Systems Airworthiness Advisory Group
(SAAG) Paper 005

Condition Survey
- Aircraft Interconnectivity

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EXECUTIVE SUMMARY

An aircraft's Interconnectivity is defined as 'the physical mechanical, electrical and fibre-optic infrastructure (including plugs, cables, mechanical pipe-work and associated connectors) that connects aircraft system elements throughout the airframe'. This paper discusses the possible ways in which the condition of that Interconnectivity (and the effectiveness of its support regime) can degrade with age, as a consequence of material degradation as well as through a range of human factors. This paper suggests methodologies for the conduct, recording and subsequent analysis of a non-intrusive Interconnectivity Condition Survey.

Whilst not a system in its own right, Interconnectivity can be treated as a virtual system and, as such, its condition can be examined and the results of such a survey analysed to provide the Responsible Authorities with a much-improved understanding of the extent of age-related deterioration and of any increased risks arising from ageing. With appropriate analysis, the improved understanding thus gained can lead to improved safety, more effective maintenance policies, better availability and reduced cost of ownership.

This virtual 'Interconnectivity System' interfaces throughout the aircraft with the fixed and line-replaceable items that make up each and every actual system; these items being listed and described within the Aircraft Documentation Set (ADS).

The operating conditions and the characteristics of the platform in question will dictate the scope, depth and focus of the most appropriate Condition Survey to be carried out.

The responsible Project Team, in conjunction with operating authorities may need to define the type of survey that needs to be developed. It might be appropriate for a series of separately focused surveys to be defined, which, together, would then form the overall Aircraft Condition Survey.

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1 INTRODUCTION

MoD experience from recent Ageing Aircraft Audit activity has shown that the overall view of the effects of ageing on an aircraft can be greatly enhanced by an on-aircraft ‘Condition Survey’. There have been a number of interpretations of the term Condition Survey and surveys, both intrusive and non-intrusive, have been carried out on aircraft from Nimrod, Hercules, VC10, and Sentry fleets. Although there may have been some variation in approach, each of these surveys identified two significant factors:

- Material degradation had taken place in components and their associated interconnects, which, in some cases, was affecting systems integrity and airworthiness and, in others, threatened to do so.
- Conflict often existed between the aircraft’s physical and documented states; an issue which, not only impacts airworthiness, but is also likely to complicate long term maintainability and increase ownership costs.

A ‘Condition Survey’ can be applied to all areas of an aircraft but this paper will focus purely on ‘Interconnectivity’.

Whilst some aspects of these factors can be attributed to the ageing (‘change over time’) of the aircraft itself, there was strong evidence that significant contributory causes were the degradation of the relevant maintenance policies and procedures plus non-compliance with required standards. Ageing of components and their associated interconnects is often insidious, as gradual degradation of material properties takes place, potentially compromising systems integrity. For instance, when protective treatments outlive their effective lives, they cease to be as effective; repairs over time will often have a contrary effect, either initiating or exacerbating damage. Degradation of one system may affect the safety of adjacent ones, either physically e.g. a corroded fuel pipe adjacent to a hot component, or by invalidating airworthiness management processes, which, in most cases, assume a serviceable, ‘As Designed’, condition.

It has not been unusual for Condition Surveys to reveal that aircraft have physically deviated from their documented state over time. The ‘As Designed’ standard is the lynch-pin of maintenance activities. However, modifications and concessions applied in production, maintenance in service, individual and compounded in-service modifications or repairs, new equipment installations, etc., all possibly exacerbated by ageing degradation, will contribute to the divergence between the following standards:

- As Designed - the aircraft as it was perceived by the original Design Organisation using the standards at that time.
- As Built - the aircraft as it was constructed, incorporating modifications and concessions applied in production, using the production standards and tolerances at the time and documented in the initial issue Aircraft Documentation Set (ADS). It should be noted that the ‘As Built’ can differ between airframes and from the original design.
- As Maintained - the standard applied after a period in service. This standard is likely to differ from the ‘As Built’ standard in places. Some ageing phenomena may already have been recognised and their effects accepted by the Project Engineer (PE); if this is the case, then any authorised divergence should have been reflected by amendment of the ADS. Before this can happen, the divergence between the ‘As Built’ and ‘As Maintained’ standards should have been thoroughly analysed to understand and manage any impact on the Safety Case.
- As Required - The standard to which, the Project Team (PT), in consultation with the Design Organisation (DO), may decide the aircraft should be restored, based upon the findings of the Survey. If the PT decides to define an ‘As Required’ state, then great care should be taken to amend the ADS to reflect that standard throughout, particularly as far as its application during maintenance is concerned. The aim of a recovery programme would be to ensure the ‘As Required’ standard became the ‘As Maintained’ standard.

The use of an ‘As Required’ standard is seen as a way of enabling a PT to make considered judgements of the various standards that may have either evolved over time or been implemented at build but that may no longer be considered pertinent. It may not be deemed cost-effective to restore every aspect of condition to that at build, and, in certain areas, the decision not to do so may generate a negligible airworthiness risk. Provided this judgement is made by a suitably competent engineer, taking independent, expert advice where necessary, the use of an ‘As Required’ standard would not have a negative impact on safety. Indeed the definition and use of a standard that can realistically be achieved and sustained in service should restore maintenance consistency and, by so doing, actually improve safety.

Safety and airworthiness management processes evolve over time (often becoming more prescriptive), sometimes leading to the imposition of conflicting standards, even on a single type or single example of that type. Safety assessment and failure prediction methodologies have spawned various toolsets including CASSANDRA (a tool used by the MoD to record hazard assessment and management), Failure Mode, Effects and Criticality Analysis (FMECA), Reliability Centred Maintenance etc. These methods are effectively desk-based ways of analysing current information, but frequently do not allow for any change in systems' integrity, including the integrity of interconnectivity, over time. The combination of progressively accepted deviations from original design and the evolution of applied standards is extremely likely to affect presumed and planned for levels of safety and airworthiness to an extent that is almost impossible to quantify in practice.

As degradation can be a gradual process, it can, if left unchecked, become accepted by operators as the norm and, amongst aircrew and engineers, this is often epitomised by the phrase 'it's always been like that'. The challenge facing Aviation Duty Holders and/or Project Engineers (ie the 'Responsible Authorities') is to be able to identify if and when the degree of degradation has reached the point when airworthiness may have become compromised. Condition Surveys can greatly assist by providing a checking process that will provide a level of reassurance that the extant maintenance regime remains effective.

Returning an in-service aircraft to its 'As Built' standard (often after a very long time) is likely to be an unrealistic option. As Charles Haddon-Cave QC stressed[1], the fact that an aircraft has flown safely for many years should never encourage complacency that its condition remains safe. It is suggested that, following a proper safety analysis, the use of an 'As Required' standard would not result in any degradation of safety. It follows, therefore, that any attempt to return the aircraft to its 'As Built' standard would probably prove disproportionately expensive, both in terms of resource and aircraft down-time. A far more pragmatic solution would be for the aircraft PT, in consultation

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[1] An independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 Aircraft XV 230 in Afghanistan in 2006 by Charles Haddon Cave QC.

with the approved design and maintenance organisations, to define and apply an 'As Required' standard, which could then be used to reset and align supporting documentation, training, practices and procedures.

Airworthiness should always be the overriding factor and an example of this in respect of Sentry is provided below. It appears that the surplus wiring was tied back, possibly during build, resulting in a bend radius that is beyond limits.

This 'As Built' standard, may no longer comply with currently defined standards.

Particularly in the case of large transport aircraft, the location and condition of the repairs to the aircraft structure may be well understood, due to a Repair Assessment Programme (RAP) However, a RAP only considers repairs, not the material condition of the basic airframe and, in particular, its structurally significant items. Aircraft systems themselves have usually been analysed during design and development using such techniques as Fault Tree Analysis and FMECA. Once, in-service, basic system serviceability is regularly confirmed by virtue of functional operation. However, system interconnectivity (be it mechanical or electrical) is rarely, if ever, considered, and there is a need to recognise the importance of an Interconnectivity Condition Survey during zonal inspections. It may, of course, be the case that some sections of wiring or pipeline have already been the subject of directed inspections, usually to mitigate a hazard identified during investigation into an earlier failure. To conclude, it is usually true that the documentation for an aircraft does not consider interconnectivity as a system. Nevertheless, deterioration of its condition can often lead to a significant number of faults. This paper will consider Interconnectivity as a virtual system and attempt to demonstrate how the effectiveness of an Interconnectivity Condition Surveys might be maximised; techniques for which do not currently appear in any formal guidance.

2 CONDITION SURVEY DEFINITION

An Aircraft Condition Survey would usually be considered to consist of a detailed visual examination of an aircraft, its systems and/or subsystems in their ‘As Maintained’ condition, but this Paper specifically considers the Interconnectivity aspects of such a survey. Whilst Ageing Aircraft Audits have been the main starting point for many recent Interconnectivity Condition Surveys, such surveys could be instigated at any time where there is concern about the condition or standard of system interconnectivity. In order to optimise the outcome of an Interconnectivity Condition Survey, it is essential at the planning stage, that the Responsible Authority first gives a ‘top-down’ consideration to likely hazardous areas and the types of interconnectivity that are considered to be at the greatest risk. Factors that should be considered here include:

- interconnectivity problem areas, where in-service experience indicates high rates of failure.
- areas of the aircraft where high risk environments exist, for instance where one or more of the following conditions exist: frequent maintenance disturbance, densely packed elements of interconnectivity, prevalent extremes of temperature, significant leakage fluid contaminants.
- individual or multiple zones which theoretical analysis has indicated may be the seat of a serious hazard or hazards for the aircraft, for instance where high temperatures and flammable substances exist in proximity or where single point failures could lead to critical aircraft components or payload such as crew, weapons, fuel tanks, flight control computers, actuators, cables or rods being exposed to thermal or other damage mechanism.

On the other hand, the practical survey itself should be ‘from the bottom-up’ and should focus on identifying physical deviations from the authorised maintenance standards. It should also aim to identify and assess the significance of specific risks that may compromise maintenance, safety or airworthiness management processes. The examination may include some, or all of the following elements: identification of damage or degradation; errors or deviations from approved design, installation or maintenance standards; zonal, cross-zonal or inter-system hazards; unexpected interactions between systems and previously undetected failure conditions. Whilst this list is not meant to be exhaustive, it covers the main points for examination. However, the actual details requiring examination must be set by the Responsible Authority, prior to the Survey.

2.1 DEFINITIONS

Condition Survey - For the purposes of this paper, a Condition Survey is:

'a non-intrusive examination to determine the condition of the installation without disconnecting or removing equipment. This term acknowledges that a detailed examination is not possible due to limited access and will have to be carried out as far as possible, given the likely constraints of the location of the installation and the time available.'

Interconnectivity is defined as:

'the physical mechanical, electrical and optical infrastructure (including cables, plugs, mechanical rods, pipework and all associated accessories) that connects aircraft system elements throughout the airframe'.

2.2 AIM OF THE SURVEY

Taking into account the above definitions, it follows that he aim of the non-intrusive Interconnectivity Condition Survey is to identify, as far as is possible, given the access and time constraints of the survey, any interconnectivity issue which fails to meet the PT's required standards. The aim of the survey will be to ensure that the aircraft concerned can remain in a safe and airworthy condition until its Out of Service Date (OSD). The Survey may also be seen as a scoping and risk reduction exercise to inform Duty Holders and the PT about issues that could affect fleet airworthiness up to and beyond the planned OSD.

2.3 SURVEY SECONDARY AIM

Where doubt exists concerning the applied maintenance standards, a survey's secondary aim might be to ascertain what measures would be required to identify an 'As Required' standard and bring the aircraft's interconnectivity up to this standard, in order to maximize aircraft safety and availability in the future.

2.4 SENTENCING

Following the Survey, a suitably constituted Sentencing Panel, consisting of PT engineers, representatives from the surveying team and external subject matter experts (usually chaired by the Project Engineer or his deputy) should be convened to sentence the observations recorded by the Survey Team. It is suggested that the observations raised during a non-intrusive Interconnectivity Condition Survey might be categorised as follows:

Category 1 An observation which warranted the Sentencing Panel's urgent consideration as it had the potential to be an immediate airworthiness issue.

Category 2 An observation which warranted the early attention of the Sentencing Panel as it had the potential to be a serious issue affecting airworthiness, or was typical of a number of issues, which taken together, could be or become a serious airworthiness issue.

Category 3 An observation on an installation which did not appear to meet the required standard, and, although it was considered unlikely to become an immediate or serious airworthiness issue, had future airworthiness and maintainability implications.

3 Forms Of Degradation

An Interconnectivity Condition Survey should consider the effects of material degradation and adverse human factors on the pipes, cables and connections that are considered to have a bearing upon the overall airworthiness of the aircraft. If sufficiently advanced, these factors could result in:

- systems not functioning as designed
- safety degradation
- new inter-system or zonal hazards
- loss of configuration control

3.1 Material Degradation

Materials used for aircraft components are invariably 'of their time' and may have been the best available when the design was initially conceived and manufactured. However, strength and low weight have traditionally been considered to be of more importance than longevity requirements, such as corrosion resistance. Polymers in cable insulation, pipes, and even 'P' clip rubbers will be degraded over time by exposure to light, oil, fuel, etc.. Protective metal treatments, such as anodizing (which might have had a nominal 25 year effective life), can have their nominal lives considerably reduced by harsh environments. Mechanical and electrical component interfaces can trap moisture and/or solid contaminants and then move in contact, accelerating material degradation. This kind of interface deterioration frequently forms the worst threat to system integrity, and can also be the most difficult to manage as it is often not readily visible, and the interface's time to failure will usually be unknown.

Essentially, all materials age and degrade over time, both through natural processes and usage, with the onset of significant ageing effects occurring at some point in a component's life-cycle. Forms of material ageing and associated considerations are:

- surface protection degradation
- material degradation (such as metallic corrosion/oxidation or the chemical breakdown of fluids or polymers)
- component interface contamination and wear due to inadvertent contact abrasion
- interaction between different materials/fluids
- reaction to local atmospheric or environmental conditions

3.2 HUMAN FACTORS

Degradation can also result from human factors, during design, through build, and from operation and maintenance over a long period. Frequently encountered examples include: absence or blockage of drain holes, cables exceeding design bend radii, surface finish damage, inadequate electrical wire protection, components bent into fretting contact, etc. The standard of aircraft documentation can also be affected and its representation of the physical state of the aircraft can deviate to the extent that divergence between the two will compromise configuration control and will inevitably, therefore, impact airworthiness management processes.

- The following types of degradation, caused by a variety of human factors, should be considered whilst planning and carrying out the survey:
- differences between design and in-use installation standards (for example, unapproved substitution by the supply chain of materials that do not meet the designer’s original specification)
- inter-system hazards that have neither been predicted theoretically nor seen in service – they may result from system degradation or a change in proximity due to the installation of new equipment or maintenance activity
- repairs that have not been properly recorded
- excessively tight wire bend radii
- incorrect security locking

- mechanical damage caused by frequent handling or repeated maintenance or access - the inadequate protection of pipes or wires may be a contributory factor
- poor attention to cleanliness, for example failure to clean up spillages.

4 INTERCONNECTIVITY CONDITION SURVEY

An Interconnectivity Condition Survey should be considered whenever the integrity of interconnectivity is suspect. Recent experience would suggest that a Condition Survey of a fleet, or representative part of it, should be conducted, as a minimum, every 10-15 years. However, experience has also shown that it is possible for the condition of interconnectivity to deteriorate in a much shorter period, if exposed to an adverse environment and/or mechanical damage due to frequent disturbance by maintainers. Safety and airworthiness are prime factors which tend to focus attention on critical systems and emergency functions; however, threats to those systems from interaction with other, apparently less critical, systems should also be considered, representing as they may, previously unrecognised inter-system or zonal hazards. For any survey, the Responsible Authority must clearly define the extent of the survey (its depth and scope of coverage), in terms of measurement of numbers of systems, or sub-systems. The defined scope must identify and document the zones or systems to be surveyed, and, of equal importance, the parts of zones, systems or components not being surveyed. Some ideas for guidance regarding the scoping exercise are provided in the Condition Survey Definition Section above. It is also important to arrange adequate access (which must also be carefully documented) in order to permit achievement of the stated aim.

A key aspect of an Interconnectivity Condition Survey is the standard which the survey will use as the ‘yardstick’. It would be most logical to consider the ‘As Maintained’ standard as the default standard, since that standard should have been agreed with the DO and documented in the ADS. However, in many cases, no ‘As Required’ standard exists and experience has shown that the ‘As Maintained’ state does not then match any that the DO would recognise. Consequently, the survey team will usually need to agree, unambiguously, the survey standard to be applied with the Responsible Authority beforehand. It is also the case that some surveys have been instrumental in highlighting the lack of a clear, useable (or, indeed, used) ‘As Required’ standard and recognition of this issue can, in itself, be a very significant and useful outcome.

A Scoping Survey can be an effective means of assessing general condition and estimating further survey requirements, thus reducing cost whilst improving understanding of the implications of likely findings in a controlled manner. The Scoping

Survey can include preliminary examination of representative accessible zones and equipment and guide the requirements for follow-up surveys. Such future interconnectivity surveys may be focused on systems, zones, part-zones or components. They could concentrate on component interfaces which are normally inaccessible or that are deemed to be high-risk or likely to benefit from more detailed or intrusive examination. A scoping survey should be given maximum reasonable access and any limitations of access or examination will need to be understood at the outset and recorded in the final report.

Prior to an Interconnectivity Condition Survey, functional testing of aircraft systems before surveying to ensure serviceability before disruption has generally been found to be of limited use. However, functional testing may be useful to identify specific threats e.g. fuel system electrical bonding breakdown due to poor contact and corrosion. After a survey, and before rectification, targeted functional testing could help to understand if, and how, any issues discovered are affecting the performance of the system concerned. It should be remembered that a functional test shows the system is working at the moment of test; it gives no measure of degradation.

Follow-up Interconnectivity Condition Surveys are valuable in increasing sample size and gaining a wider understanding of aircraft general condition, or focussing on specific identified risks.

Expanding on the definitions in 2.1, an Interconnectivity Condition Survey is, essentially, a detailed visual examination of all the pipes, cables and associated connections that join system components within the stated area/zones(s). The Interconnectivity Condition Survey differs from a general condition survey in that it focuses on interconnectivity; as such it could form a part of a general condition survey or a condition survey targeting a particular system or systems or a specific zone or zones. Whilst defined as non-intrusive for the purposes of this Paper, a Survey can, in reality, be either non-intrusive or intrusive, the difference being that the latter will require removal of equipment or components for access, or for the inspection of interfaces and is likely to introduce additional time penalties with the requirement to carry out functional checks. Indications of possible defects, damage, divergence from required standards or any other irregularity are generally termed ‘observations’. It then becomes a function of the aircraft maintenance organisation, usually after referring to evidence from suitable documentation or DO advice, to sentence the observations, ie to decide if an observation is a defect or fault and whether it is acceptable. Such sentencing would normally be carried out by the Panel mentioned in 2.4, Sentencing.

A Survey should be organised logically, perhaps by zones or similarly recognisable subdivisions. This approach, whether the survey is of a complete aircraft or single or multiple systems, ensures reliable inspection control while each system is being logically followed through from end-to-end. It may not be possible to follow systems from end to end unless the whole aircraft i.e. every zone is examined. To understand better or verify theoretical Zonal Hazard Analysis, analysis of Survey results can be useful to provide evidence of direct relationships between zones and airworthiness threats. Such evidence can then be used to assist in planning and executing future remedial action.

As a principle, cleaning should not be undertaken prior to a survey. Valuable evidence can be derived from dirt, debris, stains and leaks, which might help to identify areas of risk and possible threat. Cleaning should only occur after examination and after recording has been completed to establish levels of damage. Where it is suspected that dirt or debris might be hiding damage, then local cleaning must be carried out to fully expose the area of concern.

All initial observations, no matter how small, form the keystone of Interconnectivity Conditions Surveys. Not only do they indicate the possible presence of degradation, and evidence of a possible requirement for subsequent intrusive examination, they also provide information that can act as a guide for future surveys, either on the subject aircraft or as part of a future fleet-wide inspection. Significant issues may result from an accumulation of small observations.

If an intrusive examination is specified or required, it should always be carried out after completion of the non-intrusive examination, to allow each layer of evidence to be fully investigated and analysed. Effective control of intrusive examination can be achieved by on-aircraft, zone-by-zone assessment and with careful planning beforehand in order to avoid unnecessary dismantling. Factors that indicate when intrusive examination would be beneficial include:

- evidence from non-intrusive observations, such as deterioration due to environmental exposure, and significant accumulations of dirt or contamination

- hidden interfaces
- ageing aspects
- theoretical analysis has indicated that a zonal or inter-system hazard exists

All observations should be reviewed periodically during the survey by the Head of the Survey Team, with specialist ‘Type’ advice sought when necessary. This process acts as a filter to ensure correct assessment and helps build a balanced picture of the general condition and any specific issues. The review should include planning for any additional or intrusive examination where specified or considered necessary.

Hazards that exist because of interacting factors in more than one zone can be particularly difficult to identify. Zone boundaries are often rather arbitrary and, in many cases, do not provide a physical barrier; for instance for fluids migrating between zones. The survey team should be aware of the possibility of cross-zone hazards and, during survey preparation it is important that any in-Service or theoretical evidence that such hazards may exist should be highlighted to the team.

The extent of some observations is not always possible to determine by visual means alone, and so microscopic examination, NDT or destructive sampling may be necessary. For instance, pitting corrosion can easily be mistaken for surface corrosion, but it may represent a serious threat to airworthiness whose point of failure cannot be reliably determined visually. Material or system component testing may also be appropriate in some cases and it may be necessary to undertake more detailed (e.g. forensic) analysis on components where the damage implications cannot be identified by visual inspection. This may be true for some types of corrosion for instance. There are many different types of corrosion and visual assessment is a very limited method of identifying its implications. For example, widespread surface corrosion may appear serious but be relatively benign. On the other hand, a small 2mm pit may appear inconsequential but have disastrous implications, particularly on a critical component made of high-strength material.

5 SELECTION OF SUBJECT AIRCRAFT

Interconnectivity Condition Surveys ideally require to be carried out on an aircraft that is representatively exposed to the types of threats being investigated. Consideration should be given to the role of the aircraft, particularly if the fleet is divided between benign and damaging operational employment or environments. Other important considerations might include age, number of landings, fatigue index, flying hours, ground-air-ground cycles, modification state, etc.

Interconnectivity Condition Surveys are, in principle, non-destructive, as components are usually replaceable. However, they can be destructive if the subject aircraft is no longer required for service. Individual components may justify destructive sampling if observations representing a potential but unquantifiable safety or airworthiness threat emerge. Recommendations concerning the need and justification for further sampling should be included in the final Survey report.

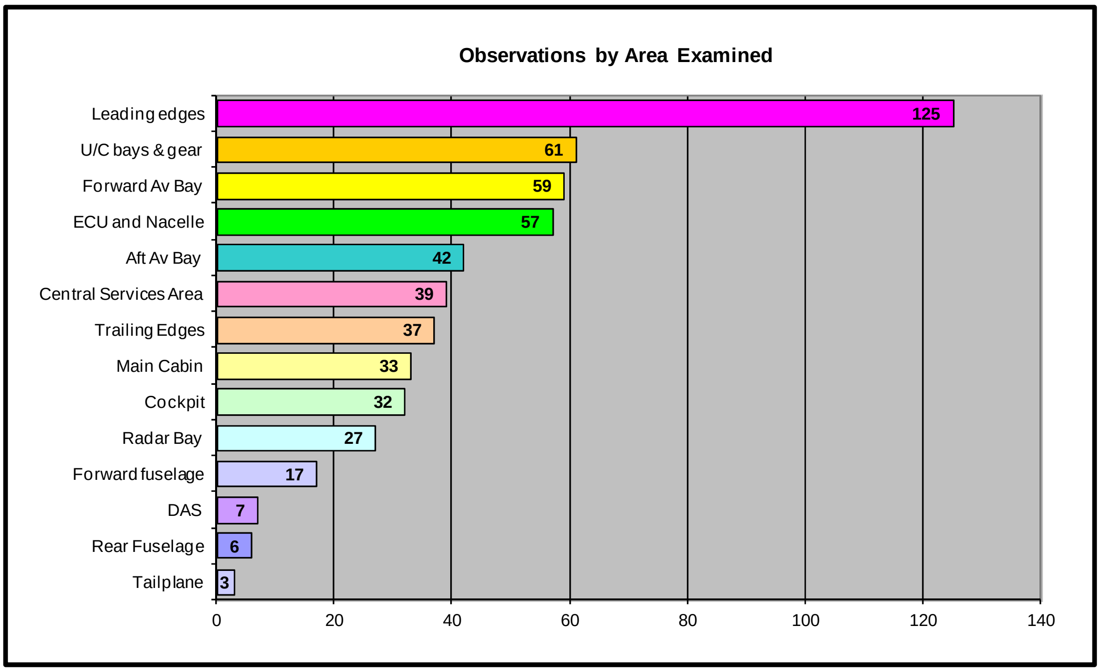
Effects on aircraft operational availability must be considered when the degree of inspection required and the necessary level of access is being decided. Surveys after operational use can be most effective as periods of exposure to dirt, dust or sand, leaks and hard use are likely to highlight initial evidence of wear as well as system contamination threats. Surveying immediately prior to depth maintenance can also be useful for reasons such as improved access and opportunity for defect rectification. Although a survey during depth maintenance may be less viable, it does provide an opportunity for greater access to systems. Carrying out a survey after deep maintenance is likely to result in greater down time, but, in specific circumstances, could be useful in order to audit the efficacy of that maintenance.

6 WORK RECORDING

During the Survey, all observations should be identified by a unique label securely attached to, or adjacent to, the observation, clearly identifying its location and ensuring that evidence is not disturbed. The label should be referenced to a corresponding work sheet, recording observation details, including the system, description of the damage or deviation from standard and any related issues e.g. existence of an inter-system hazard, etc. Strict control of identification labels is essential; not only to ensure that an observation can be followed up at a later time, but also to avoid loose article hazards. All labels should be registered when attached to the aircraft and their removal noted after recovery of the observation/defect. Maintenance Work Orders should be raised to manage and control identification labels.

A spreadsheet should be constructed from the observational work-sheets to permit:

- Observation investigation, review, analysis and any follow-up work;
- Statistical analysis, ie the use of the statistical techniques and charts and graphs compiled during the audit to quantify types and locations of findings so that the distribution of observations between types of interconnect, systems and zones can be investigated to reveal underlying factors and trends. An example is given below:



The volume of data may be large and it is important to focus on relevant information (including that specified within the scoping document) for analysis and future identification of any remedial action to the aircraft and/or its document set. Each observational entry should include details of location and system, as well as other appropriate detail such as photographs, maintenance manual references, relevant inspection reports and analysis details. Positional references, such as fuselage frame numbers, stations, butt lines and wing rib serials can all be useful for specifying the exact location of observations.

Observational records with multiple forms of damage would give greater information if cross-referred between observation categories or perhaps recorded as a matrix, e.g. pipes in contact with evidence of mechanical damage, corrosion and fretting. If 'rationalised' to a single category, e.g. corrosion, then the statistical evidence for mechanical damage and fretting would be lost. Linking observations to zones also gives valuable guidance to zonal threats.

Maximum use of photographic evidence should be used to record observations. Close-up images should be used to show the observation in fine detail whilst wider angle images should be used to situate the observation within a zone and capture any other relevant factors, for instance inter-system hazards or leaks. Care should be taken to ensure that the angle, focus, lighting and resolution of the images are optimal to record the nature of the observation and, where practicable, a scale bar should be used to show the size of the observation.

7 INTERCONNECTIVITY CONDITION SURVEY TEAM

The Interconnectivity Condition Survey requires a suitably qualified and experienced person to act as the Head of the Survey Team to guide the survey, review observations, analyse evidence, formulate conclusions and make recommendations. Team members should also be suitably qualified and experienced and will usually include one or more selected Subject Matter Experts possessing specialist knowledge of the standards to be applied during the survey and/or potential sampling techniques. Such generic breadth of experience within the Team is most useful to ensure adequate systems knowledge and to provide an independent overall view; it also helps to overcome the cultural problem of maintenance engineers insisting 'it's always been like that'. The skills represented by the survey team are, therefore, varied and the selection of 'Suitably Qualified and Experienced Personnel' is essential for its success.

8 INTERCONNECTIVITY CONDITION SURVEY RESULTS

Evidence from the Interconnectivity Condition Survey should be analysed at appropriate stages to form a picture of the general condition of the aircraft and to fully understand any particular zonal or system issues. Specific safety or airworthiness issues that might affect the in-service fleet must be promptly highlighted by the Team to the appropriate Responsible Authority's representative. In any event, it is generally advantageous to report significant issues at the end of each survey day, rather than at the end of the survey. A Sentencing Panel, at which each observation is assessed for its impact on airworthiness, can be an effective way of evaluating levels of risk, considering remedial action and estimating recovery periods. The Sentencing Panel should always include a representative of the Responsible Authority, empowered to make airworthiness decisions. Observations with significant safety and airworthiness impacts may be likely to require further, more detailed assessment to identify whether they pose longer-term threats that could impact safe operation until the planned Out of Service Date.

For an interconnectivity survey to be effective, proper planning of appropriate pre- and post-survey activities is essential and should include consideration of the following types of action:

- recovery of all observations, either by engineering or recording action
- SI(T) action
- monitoring or revision of inspection and maintenance regimes
- component replacement
- sampling
- DO action including modification
- any urgent fleet-wide implications
- the impact of any potential delays

Visual examination relies on the experience of the Condition Survey engineers, and in the event of a significant observation requiring further investigation, it is incumbent on the Survey Team to provide the Responsible Authority’s representatives with all possible advice and guidance to enable them to take the decision to authorise further investigation.

Results will usually be specific to the subject aircraft; however, if more than one aircraft is surveyed, then additional evidence can be gathered to improve understanding of issues that potentially affect the fleet. In every case, for most effective use, the report should be offered to provide guidance, as appropriate, on:

- systems’ interconnectivity condition
- threats to safety and airworthiness
- suggestions for further, more targeted, condition surveys
- potential fleet inspection or inspection of a fleet-representative sample
- advice on current and projected risks
- any possible implications for other platforms
- training implications and continuous improvement opportunities
- necessary changes to maintenance

9 SUMMARY

An Interconnectivity Systems Condition Survey should act as a check on the true state of the interconnectivity on the sample aircraft at that specific time. After surveying a representative number of aircraft, the Responsible Authority is likely to have sufficient evidence to be as sure as is reasonably practicable that the type continues to meet the required airworthiness requirements, or otherwise. As a survey is only a check at that moment in time, the Responsible Authority will usually have to ensure that the necessary actions are taken to maintain the improved interconnect standards which prevail, once observations have been addressed. Recent evidence suggests that there is likely to be an emerging requirement for the PT, in conjunction with the DO, to define within the ADS, an ‘As Required’ state for the aircraft maintainers. There is likely to be a need to increase levels of training and education to ensure that this standard is achieved and maintained fleet-wide.

An Interconnectivity Condition Survey is a most useful tool for determining the ‘as is’ state of an aircraft; however, it is only one tool that is available to maintain the overall airworthiness of an aircraft fleet. Consequently, the results of the survey should be used in conjunction with other airworthiness methods such as active hazard management, a Zonal Hazard Analysis, Safety Case Reports, Repair Assessment Programmes and Ageing Aircraft Audits. Furthermore, it is strongly recommended that survey results are published and shared with other Project Teams and with the MoD’s regulatory and safety bodies, so that any lessons which have been learned can be more widely applied.

10 Recommendations

It is recommended that:

a The recognition that for older types, an 'As Maintained' standard starts to exist, which will gradually diverge over time from the 'As Built' standard due to various forms of degradation.

b PTs are given guidance to the effect that they can use an Interconnectivity Condition Survey as a tool to identify the 'delta' between the 'As Maintained' and 'As Built' standards.

c PTs, with assistance from DOs, be permitted to define an 'As Required' standard, based upon considered judgement and safety analysis. To recover the aircraft from the 'As Maintained' state to the 'As Required' state will involve rectification of the 'delta' identified by the Survey, wherever the Project Engineer deems it prudent.

d A final Interconnectivity Condition Survey report should always contain recommendations about the need and justification for further sampling, including destructive sampling where appropriate.

e The results of future surveys be shared with other PTs and with the MoD's regulatory and safety bodies so that any lessons which have been learned can be more widely applied.

f The MAA and/or SAAG consider the need to undertake further work to more fully define and implement the necessary policy pertaining to Condition Surveys.

REPORT DOCUMENTATION FORM

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2 Report Protective Markings

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3 Title of Report

AIRCRAFT INTERCONNECTIVITY CONDITION SURVEY

4 Title Protective Markings incl. any Caveats UNCLASSIFIED

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13 Abstract (A brief (approximately 150 words) factual summary of the report)

This paper discusses the possible ways in which the condition of aircraft mechanical and electrical interconnectivity (and the effectiveness of their support regimes) can degrade with age, both as a consequence of material degradation and because of a range of human factors. The paper includes methodologies for the conduct, recording and subsequent analysis of interconnectivity condition surveys. The paper suggests that thoroughly and logically conducted surveys of aircraft interconnectivity will provide Responsible Authorities with a much-improved understanding of the extent of deterioration and any increased risks arising from ageing of the systems' interconnectivity. Such an improved understanding and subsequent analysis can lead to improved safety, more effective maintenance policies and reduced cost of ownership.

15 Keywords/Descriptors (Authors may provide terms or short phrases which identify concisely the technical concepts, platforms, systems etc. covered in the report)

Aircraft Systems, Ageing Aircraft, Condition Survey, Aircraft Systems' Interconnectivity