BCA Airplane Programs

Existing Fail-Safe/Structural Damage Capability (SDC) Practices

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Date: March 15, 2016

Fail-Safe/SDC Philosophy and Practices

Agenda

- Purpose
- Existing Fail-Safe Design Philosophy
- Examples
- Summary

Fail-Safe/SDC Philosophy and Practices

Purpose

- **Give a high level overview of existing Boeing fail-safe design philosophy**
- **Show examples of how this philosophy is applied to our design practices**

Fail-Safe/SDC Philosophy and Practices

Philosophy and Evolution

- Fail-safety typically requires redundancy for single element failures and for certain multiple element damage scenarios
- Damage tolerance can be achieved without such redundancy
- Fail-safety has been maintained as a foundational requirement even on structure certified as damage tolerant
- Fail-safety has evolved from considering any single element failed to considering large damage scenarios that consider element failure coupled with adjacent damage
- Increased use of composites has resulted in accounting for threats not previously considered

Both damage tolerance and fail-safety are essential elements of airplane safety

Fail-Safe/SDC Philosophy and Practices

Philosophy (cont.)

Generic fail-safe features can be summarized into the following categories:

- alternate/intermediate/adjacent members that pick up load from failed members
- fastener and bondline capability matched to load redistribution requirements
- damage containment features, such as fuselage tear straps
- boundaries of components and subcomponents, such as major joints or heavy frames
- material toughness, as applied to damage containment and residual strength capability in fail-safe scenarios

Fail-safe designs are intended to provide redundant load paths and damage containment

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Key points in application of fail-safe principles

- All primary flight-loaded structure, including trailing edge flaps and control surfaces, must be designed with sufficient residual strength to carry limit load with failure or partial failure of a principal structural element (PSE).
- Where fail-safe and damage tolerant designs are not practical for a PSE, such as ground-loaded structure, then the structure must be designed for safe life.
- The wing, empennage, and fuselage shall be designed for limit load assuming one stiffening member and adjacent panels failed.
- For composite wing and empennage structure, the load level considered for the above two-bay multiple element damage criterion is 70% of limit load if the damage would be pilot evident and immediately obvious.
- Fail-safe design concepts should provide for visual damage detection by minimizing hidden critical details.

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Key points in application of fail-safe principles (cont.)

- Any new design approach must have the equivalent damage containment capabilities as the "standard" which is based upon traditional fail-safe design approaches. Such equivalency must be established by analysis supported by test and/or service experience.

- Structure must meet requirements for discrete events including discrete source damage.

- Structure must be free from flutter for failure conditions described in FAR 25.629. This is particularly important for control surfaces, wing/tail tips, nacelle and struts (including their attachments), and actuator load loops.

- Integral or “monolithic” structure must be designed for fail-safety. If integral structure cannot be shown to have fail-safety with complete failure of the integral member, then the integral structure must include damage containment features.

- Primary composite structure shall be designed to carry design limit loads following skin-stringer disbond between damage arrestment features.

- Primary composite structure shall be designed to carry design limit loads following damage states which must be clearly obvious to the inspector during a general visual (GVI) planned inspection.

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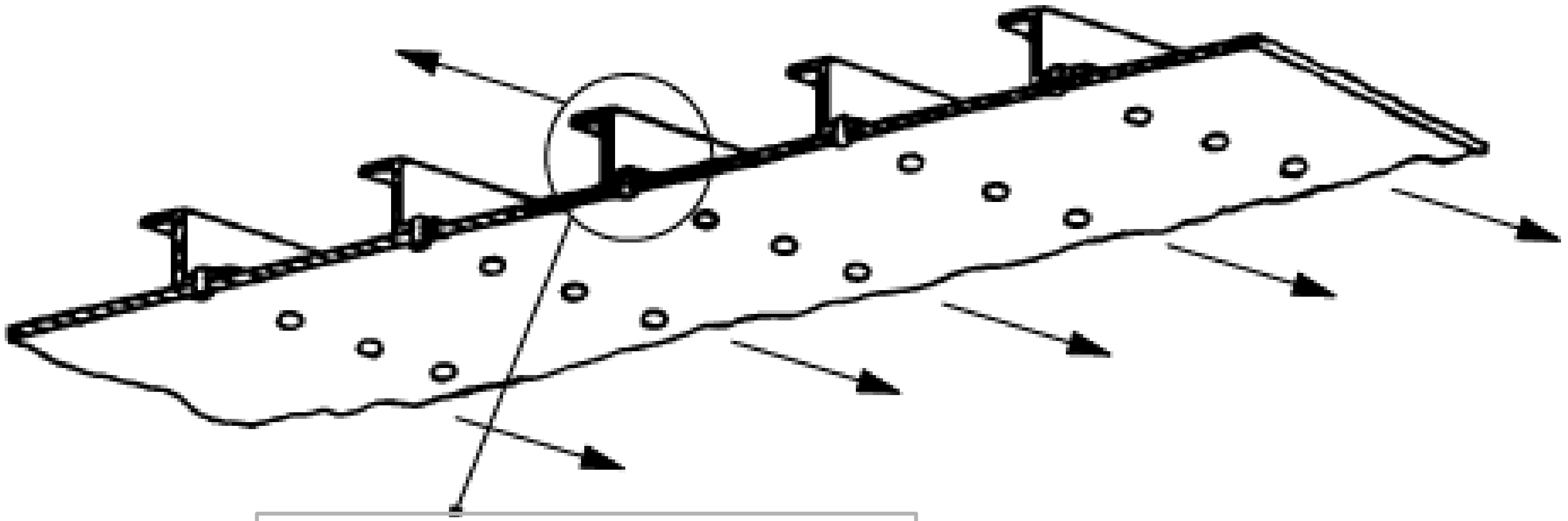
Examples of Fail-safe Design



Typical Stringer and Adjacent Skin Bays Failed

Panelized Construction

Example - Recent Boeing designs are designed with the assumption that one typical stiffening member and its adjacent bays are failed. The load is redistributed to adjacent skin and stringers.

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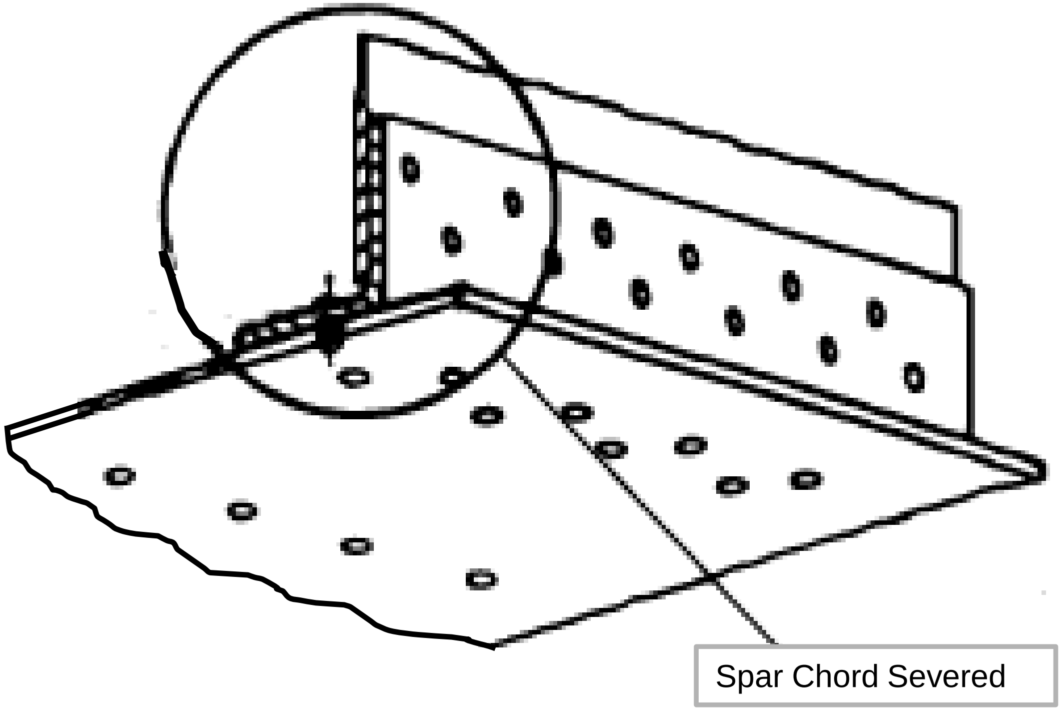
Examples of Fail-safe Design



Substructure

Example – Wing and Empennage Spars: Severed chord with chord end load redistributed to skin panel and spar web

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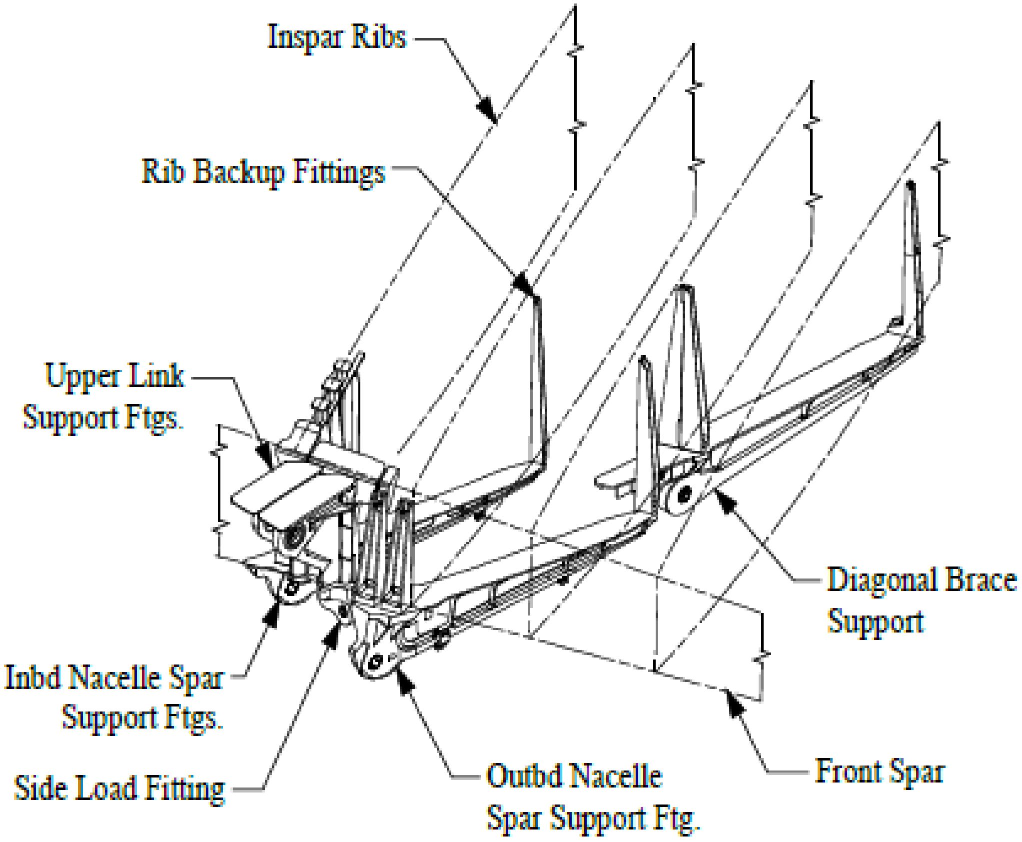
Examples of Fail-safe Design

Primary Fittings and Support Members:

Options -

1. Failure of one in group
2. Catcher design
3. Back-to-back design
4. Integral design with crack containment features



Fail-Safe/SDC Philosophy and Practices

Summary

- **Fail-safe features provide added protection against unanticipated, inadvertent damage that airplanes may encounter in their service life.**
- **Fail-safety has been a fundamental Boeing design requirement since the advent of the 707 program; Boeing will continue to utilize fail-safe design practices.**
- **Existing fail-safe practices could be captured as possible means of compliance for SDC in the advisory materials we are currently evaluating.**

There is a potential increase in complexity between meeting internal design requirements versus making formal compliance findings with respect to SDC