12.0 STRUCTURAL DAMAGE CAPABILITY – FOR METALLIC STRUCTURE (REF. AC 20-107C FOR GUIDANCE ON SDC FOR COMPOSITE STRUCTURE)

a. **General.** Structural Damage Capability (SDC) is the attribute of the structure which permits it to retain its required residual strength in the presence of large damage. The overall purpose is to prevent catastrophic failure resulting from damage not accounted for in damage tolerance analysis. SDC is a characteristic of the design of a structure, and is therefore not specifically tied to any one aspect of a maintenance program.

Damage tolerance is the ability of structure to sustain anticipated loads in the presence of damage until it is detected through inspection or malfunction, and repaired. It should be emphasized that SDC is not a replacement for damage tolerance – SDC adds robustness to the inherent structural design. SDC addresses unforeseen damage and complements existing damage tolerance inspection requirements. It does not generate any additional inspection or inspection threshold requirements; these should already be accounted for by existing baseline and damage tolerance based maintenance programs.

SDC is an inherent design attribute and complements more formal inspection programs derived through damage tolerance evaluation (DTE). At a high level, types of damage could include static and fatigue cracking, wear, environmental deterioration, impact, heat damage, disbond and delamination. General sources of damage could be from loading in service, the environment, accidental damage, maintenance errors, discrete events and manufacturing defects. Specific examples of possible damage scenarios that SDC may protect against include but are not limited to the following:

- Accelerated corrosion of a fuselage skin from a waste spill that was not neutralized
- Failure of a steel fitting due to a manufacturing processing error that causes hydrogen embrittlement
- Severe wear of the fuselage crown skin from vertical stabilizer aerodynamic seals
- Failure of a single frame or single stringer
- Damage to structure from excessive pull-up or mis-drilled holes in manufacturing or maintenance
- Accidental damage in the fuselage skin
- Damage from runway debris
- Damage from departure of small access covers in flight
- Damage from high load events

It should be noted that structure with an SDC design will not be able to withstand damage from all of the above scenarios in all cases – this would be dependent on the severity of the damage and the level of conservatism or robustness provided by the applicant’s SDC philosophy.

An SDC assessment should be performed for Principal Structural Elements (PSE) subject to in-flight loads under paragraphs (b)(1) through (b)(5) of §25.571.

b. The evaluation of a given PSE for SDC is intended to ensure that, in the event of a certain level of damage, the remaining intact structure is capable of carrying the

required residual strength loads as defined in paragraph a. The extent of SDC to be demonstrated may be used to mitigate the thoroughness** of the threat assessment and the type of PSE under evaluation. To this end, the structure is classified as Category A, B or C as follows [note that the following guidance applies to conventional type structure, and SDC for non-conventional structure (e.g. iso-grid) may need to be addressed on a case-by-case basis]:

Category A - Single Load Path (SLP) Structure
Category B - Monolithic Metallic Multiple Load Path (MLP) Structure
Category C – Discrete Element or Built-up MLP Structure

(1) Category A – Single Load Path Structure
By definition, Category A structure does not have inherent SDC capability. However, for cases where the applicant

a. establishes that Category B or C designs would be impractical; and
b. conducts a thorough** threat assessment

usage of Category A structure which is non-safe life and subject to in-flight loading may be considered.

i. Definition: Single load path PSE structure which contains no damage containment features and the failure of which may lead to a catastrophic loss of the aircraft.

FIG. 1 – Category A single load path structure

ii. Example: A single element fitting, such as a single link or lug, with no integral features to contain cracks and retard propagation, and which upon failure the remaining structure cannot withstand the required residual strength load.

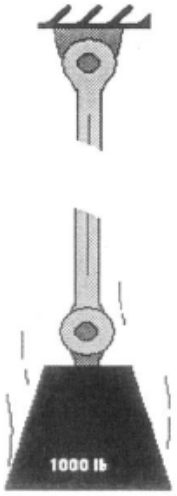

FIG. 2 – Category A single load path structure does not have SDC capability

iii. The structure must be able to withstand the loads defined in paragraph a with the extent of damage determined by the threat assessment.

The applicant should consider the following:

- Minimization of environmental and accidental damage (i.e. consider protection, different materials, etc.)
- Perform a fatigue test or complete fatigue analysis based on test to demonstrate an acceptable level of fatigue reliability.
- Perform a test or analysis based on test to demonstrate slow crack growth capabilities
- Develop a manufacturing process control and tracking plan document

(2) Category B – Monolithic Metallic Multiple Load Path Structure:

i. Definition: Monolithic metallic structure with crack retardation features

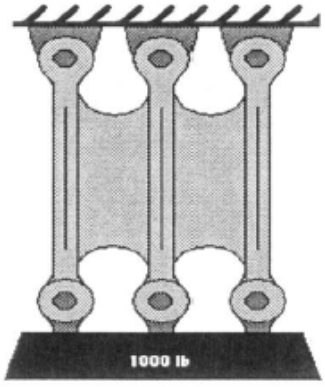

FIG. 3 – Category B monolithic structure with damage retardation features

ii. Example:

- A machined monolithic structure where features are machined into it for the purpose of restricting possible damage to a size whereby the remaining un-cracked structure can sustain residual strength loads with the loads as defined in paragraph a.

iii. Minimum level of SDC for monolithic panelized construction is capability to withstand the loads defined in paragraph a with the following level of damage:

- With only a partial/limited threat assessment in place, as a minimum*, each of the following should be evaluated:
    - A crack in one skin bay between stiffeners (see Fig. 4 Section A-A)
    - A failed stiffener plus a visually detectable crack in the integral skin (see Fig. 4 Section B-B)

  Other Considerations: Applicant should consider active crack tips and address the effectiveness of the crack retardation features.

  * Note: In rare cases, the threat assessment may yield a realistic damage size leading to a level of SDC greater than one bay crack or greater than a failed stiffener plus a visually detectable skin crack.

- With a thorough** threat assessment in place the level of SDC is the realistic damage size as determined by the threat assessment.

  Other considerations: Applicant should consider active crack tips where applicable. Mode of damage (e.g. dent damage) may not warrant consideration of active crack tips.

Minimum level of SDC for other monolithic structure (such as an integral wing spar) is capability to withstand the loads defined in paragraph a with the following level of damage:

- With only a partial/limited threat assessment in place, as a minimum*, each of the following should be evaluated:
    - the failure of the equivalent to a single element for multi-element construction (see Fig. 5A)
    - a crack between crack retardation features (see Fig. 5B).

  Other considerations: Applicant should consider active crack tips and address effectiveness of crack retardation features.

  *Note: In rare cases the threat assessment may yield a realistic damage size leading to a level of SDC greater than failure of a single element or greater than a crack between crack retardation features.

- With a thorough** threat assessment in place the level of SDC is the realistic damage size as determined by the threat assessment.

Other considerations: Applicant should consider active crack tips, where applicable. Mode of damage (e.g. dent damage) may not warrant consideration of active crack tips.

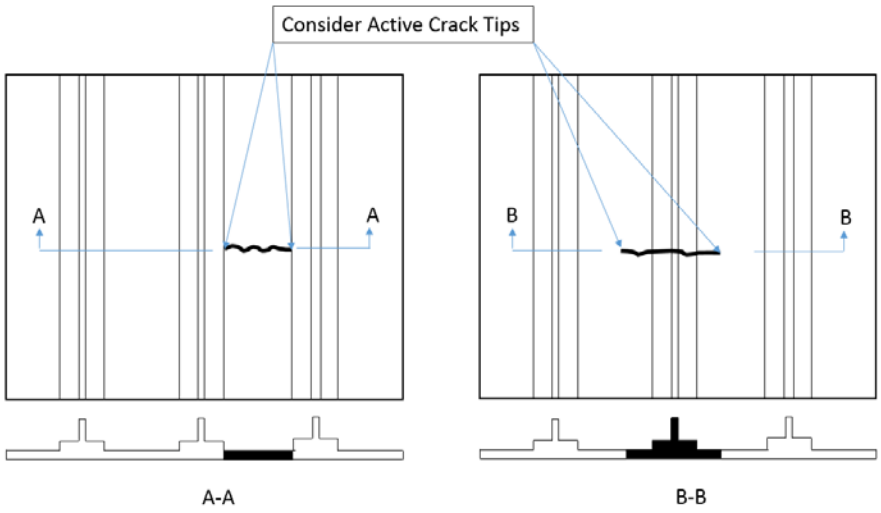

FIG. 4 – Example of minimal SDC for Category B monolithic panel structure with damage containment features which is appropriate where the applicant has completed a partial/limited threat assessment. Evaluation would include both damage scenarios shown: (A-A) One bay skin crack, (B-B) Failed stiffener plus visually detectable skin crack. **These pictures only illustrate typical configurations and damage scenarios. The applicant should consider scenarios specific to their design configuration.**

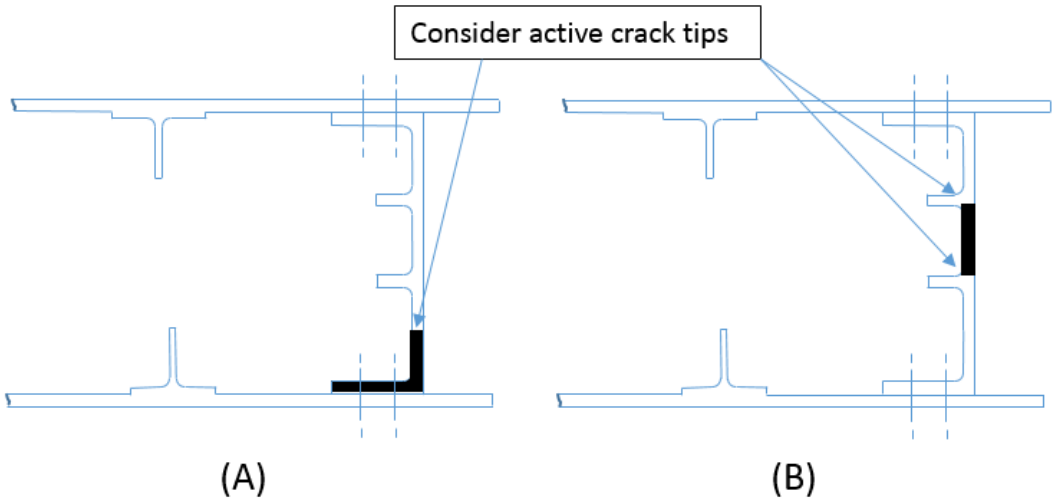

FIG. 5 – Example of minimal SDC for Category B monolithic spar structure with damage containment features which is appropriate where the applicant has completed a partial/limited threat assessment. Evaluation would include both damage scenarios shown: (A) Equivalent to single element damage for multi-element construction, (B) Crack between crack retardation features. **These pictures only illustrate typical configurations and damage scenarios. The applicant should consider scenarios specific to their design configuration.**

Category C – Discrete Element or Built-Up Multiple Load Path (MLP) Structure:

i. Definition: Structure made up of multiple, independently fastened or bonded structural members that are part of a larger redundant system with multiple load paths; the remaining damage free members can carry the required load. There are two types of Category C structure:

Type 1: Discrete Element MLP Structure, i.e. multiple independent element structure where one member of that system could be completely broken.

Type 2: Built-up MLP structure (includes structure consisting of discrete stiffening members and a continuous element).

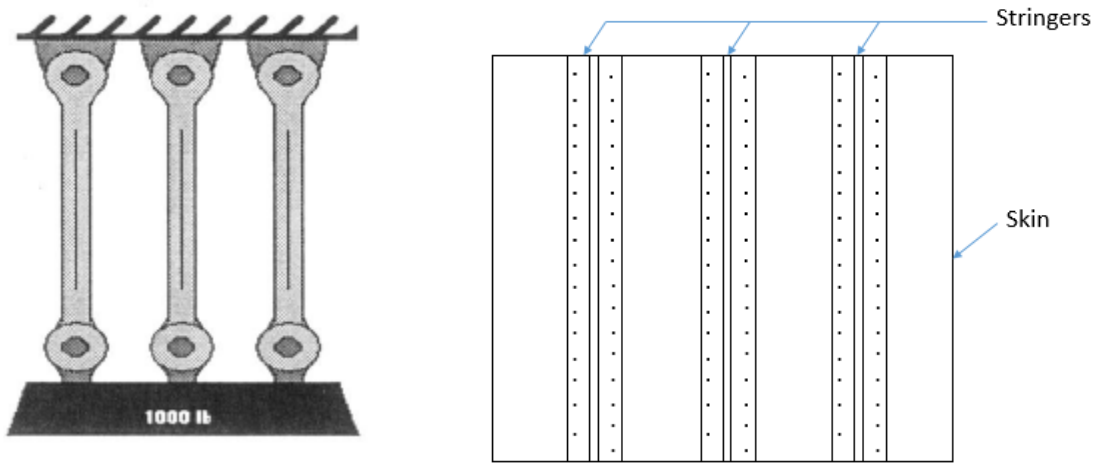

FIG. 6 – Category C multiple load path structures

ii. Examples:

Type 1 -

- Back-to-back or multiple redundant lugs and fittings.
- Multiple redundant attachments for structure such as control surface hinge ribs, engine strut attachments, thrust reverser attachments and door latches, stops and hinges.
- Finite width fastened multiple panels where required loads can be maintained with the loss of one panel.

Type 2 -

- Stiffened panels with separately fastened stiffening members such as stringers, longerons or frames, or separately bonded or fastened structural damage containment features such as metallic tear straps (where damage in the skin does not propagate into the tear straps). Note that each individual skin bay between stiffeners or damage containment features is assumed to be a separate load path.
- Built-up structure such as doorway frames and spars with separately fastened skins, chords, webs and straps.

iii. Minimum Level of SDC -

Type 1 –

- With only a partial/limited threat assessment in place, it should be ensured that the multiple load path design includes sufficient structural redundancy to allow for the failure of a single element. (see Fig. 7A). Analysis should be performed and limited to the static assessment of the ability of the remaining intact load paths to carry the loads defined in paragraph a.
- With a thorough** threat assessment in place the level of SDC is the realistic damage size as determined by the threat assessment (see Fig. 7B).

  Other considerations: Applicant should consider active crack tips, where applicable. Mode of damage (e.g. dent damage) may not warrant consideration of active crack tips.

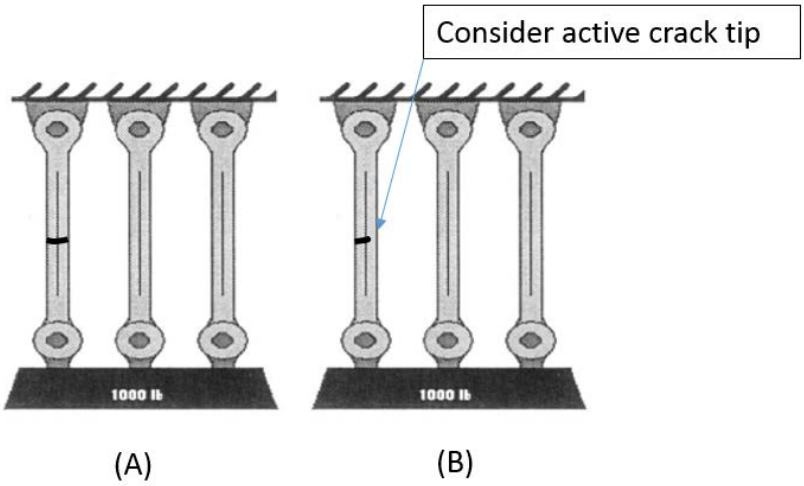

FIG. 7 – (A) Example of level of SDC for Category C Type 1 multiple load path structure where the applicant has completed a partial/limited threat assessment. Level of SDC is failure of one complete load path. (B) Example of level of SDC for Category C Type 1 multiple load path structure where the applicant has completed a thorough threat assessment. Level of SDC may be partial failure of one load path.

Type 2 – For built-up panelized construction the level of SDC is the capability to withstand the loads defined in paragraph a with the following level of damage:

- With only a partial/limited threat assessment in place, as a minimum*, each of the following should be evaluated:
  - A crack in one skin bay between stiffeners (see Fig. 8 Section A-A)
  - A failed stiffener plus a visually detectable crack in the adjacent skin (see Fig. 8 Section B-B)

Other considerations: Applicant should consider active crack tips.

*Note: In rare cases, the threat assessment may yield a realistic damage size leading to a level of SDC greater than one bay crack or greater than a failed central stiffener plus a visually detectable crack in the adjacent skin.

- With a thorough** threat assessment in place the level of SDC is the realistic damage size as determined by the threat assessment.

  Other considerations: Applicant should consider active crack tips, where applicable. Mode of damage (e.g. dent damage) may not warrant consideration of active crack tips.

For other built-up Type 2 structure (such as a built-up wing spar), the minimum level of SDC is the capability to withstand the loads defined in paragraph a with the following level of damage:

- With only a partial/limited threat assessment in place, as a minimum*, the applicant should evaluate the failure of a single element (refer to Fig. 9).

  *Note: In rare cases, the threat assessment may yield a realistic damage size leading to a level of SDC greater than a single element.

- With a thorough** threat assessment in place the level of damage is the realistic damage size as determined by the threat assessment (refer to Fig. 10).

  Other considerations: Applicant should consider active crack tips where applicable. Mode of damage (e.g. dent damage) may not warrant consideration of active crack tips.

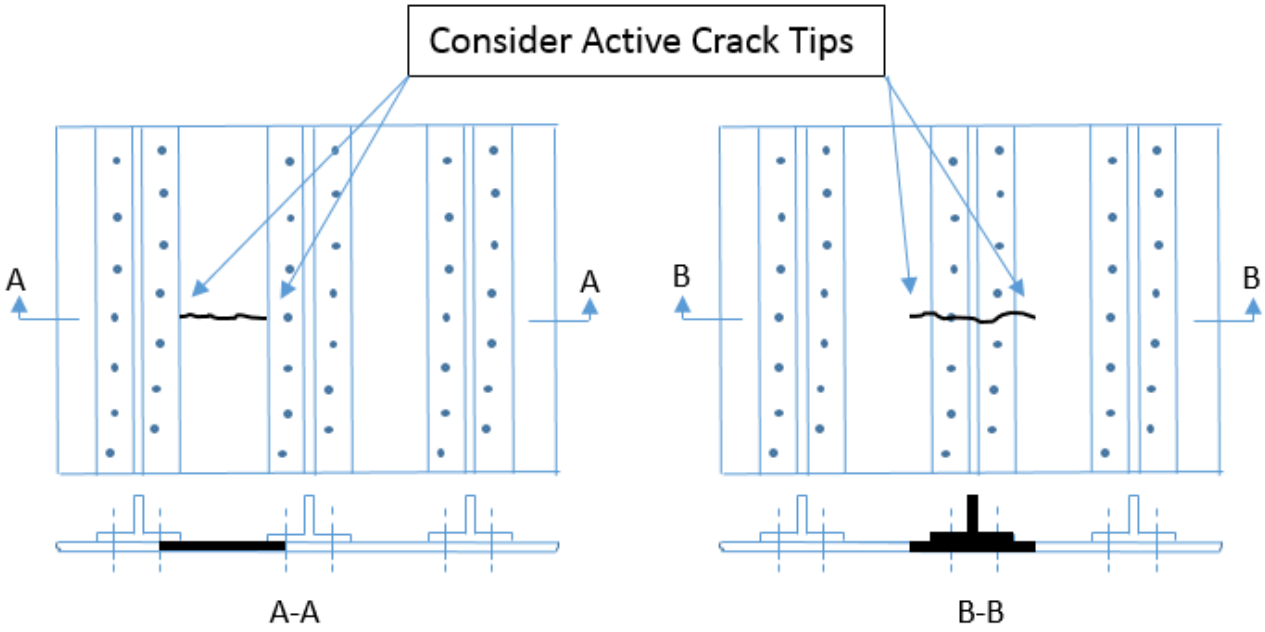

FIG. 8 – Example of minimal SDC for Category C Type 2 built up panelized multiple load path structure which is appropriate where the applicant has completed a partial/limited threat assessment. Evaluation would include both damage scenarios shown: (A-A) One bay skin crack, (B-B) Failed stiffener plus visually detectable skin crack. **These pictures only illustrate typical configurations and damage scenarios. The applicant should consider scenarios specific to their design configuration.**

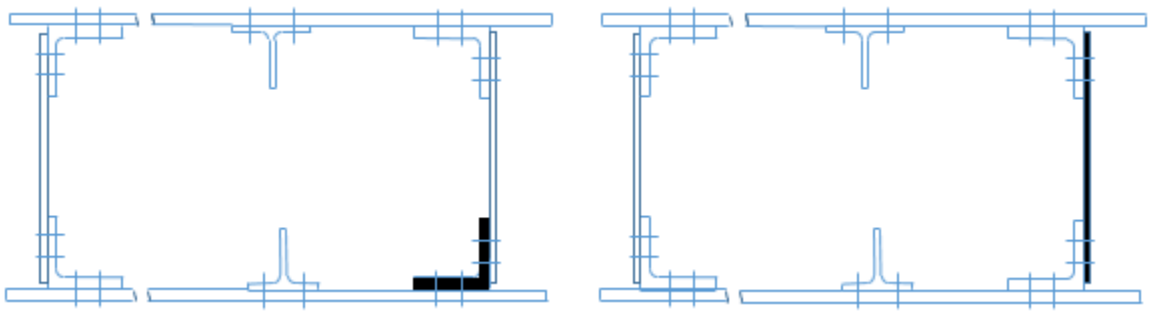

FIG. 9 – Example of minimal level of SDC for Category C Type 2 multiple load path structure which is appropriate where the applicant has completed a partial/limited threat assessment. SDC assessment would include both damage scenarios shown for the built-up spar. **These pictures only illustrate typical configurations and damage scenarios. The applicant should consider scenarios specific to their design configuration.**

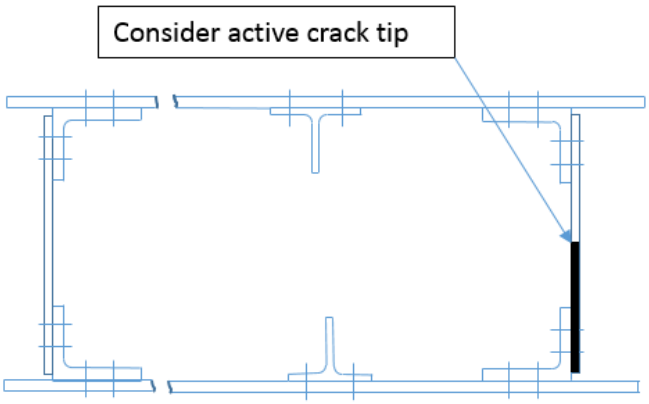

FIG. 10 – Example of level of SDC for Category C Type 2 multiple load path structure which may be appropriate where the applicant has completed a thorough threat assessment. SDC assessment may include the web damage scenario shown for the built-up spar. **These pictures only illustrate typical configurations and damage scenarios. The applicant should consider scenarios specific to their design configuration.**

**A thorough threat assessment is defined as a thorough investigation of damage threats, supported by service history, to mitigate the likelihood of catastrophic loss.