Ageing Aircraft Programmes Working Group (AAPWG)

Paper 010

# A Framework for Ageing Aircraft Audits

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# DISTRIBUTION

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# EXECUTIVE SUMMARY

The Defence Science and Technology Laboratories (Dstl), with the support of the Military Aviation Authority through the Ageing Aircraft Programmes Working Group, have initiated a research and development programme titled “Understanding Ageing Aircraft”. This paper, “A Framework for Ageing Aircraft Audits” contributes to the Dstl programme.

The MOD has been carrying out Ageing Aircraft Audits (AAA) for over 15 years initially the audits concerned only the ageing of aircraft structure. However, following the high profile loss of two commercial airliners and perhaps more poignantly the loss of Nimrod XV230 over Afghanistan in 2006[1] AAAs were extended to encompass sub-audits for Systems and Propulsion Systems. In the intervening period considerable experience has been gathered carrying out AAAs and this paper seeks to expand on selected areas of the current policy laid down in MAA Regulatory Article (RA) 5723 [2]. It provides additional guidance and introduces some new suggestions based on best practice from within the MOD and from the wider aviation community. A background is provided to events leading to the current approach to identifying Ageing in Aircraft, both Military and Civilian.

The importance of pre-audit planning is stressed and guidance is provided on the subjects that should be covered in this important phase of the Audit.

The Paper breaks the AAA tasks down into four areas. Experience has shown that there are aspects of the audit that are common to the three sub-audits areas of Structure, Systems and Propulsion System.

RA5723 [2] mandates that the audit include an independent physical examination of representative aircraft, however it does not expressly mandate intrusive forensic sampling. This paper includes details of the types of conditions survey that will satisfy the requirements and provides details of the purpose and management of a condition survey. It also provides an insight into more in depth surveys.

Finally, selection of common forms of material degradation given with a shot description of what an AAA Team should be aware of. The list is not extensive but merely seeks to provide an insight into material ageing.

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# ABBREVIATIONS

| | |
|---|---|
| ABR | Abbreviations |
| AAA | Ageing Aircraft Audit |
| AAPWG | Ageing Aircraft Programmes Working Group |
| AASA | Ageing Aircraft Structural Audit |
| AASME | Ageing Aircraft Subject Matter Expert |
| AASyA | Ageing Aircraft Systems Audit |
| AAPSA | Ageing Aircraft Propulsion Audit |
| AATF | Airworthiness Assurance Task Force |
| AAWG | Ageing Aircraft Working Group |
| AD | Airworthiness Directive |
| ADS | Aircraft Document Set |
| AECMA | Association Europeene des Constructeurs de Materiel Aerospatial (European Association of Aerospace Industries) |
| ALARP | As Low As Reasonably Practicable |
| AM | Aircrew Manual |
| AMM | Aircraft Maintenance Manual |
| AWFL | Airworthiness and Flight Limitations |
| BSI | British Standards Institute |
| CAMO | Continuing Airworthiness Management Organisation |
| CLE | Clearance with Limited Evidence |
| CLR | Component Life Register |
| CoD | Certificate of Design |
| CRL | Component Replacement List |
| CS | Condition Survey |
| CWFT | Centre Wing Fuel Tank |
| DDP | Declaration of Design and Performance |

| | |
|---|---|
| DO | Design Organisation |
| EASA | European Aviation Safety Agency |
| EAAWG | European Ageing Aircraft Working Group |
| EDPC | Environmental Damage Prevention and Control |
| ED | Environmental Damage |
| ESVRE | Establishing, Sustaining, Validating, Recovering and Exploiting |
| ERC | Engineering Record Card |
| EWIS | Electrical Wiring Interconnect System |
| FAA | Federal Aviation Authority |
| FADEC | Full Authority Digital Engine Control |
| FDR | Flight Data Recorder |
| FTR | Fatigue Type Record |
| FLC | Front Line Command |
| FMECA | Failure Modes, Effects and Criticality Analysis |
| FRCs | Flight Reference Cards |
| FRACAS | Failure Reporting, Analysis and Corrective Action System |
| FSI | Functionally Significant Item |
| JAA | Joint Aviation Authorities |
| JSP | Joint Service Publication |
| ISAwA | Independent Specialist Airworthiness Advisors |
| ICD | Interface Control Document |
| ISD | In Service Date |
| LEP | Life Extension Programme |
| LTC | Local Technical Committee |
| MAA | Military Aviation Authority |
| MASAAG | Military Aircraft Structural Airworthiness Advisory Group |
| MAOS | Maintenance Approved Organisation Scheme |
| MECSIP | Mechanical Equipment and Subsystem Integrity Programme |

| | |
|---|---|
| MED | Multi Element Damage |
| MFRI | Mandatory Fault Reporting System |
| MMS | Master Maintenance Schedule |
| MRP | Military Aviation Authority Regulatory Publications |
| MSD | Multi Site Damage |
| NDA | Non-Disclosure Agreement |
| NDT | Non-Destructive Testing |
| NTSB | National Transportation Safety Board |
| ODM | Operating Data Manual |
| OLM | Operational Loads Monitoring |
| OEC | Operational Emergency Clearance |
| OSD | Out of Service Date |
| PDS | Post Design Services |
| PT | Project Team |
| RA | Regulatory Article |
| RF | Reserve Factors |
| RTS | Release To Service |
| RTSA | Release To Service Authority |
| SAAG | Systems Airworthiness Advisory Group |
| SB | Service Bulletin |
| SDO | Service Design Organisation |
| SI(T) | Special Instruction (Technical) |
| SIWG | Structural Integrity Working Groups |
| SM | Service Modification |
| SMS | Safety Management System |
| SOIU | Statement of Operating Intent and Usage |
| SPC | Sortie Pattern Code |
| SPS | Support Policy Statement |

| | |
|---|---|
| SSI | Structurally Significant Item |
| STR | Static Type record |
| SyIWG | Systems Integrity Working Groups |
| TCH | Type Certificate Holder |
| RAP | Repair Assessment Programme |
| RCM | Reliability Cantered Maintenance |
| TSB | Transportation Safety Board |
| WFD | Widespread Fatigue Damage |
| ZHA | Zonal Hazard Analysis |

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# 1 INTRODUCTION

## 1.1 BACKGROUND

The UK MOD has now been undertaking Ageing Aircraft Structural Audits (AASA) for over 15 years. These were initiated following the well-known Aloha Flight 243, Boeing 737 pressure cabin failure in 1988 [3].

There was a time in the growth and development of aviation when the ageing of aircraft was not considered a factor as aircraft replacement was driven by the rapid advances in technology. In addition, because of the materials used large safety factors were built into designs and systems were simpler.

In 1988 the sight of the Aloha Airlines Boeing 737 sat on the ramp with part of the cabin roof missing following a structural failure galvanised regulatory authorities into action.


*Figure 1 Aloha Airlines Flight 243, Boeing 737-200, - 28 April 1988.*

Initially research and regulations concentrated on measures to indentify and mitigate ageing in aircraft structures. However, following several civil accidents in the mid 1990s, including TWA Flight 800 [4] and Swiss Air Flight 111 [5], the aviation community became aware of the need to consider ageing effects of electrical, mechanical and propulsion systems alongside structural implications.

Military aviation is not immune from the problems associated with ageing aircraft, increasingly aircraft are being operated on extended lives either for economic reasons or because of delays in replacement programmes. The UK MOD suffered a number of structural failures on ageing aircraft but the need to understand ageing systems issues was reinforced by the loss of Nimrod XV230 over Afghanistan in 2006 [1].

## 1.2 OBJECTIVES

The objectives of this paper is to expand on the content of an Ageing Aircraft Audit (AAA) laid down in RA 5723 [2] and provide advice on the methods that might be employed to ensure the Regulation is met and the audit examines all aspects of ageing. It does not set out to cover all the requirements of RA5723 [2] as some a self explanatory and need no further comment. It will also seek to describe best practice gleaned not only from previous AAAs on MOD aircraft but from similar programmes carried by other organisations that address ageing in aircraft and from the wider aviation regulatory community.

# 2 AGEING AIRCRAFT REGULATION AND POLICY

## 2.1 THE CIVILIAN AVIATION APPROACH TO AGEING AIRCRAFT.

### 2.1.1 AGEING AIRCRAFT STRUCTURAL REGULATIONS

Because of the problems revealed by the accident in Hawaii and the continued operation of older aircraft, both the regulatory authorities and industry agreed that increased attention needed to be focused on ageing fleets and on maintaining its continued operational safety.

The Federal Aviation Authority (FAA) sponsored a conference on ageing aircraft and as a result an ageing aircraft task force was established in August 1988 as a sub-group of the FAA's Research, Engineering, and Development Advisory Committee. This committee represented the interests of the aircraft operators, aircraft manufacturers, regulatory authorities, and other aviation representatives. The task force, then known as the Airworthiness Assurance Task Force (AATF) and later renamed as the Aging Aircraft Working Group (AAWG), set down five major elements of a programme for keeping an ageing fleet safe. For each aeroplane model in the ageing transport fleet these elements consisted of the following:

- Select service bulletins describing modifications and inspections necessary to maintain structural integrity.
- Develop inspection and prevention programmes to address corrosion.
- Develop generic structural maintenance programme guidelines for ageing Aeroplanes.
- Review and update the Supplemental Structural Inspection Documents (SSID) which describe inspection programmes to detect fatigue cracking?
- Assess damage-tolerance of structural repairs.

Subsequent to these 5 major elements being identified, it was recognised that an additional factor in the Aloha accident was Widespread Fatigue Damage (WFD). Regulatory and Industry experts agreed that, as the transport aircraft fleet continues to age, WFD is inevitable. Therefore the FAA determined, and the European Aviation Safety Agency (EASA) agreed that an additional major element of WFD should be added to the Ageing Aircraft Programme. Structures Task Groups sponsored by the Task Force were assigned the task of developing these elements into usable programmes

Although there was Joint Aviation Authorities (JAA) membership and European Operators and Industry representatives participated in the AAWG, recommendations for action focussed on FAA operational rules which are not applicable in Europe. It was therefore decided to establish the European Ageing Aircraft Working Group (EAAWG) to implement Ageing Aircraft activities into the European Aviation Safety Agency (EASA) regulatory system. EASA Acceptable Means of Compliance (AMC) 20-20[6] was published December 2007 and is a major part of the European adoption and adaptation of the AAWG recommendations which it follows as closely as is practicable.

### 2.1.2 Ageing Aircraft Systems Regulation

The initial work on ageing aircraft focused entirely on structures, however, during the 1990s two major incidents highlighted the importance of ageing systems in particular the Electrical Wiring Interconnect System (EWIS).

On July 17, 1996, TWA Flight 800 a 25-year-old Boeing 747-100 series aircraft broke up in flight after takeoff from Kennedy International Airport in New York, resulting in 230 fatalities. The National Transportation Safety Board (NTSB) determined [4] that the probable cause of the accident was an explosion of the Centre Wing Fuel Tank (CWFT) resulting from ignition of the flammable fuel and air mixture in the tank. The NTSB could not conclusively determine the source of ignition energy for the explosion, though the most likely cause was a wiring failure outside the CWFT. This failure allowed excessive electrical energy to enter the CWFT through electrical wiring associated with the fuel quantity indicator system.

In September 1998 Swissair Flight 111, an MD-11 aircraft, crashed off the coast of Nova Scotia, Canada. In the final accident report, The Transportation Safety Board (TSB) of Canada determined [5] that there was smoke and a fire above the ceiling in the cockpit. In the report, the TSB could not identify the exact cause of the fire but stated that “a segment of in-flight entertainment network power supply unit cable exhibited a region of resolidified copper on one wire that was caused by an arcing event” and that this was located in the area where the fire most likely originated.

Investigation of these two accidents, and subsequent examinations of many other aircraft, showed that deteriorated wiring, corrosion, and improper wire installation and repairs were common conditions in the EWIS. In addition, wire bundles contaminated with metal shavings, dust, and fluids were also common conditions in representative examples of transport airplanes. These contaminants could damage EWIS and also provide fuel for an electrical fire.

As a result of the investigations further work was carried out by the regulatory bodies resulting in the issue by EASA of the following additions to AMC 20:

- AMC 20-21 Programme to enhance aeroplane Electrical Wiring Interconnection System (EWIS) maintenance [7]
- AMC 20-22 Aeroplane Electrical Wiring Interconnection System Training Programme [8]
- AMC 20-23 Development of Electrical Standard Wiring Practices Documentation [9]

None of the Civil Authorities mandate an AAA similar to those carried out by the UK MOD, relying on the structure of the civil regulations to capture and mitigate ageing issues. However, where an MOD Project Manager has responsibility for a civil aircraft operating on the Military Register he should consider whether the content AMC 20 has been applied to his aircraft type when scoping an AAA.

## 2.2 THE MOD UK POLICY

### 2.2.1 DEVELOPMENT

The MOD's initial policy on ageing aircraft is based on work carried out by the Military Aircraft Structure Airworthiness Advisory Group (MASAAG) which followed closely the work being carried out by the FAA and JAA and concerned only ageing aircraft structure. In June 1990 MASAAG Paper 83 [10] was issued which recommended that PTs task the aircraft Design Organisation (DO) with a number of tasks including the following:

- To carry out an audit of in-service experience relating to signs of corrosion, disbonding or Multi Site Damage (MSD) affecting Primary (Grade A) structure.
- Review the effectiveness of the current inspection procedures with regard to the possibility of these being undermined by the occurrence of MSD.
- Review the results of the major fatigue test(s) in the light of any in-service experience of corrosion, disbonding or MSD from the above parallel studies.
- Review the validity of all structural Servicing Instructions (SIs), Special Technical Instructions (STIs) and Maintenance Schedules and consider whether other tests or inspections are necessary to overcome any shortcomings in fatigue and static compliance.

In October 2000 MAASAG Paper 104 [11] was issued which defined the content and frequency of a Structural AAA and which formed the basis of the policy now laid down in RA5723. This was followed by Paper 106 [12] in July 2004 which addressed Repair Assessment Programmes. A Systems Airworthiness Advisory Group (SAAG) was formed to study and advise on system matters including ageing. More recently the MOD has brought the topic of aircraft ageing under one all embracing working group the Ageing Aircraft Programmes Working Group (AAPWG). The MASAAG and SAAG continue to sit and advise on their specialist subjects.

### 2.2.2 CURRENT POLICY

The initial policy for AAA was originally laid down in Joint Air Publication (JAP) 100A-01 and other extant policy documents, however, this early policy addressed only structural audits. Subsequently the policy was expanded to include mechanical, electrical and propulsion systems. The current policy is laid down in RA 5723 [2], and requires that an AAA be conducted 15 years after the in-service date of an aircraft type, and every 10 years thereafter. The policy also covers the aims, management and scope of the audit. This Paper is largely based on the requirements of RA5723 [2] but seeks to expand on content providing additional background guidance both for Project Officers and those carrying out AAAs. It also provides an insight in to current ageing aircraft work in civil aviation and seeks to draw out best practice in the field.

### 2.2.3 MOD Defined Ageing Threats

RA 5723 [2] states that the cumulative exposure to Ageing has a potential impact on the following threats to Integrity:

- Overload
- Fatigue
- Accidental and Environmental Damage
- Compromised Configuration Control
- Maintenance/Supply Errors
- Calendar Based Environmental Ageing or Degradation.

Throughout this Paper the term ageing refers to the above threats to integrity.

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# 3 PREPARATION FOR AN AGEING AIRCRAFT AUDIT

## 3.1 INITIAL CONSIDERATIONS

Early in the planning phase the PT SME should consider the cost/benefit/risks of the extent of the audit process. Significant issues which have occurred before include the level of finance available for the Audit, the commercial access to the OEMs/DOs and commercial issues such as Non-Disclosure Agreements and the slowing effects of ITAR compliance on the Audit process. When the PT SME constructs the internal business case for the Audit, all these factors should be considered.

## 3.2 PRE-AUDIT PLANNING

An essential part of any AAA is careful planning by personnel with the correct level of experience and skills. The pre-audit planning phase will determine the scope of the audit and it is important that this is not carried out in isolation and should include all stakeholders and Audit Team members.

## 3.3 MANAGEMENT OF THE AAA

The management of the AAA should include the appointment of a Project Officer or AAA Co-ordinator, and specialist officers for each area, structure, systems and propulsion system. An initial start-up meeting should be held with all Stakeholders involved; subsequently the audit should be managed through a series of periodic Working Groups for each specialist area. Attendance at these WGs will be determined by the AAA Co-ordinator and will be dependent on the phase of the Audit.

## 3.4 STAKEHOLDER INVOLVEMENT

Whilst the AAA may be instigated, managed and financed by the Platform Project Team (PT) the Commodity PTs must be fully included in the Audit management and subsequent implementation. In the Systems Sub-Audit a significant number of the items being examined will be the responsibility of Commodity Project Teams. Other organisations who should be involved are:

- The Design Organisations (DOs) Airframe and Engine
- The Continuing Airworthiness Management Organisation (CAMO)
- Independent Specialist Airworthiness Advisors (ISAwAs)

- The Release To Service Authority (RTSA)
- Front Line Command (FLC) Operators
- The Contracted Maintenance Organisations

## 3.5 Identification of Previous Programmes

Previous programmes can be vital to the planning of an AAA as they can provide information which will prevent much nugatory work. Moreover, many programmes introduce a change of usage and there will inevitably have been new or revised design assumptions and the long term effect of these will need to be considered. Many programmes will have associated follow-up recommendations and these should be a subject for scrutiny as part of the AAA. The following are programmes that will inform the audit planning phase and provide guidance on where to focus the Audit effort.

### 3.5.1 Previous AAAs or Similar Programs

The findings and recommendations of any previous AAAs or Safety Reviews should be reviewed at the Audit planning stage. In addition, the results of any similar work, in particular any reports from the DO resulting from the requirements of MASAAG Paper 83 [10]. If the aircraft is the same as or a derivative of a Type Certified civil aircraft then the results of any ageing specific programmes including those emanating from EASA AMC20-20 [6] should be reviewed. If the Type Certificate Holder (TCH) has carried out ageing programmes then the work may be sufficient for the TAA to apply for an exclusion from part of requirements of RA5723 [2].

### 3.5.2 Zonal Hazard Analysis (ZHA) Programme.

Though not mandated ZHA surveys have proved to be a vital element in maintaining the airworthiness of an aircraft, the intent of a ZHA is described in para 49 of RA5721 [27]. The ZHA is not part of an AAA though they are often carried out at the same time. If a ZHA is to be carried out it should ideally be before the Audit planning begins as the results will serve to inform the Audit planning team when prioritising systems. Moreover, the ZHA may be used to provide additional evidence when selecting items for increased scrutiny or sampling. Further information on ZHAs is contained in AAPWG Paper 011 [13]. If the aircraft is a civil derivative then the initial design may have been subject to EASA CS25.1309 [14] which provides a civilian standard for systems design including ZHA, the earlier CAA equivalent is BCAR 670 [15]. It is important to ensure that work to incorporate military specific modifications included a System

Safety Assessment and a ZHA which will assess the potential for new zonal system interactions resulting from the modification.

#### 3.5.3 LIFE EXTENSION PROGRAMMES (LEP) AND OUT OF SERVICE DATE EXTENSION PROGRAMMES (OSDEP)

Life Extension Programmes (LEPs) and Out of Service Date Extension Programmes (OSDEPs) can be a valuable source of information when planning an AAA. The work carried out during an LEP/OSDEP to identify critical or significant systems and components can form the basis of the target areas for the AAA. Moreover, the recommendations from an LEP/OSDEP may have included additional maintenance activities to support the extension of a component life. It is essential that an AAA includes a review of these activities to ensure they have been incorporated into the Maintenance Schedule and that they are effective in mitigating ageing.

#### 3.5.4 MID-LIFE UPDATE

The content of any Mid-Life, or other significant change programmes, need to be considered during the AAA. Traditionally update programmes are capability driven and will subsequently result in a change of usage. The AAA may be the first opportunity to assess whether the assumptions made at the design stage can be substantiated in-service. The AAA should also seek to establish whether the change in usage has had an adverse effect on ageing.

#### 3.5.5 FULL SCALE AIRFRAME FATIGUE TEST AND FATIGUE MODIFICATION PROGRAMMES

The results from a Full Scale Airframe Fatigue Test can be the instigation of specific fatigue related modification embodiment programmes. If an opportunity was taken to combine several modifications together in a larger package of work, this can provide a valuable source of information to the Audit Team on the condition of the whole fleet. Strip Reports and Condition Surveys feedback may well indicate corrosion and other material degradation issues.

#### 3.5.6 ENGINE UPGRADE PROGRAMME

An engine upgrade programme, whether a replacement engine fit or an upgrade of the existing engine, will almost certainly result in more power. Calculations will have been made to quantify and assess the increased stresses imposed on the structure and systems. An AAA will possibly be the first opportunity to study the long term effects of the increased loads imposed by the upgraded engine.

#### 3.5.7 Forensic Sampling Programmes

A number of aircraft, particularly those that have been in service for some time may have undergone a structural sampling programme sometimes referred to as a teardown programme. More recently a number of the older platforms have undergone a similar programme for the systems. Again these programmes can provide valuable guidance when planning the Audit though the Audit Team should not fall into the trap of scrutinising the results of the sampling programme at the expense of investigating other areas.

#### 3.5.8 Ageing Programmes Carried Out by Other Nations

There are a number of programmes being carried out by other nations which can be valuable when planning an AAA. An example is the US Department of Defence (DOD) MIL-STD-1798 [16] which provides a framework for carrying out a Mechanical Equipment and Subsystem Integrity Programme (MECSIP). These programmes have been carried out on a number of aircraft types operated by the US Services and could prove valuable to UK operators of similar types.

## 3.6 Documentation and Data Management

#### 3.6.1 Available Records and Documentation

The experience gained from previous audits has shown that many organisations have difficulty retrieving archived information, not least because frequent reorganisations have resulted in file identification numbers and file references changing. It follows that a clear indication of what documents are available and how easy the access will help ensure a speedy and thorough Audit. The documents needed for an Audit range from the Static and Fatigue Type Records, Declarations of Design and Performance (DDPs) and Certificates of Design (CoDs) through to minutes of meetings and maintenance documentation. An Audit Team will need access to electronic records and filing systems as well as hard copy records. There will also be a need to access information held by the DOs and the reports of any Independent Advisors. In the case of DOs this will almost certainly require separate contractual cover. Meetings with DOs may also require the raising of a Non-Disclosure Agreement (NDA); again experience has shown this simple process can take an inordinate amount of time. When planning the Audit it is important not to under estimate the amount of time that will be required to research fully the background to some aspects of the aircraft.

#### 3.6.2 AAA Data Management and Access

The data management requirements for an AAA are significant, particularly when the subject aircraft is a large complex type or were an intrusive survey is required. A robust, auditable mechanism for tracking issues, references and decisions should be in place at the outset of the audit. In addition, a system should be in place that allows “real time” access to data for parties from all organisations involved in the conduct of the Audit. Without access to common data sources the effectiveness of the joint team could be diminished.

## 3.7 Establishing Sample Size

During the pre-planning phase of the Audit it will be necessary to establish aircraft sample size as, for larger fleets, it is not practicable to carry out audit activities on the whole fleet. There are various statistical methods that may be used to determine a sample size that is most likely to include any abnormalities, including BS6001 [17] issued by the British Standards Institute (BSI) though these are more applicable to production sampling. The selection of aircraft that make up the sample should include fleet leaders in terms of usage, flying hours, fatigue index or similar and the youngest and oldest aircraft in terms of calendar life. Where an aircraft type has aircraft with different equipment fits operating in differing roles (“fleets within the fleets”) examples of these aircraft should be included in the sample. As the audit progresses it may be necessary to add to the samples, for instance, should evidence emerge suggesting there may be ageing associated with the undercarriage then the fleet leader in landings might be added.

## 3.8 Prioritisation of Systems and Components

Systems with critical function, and emergency systems, must be identified and included in an AAA and whilst most PTs will be able to list those systems that might be considered high priority RA5723 [2] requires a more analytical approach. Ideally this should be part of the pre-Audit planning phase as it can be an involved task, more often it is only addressed once the Audit has started. System categorisation is covered in more detail at Paragraph 6.1

## 3.9 Condition Survey (CS)

RA 5723 [2] requires that a detailed, independent physical examination of the condition and husbandry standards of fleet representative aircraft must be carried out. The CS is an integral part of the AAA and it is important the findings and observations are used to inform other areas of the Audit. It follows that ideally the CS should be carried out before the documentation element of the Audit. In the planning stage it will be necessary to determine how many and which aircraft will be subject to a CS. The CS should be planned to coincide with a significant scheduled maintenance event, this allows the following advantages:

- Reduces the down time that a standalone CS would incur.
- Provides the CS team with an accurate picture of the maintenance standards employed.
- Will increase the scope of the CS due to components being removed as part of the maintenance activity.

Destructive sampling and forensic examination are not mandated but such measures in specific areas may be an audit recommendation. More information on Condition Surveys and the options available is provided at Section 8.

# 4 Common Audit Areas

## 4.1 Areas common to Structural, Systems and Propulsions System Audits

No matter what methodology is used to carry out the audit there will be certain areas and audit functions which will be common to all three sub-audits: Structures, Systems and Propulsion System. By considering these generic aspects repetition will be avoided and a more coherent picture of the condition of the aircraft can be obtained. Moreover, auditing these areas together ensures that no part of the audit is missed. The following paragraphs cover the main areas common to all three elements of an AAA.

## 4.2 Design Review General Considerations

Fundamental to an AAA is the understanding of what the aircraft was originally designed to meet and how, and to what standard, the aircraft was accepted into service. By understanding this `Baseline' condition, it is possible to review in a structured manner changes to the aircraft operation and usage throughout its current life and beyond which may induce ageing or accelerate the ageing process thereby imposing a threat to the airworthiness of the aircraft.

Original certification covers the aircraft as a whole, i.e. structures, aircraft systems and propulsion. For military aircraft it also includes the integration of the mission systems and weapon systems into the whole aircraft and these will generally have some impact upon the aircraft structure, aircraft systems and propulsion.

An Aircraft CoD [18] provides a statement of compliance against the aircraft specification, which although MOD owned, is generally generated by the Designer. The specification lists the major requirements, e.g. life in flying hours, number of landings, operating mass, flight duration etc. The CoD will list any exceptions or limitations against the specification and these require agreement and countersignature by the MOD on the CoD.

The aircraft CoD is underpinned by the certification of the structure, aircraft systems and its equipment. The propulsion system can be certified separately by the engine designer, or certified by the aircraft designer. Whichever the case, the aircraft designer is responsible for compatibility of intake to engine and generally for the installed performance. At aircraft level flight limitations are assembled as a composite set of limitations that have been determined initially as a result of qualification testing and analysis at structure, system and engine level, but refined through dedicated rig and flight testing. The Designer maintains these limitations in a single document, generally called the Airworthiness Flight Limitations (AWFL). These are maintained throughout the life of the aircraft, updated and amended to cover design change. They form the basis for the Release to Service (RTS), but do not replace it. The RTS is the document that authorises Service flying and contains the definitive limits which the aircraft is flown to, the `as-flown' configuration of the aircraft, and supports the overall aircraft safety case.

Familiarity with the top level `Baseline' condition should enable the Auditor to establish whether the original qualified life and the planned OSD/OSDEP are compatible and if not whether an LEP/OSDEP has been carried out. If an LEP/OSDEP has been instigated the Auditor should ensure that the conduct and rationale that has been applied to extend the lives of components is sound and that the new lives are published in the Master Maintenance Schedule (MMS). Further, the AAA should ensure that there is a robust process in place to track the LEP/OEDEP components on and between aircraft and within the logistic cycle in order not to jeopardise airworthiness.

For cases where there is sufficient margin in overall life then there may be other factors to consider. These could be where the role of the aircraft has changed which has meant a change in the operating parameters, either through physical or non-physical change, e.g. additional fuel tanks, or higher payload with consequential higher Take-Off mass. In these cases an assessment of how the change was introduced needs to be undertaken and this is best considered at the structure, aircraft system or propulsion level as a sub-audit activity.

## 4.3 CONCESSION RECORDING

During the production of an aircraft or component the MOD may accept non-conformance to the requirements of the contract, these are categorised as Major or Minor concessions. An AAA should review, as far as possible, Major concessions which are those concessions which are likely to affect health, safety, interchangeability, maintenance, strength, life, reliability, environmental, logistic sustainability or functioning of the product. The process for raising and granting concessions is laid down in Defence Standard 05-61 Part 1 [19].

The Audit should review, as far as possible, the system for recording concessions granted during production though in practice these are often difficult to verify and records may not be accessible especially on older aircraft. The review should verify that where concessions affected the life of a component or invoked a maintenance regime appropriate measures are still in place or that subsequent actions have cancelled the concession. The audit should also review the process for PT granted concessions [20] such as extensions to maintenance and other engineering concessions. The review should cover the audit trail associated with the concession including any associated DO advice.

## 4.4 THE SUPPORT POLICY STATEMENT (SPS) AND THE MAINTENANCE POLICY

The Audit Team should ensure that they have a full understanding of the SPS which defines the support arrangements necessary to maintain the Aircraft and details management responsibilities, the Maintenance Policy, Technical Information and the Supply Support Philosophy plus many other aspects of the platform support. The format and content and SPS should accord with the requirements laid down in the MAP-01 [21]

A review of the Maintenance Policy is an essential element of any ageing programme as it is the primary tool to indentify and mitigate ageing. The aim of the Audit should be to determine whether the Maintenance Policy is adequate and effective and whether the policy is being correctly implemented.

## 4.5 MAINTENANCE RECORDING AND THE MAINTENANCE SCHEDULE

Schedules should be audited for confirmation that schedule reviews have been undertaken and that all Structurally Significant Items (SSIs) inspections and airworthiness recommendations have been incorporated. If Functionally Significant Items (FSIs) have been identified then these should also be confirmed as having directed inspections. The Audit should audit the Reliability Centred Maintenance (RCM) work sheets to confirm the review process was thorough. If possible the original RCM analysis carried out at the introduction into service should also be reviewed and changes analysed. At this stage the Topic 5V should also be examined, although this primarily addresses the aircraft structure its content should be reflected in the MMS. Further information on the development of preventive maintenance programmes is available in JAP (D) 100C-22[38]. A review should be carried out of the operating procedures for the PT, and Forward and Depth Maintenance Organisations, combined with a sample audit to demonstrate compliance, such as to provide confidence that the MMS and Component Replacement List (CRL)/Component Life Register (CLR) are under control and being used correctly.

## 4.6 COMPONENT REPLACEMENT LIST /COMPONENT LIFE REGISTER

The Audit should review the procedures established for the upkeep of the CRL/CLR and its translation onto any electronic asset tracking system in use. A sample of the allotted lives should be reviewed against those published in any Designer or Manufacturers publication. Where items are maintained on a usage basis, (Fatigue Index/Flying Hour/Pressurisations/Landings etc), or on a calendar basis, these should appear logical and meet the expected degradation cause. There should also be a check to confirm if any components have a penalty factor applied to them if they are used in a particular environment or on a different mark of the same platform and how these are managed. Where a cyclic exchange rate is in use the rational should be examined and the date of the last review established. If the aircraft has been subjected to a LEP or an extension to the OSD it should be established that components lives were included in the analysis carried out prior to the extension being granted.

## 4.7 AVAILABILITY AND ANALYSIS OF MAINTENANCE DATA

The availability and correct analysis of maintenance data is essential to identify ageing trends and this was recognised in the review into the loss of the RAF Nimrod MR2 XV230 carried out by Charles Haddon-Cave QC [22]. The Audit should determine whether the available data is adequate and review the methods used to determine the reliability and maintenance requirements of the platform and its equipment from the available data. The Audit should establish what the data trends are being compared with; are there established targets or is the trend simply an historical comparison, are new failures captured and added to the data collection requirement? The Audit should also determine whether the PT participates in any data sharing with other users of the same aircraft type.

The review of trend data should cover all three sub-audit areas Structures, Systems and Propulsion System. There should be evidence that this data was available to the RCM team to allow them to derive the failure intervals along with any Failure Modes, Effects, and Criticality Analysis (FMECA) when any maintenance schedule reviews were carried out. Where an aircraft is a derivative of a civil certified type and the maintenance programme has been derived from Maintenance Steering Group 3 [23] (MSG3) logic the Type Certificate Holder should be approached to determine what, if any, reliability programmes are in place. Available trend data will be of use in the Audit planning phase and will continue to be used throughout the Audit.

There should be a Failure Reporting, Analysis and Corrective Action System (FRACAS) in place the responsibility for which should lie with the CAMO.

## 4.8 USE AND MAINTENANCE OF ENGINEERING RECORD CARDS (ERCS)

Engineering Record Cards can be divided into two types: the Airframe ERCs and Component ERCs.

### 4.8.1 THE AIRFRAME ERCS

The audit should review the manner in which the aircraft ERC pack is maintained, in particular that major occurrences in the aircraft's life such as accidents and major repairs are recorded. If repairs are recorded they should be checked against any record of repairs or Repair

Assessment Programme (RAP). It is also important to ensure modifications and Special Instructions (Technical) (SI (T) s) are recorded on the appropriate record card.

From a structural aspect it is important to review the MOD Form 751, the Aircraft Basic Weight and Moment Record Card. The amount of weight gained or lost and movement of the C of G may have a significant effect on the original design criteria; this information will be required when completing the review of the Design.

#### 4.8.2 COMPONENT ERCS

Component ERCs are normally drawn from the MOD Form 700 series of forms however, if the aircraft is a civil derivative then the manufacturer’s documentation may be used. If not carefully managed the control of Component ERCs can prove problematic. The ERCs are usually held centrally and issued to the tradesman and married with the component when it is removed from the aircraft. Similarly an ERC for a new or reconditioned component is normally contained within the packaging. Management systems come under strain when aircraft are on deployed operations and access to the location where ERCs are normally held is not possible. It is therefore important that an AAA reviews the effectiveness of the component ERC management system. A list of components requiring ERCs is contained in the MMS and a sample check should be made that aircraft ERC packs contain the correct number and type of ERC. The ERC samples should also be checked to ensure component serial numbers and lifing details are correct. The entries on the ERCs should be cross checked against the details in the MOD Form 700 and if necessary a physical check should be made to confirm that installed components match the serial number on the ERC and, where appropriate, in the MOD Form 700.

## 4.9 THE AIRCRAFT DOCUMENT SET (ADS)

The ADS are the documents that have a prime airworthiness function for each aircraft type. They are a complete suite of documents and their applicability to an AAA is described in the following paragraphs. The Topic 5A1 and Topic 5V are covered in Section 4.5 whilst the Topic 6 Repair Manual is addressed at Paragraph 5.8 as it is considered to be primarily a structures manual.

## 4.10 AIRCRAFT MAINTENANCE MANUALS (AMM)

The content and upkeep of the AMMs is reviewed as part of the Audit along with the use of these documents in work areas. The review of the amendment process is an end to end review from the raising of the unsatisfactory feature report through the staffing by the PT and production of the amendment by the DO. The process for the distribution and incorporation of amendments by the Units should also be included in the Audit.

## 4.11 AIRCREW PUBLICATIONS (AMS) AND FLIGHT REFERENCE CARDS (FRCS)

The Audit should review the upkeep of FRC and AM along with any outstanding actions with Handling Squadron. The review should also include the Operator's upkeep of these publications. The process for capturing and incorporating changes to the Release To Service (RTS) into the FRCs and AMs should also be reviewed. It should be confirmed that the limits stated on the FRCs and within the AMs accord with those published in the RTS.

## 4.12 STATEMENT OF OPERATING INTENT AND USAGE (SOIU)

In most cases the usage of an aircraft will differ from that stated in the original Statement of Requirement (SOR) that the aircraft was designed and built to. The aim of the review of the SOIU, along with other data is to establish what changes have occurred and their affect on ageing. However, there are other factors to be considered that may influence ageing, a system may have been designed for a particular temperature range but is now being operated permanently at the limits of the range. Similarly the SOR may have stipulated a typical operational sortie length of 3 hours whereas current sortie lengths with a full weapons load may be considerably more.

The Audit should include a review of the latest edition of the SOIU and confirm that it is reviewed annually with a full review every 3 years. Confirmation should be sought that Operators are familiar with the SOIU and aware of its importance. This should involve an interview with a cross section of pilots during which it should be confirmed that Sortie Profile Codes (SPCs) adequately reflect the range and type of operation. The SOIU information has the potential to be used to support airworthiness decisions; therefore it is essential that the data contained within it has been validated by the Aircraft and Engine DOs and that they are fully involved in the 3 year review. At least 2 years usage data taken from the MOD Form 725, Flying Log and Fatigue Data Sheet should be examined to confirm that assumptions contained in the SOIU relating to SPCs are accurate and that the percentage of SPCs flown accords with that published in the SOIU.

## 4.13 RELEASE TO SERVICE

The Audit should include a review of the RTS cleared flight envelope and the audit trail to test or design data that supports the published limits. The Audit should assess how design changes that may impact upon mass, C of G and flight envelope are addressed and incorporated into the RTS. A review of Clearances with Limited Evidence (CLE) and Operational Emergency Clearances (OEC) should also be carried out. The RTS amendment process should be reviewed to confirm that changes are reflected in aircrew publications.

## 4.14 OPERATING DATA MANUAL (ODM)

The Audit should include a review the procedures for the upkeep of the ODM along with sampling of amendments to establish whether an audit trail exists back to test data or analysis. The ODM is a particularly relevant and valuable document where platforms are used in environments outside those originally assumed.

## 4.15 MODIFICATIONS AND CONFIGURATION CONTROL

The Audit should review the process for Designer and Service modifications (SMs) to confirm the process for identifying, controlling, classifying and embodying modifications is robust. As a minimum the Audit should confirm all modifications classified as B/2[1] or above or a Category 1 modification if issue as a Service Bulletin under AECMA specification 1000D above have been embodied. The process of designing, approving and embodying Service Modifications should be examined. The audit should also confirm that SMs are subject to timely DO cover mod action.

Where there are “Fleets within Fleets” particular attention should paid to how these are managed. The modification process should include the incorporation of modification details into the appropriate publications in the ADS and the recording on electronic documentation systems and in the MOD Form 700 documentation including the MOD Form 746 ERC. The minutes of Local Technical Committees (LTC) or similar modification classification and approval meetings should be examined as part of the Audit. A further consideration, from a systems perspective, should be the design of modifications by third parties and equipment manufacturers, the Audit should review how these are controlled and recognised by the DO and how are they incorporated into the configuration control of the platform.

## 4.16 SPECIAL INSTRUCTIONS (TECHNICAL) (SI(T)S)

The AAA should include an end to end check of the process for managing SI(T)s from the initial identification of a requirement to fleet satisfaction. An SI (T) may require further action such as the raising of a modification or maintenance requirement, where this is the case the Audit should establish that the action was effective. Where an aircraft is a civil certified type it should be confirmed that the PT is in receipt of Service Bulletins (SBs) issued by the Type Certificate Holder (TCH) and Airworthiness Directives (ADs) issued by the civil regulatory authorities. The process for assessing the applicability of SBs and ADs and the method of satisfaction should be verified as part of the Audit.

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[1] Modification classifications laid down in Defence Standard 05-57

## 4.17 FAULT ANALYSIS AND NARRATIVE FAULT REPORTING

An AAA should review procedures used to analyse defects to determine how the collected information is applied to maintenance schedules and for possible modifications to improve reliability and maintainability and establish whether trends are identified and acted upon. The Audit should determine if defect data is read-across from other marks and if cross-fertilisation data from other platforms and operators, both military and civilian, is assessed and acted upon if appropriate.

The narrative fault reporting system using the MOD Form 760 can be one of the prime tools to identify ageing in components. An AAA should review the MOD Form 760 procedures to confirm that defect investigations undertaken are completed and that the results of investigations are considered in maintenance schedule reviews and modification meetings. The Mandatory Fault Reporting Instructions (MFRIs) should be reviewed along with the reasoning for items being selected for fault reporting. The linkages between a fault investigation and product improvements through modification action should be reviewed. For items having a high rejection rate, strip reports should be examined for indications of ageing.

## 4.18 LOGISTIC SUPPORT

All military aircraft are supported to a greater or lesser degree by Logistic Support contacts with civilian companies, and these arrangements should be included in the audit. This is particularly important where the contract includes all maintenance and spares support. The Audit should review the contracting authority's oversight of the contract to ensure there is a procedure in place to capture all events that may have a bearing on airworthiness and that these are reported to the PT or the Continuing Airworthiness Management Organisation (CAMO).

Organisations that are carrying out aircraft maintenance should hold a Maintenance Approved Organisation Scheme (MAOS) to MAA Regulatory Publications (MRP) Part 145 [24]. Whilst the AAA should not seek to repeat the approval and oversight process some areas should be examined in more detail, these include:

- The process for ensuring the competency of staff including training and authorisation, in particular it should focus on tasks where extra training and specific authorisation is required such as Zonal Surveys.
- The Organisation's Quality System and any oversight by the contracting authority should be examined.
- Where a contract is spare inclusive the process for obtaining components and piece parts, and what measures are in place to ensure the provenance and traceability of parts.

## 4.19 OBSOLESCENCE

Obsolescence is a major factor in the ageing of an aircraft and, given the design and development lead times, it can be argued that ageing begins before the aircraft enters service. Obsolescence effects on specific systems and the propulsion system are covered in the appropriate section.

All aircraft should have in place an Obsolescence Management Strategy that accords with the requirements of Joint Service Publication (JSP) 886 Vol 7 [25]. The Audit should examine the effectiveness of the strategy by selecting specific examples of replacement parts and material and examining how any changes were made and approved. Where a military registered aircraft is a derivative of a civil type and the obsolescence strategy relies on that provided by the TCH then a separate strategy should be in place for any specific military systems fitted to the aircraft.

The procedure for the use of alternative parts should be reviewed and it should be confirmed that the use of alternative parts is correctly approved. The Audit should also review the support provided by Commodity PTs for the items for which they have responsibility.

## 4.20 CHANGES IN HEALTH SAFETY AND ENVIRONMENTAL LEGISLATION

Increasingly it is becoming apparent that many of the substances in the construction and maintenance of aircraft are detrimental to the health of users and to the environment, typical examples being Asbestos and Cadmium. Legislation that bans the use of hazardous materials and substances is constantly evolving and this can present a further obsolescence problem for Project Teams. The Audit should examine what measures are in place to indentify where banned or controlled material and substances are used and to provide alternatives. Where possible the ageing properties of alternatives should be assessed.

## 4.21 ON-GOING AIRWORTHINESS

The review of on-going airworthiness should include the Project Safety Management Plan and the Hazard Log. The content will be reviewed during the system assessment phase of the Audit but additional scrutiny will focus on their upkeep.

The on-going adherence to Airworthiness policy by the PT should centre on the management of the Team in adhering to key plans and processes with a review of progress and management of emerging issues at key meetings. The Audit should review the Integrity Plans and Strategy Statements for Structures, Systems and Propulsion System to ensure that they accord with the requirements of RA5720 [26] and RA5721 [27] respectively. The Audit should also review the minutes and workings of the Project Safety Working Group, and the various Integrity Working Groups or their equivalents. The aircraft SPS should be reviewed along with any SPSs for specific equipment or components. It should be confirmed that arrangements for Post-Design Services (PDS) type functions are in place with an appropriately approved organisation and that they are adequate and function as intended. The Audit should ascertain whether the CAMO is fulfilling the responsibilities laid down in RA 4947 [28].

The Audit should seek to establish that that both the PT and the CAMO are alert to the dangers of ageing and that the processes in place are sufficient to help identify and mitigate the ageing process.

## 4.22 Environmental Damage Prevention & Control (EDPC)

Environmental Damage (ED) is the term used to describe the physical degradation of material properties as a direct result of interaction with the climate or the environment. ED includes corrosion, erosion and the degradation of surface finish and composite material properties. ED is not selective and will affect all parts of an aircraft therefore an AAA should address ED measures on structure, systems and the propulsion system. The methods of minimizing the effects of ED on metallic and composite materials have commonality in that prevention relies heavily on the effective maintenance of protective systems such as coatings, tapes and corrosion-preventive compounds (CPCs). Corrosion is the most significant form of ED to the metallic structure or systems, including component parts, of an aircraft. It can reduce static strength, initiate stress corrosion cracking, shorten fatigue lives and also detrimentally affect avionic and mechanical equipment. Through either extreme environments or adjacent systems, the strength of composite structural or system components can be adversely affected by excess heat and moisture uptake and can also suffer degradation by fuels, oils, lubricants and ultra-violet light if left unprotected.

It follows that ED is one of the major factors in the ageing of an aircraft and the AAA should review what EDPC measures are in place. These should include a system for collecting, reporting, assessing and recording ED arisings. The review should extend to the CAMO's responsibility for ensuring maintenance activities related to ED are carried out and that new arisings of ED are reported to the PT. The review should also include confirmation that the aircraft washing policy is adequate and is carried out. It should be confirmed that entries in the MOD Form 704A Acceptable Deferred Husbandry Log are appropriate and that entries are cleared as soon as is practicable. The Terms of Reference for any specific ED posts in Forward organisations should be audited as should the minutes of any EDPC meetings. Though not mandated dehumidification can be a valuable tool in combating ED and where such equipment is available the AAA should review its use and where possible its effectiveness.

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# 5 STRUCTURES SPECIFIC AUDIT

## 5.1 STRUCTURAL SUB-AUDIT GENERAL

The requirements of the AAA structural integrity sub-audit are included in RA 5723[2], however, the RA also refers to MASAAG Paper 104 [11] and the Audit Team should familiarise themselves with the content of this paper. EASA AMC20-20 [6] provides measures to be carried out by the Type Certificate Holder to assessing ageing on civil aircraft. AMC20-20 [6] and MASAAG Paper 104 [11] have much in common both having derived from original work carried out by the FAA and the JAA. Where a Military aircraft that is a derivative of a civil type is subject to an AAA the audit team should familiarise themselves with any ageing aircraft measures carried out by the TCH.

## 5.2 STRUCTURAL INTEGRITY MANAGEMENT

The management of platform structural integrity is laid down in RA5720 [26] and follows the Establishing, Sustaining, Validating, Recovering and Exploiting (ESVRE) principles. The Audit should review the Platform Structural Integrity Strategy Document and the Structural Integrity Management Plan. The Audit should review the minutes of a number of Structural Integrity Working Groups, or equivalent meetings to ensure that structural integrity is being managed to the ESVRE principles. In addition, the Audit should review the minutes of any other meetings that might have a bearing on Structural Integrity and feed into the SIWG, typically these might include, but not be limited to, Operational Loads Monitoring (OLM) or Operational Data Recording (ODR) and Structural Modification Programme meetings.

## 5.3 PUBLISHED STRUCTURAL EVIDENCE

The original qualification of the design should be documented in the Static Type Record (STR) and the Fatigue Type Record (FTR) which are compiled and held by the Designer who has responsibility for ensuring they are current. These records along with supporting documentation are a valuable source of information to the Audit team. Though the STR and FTR will be agenda items for the SIWG the AAA may be the first independent audit of these records. It is recognised that some aircraft, civil certified and foreign aircraft types, may not have STRs or FTRs in such cases those documents fulfilling the requirements should be clearly identified and treated in the same way.

The STR should provide reference to the Full Scale Static Strength Test and the associated test reports, plus major component tests, sub-assembly tests and even component tests to underpin the results for each major component. Additionally, ground resonance and structural coupling test reports in furtherance of a flutter clearance should be given. The Designer must ensure that any subsequent design change that may impact upon the static strength is addressed. For example where the overall mass of the aircraft is increased the Designer should show that this can be accommodated within the existing design loads or if not, that a modification to the structure is required, or a limitation applied to remain within the design limits. The audit team should assess the STR with these points in mind.

An assessment of the Static Type Record (STR) should be carried out to ensure the basic stressing data with the various flight cases and details of the critical cases for the major components of the structure; wing, front/centre/rear fuselage, fin and tail-plane are included. The Reserve Factors (RF), (ratio of allowable load against actual load), for the critical areas within the major component, should be tabulated in the STR. The review of the STR should seek to establish whether incremental mass growth or mass distribution changes have been adequately taken into account. As already stated it is recognised that information such as that contained in the STR may not be readily available for aircraft that are derivatives of civil certified types, however, it should be confirmed that the implications of any variation in the civil and military usage has been assessed by the in TCH.

### 5.3.1 FATIGUE TYPE RECORD (FTR)

Requirements on the aircraft Design Organisation to produce a Fatigue Type Record (RA5309) [29] have been embodied within Defence Standards since the 1980s. Experience has shown that, for legacy aircraft, Design Organisations rarely progress past Part 1 the Historical Record stage of the FTR. Consequently their use in providing a comprehensive record of re-assessing the fatigue life and revising inspection requirements for audit purposes may not be possible. Alternative sources of information therefore need to be pursued. This could take the form of a review of past SIWG Minutes, specific Operational Loads Monitoring (OLM)/ODR) Meetings, regular briefings and status reports. Consideration should be given to seeking a detailed brief directly from the Designer to specific questions raised by the Audit Team. The aim of the audit is to establish that the fatigue clearance of the aircraft is adequate, in terms of service usage, to enable the aircraft to reach its planned OSD. The review should confirm that the effects of any weight growth or role changes on the Fatigue Life have been considered. The review should also include fatigue modification or refurbishment programmes and their impact on fatigue lives, and inspection intervals, as appropriate.

## 5.4 WIDESPREAD FATIGUE DAMAGE (WFD)

Fatigue damage can develop into WFD which is a function of ageing. WFD is defined as the simultaneous presence of cracks at multiple structural details that are of sufficient size and density whereby the structure will no longer meet its residual strength requirements. The two sources of WFD are

- Multiple Site damage (MSD): the simultaneous presence of multiple fatigue cracks in the same structural element
- Multiple Element Damage (MED): the simultaneous presence of fatigue cracks in similar adjacent structural elements.

An AAA should review what measures are in place to assess which areas of the structure are susceptible to WFD and where identified what corrective actions have been put in place. Full details of WFD can be found in MASAAG Paper 116 [30].

## 5.5 FATIGUE MANAGEMENT

Changes in the usage of an aircraft may render the initial fatigue test, based on the original planned usage inadequate; the Audit should review whether this has been considered by the PT and what measures have been put in place to ensure the aircraft reaches its planned OSD. Such measure may include additional fatigue testing or an OLM/ODR programme.

The Audit should assess whether the current fatigue budget is sufficient to reach the planned OSD and review the adequacy of monitoring methods and systems to establish whether parameters are being monitored with sufficient accuracy. Recordings can be cross checked against OLM/ODR results and downloads from the Flight Data Recorder (FDR). It should be confirmed that the quantity of unmetered sorties is being monitored by the PT and that the rate is acceptable. During this phase of the audit all fatigue parameters applicable to the type should be considered, typically these would include but not be limited to: fatigue meter formula, fatigue index, pressurisations and full stop and roller landings.

## 5.6 OPERATIONAL LOADS MONITORING/OPERATIONAL DATA RECORDING (OLM/ODR) PROGRAMMES

OLM/ODR programmes are mandated for MOD aircraft and the Audit should establish what OLM/ODR exercises have been carried out and review the need to repeat or instigate limited OLM/ODR programmes following a change in usage. The Audit should assess how comprehensive the OLM/ODR programmes have been, for example, has undercarriage loading been considered in addition to flight loads. The Audit should establish that recommendations resulting from any OLM/ODR programmes have been implemented and are effective.

## 5.7 STRUCTURALLY SIGNIFICANT ITEMS (SSIS) AND THE TOPIC 5V

A list of SSIs is furnished by the DO[2], where possible these items are subject to directed inspections, either visual or by Non-Destructive Testing (NDT) techniques. Details of the inspections should be published in the Topic 5V and the MMS. The Topic 5V includes a reporting procedure for faults found in SSIs. The Audit should consider the provenance of the SSIs and that the list appears to be commensurate with the type and complexity of the aircraft. The Audit should also confirm that those SSIs listed in the Topic 5V are also included in the MMS. Where for reasons of accessibility SSIs are not subject to inspection it should be confirmed whether they have been included in any sampling or teardown programme. There should be clear identification of mitigation if there are any at risk uninspectable SSIs. The reporting of SSI faults should be reviewed including the PTs actions in response to any findings.

## 5.8 REPAIRS AND THE REPAIR ASSESSMENT PROGRAMME

An AAA should review the end to end process of embodying a structural repair, including applying for the repair scheme, through either a Service Design Organisation (SDO) or a DO, embodying the repair on the aircraft and recording the embodiment. The Audit should also cover the use of the Topic 6 or equivalent for standard repairs.

Where an aircraft is a pressurised military transport aircraft a Repair Assessment Programme (RAP) should have been carried out. The programme should identify all structural repairs carried out including those carried out to schemes detailed in the Topic 6 Repair Manual. Repairs are then assessed and categorised into three categories

- Category A: A permanent repair for which the existing structural inspection programmes are sufficient to ensure continued airworthiness.
- Category B: A permanent repair that requires supplemental inspections to ensure continued airworthiness.
- Category C: A temporary repair that will need to be reworked or replaced prior to an established time limit. Supplementary inspections may be necessary to ensure continued airworthiness prior to this limit.

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[2] Some DO's,TCHs and other Military Organisations use different terminology to indentify SSIs

It should be noted that the identification of repairs on older aircraft can be problematic particularly Topic 6 repairs and those Designer repair schemes prepared for one aircraft but with a caveat on the drawing stating that the scheme can be used for any aircraft with similar damage. Whilst minor repairs such as blending were recorded on the work card traditionally these were not recorded elsewhere. The purpose and methodology of a RAP is detailed in MASAAG Paper 106 [28] The Audit should review the RAP process and assessment of repairs and confirm that any actions raised against category B and C Repairs have been completed.

For aircraft that do not fall into the category of transport aircraft a record should be maintained of all repairs and the process for raising repair schemes should confirm that a check whether there are any adjacent repairs to be taken into consideration.

## 5.9 STRUCTURAL TREND DATA

The AAA review of maintenance data should include arisings relating to corrosion, vibration, cracking and loose fasteners. Where there are significant raisings of any one type evidence should be sought of any age related failures. The record of faults relating to SSIs should be examined for ageing trends.

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# 6 SYSTEMS SPECIFIC AUDIT

In addition to the general audit tasks listed in Paragraph 4 the following audit areas are specific to Ageing Aircraft Systems Sub-Audit.

## 6.1 PRIORITISATION OF SYSTEMS AND COMPONENTS

There are various methods for prioritising systems, the flow chart at Figure 2 below is but one example but all rely on analysing data to determine the criticality of the systems. Once the basic priority is determined the interaction of system failures should be considered. This later stage will be dependent on existing information emanating from Design analysis, ZHAs and RCM analysis.

### 6.1.1 SIMPLE CATEGORISATION METHOD

The categorisation of the aircraft systems into High, and Low priority for subsequent scrutiny within the audit can be achieved by applying 3 filters to the systems. The first filter identifies those systems that feature in the Hazard Accident/Hazard Log where the level of accident risk is high and where there are linked hazards. It is important to determine where the hazard in question is justifiably included in the Log and not just a repeat of a previous occurrence. The second filter considers RCM analysis of the system where the functional failure of components within the system has flight safety implications; such components are described as Functionally Significant Items (FSIs). This filter looks at the functional failure, its failure mode and effect. The number of arisings over the past 5 years should have been considered in the RCM assessment. The third filter is a review and assessment of the underpinning evidence that has been accumulated in relation to a system. This takes the form of:

- Designer modifications to the system and its components,
- Air Occurrences that have been logged over a period of time,
- SI(T)s raised,
- F760 Fault arisings.
- If a ZHA or equivalent has been carried out then the results should be considered.

Once the initial assessment has taken place the system should be reassessed for inter-system conflicts. Any System Safety Assessment carried out by the Civil TCH under CS25.1309 [14]or BCAR 670 [15] will prove useful at this stage.

RA5723 [2] requires that Emergency Systems be treated as high priority whilst the criticality of the EWIS combined with experience from previous audits ensures it is also treated as high priority without further analysis.

**SYSTEM CATEGORISATION FLOW CHART**

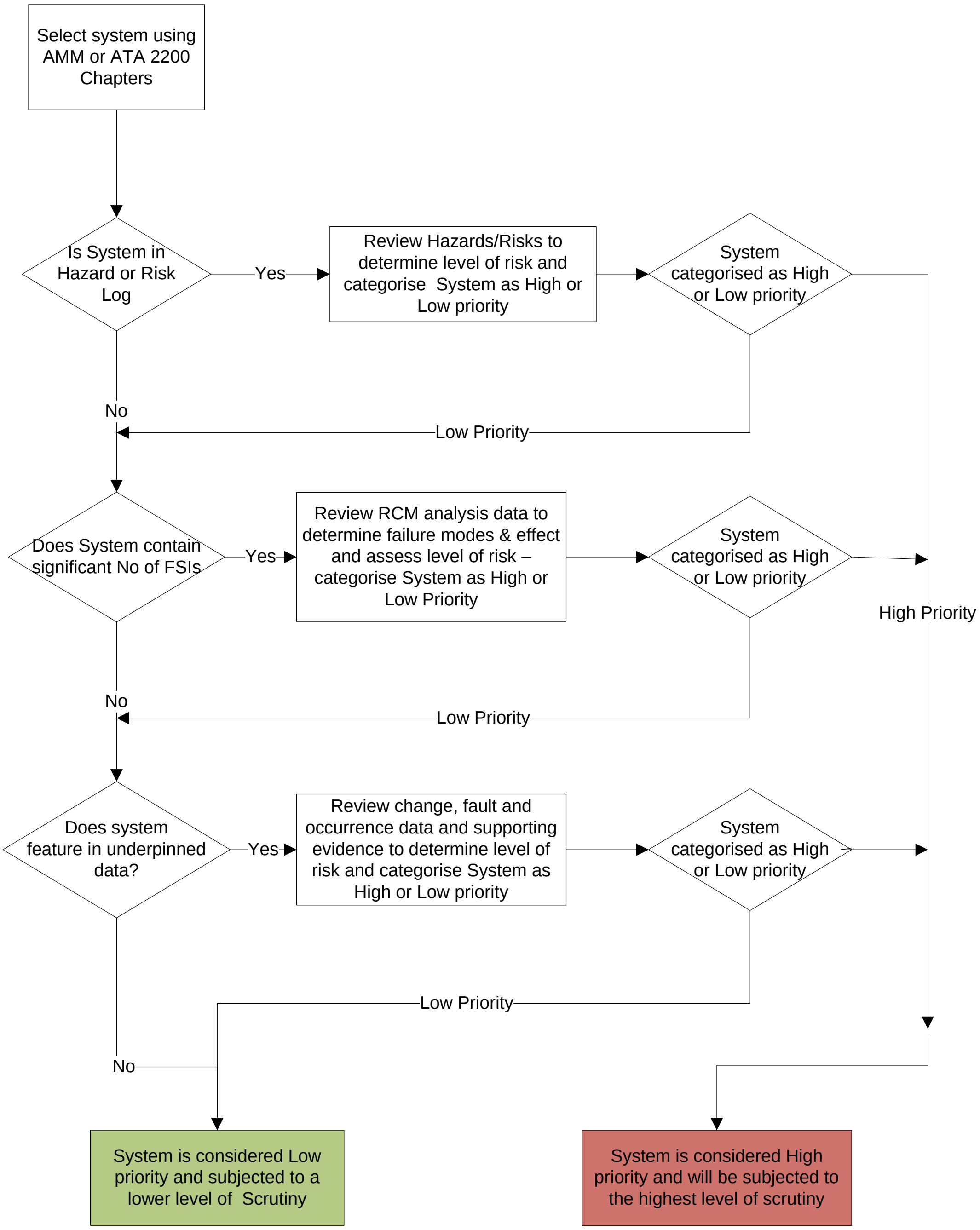


*Figure 2- System Categorisation Flow Chart*

## 6.2 ANALYSIS OF COMPONENTS

Following the categorisation of the systems it will be necessary to identify which components within each system should be subject to scrutiny for signs of ageing. Much of this work will have been carried out as part of the process for categorising systems described above. However, the Design process should have included some form of Failure Mode and Effect Analysis (FMEA) if available this data will assist greatly in identifying those components that might warrant greater scrutiny. It is important to understand that the components identified may embrace pipelines and other interconnection items. Though not mandated in RA5723 [2] further scrutiny of these items may include a programme of forensic sampling. Any such sampling must be carefully controlled to ensure the condition of the item is compared against a set standard and the focus is on deterioration due to ageing.

## 6.3 SYSTEM QUALIFICATION AND CERTIFICATION EVIDENCE

The original qualification of the aircraft systems design is, unlike structures, not documented in a single place. As an intrinsic part of the aircraft the aircraft systems are the responsibility of the aircraft Designer. Due to the various specialist design disciplines required the responsibility is typically vested in several Senior Systems Engineers that are responsible for certifying the aircraft system and its interfaces with other systems and the airframe to produce a System Certificate of Design (CoD) [18]. Equipment suppliers provide the certification for their equipment. This certificate is in the form of a Declaration of Design and Performance (DDP), which provides a statement on the mass, operating parameters, qualification tests undertaken and a statement of compliance against the equipment specification. Any non-compliance must be listed, and those which may impose aircraft level limitations are reflected in the RTS Part B.

System level qualification testing is utilised to provide the evidence that the integrated system is airworthy. Systems can be combined for a qualification test and it is usual to combine the flight control system, hydraulic system, landing gear and utilities control system in one large rig fully representative of the aircraft. Similar systems rigs are used for fuel, environmental control system, avionics, electrical power generation and distribution. On aircraft tests are also used as part of the qualification testing. Flight test in most cases provides the final evidence of qualification. All these tests must be documented and should be listed in each System CoD and should be available if required for review by the Audit Team.

In addition, to reviewing the initial qualification and certification evidence it is important the Audit examines changes that have taken place since initial certification. There will almost certainly have been design changes that will have required certification in their own right and evidence should be sought that the impact on the original certification has been considered.

## 6.4 EMERGENCY SYSTEMS

Emergency systems must always be treated as requiring special attention in an AAA as by definition, their use in anger will occur when a few steps down an accident sequence have already been taken. Furthermore, these systems figure heavily in Safety Case mitigations and these assumptions should be validated. Evidence from previous audits has shown that some components in emergency systems often have little or no preventive maintenance applied, the maintenance philosophy is in effect on-condition and a failure can lie dormant until the system is used in anger. The Audit should seek to identify the emergency systems and determine the adequacy of the maintenance policy for individual systems down to component level.

## 6.5 ELECTRICAL WIRING INTERCONNECT SYSTEM (EWIS)

EWIS is defined as any wire, wiring device, or combination of these, including termination devices, installed in any area of the aircraft for the purpose of transmitting electrical energy between two or more intended termination points. Experience in both military and civil aviation has shown that EWIS is particularly susceptible to ageing and this has been confirmed during AAAs and Condition Surveys. For this reason the EWIS should always be treated as a high priority system. The policy for EWIS is laid down in RA 4550 [31] whilst the policy for Aircraft Wiring Husbandry is given in RA 4551. Further guidance is provided in AP 101A-0005-1 [32] and SAAG Paper 002 [33]. The Audit should review the EWIS Maintenance and Husbandry policies put in place by the PT for the aircraft for which they are responsible, these measures should accord with current policy and be effective. Major threats to EWIS integrity include contamination of wiring by fluids and mechanical damage caused by maintenance traffic. The Condition Survey should identify areas of contamination or damage to EWIS that will allow the Audit Team to assess the effectiveness of the PT's EWIS Maintenance Policy in ensuring high standards of EWIS husbandry.

The civilian regulations appertaining to EWIS and contained in the following AMCs:

- AMC 20-21 Programme to enhance aeroplane Electrical Wiring Interconnection System (EWIS) maintenance [7].
- AMC 20-22 Aeroplane Electrical Wiring Interconnection System Training Programme [8].
- AMC 20-23 Development of Electrical Standard Wiring Practices Documentation [9].

# 7 PROPULSION SPECIFIC AUDIT

## 7.1 PROPULSION SYSTEM AAA GENERAL CONSIDERATIONS

It is recognised that the propulsion system, in particular the engine, is a highly specialised area and in some cases the PT engine desk officers are located remotely from the aircraft element of the PT and the processes and procedures are unique to the engine. Therefore in addition to the general audit tasks listed in Paragraph 4 the following audit areas specific to an Ageing Aircraft Propulsion System Sub-Audit will require scrutiny.

## 7.2 PROPULSION SYSTEM USAGE

As with the other areas of an AAA changes in the usage of the aircraft/engine from the original Design usage may have a marked affect on ageing of the system. It is therefore necessary to determine that all assumptions made during initial system qualification are still valid. These should include:

- Aircraft to engine loads,
- Off takes,
- Engine bay clearances,
- Vibration levels,
- Thermals,
- Intake effects.

It should also be determined whether operating conditions or usage has changed sufficiently to have a detrimental effect on the engine or warrant a review of engine component lifing.

## 7.3 CONFIGURATION CONTROL AND MODIFICATIONS

The AAA should establish that there is an effective procedure in place that ensures that the engine DO is aware of any airframe modifications, including electrical changes which may have an impact on electromagnetic compatibility, and that the aircraft DO is made aware of any engine modification which might impinge on the airframe. To this end it should be ascertained that an up to date Interface Control Document (ICD) exists.

The Audit should ensure there is an effective process in place for the raising of modifications and that all safety modifications have fleet wide embodiment, or that there is a plan in place for full embodiment.

The audit should review the technical approval process for repairs and establish that repairs are correctly embodied and recorded.

## 7.4 PROPULSION INTEGRITY MANAGEMENT STRATEGY

As part of the AAA the Audit Team should confirm that a Propulsion System Integrity Strategy Document and a Propulsion System Integrity Plan are in place and that they meet the requirements of RA 5722[34]. The Audit should review the planning and recording of Integrity Management activities against MOD Propulsion Integrity requirements, and confirm their inclusion in the platform level Safety Management Plan. The Audit should also examine the process for managing propulsion integrity including the proceeds of Propulsion System Integrity Meetings or the equivalent. The Audit should also confirm that Engine Technical Certificate or equivalent documentation is up to date and is consistent with the propulsion system information provided elsewhere in the ADS.

## 7.5 PROPULSION COMPONENT LIFING

Engine life limited components are broadly divided into Critical or Group A parts and components described as Accessories. The Audit should confirm that the component lives used match those recommended by the DO. A review should be carried out to ensure the process for managing lives, including life extensions, if applicable, is adequate and that any life and usage monitoring systems are fit for purpose. The Audit should also review the use of cyclic exchange rates including their origin and the process is in place to verify their continued validity.

The process for recording lives and life usage should be examined and a sample check carried out to determine that lives shown in the Engine Log Book or ERCs match the authorised lives. Where an electronic management or tracking system is used a further cross check should be carried out against the authorised lives. Where lifing details are published in AP100E- 01B[35]. The validity of these should be checked against the authorised lives.

## 7.6 ENGINE ELECTRONIC CONTROL SYSTEMS

The control systems used in modern engine are either Full Authority Digital Engine Control (FADEC) or partial electronic control and this aspect should be subject to scrutiny. The ageing threats to electronic control systems which the AAA should assess are:

- Obsolescence issues affecting components within the electronic control systems.
- Degrading of the memory in any programmable devices.
- Degradation in cable shielding or product grounding that might compromise protection from lightning strikes, HIRF and EMC.

- Lack of suitable software development resources (including rigs), knowledge and skilled software engineers.

## 7.7 MAINTENANCE POLICY

As part of the AAA a review of the SPS for the Engine should be carried out and the maintenance policy established. If the engine is civil type certified and is supported by a total care package the extent of the support package should be established. The Audit should include a visit to the Engine Depth Maintenance Organisation to review the Organisations interface with the PT and examine the strip and build process. A review of the approved maintenance documentation should be included and it should be established what work recording system is being used.

## 7.8 PROPULSION SYSTEM TREND MONITORING

Propulsion System faults recorded during engine strip at Depth are unlikely to be captured in the overall aircraft fault data, therefore, additional measures need to be in place to manage trend identification and monitoring of such faults. The Audit should review fleet operational statistics, including accidents, incidents, in-flight shut down rates, engine rejections, aborted take-offs and performance to identify any trends or patterns that suggest future airworthiness and integrity problems. The Audit should establish whether engine strip reports are provided to the PT and if so what use is made of the information.

## 7.9 PROPULSION SYSTEM CONDITION SURVEY

For reasons of availability an aircraft CS is normally carried out concurrent with a scheduled maintenance activity. The engines will normally be removed for this activity and will not be included in the survey therefore a separate ageing condition survey of the engine and components will be required. An Audit visit to the Depth maintenance organisation should include a review of the condition of a stripped engine however this will be limited and a strip and examination to piece part level of a high-life-since-last-overhaul fleet representative engine should be considered. This examination should include a targeted inspection of less-frequently overhauled and on-condition components such as harnesses, pipelines and brackets and should where necessary include forensic examination. The engine strip and examination would normally be carried out by the overhaul agency. Another valuable source of information that will help establish the condition of the engine fleet is the engine post overhaul reports and part of the Audit should include a review of these reports.

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# 8 THE CONDITION SURVEY

## 8.1 INTRODUCTION

As an integral part of an AAA RA5723 [2] calls for an independent physical examination of the condition and husbandry standards of selected aircraft that are representative of the fleet. This examination is generally referred to as a Condition Survey (CS). The condition surveys carried out to date have demonstrated the importance and value of a physical examination for ‘ageing’ in structures and systems. They have identified conditions exacerbated by long service including a gradual deviation from the ‘as designed’ to the current ‘as maintained’ condition both in the documented and physical state. These conflicts represent a loss of configuration control and a threat to the safety and airworthiness of ageing aircraft.

CS is a method of examining elements of structures and systems not generally covered by standard maintenance. It has been found that although training and maintenance should be sufficient to detect ‘expected’ forms of wear and tear, degradation due to ageing extends beyond that range of subject matter and experience.

CS has been carried out to both structures and systems. Structural CS is longer standing, and is planned by analysis around components and assemblies by the Design Organisation (DO), through design calculation, full-scale fatigue testing, and in-service experience etc. and is well established and effective.

System CS is relatively new, and has been carried out by a number of methods, including ‘Non-Intrusive’, the inspection of visible surfaces without dismantling, and ‘Intrusive’, which includes dismantling and examination of hidden surfaces and interfaces. The extent of the survey has also ranged between single system and the entire aircraft. The variations are considerable, and clearly have financial and operational availability implications.

This Section describes a framework and aims for both Structural and Systems Condition Surveys, formulated as a result of military AAAs which included CS, and also a number of independent failure investigations. The survey extent and depth described are based on that experience, and considered essential for an As Low As Reasonably Practicable (ALARP) condition, cognisant of practicality and cost. Further details of System Condition Surveys are given in SAAG Paper 004 [36]

## 8.2 AGEING FACTORS

RA 5723 [2] requires that an AAA should be conducted 15 years after a type's declared In Service Date (ISD) and thereafter at 10-yearly intervals, however, it should be recognised that:

- Ageing degradation can start at manufacture and occur before an AAA is due and propagate in places outside the boundaries of scheduled maintenance
- Repairs SI (T)s etc. may induce factors that cause or exacerbate degradation.
- Component protection effective life can be reduced by human and environmental factors, resulting in significant and unexpected degradation before an AAA becomes due.

The AAA should consider all elements of the aircraft (including, but not limited to structure, mechanical, propulsion, avionic, electrical and weapons systems).

## 8.3 CONDITION SURVEY FRAMEWORK

### 8.3.1 CONDITION SURVEY DESCRIPTION

An Ageing Aircraft Condition Survey is a risk based detailed physical examination of an aircraft's structure and systems, to identify physical degradation and deviations as a result of 'ageing', which may compromise safety and airworthiness.

Aircraft examination is from an 'in-service', 'as-maintained' condition, taking a 'bottom up' approach, initiated by a general, non-intrusive visual examination. Specific observational examples may then be subjected to intrusive examination using increasingly detailed methods including enhanced visual, NDT, forensic, and in some cases, destructive (teardown) examination as appropriate.

Examination includes identification and analysis of conditions that are, may lead to, or exacerbate ageing degradation, including errors of design, manufacture and installation; maintenance or damage; reduced clearances and unexpected interactions between systems, or materials. In addition, examination of a number of aircraft could reveal trends in maintenance practices and material degradation which may require changes to maintenance policies.

Each stage of the survey must be managed, including review and authorisation to proceed to more detailed examination. The results should formulate a degradation history, indicating the causes of initiation, exacerbating conditions and likely future propagation effects.

### 8.3.2 Management of a Condition Survey

Experience from CS programmes as part of AAA has identified 'ageing' as a combination of practical aircraft engineering and science. It has also found that aircraft engineering based on standard maintenance and operational use can be insufficient to effectively identify factors and evidence of ageing. It has also identified that the science of ageing, materials and corrosion etc. requires an engineering input to address practicality.

The study of 'ageing' therefore requires the integration of aircraft engineering and science, and requires personnel with experience of deep maintenance, repair, and aircraft operation, along with scientific knowledge of 'ageing' effects, materials, degradation, and detections techniques working as a team. The size and composition of the team will be dependent on the level of survey.

Other specialisations to support this activity include NDT, at sufficient levels of experience for both in-service techniques and access to a Level 3 qualified specialist able to devise novel methods of examination for which formalised techniques are not available.

Materials, and corrosion science are also essential, and the use of forensic engineering to analyse ageing degradation, defects and materials found in ageing aircraft.

Full Aircraft/System functional tests can be beneficial particularly on emergency systems. If possible a record of functions test parameters leading up to the AAA should be recorded to establish how systems are meeting the prescribed performance limits and how far they are within any allowable tolerances. The aim of gathering this data is to establish whether a systems performance is progressively deteriorating as this may be an indication of ageing. Testing of system assemblies to reproduce conditions of operation has also been found useful.

The following specialisations are required when carrying out a full intrusive CS and whilst this is most unlikely to be the case for most AAAs, the list is included for completeness' sake. The list may be reduced for a normal CS and SMEs would be co-opted to the team when required:

a) Ageing Aircraft Subject Matter Expert (AASME)

b) Materials and Corrosion Specialists

c) Access to NDT technique development capability.

d) Forensic Engineers

e) Test Engineers

f) Aircraft Engineers with a high level of experience either on type or with extensive experience in a Depth maintenance environment.

## 8.4 PRIMARY AIM OF CONDITION SURVEY

### 8.4.1 PRIMARY AIM OF CONDITION SURVEY

The primary aim of the CS is to confirm that the actual condition of the fleet matches the official record and to provide assurances that standards of husbandry, maintenance and, ultimately, airworthiness are acceptable. The CS should also seek to indentify hidden faults and those masked by poor husbandry. Ideally the CS will be carried out on a representative sample of the fleet ahead of the bulk of the AAA thereby allowing the CS findings to be fed into the Audit. The CS can further support the management of an ageing aircraft fleet by:

- Providing support to structural, systems and Propulsion System integrity by identifying physical evidence of ageing degradation and damage as a result of material degradation and operational use.
- Identifying ‘ageing’ conditions that may affect current SMS assessment and identifying previously unknown conditions that may be additional to the documented SMS assessment
- Identifying evidence of inconsistency between the physical and documented configurations.

## 8.5 CONFIGURATION CONTROL AND DOCUMENTATION

An ADS document set describes the state of the aircraft type and how it is to be operated and maintained. Ageing may compromise configuration control creating conflict between the physical or documented standard. The CS will seek to:

- Identify any inconsistencies between the physical aircraft and its documentation suite
- Identify inconsistencies and deficiencies in the scheduled maintenance regime, with respect to maintenance, ageing degradation, or environmental exposure, etc.
- Depth Bay Maintenance or Overhaul/Reconditioning maintenance efficacy with respect to ageing degradation and in conjunction with material types and threats to integrity

## 8.6 CONDITION SURVEY RESULTS

A CS output should be a means of advising on future aircraft fleet management, including reducing the effects of ageing through preventive and corrective maintenance. Recommendations should consider:

- Recovery considerations (replace / monitor)

- Changes to improve the effectiveness of the maintenance regime.
- Trends and material degradation considerations

## 8.7 CONDITION SURVEY TYPES

Condition Surveys can be divided into three types which vary in extent and depth. Level One fulfils the requirements of RA5723 whilst Levels Two and Three provide a more comprehensive indication of the condition of an aircraft and the level of ageing taking place. Each level of survey can support the next higher level:

### 8.7.1 LEVEL ONE SURVEY

The Level 1 survey forms an essential initial examination that fulfils the requirement of RA5723. It is largely a maintenance directed audit of the aircraft in the ‘as flown’ configuration and should seek to identify:

- General condition, dirt, debris, leaks, and signs of wear
- Poor maintenance standards and practices.
- Signs of surface finish, protection and sealant degradation on visible surfaces only
- Differences between the physical and documented state of the aircraft
- Evidence or sites hidden by components or other structure that might be prone to degradation.

### 8.7.2 LEVEL TWO SURVEY

A Level Two survey should include the removal of blockages such as components by normal maintenance methods to enable further survey of a zone or particular components, typically these may include:

- Removal of components to allow access to structure.
- Removal of pipe insulation or heat protection.
- Removal of clamps and supports to allow full examination of pipe work.

#### 8.7.3 Level Three Survey

The Level Three survey is a detailed examination of components where deterioration or ageing are considered to be likely and where the components could present a threat to the airworthiness of the platform. This detailed examination could involve NDT, forensic examination and may include destructive testing rendering the item unfit for further service.

## 8.8 Forms of Condition Survey

Condition Survey's have been carried out in a number of forms and depths since introduction as part of AAA. Experience has found that CS can be used in various ways, but that due consideration is required to understand the outcome of that activity in relation to the requirement that initiated it.

Clearly an AAA requirement indicates that a holistic CS approach should be applied to the aircraft structure and its systems. CS can however, be used at any time in an aircraft's service as a means of applying engineering and science to resolve concerns over the integrity of a system, assembly, material or component etc. It is considered that a CS can be applied to:

- Structure
- All aircraft systems
- Selected systems
- A Targeted system
- Targeted components

As already stated a Level One survey will meet the AAA requirement laid down in RA5723 however, for a greater appreciation of an aircraft's condition a Level Two survey should be considered. In considering what level of survey should be carried out the following principles should apply:

- A Level One survey can be used for a general appreciation of an aircraft's state, but because interfaces and hidden surfaces have not been examined it cannot provide a complete understanding of the aircraft's condition. A Level One survey should include an SME analysis and recommendation for examination of any surfaces considered to represent a threat.
- A CS for the examination of targeted systems etc. is considered effective if used in conjunction with previous AAA or as a means of verifying a localised integrity threats

- Fleet size, or sub fleets play a part but ultimately a complete aircraft requires analysis, and larger more diverse fleets would benefit from a wider approach, possibly the addition of targeted surveys after the initial AAA Level One Survey.

# 9 MATERIAL DEGRADATION

## 9.1 INTRODUCTION

A modern aircraft comprises wide variety materials all of which, to a greater or lesser degree, suffer from age related degradation. Such degradation can be accelerated by exposure to extremes of usage and/or environment. It is vital an AAA considers the susceptibility of material to ageing. The following list is not exhaustive but covers some of the materials that should be considered in an AAA.

## 9.2 METALS

Metals can suffer unobserved/unknown changes to their properties as a result of 'ageing' that an Audit Team should look to explore. These may include the following:

- Changing from corrosion resistant, to susceptible, or from ductile to brittle.
- Corrosion
- Fretting
- Fatigue
- Overload cracking

Older aircraft were often built using metal that, at the time, was considered the most suitable, in terms of weight v strength, however, experience in use often exposed frailties in other areas. A prime example of this was DTD 683 a high-strength, low weight aluminium alloy with excellent fatigue resistant properties, unfortunately in service this proved to be highly susceptible to stress corrosion cracking. This material was developed in the 1940s/50s and the aircraft using it are no longer in service but it provides an example that a material can exhibit undesirable properties once exposed to the ravages of in-Service use.

## 9.3 COMPOSITE MATERIALS

The extensive use of composite materials in modern aircraft is now common place and whilst there is a reasonably good understanding of the degradation of composites as yet there is little in-Service experience. Composite materials can degrade by exposure to heat, moisture ingress, and contact with fuels, oils and lubricants, plus exposure to UV light. In addition, even low levels of impact energy (e.g. dropped tools) can lead to fibre damage and de-lamination that in turn reduces compressive strength and can lead to further cyclic damage growth if left unrepaired.

This phenomenon is due in part to the laminated construction providing little in the way of through-thickness strength; composite panel edges and fastener holes are extremely vulnerable to impact and crush damage. Following a high-energy impact, the surface is likely to exhibit surface evidence of damage; however, lower energy impacts could result in sub-surface damage that would impair the structural integrity of the item without leaving any external sign of the impact having occurred. Degradation of composite structure and components is proportional to the exposure to excess heat and moisture ingress. Composites can also suffer degradation by fuels, oils, lubricants and UV light if left unprotected. Careful management and recording of repairs to composite structures and components is also necessary to ensure strength is retained. Audit Teams should carefully review methods in place to manage the exposure of composite structure to environment elements and the system in place for managing and recording repairs to composite structure. Where it is possible composite structure/components should be subjected to a sampling programme.

## 9.4 PROTECTIVE COATINGS AND ANTI-CORROSIVE TREATMENTS

Environmental damage is prevented by the use of protective coatings and anti-corrosive treatments; these can broadly be divided into two groups as follows:

- Compounds including surface finishes such as paints and anti-corrosive compounds
- Electro-plating such as anodic, zinc and cadmium coatings.

### 9.4.1 COATINGS AND COMPOUNDS

Paint coatings are known to degrade with time and environmental exposure therefore; the Audit should review the surface finish policy for the aircraft and determine whether the measures in place are sufficient to protect the structure from ED whilst monitoring the finish for deterioration. Anti-corrosive compounds can deteriorate over time particularly if subjected to prolonged exposure to heat or oils and fluids.

### 9.4.2 ELECTRO-PLATING

Anodizing is the most common surface protection treatment for non-clad aluminium alloy surfaces. Many see anodizing as a “for life treatment” however, it only has an effective life of 6 to 25 years dependent on the operating environment. Moreover, it is not visually apparent that the Anodic coating is no longer effective. Within its life an anodized coating provides excellent resistance to corrosion however, it is susceptible to mechanical damage and scratches and is not easily repaired.

Until recently cadmium plating was the principle plated anti-corrosive treatment for ferrous metals however, its use has now been curtailed due to safety and environmental considerations. The effectiveness and longevity of replacement plating medium has yet to be established.

## 9.5 ELASTOMERIC AND POLYMER SEALS

Since the loss of Nimrod XV230 interest has focused on the susceptibility to ageing of elastomeric seals used in aircraft systems. Seal condition and associated life will be governed by factors such as fluid immersion, exposure to UV radiation, ozone, storage temperature, polymer type etc). Some elastomerics are more susceptible to ageing and compression set than others. Those worst affected by compression set tend to be the Fluorinated Polymers like Fluorocarbons (Viton types) and Fluorosilicones. Compression set is also exacerbated by increased temperature.

## 9.6 PIPES LINES AND HOSES

It is easy for pipelines, particularly solid pipelines, and hose to be treated as “on condition” items subject only to a maintenance Zonal Survey. Solid pipelines can suffer ageing effects such as cracking embrittlement caused by exposure to heat and vibration. Twin wall pipes frequently used in fuel systems can be susceptible to corrosion between the walls. Consideration should be given to forensic sampling of selected pipes.

The construction of flexible hoses varies considerably ranging from simple elastomer/polymer hose through to stainless steel braided Teflon hose. End fittings can be either swaged or re-useable. The major threats to flexible hoses come from excessive movement or maintenance induced damage. Such hoses are normally fitted between a moveable item such as a hydraulic actuator and a solid mounting and are therefore subject to constant flexing. Flexible hoses are also often fitted in locations with limited access, in these situations they may be subjected to maintenance induced stress.

## 9.7 FUELS, OILS AND LUBRICANTS

Fuels, oils and lubricants are prime items for being subjected to environmental or Health and Safety legislation. It is important to ensure that any alternatives have the same functional properties as the original and its use is approved by the DO.

## 9.8 SEALANTS

Sealants used on aircraft vary considerable but they all suffer from ageing to a greater or less degree. Sealants used in fuel tanks can be susceptible to cracking if left dry for long period, if the sealant used falls into this category then the maintenance should contain a warning and a process for keeping the sealant wetted.

## 9.9 POLYMERS

In addition to their use in seals polymers are used extensively throughout modern aircraft not least in the EWIS. The threats to polymers are primarily from ageing and exposure to environmental conditions including, heat, light, water and oils the effects of which can be embrittlement and perishing. Polymers are also highly susceptible to maintenance induced damage.

## 9.10 TUBULAR STRUCTURE, CONTROL RODS

Tubular structure such as engine bearers and control rods can be considered as ‘on condition’ items that are only subject to a visual examination as part of a Zonal Survey carried out during scheduled maintenance. Clearly these visual examinations give no indication of the internal condition of the tubes, consequently; such item should be subject to a sampling programme either by Non-Destructive Testing or by destructive examination. An AAA should establish whether any sampling has been carried out and that the results are still valid.

## 9.11 FLYING CONTROL CABLES

Flying control cables can be damaged or stressed without showing any visual signs, such damage is normally broken strands within the cable itself. It follows that the maintenance regime including removal, installation and handling of cables should be detailed and strictly followed. Flying control cables are considered to be critical components and should have a finite life, the life should be supported by a sampling programme. Further details of the policy and management of flying control cables can be found in AP101A-0206-1 [37]

## 9.12 BEARINGS

Bearings described as Sealed Bearings are a relatively modern innovation and they have been readily incorporated into the design of many aircraft types. Such bearings are generally rod end bearings but they can be staked into solid items such as control bellcranks. These bearings are used extensively in aircraft control systems, though they may be fitted on any system with moving parts. There is the potential for individual bearings to wear without producing enough play or restriction to place a system out of limits. Some aircraft types have already had finite lives placed on such bearings. Hydraulic and similar actuators frequently have end fittings containing spherical bearings, the AAA should seek to determine whether such bearings are changed when the component is overhauled/reconditioned and re-lifed.

## 9.13 Ageing Aircraft Specifications

Over time the specification of aircraft material may change as regulations require more stringent standards, such changes can present a risk to the aircraft that was not considered when the aircraft was designed. An example is changes to the fire retardant standard of acoustic insulation. Whilst not a physical degradation of the material this can be considered degradation against the latest requirement and a risk assessment should be made against the continued use.

## 9.14 Historic aircraft materials

When looking into material degradation historic aircraft can bring new challenges with wood and fabric being the 2 main materials to be considered. There is little MOD published information on these materials but the Civil Aviation Authority (CAA) has leaflets covering the maintenance examination and repair of wooden structure and fabric covering. An AAA team should acquaint themselves with these documents before commencing an Audit and should confirm the competency of tradesmen maintaining these materials as the skills are no longer taught. If repairs are outsourced then the approvals and competency of the contracted Organisation should be audited.

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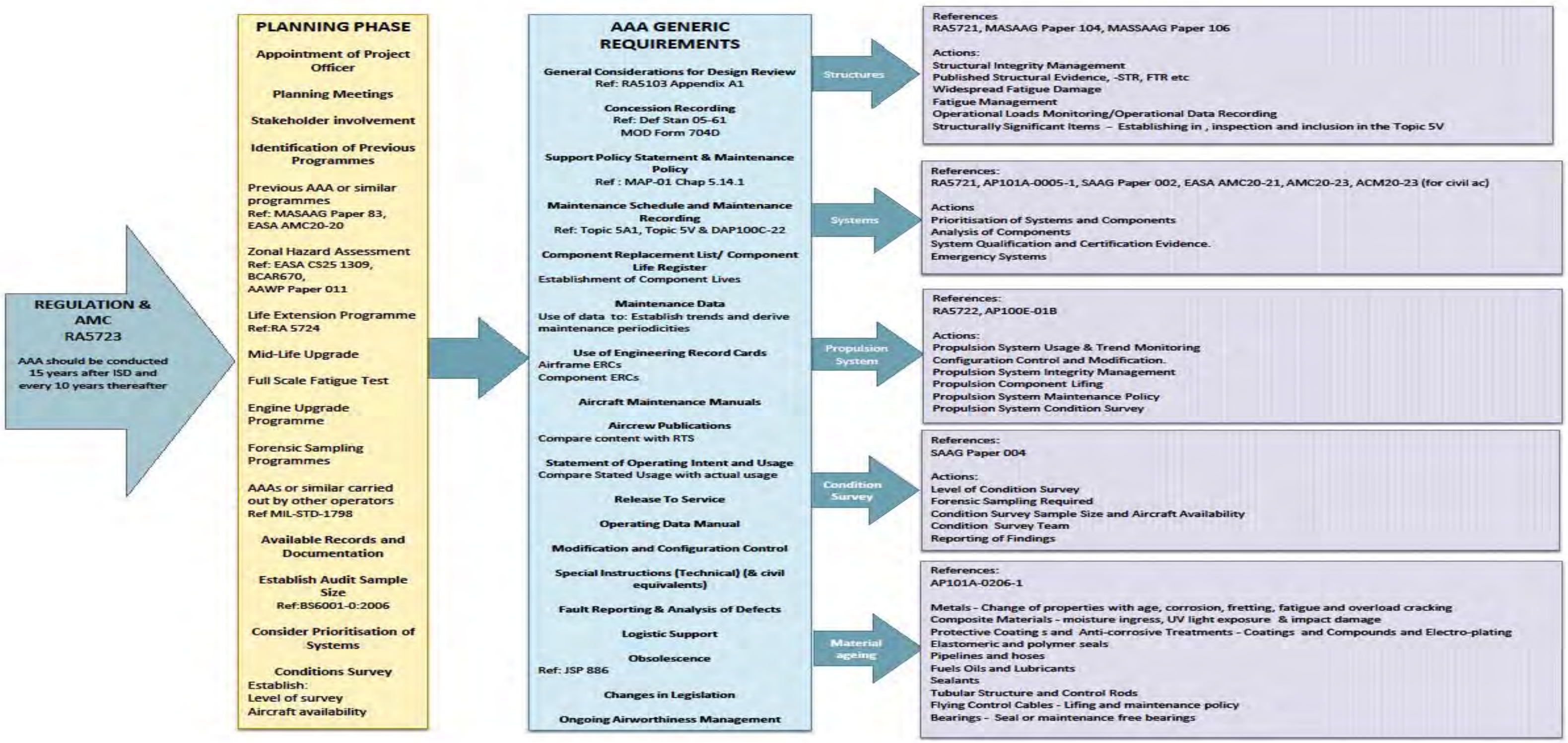
# Appendix A: Ageing Aircraft Audit Framework – Schematic Diagram



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| 13. Abstract (A brief (approximately 150 words) factual summary of the report)<br>This Paper contributes to the Dstl "Understanding Ageing Aircraft" research and development programme. It seeks to provide a framework for the Ageing Aircraft Audits (AAA) by expanding on the current MOD regulations and providing additional guidance based on experience of Audits to-date and best practice drawn from the wider aviation community. In addition, to the auditing activities covering Structures, Systems and Propulsion System also included is guidance on the planning and management of an AAA. The Paper includes detail of the Aircraft Condition Survey which should be considered as part of the AAA. Finally, the subject of material degradation is covered. | | |
| 15. Keywords/Descriptors (Authors may provide terms or short phrases which identify concisely the technical concepts, platforms, systems etc. covered in the report).<br>Aircraft, Structure, Systems, Propulsion System, Ageing Aircraft, Audit | | |