and Noise
 - Radiation
 - Contamination / Chemical Reactions
 - Miscellaneous



10. Ageing Aircraft System Audit– Outcome

- 639 threats to PC-9/A fleet identified throughout aircraft systems, sub-systems and zones.
 - 64 Category A Recommendations Specific response proposed.
 - 30 Category B Recommendations Further investigation required.
- Recommendations for physical audit of fleet, currently being implemented by TASPO.





11. ASIP Recovery

- Aircraft Structural Integrity Program:
 - USAF MIL-STD-1530D
 - certification and sustainment requirements
 - acceptable level of risk
 - costs and availability



- DASA-ASI lost confidence in management of PC-9/A ASIP
 - Degradation, Condition Monitoring and Fatigue Management System (SCMS and FMS))
 - Recommendations backlog
 - Configuration control
 - Certification issues
 - Successive small extensions to PWD limiting the feasibility of large scale improvements.



11. ASIP Recovery – Deficiencies





11. ASIP Recovery – Consolidation of SBI Locations

Example - Frame 9:

- SBI to include all inspection locations and configurations rather than having
 - four different SBI locations with
 - varying thresholds and intervals that require
 - different NDT reports, etc.
- Consolidation improved clarity and efficiency^{16.10}
 of the SBI program by
 - reducing the number of inspections and
 - rationalising inspection intervals





11. ASIP Recovery – Fleet Inspection

- Fleet-wide audit to determine structural configuration of fatigue critical locations.
- Inspection layout based on consolidated ASIMP Volume 2.
- Example Findings
 - Non-standard repairs versus repair authorised by latest ICA / SBI policy
 - Stop drilled cracks in SBI locations do not adhere to current repair policy
- Also, new structural condition database 'VISION' used to record all NDT reports, structural defects and Other Configuration Records (OCRs).







11. ASIP Recovery– ICA Revision

- End to end audit of SBI ICA to identify deficiencies.
- Revision of current ICA / SBI policy to:
 - Ensure all inspections included in NDT manual.
 - Simplify implementation policy.

 Remove contradicting instructions.

 Ensure all existing repairs to fatigue critical structure are appropriately captured.

ASIMP Vol 2 **Deviations Structural Repair Manual Technical Maintenance Plan Carried Forward Aircraft Maintenance Manual Computer Aided Un-serviceabilities Maintenance Management NDT Manual** System **Special Maintenance Requirements** Inspection and repair instructions Not always aligned with Non-standard configurations in various pubs, not always SBI policy not tracked consistently aligned with ASIMP Volume 2



11. ASIP Recovery – Rectification Activities Summary



Revise ASIMP Vol2 and all supporting ICA:

configuration, include fatigue management for nonbaseline configuration, outcomes from OLM program



12. Summary

- Basis for continuing airworthiness management established through FSFT and Routine ASIP.
- Other non-routine activities such as SLA, OLM, AAA are resource intensive, but also key ASIP components.
- PC-9 ASIP suffered from lack of resources and forward investment due to 'impending PWD' since 2005.
- Latest PWD extension was catalyst for significant investment in ASIP recovery.
 - OLM/FEA Program, AAA, Fleet Configuration Audit, ICA revision, investment in condition monitoring system
 - Minimised ageing aircraft risks to safety, sustainability and capability.
- ASIP continues to manage a variety of issues including developing Fatigue Management policy to address build quality issues.
- Combined outcomes of these projects contribute to stakeholder confidence that PC-9/A is being managed safely and effectively, ability of fleet to safely meet PWD.



Questions





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