Understanding Ageing Aircraft Threats - An Overview of QinetiQ Practical Experience from UK MOD Ageing Aircraft Programmes

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Background

- Following the loss of Nimrod XV230 over the skies of Afghanistan in 2006, the UK Military Air Authority has mandated that all UK MoD aircraft shall be the subject of an Ageing Aircraft Audit at the 15 year in service point.
- RA5723 details the regulation for the conduct of Ageing Aircraft Audit.
- Since 2008 QinetiQ have conducted over twenty Ageing Aircraft Programmes including BAE146, C130-J, Tornado GR Mk4/4A, Hawk T Mk 1/1A, Merlin, Apache AH Mk1 and C17A.
- To satisfy the requirements of RA5723 QinetiQ have developed a methodology that divides the AAA into two discrete areas:
    1. Documentation and Maintenance Audit
    2. Condition Survey
- Although not part of the Ageing Aircraft Audit, many Project Teams have opted to include a Zonal Hazard Analysis within the scope of an Ageing Aircraft Programme, as a means of understanding the risk posed by system to system interaction.

AAA Overview

- Broken into sub audits for Structures, Systems and Propulsion the AAA provides assurance that the Structural, Systems & Propulsion Integrity are being managed appropriately and in accordance with the relevant airworthiness regulations. This is achieved by conducting a periodic independent assessment of the airworthiness of the fleet as it ages, including:
    1. Review the applicability of procedures, management processes, technical information and documentation.
    2. Undertake independent physical examination of the condition of representative aircraft from the fleet.

- This presentation will provide a synopsis of a typical Ageing Aircraft Programme, with a particular focus on Condition Survey and Zonal Hazards.

Documentation and Maintenance Audit

- The documentation and maintenance audit is a process and system audit that carries out an independent assessment of the integrity, functionality & airworthiness of the aircraft and its vulnerability to ageing effects.
- The audit collates management activities to build a coherent picture of the airworthiness and Integrity Management processes supporting the platform.
- The audit follows an established Work Package approach and can be grouped into the following categories:
  - Maintenance Management – inc work recording, maintenance policy, maintenance manuals, logistics support;
  - Operational Documentation – inc flight reference cards, operational usage, release to service;
  - Airworthiness Management – inc fault reporting, air occurrences, ongoing airworthiness management, authorisation and training;
  - Configuration Management – inc repairs, concessions, config. management;
  - Design, Qualification & Analysis – inc design substantiation, systems analysis

Documentation and Maintenance Audit

Example of Non Compliance

- During a condition survey as part of a fast jet Ageing Aircraft Audit, it was observed that in-use aircraft had installed hydraulic flexible hoses which were up to 37 years old. This age is based on component date stamps (cure dates) dating back to 1979.
- The pipes did not appear in the component life register, as such they had an ‘on condition’ maintenance policy.
- The Design Organisation/Original Equipment Manufacturer ‘recommended lives’ was checked and it was identified that the pipes should have been allocated a calendar life of 10 years, yet this was not reflected in the master maintenance schedule.
- Further investigation during the audit concluded that other aircraft types using the same type of pipes had applied a calendar life.

Condition Surveys and Zonal Hazard Analysis

- QinetiQ has extensive experience in Condition Surveys and ZHA

Condition Surveys

- Nimrod (2008)
- Hercules (2009)
- VC10 (2009)
- Tornado (2010)
- BAe 146 (2012)
- BAe 125 (2013)
- Bassett (2014)
- Harvard (2014)
- Merlin (2015)
- C130-J (2015)
- Hawk (2015)
- Apache (2015)
- C17A (2016)

Zonal Hazard Analysis

- Puma (2010)
- Gazelle (2010)
- Sea King (2011)
- Tucano (2012)
- Tornado (2012)
- VC10 (2012)
- BAe125 (2013)
- BAe146 (2013)
- Sentinel (2013)
- Sentry (Scoping Study)
- Hawk (2015)
- Apache (2015)
- C17A (2016)

Condition Survey - Overview

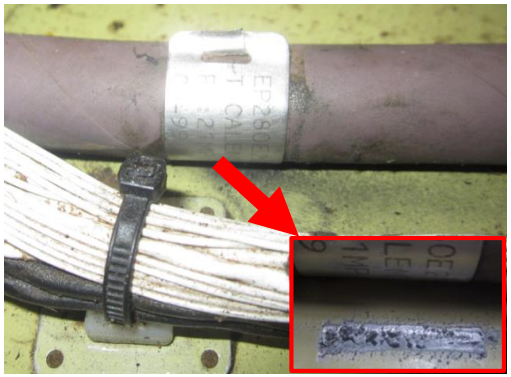
Condition Survey

- The Condition Survey is a detailed, independent physical examination of the condition and husbandry standards of representative aircraft from the fleet.
- As acknowledged within RA5723 this should be carried out by experienced engineering tradesmen, but whom are not currently employed on aircraft type.
- Using processes developed from experience gained on Nimrod, Hercules and VC10 AAPs this activity surveys, records and identifies condition related trends.
- The results of a Condition Survey can be used for strategies employed by the aircraft's Continued Airworthiness team to inform training, improve the maintenance policy and recommend design improvements.
- A Condition Survey ultimately measures the effectiveness of maintenance standards/policy and will lead to subsequent improvements in Airworthiness and safety.

Condition Survey - Trends

- One of the aims of the Condition Survey is to identify trends or patterns that suggest future airworthiness and integrity problems.
- Examples of such trends from a recent Condition Survey activity include;

Issues associated with sharp edge of pipe ident tags



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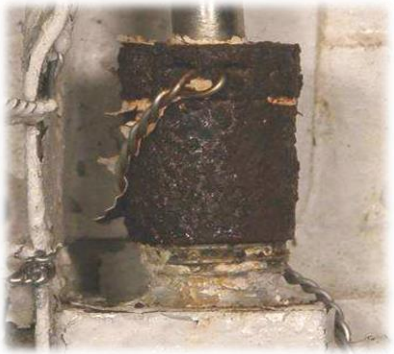

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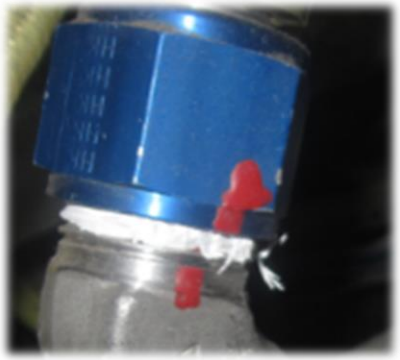

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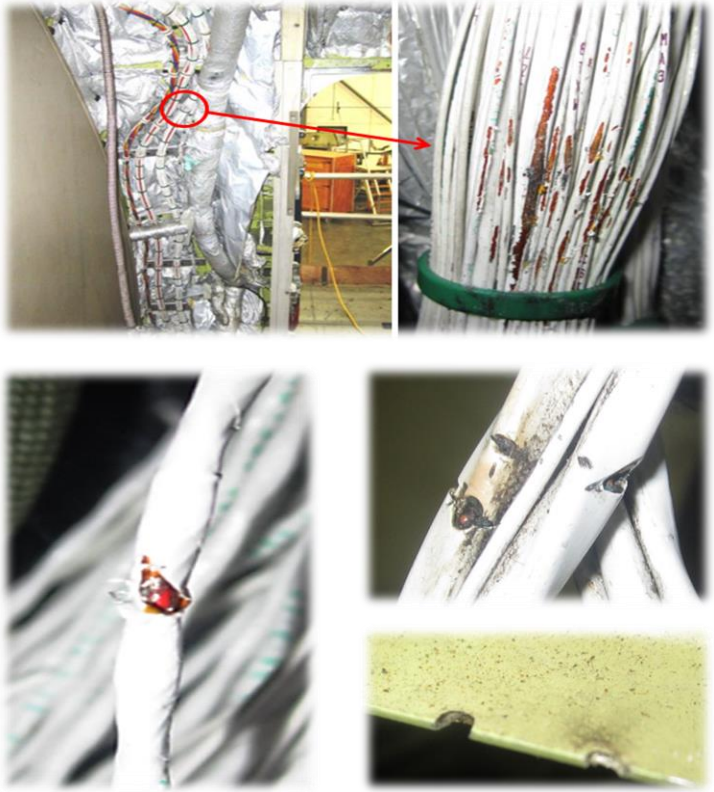

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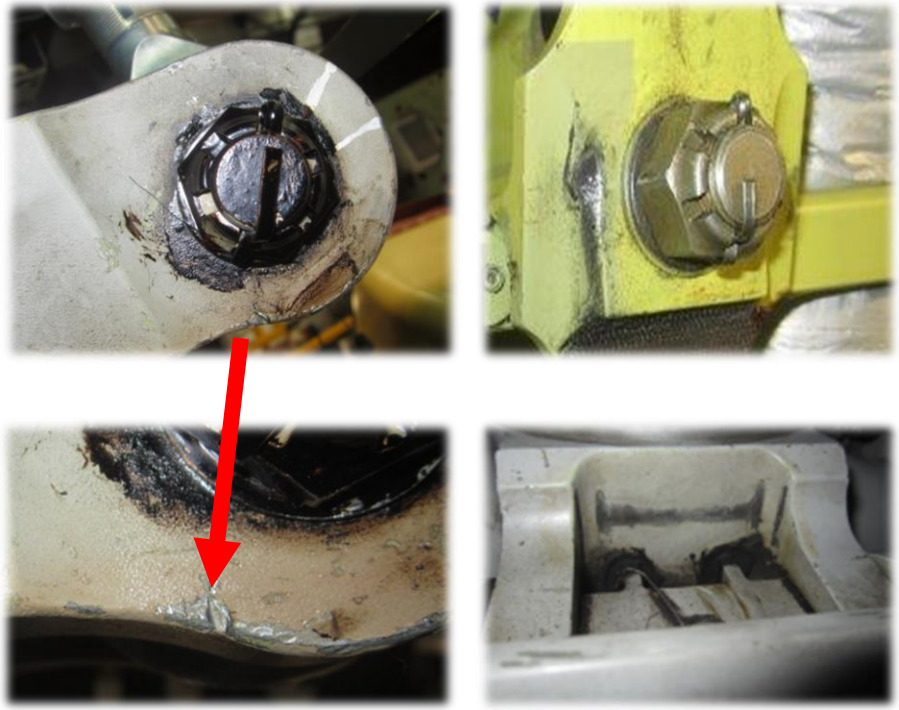

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Polymer degradation

Cable Contamination

Condition Survey Summary

- Condition Surveys conducted on numerous UK fleets have:
  1. Identified patterns or trends that could suggest future airworthiness and integrity problems.
  2. Established that the true physical condition of an aircraft may not necessarily be reflected in the aircraft documentation set.
  3. Detected hidden faults and those that are masked by poor husbandry.
- A robust preventative maintenance policy should prevent / detect such threats to integrity, yet surveys conducted across a broad spectrum of platforms shows this is not always the case.

Conclusion – Conducting a physical condition survey on a representative sample of a fleet can only enhance the fleets Continued Airworthiness no matter how robust the maintenance regime.

Zonal Hazard Analysis - Overview

Zonal Hazard Anlysis (ZHA)

- Although not part of the Ageing Aircraft Audit many Project Teams have opted to include a ZHA within the scope of an Ageing Aircraft Programme.

"A Zonal Hazard Analysis will validate the design for potential undesirable system interactions based on system composition within a zone and/or adjacent zone." RA5721

- ZHA is recognised by the UK Military Aviation Authority as an important technique for identifying and analysing credible zonal hazards, and should be used to inform the platform Safety Case.
- A ZHA should be carried out by experienced safety engineers, whom are not familiar with the aircraft type.
- Support should be sought from the Design and Maintenance organisations in order to understand specific platform design characteristics such as operating parameters.

Zonal Hazard Analysis - Definitions

Zonal hazard – An unsafe interaction between one system and another system or structure within a defined zone arising as a consequence of their relative spatial separation.

Zonal hazard cause – A necessary initiating event or property within a component or system that must occur for the zonal hazard to exist.

Zonal Hazard Analysis – Examples of hazard cause

Exposed Hot Surface – Accidental Damage

Situation: Insulation covering a bleed air component had been torn.

Hazard Cause Analysis: The surface of the bleed air component can reach temperatures above the flash point and auto ignition temperature of accelerants in the zone due to the presence of hot gas in the pipe/component.

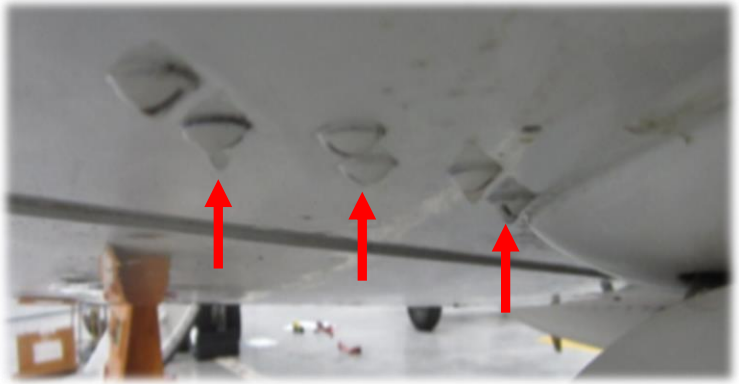
Normally, this potentially hazardous feature is mitigated by the use of insulation.

Post ZHA Action:

- The issue of a Technical Instruction to regain the design configuration of the insulation.
- Reviewing the installation instructions in the platform AMM to ensure they are effective and not open to misinterpretation.
- Increasing awareness of the wider implications of exposed hot surfaces to maintenance personnel.

Zonal Hazard Analysis – Examples of hazard cause

Leakage of Fuel – Ageing Effects



Situation: Fuel leaks along the wing.

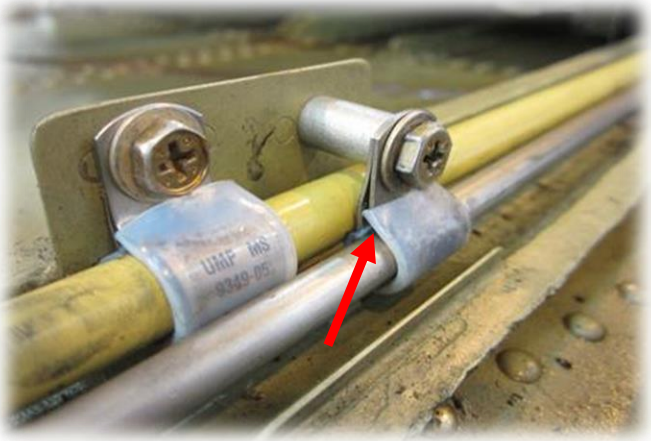
Hazard Cause Analysis: If the fuel migrates cross-zonally and combines with a source of ignition it can result in fire and explosion.

Post ZHA Action:

- Review the maintenance policy associated with the tank sealing.
- Ensure the CAMO briefs maintenance personnel on the potential for this problem to occur, increasing the likelihood that any instances of occurrence are spotted

Zonal Hazard Analysis – Examples of hazard cause

Leakage of Hydraulic Fluid – Design Issue



Situation: Hydraulic pipes serving the tail rotor servo chafing on adjacent P clips.

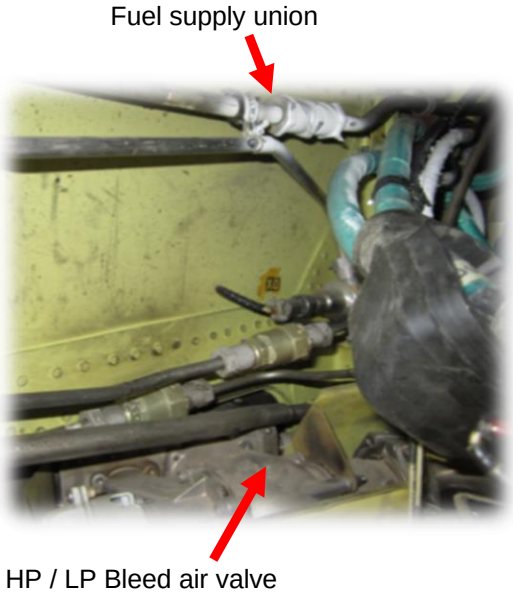
Hazard Cause Analysis: Continued chafing could cause a loss of pipe integrity and the loss of hydraulic system pressure and introduction of accelerant into the zone.

Post ZHA Action:

- Initiate modification action to increase the spatial separation between the hydraulic pipe and adjacent components.
- Review the zonal inspection regime to ensure that the zone is being inspected at a suitable frequency to minimise the exposure of any chafes.

Zonal Hazard Analysis – Examples of zonal hazards

Ignition of Fuel by Hot Surface – Design Issue



Situation: There is a potential source of fuel leaks near to a hot surface.

Hazard Analysis: The fuel supply union has the potential to leak fuel.

The surface HP/LP bleed air valve can reach high temperatures, estimated to be above the AIT of fuel.

As the two hazard causes are in close proximity to one another, a leak of fuel could be ignited by the hot surface of the bleed air valve and result in fire and explosion.

Post ZHA Action:

- Initiate design modification action to shield the hot surface from any fuel leaks.

Zonal Hazard Analysis – Examples of zonal hazards

Control Restriction – Ageing & Design Issue

Cockpit trim becoming detached

Situation: The trim in the cockpit foot wells was loose.

Hazard Analysis: The trim in the foot wells is secured in place by Velcro strips. Over time the effectiveness of the Velcro strips had degraded with the effect that the trim had become detached in places.

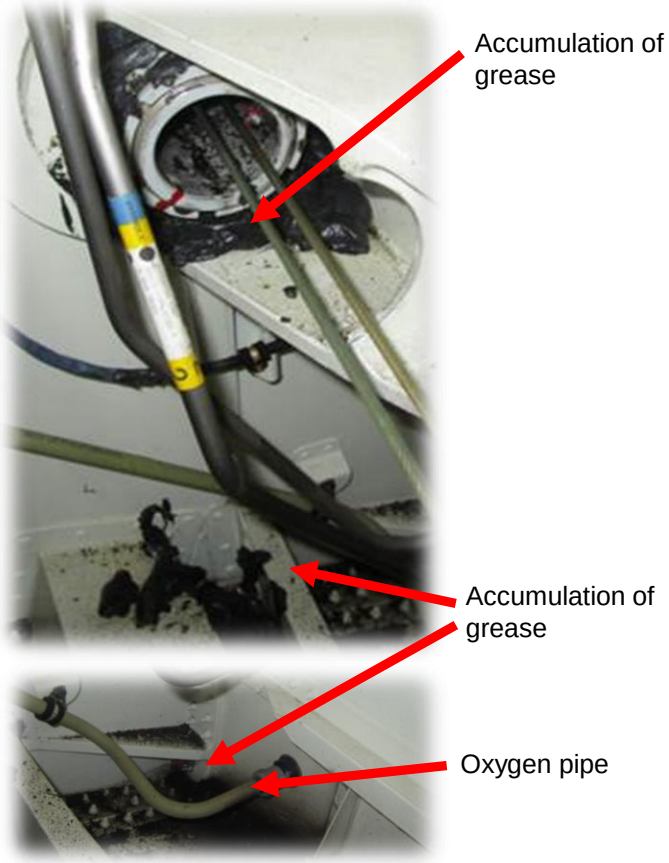
The detached trim could snag on the rudder pedals creating a control restriction hazard that could result in a loss of control accident.

Post ZHA Action:

- Initiate design action to remove the hazard. This could involve a modification that removes the Velcro and replaces it with a trim secured by a fastener.
- Mitigate the hazard by issuing a Technical Instruction to replace the existing Velcro with new material and change the maintenance policy to conduct directed inspections of the trim.

Zonal Hazard Analysis – Examples of zonal hazards

Grease and Oxygen interaction – Maintenance & Design Issue



Situation: Grease accumulated in the liquid oxygen compartments (LOX) of a large transport aircraft.

Hazard Analysis: Nose Landing Gear (NLG) support beams lubricated with grease on a periodic basis. This activity resulted in grease extruding from the beam trunnions into the adjacent zones, containing LOX pipes.

Oxygen interacting with grease can lead to explosion.

Post ZHA Action:

- Issue a Technical Instruction to ensure that grease has not accumulated in the LOX zones on other aircraft in the Fleet.
- Amend the existing maintenance policy in the platform AMM for the lubrication of the NLG support beam to include a specific requirement to remove extruded grease from the trunnion in the LOX zones.

Zonal Hazard Analysis – Examples of zonal hazards

System Fluids and LRU interaction – Maintenance & Design Issue

Situation: Fuel and hydraulic systems pipes / unions located directly above high power static inverter.

Hazard Analysis: Leaks from the system pipes can be ingested into the inverter, leading to arcing and electrical fire.

The LRU top cover was installed upside down.

Post ZHA Action:

- Issue a Technical Instruction to ensure correct orientation of the static inverter top cover.
- Initiate dialogue with the OEM to prevent reoccurrence.

Zonal Hazard Analysis Summary

- Zonal Hazard Analysis conducted on numerous UK fleets have:
  1. Informed the platform Hazard Log and Loss Model with credible hazards identified following a comprehensive on-aircraft survey.
  2. Identified undesirable system to system interactions, which in some cases has led to design change, issuing of Technical Instructions and changes to maintenance policy.

Conclusion – Conducting a Zonal Hazard Analysis can identify unknown zonal issues as a result of system disposition within a zone. These issues can then be managed within the platform Hazard Log and aggregated in the Loss Model.

Capturing Good Practice

- In June 2016, QinetiQ UK completed authorship of a Paper entitled *“Guidance on the Conduct of Aircraft Zonal Hazard Analysis (ZHA)”.*
- The Paper has been endorsed by the UK’s Ageing Aircraft Programmes Working Group (AAPWG), which includes representation from [dstl], UK MAA and industry (inc BAE SYSTEMS, AgustaWestland).
- The paper reference is AAPWG Paper 011 and will soon be available to view on the www.gov.uk website.

Any Questions?

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