U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: Damage Tolerance and Fatigue Evaluation of Structure
Date: 1/13/2011
Initiated By: ANM-115
AC No: 25.571-1D

1. Purpose.

a. This advisory circular (AC) provides guidance for compliance with the provisions of Title 14, Code of Federal Regulations (14 CFR) part 25, pertaining to the requirements for damage-tolerance and fatigue evaluation of transport category aircraft structure, including evaluation of widespread fatigue damage (WFD) and establishing a limit of validity of the engineering data that supports the structural-maintenance program (hereafter referred to as the LOV). This AC also includes guidance pertaining to discrete source damage.

b. The following appendices appear at the end of this AC:

- Appendix 1 – References and Definitions
- Appendix 2 – Full-Scale Fatigue Testing
- Appendix 3 – Process for Compliance with 14 CFR 25.571(a), (b) and (c) for Fatigue Damage
- Appendix 4 – Examples of Alterations that May Require Full-Scale Fatigue Testing
- Appendix 5 – PSE, FCS and WFD-Susceptible Structure
- Appendix 6 – Acronyms and Abbreviations Used in this AC

2. Applicability.

a. The guidance provided in this document is directed to airplane manufacturers, modifiers, foreign civil-aviation authorities, and Federal Aviation Administration (FAA) transport airplane type certification engineers and designees.

b. This material is neither mandatory nor regulatory in nature and does not constitute a regulation. It describes acceptable means, but not the only means, for demonstrating compliance with the applicable regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. While these guidelines are not mandatory, they are derived from extensive FAA and industry experience in determining compliance with the relevant regulations. On the other hand, if the FAA becomes aware of circumstances that convince us that following this AC would not result in compliance with the applicable regulations, we will not be bound by the terms of this AC, and we may require additional substantiation or design changes as a basis for finding compliance.

c. This material does not change, create additional, authorize changes in, or permit deviation from regulatory requirements.

3. Cancellation. AC 25.571-1C, dated April 29, 1998, is canceled.

4. Background.

a. Since the early 1970s, there have been significant developments in the state-of-the-art and industry-practice in the area of structural-fatigue and fail-safe strength evaluation of transport category airplanes. Recognizing that these developments could warrant some revision of the existing fatigue requirements of §§ 25.571 and 25.573, on November 18, 1976 (41 FR 50956), the FAA gave notice of the Transport Category Airplane Fatigue Regulatory Review Program, inviting interested persons to submit proposals to amend those requirements. The proposals and related discussions formed the basis for the revision of the structural-fatigue-evaluation standards of §§ 25.571 and 25.573, and the development of guidance material. To that end, § 25.571 was revised, § 25.573 was deleted (the scope of § 25.571 was expanded to cover the substance of the deleted section), and guidance material (AC 25.571-1) was prepared.

b. After issuance of AC 25.571-1 on September 28, 1978, additional guidance material, including guidance on discrete source damage, was developed and incorporated in revision 1A, issued on March 5, 1986. The AC was further revised on February 18, 1997; revision 1B added guidance on the elements to be considered in developing scatter factors for certification. Revision 1C of the AC was issued April 29, 1998, to add guidance pertaining to precluding widespread fatigue damage within the design service goal of the airplane and determining thresholds for fatigue inspection. This revision removes guidance material for precluding WFD up to the design service goal and replaces it with guidance material for precluding WFD up to the LOV.

5. Introduction.

a. General. The FAA considers the contents of this AC in determining compliance with the damage-tolerance, fatigue, and discrete source damage requirements of § 25.571.

(1) The requirements of § 25.571 apply equally to metallic and composite structure. The focus of this AC is metallic structure. Refer to AC 20-107B for guidance on composite structure.

(2) Section 25.571 requires applicants to evaluate all structure that could contribute to catastrophic failure of the airplane with respect to its susceptibility to fatigue, corrosion, and accidental damage. The applicant must establish inspections or other procedures (herein also referred to as maintenance actions) as necessary to avoid catastrophic failure during the operational life of the airplane based on the results of these evaluations. Section 25.571 also

requires the applicant to establish an LOV. The LOV, in effect, is the operational life of the airplane consistent with evaluations accomplished and maintenance actions established to prevent WFD. Although the LOV is established based on WFD considerations, it is intended that all maintenance actions required to address fatigue, corrosion, and accidental damage up to the LOV are identified in the structural-maintenance program. All inspections and other procedures (e.g., modification times, replacement times) that are necessary to prevent a catastrophic failure due to fatigue, up to the LOV, must be included in the Airworthiness Limitations section (ALS) of the Instructions for Continued Airworthiness (ICA), as required by § 25.1529, along with the LOV.

(3) Although a uniform approach to the evaluation required by § 25.571 is desirable, the FAA recognizes that, in such a complex field, new design features and methods of fabrication, new approaches to the evaluation, and new configurations could necessitate variations and deviations from the procedures described in this AC.

(4) Compliance with § 25.571(b), *Damage-tolerance evaluation*, is not required if the applicant establishes that it is impracticable to apply the regulation to particular structure. An example of structure that may not be conducive to damage-tolerant design is the landing gear and its attachments. In this case, the applicant may comply instead with § 25.571(c), *Fatigue (safe-life) evaluation*. The FAA does not allow exclusive reliance on damage-tolerance-based inspections for structure susceptible to WFD. The applicant must demonstrate that WFD is unlikely to occur prior to the LOV for the airplane. An applicant may use damage-tolerance-based inspections for multiple site damage (MSD)/multiple element damage (MED) to supplement replacement or modification required to preclude WFD when shown to be practical.

(5) The applicant should perform crack-growth and residual-strength testing to produce the design data needed to support crack-growth and residual-strength analyses. Full-scale fatigue-test evidence is required to support the evaluation of structure that is susceptible to WFD. Test evidence is needed to support analysis used to establish safe-life replacement times.

(6) Replacement times, inspections, or other procedures to address fatigue cracking must be established as necessary. These actions must be based on quantitative evaluations of the fatigue characteristics of the structure. In general, analysis supported by test evidence will be necessary to generate the information needed; service experience may also be used. The applicant should identify the intended approach in a compliance plan. All inspections, modification times, replacement times, and LOVs that are necessary to prevent a catastrophic failure – based on the damage-tolerance, fatigue, and WFD evaluations – must be included in the ALS of the ICA as required by § 25.1529.

(7) The applicant must establish inspections or other procedures for environmental damage and accidental damage as necessary to prevent catastrophic failure. Guidance for establishing environmental damage and accidental damage maintenance actions is included in section 6 of this AC.

b. Typical loading spectrum expected in service. The loading spectrum used for crack-growth and fatigue-crack-initiation assessments (tests or analyses) should be based on measured statistical data of the type derived from government and industry load-history studies and, where data is insufficient or unavailable, on a conservative estimate of the anticipated use of the airplane. The principal loads that should be considered in establishing a loading spectrum are flight loads (gust and maneuver), ground loads (taxiing, landing impact, turning, engine run-up, braking, thrust reversing, and towing), and pressurization loads. The development of the loading spectrum includes the definition of the expected flight plan, which involves climb, cruise, descent, flight times, operational speeds and altitudes, and the approximate time to be spent in each of the operating regimes. Operations for crew training and other pertinent factors, such as the dynamic stress characteristics of any flexible structure excited by turbulence or buffeting, should also be considered. For pressurized cabins, the loading spectrum should include the repeated application of the normal operating differential pressure, and the superimposed effects of flight loads and external aerodynamic pressures.

c. Structure to be evaluated. When assessing the possibility of fatigue failures, the applicant should examine the design to determine probable points of failure in service. In this examination, consideration should be given, as necessary, to (1) the results of stress analyses, static tests, fatigue tests, strain-gauge surveys, and tests of similar structural configurations and (2) service experience. Service experience has shown that special attention should be focused on the design details of important discontinuities, attachment fittings, tension joints, splices, and cutouts such as windows, doors, and other openings. Locations prone to accidental damage (such as that due to impact with ground servicing equipment near airplane doors) or to corrosion should also be considered.

d. Analyses and tests. Repeated load analyses or tests should be conducted on structures representative of components or subcomponents of the wing, control surfaces, empennage, fuselage, landing gear, and their related primary attachments. Analyses and tests need not be conducted if it is determined from the foregoing examination that the normal operating stresses in specific regions of the structure are of such a low order that significant damage growth is extremely improbable. Test articles should include structure representative of attachment fittings, tension joints, splices, changes in section, cutouts, and discontinuities. Any method used in the analyses should be supported, as necessary, by test or service experience. Typical (average) values of material properties that account for the quantifiable effects of environment and other parameters may be used in residual-strength, crack-growth, and damage-detection analyses for damage-tolerance assessments and for discrete source damage. These are described, respectively, in sections 6 and 9 of this AC.

6. Damage-Tolerance Evaluation.

a. General. The damage-tolerance evaluation of structure is intended to ensure that—should fatigue, corrosion, or accidental damage occur within the LOV of the airplane—the remaining structure can withstand reasonable loads without failure or excessive structural deformation until the damage is detected. The damage-tolerance evaluation should include the following:

- identification of the structure to be evaluated,
- definition of the loading conditions and extent of damage,

- structural tests or analyses, or both, to substantiate that the design objective has been achieved, and

- generation of supporting data for inspection programs to ensure detection of damage.

Although this evaluation applies to either single- or multiple-load-path structure, the use of multiple load path structure should be given high priority in achieving a damage-tolerant design. Design features that should be considered in attaining a damage-tolerant structure include the following:

(1) Multiple load path construction, and the use of crack stoppers to control the rate of crack growth and to provide adequate residual strength;

(2) Materials and stress levels that, after initiation of cracks provide a controlled slow rate of crack propagation combined with high residual strength;

(3) Arrangement of design details to ensure a high probability that a failure in any critical structural element will be detected before the strength of the element has been reduced below the level necessary to withstand the loading conditions specified in § 25.571(b), thereby allowing timely replacement or repair of the failed elements.

b. Damage-Tolerance Assessment Methodologies. Normally, the damage-tolerance assessment consists of a deterministic evaluation of the design features described in this section. Sections 6c through 6j below provide guidelines for this approach. In certain specific instances, however, damage-tolerant design might be more realistically assessed by a probabilistic evaluation, employing methods such as risk analysis. Risk analyses are routinely employed in fail-safe evaluations of airplane systems and have occasionally been used where structure and systems are interrelated. These methods can be of particular value for structure consisting of discrete elements, where damage tolerance depends on the ability of the structure to sustain redistributed loads after failures resulting from fatigue, corrosion, or accidental damage. Where considered appropriate on multiple load path structure, a probabilistic analysis may be used if it can be shown that (1) loss of the airplane is extremely improbable, and (2) the statistical data employed in the analysis of similar structure is based on tests or operational experience, or both.

c. Identification of principal structural elements. As defined in this AC, a principal structural element is an element of structure that contributes significantly to the carrying of flight, ground, or pressurization loads and whose integrity is essential in maintaining the overall structural integrity of the airplane. Principal structural elements include all structure susceptible to fatigue cracking, which could contribute to a catastrophic failure. Refer to appendix 5 of this AC for clarification on how this term relates to the terms, fatigue critical structure (FCS) and WFD – susceptible structure. Examples of such elements are as follows:

(1) Wing and empennage.

(a) Control surfaces, slats, flaps, and their mechanical systems and attachments (hinges, tracks, and fittings);

(b) Integrally stiffened plates;

(c) Primary fittings;

(d) Principal splices;

(e) Skin or reinforcement around cutouts or discontinuities;

(f) Skin-stringer combinations;

(g) Spar caps; and

(h) Spar webs.

(2) Fuselage.

(a) Circumferential frames and adjacent skin;

(b) Door frames;

(c) Pilot-window posts;

(d) Pressure bulkheads;

(e) Skin and any single frame or stiffener element around a cutout;

(f) Skin or skin splices, or both, under circumferential loads;

(g) Skin or skin splices, or both, under fore and aft loads;

(h) Skin around a cutout;

(i) Skin and stiffener combinations under fore and aft loads;

(j) Door skins, frames, and latches; and

(k) Window frames.

(3) Landing gear and their attachments.

(4) Engine mounts.

d. Extent of damage. Each particular design should be assessed to establish appropriate damage criteria in relation to inspectability and damage-extension characteristics. In any damage determination, including those involving multiple cracks, it is possible to establish the extent of damage in terms of the following parameters:

- detectability with the inspection techniques to be used,

- the associated, initially detectable crack size,
- the residual-strength capabilities of the structure, and
- the likely damage-extension rate.

This determination should consider the expected stress redistribution under the repeated loads expected in service at the expected inspection frequency. Thus, an obvious partial failure could be the extent of the damage for residual-strength assessment, provided that the fatigue cracks will be detectable at a sufficiently early stage of crack development. The following are examples of partial failures that should be considered in the evaluation:

(1) Detectable skin cracks emanating from the edge of structural openings or cutouts;

(2) A detectable circumferential or longitudinal skin crack in the basic fuselage structure;

(3) Complete severance of interior frame elements or stiffeners in addition to a detectable crack in the adjacent skin;

(4) A detectable failure of one element of components in which dual construction is used, such as spar caps, window posts, window or door frames, and skin structure;

(5) A detectable fatigue failure in at least the tension portion of the spar web or similar element; and

(6) The detectable failure of a primary attachment, including a control surface hinge and fitting.

e. **Inaccessible areas.** Every reasonable effort should be made to ensure inspectability of all structural parts and to qualify those parts under the damage-tolerance provisions (see § 25.611).

f. Testing of principal structural elements. The nature and extent of residual-strength tests on complete structures or on portions of the primary structure depends upon applicable previous design, construction, tests, and service experience with similar structures. Simulated cracks should be as representative as possible of actual fatigue damage. Where it is not practical to produce actual fatigue cracks, damage can be simulated by cuts made with a fine saw, sharp blade, guillotine, or other suitable means. If saw cuts in primary structure are used to simulate sharp fatigue cracks, sufficient evidence should be available from element tests to indicate equivalent residual strength. In those cases where bolt failure or its equivalent is to be simulated as part of a possible damage configuration in joints or fittings, bolts can be removed to provide that part of the simulation.

g. Identification of locations to be evaluated. The locations of damage to structure for damage-tolerance evaluation should be identified as follows:

(1) Determination of general damage locations. The evaluation would include a determination of the probable locations and modes of damage due to fatigue, corrosion, or accidental damage. Repeated load and static analyses, supported by test evidence and (if available) service experience, would also be incorporated in the evaluation. Special consideration for widespread fatigue damage must be included where the design is such that this type of damage could occur. The location and modes of damage can be determined by analysis or service experience, or by fatigue tests on complete structures or subcomponents. However, tests may be necessary when the basis for analytical prediction is not reliable, such as for complex components. If less than the complete structure is tested, ensure that the internal loads and boundary conditions are valid.

(a) If a determination is made by analysis, take into account factors such as the following:

1 Strain data on undamaged structure to establish points of high-stress concentration as well as the magnitude of the concentration;

2 Locations where permanent deformation occurred in static tests;

3 Locations of potential fatigue damage identified by fatigue analysis; and

4 Design details that service experience, of similarly designed components, indicates are prone to fatigue or other damage.

(b) In addition, the areas of probable damage from other sources, such as severe corrosion or accidental damage, should be determined from a review of the design and past service experience.

(2) Selection of critical damage areas. The process of actually locating where damage should be simulated in principal structural elements (identified in section 6d of this AC) should take into account factors such as the following:

(a) Review analysis to locate areas of maximum stress and low margin of safety;

(b) Select locations in an element where the stresses in adjacent elements would be the maximum with the damage present;

(c) Select partial-fracture locations in an element where high stress concentrations are present in the residual structure; and

(d) Select locations where detection would be difficult.

h. Damage-tolerance analysis and tests.

(1) Analysis, supported by test evidence, should determine that:

(a) The structure with the extent of damage established for residual-strength evaluation can withstand the specified design-limit loads (considered as ultimate loads); and

(b) The damage-growth rate under the repeated loads expected in service – between the time the damage becomes initially detectable and the time the extent of damage reaches the value for residual-strength evaluation – provides a practical basis for development of the inspection program and procedures described in section 6j of this AC.

(2) The repeated loads should be as defined in the loading, temperature, and humidity spectra. The loading conditions should take into account the effects of structural flexibility and rate of loading where they are significant.

(3) The damage-tolerance characteristics can be shown analytically by reliable or conservative methods, such as the following:

(a) Demonstrating quantitative relationships with structure already verified as damage tolerant;

(b) Demonstrating that the damage would be detected before it reaches the value for residual-strength evaluation; or

(c) Demonstrating that the repeated loads and limit-load stresses do not exceed those of previously verified designs of similar configuration, materials, and inspectability.

(4) The maximum extent of immediately obvious damage from discrete sources should be determined, and the remaining structure shown to have static strength for the maximum load (considered as ultimate load) expected during the remainder of the flight. Normally, this would be an analytical assessment. In the case of uncontained engine failure, the fragments and paths to be considered should be consistent with those used in showing compliance with § 25.903(d)(1) and with typical damage experienced in service. (See AC 20-128, "Design Considerations for Minimizing Hazards Caused by Uncontained Turbine Engine and Auxiliary Power Unit Rotor and Fan Blade Failures.")

i. Inspection.

(1) Detection of damage before it becomes critical is the ultimate control in ensuring the damage-tolerance characteristics of the structure. For this reason, Amendment 25-54 revised § 25.571 to require that the applicant (1) establish inspections or other procedures, as necessary, to prevent catastrophic failure from accidental, environmental, or fatigue damage, and (2) include those inspections and procedures in the ALS of the ICA, as required by § 25.1529 (see also appendix H to part 25).

(2) Due to the complex interactions of the many parameters affecting damage tolerance – such as operating practices, environmental effects, load sequence on crack growth, and variations in inspection methods – take into account related operational experience in

establishing inspection procedures. Additionally, give careful consideration to the practical nature of inspection procedures.

(3) Comparison with past successful practice is the primary means of substantiating inspections or other procedures for accidental and environmental damage. For a new-model transport category airplane, the Maintenance Review Board generally conducts such comparison to substantiate inspections or other actions using the Air Transport Association of America, Inc. (ATA) Maintenance Steering Group's MSG-3 or other accepted version of the "Operator/Manufacturer Scheduled Maintenance Development" procedures. If this process is used, the required maintenance actions for accidental and environmental damage must be documented in the Maintenance Review Board Report for the airplane model and must be complete not later than when the first airplane enters service. These inspections or other procedures, as necessary to prevent catastrophic failure of the airplane, must be included in the Airworthiness Limitations section of the ICA. Alternatively, the applicant may reference, in the ALS of the ICA, the maintenance documents that contain those tasks. The ALS should also contain reference to any corrosion prevention and control program (CPCP) developed to maintain corrosion to "Level 1" or better for that airplane model. "Level 1" corrosion is damage occurring between successive inspections that is local and can be reworked/blended-out within allowable limits as defined by the manufacturer's service information, such as structural-repair manuals and service bulletins.

(4) In some cases, the experience of an operator may indicate that different inspections or other procedures are appropriate for that operator. Title 14 CFR 43.16 and 14 CFR 91.403(c) provide a means for FAA approval of alternatives to the airworthiness limitations. The FAA will evaluate such proposed alternatives, using the methods described in this AC or other acceptable methods proposed by the type-certificate holder and operators, to ensure that the objectives of 14 CFR 25.571 continue to be met.

j. Threshold for Inspections.

(1) Where it can be shown by observation, analysis, and/or test that a load path failure in multiple load path "fail-safe" structure or partial failure in crack-arrest "fail-safe" structure will be detected and repaired during normal maintenance, inspection, or operation of an airplane prior to failure of the remaining structure, the thresholds can be established using either:

(a) Fatigue analysis and tests with an appropriate scatter factor; or

(b) Slow-crack-growth analyses and tests, based on appropriate initial manufacturing damage.

(2) For single load path structure and for multiple load path and crack-arrest "fail-safe" structure – where it cannot be demonstrated that load-path failure, partial failure, or crack arrest will be detected and repaired during the normal maintenance, inspection, or operation of an airplane prior to failure of the remaining structure – the thresholds should be established based on crack-growth analyses and/or tests, assuming the structure contains an initial flaw of the maximum probable size that could exist as a result of manufacturing- or service-induced damage.

7. Establishing an LOV.

a. Structural-maintenance program.

(1) If an airplane is properly maintained, theoretically it could be operated indefinitely. However, it should be noted that structural-maintenance tasks for an airplane are not constant with time. Tasks typically are added to the maintenance program as the airplane ages. It is reasonable to expect, then, that confidence in the effectiveness of current structural-maintenance tasks may not, at some future point, be sufficient for continued operation. Maintenance tasks for a particular airplane can only be determined based on what is known about that airplane model at any given time; from analyses, tests, service experience, and teardown inspections. Widespread fatigue damage is of particular concern because inspection methods cannot be relied on solely to ensure the continued airworthiness of airplanes indefinitely. To prevent WFD from occurring, the structure occasionally must be modified or replaced. Establishing all the replacements and modifications required to operate the airplane indefinitely is an unbounded problem. This problem is solved by establishing limit of validity of the engineering data that supports the structural-maintenance program. All necessary modifications and replacements are required to be established to ensure continued airworthiness relative to WFD up to the LOV. To operate beyond the LOV, the full-scale fatigue-test evidence and the structural maintenance program must be re-evaluated to determine if additional modifications or replacements are required. See paragraph 7.g for the steps to extend the LOV.

b. Widespread Fatigue Damage.

(1) Structural fatigue damage is progressive. It begins as minute cracks, and those cracks grow under repeated stresses. It can initiate as a result of normal operational conditions and design attributes, or from isolated incidents, such as material defects, poor fabrication quality, or corrosion pits, dings, or scratches. Fatigue damage can occur locally, in small areas or structural design details, or globally. Global fatigue damage is a general degradation of large areas of structure that share similar structural details and stress levels. Global damage may occur in a large structural element, such as a single rivet line of a lap splice joining two large skin panels (multiple site damage). Or, it may be found in multiple elements, such as adjacent frames or stringers (multiple element damage). Multiple site damage and multiple element damage cracks are typically too small, initially, to be reliably detected with normal inspection methods. Without intervention, these cracks will grow, and eventually compromise the structural integrity of the airplane, in a condition known as widespread fatigue damage. Widespread fatigue damage is increasingly likely as an airplane ages, and is certain if an airplane is operated long enough without any intervention.

c. Steps for Establishing an LOV.

(1) Under § 25.571, persons applying for type certificates (TC) must establish an LOV for each new type design. For new airplane models, or design changes to existing models that are added to the TC, the type-certificate holder must either establish an LOV for the new or design-changed model, or show that the LOV for the originally certificated model can also be applied to the new or design-changed model. The LOV is the period of time (in flight cycles, flight hours, or both) up to which it has been demonstrated that widespread fatigue damage is

unlikely to occur in an airplane's structure by virtue of its inherent design characteristics and any required maintenance actions. An airplane may not operate beyond the LOV. To support establishment of the LOV, the applicant must demonstrate, by test evidence and analysis at a minimum and, if available, service experience, or service experience and teardown-inspection results of high-time airplanes, that WFD is unlikely to occur in that airplane up to the LOV. An LOV applies to an airplane structural configuration common to a fleet.

(2) The process for establishing an LOV involves four steps—

- Identifying a "candidate LOV."
- Identifying WFD-susceptible structure.
- Performing a WFD evaluation of all susceptible structure.
- Finalizing the LOV and establishing necessary maintenance actions.

(a) Step 1 – Candidate LOV. Any LOV can be valid as long as it has been demonstrated that the airplane model will be free from WFD up to the LOV based on the airplane's inherent fatigue characteristics and any required maintenance actions. Early in the certification process, applicants typically establish design service goals or their equivalent and set a design service objective to have structure remain relatively free from cracking, up to the design service goal. A recommended approach sets the "candidate LOV" equal to the design service goal. The final LOV would depend on both how well that design objective was met and the applicant's consideration of the economic impact of maintenance actions required to preclude WFD up to the final LOV.

(b) Step 2 – Identify WFD-Susceptible Structure. The applicant should identify the structure that is susceptible to WFD to support post-fatigue-test teardown inspections or residual-strength testing necessary to demonstrate that WFD will not occur in the airplane structure up to the LOV. Appendix 5 of AC 120-104 provides examples and illustrations of structure where multiple site damage or multiple element damage has been documented. The list in appendix 5 is not meant to be inclusive of all structure that might be susceptible on any given airplane model and it should only be used for general guidance. It should not be used to exclude any particular structure. The applicant should do the following when developing the list of structure susceptible to WFD:

1 Establish criteria that could be used for identifying what structure is susceptible to WFD based on the definitions (see appendix 1) of multiple site damage, multiple element damage, and WFD. For example, structural details and elements that are repeated over large areas and operate at the same stress levels are obvious candidates. The criteria should be part of the applicant's compliance data.

2 Provide supporting rationale for including and excluding specific structural areas. This should be part of the applicant's compliance data.

3 Identify the structure to a level of detail required to support post-test activities that the applicant will use to evaluate the residual-strength capabilities of the structure. Structure is free from WFD if the residual strength meets or exceeds that required by § 25.571(b). Therefore, the post-test activities, such as teardown inspections and residual-strength tests, must provide data that support the determination of strength.

- For teardown inspections, specific structural details (e.g., holes, radii, fillets, cutouts) need to be identified.

- For residual-strength testing, the identification at the component or subcomponent level (e.g., longitudinal skin splices) may be sufficient.

(c) Step 3 – Evaluation of WFD-Susceptible Structure. Applicants must evaluate all susceptible structure identified in Step 2. Applicants must demonstrate, by full-scale fatigue-test evidence, that WFD will not occur in the airplane structure prior to the LOV. This demonstration typically entails full-scale fatigue testing, followed by teardown inspections and a quantitative evaluation of any finding or residual-strength testing, or both. Additional guidance about full-scale fatigue-test evidence is included in appendix 2 of this AC.

(d) Step 4 – Finalize LOV. After all susceptible structure has been evaluated, finalize the LOV. The results of the evaluations performed in Step 3 will either demonstrate that the strength at the candidate LOV meets or exceeds the levels required by § 25.571(b), or not. If it is demonstrated that the strength is equal to or greater than that required, the final LOV could be set to the candidate LOV without further showing. If it is demonstrated that the strength is less than the required level, at least two outcomes are possible.

1 Final LOV may equal the candidate LOV. However, this would result in maintenance actions, design changes, or both maintenance actions and design changes to support operation of airplanes up to LOV. For MSD/MED, an applicant may use damage-tolerance-based inspections to supplement replacement or modification required to preclude WFD when those inspections have been shown to be practical and reliable.

(aa) Maintenance actions. In some cases, maintenance actions may be necessary for an airplane to reach its LOV. These maintenance actions could include inspections, modifications, replacements, or any combination of these. The applicant must substantiate the maintenance actions per the guidance contained in this AC.

- For initial certification, these actions should be both specified as airworthiness-limitation items and incorporated into the ALS of the ICA.

- For post-certification airplanes, these actions should be specified as service information by the TC holder and may be mandated by FAA airworthiness directives. Refer to AC 120-104 for additional maintenance-action guidance.

(bb) Design changes. The applicant may determine that developing design changes to prevent WFD in future production airplanes is to their advantage. The applicant must substantiate the design changes per the guidance contained in this AC.

2 Final LOV may be less than the candidate LOV. This could preclude having maintenances actions or making design changes.

(aa) In addition to the technical considerations, the LOV may be based on several other factors, including—

- Maintenance considerations.
- Operator input.
- Economics.

d. Airworthiness Limitations section (ALS). In accordance with 14 CFR 21.50, the type-certificate holder must provide the ICA, which includes the ALS, with the airplane. However, the type-certificate holder may or may not have completed the full-scale fatigue-test program at the time of type certification.

(1) Fatigue testing is not completed. Under 14 CFR 25.571, the FAA may issue a type certificate for an airplane model prior to the applicant's completion of full-scale fatigue testing, provided that the Administrator has approved a plan for completing the required tests. Until the full-scale fatigue testing is completed and the FAA has approved the LOV, the type-certificate holder must establish a limitation that is equal to one-half the number of cycles accumulated on the test article. (See appendix 2 in this AC for more information about the test article.) At the time of type certification, the applicant should show that at least one calendar year of safe operation has been substantiated using fatigue-test evidence. Under appendix H to part 25, the ALS must contain a defined limitation equal to one-half the number of cycles accumulated on the fatigue-test article approved under § 25.571. This limitation is an airworthiness limitation. No airplane may be operated beyond this limitation until the fatigue testing is completed and an LOV is approved. As additional cycles on the fatigue-test article are accumulated, this limitation may be adjusted accordingly. Upon completion of the full-scale fatigue test, applicants should perform specific inspections and analyses to determine whether WFD has occurred. Additional guidance about post-test WFD evaluations is included in appendix 2 of this AC.

(2) Fatigue testing is completed. After the full-scale fatigue test has been completed, the applicant must include the following in the ALS (see appendix 2 of this AC for additional guidance):

- Under appendix H to part 25, the ALS must contain the LOV stated as a number of total accumulated flight cycles or flight hours approved under § 25.571.
- Depending on the results of the evaluation under Step 3, the ALS may also include requirements to inspect, modify, or replace structure.

e. Type-design changes (Amendment 25-96 or later). Any person applying for an amended type certificate or a supplemental type certificate to introduce a type design change that adds or affects WFD-susceptible structure must demonstrate that new and affected structure are free from WFD up to the LOV of the airplane. This demonstration may include analysis supported by fatigue-test evidence (see appendix 2 of this AC), analysis that correlates to relevant existing full-scale fatigue-test results, or both. Where analysis supported by test evidence demonstrates freedom from WFD, the applicant may use one of the following approaches to demonstrate freedom from WFD. One approach is based on fatigue-crack initiation and relies on fatigue data. Another approach is based on crack growth and requires the application of fracture-mechanics methods. Inspections or other procedures necessary to prevent catastrophic failure from accidental, environmental, or fatigue damage (including WFD) up to the LOV must be included in the ALS of the ICA, as required by § 25.1529. (See also appendix H to part 25). As an alternative for accidental and environmental damage, the documents containing the ICA may be referenced in the ALS of the ICA. See section 6i of this AC for further guidance.

f. Repairs (Amendment 25-96 or later). Any person performing a major repair that adds or affects WFD-susceptible structure must demonstrate that any new and affected structure is free from WFD up to the LOV of the airplane. If a repair does not add or affect WFD-susceptible structure, no further WFD evaluation is required. Where analysis supported by test evidence demonstrates freedom from WFD, the applicant may use one of the following approaches to demonstrate freedom from WFD. One approach is based on fatigue-crack initiation and relies on fatigue data. Another approach is based on crack growth and requires the application of fracture-mechanics methods. Refer to appendix 5 of AC 120-93 for the repair-approval process. If WFD is determined likely to occur before the LOV is reached, the applicant must either—

(1) redesign the proposed repair to preclude WFD from occurring before the airplane reaches the LOV, or

(2) develop maintenance actions to preclude WFD from occurring before the airplane reaches the LOV. For repairs, an applicant must identify and include these actions as part of the repair data.

g. Extended LOV. If an applicant proposes to extend an LOV, they must comply with the requirements of 14 CFR 26.23. Refer to AC 120-104 for guidance on extending an LOV. Typically, the data necessary to extend an LOV includes additional full-scale fatigue-test evidence. The primary source of this test evidence should be full-scale fatigue testing. This testing should follow the guidance contained in appendix 2 of this AC.

8. Fatigue Evaluation.

a. General. The evaluation of structure under the following fatigue- (safe-life) strength-evaluation methods is intended to ensure that catastrophic fatigue failure – as a result of the repeated loads of variable magnitude expected in service – will be avoided throughout the structure's operational life. Under these methods, the fatigue life of the structure should be determined. The evaluation should include the following:

(1) Estimating or measuring the expected loading spectra for the structure;

(2) Conducting a structural analysis, including consideration of the stress concentration effects;

(3) Performing fatigue testing of structure that cannot be evaluated, based on previous testing, to establish response to the typical loading spectrum expected in service;

(4) Determining reliable replacement times by interpreting the loading history, variable-load analyses, fatigue-test data, service experience, and fatigue analyses;

(5) Evaluating the possibility of fatigue initiation from sources, such as stress corrosion, disbonding, environmental (e.g., corrosion) and accidental damage, and manufacturing defects, based on a review of the design, quality control, and past service experience; and

(6) Providing necessary maintenance programs and replacement times to the operators. The maintenance program should be included in the ICA in accordance with 14 CFR 25.1529.

b. Scatter Factor for Safe-life Determination. In the interpretation of fatigue analyses and test data under § 25.571(c), the effect of variability should be accounted for by an appropriate scatter factor. The applicant should justify the scatter factor chosen for any safe-life part. The following guidance is provided (See Figure 1):

(1) The base scatter factors applicable to test results are $BSF_1 = 3.0$ and $BSF_2 \geq 3.0$ (see section 8b(5) of this AC). If the applicant can meet the criteria of section 8b(3) of this AC, they may use BSF_1. As an option, the applicant may elect to use BSF_2. If the applicant cannot meet the criteria of section 8b(3) of this AC, they must use BSF_2.

(2) Base scatter factor BSF_1 development. The base scatter factor BSF_1 is developed using test results of one representative test specimen.

(3) Justification for use of BSF_1. BSF_1 may be used only if the following criteria are met:

(a) Understanding of load paths and failure modes. Service and test experience of similar in-service components that were designed using similar design criteria and methods should demonstrate that the load paths and potential failure modes of the components are well understood.

(b) Control of design, material, and manufacturing process quality. The applicant should demonstrate that his quality system (e.g., design, process control, and material standards) ensures that the scatter in fatigue properties is controlled and that the design of the fatigue-critical areas of the part account for the material scatter.

(c) Representativeness of the test specimen.

1 The test article should be full-scale (component or sub-component) and represent that portion of the production aircraft requiring test. All differences between the

test article and production article should be accounted for either by analysis supported by test evidence or by testing itself.

2 Construction details, such as bracket attachments and clips, should be accounted for, even though the items themselves may be non-load bearing.

3 Points of load application and reaction should accurately reflect those of the aircraft, ensure correct behavior of the test article, and guard against uncharacteristic failures.

4 Systems used to protect the structure against environmental degradation can have a negative effect on fatigue life and, therefore, should be included as part of the test article.

(4) Adjustments to base scatter factor BSF_1. If the criteria in section 8b(3) justifying the use of BSF_1 have been met, the base value of 3.0 should be adjusted to account for the following factors, where these factors are not wholly taken into account by design analysis. As a result of the adjustments, the final scatter factor may be less than, equal to, or greater than 3.0.

(a) Material fatigue scatter. Material properties should be investigated up to a 99% probability of survival and a 95% level of confidence.

(b) Spectrum severity. The test-loads spectrum should be derived, based on a spectrum-sensitive analysis accounting for variations in utilization (e.g., aircraft weight and center of gravity), as well as for the occurrence and size of loads. The test-loads spectrum applied to the structure should be demonstrated to be conservative when compared to the usage expected in service.

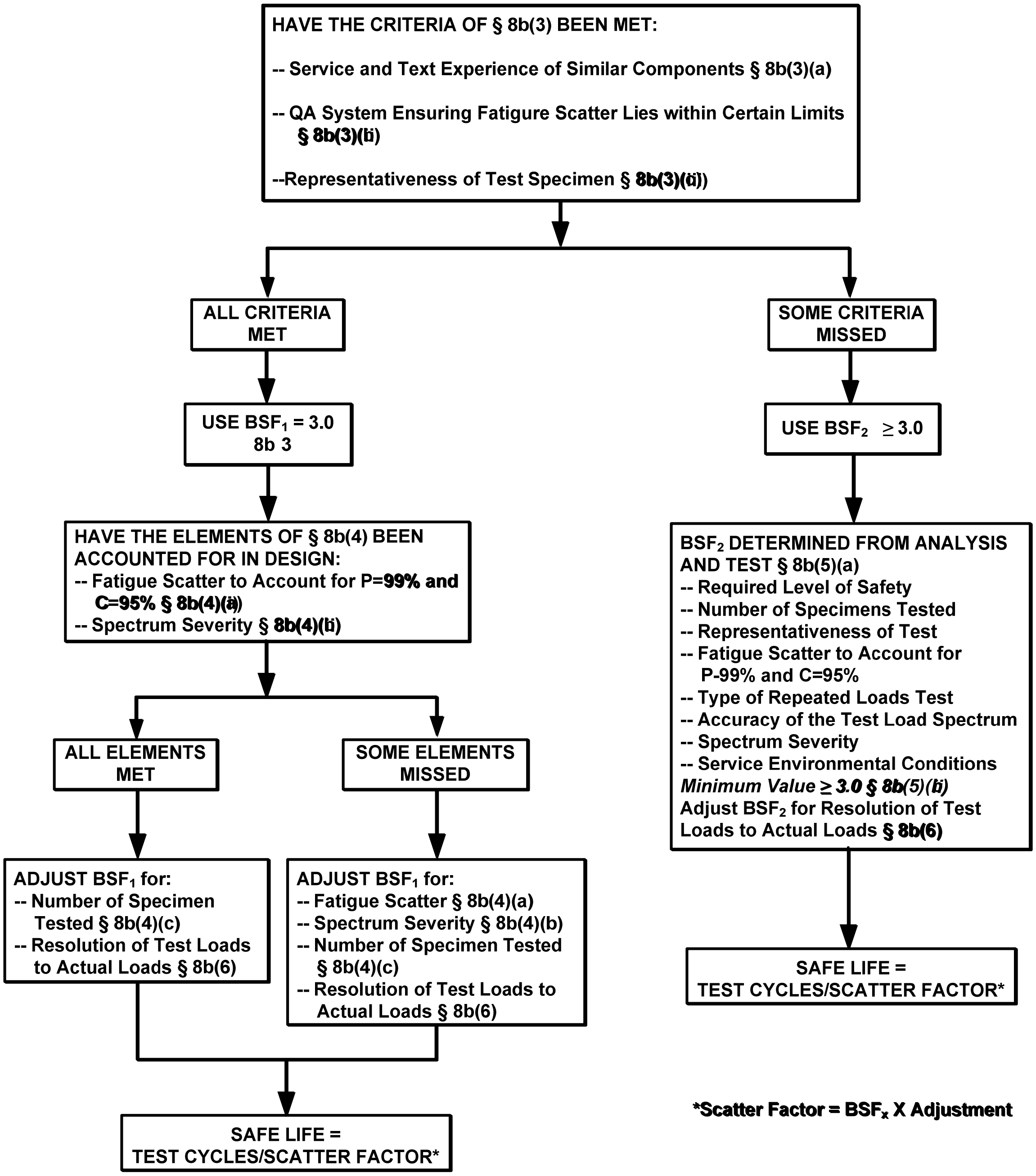
(c) Number of representative test specimens. Well established statistical methods should be used that associate the number of items tested with the distribution chosen to obtain an adjustment to the base scatter factor.

(5) Adjustments to base scatter factor BSF_2. If section 8b(3) of this AC cannot be satisfied in its entirety, the applicant should use BSF_2.

(a) The applicant should propose scatter factor BSF_2 based on careful consideration of the following issues:

- required level of safety,
- number of representative test specimens,
- how representative the test is,
- expected fatigue scatter,

Figure 1 – Safe-Life Determination



- type of repeated load test,
- accuracy of the test-loads spectrum,
- spectrum severity, and
- expected service environmental conditions.

(b) In no case should the value of BSF_2 be less than 3.0.

(6) Resolution of test loadings to actual loadings. The applicant may use a number of different approaches to reduce both the number of load cycles and number of test set-ups required. These include the following:

- spectrum blocking (i.e., a change in the spectrum load sequence to reduce the total number of test setups);
- high-load clipping (i.e., reduction of the highest spectrum loads to a level at which the beneficial effects of compression yield are reduced or eliminated); and
- low-load truncation (i.e., the removal of non-damaging load cycles to simplify the spectrum).

(7) Due to the modifications to the flight-by-flight loading sequence caused by these changes, the applicant should propose either analytical or empirical approaches to quantify an adjustment to the number of test cycles which represents the difference between the test spectrum and the assumed flight-by-flight spectrum. In addition, an adjustment to the number of test cycles may be justified by raising or lowering the test-load levels, as long as data support such adjustment. Other effects to consider are different failure locations, different response to fretting conditions, and temperature effects. The analytical approach should either use well-established methods or be supported by test evidence.

c. Replacement times. Under § 25.571(a)(3), replacement times should be established for parts with established safe-lives and should be included in the ALS of the ICA. These replacement times can be extended if additional data indicate an extension is warranted. Factors that should be considered for such extensions include the following:

(1) Comparison of original evaluation with service experience.

(2) Recorded load and stress data. Recorded load and stress data entails the installation of instrumentation on airplanes in service to obtain a representative sampling of actual loads and stresses experienced. The data to be measured include airspeed, altitude, and load-factor-versus-time data; or airspeed, altitude, and strain-ranges-versus-time data; or similar data. The data obtained from airplanes in service provide a basis for correlating the estimated loading spectrum with the actual service experience.

(3) Additional analyses and tests. If test data and analyses are obtained based on repeated load tests of additional specimens, a re-evaluation of the established safe-life can be made.

(4) Tests of parts removed from service. Repeated load tests of replaced parts can be used to re-evaluate the established safe-life. The tests should closely simulate service loading conditions. Repeated load testing of parts removed from service is especially useful where recorded load data obtained in service are available, since the actual loading experienced by the part prior to replacement is known.

(5) Repair or rework of the structure. In some cases, repair or rework of the structure can gain further life.

d. Type-design developments and changes. For design developments or design changes involving structural configurations similar to those of a design already shown to comply with the applicable provisions of § 25.571(c), it may be possible to evaluate the variations in critical portions of the structure on a comparative basis. Examples would be (1) redesign of the wing structure for increased loads or (2) the introduction, in pressurized cabins, of cutouts having different locations or different shapes, or both. This evaluation should involve analysis of the predicted stresses of the redesigned primary structure, and correlation of the analysis with the analytical and test results used in showing compliance with § 25.571(c) of the original design.

e. Environmental effects such as temperature and humidity should be considered in the damage-tolerance and fatigue analysis, and should be demonstrated through suitable testing.

9. Discrete Source Damage.

a. General. The purpose of this section is to establish FAA guidelines for consistent selection of load conditions for residual-strength substantiation in showing compliance with § 25.571(e), *Damage-tolerance (discrete source) evaluation*. The intent of these guidelines is to define, with a satisfactory level of confidence, load conditions that will not be exceeded on the flight during which the specified incident of § 25.571(e) occurs. In defining these load conditions, consideration has been given to the expected damage to the airplane, the anticipated response of the pilot at the time of the incident, and the actions of the pilot to avoid severe load environments for the remainder of the flight consistent with pilot knowledge that the airplane may be in a damaged state. With these considerations in mind, use the following ultimate loading conditions to establish residual strength of the damaged structure.

b. The maximum extent of immediately obvious damage from discrete sources (§ 25.571(e)) should be determined, and the remaining structure shown with an acceptable level of confidence, to have static strength for the maximum load (considered as ultimate load) expected during completion of the flight.

c. The ultimate loading conditions should not be less than those developed from the following conditions:

(1) At the time of the incident:

(a) The maximum, normal, operating differential pressure, multiplied by a 1.1 factor, plus the expected external aerodynamic pressures during 1g level flight combined with 1g flight loads.

(b) The airplane, assumed to be in 1g level flight, should be shown to be able to survive any maneuver or any other flight-path deviation caused by the specified incident of § 25.571(e), taking into account any likely damage to the flight controls and pilot normal corrective action.

(2) Following the incident:

(a) Seventy percent (70%) limit flight-maneuver loads and, separately, 40% of the limit gust velocity (vertical and lateral) at the specified speeds, each combined with the maximum appropriate cabin differential pressure (including the expected external aerodynamic pressure).

(b) The airplane must be shown by analysis to be free from flutter up to V_D/M_D with any change in structural stiffness resulting from the incident.

Jeffrey E. Duven
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Aircraft Certification Service

Appendix 1
References and Definitions

1. References.

a. AC 20-107B, "Composite Aircraft Structure"

b. AC 25.1529-1A, "Instructions for Continued Airworthiness of Structural Repairs on Transport Airplanes"

c. AC 91-56B, "Continuing Structural Integrity Program for Airplanes"

d. AC 120-93, "Damage Tolerance Inspections for Repairs and Alterations"

e. AC 120-104, "Widespread Fatigue Damage and Establishing LOV"

2. Definitions of Terms Used in this AC.

a. Airworthiness Limitation item (ALI) — A mandatory-maintenance action identified in the Airworthiness Limitations section of a design-approval holder's Instructions for Continued Airworthiness. These items may contain mandatory modification or replacement times, mandatory inspection thresholds, intervals, and inspection procedures.

b. Airworthiness Limitations section (ALS) — Relative to the Instructions for Continued Airworthiness, the ALS is a collection of mandatory-maintenance actions required for airplane structure and fuel-tank systems. For structural-maintenance actions, the ALS includes structural-modification times, structural-replacement times, structural-inspection thresholds and intervals, and structural-inspection procedures.

c. Alteration or modification — A design change that is made to an airplane. Within the context of this AC, the two terms are synonymous.

d. Damage tolerance — The attribute of the structure that permits it to retain its required residual strength for a period of use after the structure has sustained a given level of fatigue, corrosion, or accidental or discrete source damage.

e. Design service goal — The period of time (in flight cycles or flight hours, or both) established at design and/or certification during which the airplane structure is reasonably free from significant cracking.

f. Fail-safe — The attribute of the structure that permits it to retain its required residual strength for a period of unrepaired use after the failure or partial failure of a principal structural element.

g. Instructions for Continued Airworthiness (ICA) — Documentation that sets forth instructions and requirements for the maintenance that is essential to the continued airworthiness of an aircraft, engine, or propeller.

h. Multiple load path — Applies to structure, the applied loads of which are distributed through redundant structural members, so that the failure of a single structural member does not result in the loss of structural capability to carry the applied loads.

i. Limit of validity (of the engineering data that supports the structural maintenance program) — The period of time (in flight cycles, flight hours, or both), up to which it has been demonstrated by test evidence, analysis and, if available, service experience and teardown inspection results of high-time airplanes, that widespread fatigue damage will not occur in the airplane structure.

j. Principal structural element (PSE) — An element that contributes significantly to the carrying of flight, ground, or pressurization loads, and whose integrity is essential in maintaining the overall structural integrity of the airplane. Principal structural elements include all structure susceptible to fatigue cracking, which could contribute to a catastrophic failure. Refer to appendix 5 of this AC for clarification on how this term relates to the terms, fatigue critical structure (FCS) and WFD – susceptible structure.

k. Safe-life — The number of events, such as flight cycles, landings, or flight hours, within which the structure strength has a low probability of degrading below its design ultimate value due to fatigue cracking.

l. Scatter factor — A life-reduction factor used in interpreting fatigue analysis and test results.

m. Single load path — Describes structure, the applied loads of which are eventually distributed through a single structural member, the failure of which would result in the loss of the structural capability to carry the applied loads.

n. Teardown inspection — The term used for the process of disassembling structure and using destructive inspection techniques or visual (e.g., magnifying glass and dye penetrant) or other non-destructive (e.g., eddy current, ultrasound) inspection techniques to identify the extent of damage, within a structure, caused by fatigue, corrosion, and accidental damage.

o. Widespread fatigue damage (WFD) — The simultaneous presence of cracks at multiple structural locations that are of sufficient size and density such that the structure will no longer meet the residual-strength requirements of § 25.571(b).

(1) Multiple site damage (MSD) — A source of widespread fatigue damage characterized by the simultaneous presence of fatigue cracks in the same structural element.

(2) Multiple element damage (MED) — A source of widespread fatigue damage characterized by the simultaneous presence of fatigue cracks in adjacent structural elements.

(3) Structural modification point (SMP) — The point in time when a structural area must be modified to preclude WFD.

(4) Inspection start point — The point in time when special inspections of the fleet are initiated due to a specific probability of having a MSD/MED condition.

p. $\mathbf{WFD_{(average\ behavior)}}$ — The point in time, without intervention, when 50% of the fleet is expected to develop WFD for a particular structure.

Appendix 2
Full-Scale Fatigue Testing

1. Overview. Section 25.571(b) requires that special consideration for WFD be included where the design is such that this type of damage could occur. Many such areas typically are found in metallic transport airplane structure. Refer to AC 120-104 for examples of WFD-susceptible structure. These areas have in common the same or similar structural details over large areas that are subject to similar repeated tension-stress levels.

a. Without intervention, simultaneous fatigue cracking would eventually occur at multiple locations that would be very difficult to detect before the structure strength degrades below required levels. A strategy must be in place to prevent such fatigue cracking from occurring, as mere inspection of these areas is not reliable to maintain continued airworthiness of the airplane. Section 25.571(b) requires the applicant to demonstrate with sufficient full-scale fatigue-test evidence that WFD will not occur in any susceptible area within the LOV of the airplane.

b. As discussed in section 2 of this appendix, full-scale fatigue-test evidence may be obtained from in-service experience. Testing should involve subjecting a full-scale fatigue-test article to repeated loads followed by an evaluation to determine residual-strength capability. For new type certificates and derivative models, the applicant should use the results of the evaluation to help establish the LOV for the airplane as discussed in section 7 of this AC.

c. Section 3 of this appendix discusses the key elements of a full-scale fatigue-test program. The scope of the full-scale fatigue-test article required will depend on the type of the certification project as discussed in section 4 of this appendix. For the purposes of this AC, certification projects include: (1) new type certificates, (2) derivative models, (3) type design changes – service bulletins, (4) type design changes – supplemental type certificates, and (5) major repairs. In some cases, data from previous full-scale fatigue testing may exist and may be relevant to the certification project.

d. Applicants must consider the issues identified in section 5 of this appendix when using existing test data as evidence to support compliance.

e. Applicants must consider the issues identified in section 6 of this appendix when using in-service data as evidence to support compliance.

2. Full-Scale Fatigue-Test Evidence. Full-scale fatigue-test evidence in the context of § 25.571 makes up the body of evidence (which may also include service experience) that supports the WFD evaluation for a certification project. It includes data used in determining or bounding the time to develop MSD/MED cracks of a certain size, MSD/MED crack-growth scenarios, and residual-strength capability with MSD/MED cracks present. Types of data include strain-survey results, non-destructive and destructive inspection results, and residual-strength test results. The primary source of full-scale fatigue-test evidence is full-scale fatigue testing. The guidelines contained herein should ensure that sufficient test evidence is produced to provide a high degree of confidence that WFD will not occur within the LOV. This involves a laboratory test in which structure that is representative of the type design being considered is subjected to loading that simulates typical service operation. The test article may be the entire airframe or a portion of it. A source of data that may supplement full-scale fatigue-test evidence is data from operational airplanes. This "in-service" data includes maintenance findings and results of teardown inspections.

3. Elements of a Full-Scale Fatigue-Test Program. The following guidance addresses elements of a test program used in generating the data necessary to support compliance. It is generally applicable to all certification projects.

a. Article. The test article should be representative of the structure of the airplane to be certificated (i.e., a production article). The test article should be conformed in accordance with 14 CFR 21.23. Attributes of the type design that could affect MSD/MED initiation, growth, and subsequent residual-strength capability should be replicated as closely as possible on the test article. Critical attributes include, but are not limited to, the following:

- material types and forms,
- dimensions,
- joining methods and details,
- coating and plating,
- use of faying surface sealant,
- assembly processes and sequences and,
- influence of secondary structure (e.g., loads induced due to proximity to the structure under evaluation).

b. Test setup and loading. The test setup and loading should result in a realistic simulation of expected operational loads.

(1) Test setup. The test setup dictates how the loads are introduced into the structure and reacted. Every effort should be made to introduce and react loads as realistically as possible. When compromises are made (e.g., wing-air loading), the resulting internal loads should be evaluated (e.g., using finite-element methods) to ensure that the structure is not being unrealistically underloaded or overloaded, locally or globally.

(2) Test loading. Test loading includes the sequence of statically balanced end conditions that are applied to represent some amount of operational usage. Typically, a test sequence representing 1/10 of an anticipated service life is repeated over and over again until the desired test duration is achieved. The sequence used should include loads from all sources (e.g.,

cabin pressurization, maneuvers, gusts, engine thrust, control-surface deflection, and landing impact) that are significant for the structure being evaluated. The applicant should provide supporting rationale when a load source is not included in the sequence. Differences between the test sequence and expected operational sequence should be justified. For example, standard practice eliminates low loads considered to be non-damaging, and clip high, infrequent loads that may bias the outcome, but care should be taken in both cases so that the test results are representative. Section 8b(6) of this AC provides guidance on resolving test loading to actual loading.

c. WFD$_{\text{(average behavior)}}$. Fatigue damage is the gradual deterioration of a material subjected to repeated loads. This gradual deterioration is a function of use and can be statistically quantified. Widespread fatigue damage therefore can be statistically quantified. Widespread fatigue damage cannot be absolutely precluded because there is always some probability of occurrence. The average time in flight cycles and/or flight hours to develop WFD is referred to as the WFD$_{\text{(average behavior)}}$ for WFD-susceptible structure. AC 120-104 provides guidance how to determine when structure should be modified or replaced to minimize the probability of having WFD in the fleet. The point at which a modification or replacement is undertaken is referred to as the "structural modification point" (SMP). The SMP is generally a fraction of the number representing the point in time when WFD$_{\text{(average behavior)}}$ will occur. As an example, the SMP may be determined by dividing the number representing the timing of when WFD$_{\text{(average behavior)}}$ will occur by a factor of 2 if inspections are deemed effective, or by a factor of 3 if inspections are not effective. If an inspection is determined to be effective, the "inspection start point" (ISP) may be determined by dividing the number representing the timing of when WFD$_{\text{(average behavior)}}$ will occur by a factor of 3.

d. Test duration. The duration of the full-scale fatigue test varies depending on the test objective, and whether the test is to be used for a new type certificate, design change, or repair. It is standard practice to interpret the unfactored fatigue life of one specimen as the average life. It follows, then, that if one full-scale fatigue-test article maintains the minimum residual-strength requirements of § 25.571(b) for test duration X, one can conservatively assume that the WFD$_{\text{(average behavior)}}$ of all WFD-susceptible structure is equal to X. Assuming inspection for MSD/MED is impractical, replacement or modification would be required at X divided by 3 per the guidance in AC 120-104. For areas where inspections for MSD/MED are practical, the applicant may defer replacement or modification until X divided by 2, provided inspections for MSD/MED start at X divided by 3. The applicant should consider these factors when deciding on the duration of a full-scale fatigue test.

(1) New type certificates and derivatives. The applicant must establish an LOV for new type certificates and derivative models. There are no requirements regarding the value of LOV. The full-scale fatigue-test duration should not be less than 2 times the LOV. Although not required, a longer test may identify unanticipated fatigue-sensitive areas as well as help validate cracking sites, cracking scenarios, crack-growth lives, and residual-strength capabilities. The applicant may also use a longer test to reduce or eliminate the need for WFD-related mandatory-maintenance actions. Consistent with the guidance in section (3)(d) of this appendix, and AC 120-104, a test duration of 3 times the LOV, without an occurrence of WFD, would eliminate the need for WFD-related mandatory-maintenance requirements. On the other hand, a

test duration of 2 times the LOV may result in required inspections and/or replacements/modifications prior to the LOV.

(2) Repairs and type design changes. The test duration should support the installation of repairs and type design changes up to the LOV of the affected airplane model. If it is conservatively assumed that the repair or type-design change is implemented before an airplane has accumulated any time in service, the rationale discussed in section 3d(1), above, applies. A test duration of 3 times the LOV would be recommended. However, consideration of the age of the airplane being repaired or modified could reduce the test duration. For example, an applicant for a repair or type design change to an airplane that has reached an age equivalent to 75 percent of its LOV must demonstrate that the repaired or modified airplane will be free from WFD for at least the remaining 25 percent of the LOV. In this example, a test duration of 75% of the LOV would be recommended (i.e., 3 times the time remaining until the LOV is reached).

e. Post-test evaluation. One of the primary objectives of the full-scale fatigue test is to generate data needed to determine the $WFD_{(average\ behavior)}$ for each susceptible area or establish a lower bound. The definition of $WFD_{(average\ behavior)}$ is the average time required for MSD/MED to initiate and grow to the point that the static-strength capability of the structure is reduced below the residual-strength requirements of § 25.571(b). A residual-strength assessment is required at the end of the full-scale fatigue test to demonstrate that the structure meets this requirement.

(1) Residual-strength tests. The direct way to demonstrate freedom from WFD at the end of a full-scale fatigue test is to subject the article to the required residual-strength loads specified in § 25.571(b). If the test article sustains these loads, the applicant has demonstrated that the structure has a minimum $WFD_{(average\ behavior)}$ equal to the number of flight cycles and/or flight hours tested. However, because fatigue cracks that might exist at the end of the test are not quantified, it is not possible to determine how far beyond the test duration WFD would occur in any of the susceptible areas without additional work (e.g., teardown inspection). Residual-strength testing could preclude the possibility of using an article for additional fatigue testing. For example, the application of loads in excess of representative operational loads on a metallic test article may result in local material yielding at existing crack tips that may slow or temporarily stop crack growth.

(2) Teardown inspections. The residual-strength capability may be evaluated indirectly by performing teardown inspections to quantify the size of any MSD/MED cracks that might be present, or to establish a lower bound on crack size based on inspection-method capability. After this is done, the residual-strength capability can be estimated analytically. Depending on the results, crack-growth analyses may also be required to project backward or forward in time to estimate the $WFD_{(average\ behavior)}$ for an area. As a minimum, teardown-inspection methods should be capable of detecting the minimum size of MSD or MED cracking that would result in a WFD condition (i.e., residual strength degraded to below the level specified in § 25.571(b)). Effective teardown inspections required to demonstrate freedom from WFD typically require significant resources. They usually require disassembly (e.g., fastener

removal) and destruction of the test article. All areas that are susceptible to WFD should be identified and examined.

4. Scope of the Full-Scale Fatigue-Test Article. The scope of the full-scale fatigue-test article is generally dependent on the type of certification project. Guidance on the expected scope for various certification projects is as follows:

a. New type certificates. As previously discussed, for any metallic airplane design, it is likely that multiple areas are susceptible to WFD based on the examples given in AC 120-104. Likewise, testing a complete airframe is probably the most practical approach. Regardless, the applicant is expected to subject all susceptible areas to full-scale fatigue testing. The only exception involves existing full-scale fatigue-test evidence that could be used to support compliance.

b. Derivative models – amended type certificates. The default for a derivative model would be to test the entire airframe. However, it is considered likely that existing data was developed and is available to support compliance of the original model. If this is the case, the article may be limited to only a portion or portions of the complete airframe.

c. Type-design changes – service bulletins. The default for a type-certificate holder 's type design change is to test an article consisting of the design change and any original structure that is susceptible to WFD, and which the design change could negatively affect in terms of fatigue. See appendix 4 for examples of types of alterations for which the type-certificate holder should perform full-scale fatigue tests, unless the type-certificate holder can show that fatigue testing is not required (e.g., an alteration is not susceptible to WFD, or sufficient test data already exists). It is expected that the type-certificate holder has existing relevant data. If this is the case, this type of certification project would not require a test, provided that the type-certificate holder demonstrates, with the existing data, that the design change and any of the original structure that it affects will be free from WFD up to the LOV of the airplane to which the design change applies.

d. Type-design changes – supplemental type certificates. Because supplemental type certificate applicants often do not have access to the type-certificate holder's full-scale fatigue-test data, a full-scale fatigue-test article is expected. The article should consist of the design change and any original structure that is susceptible to WFD, and any structure that the design change could negatively affect in terms of fatigue. See appendix 4 for examples of types of alterations for which the applicant for an supplemental type certificate should perform full-scale fatigue tests, unless the applicant can show that fatigue testing is not required (e.g., an alteration is not susceptible to WFD, or sufficient test data already exists).

e. Major repairs. In general, major repairs do not require testing of a full-scale test article. For those repairs where testing is required, the test article should consist of the repair and any original structure that is susceptible to WFD, and which the repair could negatively affect in terms of fatigue.

(1) Published repair instructions (Amendment 25-96 or later). The applicant for a type certificate usually develops published repair instructions, such as a structural repair manual, for an airplane model. The applicant should perform analyses, such as fatigue and damage-tolerance analyses, that correlate to results of relevant full-scale fatigue tests to show the repairs in that manual are free from WFD up to the LOV. Alternatively, the applicant could perform component fatigue testing to show the published repairs are free from WFD up to the LOV.

(2) Non-published repair instructions (Amendment 25-96 or later). The applicant should correlate analysis methods to results of relevant full-scale fatigue tests, or perform component fatigue testing to evaluate the repair. Repairs for which correlated analysis is acceptable are those that are the same as, or comparable to, those found in FAA-approved published data, such as the type-certificate holder's structural repair manual. For the purpose of this AC, a repair is comparable when the operating stress levels and fatigue characteristics are approximately the same as those of the FAA-approved published data. To achieve this, the repair needs to have design aspects, such as design details, airframe materials, and production processes that are similar to the FAA-approved published data. For other repairs and depending on the type of repair, the applicant may need to perform full-scale fatigue testing. Alternatively, the applicant may propose analysis methods, such as fatigue and damage-tolerance analyses, that compare the fatigue characteristics of the original type design to the repaired structure and affected areas.

5. Use of Existing Full-Scale Fatigue-Test Data. In some cases, especially for derivative models and type-design changes the type-certificate holder accomplished, existing full-scale fatigue-test data may be used in supporting compliance and mitigating the need to perform additional testing. This is most probable when the data are from testing performed to support compliance with § 25.571 at Amendment 25-96 or later. This is less likely with other data.

a. Amendment 25-96 or later. Because the primary objective for developing the original full-scale fatigue-test data is to establish an absolute or lower-bound $WFD_{(average\ behavior)}$, for WFD-susceptible areas to support compliance, the original test article should be conformed and a rigorous post-test evaluation should be completed to demonstrate the remaining residual-strength capability. In addition to demonstrating residual-strength capability, the applicant must identify and reconcile any physical differences between the structure originally tested and the structure being considered that could affect its fatigue behavior. Differences that should be addressed include, but are not limited to, differences in any of the physical attributes listed in section 3a of this appendix. Additionally, the applicant should identify and reconcile differences in operational loading. As a minimum, the applicant should address the following:

- Gross weight (e.g., increases)
- Cabin pressurization (e.g., change in maximum cabin or operating altitude)
- Flight-segment parameters

b. Other data. Performing full-scale fatigue testing to support compliance with § 25.571(b) was not required prior to Amendment 25-96. It was accepted that fatigue would be managed solely by inspection, and that inspection requirements adequately could be determined based on analysis supported by limited testing at the coupon and component level. Nevertheless, many OEMs performed their own full-scale fatigue tests with the primary objective to evaluate the economic life of the structure. However, most test articles were not conformed in accordance with 14 CFR 21.33. Since no regulation required such tests, applicants did not submit test plans or reports to the FAA. Testing philosophies and protocols were not standardized, and the rigor of methods used for load-sequence development varied significantly over the years and from one OEM to another. Post-test evaluations (if performed) varied significantly and, in some cases, consisted of nothing more than limited visual inspections. An applicant may propose to use full-scale fatigue-test data from airplanes certificated to 14 CFR 25.571 (pre-Amendment 25-96) to support compliance with Amendment 25-96 or later requirements. In such cases, the applicant must consider the issues identified in section 5a of this appendix.

6. Use of In-Service Data. In-service data may be available to be used in supporting WFD evaluations. Examples of such data are as follows:

- Documented positive findings of MSD/MED cracks that include location, size, and the time in service of the affected airplane, along with a credible record of how the airplane had been operated since original delivery.

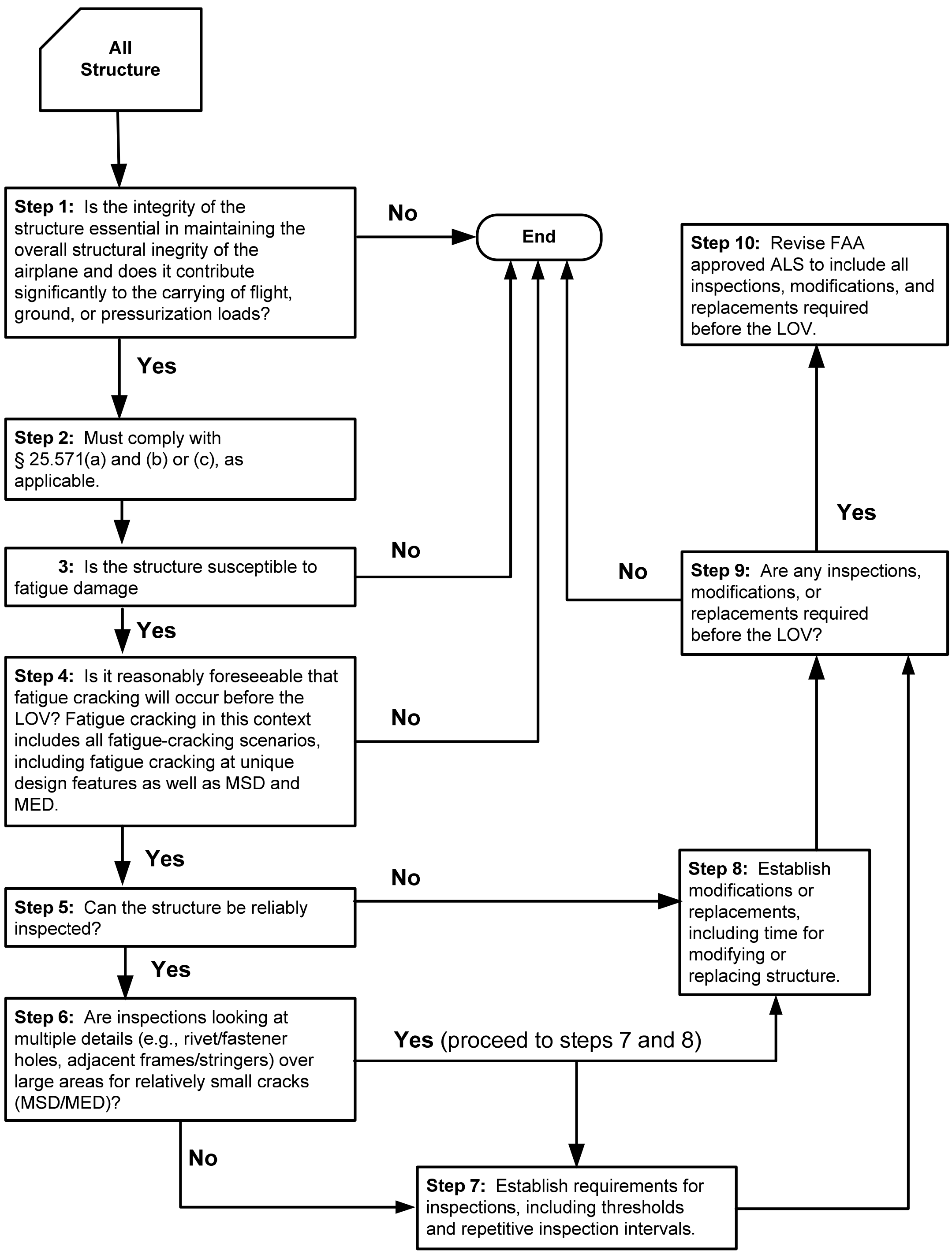
- Documented negative findings from in-service inspections for MSD/MED cracks on a statistically significant number of airplanes, with the time in service of each aircraft and a credible record of how each aircraft had been operated since original delivery. For this data to be useful, the inspection methods used should be capable of detecting MSD/MED crack sizes equal to or smaller than those sizes that could reduce the strength of the structure below the residual-strength levels specified in § 25.571(b).

- Documented findings from the destructive teardown inspection of structure from in-service airplanes. This might be structure (e.g., fuselage splices) removed from airplanes that were subsequently returned to service or from retired airplanes. It would also be necessary to have a credible record of the operational loading the subject structure experienced up to the time it was taken out of service.

a. Prior to using in-service data, any physical and loading differences that exist between the structure of the in-service or retired airplanes, and the structure being certified, should be identified and reconciled as discussed in section 5a of this appendix.

Appendix 3
Process for Compliance with 14 CFR 25.571(a), (b) and (c) for Fatigue Damage

This chart applies only to § 25.571(a), (b), and (c) for fatigue damage (FD), relative to LOV.



For the purposes of this flowchart "All Structure" refers to all structure within the scope of § 25.571. This includes fatigue critical structure, as defined in 14 CFR 26.41.

Step 1: Is the integrity of the structure essential in maintaining the overall structural integrity of the airplane, and does it contribute significantly to the carrying of flight, ground, or pressurization loads?

If **Yes**, go to Step 2. Structure meeting these criteria are within the scope of § 25.571. See section 6c of this AC for examples.

If **No**, then the structure under consideration is not within the scope of § 25.571. Terminate the process.

Step 2: Evaluate each structure in accordance with § 25.571(a) and (b) or (c), as applicable.

Structure identified to be within the scope of the § 25.571 requires a showing of compliance with § 25.571 (a) and (b) or (c), as applicable, relative to fatigue damage. Corrosion damage and accidental damage, including manufacturing defects, are not addressed in this flowchart.

- Corrosion typically has been addressed by maintaining corrosion to Level 1 or better, and to corrosion control and accidental damage programs. These programs are developed under the Air Transport Association of America, Inc. (ATA) Maintenance Steering Group's MSG-3 or other accepted version of the "Operator/Manufacturer Scheduled Maintenance Development" procedures.

- As airplanes are subjected to these programs, operators should evaluate the programs and adjust them to fit their operations.

Note: Section 25.571 requires applicants to evaluate the strength, detail design, and fabrication to show that catastrophic failure due to fatigue, corrosion, manufacturing defects, or accidental damage will be avoided throughout the operational life of the airplane. It also requires that, based on the evaluations, inspections, or other procedures be established, as necessary, to prevent catastrophic failure, and be included in the ALS of the ICA, as required by § 25.1529.

As discussed in section 6i(3) of this AC, the applicant may use the Maintenance Review Board process to develop maintenance tasks that require inspections or other procedures for addressing accidental and environmental (corrosion) damage. If this process is used as a means of compliance, the applicant should reference, in the ALS, the maintenance documents that contain those tasks.

Step 3: Is the structure susceptible to fatigue damage?

If **Yes**, go to Step 4.

If **No,** no further showing of compliance is necessary. Terminate the process.

Structure that is susceptible to fatigue cracking, which could, without intervention, eventually lead to catastrophic failure of an airplane, typically includes structure critical to carrying flight, ground, or pressurization loads that are subjected to tension-dominated repeated loads during operation (as discussed previously in this document). This structure also includes structure which, if repaired or altered, could be susceptible to fatigue cracking and contribute to a catastrophic failure.

Step 4: Is it reasonably foreseeable that fatigue cracking will occur before the LOV? Fatigue cracking in this context includes all fatigue-cracking scenarios, including fatigue cracking at unique design feature as well as MSD and MED.

If **No**, no further showing of compliance is necessary. Terminate the process. Note that sufficient evidence must support a high degree of confidence that WFD will not occur within the LOV.

If **Yes**, go to Step 5.

To address this question, estimate the fatigue life for all susceptible structure. The evaluation should be based on analysis, test, or service experience, or a combination of these, as necessary. An applicant may screen out areas that exhibit long fatigue lives. This means that the average fatigue life is a multiple of the LOV. Typically, the predicted fatigue life should be at least 3 times the LOV to justify eliminating the structure from further consideration. This may be the case for basic fuselage structure, away from discontinuities such as splices, windows, or doors, where the working-stress levels are relatively low. For structure that cannot be eliminated, additional evaluations are required.

Step 5: Can the structure be inspected reliably?

If **Yes**, go to Step 6.

If **No**, go to Step 8.

To address this question, crack-growth and residual-strength evaluations (damage-tolerance evaluation) must be performed. These evaluations typically are based on analyses supported by test evidence. Sections 6, 7, and 8 of this AC contain discussions of damage-tolerance evaluations, and fatigue and widespread-fatigue evaluations. Use the results to determine if inspections reliably can detect cracking before it reduces the material strength below the required strength level.

For the purposes of this AC, an inspection is "effective" if, when performed by properly trained maintenance personnel, the inspection readily detects the damage in question.[1]

Step 6: Are inspections looking at multiple details (e.g., rivet/fastener holes, adjacent frames/stringers, etc.) over large areas for relatively small cracks (MSD/MED)?

If **Yes**, go to **Step 7** to establish inspections, **then** to **Step 8** to establish modifications or replacements.

If **No**, go to **Step 7**, then to **Step 9**.

This step determines whether inspections by themselves are adequate for precluding a catastrophic failure, or whether they are supplementary to modifying or replacing structure.

- When inspections are focused on details in small areas and have a high probability of detection, they may be used by themselves to ensure continued airworthiness, unless or until there are in-service findings. Based on findings, these inspections may need to be modified, and it may be necessary to modify or replace structure.

- When inspections examine multiple details over large areas for relatively small cracks, they should not be used by themselves. Rather, they should be used to supplement the modification or replacement of structure. This is because it would be difficult to achieve the probability of detection required to allow inspection to be used indefinitely as a means to ensure continued operational safety.

Step 7: Establish requirements for inspections, including thresholds and repetitive inspection intervals.

Using the results of your damage-tolerance evaluation, select an inspection method (or methods), and establish the inspection threshold and repetitive inspection interval.

- Inspection thresholds must be based on crack-growth analyses and/or tests, with the assumption that the structure contains an initial flaw of the maximum probable size that could exist as a result of manufacturing or service-induced damage.

- Thresholds established for cracking at multiple details that are over large areas (WFD-related cracking) should be determined through a statistical analysis of crack

[1] The cracking identified in airworthiness directive 2002-07-09 is an example of the type of cracking that MSD inspections effectively detect. These cracks grow from fastener holes in the lower row of the lower skin panel in such a way that the cracking is readily detectable using non-destructive inspection methods. The cracking identified in airworthiness directive 2002-07-08 is an example of where MSD inspections are not "effective." These cracks grow in the outer surface and between fastener holes in the lower row of the lower skin panel in such a way that the cracking is not readily detectable using non-destructive inspection methods. Therefore, modification is the only option to address this type of cracking.

initiation based on fatigue testing, teardown, or in-service experience of similar structure. If an inspection is determined to be effective, the "inspection start point" (ISP) may be determined by dividing the number representing the timing of when $WFD_{(average\ behavior)}$ will occur by a factor of 3.

If the answer to the question in **Step 6** was **Yes**, go to **Step 8** to establish modifications or replacements.

If the answer to the question in **Step 6** is **No**, go to **Step 9** to determine if the inspection requirements established in this step need to go into the ALS.

Step 8: Establish modifications or replacements, including time for modifying or replacing structure.

Based on the results of the fatigue and damage-tolerance evaluations performed, determine the replacement time or SMP (i.e., replacement time or modification time) for affected structure.

- For structure that is not susceptible to damage at multiple sites and where the applicant has shown that the damage-tolerance-based inspections are impractical, a replacement time must be established per § 25.571(c). See section 8 of this AC for further guidance.

- For structure that is susceptible to damage at multiple sites and where the applicant has shown that damage-tolerance-based inspections are practical, a SMP must be established per § 25.571(b). The Step 6 inspections supplement the required SMP. An acceptable approach for determining the SMP is to divide the $WFD_{(average\ behavior)}$ by a factor of 2. To determine ISP, divide the $WFD_{(average\ behavior)}$ by a factor of 3. See AC 120-104 for further guidance on establishing SMP and ISP.

- For structure that is susceptible to damage at multiple sites and where the applicant has shown that damage-tolerance-based inspections are not reliable in Step 5, an SMP must be established per § 25.571(b). An acceptable approach would be to divide the $WFD_{(average\ behavior)}$ by a factor of 3.

Go to Step 9 to determine if the modification or replacement requirements need to be included in the ALS.

Step 9: Are any inspections, modifications, or replacements required before the LOV?

If **Yes**, go to Step 10.

If **No**, terminate the process.

Based on the results of Steps 7 and 8, determine if any maintenance actions need to be included in the ALS of the ICA. Any inspection with thresholds less than the LOV, or replacements or modifications that must occur prior to the LOV, must be included in the ALS.

Step 10: Revise the FAA-approved ALS to include all inspections, modifications, and replacements required before the LOV.

Based on the results of Step 9, include, in the ALS of the ICA (per § 25.1529), the inspections or other procedures determined to be necessary to prevent catastrophic failure up to the LOV. The LOV must also be included.

For each required inspection, the operator should include—

- The structure to be inspected.
- The method of inspection.
- The inspection threshold (the point in time at which to begin inspections).
- The inspection repetitive interval.

For required modifications or replacements, the operator should include—

- The structure to be modified or replaced.
- The method of modification or replacement.
- The replacement time or structural-modification point (the point in time to begin the modification), as applicable.

Appendix 4
Examples of Alterations that May Require Full-Scale Fatigue Testing

1. The following are examples of types of alterations that may require full-scale fatigue testing:

a. passenger-to-freighter conversions (including addition of cargo doors);

b. gross-weight increases (e.g., increased operating weights, increased zero-fuel weights, increased landing weights, and increased maximum-takeoff weights);

c. installation of fuselage cutouts (e.g., passenger-entry doors, emergency-exit doors or crew-escape hatches, fuselage-access doors, and cabin-window relocations);

d. complete re-engine or pylon alteration;

e. engine-hush kits;

f. wing alterations (e.g., installation of winglets; changes in flight-control settings such as flap droop; and alteration of wing trailing-edge structure);

g. modified or replaced skin splice;

h. any alteration that affects three or more stiffening members (e.g., wing stringers and fuselage frames);

i. an alteration that results in operational-mission change, which significantly changes the original equipment manufacturer's load/stress spectrum (e.g., extending the flight duration from 2 hours to 10 hours); and

j. an alteration that changes areas of the fuselage from being externally inspectable using visual means to being uninspectable (e.g., installation of a large, external, fuselage doubler that results in hiding details beneath it).

Appendix 5
PSE, FCS and WFD-Susceptible Structure

1. Overview. Three key terms used when showing compliance to the damage-tolerance and fatigue requirements of 14 CFR parts 25 and 26 are, "principle structural element" (PSE), "fatigue critical structure" (FCS), and "widespread fatigue damage (WFD) susceptible structure." This appendix provides clarification on the intended meanings of these terms and how they relate to one another. This appendix describes the items that should be included in an airplane's Airworthiness Limitations section based on the evaluation of each PSE, FCS, and WFD-susceptible structure.

2. PSE – Principal Structural Element.

a. The term "principal structural element" (PSE) is defined in this AC as follows:

b. Principal structural element, PSE, is an element that contributes significantly to the carrying of flight, ground, or pressurization loads, and whose integrity is essential in maintaining the overall integrity of the airplane.

c. While this definition does not specifically address the fatigue susceptibility of structure, or environmental or accidental damage, it is intended to address all structure that must be evaluated under § 25.571. Section 25.571(a) states the following:

> "This evaluation must be conducted … for each part of the structure that could contribute to a catastrophic failure (such as wing, empennage, control surfaces and their systems, the fuselage, engine mounting, landing gear, and their related primary attachments)."

d. The above reinforces the notion that the identification of PSEs should be based solely on the importance of the structure to assure the overall airplane integrity.

e. Section 6c of this AC provides guidance for identifying PSEs. Many manufacturers use this list as a starting point for their list of fatigue critical structure (FCS), because AC 120-93 specifically refers to this AC for identifying FCS. Section 25.571 is intended to address all structure that could contribute to a catastrophic failure resulting from fatigue, environmental, and accidental damage, and therefore may include some structure that is not considered FCS. Nevertheless, PSE should be considered when developing a list of FCS.

f. The definitions used by applicants to identify PSEs have not been consistent between applicants and, in some cases, between models produced by the same applicant. The lack of standardization of the usage and understanding of the term "PSE," and the resultant diversity that exists between type-design PSE lists, have required the FAA to introduce a new term, "fatigue-critical structure," in the *Aging Airplane Safety—Damage Tolerance Data for Repairs and Alterations* found in 14 CFR part 26, subpart E, and corresponding advisory material.

3. FCS – Fatigue Critical Structure.

a. Under 14 CFR 26.41, fatigue critical structure is defined as airplane structure that is susceptible to fatigue cracking, which could contribute to a catastrophic failure, as determined in accordance with 14 CFR 25.571. Fatigue critical structure includes structure susceptible to fatigue cracking, which could contribute to a catastrophic failure. Fatigue-critical structure also includes structure which, if repaired or altered, could be susceptible to fatigue cracking and contribute to a catastrophic failure. Structure may be susceptible to fatigue cracking when subjected to tension-dominated repeated loads during operation. Such structure may be part of the baseline structure or part of an alteration. "Baseline structure" means structure that is designed under the original type certificate or amended type certificate for that airplane model (i.e., the as-delivered airplane model configuration).

b. Fatigue critical structure is a subset of principal structural elements, specifically those elements that are susceptible to fatigue damage.

4. Widespread Fatigue Damage Susceptible Structure.

a. Widespread fatigue damage is the simultaneous presence of cracks at multiple structural locations, which are of sufficient size and density such that the structure no longer meets the residual-strength requirements of § 25.571(b).

b. Multiple site damage (MSD) and multiple-element damage (MED) are conditions that, with no intervention, can lead to WFD. The term "WFD-susceptible structure" refers to areas of structure that, under normal circumstances, could be expected to eventually develop MSD and/or MED cracks, which could lead to WFD.

c. Although not explicitly stated, structure susceptible to WFD cannot be inspected reliably to preclude WFD. Unless a flight cycles and/or flight hours limit is placed on an airplane, modifications may be needed to preclude WFD. Structure susceptible to WFD is a subset of FCS, which, in turn, is a subset of PSE.

Appendix 6
Acronyms and Abbreviations used in this AC

Term	Definition
AC	Advisory circular
ALI	Airworthiness Limitation item
ALS	Airworthiness Limitations section
FCS	Fatigue critical structure
ICA	Instructions for Continued Airworthiness
ISP	Inspection start point
LOV	Limit of validity of the engineering data that supports the structural maintenance program
MED	Multiple element damage
MSD	Multiple site damage
PSE	Principal structural element
SMP	Structural modification point
WFD	Widespread fatigue damage