Teardown Inspections – Guidance and best practice MASAAG 105

QINETIQ/FST/TR026557

Cover + vii + 28 pages
December 2002

This document is subject to the release conditions printed on the reverse of this page

Customer Information	
Package Number	05
Package Title	Contol & Denial Theatre Airspace
Package Customer	RD/TA (Mr G Butler)
Package Manager	Mr S. Lamsey
Research Objective	8
Assignment Number	RE804
Milestone Number	n/a
Date Due (dd/mm/yyyy)	n/a

Authorisation

Prepared by		Alison B. Mew, CEng, MRAeS
	Title	Technical Leader – Requirements
	Signature	
	Date	
	Location	Airworthiness & Structural Integrity, Farnborough
Approved by		Dr J. E. Moon. CEng, FRAeS
	Title	Technical Manager – Airworthiness & Structural Integrity
	Signature	
	Date	
Authorised by		Mr P. A. Best
	Title	Project Manager, Airworthiness & Structural Integrity
	Signature	
	Date	
Principal authors		
	Name	Alison B. Mew, CEng, MRAeS
	Appointment	Technical Leader – Requirements
	Location	Airworthiness & Structural Integrity, Farnborough
	Name	
	Appointment	
	Location	
	Location	

Record of changes

Issue	Date	Detail of Changes
1.0	09-Dec-02	First issue

Executive summary

A teardown inspection (often simply referred to as a teardown) is the process whereby airframe structure is progressively dismantled under controlled conditions. At each stage, the structure is inspected, using a variety of examination techniques of increasing resolution. The teardown inspection is usually a destructive process, as the structure is broken down into individual parts, some of which may require further sectioning for detailed analysis.

To do a teardown either of the major fatigue test article, or of an in-service aircraft (preferably high life) is a requirement of structural integrity management policy. However, it is becoming increasingly common to do teardown inspections of both the fatigue test specimen(s) and an ex-service airframe, especially as teardowns of the latter are seen as important to support life extension programmes and the Ageing Aircraft Structural Audit.

The purpose of this report is to provide a comprehensive guide to the teardown inspection process, which is described in detail, including a discussion of the rationale behind the teardown inspection, and an account of best practice, derived from experience of a number of teardown inspections. The report is divided into two sections.

In the first section, the philosophy of the teardown, starting with a definition, is discussed. Other sections cover the purpose of the inspection, likely benefits and how to scope and do an inspection, to achieve the objective.

In the second part of the report, best practice for the conduct of teardown inspections is described. This includes advice on the storage and disassembly of the teardown article, facilities required, reporting and follow-on actions.

List of contents

1 Introduction

1.1 It is now a requirement in Leaflet 315 of AP100A [1][1] for all IPTs to do a teardown inspection, either of the major fatigue test article, or of an in-service airframe (on an opportunity basis) from their fleet. In addition, it is a requirement Def Stan 00-970 Clause 3.2 [2], that the major fatigue test articles are torn down, to check for undetected fatigue damage and to support substantiation that the residual static strength requirement has been met.

1.2 It is becoming increasingly common to do teardown inspections of both the fatigue test specimen(s) and an in-service airframe, especially as teardowns of the latter are seen as important to support life extension programmes and the Ageing Aircraft Structural Audit.

1.3 A number of teardown inspections have been done, both by Design Authorities and by QinetiQ, from which lessons have been learned. It was decided by MASAAG that it would be appropriate to produce a report, with the purpose of promulgating best practice. The intention of the report would also be to provide extensive guidance on the purpose and potential benefits of teardown inspections; the content would complement and extend the guidance currently available in Leaflet 315, Annex B, Appendix 1.

1.4 The report is intended for all “stakeholders” in the teardown inspection process. For Integrated Project Team Leaders, it is to persuade them of the need to do a teardown and to assist them in justifying a teardown programme by improved understanding of the purpose and benefits. For Design Authorities and others, who might do teardown inspections, or be involved in their management, it aims to give independent guidance on how to meet the IPT’s needs and an assessment of best practice, based on the lessons learned from previous teardown inspections.

1.5 The main body of the report is divided into two main sections, the first covering the “philosophy” of the teardown inspection, the second describing “best practice”. In each section, the teardown of fatigue test articles and in-service airframe is generally treated separately, because of the significant differences between the two types of inspection in terms of guiding philosophy, benefit, purpose and interpretation.

1.6 It should be noted that, in general, only structural teardown inspections are considered in this report. However, such an inspection does provide an opportunity to look at other systems within the aircraft, which may also be subject to degradation and be otherwise inaccessible, such as mechanical, electrical, hydraulic or fuel systems.

1 AP100A is soon to be replaced with a corresponding Joint Airworthiness Publication, JAP 100A; a new leaflet mirroring the current Leaflet 315 is being prepared.

PART A – THE PHILOSOPHY OF THE TEARDOWN

2 The teardown inspection

2.1 What is a teardown?

2.1.1 Before embarking on the extensive planning needed to do a teardown inspection, it is first necessary to understand what the process entails, and thus an explanation is given here.

2.1.2 A teardown inspection is the process whereby airframe structure is progressively dismantled under controlled conditions. At each stage, the structure is inspected, using a variety of examination techniques of increasing resolution. The teardown inspection is usually a destructive process, as the structure is broken down into individual parts, some of which may require further sectioning for detailed analysis.

2.1.3 The level of “strip” of the structure should be appropriate to the purpose of the teardown. There are two generic types of teardown inspection: of a fatigue test article, and of an ex-service airframe. Teardown inspections of ex-service airframes, in particular, may vary considerably in depth and scope, depending on the specific purpose of the exercise. Some examples are described in more detail in the following sections, to illustrate particular points.

2.1.4 The inspection techniques to be used as the teardown progresses will vary in complexity, from visual to electron microscopical examination of crack faces and chemical analysis of residues, to standard non-destructive examination techniques such as eddy current and dye penetrant. It is important to use appropriate levels of inspection, and record the findings, at each stage of the disassembly.

2.1.5 This general description of the teardown process is true for both the inspection of fatigue test articles and ex-service airframes. The main difference, in practice, will be that for the ex-service airframe more detailed chemical analyses will be required to determine the nature of corrosion products or the nature of any other residues found during the inspection. These techniques will generally be unnecessary for the inspection of test articles, because these will not have had the same level of environmental exposure.

2.1.6 Where a teardown inspection of an ex-service airframe is being done, it may also provide the opportunity to inspect other aircraft systems, such as mechanical, electrical, hydraulic or fuel systems.

2.2 Timing

2.2.1 Planning for a teardown inspection is a lengthy process and the teardown itself may involve considerable cost. Therefore, it is important to consider carefully when the best value is likely to be obtained from doing such an inspection.

2.2.2 The timing of the fatigue test article teardown should be considered in the light of a number of factors. The main ones include the possibility of the need for additional fatigue cycling, the need for the final clearance to be given (the clearance is restricted to 90% of the test clearance, pending the teardown) and pressure on space at the testing facility. If a teardown inspection of the preliminary (prototype or pre-production) fatigue test article is being considered, the teardown should obviously be completed as soon as possible. This is because it will be necessary to find any fatigue damage as quickly as possible, if any re-design is to be done before finalizing the design for production.

2.2.3 However, with the production fatigue test article, the situation may be a little more complex and will depend on the timing of the fatigue test, how quickly it has progressed and how far ahead of fleet flying the clearance given by the test is. At the planning stage for the fatigue test, provision should be made for long term storage of the fatigue test specimen, so that the teardown can be done. Ideally, the teardown inspection should be done within a reasonable period after the fatigue test is complete, following confirmation (by calculation) that the test has exercised the structure sufficiently to provide adequate clearance.

2.2.4 When electing to do a teardown inspection of an ex-service airframe, the decision is also complex. A teardown inspection represents the investment of considerable resources and so therefore should be timed carefully to obtain maximum benefit. In the recent past, most teardown inspections of ex-service airframes have been done in support of life extension programmes and so have been done when the fleet is relatively mature.

2.2.5 In general, it is considered that there is little to be gained from an early teardown, because there is unlikely to be a suitable airframe available and the value of the airframe will be too great to commit to the destructive teardown process. Also, it is unlikely that there will be significant structural integrity problems (unless the fleet has had a significant change in role from that originally envisaged at the design stage) before at least half of the design life has elapsed. Thus, the value of the teardown inspection in predicting structural integrity problems, that may afflict the fleet in later life, is likely to be limited, if the teardown is done too early.

2.2.6 Therefore, it is from the teardown of an ageing aircraft that most benefit is likely to be gained, in terms of information to support on-going structural integrity activities. However, it should be considered that if the teardown is delayed for too long, there will not be sufficient time to reap these rewards and implement modifications, changes to the maintenance procedures, or whatever, before the aircraft goes out of service, or before the available airframe life is expended.

3 Purpose

It is difficult to define a single purpose for doing a teardown inspection, as the desired outcome will vary, depending on the individual circumstances of the fleet in question. In this section, a number of possible purposes are explained and some examples of teardown inspections, done with specific objectives in mind, are given.

3.1 Fatigue test articles

3.1.1 The purpose of the teardown inspection of a fatigue test article, once the testing has been completed is three-fold: to look for previously undetected fatigue damage, to support the substantiation of the residual strength requirement and to aid the development of in-service inspection regimes.

3.1.2 The teardown of a fatigue test article may also be used to support life extensions, by providing evidence to support continuation via an inspection-based regime.

3.1.3 A recent example of a teardown inspection of a fatigue test article is of the Tucano T Mk1 first full-scale fatigue test airframe. The first fatigue test was done as part of the civil certification of the aircraft. A second fatigue test has been planned to clear the aircraft for RAF usage.

3.1.4 The first full-scale fatigue test was done at the Embraer Test Facility in Brazil, where 24,000 hours of testing were completed. The test duration represented 2 life-times to the design spectrum. Therefore, damage found on the fatigue test article, could reasonably be expected to occur in service, due to the low scatter factor. Indeed, in some instances, this has been found to be the case.

3.1.5 The prime purpose of the teardown inspection was to identify significant damage present at completion of the test. Areas targeted included regions where damage had already been found in the surrounding structure, and “buried” structure behind it was examined to find the source of emergent cracks. The secondary reason was to identify fatigue “hotspots”, which, although not requiring modification, would benefit from close examination during the second fatigue test.

3.1.6 The fatigue test specimen was returned to Short Brothers, Belfast for examination. The areas to be torn down were identified by Shorts, and the teardown was completed in three phases. It was considered to be an extensive inspection, and covered those areas thought to be structurally critical. The examination techniques used included visual (with a magnifying glass, where necessary) and standard non-destructive (dye penetrant and magnetic particle). Some of the findings of fatigue cracking in the first test have led to modifications, introduced fleet-wide. These will be introduced onto the second fatigue test at the appropriate embodiment points, to allow qualification for the fleet.

3.2 Ex-service aircraft

3.2.1 Fatigue tests are carried out under laboratory conditions, so adverse environmental effects are not present. Maintenance schedules are based on an assessment of the likelihood of accidental or environmental damage to structurally significant areas. However, experience has shown that there are always areas of the structure, which are inaccessible or which suffer unanticipated fatigue damage.

3.2.2 Therefore, the overall purpose of the teardown inspection is to gain knowledge of the structural condition of the airframe, especially in structurally significant areas, not normally inspected in detail. This is done by looking for signs of fatigue damage, corrosion, wear, distortion, disbonding, delamination, and for damage to surface finish or protective coatings, and for evidence of moisture ingress. This information can then be used to plan future structural integrity management activities for the fleet.

3.2.3 In part, a teardown inspection of an ex-service aircraft can be used to assess the effectiveness of inspection procedures. If service inspections, whether part of the master maintenance schedule, or not, are applied to the airframe before it is torn down, the results can be compared to those of more detailed inspections done during the teardown. These data can then be used to obtain qualitative probability of detection information. In order to obtain statistically meaningful, quantitative probability of detection data, however, a large number of inspections would have to be done. Although it would be possible to obtain such data, normally within the scope of a teardown there would be insufficient time and other resources available to do an extensive investigation.

3.2.4 In other cases, a directed teardown can be used to support the life extension of a fleet, by providing substantiating evidence for theoretical assessments of the potential to continue in service. An example of a teardown inspection done with this purpose in mind, was part of the VC10 teardown. In the case of the VC10, the fleet has been in service for longer than covered by the original certification testing; it had been agreed, that the best way to ensure continued structural integrity would be to adopt a damage tolerance approach to structural integrity assurance. With a damage tolerance approach, it is important to have a structural inspection regime, related to crack propagation rates and the detectability of such cracks before they reach critical size, but it is also necessary to consider other threats to structural integrity, such as corrosion, accidental damage and past repairs. However, adoption of this philosophy would have required a large number of inspections, which in some cases would have meant the replacement of a large number of bolts in structurally significant areas. Not only would this have increased the maintenance burden to impracticable levels, there would also have been the risk of introducing further damage when preparing the structure for inspection. Furthermore, while it is possible to assess corrosion in open structure, it is difficult to determine the extent of damage in joints without dismantling them.

3.2.5 In some cases, where there is a need to develop and substantiate the effectiveness of an inspection for a particular problem, it may be appropriate to do a specifically directed teardown. In such a case, it would be necessary to inspect, in detail, a number of items. An example of this type of teardown would be one to allow a safe life aircraft component continue in service on a “by inspection” basis, to supplement theoretical crack growth calculations where suitable test evidence was unavailable, and further testing was impractical.

3.2.6 Generally, by the time a teardown inspection of an ex-service airframe is done, there will already have been some structural integrity problems. Thus there will be areas of the structure, where, for example, there is a known susceptibility to corrosion or fatigue damage. If there is knowledge of problems in a particular area, and remedies have already been implemented, there is little point in tearing these areas down, except to confirm the effectiveness of an inspection technique. Thus, one of the main purposes of a teardown inspection is to look in areas of the structure, where problems have not been encountered previously, to find out whether there are incipient threats to structural integrity.

3.2.7 Allied to searching for incipient structural problems, is a need to inspect areas that are not normally accessible and to assess the accessibility of parts of the structure that may require inspection in the future. For smaller (combat) aircraft in particular, there are many areas of the structure that cannot be reached easily during routine maintenance. A teardown inspection provides the opportunity to remove wing and control surface skins, fuselage panels, and dismantle critical joints to a greater extent than normally possible.

3.2.8 Evidence from teardown inspections may also be used to support ageing aircraft structural audits and life extension programmes. An example of this type of teardown, is that of the Jaguar. It is necessary to extend the life of the Jaguar from 6000 to 7500 flying hours and therefore a life extension programme is in progress. In order to gain confidence in the structural integrity of the airframe, especially in areas where there had been no known problems, it was decided to do a directed teardown inspection as part of the ageing aircraft audit. Some of the Jaguar fleet have experienced stress corrosion cracking in one of the major structural frames, and therefore a number of retired airframes were available for selection as the teardown article.

3.2.9 A high life airframe was selected from those available; although not the fleet leader, at the time that the airframe was chosen, its age was representative of a large number of the fleet. It had accumulated approximately 4500 flying hours, out of a design life of 6000. The Jaguar mainplane is lifed in FI (fatigue index); the article chosen for teardown inspection had reached its cleared FI limit. Both articles were of sufficient age to obtain meaningful results in terms of likely future structural problems.

3.2.10 Since the purpose of the teardown was to support the Ageing Aircraft Audit, the inspection was carefully directed. The objectives were to look at inaccessible areas, not subject to inspection during scheduled servicing, and areas that had previously been repaired and might be subject to the interaction of adjacent repairs. Samples from structurally significant areas of the front, centre and aft fuselage were taken.

4 Benefits

4.1 Test articles

4.1.1 It is a requirement of Clause 3.2 of Def Stan 00-970 [2], that the test life used for the substantiation of any components, that have not failed during the course of the fatigue test, must be limited to 90% of the life demonstrated on test. This limitation is applied to account for the uncertainty that there may be significant undetected fatigue damage present, which would cause the airframe to fail the residual strength criterion. Therefore, an immediate benefit of the teardown inspection is to allow the full test cleared life to be declared, once the residual strength analysis it supports has been completed.

4.1.2 In some cases, the teardown inspection of a fatigue test article can also be used to provide evidence to support a life extension. This will usually be in circumstances where fatigue damage has been detected and evidence of slow crack growth can be obtained. In conjunction with residual strength analysis, crack growth data may be used to support a damage tolerance approach.

4.1.3 Information gained from the teardown of the Tucano fatigue test led to the extension of some the modifications planned as a result of damage found during normal inspection of the first major fatigue test article. In many cases, the teardown revealed that the fatigue cracking was more widespread than had been thought from inspections done during the test. Most of these findings applied to the centre section of the fuselage and wing. A number of possible interventions were also obviated by analysis of the teardown findings, where damages could be identified as “test artefacts”.

4.2 Ex-service aircraft

4.2.1 In general, the benefits of any teardown inspection are very difficult to quantify directly in monetary terms. Indeed, teardown may lead to additional cost, for follow-up action. However, it is not usually possible to put a value on structural integrity assurance, or a cost on the failure to do so. Therefore, instead of a cost appraisal, it is necessary to assess the benefits of teardown in structural engineering terms.

4.2.2 One of the benefits of teardown, can be on fleet availability. By doing the inspection, an early indication of incipient structural problems is obtained. This gives time to implement fixes (repair or modification action) or inspections, that can be scheduled in, in a timely manner. In this way, the impact on fleet availability is minimized and the need to continue flying with known structural integrity risks, without appropriate mitigation, is obviated.

4.2.3 In the case of the VC-10 teardown inspection, whose purpose is described in Section 3, the major benefit of the teardown has been to reduce the number of inspections required. Also, this teardown is perhaps the exception to the notion that it is not possible to quantify the benefits financially. In this case, the cost of the teardown could be balanced against the cost of the inspections that would otherwise have been necessary to ensure structural integrity. In addition, since it was possible to reduce the inspection regime because of the teardown results, the potential availability of the fleet was increased over what it would have been otherwise.

4.2.4 However, the VC-10 teardown is perhaps somewhat unusual, because a significant number of samples were available from retired airframes for inspection. Therefore, it was possible to obtain sufficient supporting evidence to support the reduction in in-service inspections, and the number of inspections that would have been required without this evidence was already known.

5 Obtaining the evidence

This section describes the means of choosing a teardown article and what sources of complementary or alternative evidence are available, thus it is only relevant to the teardown inspection of an ex-service aircraft.

5.1 Alternative and complementary sources of evidence

5.1.1 In addition to the requirement to do a teardown inspection, AP100A-01 also contains a requirement for structural sampling. This can be either done by opportunity sampling, or directed sampling, which are described in outline below. For reasons given at the end of this section, however, such sampling is not a substitute for a teardown inspection, but rather is a valuable adjunct to it.

5.1.2 Provision for directed sampling can be made through the Topic 5V. In most cases, directed sampling will only allow the inspection of structurally significant items, which are readily accessible during major maintenance. Available inspection techniques will be limited to visual inspection and possibly some NDT methods; only the exposed surface of the structure will be inspectable, unless access can be gained through lightening holes, for example.

5.1.3 Opportunity sampling can be done in a number of ways: inspection of a damaged airframe, examination during repair, or taking advantage of the greater degree of disassembly during a modification or refurbishment programme. Indeed, it is through opportunity sampling that many structural problems have been discovered.

5.1.4 Inspection of a damaged airframe can include destructive teardown, if the aircraft is not to be repaired and returned to service. Although inspection of an airframe in this category can provide valuable evidence, it is of course heavily dependent on the level of damage present. It should be taken into account that interpretation of the results, and read-across to the remainder of the fleet, may be difficult in these circumstances.

5.1.5 Repair, modification and refurbishment activities can all provide excellent opportunities for structural sampling, especially where the level of disassembly is significantly higher than normal maintenance. For example, the refurbishment of a tailplane, where the skins are removed, will provide an ideal chance to examine the internal structure non-destructively.

5.1.6 The examples given above (with exception of the examination of a damaged airframe), are a valuable aid to structural integrity assurance, but don't offer the same benefits as a full teardown inspection. This is because in general, it is not possible to remove the defective structure for failure investigation, without destructive teardown. On the other hand, if these inspections show indications of incipient structural problems, they could provide a good trigger for a limited teardown of a particular area. An important factor in making such structural sampling effective, is to implement it quickly and efficiently, through the structural integrity management procedures at the disposal of the aircraft support authority within the IPTs.

5.2 Choice of teardown article

5.2.1 Obviously, the choice of teardown article will be limited to what can be spared, however, if more than one potential candidate has been identified, the following guidelines may help to inform the selection. Wherever possible, the teardown article should be as high a life airframe as possible. It should also be as representative as possible, in terms of build standard and modification state, of the remainder of the fleet, or the part of the fleet that is of interest.

5.2.2 In order to facilitate read-across to other aircraft in the fleet, it is necessary to have as much information as possible about the candidate airframe. This will include its life in all appropriate metrics (flying hours, Fatigue Index, landings, pressurisations, etc.). Information on the embodiment point of modifications will also be needed, where applicable.

5.2.3 Depending on the purpose of the teardown inspection, it may not be appropriate to use calendar life or flying hours as the metric for selecting the teardown article, but it would be better to consider other lifeing parameters such as Fatigue Index, pressurisation cycles or landings. For example, it may be more appropriate to choose an aircraft with a high number of landings, if it is the undercarriage back-up structure that is of particular interest.

6 Targeting and scope of the teardown

6.1 Fatigue test articles

6.1.1 For the teardown of fatigue test articles, the scope is straightforward to define. In order to meet the requirements of Def Stan 00-970, the major load paths and primary structure should be the principal targets of the inspection.

6.1.2 Particular attention should be paid to fastener holes, changes of section and cut outs. Structure loaded in compression should be included.

6.1.3 Attention should also be given to areas of the structure where there has already been cracking during the fatigue test, or to modifications made to the fatigue test article, particularly where these are to be applied to service aircraft.

6.2 Ex-service aircraft

6.2.1 As discussed in Section 3, there are a number of possible reasons for doing a teardown inspection of an ex-service aircraft. The particular purpose, therefore, will naturally have an effect on the targeting and scope of the inspection done.

6.2.2 In addition, due to the cost and planning associated with a teardown, most inspections will of necessity be limited to specific areas, to get best value from them. These areas will be selected on the basis of Design Authority and independent advice, and should be related to the structural integrity needs of the fleet.

6.2.3 Areas may be chosen because they are not covered in depth by routine maintenance inspections, are not accessible or to look for incipient problems. For example, the underlying purpose of the Jaguar teardown was to support the Ageing Aircraft Audit and the life extension programme, and so information on the general condition of critical areas of the structure was being sought. However, areas, which had in the past had structural integrity problems, such as one of the major fuselage frames incorporating the main undercarriage attachment lugs, were specifically excluded from the investigation, because it was judged that no significant benefit would be gained. The Jaguar teardown inspection was therefore directed to inaccessible areas and areas where repairs had been done, in order to see if there were any undiscovered problems, particularly corrosion, or fatigue damage.

6.2.4 In other cases, the teardown can be directed towards obtaining additional information to support study of known problems. A particular example of this, was the teardown inspection of the wing root joint of the VC10. The damage tolerance assessment of this joint, which consists of two rows of steel taper bolts either side of the skin bolt, required that all 688 bolts per aircraft be removed, so that the hole bores could be inspected. Obviously, this represented a considerable maintenance burden, required a large number of non-standard replacement bolts, would be a risk to fuel tank sealing and posed a potential of accidental damage while removing the bolts. Furthermore, the damage tolerance assessment had shown that all of the aircraft were already beyond the inspection threshold. In order to mitigate this potential problem, it was decided to do a directed teardown of the wing root joint, concentrating on 15 samples from 3 aircraft (6 joints), with a complementary analysis of the individual aircraft's fatigue histories. Evidence from these activities would allow a correction factor to be derived, which could be applied to the calculated inspection threshold. This would provide a means of increasing the inspection threshold. Eventually evidence from the teardown also produced a means of reducing the inspection burden further: it was proposed that the overall condition of the joint could be assessed on the basis of the corrosion levels found on a smaller sample of bolts removed from the joints.

7 Management

7.1 The IPT is obviously the prime motivating force in initiating the teardown inspection activity. In accordance with structural integrity policy, the decision to do the teardown should be endorsed and guided by the SIWG. After the teardown is complete, the SIWG should also endorse the recommendations arising from the inspection, in terms of further actions to be taken, where appropriate.

7.2 However, in order to ensure success, Design Authority involvement is essential, even if they are not the agency, who ultimately does the inspection itself. This is because they have at their disposal the necessary drawings, structural knowledge and expertise to specify the areas to be inspected and guide the process. In addition, the Design Authority should be responsible for interpreting the results, in terms of implications for the fleet.

7.3 In some cases, it may be desirable for an expert third party to do the teardown inspection itself, working to instructions typically prepared by the DA. This may be due to availability of suitable resources, expertise and facilities, and/or the time-scales required, as individual circumstances dictate. In such circumstances, it is essential to establish a good working relationship between the third party and the DA. This is not only important for the overall management of the inspection, but also for the exchange of day to day information. It is recommended that points of contact be established between the parties involved, to ensure continuity and focus. Further guidance on the competencies required of the teardown team is given in Section 8.6.

7.4 As with all structural integrity matters, the IPT should be supported by independent structures advice.

PART B – BEST PRACTICE FOR TEARDOWN INSPECTIONS

8 The conduct of a teardown inspection

8.1 Introduction

8.1.1 Having decided to do a teardown inspection, there are a number of factors that will have to be taken into account, to ensure that the teardown is done in such a way as to gain maximum benefit.

8.1.2 The planning and execution of a teardown inspection is a complex process. It therefore requires good organisation to succeed.

8.1.3 The purpose of this section is to give an outline of some of the procedures to be followed for a successful teardown. In the subsequent sections in Part B, more details of these procedures are given, with specific guidance and examples of best practice, where appropriate.

8.2 Directing the teardown

8.2.1 The decision to do a teardown inspection should normally be endorsed by the Structural Integrity Working Group.

8.2.2 For routine matters, it is recommended that a teardown working group is established. The activities of this group will fall broadly into two categories: management of the project and technical discussions. The project management activity will monitor progress of the inspection, while technical discussions will be necessary to discuss the disassembly procedure and review findings. It is important to establish clear lines of contact for both these activities, both within the organisations involved and between them. It is recommended that this group meet fairly regularly, at intervals partly determined by the anticipated duration of the inspection, to ensure good progress.

8.2.3 The technical specialists should also be responsible for deciding how the specimen is to be disassembled. This will include establishing “cut lines”, that is, where to section the parts of the airframe to be disassembled, so as to cause minimal damage to the areas of interest. It is strongly recommended that representatives of the DA are present when the cut lines are marked out on the specimen. In addition, advice from the DA may be useful in deciding the best order for doing the disassembly.

8.2.4 Although the deliverable will normally be a final report (see Section8.4), it is beneficial, if any defects discovered during the inspection are brought to the attention of the DA as soon as possible. In this way, the possible fleet implications of any finding can be assessed and any necessary remedial action can be taken as quickly as possible.

8.3 Establish purpose and scope

8.3.1 The need to do a teardown is partly driven by structural integrity management policy, but the inspection should not be seen as simply a means to fulfil this requirement. Therefore, the purpose and scope of the teardown inspection will normally be recommended by the Design Authority, following discussions with independent structures specialists and the IPT.

8.3.2 The guidelines given in the first Part of this report can assist in determining what should be inspected, but the individual circumstances of the fleet should also be taken into account.

8.4 Statement of work

8.4.1 When doing a teardown inspection, it is important to have clear instructions from which to work. These will often be derived from a statement of work, produced by the aircraft DA. The statement of work should define out, clearly and concisely, the purpose and scope of the teardown. This is necessary, whether the teardown inspection is being tasked internally within the DA, or it is being contracted to a third party. Not only does the Statement of Work give the definitive set of instructions for the teardown inspection, it also gives the team doing the inspection the means to estimate the amount of effort involved.

8.4.2 The Statement of Work should state the programme deliverables. Normally, the final deliverable will be a report, describing the general condition of the specimen, the general appearance of each of the prescribed samples as they are removed, and the results of examination of the samples, at each level of detail.

8.4.3 It will be beneficial, if the form in which the report is to be produced, is laid down in the Statement of Work, and agreed to by the parties involved. This may include the specification of particular pro formas to be used for NDT examination reports. It should be stated what level of NDT examination is required prior to sectioning and disassembly of the specimen, as well as post disassembly.

8.4.4 The Statement of Work should detail the samples to be removed from the specimen. Clear illustrations are essential here. Cut lines should be specified using a co-ordinates system. It is also essential that a convention of identifying the samples is laid down and adhered to by all parties involved. This should include a system for numbering fasteners and their associated holes.

8.5 Obtaining the article

8.5.1 When an airframe has been designated as the teardown article, arrangements need to be made by the IPT to grant permission to the agency doing the teardown, in effect, to destroy the aircraft. A document, recording that this permission has been granted by the IPT should be issued to the teardown agency. This document should also include an inventory of what is actually being supplied, as the IPT will usually wish to recover as much as possible from the airframe, for re-use.

8.5.2 Normally, it will be easiest for the IPT to arrange shipping of the teardown article to the facility.

8.6 Competency requirements

8.6.1 In order to do a teardown inspection the assembled team needs to have the required mix of skills. Throughout the inspection, trained NDT staff will be required. At the disassembly stage, it is beneficial to be able to use staff with aircraft maintenance and repair experience, because they will have an understanding of how aircraft are constructed and dismantled.

8.6.2 For the detailed examination of the samples, staff with expertise and experience of a wide variety of failure investigation techniques are required. The services of a laboratory offering comprehensive metallographical examination facilities, including electron microscopy, will be required, along with techniques to identify residues and corrosion products, such as chemical analysis and spectroscopy. It is beneficial, if these capabilities are in an integrated suite, so that data may be shared efficiently among members of the teardown team.

8.7 Background information

8.7.1 As much information as possible on the teardown article will be required, whether it be of a test article or an ex-service aircraft. This will not only be necessary to assist in planning the teardown, but also in the interpretation of the result. The following is a list of the documents that will typically be required: drawings, history of the article (in the case of a fatigue test article, the spectrum applied and test duration; in the case of an ex-service aircraft, all available lifeing information, in terms of all relevant parameters), modification state (including modification embodiment points), concessions, repairs, STIs and SIs, inspection techniques used, etc. It will also be helpful to know how the candidate airframe has been stored and how long for.

9 Preparing the teardown article

9.1 A number of things need to be done, to prepare the teardown article. In the case of a fatigue test article, there will not be a great deal to do, since the test article will not usually be fitted with, for example, hydraulic systems, and only the test fixtures will need careful removal. In the case of an ex-service aircraft, however, there is a greater number of systems that should be removed, either because they can be recovered for re-use, or for safety reasons. For example, it will be necessary to remove all armament systems, including the ejection seat and miniature detonating cord, or other canopy jettison mechanism, if present. . Fuel systems may also present a safety hazard. Other systems should be removed, wherever possible It is recommended that this be done, before the airframe is supplied to the teardown facility. Documentation, describing the state of the airframe should accompany the airframe (see also Section 8.5).

9.2 The teardown facility should be equipped with suitable jigs, supports, trestles and the like, to support the test article during disassembly. If the teardown is not to commence immediately, arrangements should be made to store the article in appropriate conditions, preferably in a controlled environment (such as a dry, heated hangar). This is to limit corrosion and other environmental damage, which may hinder interpretation of the results of the inspection.

9.3 When preparing for disassembly, a safety assessment should be done, taking account of any hazardous materials that might be present: these may include residues of fuel, hydraulic fluid, for example. On older aircraft, such materials might include asbestos. Suitable arrangements for safe lifting and movement of aircraft components should also be made.

9.4 Before starting the teardown proper, it will be necessary to inspect the article and record its general condition, noting in particular any superficial external damage (ex-service as well as possible transit damage), evidence of fuel, oil or hydraulic leaks, and evidence of environmental damage. It is recommended that photographs be taken to accompany the report.

9.5 Prior to disassembly it may also be necessary to repeat in-service inspections, either those done during routine maintenance, Special Inspections or Special Technical Instructions. This is recommended, because not only can the results provide an independent confirmation of the results of service inspections, it can also provide data to support a qualitative probability of detection assessment, when the structure is re-examined, during the disassembly.

10 Disassembly of the teardown article

10.1 Normally, in addition to disassembling the airframe at major transport joints, the airframe will have to be cut into samples. Cut lines should be specified in the Statement of Work and it is strongly recommended that the location of these be verified, in the presence of representatives from the DA, on the actual teardown article. This is to prevent damage to significant structure.

10.2 Photographs should be taken at every stage of disassembly. Attention should be paid to recording the state of the sample at each stage, with particular attention to evidence of cracking, corrosion, distortion and missing or loose fasteners.

10.3 It is important to arrange for correct storage of the teardown article, not only before the teardown, but also during and after it. Arrangements also need to be made for disposal of any scrap portion. It is recommended that provision be made to store the samples for a minimum of 5 years following completion of the teardown, preferably for longer. Permission from the IPT will usually be necessary, before any remains can be disposed of as scrap. It is frequently the case that further investigations need to be done, and therefore any samples should be kept as evidence. For example, in the case of a Jaguar wing fatigue test specimens, further investigations were required over 15 years after completion of the test; fortunately, the specimen was still available, to support theoretical fracture mechanics calculations.

10.4 The teardown specimen should be protected from environmental degradation, if possible, since corrosion during storage might mask in-service or on-test damage and make interpretation of the teardown results difficult.

10.5 It should be noted that many protective coatings will be difficult to remove, often requiring repeated applications of paint remover, for example; thick layers of paint and sealant will also be time-consuming to remove, whilst taking sufficient care not to damage of structural degradation, like fatigue cracking, that might be present. It may be necessary to consider other techniques for sealant removal, such as high pressure water stripping, which may require investment in appropriate equipment. Special tools may be needed to remove fasteners, particularly ones of a non-standard type; such tools may be difficult to obtain within a reasonable time-scale. These factors will need to be taken into account, when estimating the effort needed to complete the teardown inspection.

10.6 During disassembly, each portion of structured required for examination should be labelled carefully, to allow specimens to be traced to their exact location, including their orientation with respect to the remainder of the structure. Where a hole and fastener numbering scheme has been stipulated in the Statement of Work, this should be adhered to strictly; if a scheme has not been, it is strongly recommended that one is devised, so that samples can be tracked. Consideration should be given to using a shared database, to record findings, so that they can be identified uniquely. Use of such a database will also enable different members of the team, working on each specimen, to record and share their findings.

10.7 If systems other than structure are being considered during teardown inspection, appropriate arrangements for their removal should be stipulated in the Statement of Work.

11 Sample examination

11.1 A wide variety of techniques will need to be applied, to complete the teardown examination, particularly for ex-service aircraft, where analysis to identify corrosion products, and other residues, will be needed, in addition to the normal NDT and metallographic techniques.

11.2 Therefore, the services of experienced staff, at a suitably equipped facility, will be required to examine the samples taken from the teardown article, and to investigate the cause of any faults found.

12 Reporting

12.1 The main deliverable from the teardown examination will be a report. Often, the format for this report, and the information to be included will have been specified in the Statement of Work. Reporting will normally need to be done in two parts: a detailed report of the findings of the teardown examination itself, describing the condition of the structure from the as-received airframe, down to the individual sample level; and a second summary report, providing an assessment of the fleet implications of the investigation and recommendations for remedial action where necessary. In some cases, individual failure investigation reports will be requested in addition to the main teardown report.

12.2 The results of the examination should be supported by photographic evidence. It is useful, when providing photographs, to include evidence at various stages of disassembly, from the sample level downwards. Where small sections have been removed from larger samples, their location should be indicated on a photograph of the larger sample, for instance. This helps to keep the location of any defects found in their correct structural context. For the same reason, the orientation and position of the samples relative to the airframe should also be indicated on the photo (for example, forward and aft, port and starboard should be shown), as well as some sort of indication of sample size. This can be done, by including an appropriate scale.

12.3 While the need to photograph the whole teardown process comprehensively cannot be over-emphasised, it is also important to label and catalogue the photographs meticulously. A high quality camera and an appropriate database are useful here. Digital cameras are extremely useful for the recording of all stages of the process, because of their speed and ease of use. It is possible to become overwhelmed with data, however and image storage and retrieval could become a problem.

13 Interpretation

13.1 As has been discussed in the previous section, reporting of the teardown inspection results will normally take place in two stages: a detailed report of the teardown itself, followed by an assessment of the fleet-wide implications of the findings. This second report should be done by the DA, because they have the necessary experience of the aircraft and any in-service arisings.

13.2 Where the DA concludes, in their assessment, that there are possible fleet-wide threats to structural integrity, recommendations for follow-up action should be made. Where appropriate, the IPT should record these threats, at an appropriate hazard level, in the project hazard log.

13.3 The recommendations should also be presented to the SIWG for discussion. The SIWG should then endorse appropriate follow-up action.

14 Conclusions

14.1 Due to the varied nature of teardown inspections, it is not possible to give definitive advice that will be universally applicable. However, this report incorporates an account of best practice, derived from a number of teardown inspections done by aircraft DAs and by QinetiQ.

15 Recommendations

15.1 It is recommended that this report is used as guidance for any IPT and DA considering a teardown inspection, in addition to independent expert advice.

16 Acknowledgements

The contribution of members of MASAAG and of QinetiQ's Airworthiness and Structural Integrity Group to this report, is gratefully acknowledged.

17 References

1. AP 100A-01, Leaflet 315, *‘Structural Integrity of RAF Aircraft”*, AL271, September 1998.
2. Ministry of Defence. *Design and Airworthiness Requirements for Service Aircraft. Part 1 Combat Aircraft.* Defence Standard 00-970, Issue 2, 1 December 1999.

Distribution list

MoD

Mr G Butler, RD/TA

Mr D. Barker, ALTG-ADRP2

Wg Cdr R. Eckersley, SSG ASI, RAF Wyton

Lt Cdr C Robertson RN, ADAS Air Technology 2

Mr J. T. Cansdale, Dstl

Mr R. P. Bull, Dstl

QinetiQ

Dr J. E. Moon, Technical Manager, Airworthiness and Structural Integrity, Chairman

Mr R. Cansdale, Airworthiness and Structural Integrity

Mr P. Cross, Airworthiness and Structural Integrity

Mr M. Duffield, Airworthiness and Structural Integrity

Mrs D. Holford, Senior Fellow Loads Data

Mr D. Jones, Airworthiness and Structural Integrity

Eur Ing Dr R. T. Jones, Technology Chief, Airframe Structural Integrity

Mr A. J. Mountfort, Airworthiness and Structural Integrity

Mr B. H. Perrett, Airworthiness and Structural Integrity

Sqn Ldr S. Reed, Airworthiness and Structural Integrity

Mr D. Taylor, Airworthiness and Structural Integrity

Mr G. K. Terry, Airworthiness and Structural Integrity

Mrs A. Mew (author) 5 copies

External

Prof J. Bristow, Head Structures and Materials Department, CAA Safety Regulation Group

Mr C. Hoyle, Engineering Team Leader, Structural Integrity TTRO

Mr D. Patterson, Chief Stress and Weights Engineer, Short Brothers

Mr P. Gates, Chief Structures Engineer, BAE SYSTEMS, Farnborough

Mr M. Overd, Head of Structures and Materials, Westland Helicopters

Mr G. Redgrave, Chief Structural Engineer, Marshall Aerospace

Report documentation page

1. Originator's report number:	QINETIQ/FST/TR026557
2. Originator's Name and Location:	Alison B. Mew, QinetiQ, Cody Technology Park, Room 2008, Griffith Building A7, Ively Road, Farnborough, GU14 0LX
3. MOD Contract number and period covered:	A/CTA/N02509; 01/04/2002 to 28/02/2005
4. MOD Sponsor's Name and Location:	Mr G. Butler, RD TA; Room G020, A2 Bdg, Cody Technology Park, Ively Road, Farnborough, GU14 0LX
5. Report Classification and Caveats in use: Unclassified	6. Date written: December 2002 — Pagination: vii + 28 — References: 2
7a. Report Title:	Teardown Inspections – Guidance and best practice
7b. Translation / Conference details (if translation give foreign title / if part of conference then give conference particulars): Not applicable	
7c. Title classification:	uc
8. Authors:	Alison B. Mew, CEng, MRAeS
9. Descriptors / Key words:	STRUCTURAL INTEGRITY, AIRFRAME, TEARDOWN INSPECTION

10a. Abstract. (An abstract should aim to give an informative and concise summary of the report in up to 300 words).

A teardown inspection is the process whereby airframe structure is progressively dismantled under controlled conditions. At each stage, the structure is inspected, using a variety of examination techniques of increasing resolution. The teardown inspection is usually a destructive process, as the structure is broken down into individual parts, some of which may require further sectioning for detailed analysis. It is structural integrity management policy, that a teardown of either the major fatigue test article, or an in-service aircraft, is done. Frequently, both are now done.

The report is intended for all "stakeholders" in the teardown inspection process. For Integrated Project Team Leaders, it is to persuade them of the need to do a teardown and to assist them in justifying a teardown programme by improved understanding of the purpose and benefits. For Design Authorities and others, who might do teardown inspections, or be involved in their management, it aims to give independent guidance on how to meet the IPT's needs and an assessment of best practice, based on the lessons learned from previous teardown inspections.

10b. Abstract classification:	FORM MEETS DRIC 1000 ISSUE 5

This page is intentionally blank