CASA Ageing Aircraft Management Plan

‘Ageing 101’ Awareness Seminar

“Discovery consists in seeing what everyone else has seen and thinking what no one else has thought”
Albert Szent-Gyorgi, 1937 Nobel Prize in Physiology and Medicine
An Owner’s Perspective…

- The real questions for you are:
  - What do I have to do?
  - When do I have to do it by?
  - How much it will cost?
  - Who can I go to for help or further information and assistance?
The Menu

• At completion of the Ageing 101 awareness seminar, each participant will have some knowledge of:
  – the definition of an ageing aircraft
  – the common manifested effects of ageing i.e. fatigue, corrosion, wiring degradation, increased wear/deterioration rates, reduced aerodynamic and system performance, etc
  – the potential consequences of such ageing effects i.e. catastrophic failures, in-flight emergencies, repair costs, foregone revenue, etc
  – the common causes of or contributors to such ageing effects
  – the likely locations of occurrence of such ageing effects
  – the warning signs of existence of such ageing effects
  – methods of detecting such ageing effects i.e. systems, processes, procedures, tools, techniques, education and training, shared information, etc
  – methods of preventing and/or mitigating the impact of such ageing effects i.e. systems, processes, procedures, tools, techniques, education and training, shared information, etc
  – where to find more information on the ageing aircraft phenomenon
AAMP Stage 1 Summary

What We Don’t Know We Don’t Know
1 recommendation

What We Know We Don’t Know, But Have Not Yet Addressed
16 recommendations

What We Know, Have Addressed, but Don’t Do Well
8 recommendations

What We Know, Have Addressed And Do Well
3 recommendations
Life Discussion

- **Notional Life**
  - How long did the design engineer expect it to last?
    - What were the design assumptions?

- **Fatigue Life**
  - What was the load spectrum? Has it changed?

- **Corrosion Life**
  - Where is it hangared?

- **Exposure Life**
  - How long do non-lifed items last in air?
    - On-Condition - is it inspectable?
Life Discussion

• **Document Life**
  – Is it still appropriate today?
  – Was the document meant to be read with a certain level of inherent knowledge?
  – Do the current maintainers have that knowledge?

• **Airworthiness System Life**
  – Has the airworthiness system changed?
  – Has the maintenance, engineering, technology, etc changed?

• **Economic Life**
  – What does this mean?
Extending the Bathtub Curve

![Bathtub Curve Diagram]

**Figure: The Bathtub Curve**
Why?

• Again, why do I have to do anything differently, when my aircraft seems to be perfectly good now according to the Manufacturer’s manual?
Why?

- **Regulations**
  - Registered Operator must prove airworthiness, not by omission
  - Remember CASA’s perspective

- **Finite Life**
  - Recall discussion on finite life of data/understanding
  - We’ve seen aircraft that are not safe, even though they are operated/maintained in accordance with Manufacturers’ manuals

- **Business Imperatives**
  - Profit, given business decision to keep old aircraft
    - Reduce costs
    - Increase revenue/utility
  - Increased on-line availability
  - Need an airworthy aircraft to operate and produce revenue safely
  - Reputation/business risk
Colin’s “Equation of Life”

\[ \text{SALES} - \text{COSTS} = \text{PROFIT} \]

Less Unscheduled Maintenance + Less Repair COSTS
= More Flying Availability

*Unlike classic maintenance, AAMP delivers on both fronts!!*
## Aircraft Accident Causal Factors

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<th>AIRFRAME</th>
<th>ENGINES</th>
<th>FUNCTIONAL</th>
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- **Airframe Failures**: 28%
- **Engine Failures**: 18%
- **Functional Failures**: 54%
Is it Safe?

Where are the missing parts now?
Corrosion

Generally Corrosion rate naturally slows with time
Cost of Corrosion

This is actual data

The better prepared, the longer they last and the cheaper to operate in the longer term
Corrosion Types

- Corrosion is commonly classified based on the appearance of the corroded material.

- The classifications used vary slightly from reference to reference but there is generally considered to be several different forms of corrosion.
Corrosion Types

- **Uniform or general** – corrosion that is distributed more or less uniformly over a surface.

- **Localized** – corrosion that is confined to small area. Localized corrosion often occurs due to a concentrated cell. A concentrated cell is an electrolytic cell in which the electromotive force is caused by a concentration of some components in the electrolyte. This difference leads to the formation of distinct anode and cathode regions.
  - **Pitting** – corrosion that is confined to small areas and take the form of cavities on a surface.
  - **Crevice** – corrosion occurring at locations where easy access to the bulk environment is prevented, such as the mating surfaces of two components.
  - **Filiform** – Corrosion that occurs under some coatings in the form of randomly distributed threadlike filaments.
Corrosion Types

- **Intergranular** – preferential corrosion at or along the grain boundaries of a metal.
  - Exfoliation – a specific form of corrosion that travels along grain boundaries parallel to the surface of the part causing lifting and flaking at the surface.
  - The corrosion products expand between the uncorroded layers of metal to produce a look that resembles pages of a book.
  - Exfoliation corrosion is associated with sheet, plate and extruded products and usually initiates at unpainted or unsealed edges or holes of susceptible metals.
- **Galvanic** – corrosion associated primarily with the electrical coupling of materials with significantly different electrochemical potentials.
- **Erosion corrosion** – a corrosion reaction accelerated by the relative movement of a corrosive fluid and a metal surface.
- **Fretting corrosion** – damage at the interface of two contacting surfaces under load but capable of some relative motion. The damage is accelerated by movement at the interface that mechanically abraded the surface and exposes fresh material to corrosive attack.
Corrosion Types

– **Environmental Cracking** – brittle fracture of a normally ductile material that occurs partially due to the corrosive effect of an environment.
  - Corrosion fatigue – fatigue cracking that is characterized by uncharacteristically short initiation time and/or growth rate due to the damage of corrosion or buildup of corrosion products.
  - High temperature hydrogen attack – the loss of strength and ductility of steel due to a high temperature reaction of absorbed hydrogen with carbides. The result of the reaction is decarburization and internal fissuring.
  - Hydrogen Embrittlement – the loss of ductility of a metal resulting from absorption of hydrogen.
  - Liquid metal cracking – cracking caused by contact with a liquid metal.
  - Stress corrosion – cracking of a metal due to the combined action of corrosion and a residual or applied tensile stress.

– **Dealloying** – the selective corrosion of one or more components of a solid solution alloy.
  - Dezincification – corrosion resulting in the selective removal of zinc from copper-zinc alloys.
Corrosion Pitting

Corrosion Pits

Spar cap
Exfoliation Corrosion

Floor beam
Filiform Corrosion
Crevice Corrosion

Fuselage skin beneath antenna
Galvanic Corrosion

Non-passivated stainless steel screw and aluminium sheet
Uniform Corrosion

Corrosion of cadmium on fastener
Mum goes in this

Not covered by Manufacturer’s Maintenance Schedule

Found by accident
Corrosion inside rudder, indicator = 1 missing rivet
Fatigue - Cracks

Cracks take a while to initiate but move quickly
Tests are done on a factory part
Cracking

- Aircraft fuselage structure is a good example of structure that is based largely on a slow crack growth rate design.
- Many years ago, the USAF reviewed a great number of malfunction reports from a variety of aircraft.
- The reports showed that the preponderance of structural failures occurred from 1) built-in preload stresses, 2) material flaws and 3) flaw caused by in-service usage.
- These facts led to a design approach that required the damage tolerance analysis to assume a material flaw exists in the worst orientation and at the most undesirable location.
- The analysis helps to ensure that structures are designed that will support slow stable crack growth until the crack reaches a length where it can reliably be detected using NDT methods.
Fatigue Cracks

Crack started by corrosion on other side
Stress Corrosion Cracking
Cracking

Cracks from fastener holes

Note before and after
Finding Cracks

May be difficult
May not be guaranteed
May be expensive
Wiring

Who does this?

USE OLD WIRE

MIX WIRE TYPES

NOT USE CLAMPS

How many times can you depend on the operation of a relay or switch?
Wiring Considerations

Categorization
Grounding
Shielding
Replace wire
Replace connectors
What is the failure mode?
Reduce cost
Increase safety
Design out problems
Trade-off weight
Finding Problems

Look using a different spectrum

Not as expensive as you might think
Hidden Treasures

But… it’s a Manufacturer’s sealed cable – with no specified inspection!
The Passage of time, Certain Death

Not able to be inspected

Not lifed

On-condition
Ageing Wiring

TWA 800 was another one, 17 July 1996
This was a Boeing 747, 25 years old
All 230 people were lost
Ageing wiring caused a fuel tank explosion.
More Ageing Wiring

Some GA examples
Finding the “Unknowns”

• “Those issues lurking just beneath the surface waiting to happen, or those things that could potentially happen, given the right set of circumstances”
• Identify and investigate “unseen” components or areas of structure
• Review “on condition” components – is this still the most appropriate maintenance policy?
• What does “on-condition” actually mean?
• Design deficiencies can strike at any time in an aircraft’s life – day one, ten years, or maybe never.....
Infrared – Other applications

May show up issues not addressed by the Manufacturer’s Maintenance Schedule

Where are the leaks?
“On condition” item

Difficult to access
How do you know they are still serviceable?
- Boroscope?
- x-rays, MRI?
Ageing Effects

• May be cumulative over time

• Beyond scope of designer’s original expected life

• Why Supplemental Inspection Documents (SIDs) exist (for some aircraft)

• Potential need for enhanced maintenance schedules (accumulation of unknowns)
Consequences

• Linked back to Profit via reduced costs or increased revenue or both
  – Failures, possibly catastrophic
  – Decreased availability – may mean loss of revenue
  – Increased maintenance costs
  – Increased operating costs
  – Need for upgrades
  – Spares harder to source – increased costs
  – Increased fuel consumption – increased costs

• Swiss Cheese model
Definition of Ageing Aircraft

• Logical conclusion is that an aircraft is ageing from day dot

• Every aircraft is an ageing aircraft

• Every part of the aircraft is ageing

• Every aircraft ages at a different rate

• Every aircraft requires different management strategies to maintain airworthiness and cost-effectiveness
What do I do?

- Take a closer look!
- Tools/techniques
- Think beyond existing documentation

- Systematic review to validate Airworthiness
- Review documentation
- Get into the red zone of the Venn diagram – look for the “unknowns”
What?

Preventive maintenance
Replace
Upgrade
Alter environment
Corrosion Prevention Control Programs
Storage
Dehumidify
Etc.
Who do I talk to?

LAMEs

Engineers (CAR35 and/or 42)

Type Clubs

Manufacturers

Type Certificate Holders

Non Destructive Testing (NDT) Specialists

The challenge of designing a fail-safe Space Shuttle
What Next?

• Familiarise yourself with your System of Maintenance
  – System of Maintenance?
  – Manufacturer’s Maintenance Program?
  – CASA Maintenance Schedule 5?

• Continue with your own education
  – Read journals and magazines eg Flight Safety Australia
  – Visit websites eg CASA, FAA
  – Discuss ageing issues with experts

• Contribute to CASA’s Ageing Aircraft Management Plan
  – Discussion Paper
  – Notice of Proposed Rule Making
Revisiting Your Business/Ownership Plan…

• Consider…

• If your aircraft:
  – Is “really” old, or has flown significant hours
  – Is operated and/or hangared in a corrosive environment
  – Has accumulated many take-offs and landings
  – Is not supported by an adequate manufacturers continuing airworthiness program, or is on Schedule 5
Revisiting Your Business/Ownership Plan

• Then you will need to do something……
  – Consult with the manufacturer or industry to develop a continuing airworthiness program for your aircraft
  or
  – Change aircraft operating category
  or
  – Retire the aircraft

….Because remember, the onus is on YOU to prove that your ageing aircraft is airworthy.
The end