

SDC Option 1  
Mark-Up of 2003 GSHWG Recommendation

**02/25/16**  
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# Critique of 2003 SDC Recommendations

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## Summary

- *Address issue: Comment on the proposed rule change to 25.571 as detailed in the 2003 GSHWG recommendation related to Structural Damage Capability (SDC).*

## Objectives

- Address AAWG OEM Responses:
  - Benefits of SDC, Industry Practice, Feasibility and Guidance
- Address ARAC Comments:
  - Damage Propagation, Design Elements, Composite Structures
- Address Original Industry Comments
- Provide Mark-Up of the Proposed Rule
- Provide Benefits and Drawbacks of Proposed Approach

# Critique of 2003 SDC Recommendations

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## Proposed Rules 25.571(a)(4) thru (a)(6)

- (4) Damage tolerant design is primarily associated with the use of multiple load path structure or structure that contains damage containment features that significantly retard or arrest a crack.
- (5) When special inspections are required to prevent catastrophic fatigue failure, inspection thresholds must be established to ensure that cracking in a PSE will be detected before it results in a catastrophic failure. The inspection thresholds must account for the variations of manufacturing quality.
- (6) Inspection programs for corrosion and service induced accidental damage must be proposed to protect the structure against catastrophic failure.

## Proposed Rule 25.571(f)

### (f) Structural damage capability.

- 1) Except as noted in subparagraph f(2), for structure evaluated according to the damage-tolerance requirements of paragraph (b) of this section, it must be shown by analysis, supported by test evidence, that the structure is able to withstand the loads specified in paragraphs (b)(1) to (b)(6) of this section in the presence of damage equivalent to:
  - i) the complete failure of any single element, or
  - ii) partial failure between damage containment features that significantly retard or arrest a crack
- 2) For single load path structure, the intent of the SDC requirement shall be achieved through the demonstration of slow crack growth, an upper bound inspection threshold of 50% DSG and consideration of the quality control procedures used in manufacture. The requirement for an upper bound inspection threshold of 50% DSG may be extended based upon a rational analysis that is approved by the Administrator.

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## Proposed Rule 25.571(g)

**(g) Inspectability.** The inspectability of the extent of damage established in accordance with paragraph (f) must be addressed and reflected in the threshold determination required by paragraph (a)(5).

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## Proposed Rules 25.571(a)(4)

(4) Damage tolerant design is primarily associated with the use of multiple load path structure or structure that contains damage containment features that significantly retard or arrest a crack.

- Written as a statement of opinion, not a standard.
  - Compliance by demonstrating >51% of the airframe is MLP or has crack arrest???
- Ignores composite structures
  - “No Growth” is generally achieved through selection of design strain levels
- Delete this proposed statement. It is currently addressed in the guidance material.

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## Proposed Rules 25.571(a)(5)

(5) When special inspections are required to prevent catastrophic fatigue failure, inspection thresholds must be established to ensure that cracking in a PSE will be detected before it results in a catastrophic failure. The inspection thresholds must account for the variations of manufacturing quality.

- This rule is primarily being addressed by the Metals & Composites ARAC
  - Current working version is below
  - Assumes applicant will then go do separate fatigue, AD and ED evaluations depending on the threats.
- When ~~special~~ inspections are required to prevent catastrophic fatigue failure, inspection thresholds must be established to ensure that ~~cracking in a PSE~~ **damage** will be detected before it results in a catastrophic failure. The inspection thresholds must account for ~~the variations of manufacturing quality~~ **the range of damage threats to the structure.**

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## Proposed Rules 25.571(a)(6)

(6) Inspection programs for corrosion and service induced accidental damage must be proposed to protect the structure against catastrophic failure

- How is the program “proposed” by structures engineering incorporated?
  - Does the act of proposing something show compliance?
- 25.1529 and Appendix H.25 generally address this requirement
- Does not really reflect Cat 2 Composite Structures in AC20-107B
  - You must develop inspections and show they are adequate
- The scope and intervals of the inspection programs for accidental and environmental damage developed for 25.1529 must be supported by an engineering evaluation if that damage could lead to catastrophic failure.

# Critique of 2003 SDC Recommendations

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## Proposed Rules 25.571(f)(1)

- 1) Except as noted in subparagraph f(2), for structure evaluated according to the damage-tolerance requirements of paragraph (b) of this section, it must be shown by analysis, supported by test evidence, that the structure is able to withstand the loads specified in paragraphs (b)(1) to (b)(6) of this section in the presence of damage equivalent to:
  - i) the complete failure of any single element, or
  - ii) partial failure between damage containment features that significantly retard or arrest a crack
- **Pre-supposes that a specific design feature is the only means to protect against the range of threats**
  - **Stable or arrested growth of visually detectable damage should meet the requirement**
- **Does not really reflect Cat 3 Composite Structures in AC20-107B**
  - ***... ensure limit or near limit load is maintained with easily detectable Cat 3 damage***
- **“supported by test evidence” implies a test is always required**
- **Residual strength requirements are too severe for short duration exposure**
  - **Review 25.671(c) and 25.571 Amdt. 25-23**
- **Adjustments may be required to flutter in 25.629(d) to accomodate**



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## Proposed Rules 25.571(f)(1)

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  - i) the complete failure of any single element, or
  - ii) partial failure between damage containment features that significantly retard or arrest a crack

- **ATA MSG-3 Rev. 2007.1 Instructions For Accidental Damage (para. 2-4-5)**

*Accidental damage rating systems should include evaluations of the following:*

*c. Timely detection of damage, based on the relative rate of growth after damage is sustained and visibility of the SSI for inspection. Assessments should take into account damage growth associated with non-chemical interaction with an environment, such as disbond or delamination growth associated with a freeze/thaw cycle.*

**If you demonstrate this using damage tolerance principles, you have met the SDC requirement.**

**AC 25-20 and AC20-107B Cat 2/3 Damage are examples.**

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  - i) the complete failure of any single element, or
  - ii) partial failure between damage containment features that significantly retard or arrest a crack

- **Review 25.671(c) – Control System, General**

(c) The airplane must be shown by analysis, tests, or both, to be capable of continued safe flight and landing after any of the following failures or jamming in the flight control system and surfaces (including trim, lift, drag, and feel systems), within the normal flight envelope, without requiring exceptional piloting skill or strength. Probable malfunctions must have only minor effects on control system operation and must be capable of being readily counteracted by the pilot.

- (1) Any single failure, excluding jamming (for example, disconnection or failure of mechanical elements, or structural failure of hydraulic components, such as actuators, control spool housing, and valves).
- (2) Any combination of failures not shown to be extremely improbable ...
- (3) Any jam in a control position normally encountered ...

- **This requirement generally forces fail-safe control surface hinges, etc.**

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## Proposed Rules 25.571(f)(1)

- 1) Except as noted in subparagraph f(2), for structure evaluated according to the damage-tolerance requirements of paragraph (b) of this section, it must be shown by analysis, supported by test evidence, that the structure is able to withstand the loads specified in paragraphs (b)(1) to (b)(6) of this section in the presence of damage equivalent to:
- i) the complete failure of any single element, or
  - ii) partial failure between damage containment features that significantly retard or arrest a crack

### • Review 25.571 Amdt. 25-23 – Fail-Safe Strength

(c) *Fail safe strength.* It must be shown by analysis, tests, or both, that catastrophic failure or excessive structural deformation, that could adversely affect the flight characteristics of the airplane, are not probable after fatigue failure or obvious partial failure of a single principal structural element. After these types of failure of a single principal structural element, the remaining structure must be able to withstand static loads corresponding to the following:

- (1) An ultimate maneuvering load factor of 2.0 at  $V_C$ .
- (2) Gust loads as specified in Secs. 25.341 and 25.351(b), ...
  - (i) At speed  $V_B$ , 49 fps from sea level to 20,000 feet, thereafter decreasing linearly to 28 fps at 50,000 feet;
  - (ii) At speed  $V_C$ , 33 fps from sea level to 20,000 feet, thereafter decreasing linearly to 16.5 fps at 50,000 feet; and
  - (iii) At speed  $V_D$ , 15 fps from sea level to 20,000 feet, thereafter decreasing linearly to 6 fps at 50,000 feet.
- (3) Eighty percent of the limit loads resulting from the conditions specified in Sec. 25.427 ...
- (4) Eighty percent of the limit maneuvering loads resulting from the conditions specified in Sec. 25.351(a), ...

(e) The loads prescribed in this paragraph and paragraph (c) of this section must be multiplied by a factor of 1.15 unless the dynamic effects of failure under static load are otherwise considered.

**Required Demonstration to ~80 – 92% of Design Limit Load**

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## Proposed Rules 25.571(f)(1)

- 1) Except as noted in subparagraph f(2), for structure evaluated according to the damage-tolerance requirements of paragraph (b) of this section, **the airplane must be shown by analysis, tests, or both, to be capable of continued safe flight and landing after the following:**
  - i) the complete failure of any single element, or
  - ii) **obvious partial failure (*stable for a period of time???*), or**
  - iii) partial failure between damage containment features that significantly retard or arrest damage

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## Proposed Rules 25.571(f)(2)

- 2) For single load path structure, the intent of the SDC requirement shall be achieved through the demonstration of slow crack growth, an upper bound inspection threshold of 50% DSG and consideration of the quality control procedures used in manufacture. The requirement for an upper bound inspection threshold of 50% DSG may be extended based upon a rational analysis that is approved by the Administrator.
- **Ability of the arbitrary 50% DSG upper bound to provide protection against the full range of threats including accidental damage?**
    - **Pre-supposes the locations selected for the fatigue damage evaluation are also those susceptible to all other threats**
    - **Can certain known quality escapes, load sources, or accidental damage defeat this supposed safety valve?**
- 2) Where the capability required is (f)(1) is not feasible, the damage tolerance evaluation in (b) must demonstrate the slow damage growth rates and associated inspections adequately address all threats to the structure considering failures in the quality control procedures used in manufacture and service.

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## Proposed Rule 25.571(g)

(g) **Inspectability.** The inspectability of the extent of damage established in accordance with paragraph (f) must be addressed and reflected in the threshold determination required by paragraph (a)(5).

- This rule is primarily being addressed by the Metals & Composites ARAC
  - The proposed wording seems okay, but input from the Composites COGs is needed to see if it properly addresses Cat 2 damage
    - The resulting proposed guidance is rather problematic, however
  - If (a)(5) is reworded to include a threat assessment, is this requirement even needed?

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## Benefits Of Proposed SDC Rule

- **Provides A Means To Ensure Structure Is Robust Enough To Withstand Rare Events**
- **Damage Capability Requirements Have Historically Been Addressed in 25.571**
  - **vs. a 25.6xx Design Requirement**
- **Provides A Means To Address Damage Detection And Growth Rates**
- **Provides A Means To Address Single Load-Path Structures**
  - **vs. a 25.6xx Design Requirement**

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## Drawbacks Of Proposed SDC Rule

- **Will Be Costly To Certify And May Be An Open-Ended Requirement**
  - **Large Number of Compliance Demonstrations**
- **Damage Failure Modes Assumed May Not Be Representative Nor Obviously Detectable**
  - **Does SDC Envelope A Robust Threat Assessment?**
- **Justification And Management of S.L.P. Structures Will Require Extensive Guidance**