U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: Fatigue Management Programs for In-Service Issues

Date: 8/23/11 **AC No:** 91-82A

Initiated by: ACE-100

1. Purpose.

a. This advisory circular (AC) provides guidance on developing and implementing a Fatigue Management Program (FMP) to address in-service issues for metallic fatigue critical structure. An applicant may develop an FMP as one method to address an unsafe condition when the Federal Aviation Administration (FAA) determines an airplane type design has a demonstrated risk of catastrophic failure due to fatigue. In such cases, the FMP should incorporate damage-tolerance based inspections or a part replacement/modification program to mitigate the demonstrated risk. The FMP should also incorporate other fatigue critical structure inspections to address the broader risk posed by potential cracking of these structures in the airplane. The FAA will mandate the FMP by Airworthiness Directive (AD). The FAA may also approve the FMP as an alternative method of compliance (AMOC) to an AD.

b. This AC includes guidance relevant to developing FMPs for other purposes such as life extensions, type certification requirements, or non-mandatory maintenance programs. This guidance supplements other ACs that contain guidance for developing damage-tolerance based inspection programs to look proactively for potential cracks. Such guidance includes AC 91-56B, Continuing Structural Integrity Program for Airplanes, AC 25.571-1D, Damage Tolerance and Fatigue Evaluation of Structure, and AC 23-13A, Fatigue, Fail-Safe, and Damage-Tolerance Evaluation of Metallic Structure for Normal, Utility, Acrobatic, and Commuter Category Airplanes. Applicants should use product specific guidance in conjunction with this AC.

c. This AC is not mandatory and does not constitute a regulation. It describes an acceptable means, but not the only means, for maintaining the continued operational safety for airplane type designs that have a demonstrated risk. In this AC, the FAA uses terms such as "must" or "require" only in the sense of ensuring applicability of a particular method of compliance when using a specific acceptable method of compliance described herein.

2. Applicability.

a. This AC is applicable to:

- Small airplanes certificated under part 23 or predecessor regulations,
- Transport category airplanes certificated to part 25 or predecessor regulations, and

- Airplanes certificated in the primary and restricted categories.

b. The following may use this AC to develop FMPs:

- DAHs,
- Applicants for STCs,
- Applicants for AMOC to ADs,
- Applicants for PMA,
- FAA aircraft certification engineers, and

3. FAA Designated Engineering Representatives (DER) or delegated organizations.

4. Cancellation. This AC cancels AC 91-82, Fatigue Management Programs for Airplanes with Demonstrated Risk of Catastrophic Failure Due to Fatigue, dated April 29, 2008.

5. Related Regulations. Refer to the following Title 14 of the Code of Federal Regulations (14 CFR) sections, as applicable.

a. Design approval holder responsibilities for reporting of failures, malfunctions and defects included in part 21, § 21.3.

b. Certification procedures for instructions for continued airworthiness (ICA) and airworthiness limitations included in part 21, § 21.50.

c. Certification procedures for changes to type designs included in part 21, § 21.93.

d. Requirements for Supplemental Type Certificates (STC) included in part 21, § 21.113.

e. Small airplane requirements for strength and deformation included in part 23, § 23.305.

f. Small airplane requirements for fatigue, fail-safe, and damage-tolerance evaluations included in part 23, §§ 23.571, 23.572, 23.573, 23.574, and 23.627.

g. Small airplane requirements for inspections and ICAs included in part 23, §§ 23.575, 23.611, and 23.1529.

h. Transport category airplane requirements for strength and deformation included in part 25, § 25.305.

i. Transport category airplane requirements for fatigue and damage-tolerance evaluations included in part 25, § 25.571.

j. Transport category airplane requirements for inspections and ICAs included in part 25, §§ 25.611 and 25.1529.

k. AD requirements included in part 39.

6. Definitions. The following definitions apply for this AC:

a. Accident. An occurrence associated with the operation of an aircraft, which takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.

b. Applicant. An applicant is any interested party who is developing a fatigue management program.

c. Damage-Tolerance Based Inspection. An inspection based on consideration of the crack growth and residual strength characteristics of the structure, the physical access to the structure, and the inspection method reliability. The inspection should provide a high probability of detecting fatigue damage before the residual strength degrades below a specified value.

d. Demonstrated Risk.

(1) An airplane type design has a "demonstrated risk" when an unsafe condition due to fatigue exists in that type design and the condition is likely to exist or develop in other airplanes of the same or similar type design. The FAA will determine the necessary action to address a fatigue cracking scenario using the corrective action review board process in accordance with FAA Order 8110.107.

(2) Situations that could precipitate a risk analysis may include:

- An airplane has experienced a catastrophic failure due to fatigue and the same scenario is likely to occur on other airplanes in the fleet,

- Airplanes of the type design have a service history that indicates a significant likelihood of catastrophic failure due to fatigue in the fleet,

- Fatigue testing of the type design indicates a significant likelihood of catastrophic failure due to fatigue in the fleet, or

- The type design has a structural area sufficiently similar to another type design's structural area determined to present a demonstrated risk.

e. Design Approval Holder (DAH). For the purposes of this AC, a holder of a type certificate (TC), STC, or Part Manufacturing Approval (PMA) issued under part 21.

f. Fatigue Critical Structure. For purposes of this AC, structure that is susceptible to fatigue cracking that could contribute to catastrophic failure of an airplane if there is no intervention. This would typically include all structure critical to carrying flight, ground or pressurization loads that are subjected to tension dominated repeated loads during operation.

Examples of fatigue critical structures include, but are not limited to:

- The fuselage pressure shell consisting of all skin panels, stringers, frames and pressure bulkheads including skins and stiffening members;
- The lower wing cover consisting of all skin panels, stringers and lower spar caps; and
- The horizontal stabilizer upper cover consisting of all skin panels, stringers, and upper spar caps.

(1) For airplanes designed to high negative g loads (such as acrobatic category), joints, splices and maximum compression bending moment locations on the wing and horizontal tails may also be fatigue critical.

(2) For some designs, the loss of control surface and flap hinge fittings, including their attach structure, may be catastrophic under certain conditions. Unless documentation exists to show these areas are not critical to safe flight, they should be considered fatigue critical structure if they are subject to tension dominated repeated loads during operation. (Documentation such as that normally provided at time of certification may be sufficient.)

g. Fatigue Management Program (FMP). An FMP is a set of maintenance actions whose purpose is to prevent catastrophic failure due to fatigue. The maintenance actions may include fatigue critical structure inspection, modification, or replacement. Component or airframe safe-life is also considered an FMP.

h. Fleet. For the purposes of this AC, a fleet is all airplanes of the same type design.

i. Incident. For the purposes of this AC, an incident is an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations. This includes in-service findings reported according to § 21.3.

j. Residual Strength. For the purposes of this AC, the capability of structure to carry static load with fatigue damage present.

k. Service History Based Inspection. An inspection based on qualitative information derived from experience with the same or similar structure. Although directed at a specific area of a fatigue critical structure, the applicant does not typically quantify or validate the inspection's effectiveness.

l. Safe-Life. The number of events, such as flights, landings, or flight hours time in service, during which there is a low probability the strength will degrade below its design ultimate value due to fatigue.

m. Unsafe Condition. For the purposes of this AC, an unsafe condition is fatigue cracking that either resulted in a catastrophic failure or without intervention could directly result in, or indirectly lead to, a catastrophic failure.

7. Related Publications (current editions).

a. ACs**.**

(1) AC 21-40A, Application Guide for Obtaining a Supplemental Type Certificate, dated September 27, 2007.

(2) AC 23-13A, Fatigue, Fail-Safe, and Damage-Tolerance Evaluation of Metallic Structure for Normal, Utility, Acrobatic, and Commuter Category Airplanes, dated September 29, 2005.

(3) AC 25.571-1D, Damage Tolerance and Fatigue Evaluation of Structure, dated January 13, 2011.

(4) AC 43-4A, Corrosion Control for Aircraft, dated July 25, 1991.

(5) AC 43.13-1B, Acceptable Methods, Techniques, and Practices – Aircraft Inspection and Repair, dated September 27, 2001.

(6) AC 91-56B, Continuing Structural Integrity Program for Airplanes, dated March 7, 2008.

b. Orders.

(1) FAA Order 8040.1C, Airworthiness Directives, dated October 3, 2007.

(2) FAA Order FAA-IR-M 8040.1C, Airworthiness Directives Manual, dated May 17, 2010.

(3) FAA Order 8110.4C CHG 3, Type Certification, dated March 15, 2010.

(4) FAA Order 8110.54A, Instructions for Continued Airworthiness: Responsibilities, Requirements, and Contents, dated October 23, 2010.

(5) FAA Order 8110.103A, Alternative Methods of Compliance (AMOC), dated September 28, 2010.

(6) FAA Order 8110.107, Monitor Safety/Analyze Data, dated March 12, 2010.

(7) FAA Order 8900.1, Flight Standards Information Management System (FSIMS), dated September 13, 2007.

c. Others.

(1) Best Practices Guide for Maintaining Aging General Aviation Airplanes, Appendix 1, Aging Airplane Inspection & Maintenance Baseline Checklist for Airplanes Without a Type Specific Checklist, dated September 2003. An electronic version is available at http://www.faa.gov/aircraft/air_cert/design_approvals/small_airplanes/cos/aging_aircraft/media/aging_aircraft_best_practices.pdf.

(2) Commercial Airplane Certification Process Study, An Evaluation of Selected Aircraft Certification, Operations, and Maintenance Processes, FAA, March 2002.

(3) DOT/FAA/CT-93/69.1 and DOT/FAA/CT-93/69.2, Damage Tolerance Assessment Handbook, Volumes 1 and 2, dated October 1993.

(4) FAA and Industry Guide to Product Certification, Second Edition, dated September 2004.

(5) General Aviation Manufacturers Association's Specification No. 2, Maintenance Manual.

(6) Nondestructive Evaluation (NDE) Capabilities Data Book, W.D. Rummel and G.A. Matzkanin, Nondestructive Testing Information Analysis Center (NTIAC), Texas Research Institute, Austin, Texas.

8. Background.

a. In the early 1980s, because of concerns about the continued airworthiness of older airplanes certified to the Civil Air Regulation (CAR) 4b fail-safe requirements, the FAA began issuing ADs mandating damage-tolerance based structural inspection programs. The intent of the programs mandated by these ADs was to prevent unacceptable degradation of the structural integrity of the affected airplanes to assure long-term continued operational safety of the fleet. These programs proactively addressed potential fatigue that could develop into a demonstrated risk. Per the definition in this AC, these programs are considered FMPs.

b. There have been airframe fatigue-related accidents and incidents that have required certain follow-on actions to maintain the continued operational safety of the fleet. Except for the requirement to report failures, malfunctions, and defects in § 21.3, no specific regulation or guidance exists to assist an applicant on what actions to take following a catastrophic failure due to fatigue or an in-service finding of fatigue cracking. Consequently, the FAA has worked on a case-by-case basis with applicants, owners, and operators to determine the actions needed to maintain the continued operational safety of these airplanes.

c. Reactively, to address a known unsafe condition that is likely to occur on other airplanes of the same type design, the FAA has mandated actions that deal with the specific unsafe condition. These actions typically include inspections, repair, or replacement of specific fatigue critical structural parts. However, in-service experience and fatigue test data have shown that actions to address one unsafe condition and extend the operation of a model fleet allowed a second unsafe condition to develop. Therefore, occurrence of fatigue in one critical part may be a precursor to fatigue in other critical structure that should be addressed proactively.

d. Based on the above, the FAA developed this guidance to assist an applicant on what actions to take following a catastrophic failure due to fatigue or an in-service finding of fatigue cracking that poses a demonstrated risk. The FAA determined that any proposed inspection of the structural elements directly related to the unsafe condition should be based on damage tolerance principles. The FAA also determined that, at a minimum, service history based inspections should be established for other areas considered fatigue critical.

9. Applicability of Certification Requirements to Address a Demonstrated Risk. The guidance in this AC describes how applicants may apply concepts contained in the metallic structure fatigue requirements in 14 CFR to address a demonstrated risk. The requirements include several approaches[1] for preventing catastrophic failure due to fatigue in new type designs. These approaches may also be used to address a demonstrated risk. To apply any of these approaches successfully, applicants should have demonstrated knowledge, abilities, skills, and understand:

- The intent of the 14 CFR fatigue and damage tolerance requirements,
- The underlying philosophy of the fatigue prevention approaches, and
- How to apply these approaches to address a specific demonstrated risk.

For airplanes that have experienced a demonstrated risk, the FAA considers compliance to the latest fatigue requirements will materially contribute to the product level of safety. Therefore, normal, utility, acrobatic, or primary category airplanes with a type certification basis that does not include fatigue requirements should comply with the latest fatigue requirements amendment for any replacement or modified structure. Airplanes with a type certification basis that includes fatigue requirements must comply with those fatigue requirements for any replacement or modified structure. The applicant must calibrate a safe-life or inspection program to the service history that resulted in the demonstrated risk. For a fail-safe design, an applicant must address the challenges associated with achieving a fail-safe design, as described in AC 23-13A, Chapter 3. For commuter and transport category airplanes whose certification basis includes damage-tolerance, any replacement or modified structure must comply with the applicable damage-tolerance requirements. For restricted category airplanes, any replacement or modified structure must comply with the airplane category used for type certification under § 21.25.

a. Safe-Life. For airplanes certificated using the safe-life approach, the safe-life of a structure is the number of events, such as flights, landings, or flight hours time in service during which there is a low probability the strength will degrade below its design ultimate value due to fatigue. The safe-life is a point in the airplane's operational life when the operator must replace, modify, or take the structure out of service to prevent it from developing fatigue cracks that can degrade the strength below its design ultimate value.

(1) An applicant can use the safe-life approach to address a demonstrated risk by establishing a point in the operational life of the airplane when the operator must replace,

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[1] For new type designs constructed with metallic structure seeking certification in the normal, utility, and acrobatic categories, 14 CFR part 23 allows the applicant to choose between the safe-life, damage-tolerance, and fail-safe design approaches. For new type designs in the commuter category or designs using composite materials, part 23 requires the applicant to use damage-tolerance, unless the applicant shows that damage-tolerance is impractical. For transport category airplanes, 14 CFR part 25 requires the use of damage-tolerance, unless the applicant shows that damage-tolerance is impractical.

modify, or take the structure out of service. If a catastrophic failure due to fatigue has occurred, or if an inspection finds cracks in-service, the safe-life of that structure likely has already passed. Based on service history, an applicant could establish a retroactive safe-life for the structure. Airplanes below this service history based safe-life could continue to operate until they reach the retroactive safe-life. For airplanes already at or beyond the service history based safe-life, the applicant could immediately replace or modify the structure or establish a schedule for completing these actions acceptable to the FAA. To manage the risk, the FAA coordinates any schedule with the applicant and considers:

- The number of airplanes used in commercial service,
- The risk of allowing operation beyond the service history based safe-life,
- The effectiveness of inspecting the structure,
- The residual strength characteristics of the structure,
- The availability of replacement parts, and
- Other relevant factors.

b. Damage-Tolerance. For a new type design, the regulations include the damage-tolerance approach for preventing catastrophic failure due to fatigue. The damage-tolerance approach depends on directed inspection programs to detect fatigue damage before strength degrades below the required level.

(1) A damage-tolerance based inspection of fatigue critical structure allows that structure to operate indefinitely until cracks are detected. However, once cracks are detected in one or more aircraft in a fleet, a risk analysis will be performed per the process described in Order 8110.107. This analysis will determine if any additional airworthiness actions (e.g., more rigorous inspection requirements or fleet-wide replacement or modification of the structure) are required. This analysis is necessary because continuing with the previously established inspections could result in an unacceptable probability of aircraft not meeting type design strength requirements as discussed in the following paragraph.

(2) Cracking is a continued airworthiness concern because cracking can potentially reduce the strength of the structure. The loss of certificated ultimate load capability should be a rare event and the FAA does not knowingly allow the strength of airplanes to drop below the certificated ultimate load requirement. However, service history has shown that the reliability of directed inspections is never sufficient to detect all cracks and as the number of crack reports increases, the likelihood that a number of airplanes in the fleet have undetected fatigue cracks also increases. Additionally, most damage tolerance based inspections are developed to ensure the structure always retains approximately design limit load capability. Therefore, for areas where fatigue cracks are reported, the likelihood increases with time that a number of airplanes in the fleet will have strength below the certificated ultimate load requirement. At some time during operation of the fleet, the likelihood that the strength of any given structure in a fleet is less than the certificated ultimate load requirement becomes unacceptably high and inspections must be modified (e.g., shorter intervals) or the problem must be terminated (e.g., fleet wide replacement/modification as a specified time in service).

(3) An applicant can use the damage-tolerance approach to address a demonstrated risk. However, the applicant must understand that damage-tolerance based inspections may not provide a permanent solution, as explained in subparagraph (2) above, if cracks are expected to continue to develop in the fleet. In this case, the FAA may require the fleet-wide replacement or modification of the structure. The schedule for completing these actions for a structure with demonstrated damage-tolerant capability may allow a limited increase in operational life compared to the schedule for a structure with no directed inspection program or demonstrated residual strength capability.

c. Fail-Safe Design. A fail-safe design retains its required residual strength after a readily detectable failure or partial failure of primary structure. A fail-safe design typically consists of redundant structural element(s) and/or crack arrest or crack containment features.

(1) The redundant structure provided by fail-safe design has sometimes prevented catastrophic failures. However, the FAA has documented cases in which a design thought to be fail-safe was not, and the design failed to prevent a catastrophic failure because the failure was not readily detected. AC 23-13A and the reference in paragraph 6c(2) identify several potential shortcomings of designs mistakenly thought to be fail-safe.

(2) Applicants can use the fail-safe design concept to evaluate the metallic structures of normal, utility, and acrobatic category airplanes. Prior to 14 CFR parts 25 and 23 Amendments 25-45 and 23-48, respectively, fail-safe design was a fatigue evaluation option for transport category and commuter category airplanes. Fail-safe was removed as a fatigue evaluation option for transport category airplanes certificated to Amendment 25-45 and subsequent, and commuter category airplanes certificated to Amendment 23-48 and subsequent.

(3) Applicants who apply the fail-safe design approach to a demonstrated risk should fully understand and address the potential shortcomings discussed in the documents listed in paragraph 6. An applicant should also understand if cracks are expected to continue to develop in the fleet, which increases the likelihood that the strength of some airplanes' structure may deteriorate below design ultimate strength level, a fail-safe modification might not provide a solution to the demonstrated risk. In this case, the FAA will require the fleet-wide replacement or modification of the structure. As in the case of damage-tolerance, the schedule for completing these actions for a fail-safe design may allow a limited increase in operational life compared to the schedule for a structure with no demonstrated fail-safe characteristics.

(4) The FAA will require a damage-tolerance based inspection program for any application of fail-safe design to address a demonstrated risk. Inspections are necessary due to the difficulties in achieving a truly fail-safe design, as described in AC 23-13A, Chapter 3. Also, even with added redundant structure, cracks may continue to develop in the fleet. Applicants should determine inspection methods and repeat intervals using damage-tolerance principles. Initial inspections should take place when the structure is modified with the fail-safe design or at the time in service at which the FAA requires an FMP, whichever occurs later.

(5) For commuter and transport category airplanes whose certification basis includes damage-tolerance, any fail-safe modification of the structure must comply with the applicable damage-tolerance requirements.

10. Overview of Fatigue Management System. In cases where accidents or incidents involve fatigue cracking, the FAA will act to determine if the type design (or supplemental type design) has a demonstrated risk. If the FAA determines a demonstrated risk exists, the FAA may require maintenance actions to address the risk. An FMP, as described in this AC, is one method applicants may use to address the demonstrated risk. This AC also provides proactive means to address the broader risk, which are inspections for cracks in other fatigue critical structure of airplanes of the same type design.

a. The FAA may require an FMP to meet the risk management guidelines established by the accountable directorate under the FAA Safety Management System (SMS). Appendix 1 contains more information regarding SMS.

b. Figure 1 provides an overview of a fatigue management system. It depicts steps the FAA and applicants should follow when they suspect a risk of catastrophic failure due to fatigue. Appendix 2 describes in detail the steps the FAA takes to determine if a demonstrated risk exists. Paragraphs 10, 11, and 12 describe the actions needed once the FAA has determined a demonstrated risk exists.

(1) In some instances, the FAA will mandate initial, short-term actions to provide short-term mitigation of the demonstrated risk and allow the fleet to return to service. These short-term actions often include operating limitations or immediate and short-interval inspections. The FAA often mandates these short-term actions with an emergency AD or immediately adopted rule (IAR) AD.

(2) In some instances, applicants may develop other interim actions and gain FAA approval after the FAA has issued an AD. 14 CFR 39.19 and 39.21 permit an AMOC to an AD. In accordance with those regulations, if the interim actions adequately mitigate the demonstrated risk, the FAA may approve the interim actions as an AMOC to the AD. The aircraft certification office (ACO) responsible for the AD will approve the AMOC. The AMOC approval will stipulate all the specific requirements and limitations of the interim action. When properly coordinated between the ACO, interim action applicant, and appropriate flight standards district office (FSDO), the combination of the AMOC approval and performance of the actions stated in the approval suffices as compliance with the AD portion the AMOC addresses. The Alternative Method of Compliance Order, 8110.103C, provides detailed guidance regarding use and approval of AMOCs.

(3) Appendix 3 contains examples of suitable AD language if the FAA decides to mandate an FMP with an AD.

c. Figure 1 also outlines the basic actions an applicant should take to develop an FMP to address a demonstrated risk. The purpose of an FMP is to prevent future catastrophic failures due to fatigue and to maintain the type design strength and stiffness of the airframe throughout the operational life of the airplane. As shown in Figure 1, there are two main components to an FMP to address a demonstrated risk developed in accordance with this AC.

(1) Damage-Tolerance Based Inspections or Replacement/Modification of Structural Elements Directly Related to the Unsafe Condition. Applicants should base this component of the FMP on a comprehensive damage-tolerance or fatigue evaluation, as applicable, and as explained in paragraph 10. The applicant may limit the scope of the detailed evaluation to the structural elements directly related to the unsafe condition.

(2) Inspections of Other Fatigue Critical Structure in the Airplane. This component of an FMP provides for proactive inspections of other fatigue critical structure. These inspections address the broader risk affecting the type design. The inspection requirements may be service history based or damage-tolerance based depending on whether or not an FMP already exists and what it contains.

d. Paragraph 10 describes the FMP development process. Applicants should document the FMP maintenance actions in the ICA.

e. Paragraph 11 explains the approval of an FMP and the coordination needed for those approvals.

f. Paragraph 12 discusses FMP implementation. The operator accomplishes implementation of the FMP by following the instructions prescribed in the ICA.

11. Developing an FMP. This paragraph describes the development of an FMP. The flowchart in Figure 2 outlines the decisions and actions an applicant should follow when developing an FMP.

a. Components of an FMP. Any FMP proposed by an applicant to address a demonstrated risk should include each of the following components:

(1) Damage-Tolerance Based Inspections or Replacement/Modification of the Structural Elements Directly Related to the Unsafe Condition.

(a) An applicant may limit the scope of this component of an FMP to the structural elements directly related to the unsafe condition.

(b) An applicant may propose an inspection or a part replacement/modification program to address the demonstrated risk. An applicant should base any inspection program on a damage-tolerance evaluation of the affected structure. They should base the time in service for a part replacement/modification (effectively a safe-life) on a fatigue analysis or crack growth analysis. Any part replacement/modification program should demonstrate compliance to the applicable regulations. This includes any subsequent inspection requirements. Any proposed program should incorporate the lessons learned from the service history that led to the FAA's determination of a demonstrated risk.

FIGURE 1. OVERVIEW OF A FATIGUE MANAGEMENT SYSTEM

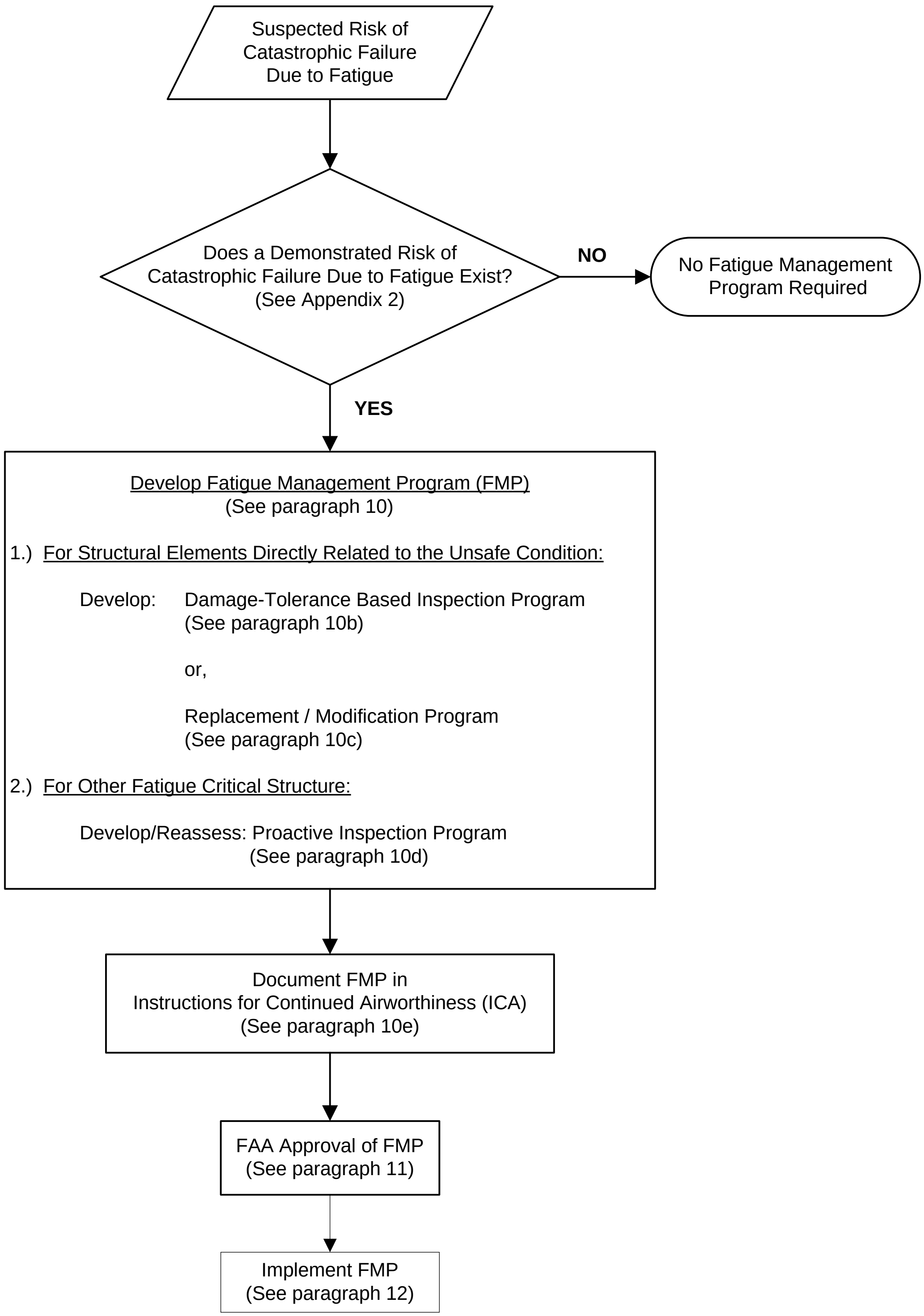
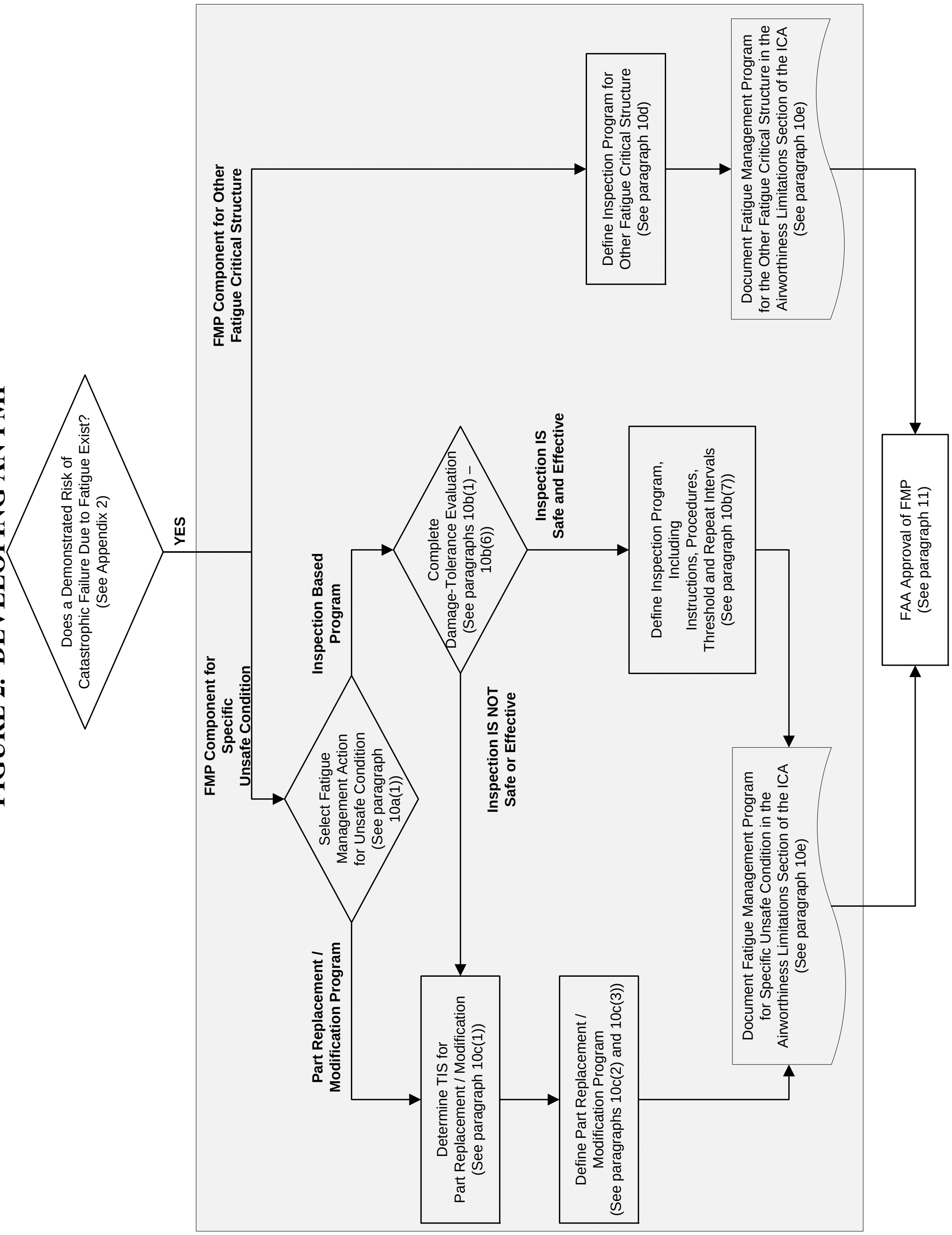


FIGURE 2. DEVELOPING AN FMP



(c) In addition to the effectiveness of an FMP, an applicant should also consider the practicality of each potential inspection and part replacement/modification program. An applicant should consider:

- Availability of parts needed for a replacement or modification program;
- Availability of qualified facilities, mechanics, and necessary tooling to complete the part replacement or modification;
- Risk of damaging surrounding structure during part replacement or modification;
- Complexity of inspection program, including inspection method and potential modification of structure to gain access to inspection sites;
- Availability of qualified NDE inspectors and proper equipment;
- Burden of repetitive inspections and associated reporting;
- Risk of damage to structure when performing inspections – usually damage to fastener holes when removing and reinstalling fasteners; and
- Preference of operators. Some operators may prefer an inspection program while others may prefer a one-time fix by either replacing a part or modifying structure.

(d) For some airplane type designs, certain fatigue management actions such as component life limits, life-extending modifications, or a Supplemental Inspection Program (SIP) are already in place to maintain the continued operational safety of that fleet (an existing FMP). Actions contained in an existing FMP for structural elements directly related to the unsafe condition that did not adequately consider this demonstrated risk should be reassessed.

(i) If the existing FMP action is an inspection, the FMP holder should determine why the existing inspection method, procedure, threshold, and/or interval was not adequate. The FMP holder should adjust the inspection program accordingly.

(ii) If the existing FMP action is a safe-life limit, part replacement, or modification, the FMP holder should determine why the action did not prevent the unsafe condition and adjust the safe-life limit, replacement/modification threshold, and/or modification actions accordingly. An FMP holder typically bases the safe-life limit on the most fatigue critical area in the structure. Therefore, if modifications or replacements extend this limit, the FMP holder should show there are not other areas in the structure more limiting than the extended limit.

(iii) If the existing FMP does not include actions for structural elements directly related to the unsafe condition, the FMP holder should develop appropriate actions as explained in paragraphs 10a(1)(b) and 10a(1)(c).

(e) Generally, the FAA will issue an AD requiring the selected program to address the demonstrated risk effectively.

(2) Inspections of Other Fatigue Critical Structure. This component of an FMP includes directed inspections of specific areas of other fatigue critical structure in the airplane. The purpose of this component is to proactively inspect for indications that may be precursors to an unsafe condition. The most likely areas are those where it is determined fatigue cracking may be expected to occur prior to their surrounding areas. These areas typically include the most fatigue sensitive details of joints, cutouts, run-outs and other discontinuities where local peak stresses are higher than the surrounding areas due to local geometry. The inspection requirements (e.g., where to look, how to look, how often to look, and when to start looking) may be service history or damage-tolerance based depending on whether or not an FMP already exists and what it contains.

(a) No Existing FMP or Safe-Life Based FMP. For a type design with a demonstrated risk that does not have an FMP or when the existing FMP contains only safe-life limits or life-extending modifications, the FAA expects an applicant to develop service history based inspections. An applicant may base these inspections on service history and engineering judgment. These types of inspections have been successful, in some cases, at detecting cracking before an incident occurs. However, an applicant does not typically quantify or validate the inspection effectiveness.

(b) Existing FMP – Damage-Tolerance Based. For a type design with a demonstrated risk and an existing FMP with damage-tolerance based inspections, the FAA expects an applicant to re-evaluate the inspections in that FMP. The applicant should take into account the lessons learned from the unsafe condition and revise and/or supplement the FMP as needed.

b. Damage-Tolerance Based Inspections. In considering a damage-tolerance based inspection program to address the demonstrated risk (paragraph 10a(1)), an applicant should complete a damage-tolerance evaluation. A thorough damage-tolerance evaluation will identify the crack location, scenario, critical crack size, the detectable crack size, inspection threshold, and the inspection interval (in number of flights or flight hours time in service) during which the crack grows from the detectable crack size to the critical crack size. AC 25.571-1D and the reference listed in paragraph 6c(3) provide additional information on performing a damage-tolerance evaluation.

(1) Evaluation Considerations. The damage-tolerance evaluation should consider the actual sites, cracking scenarios, and crack progression observed in the unsafe condition. Actual cracking scenarios can be complex, involve multiple sites, and at some point, include crack interaction.

(a) When performing a damage-tolerance evaluation to predict the residual strength and crack growth life, the applicant should address the most probable cracking scenario and appropriate loading conditions. If the scenario includes cracks in multiple elements, or multiple cracks in one element, the applicant must account for that in determining where, when, how, and how often to inspect for cracks.

(b) The damage-tolerance evaluation should not use an easily evaluated solution if it is not a representative scenario (for example, a handbook solution for a single crack growing from a hole when the actual scenario involves multiple cracks). Such an evaluation could result in an ineffective inspection program. However, in many cases, it may be acceptable to evaluate a conservative, but easier to analyze, scenario than the actual scenario. If an applicant uses such an approach, the applicant should explain and justify all simplifying assumptions.

(2) Critical Crack Size. The critical crack size is the size of crack that degrades the strength of the structure to the minimum strength required. The applicant should use fracture mechanics analysis, supported by test evidence, to determine the relationship between crack size and residual strength. The minimum strength requirements for determining the critical crack size are listed in (a) through (e) below.

(a) For airplanes certificated in the primary, normal, utility, acrobatic, and commuter categories, § 23.573(b), current amendment level, defines the residual strength requirement.

(b) For airplanes certificated in the transport category, § 25.571(b), current amendment level, defines the residual strength requirement.

(c) For airplanes certificated in the restricted category, the residual strength requirements should be consistent with the airplane category used for type certification under § 21.25.

(d) The FAA may require higher levels of minimum strength in instances of high probability of in-service cracking (several reports of cracks) or in airplanes with severe operational profiles such as aerobatics, aerial application, and low-level survey.

(e) For an individual airplane with a known crack in the structure, the FAA may impose specific requirements before the FAA will allow further flight. See AC 23-13A for the FAA Small Airplane Directorate's policy for flight with known cracks in small airplane structure.

(3) Detectable Crack Size. The detectable crack size is the minimum size crack that an inspector can find reliably and repeatedly. The first prerequisite for an effective inspection program is that the detectable crack size must be smaller than the critical crack size. An applicant should address, at a minimum, the following issues in determining the detectable crack size:

- What inspection methods are potential candidates for this specific application?

- What crack size is detectable using these candidate methods in this specific application?

- What is the probability of detection for the average inspector given the specific application? (See the reference in paragraph 6c(6) for information on probability of detection.)

- What qualifications will the inspector need to have? Will qualified inspectors be available?

- How accessible is the structure? In some cases, the inspector or mechanic may need to remove or modify the structure to gain access.

- Does sealant or paint cover the area? Can an inspector or mechanic easily remove the sealant or paint? Does the inspector or mechanic need to reapply the sealant or paint after the inspection?

- Will the inspector need to have fasteners removed to complete the inspection? If so, what is the potential for damaging the structure in this process?

- Will the fastener holes require additional reaming before inspection? Is the edge margin adequate? Will the reinstallation require special oversize fasteners?

In addressing these and other related issues, the applicant is ensuring the average inspector can find a crack of a given size with a high probability of detection (POD). Any applicant using inspection data (including probability of detection) from industry, military, or the National Aeronautics and Space Administration (NASA) sources should be able to justify their use and applicability. For example, a published probability of detection does not mean it is acceptable to the FAA if the personnel, equipment, or conditions (lighting, cleanliness, etc.) on which the POD is based are not reasonably expected to exist for each inspection.

(4) Crack Growth Life. Crack growth life is the time (in number of flights or flight hours time in service) it takes the detectable crack to grow to critical size. The second prerequisite for a viable inspection program is that the crack growth life has to be sufficiently long to allow for practical inspection.

(a) An applicant typically determines the crack growth life based on a fracture mechanics-based crack growth analysis. However, in some cases, it may be possible to determine crack growth life by counting the striations on the fracture surface of the accident, incident, or test structure.

(b) If the crack growth life for the initially selected inspection method does not result in sufficient time between when the crack reaches the detectable crack size and when it reaches the critical crack size, inspections may not be a safe and effective method for addressing the demonstrated risk. In some instances, an applicant may want to consider other inspection methods that may be able to increase the crack growth life based on detecting smaller cracks. An applicant will often base their preference of inspection method on method sensitivity and cost versus inspection frequency. If the applicant cannot show the inspection program is safe and effective, then the applicant should pursue a part replacement/modification program as explained in paragraph 10c of this AC.

(5) Inspection Repeat Interval. The inspection repeat interval is typically a fraction of the length of time for the crack to grow from the detectable crack size to the critical crack size. Appendix 4 provides acceptable methods for determining the repeat inspection interval. It is the applicant's option to determine how complex or simple the analysis should be. The applicant may determine that a simple analysis using conservative assumptions and scatter factors produces an acceptable inspection interval. An applicant may also use a more detailed analysis to justify a longer inspection interval. The applicant should explain and justify all simplifying assumptions.

(6) Inspection Threshold. The inspection threshold is the time when the operator must perform the first inspection. The FAA has accepted several different methods for determining the inspection threshold. No matter what method an applicant uses, the applicant should always ensure that the thresholds are rational, given the accident, incident, or in-service findings. For example, if cracks are found in-service at 5,000 hours time in service, it is rational to set the inspection threshold at some time well before 5,000 hours, even if analysis produces a larger threshold.

(a) The applicant may determine the inspection threshold based on information learned from the airplane involved in an accident, incident, or in-service finding. Probabilistic methods, including Weibull analysis, allow an applicant to estimate the probability of a crack at a specific time in service. For small airplanes, the FAA's Small Airplane Directorate typically accepts an inspection threshold corresponding to the time in service when the probability of developing a crack reaches 1-in-1,000.

(b) The applicant may determine the inspection threshold using a fatigue (stress-life or strain-life) evaluation. The applicant should correlate the results of the fatigue evaluation with the time in service of the airplanes involved in the accident, incident, or in-service findings. See AC 23-13A for guidance on performing small airplane fatigue evaluations.

(c) The inspection threshold may also be based on crack growth analysis results. There are two accepted crack growth based approaches. In the first approach, the inspection threshold is set equal to the repeat inspection interval. In the second approach the inspection threshold is based on the time (divided by a factor) a crack would grow from an initial assumed size to the time that the crack reaches the critical crack length. The reference in paragraph 6c(3) provides additional detail on the crack growth method.

(d) Ample literature is available that describes the details of any of the above analysis approaches. Whichever approach an applicant chooses, it is the applicant's option to determine how complex or simple the analysis should be. The applicant may determine that a simple analysis using conservative assumptions and scatter factors produces an acceptable inspection threshold. An applicant may also use a more detailed analysis to justify a longer inspection threshold. The applicant should explain and justify all simplifying assumptions.

(e) If any airplanes in a fleet exceed the inspection threshold, the FAA expects inspection of those airplanes as soon as possible, allowing an appropriate grace period to prevent unnecessary disruption.

(7) Define Inspection Requirements and Procedures. An applicant should document the inspection program in sufficient detail to support implementation of the program as an airworthiness limitation item. The inspection program documentation should include, but not necessarily be limited to:

- Reasons for the inspection, including applicable ADs and Service Bulletins (SB);

- Description of the inspection area, including illustrations depicting the inspection area, anticipated crack locations, probe/transducer placement, and crack signal;

- Instructions for preparing the inspection site, including required access, cleaning requirements, fastener removal, and safety (e.g., fuel tank purging);

- Description of inspection method; for example, dye penetrant, ultrasound, high/low frequency eddy current, visual, or magnetic particle;

- Required equipment, including any crack calibration standards used to calibrate inspection equipment;

- Calibration requirements;

- Required qualifications of inspectors;

- Accept/reject criteria;

- Repeat inspection interval (as determined in paragraph 10b(5));

- Inspection threshold (as determined in paragraph 10b(6));

- Reporting requirements; and

- Approval and revision status of the inspection instructions.

(8) Criteria for Developing a Damage Tolerance Based Inspection Program. When a demonstrated risk is identified in a type design, the criteria used for developing an inspection program need to be tailored to the demonstrated risk being considered. These criteria may deviate from the criteria specified in the certification basis for that type design. This is because at the time of certification, criteria apply to potential fatigue not yet realized in service and its probability of occurrence should be relatively low when the inspections start. This is not the case for a demonstrated risk. Therefore, the applicant should work with the FAA to establish tailored criteria appropriate for the demonstrated risk being addressed. Items to address include, but are not limited to, the residual strength that must be assured, inspection threshold methodology, establishment of the inspection interval, and inspection POD.

c. Part Replacement/Modification Programs. There are three reasons why an applicant may select a part replacement/modification program.

- Part replacement/modification may be necessary if a damage-tolerance based inspection program is not safe or effective.

- Part replacement/modification may provide a more efficient solution to the demonstrated risk than a damage-tolerance based inspection program.

- The applicant may desire a part replacement/modification program.

(1) An applicant must determine the time in service at which to accomplish the part replacement/modification, substantiate compliance to the applicable regulations, and develop detailed instructions for accomplishing the part replacement/modification. The applicant should be aware that by strengthening the location where the fatigue cracking occurred, the load path may change and transfer load to surrounding structure, creating a new fatigue location.

(2) Determine Time in Service for Part Replacement/Modification.

(a) The time in service for part replacement/modification is the point in the operational life of each airplane at which the operator must modify or replace the structure, regardless of condition. The applicant should establish the time in service to minimize the probability of having a crack initiate in the structure.

(b) For small airplanes, the FAA's Small Airplane Directorate has accepted a time in service corresponding to a probability of 1-in-1,000 of developing cracks in structure. The applicant typically uses a fatigue analysis correlated to in-service findings or a probabilistic analysis of all in-service crack findings to determine the time in service for part replacement/modification.

(c) Under certain circumstances, a fleet may be operated beyond an established time in service for parts replacement/modification. For instance, parts for all affected airplanes may not be immediately available. Or, there may be limited maintenance facilities with appropriate tooling, equipment, or expertise readily available. The FAA may allow an alternative schedule under these circumstances if the risk can be reduced to an acceptable level with an interim inspection program. To determine the rate of fleet part replacement/modification compliance, a data-driven risk assessment approach using fleet demographics should be used. Individual airplane and fleet risk should be assessed for any such alternative schedule. The FAA may approve the plan if the risk is acceptable.

(3) Method of Compliance for Part Replacement/Modification. An applicant must demonstrate compliance to the applicable regulations for any replacement or modification of existing structure. Since the applicant knows the location is critical in fatigue, any part replacement or modification should demonstrate compliance to the most appropriate amendment fatigue regulations regardless of certification basis. In all cases, an applicant should establish a safe-life limit or develop a damage-tolerance based inspection program for both the modified or replaced structure and existing surrounding structure it affects.

(a) For small airplanes, Amendment 23-48 to §§ 23.571 and 23.572 are appropriate.

(b) For transport airplanes certificated prior to Amendment 25-45, use § 25.571 at Amendment 25-45.

(c) For transport airplanes certificated under Amendment 25-45 or later, use § 25.571 at the amendment level used for its TC basis.

(4) Instructions for Part Replacement/Modification. An applicant should document the part replacement/modification instructions in sufficient detail to support implementation as an airworthiness limitation item. Details of the mandatory actions include, but are not limited to:

- Development of service kit details,

- Determination of a part replacement/modification threshold and any part replacement/modification intervals, and

- Development of inspection and reporting instructions for structure prior to modification.

(a) Inspections and reporting instructions may be necessary as part of the service kit instructions or replacement procedures. One of the purposes of these inspections is to ensure the modified structure is crack free. These additional instructions should provide detailed procedures to inspect for cracks in the affected parts. (Paragraph 10b(7) discusses inspection procedures.) These instructions should also outline procedures for reporting the inspection findings to the applicant and crack findings to the FAA. Appendix 3 contains examples of reporting requirement language suitable for FAA ADs that mandate an FMP.

(b) If cracks are found, the FMP holder should make arrangements and subsequently develop instructions to provide for the return of removed parts (or the applicable portions of removed parts) to the FMP holder or the FAA for evaluation. In either case, the instructions should encourage maintenance facilities to return removed parts to the FMP holder for evaluation.

(c) Accurate inspection and reporting can facilitate further refinement of modification/replacement thresholds and intervals. This refinement may be beneficial where the original analysis was conservative, there are few or no Service Difficulty Reports (SDR), the FMP holder suspects anomalies exist, or where modifications and replacements are difficult, costly, or time-consuming.

d. Inspections for Other Fatigue Critical Structure. In addition to dealing with the known unsafe condition, an FMP that addresses a type design with a demonstrated risk should include other fatigue critical structure inspections (see paragraph 10a(2)). As explained in paragraph 10a(1), inspection or modification/replacement of a specific part or parts mitigates a demonstrated risk for a known unsafe condition. However, continued operation allows more fatigue cycles to accumulate on other likely fatigue critical structure and may lead to another unsafe condition. Historically, fatigue cracking in another part of the structure follows fatigue cracking in one location of the airplane structure. This occurs because fatigue cracking is time in service related and a type design typically uses similar materials, construction techniques, and attention to fatigue detail throughout the structure. If the affected type design has an existing FMP with damage-tolerance based inspections, these inspections should be reviewed for necessary revisions as discussed in paragraph (1) below. If the affected type design has no FMP or the existing FMP only includes safe-life limits, an inspection program should be developed as discussed in paragraph (2) below.

(1) Type Designs with Existing FMPs that Include Damage-Tolerance Based Inspections.

(a) For some airplane type designs, FMPs already exist that include damage-tolerance based inspections and may also include safe-life limits and/or mandatory replacement/modifications. The applicant should examine the existing FMP maintenance actions for these designs to determine their adequacy based on lessons learned from the unsafe condition. Existing life limits, modification/replacement times, inspection thresholds, inspection intervals, inspection methods, procedures, etc., should be revised as necessary.

(b) The applicant should also assess other fatigue critical structure for design similarity to the unsafe condition and determine if any new FMP maintenance actions are required for similar structures. The assessment should include a service history review as discussed in paragraph (3) below. The FMP should adequately address structural details of areas historically prone to fatigue. A generic list of such areas is included in paragraph (4) below. Any new inspections should be damage-tolerance based.

(2) Type Designs Without an Existing FMP or With an FMP with Safe-Life Limits Only. Some type designs may have no FMP because the certification basis was based on fail-safe requirements or did not include any fatigue requirements. The applicant should develop an inspection program to address other fatigue critical structure for these type designs and type designs where an existing FMP contains only safe-life limits. The applicant should include this component in the new FMP or add it to the existing FMP along with the actions developed to address the demonstrated risk as described in paragraph 10b and 10c. An applicant may base this component of the FMP on service history and engineering judgment. Additionally, an applicant may limit this component to directed visual inspections of details in areas known to be problematic in other type designs. Paragraph (3) below provides a list of potential sources of relevant service history and paragraph (4) provides a generic list of areas that past experience has shown can be problematic from a fatigue perspective. The resulting inspection program may provide some protection from future catastrophic failure due to fatigue. Directed inspections of probable cracking locations (beyond routine annual or other scheduled inspections) are generally beneficial. These types of inspections have prevented catastrophic failures. However, they may not provide the same level of safety as a damage-tolerance based inspection program.

(3) Service History Review. In reassessing existing fatigue management actions or in developing new actions, an applicant should thoroughly review the type design's service history. A review should look for precursors such as repeated repairs, working or broken rivets, fretting, chafing, fluid or pressurization leaks, part replacement, etc. Service history is an important aspect of setting up or adjusting an FMP. Sources of relevant service history information include:

- Existing mandatory actions, including ADs and the Airworthiness Limitations Section (ALS) of ICAs;
- Manufacturer's SBs;
- FAA SDR database;
- In-service findings reported according to § 21.3;
- Repairs that received field approvals;

- History of part replacement;
- Discussions with type clubs of the specific type design; and
- Discussions with repair facilities that maintain the specific type design.

(4) Areas of Fatigue Critical Structure to Consider for Inspection. As defined in this AC, all fatigue critical structure with few exceptions can be expected to develop fatigue cracks eventually. However, based on past experience there are certain areas of fatigue critical structure that may be expected to develop fatigue cracks prior to its surrounding structure. These are typically areas of relatively high-tension stress combined with geometric features and/or internal load redistribution that result in high local stresses at detail design points (e.g., holes, door corners, transition radii, eccentricities, notches). Examples of such areas are given below:

- Wing and empennage joints, splices, and cut-outs of tension dominant load path, e.g., lower spar caps, skins, stringers, fittings, bolts, etc;
- Fuselage carry-through structure areas similar to the above items, as applicable;
- Maximum tension bending moment location on the wing, horizontal tail, and vertical tail;
- Areas in primary wing load path where other loads are introduced such as engine or landing gear attachments;
- Wing strut attachments – both ends;
- Empennage attach areas;
- Pressurized fuselage joints, splices, and cut-outs.

e. Documenting the FMP. For FMPs that address a demonstrated risk, the applicant should incorporate instructions associated with both components of an FMP into a document suitable for FAA approval and for use by maintenance personnel.

(1) If the airplane model has an ICA, the applicant should add the FMP to the existing ALS of the ICA. If the airplane model does not have an ICA (or an ALS associated with the ICA), then the applicant should write the FMP instructions in a document that contains pertinent information equivalent to the ALS portion of an ICA.

(2) Write instructions in plain English and provide clear and concise instructions for completing the tasks. The instructions should include, but not necessarily be limited to, the following:

- The type and the extent of inspection programs;
- Steps involved in part replacement or modification;

- Information describing the order and method of removing and replacing parts and any precautions necessary to facilitate inspection;

- Diagram of structural access plates, or how to gain access when access plates do not exist;

- Details for utilizing special inspection techniques, including procedures for these techniques;

- Identification of fatigue critical structure;

- All data on structural fasteners, such as identification and torque values;

- List of required special tools;

- Any necessary shoring, jacking, or other special handling requirements;

- Any subsequent required inspections; and

- Instructions for notifying the FMP holder of positive and negative findings for structural elements directly related to the unsafe condition and positive findings for other fatigue critical structure. Normally, the ICA will include a form specifying all pertinent information about the finding.

(3) Order 8110.54A, Instructions for Continued Airworthiness, Responsibilities, Requirements and Contents, provides guidance about the content of an ICA or its equivalent. The reference in paragraph 6c(5) gives direction in the preparation of maintenance data for the maintenance of general aviation airplanes, including ICA.

(4) Paragraph 11 provides guidance regarding the approval process for documenting the actions associated with an FMP.

12. Coordination and Approvals.

a. When addressing in-service issues, the FAA will approve FMPs that address the demonstrated risk and when an AD mandating an FMP is proposed or issued. The FAA may also approve an FMP as an AMOC to an AD. If approval is required, use the process explained in this paragraph.

b. When following the steps described in this AC, the applicant should communicate and coordinate with the cognizant FAA ACO and FSDO, as appropriate. These offices will coordinate with their respective Directorate and Aircraft Evaluation Group (AEG) offices when necessary. The FAA orders and ACs referenced in this paragraph describe roles and responsibilities depending on the method of approval needed for the specific application.

c. The process an applicant uses to get its FMP approved by the FAA varies according to whether the DAH or another applicant is seeking approval. The FAA encourages applicants to use the appropriately authorized designees to approve, or recommend for approval, the substantiating data. Because of the detailed engineering evaluation required to develop an FMP, the FAA will, in general, consider an FMP to be a major change to the type design (see § 21.93). The cognizant FAA ACO should coordinate with the appropriate Directorate to verify that the proposed FMP is a major change to the type design.

(1) If the DAH is seeking approval of its FMP, it typically documents the required actions in a SB, Service Letter, or similar document. These instructions should include a section that specifies the actions needed to mitigate the demonstrated risk and those actions that address other fatigue critical structure. If the affected model has an ICA, then the DAH should revise the ICA to incorporate the FAA-approved FMP. If the affected model does not have an ICA, the DAH should create an ICA and incorporate the FMP to implement it. As a part of the design approval process, when the DAH submits an ICA to the FAA, the ACO and the AEG review the ICA in accordance with Order 8110.54A. The DAH could also use the TC process to gain FAA approval of their FMP as an STC.

(2) If the applicant is not the DAH, the applicant should apply for an STC to gain FAA approval of the FMP (see § 21.113). The STC should include instructions similar to those normally contained in a DAH's SB. These instructions, which make up an ICA, should include a section that specifies the actions needed to mitigate the demonstrated risk and those actions that address other fatigue critical structure (new STCs require an ICA as part of a design change per § 21.50(b)). As a part of the design approval process, when the applicant submits an ICA to the FAA, the ACO and the AEG review the ICA in accordance with Order 8110.54A. AC 21-40A and Order 8110.4 provide policy and guidance on the STC process.

(3) See paragraph 10c(3) for discussions regarding certification basis of modifications. The ALS of the ICA must be approved by the cognizant ACO. Appropriately authorized DERs or delegated organizations are expected to review and approve all technical aspects of the substantiating data and underlying technical changes per the applicable regulations in support of the STC process. These regulatory compliance findings will be to the agreed upon certification basis. Up-front planning should be in accordance with Partnership for Safety (PSP) or Project Specific Certification Plans (PSCP) developed between the FAA and the applicant at the beginning of the STC project. See the reference in paragraph 6c(4) for information regarding PSPs and PSCPs.

d. The FAA may issue an AD to mitigate the demonstrated risk before the DAH or other applicant develops an FMP. In these cases, the applicant will submit their FMP to the cognizant ACO either as a method of compliance to the AD or as an AMOC to the AD. The ACO will evaluate the applicant's justification and, if found acceptable, approve the FMP. Since the FAA determines if actions comply with an AD, ACO approval is the avenue toward granting a method of compliance for the AD. The manager of the cognizant ACO will grant approval to the applicant.

e. Appendix 3 contains examples of suitable AD language if the FAA decides to mandate an FMP with an AD.

13. Implementing an FMP. Figure 3 on the next page illustrates the key elements of implementation discussed in detail below.

a. FMP Actions to Address the Demonstrated Risk.

(1) Part Replacement/Modification. Perform part replacement/modification per the instructions included in the ICA.

(2) Damage-Tolerance Based Inspections. Complete inspections per the instructions included in the ICA.

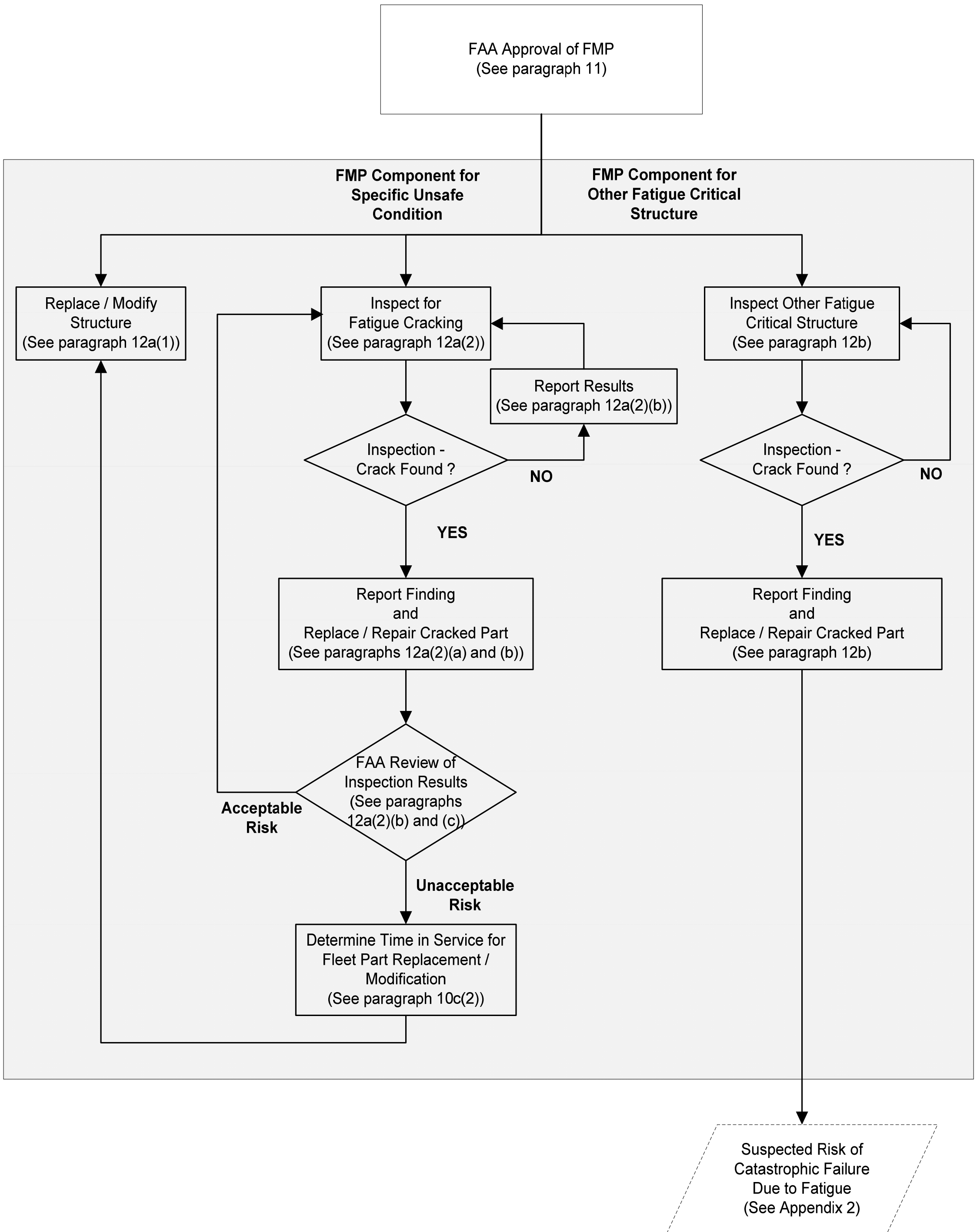
(a) If the inspections detect fatigue cracking, repair or replace the cracked part per FAA-approved repair instructions.

(b) Typically, the FAA includes instructions in the AD for operators to report to the FMP holder both negative and positive crack indications along with the time in service on the aircraft inspected. The AD may also require operators to report positive crack indications and time in service to the FAA. In some cases, the FAA may require reporting of negative crack findings. (Appendix 3 contains examples of crack reporting requirements suitable for an AD.) History of inspection results provides data to measure the success of an inspection program. The FMP holder uses reports of cracks found and their sizes, negative inspection results, and the airplane time in service to assess the inspection program effectiveness. Damage-tolerance based inspections must have a demonstrated high probability of detection so both positive and negative findings are statistically relevant to verify the inspection method is as reliable as assumed. Report results per the instructions contained in the ICA.

(c) If the inspection program finds a crack and verifies another occurrence of the unsafe condition, the FAA will assess the overall risk to the fleet if inspections were to continue. The inspections may continue if the FAA determines the risk level is acceptable. However, the FAA will mandate termination of the inspection program and development of a part replacement/modification program if the FAA determines continued reliance on inspections poses an unacceptable risk level. AC 91-56B contains guidance about the need for mandatory modification programs when reliance on repetitive inspections no longer provides adequate safety. The FAA uses a data-driven SMS approach for determining acceptable risk associated with continued reliance on repetitive inspections. SMS, as it relates to FMPs, is described in Appendix 1.

b. FMP Actions to Address Other Fatigue Critical Structure. Generally, an AD will require operators to accomplish the established inspections for other fatigue critical structure per the instructions specified in the ICA. A crack found by these inspections would require evaluation as a suspected risk of catastrophic failure due to fatigue, as described in Appendix 2. The inspector should report positive inspection findings to the FMP holder and the FAA per the instructions contained in the ICA. Appendix 3 contains examples of suitable AD reporting requirement language for when the FAA uses an AD to mandate an FMP with crack reporting instructions.

FIGURE 3. IMPLEMENTING AN FMP



14. List of Acronyms.

a. **AC.** Advisory Circular

b. **ACO. Aircraft Certification Office**

c. **AD. Airworthiness Directive**

d. **AEG. Aircraft Evaluation Group**

e. **ALS. Airworthiness Limitations Section**

f. **AMOC. Alternative Method of Compliance**

g. **CAR. Civil Air Regulation**

h. **CFR. Code of Federal Regulations**

i. **CPCP. Corrosion Prevention and Control Program**

j. **DAH. Design Approval Holder**

k. **DER. Designated Engineering Representative**

l. **FAA. Federal Aviation Administration**

m. **FMP. Fatigue Management Program**

n. **FSDO. Flight Standards District Office**

o. **IAR. Immediately Adopted Rule**

p. **ICA. Instructions for Continued Airworthiness**

q. **NASA. National Aeronautics and Space Administration**

r. **NDE. Nondestructive Evaluation**

s. **NTIAC. Nondestructive Testing Information Analysis Center**

t. **NTSB. National Transportation Safety Board**

u. **PMA. Part Manufacturing Approval**

v. **POD. Probability of Detection**

w. **PSCP. Project Specific Certification Plan**

x. **PSP. Partnership for Safety Plan**

y. **SB. Service Bulletin**

z. **SDR. Service Difficulty Report**

aa. **SIP. Supplemental Inspection Program**

bb. **SMS. Safety Management System**

cc. **SRM. Structural Repair Manual**

dd. **STC. Supplemental Type Certificate**

ee. **TC. Type Certificate**

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APPENDIX 1. FATIGUE MANAGEMENT PROGRAMS (FMP) AS THEY RELATE TO SAFETY MANAGEMENT SYSTEM (SMS)

The FAA Aircraft Certification Service (AIR) SMS is the foundation for decision making in managing safety throughout an airplane model's complete life cycle. SMS is a systematic approach to identifying hazards and managing the risks associated with those hazards.

In support of SMS, each Directorate has developed risk analysis methods and acceptable risk guidelines unique to each area of product responsibility for addressing potential unsafe conditions. If the FAA determines an unsafe condition exists (based largely on the risk analysis of the airworthiness concern and the product risk guidelines), the FAA will work with the design approval holder (DAH) and other interested parties to develop potential mitigating actions (called "candidate control programs" in SMS).

The FAA will evaluate candidate control programs based largely on their effectiveness of reducing risk to an acceptable safe and practical level. The FAA may also consider other factors including availability of resources and financial impact.

An FMP is a control program that addresses the long-term risk associated with fatigue in metallic structures. (The FAA often addresses the short-term risk associated with fatigue by issuing immediate airworthiness actions requiring inspections or reducing the airplane's operating envelope.) An FMP may incorporate damage-tolerance based inspections, part replacement or modification, or a combination of these two approaches. More than one FMP can be developed to address a specific unsafe condition. The FAA will evaluate candidate FMP(s) using the appropriate product risk analysis methods and risk guidelines.

The FAA's policy is that design changes that remove the source of the unsafe condition provide a higher level of continued operational safety over time than long-term reliance on repetitive inspections. AC 91-56B and FAA-IR-M-8040.1C, chapter 8, explain that policy. Each Directorate will use its risk analysis methods, risk guidelines, and product specific policy and guidance to determine when repetitive inspections should cease and part replacement or part modification must take place.

APPENDIX 2. INVESTIGATION OF IN-SERVICE FINDINGS

1. Summary.

The FAA may suspect an airplane type design has a risk of catastrophic failure due to fatigue when fatigue may be a causal factor to an in-service finding such as an accident, incident, or service difficulty report, or after reports of in-service findings of fatigue cracks in a flight critical structure. In an accident or incident, the FAA is a party to the NTSB[1] led investigation of the accident or incident. For reports of in-service findings of fatigue cracks, the FAA typically works with the DAH to investigate the reports of cracking.

In both cases, the FAA works to determine whether the suspected risk is an actual demonstrated risk of catastrophic failure due to fatigue.

When the NTSB or FAA/DAH investigation finds that fatigue contributed to the accident, incident, or in-service finding, and that the unsafe condition is likely to develop on other airplanes of the same type design, the FAA may determine that a demonstrated risk exists. The FAA may then consider AD action to maintain the continued operational safety of the fleet (see § 39.5).

2. Failure Investigation.

Failure investigations should look at the evidence from a broad perspective, including the conditions and circumstances surrounding the accident or incident. If partial or complete structural fracture(s) contributed to the accident or incident, the investigator[2] should determine if fatigue was a contributor and if it is likely to occur in other airplanes.

[1] The NTSB is responsible for the organization, conduct, and control of all accident and incident investigations within the United States where the accident or incident involves any civil aircraft or certain public aircraft (see 49 CFR § 831.2(a)(1)). The NTSB may designate additional parties to accident or incident investigations. The NTSB limits these designated parties to those persons, government agencies, companies, and associations whose employees, functions, activities, or products were involved in the accident or incident and who can provide suitable qualified technical personnel to assist in the investigation (see 49 CFR § 831.11(a)(1)). The FAA is the only entity afforded the right to be a designated party of an NTSB accident or incident investigation.

The NTSB determines the probable cause of an accident and may also issue safety recommendations to address safety issues identified during the accident investigation. The FAA, based on the findings of the NTSB-led investigation and NTSB-issued safety recommendations, may make a determination that an unsafe condition exists and that airworthiness directive action is necessary to maintain the continued airworthiness of the airplane type.

[2] "Investigator" could be someone from the NTSB, the FAA, the DAH, or an owner's group. Typically, it is a combination of any or all of these.

a. Did fatigue contribute to failure?

The failure investigation will answer this question by considering the airplane loading at the time of the failure, usage and maintenance history of the airplane, and examining the fracture surfaces.

Accident and Incident Investigation. Airplane accidents result in many broken parts and therefore many fracture surfaces. Investigators will examine all fracture surfaces of primary structure for the mode of failure, including evidence of fatigue. An investigator can sometimes observe evidence of fatigue cracking in the field; however, a laboratory fractographic analysis should verify all potential fatigue damage sites.

Many fracture surfaces will indicate static overload resulting from the accident impact or flight loads. Examination of these fracture surfaces, including the failure direction (e.g., wing bending up or down), can assist in determining whether fatigue contributed to the failure.

Investigators will review all available airplane logs. The airplane usage and maintenance history may reveal that it was susceptible to the effects of fatigue.

Investigators will also study the conditions associated with the accident. A qualitative estimate of the loading at the time the failure occurred, as a minimum, can help determine if the airplane exceeded its design limits. Investigators will review the operating environment, including weather conditions, at the time of the failure. This information will help determine if the pilot was operating the airplane outside its design envelope or if turbulence or upset recovery maneuvers subjected the airplane to high loads. The investigator should also consider the flight phase and attitude at the time of the accident. For example, if the aircraft was in level flight in good weather, it is unlikely that the failure was due to static overload based on load considerations only.

In an incident, the fracture surfaces may not be accessible for examination. The investigator may need to rely on indications of deformation in primary load path as well as secondary load paths (e.g., ribs and stringers). In these cases, the investigator may excise the fracture surfaces from the airplane so metallurgists can examine the fractures.

(Note: When the NTSB investigates accidents or incidents, it documents all of the above information to the greatest extent possible. If structural failure is a possible cause, the NTSB's metallurgists will thoroughly examine the fracture surfaces.)

In-Service Findings. In-service findings of failures or cracks are similar to an incident in that the fracture surfaces may not be easily accessible for examination. If the repair of the failed area removes and replaces the failed or cracked part, the investigator should obtain the removed part for examination.

Summary. Conclusively determining whether or not fatigue contributed to the failure is usually possible based on examination of fracture surfaces and consideration of the loads likely experienced during the accident sequence. If the investigation determines fatigue contributed to the accident, incident, or in-service finding, the investigation must then determine whether other airplanes in the fleet are likely to develop similar fatigue damage.

b. Is the Fatigue Cracking Scenario Likely to Occur on Other Airplanes?

If the investigation determines fatigue contributed to the accident, incident, or in-service finding, then it is important to determine if fatigue is likely to occur on other airplanes in the fleet. An investigator can answer this question by performing a detailed investigation that identifies all fatigue cracking sites in the structure, the possible cause of the cracking, and how the cracks progressed.

Site. In addition to the initial fatigue crack(s) identified, the failure investigation may find other fatigue cracking sites in the structure. This is often the case when cracking is due to normal fatigue (often called "fatigue wear-out"). For example, the general location of a failure may be the attachment of the wing at the wing root. However, signs of fatigue cracking could also exist at other locations in the same load path, such as at hole(s) in a spar cap, wing skin, or wing/stringer details. This would be an indication of fatigue wear-out and therefore likely to occur in other airplanes.

It is also possible that evidence of fatigue exists in other load paths. For example, the accident, incident, or in-service finding may involve a fatigue crack in the attachment of the wing at the wing root. However, additional fatigue cracks may exist in other wing fittings further outboard, in the horizontal tail, or control surface attachments.

Identification of all sites of fatigue cracking can help determine the likely scenario that caused the cracking.

Scenario. An effort should be made to determine if there is any correlation between the fatigue cracking sites and the most fatigue critical area on the component under investigation. This requires some knowledge of relative gross area stress levels and physical details of the type design. If the observed cracks are in areas of high gross or local stress, it would be reasonable to expect that similar cracking would eventually occur in other airplanes in the fleet.

Anomalies. The investigator should evaluate the fatigue cracking sites to determine if they contain signs of physical anomalies not expected to occur in the rest of the fleet. These anomalies could be significant manufacturing or service-induced defects exceeding what would be expected or allowed to exist normally. One indication of an anomaly might be if the fatigue-cracking site is in an area of relatively low stress while there are no sites identified in more highly stressed areas. If this is the case, the inspector should carefully examine the site(s) for evidence of tool marks, corrosion, accidental damage or other distress that could have precipitated the apparent premature cracking.

If corrosion is a likely causal factor, the investigation should determine if there are environmental conditions unique to this airplane. SDRs should be searched for other similar occurrences. If a CPCP exists, it should be reviewed. AC 43-4A, Corrosion Control for Aircraft, is a good source for information regarding corrosion prevention, detection, and control.

On occasion, fatigue cracking occurs in one airplane of a fleet due to an anomaly. If demonstrated that the site and scenario observed are unique to the accident or incident airplane, there would be no need to develop a fleet wide FMP. However, the demonstration should include data from a survey of part or all of the fleet to validate the uniqueness of the condition observed. The survey should include an SDR search for other reported occurrences of cracking. Reports of similar cracking on other aircraft could confirm likelihood. However, you should not conclude that cracking is unlikely because of a lack of reports. Experience shows that in many cases cracking incidents go unreported. (Often repairs are made to cracked structure using the DAH published SRM or standard repair procedures per AC 43.13-1B. Although the damage causing the repair should be reported, it is often not.)

Summary. Historically, fatigue cracking found in service or test is later found in other airplanes in the fleet. Although singular fatigue cracking events do occur, they are rare. In making the final determination of whether or not the cracking is likely to occur in other airplanes, one should err on the side of caution. In most cases, discovery of fatigue cracking in an airplane identifies a fatigue critical detail in the basic type design. When this occurs, one should not ignore the warning.

3. FAA Determination of Demonstrated Risk.

The investigation may find fatigue cracking did not contribute or was a singular event not likely to occur in other airplanes of the same type design. In this case, a demonstrated risk due to fatigue does not exist.

If the investigation finds that fatigue cracking contributed to the accident, incident, or in-service finding, and it is likely to exist or develop in other airplanes of the same type design, the FAA would analyze the risk per accountable directorate risk analysis guidelines to determine if a demonstrated risk exists. If a demonstrated risk exists, the FAA would consider issuing an AD requiring mandatory actions to maintain the continued operational safety of the affected fleet. These actions would be included in an FMP to mitigate the demonstrated risk and proactively address the broader risk posed by other fatigue critical structure.

In some instances, the FAA will issue an AD mandating initial, short-term actions to provide short-term mitigation of the demonstrated risk and allow the fleet to return to service. These short-term actions often include operating limitations or immediate and short-interval inspections. The FAA often issues these short-term actions as emergency ADs or IAR ADs. Information learned from these short-term actions, including inspection results, will help the FAA and the applicant to determine a long-term or permanent solution to mitigate the demonstrated risk.

Designers commonly use an exact or similar design detail (e.g., skin splice) previously used on a prior type design for a subsequent type design. For example, when a design detail is simply scaled up or down dimensionally to accommodate higher or lower loads respectively without changing materials. When this is done, it is a common practice for the applicant to demonstrate compliance with the same analysis and test results they used to demonstrate compliance for the prior type design. If the FAA determines the original design detail and its derivative are sufficiently similar, no further showing is required. Consistent with this practice, if the FAA determines a demonstrated risk exists for a design detail for one type design, it may also determine a demonstrated risk exists for other type designs based on the similarity of the design detail. Consequently, ADs would be issued for all those type designs.

APPENDIX 3. AIRWORTHINESS DIRECTIVES WORDING EXAMPLES FOR FATIGUE MANAGEMENT PROGRAMS

1. Summary.

FMPs are essential to continued airworthiness when the FAA identifies an unsafe condition due to fatigue. When the FAA determines a demonstrated risk exists and an FMP is necessary, the FAA will work with the design approval holder or other applicant to determine the appropriate scope of the FMP and necessary steps to execute it properly.

The FAA is also responsible to mandate necessary actions with an AD. Because an AD is a rule change, the FAA requires specific language to meet certain legal standards. The following paragraphs are examples of wording that can be inserted into an AD when the specific actions are necessary.

2. Fatigue Management Programs.

When the FAA determines an FMP is necessary to mitigate an unsafe condition, the following language is suitable for stating the necessary AD action:

> Within *(insert appropriate length of time)* months after the effective date of this AD, do the specified actions at the times identified in the FMP approved specifically for this AD by the Manager, *(insert name of authorizing ACO)*, FAA.
>
> Note: Guidance for developing an FMP that the FAA may approve can be found in FAA Advisory Circular 91-82A, Fatigue Management Programs for In-Service Issues. You may find this document at: http://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.list/parentTopicID/129.

In some cases, an AD may specify interim actions until an FMP is approved or they are specified in a separate AD. In that case, the following additional language is suitable:

> Accomplishment of an FMP approved specifically for this AD by the Manager, *(insert name of authorizing ACO)*, FAA, terminates the requirements of *(insert paragraphs that contain interim action requirements, or AD number that specifies those actions)*.

The above examples are worded in a general nature. For any application, the FAA ACO engineer should work with the AD writers and legal counsel to ensure necessary actions are clearly described and achievable.

3. Inspection Reporting Requirements.

This AC explains the importance of reporting cracks found as a result of an FMP's inspection program. It states inspection results should be reported to the holder of the approved FMP. All cracks found may also be reported to the FAA. If the FAA mandates an FMP with an AD, include crack-reporting instructions in the AD. The following AD language is suitable for stating the information to report when a crack is found:

Report any cracks you find within *(insert a reasonable time frame, 30 days is typical)* days after the cracks are found or within 30 days after *(insert the effective date of this AD)*, whichever occurs later. Send your report to *(insert the name of the responsible ACO engineer, including pertinent contact information, e.g., address, telephone and facsimile number, and email address).* The Office of Management and Budget (OMB) approved the information collection requirements contained in this regulation under the provisions of the Paperwork Reduction Act and assigned OMB Control Number 2120-0056. Include in your report the following information:

(1) Aircraft model and serial number;

(2) Number of cycles *(if applicable)*;

(3) Aircraft hours Time in Service (TIS);

(4) *(insert part description, e.g., right wing front lower spar cap)* hours TIS *(and/or cycles, if applicable, if it is possible for the part to be removed from one aircraft and installed on another)*;

(5) Hours TIS *(and/or cycles, if applicable)* on the *(insert part description)* since last inspection;

(6) Crack location and size;

(7) Procedure (visual, penetrant, magnetic particle, ultrasonic, eddy current, etc.) used for the last inspection *(if the AD permits more than one inspection method)*;

(8) Description of any previous modifications and hours TIS when the modification was done, *(list pertinent examples, if applicable, such as engine model change, installation of winglets, cold working procedures, repairs, or reinforcements of the area cracked area)*;

(9) Corrective action taken;

(10) Point of contact name and phone number; and

(11) Clearly identify the AD No., Docket No., and Directorate Identifier of the AD action requiring the report.

The above list should cover most situations. In some instances, the FAA may request photographs and/or reports of damage other than cracks (corrosion, working rivets, nicks, scratches, etc.). If this is the case, then add that requirement to the list. If items on the list are not applicable, do not include them. Adjust these instructions accordingly if circumstances require inspectors to report additional information or a different report format. Exact wording should be coordinated with the accountable FAA Aircraft Certification Directorate's AD writer-editor staff.

In most instances, the FMP holder (typically the TC holder) will include an inspection reporting form in the FMP instructions. If the reporting form contains the necessary information, then the

AD can specify that form be used to report cracks. The following language is suitable for stating this requirement:

> Report any cracks you find within *(insert a reasonable time frame, 30 days is typical)* days after the cracks are found or within 30 days after *(insert the effective date of this AD)*, whichever occurs later. Report the results to *(insert the FMP/TC holder name here)* using the form in the service bulletin *(or the applicable FMP document)*. Send a copy of this report to *(insert the name of the responsible ACO engineer, including pertinent contact information, e.g., address, telephone and facsimile number, and email address)*. For the reporting requirement in this AD, under the provisions of the Paperwork Reduction Act, the Office of Management and Budget (OMB) has approved the information collection requirements and has assigned OMB Control Number 2120-0056.

In most cases, reporting is necessary only when cracks are found. However, there are some circumstances when it is important for the FAA to know when cracks are not found. The FAA can use this knowledge to help determine the frequency of cracking fleet-wide and the associated safety risk. The following language is suitable for either of the above instructions when all inspection results need to be reported:

> Report all inspection results, positive or negative, within *(insert a reasonable time frame, 30 days is typical)* days after the cracks are found or within 30 days after *(insert the effective date of this AD)*, whichever occurs later. Send your report to *(insert the name of the responsible ACO engineer, including pertinent contact information, e.g., address, telephone and facsimile number, and email address)*. The Office of Management and Budget (OMB) approved the information collection requirements contained in this regulation under the provisions of the Paperwork Reduction Act and assigned OMB Control Number 2120-0056. Include in your report the following information:

FAA-IR-M-8040.1C, Chapter 8, explains the OMB information regarding collection requirements as they relate to the Paperwork Reduction Act.

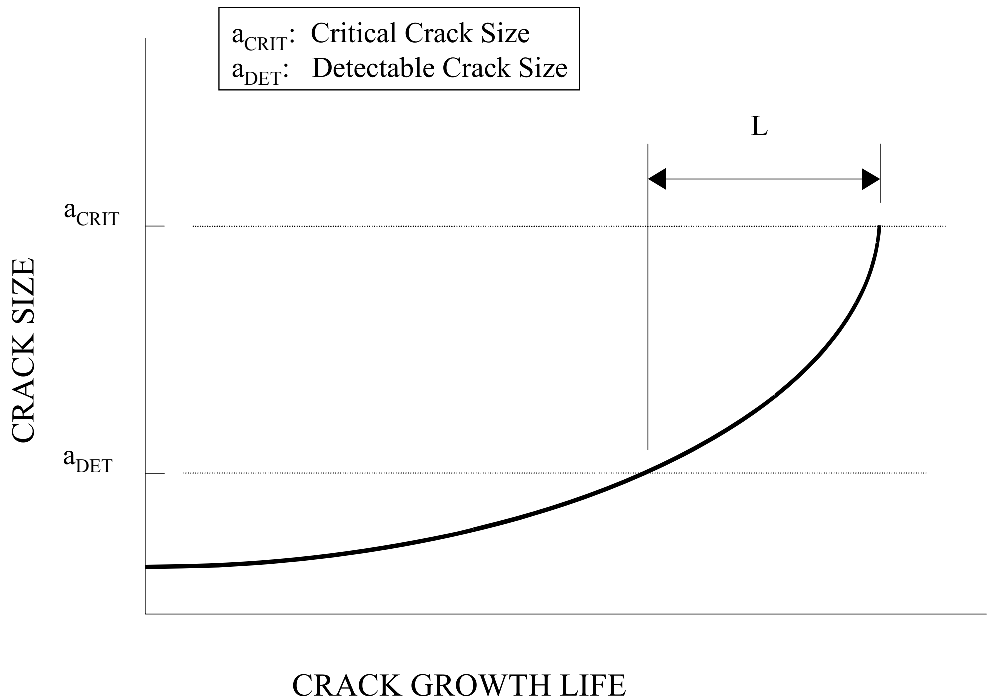
APPENDIX 4. METHODOLOGY FOR DETERMINING REPEAT INSPECTION INTERVALS

The reliability of repeat inspections should assure crack detection before the residual strength degrades below the required level. The inspection method chosen will define the initial detectable crack that will be used to perform the damage-tolerance evaluation. Once the initial detectable crack is defined, crack growth and residual strength assessments must be performed to determine the time for the initial detectable crack (a_{DET}) to grow to a critical size (a_{CRIT}) that would result in failure if the required residual strength loads were applied. These assessments could be performed analytically or by test; however, in most cases they are performed analytically using fracture mechanics methods. It is the applicant's option to determine how complex or simple the analysis should be. The applicant may determine that a simple damage tolerance analysis using conservative assumptions and inspection safety factors produces an acceptable inspection interval.

An applicant may also use a more detailed analysis to justify a longer inspection interval. The applicant should explain and justify all simplifying assumptions. The resulting time for a_{DET} to grow to a_{CRIT} is used to set the inspection interval. This general process applies to both single and multiple load path structure regardless of the level of inspection (e.g., for complete load path failure or less than load path failure in a multiple load path structure). The details are discussed further below.

1. Single Load Path Structure. The time for a detectable crack (a_{DET}) to grow to critical size (a_{CRIT}) in a structure is denoted as L in Figure 4-1. The inspection interval would be established as L divided by an inspection safety factor, K_1, of not less than 2.0. This provides at least two opportunities to find a crack between the time it reaches a detectable size and before it grows to a critical size.

FIGURE 4-1. CRACK GROWTH IN SINGLE LOAD PATH STRUCTURE



2. Multiple Load Path Structure. An acceptable, but potentially conservative approach for multiple load path structure is to treat each element as a single load path and establish inspections, as required, to detect cracking before any single element would fail under the required residual strength loading. However, if the residual strength subsequent to a complete element failure exceeds the required residual strength loading, it might be possible to take advantage of redundancy. Any benefits (e.g., less onerous inspection method and/or longer repeat inspection intervals) would depend on inspectability and the remaining life of the structure with the element failed. When this is done, the likelihood of simultaneous cracking in multiple elements should be considered and accounted for as necessary.

When taking advantage of redundancy in a multiple load path structure there are two scenarios: when the inspection is for a completely failed load path, and when the inspection is for a cracked but not completely failed load path. In either case, the repeat inspection interval will be a function of the secondary load path remaining life (L_S) after primary load path failure. It follows that the resulting interval is only valid out to the time that the cumulative fatigue damage and/or crack growth in the intact structure is accounted for. This issue is illustrated in a crack growth context in Figure 4-2.

FIGURE 4-2. DECREASING REMAINING LIFE IN SECONDARY LOAD PATH WITH TIME FOR MULTIPLE ELEMENT STRUCTURE

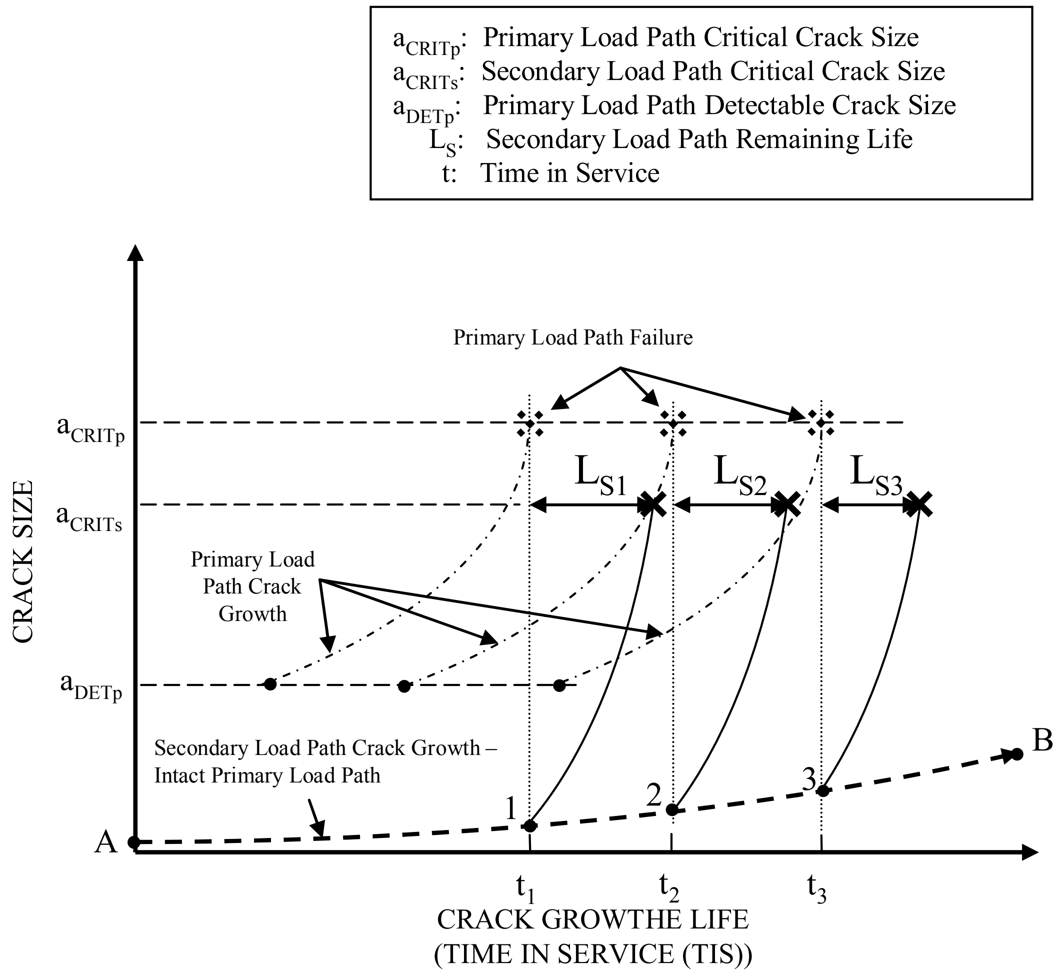


Figure 4-2 illustrates the damage tolerance characteristics of a simple redundant structure consisting of two load paths. The primary load path is the one that is inspected for a crack or complete failure while the secondary load path provides the necessary redundancy. The residual strength of the structure with the primary load path failed and a crack in the secondary load path exceeds the required residual strength until the crack in the secondary load path grows to critical size (a_{CRITs}). Three different crack growth scenarios are shown for a detectable size crack in the primary load path. Each scenario corresponds to the crack in the primary load path becoming detectable at a different point in time and then growing to critical size (a_{CRITp}) and causing complete failure of the primary load path at different points in time (i.e., t_1, t_2 and t_3). At the time of primary load path failure, loading on the secondary load path will increase due to load redistribution and crack growth will accelerate (e.g., subsequent growth from point 1, 2, or 3 depending on if the failure occurs at time t_1, t_2 or t_3). Note that the amount of remaining life in the secondary load path (L_S) has an inverse relationship to the time at which primary load path failure occurs. For example, L_{S3} is less than L_{S2}, which is less than L_{S1} because the longer crack growth life of the primary load path means that a crack in the secondary load path will have also grown longer and thus have a shorter remaining crack growth life once the primary load path fails. Since the repeat inspection interval is a function of L_S and L_S decreases as the time in service increases, the interval will have to be adjusted when the actual time in service exceeds the time in service considered when the interval was originally established.

a. Inspection for Complete Load Path Failure. Detection of a crack prior to load path failure may be feasible, but difficult. If, on the other hand, a failed load path is easily detectable and the remaining life and residual strength of the structure after load path failure is sufficient, it may be desirable to establish an inspection for complete load path failure instead. Analysis or tests as described in the following paragraphs can be used to determine the inspection interval.

(i) Evaluation by Analysis. Figure 4-3 illustrates an example of multiple load path structure for which a completely failed load path is easily detectable. The inspection interval is based on the life of the secondary load path (L_S) after time to primary load path failure (N_F). Consistent with this, damage accumulated in the secondary load path prior to primary load path failure must be accounted for in the analysis. In order to do this within the context of a crack growth analysis it is necessary to assume some initial crack, of size a_i, exists in the secondary load path at time zero. This initial crack size should be representative of normal manufacturing quality. Analytical crack growth in the secondary load path accumulated prior to an assumed primary load path failure is accounted for by calculating the amount of growth, (Δa_i), between time zero and N_F. Load redistribution that may occur prior to N_F should be considered. The secondary load path remaining life (L_S) is the time for a crack of size $a_i + \Delta a_i$ in the secondary load path to grow to critical size assuming a complete primary load path failure has occurred (i.e. "failed" condition loads used – all load now carried by the secondary load path). It should be noted that the calculated time to primary load path failure (N_F) would also represent an upper limit of applicability for any repeat inspection period based on L_S. This is because if the primary load path failed shortly after N_F the time for the assumed crack in the secondary load path to grow to its critical size is less than L_S. (The analyst's selection of L_S and N_F requires judgment based on a balance between a reasonable inspection interval and reasonable period of applicability of the inspection. A longer N_F will result in a shorter L_S and vice versa.) Based on the above discussion, the following applies:

- Inspection Interval = L_S/K_1.
- Inspection Interval Period of Applicability = N_F/K_{SF}.

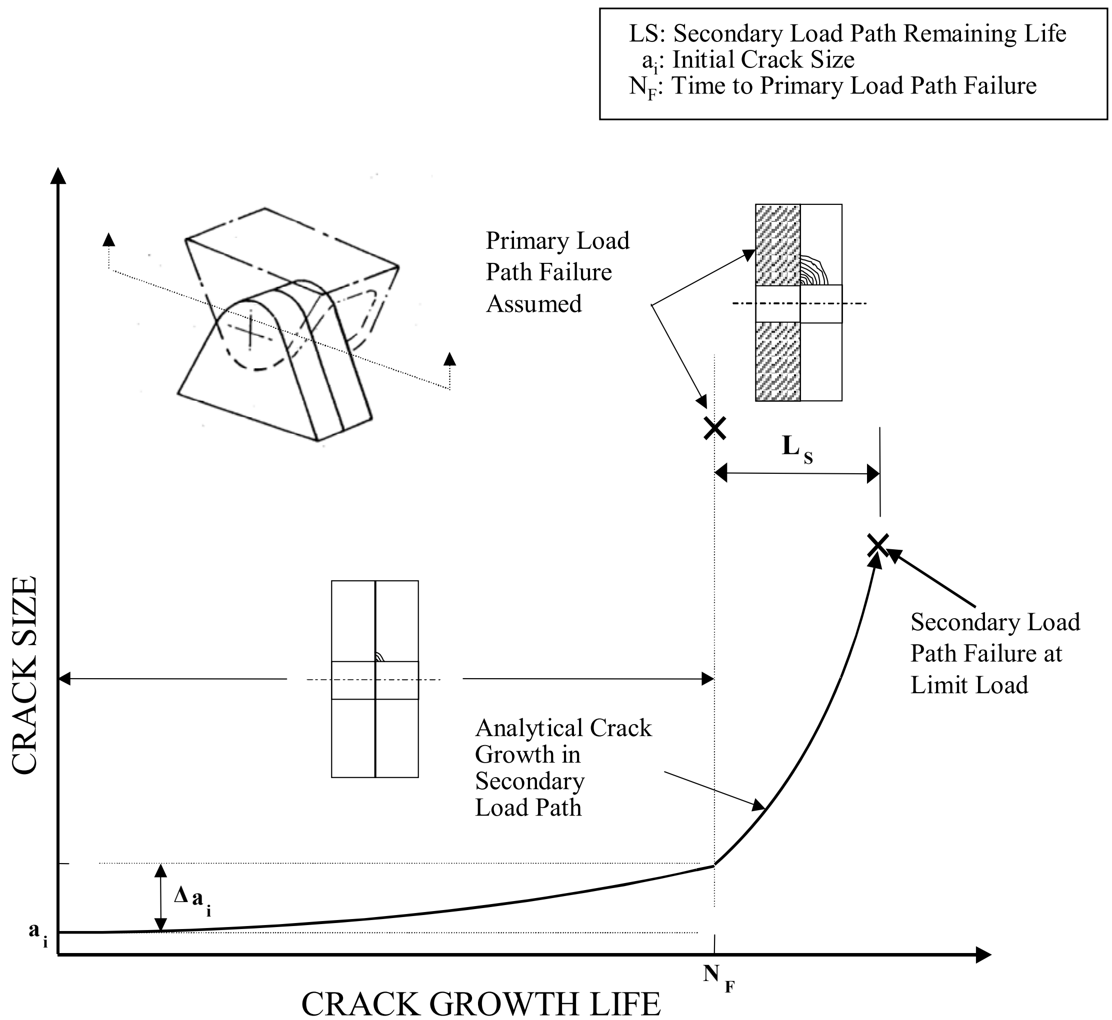
Note 1: Inspection safety factor, K_1, should normally be 2.0 or greater.

Note 2: Life safety factor, K_{SF}, should normally be 1.0 to 2.0 depending on the overall conservatism in the analysis.

Note 3: L_S is remaining life in secondary load path.

Note 4: N_F is time to primary load path failure.

FIGURE 4-3. MULTIPLE LOAD PATH STRUCTURE ANALYTICAL EVALUATION TO SUPPORT INSPECTION FOR A COMPLETELY FAILED LOAD PATH



(ii) Evaluation by Test. Figure 4-4 illustrates some key points if an inspection for a complete load path failure is to be developed based on testing. The inspection interval is based on the test demonstrated remaining life (L_S) subsequent to load path failure. Because the remaining life decreases with the time accumulated prior to a load path failure as previously discussed, there will be a period of applicability for the L_S and it will be dependent on the time at which a primary load path failure (N_F) is simulated.

(iii) The test article should consist of as-manufactured production parts. Representative "well" condition loading should be applied for some predetermined period of time (N_F). At the end of this period the load path that is to be inspected for complete failure should be disabled (e.g., saw cutting, attachment(s) removal, member removal) to simulate its failure. The test should then be restarted with a representative "failed" condition loading. (Note that the external loads may be the same as for the "well" condition if the member failure simulation results in the correct "failed" condition internal load redistribution.) The test should continue until the desired remaining life has been achieved or to the time at which the secondary load path can no longer support the required residual strength loads (N_S), whichever is less. Based on the above discussion, the following applies:

- Demonstrated remaining life = $L_S = N_S - N_F$.
- Inspection interval = L_S/K_1.
- Inspection Interval Period of Applicability = N_F/K_{SF}.

Note 1: Inspection safety factor, K_1, should normally be 2.0 or greater.

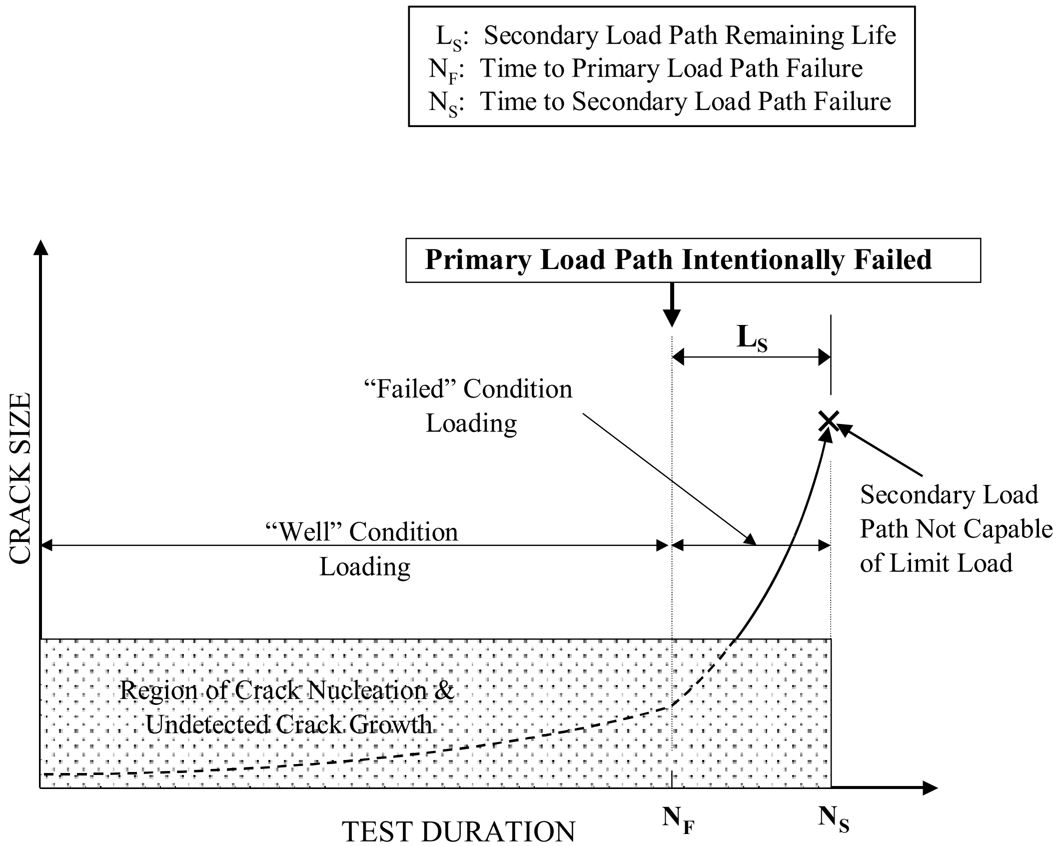
Note 2: Life safety factor, K_{SF}, should be 2.0 for test.

Note 3: L_S is remaining life in secondary load path.

Note 4: N_F is time to primary load path failure.

Note 5: N_S is time to secondary load path failure.

FIGURE 4-4. MULTIPLE LOAD PATH STRUCTURE EVALUATION BY TEST TO SUPPORT INSPECTION FOR A COMPLETELY FAILED LOAD PATH



b. Inspection for Less Than a Complete Load Path Failure. Inspection for less than a load path failure may require special NDE procedures. However, it should result in a longer inspection interval than intervals for detecting more obvious complete load path failure as discussed in paragraph 2a. Figure 4-5 illustrates how inspection intervals could be established based on crack growth and residual strength evaluation.

In this case, the inspection interval is based on the life of the secondary load path (L_S) subsequent to primary load path failure at N_F plus the time (L_P) for a detectable crack size (a_{DET}) in the primary load path to grow to critical size under in-service loads. The determination of L_S is the same as discussed in paragraph 2(a)(i) above. Based on the above discussion, the following applies:

- Inspection Interval = $(L_P + L_S)/K_1$.

- Inspection Interval Period of Applicability = N_F/K_{SF}.

Note 1: Inspection safety factor, K_1, should normally be 2.0 or greater.

Note 2: Life safety factor, K_{SF}, should normally be 1.0 to 2.0 depending on the overall conservatism in the analysis.

Note 3: L_P is life from a_{DET} to primary load path failure.

Note 4: L_S is remaining life in secondary load path.

Note 5: N_F is time to primary load path failure.

FIGURE 4-5. MULTIPLE LOAD PATH STRUCTURE ANALYTICAL EVALUATION TO SUPPORT INSPECTION FOR LESS THAN A FAILED LOAD PATH

L_P: Primary Load Path Life
L_S: Secondary Load Path Remaining Life
N_F: Time to Primary Load Path Failure
a_{DET}: Detectable Crack Size
a_i: Initial Crack Size