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Standard Guide for Structural Durability Component Selection¹

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1. Scope

1.1 This guide is intended for tutorial purposes only. It describes criteria that some aircraft authorities have allowed when applicants have selected structural components for durability assessment and provides some history regarding the evolution of some of the criteria.

1.2 Guidance material will be provided to assist users of Specification **F3115/F3115M** when selecting structural components for the durability evaluations identified in Specification **F3115/F3115M**. The guidance information is presented as a way to inform users of the historical and practical considerations related to component selection and may provide a way to harmonize selection criteria across various certification authorities.

1.3 It is not intended that this information be mandatory for selection of durability components for evaluation, but rather serve as a guide when making decisions regarding the application of Specification **F3115/F3115M** durability assessments to structural components.

1.4 This guide neither endorses nor recommends the use of any of the methods presented. The information contained in the guide may be useful during discussions between certification applicants and authorities.

1.5 *Units*—This guide may present information in either SI units, English Engineering units, or both; the values stated in each system may not be exact equivalents. Each system shall be used independently of the other; combining values from the two systems may result in nonconformance with the standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards*:²

F3060 Terminology for Aircraft

F3115/F3115M Specification for Structural Durability for Small Aeroplanes

3. Terminology

3.1 The following are a selection of relevant terms. See Terminology **F3060** for more definitions and abbreviations.

3.2 *Definitions*:

3.2.1 *catastrophic loss or catastrophic failure, n*—failure condition that is expected to result in fatalities of the occupants, normally with the loss of the aeroplane.

3.2.2 *damage tolerance, n*—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, environmental degradation, manufacturing defects, accidental, or discrete source damage.

3.2.3 *durability, n*—the ability of the structure to withstand catastrophic failure for a period of use; failure may be induced by fatigue, environmental degradation, manufacturing defects, accidental, or discrete source damage.

3.2.4 *fail safe, n*—the attribute of the structure that permits it to retain its required residual strength for a period of unrepaid use after the failure or partial failure of a structural element.

3.2.5 *fatigue, n*—the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point or points, which may result in damage or complete fracture after a sufficient number of fluctuations.

3.2.6 *primary structure, n*—structure that carries flight, ground, crash or pressure loads, and whose failure would

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

reduce the structural integrity of the airplane or may result in injury or death to passengers or crew [Ref. PS-ACE-100-2004-10030].

3.2.7 *principal structural element (PSE), n*—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. [Ref. AC23-13A Section 7a.]

3.2.8 *residual strength, n*—the strength capability of a structure after the structure has been damaged due to fatigue, corrosion, accidental, or discrete source damage; the residual strength capability includes consideration of static strength, fracture, and stiffness.

3.2.9 *safe life, n—of a structure*, that number of events, such as flights, landings, or flight hours, during which there is a low probability that the strength will degrade below its design ultimate value due to fatigue-induced damage.

3.2.10 *secondary structure, n*—structure that is not primary structure, and its failure neither reduces the airframe structural integrity of the airplane nor result in injury or death to passengers or crew.

3.2.11 *structure, n*—any element that carries flight, ground, or pressurization load; includes all primary and some secondary structure.

3.2.12 *S-N or ϵ -N, n*—Stress-Life (S-N) or Strain-Life (ϵ -N) curves depict the magnitude of applied stress (S) or strain (ϵ) necessary to develop a given level of fatigue damage in a specimen at a given life (N), where N is expressed in the number of cyclic applications of stress or strain.

4. General Structural Durability—Design Rule

4.1 A general design requirement exists to ensure structural parts do not fail due to fatigue. Here, “structural parts” are parts that carry flight, ground, emergency landing, or pressure load (see 3.2). Note that the requirement is to avoid failure within the “normal service” (or more appropriately, operational usage) of the aeroplane. The applicant must design the structure to avoid part failures during the operational life of the aeroplane by making sure stress concentrations are not high.

4.1.1 The origin of this requirement is FAA’s 14 CFR 23.627: *The structure must be designed, as far as practicable, to avoid points of stress concentration where variable stresses above the fatigue limit are likely to occur in normal service.*

4.1.2 Prior to 23.627, see CAR 3.307 (same text as 23.627).

4.2 Compliance is often by design review by a structures engineer for acceptable forms or levels of stress concentration. Historically, this has been stress concentrations less than 4.0. An analytical assessment would be to show stresses on the part during typical usage operation would be less than a defined fatigue limit. Further analysis would be to perform a fatigue analysis and show that a factored mean fatigue life is greater than the assumed operational life.

4.2.1 What is meant by “fatigue limit”? Fatigue limit is generally considered the value of stress on an S-N fatigue chart where failure, or N_f , is very large (generally, $1e7$ cycles or more).

4.2.2 Fail safe aspects of the part would generally not be an acceptable method to show compliance to this general design rule. While it is a good practice to design for fail safe capability (and, a fail safe option satisfies the additional requirements for primary structure, as noted in 5.1), the intent of this general design rule is to ensure all parts avoid part failure during the operational life, regardless of load redistribution or avoidance of catastrophic effects of failure.

5. Durability Assessment for Primary Structure

5.1 If a part is primary structure and the part is susceptible to fatigue damage, structural durability assessment using Specification F3115/F3115M will be applicable. Therefore, one of the following durability assessment methods would need to be applied for the part: fatigue (safe life), fail safety, or damage tolerance.

5.2 A general question when performing a durability assessment is: *Could failure due to fatigue, environmental degradation, manufacturing defect, accidental, or discrete source damage of the part contribute to catastrophic failure of the aeroplane?* This has consistently been the basis for the selection of parts for durability assessment since the beginning of FAA Part 23 and continues today in all structural durability regulations.

5.3 Past regulations, however, have used this basic criterion to further identify specific aircraft components that require durability assessments and to simplify the selection process. These simplifications are not considered harmonized across certification authorities. This is summarized in Table 1.

6. FAA: Structural Durability for Metallic Parts

6.1 The following metallic components are “pre-identified” in Specification F3115/F3115M as requiring durability assessment due to potential for catastrophic loss.

6.1.1 Metallic pressurized cabin structure,

6.1.2 Metallic wing (includes tandem wings, canards, winglets, and tip fins) and attachment structure, and

6.1.3 Metallic empennage and attachment structure.

6.2 An underlying assumption regarding these simplifications is that application is for a typical aircraft platform—centerline fuselage, cantilever or strut-braced wings, and an empennage, with thrust provided as a fixed horizontal load.

6.3 Specification F3115/F3115M presents three methods as options for these metallic components: fatigue (safe life), fail safety, and damage tolerance. See Specification F3115/F3115M for more details. Note, AC 23-13A provides additional information regarding selection of components for fail safety and damage tolerance assessment with a suggested principal structural element list. This list is also presented in Table 2.

6.4 There are components that are not identified as being required for durability assessment. Notably, these components are landing gear and engine mounts. The origin of this is a 1998 FAA policy letter. It addressed landing gear components directly by noting service history of general aviation aircraft with regards to fatigue failure and catastrophic loss. The policy goes on to say that landing gear, engine mounts, and other