

# Composite Structure Fatigue and Damage Tolerance Experience

Boeing Commercial Airplane  
17 September 2015

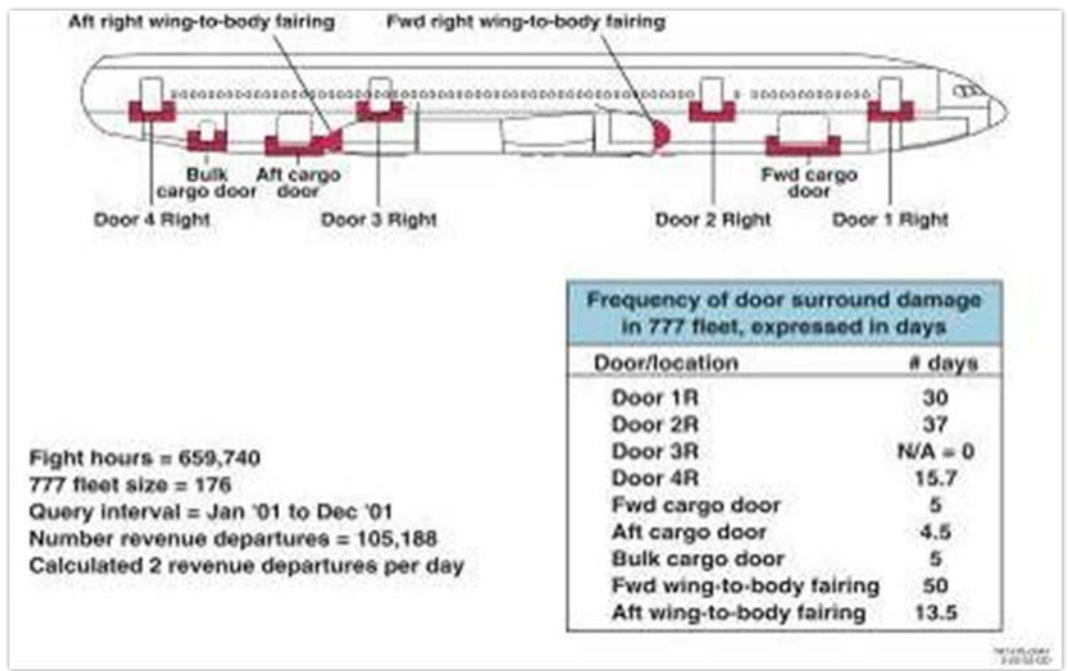
*FAA/Bombardier/TCCA/EASA/Industry  
Composite Transport Damage  
Tolerance and Maintenance Workshop*

# Composite Fatigue and Damage Tolerance Experience

- **Damage Threats**
- **Maintenance Inspections**
- **LEF and Testing**
- **Flight with Known Damage**

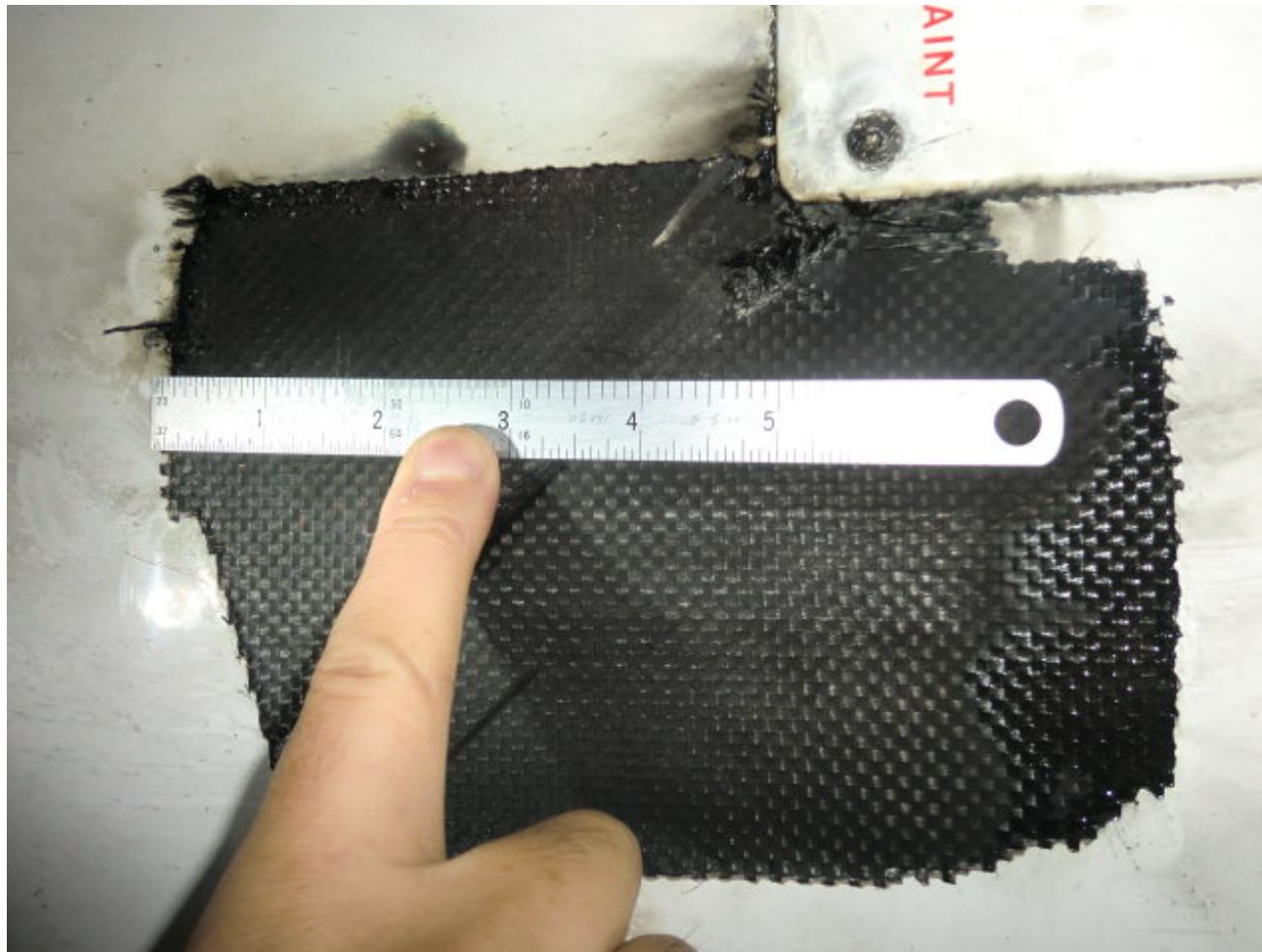
# Threat Assessment During 787 Design Phase

- Threat assessment was made for all major 787 structures
- 767 and 777 in-service damage history mined from many sources
  - Logbook data, Service Request data, AOG experience, Service Bulletins, Service Letters, Service Related Problems, 787 Technical Forum
- Impact tests
  - 767 Door surround
  - 787 Door surround



# In-Service Example – Lightning Strike

## Lightning strike from the ground – Original damage



# In-Service Examples – Damage Resistance – Servicing Vehicle Impact

- The platform of a servicing vehicle hit the airplane fuselage skin at section 47 between STA 1605 and STA 1875
- Both an external non-destructive inspection and an internal visual inspection per AMM 05-51-58 showed no findings of structural damage and only cosmetic paint damage.
- The airplane returned to service.



# In-Service Examples – Damage Resistance – Food Service Truck Impact

- **Food service truck made contact with the rear of fuselage**
- **Black mark is aft of the bulk cargo door, directly below and in line with the aft edge of door 4L.**
- **The contact caused the airplane to make contact with the cargo loader on the other side and the left front of the airplane made contact with the jetway at door L1**
- **NDI revealed no damage. The airplane returned to service the next day**



*787 Structure is proven to be robust and damage tolerant*

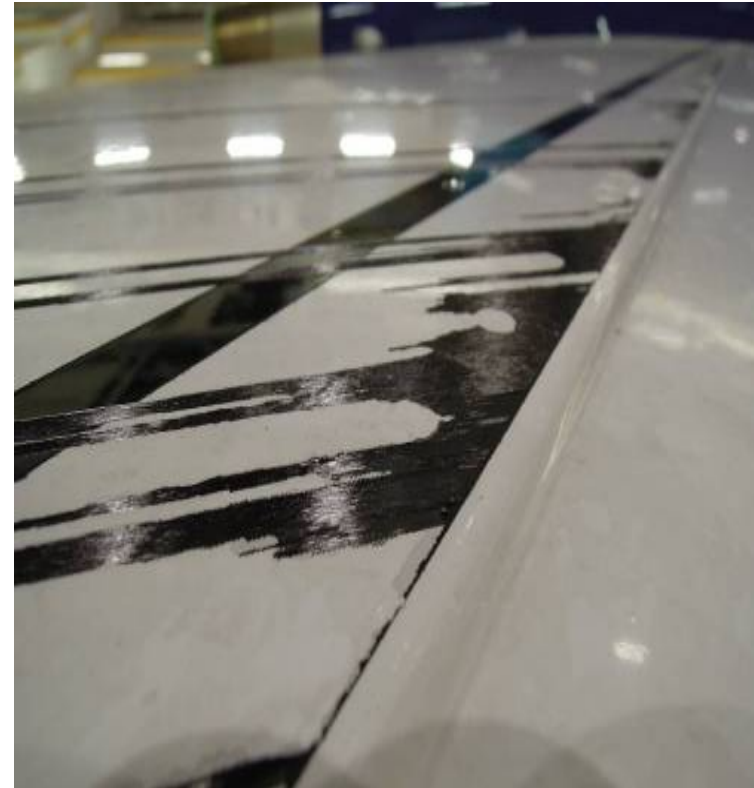
# Erosion of Composite Parts – Horizontal Stabilizer Main Box

## Issue

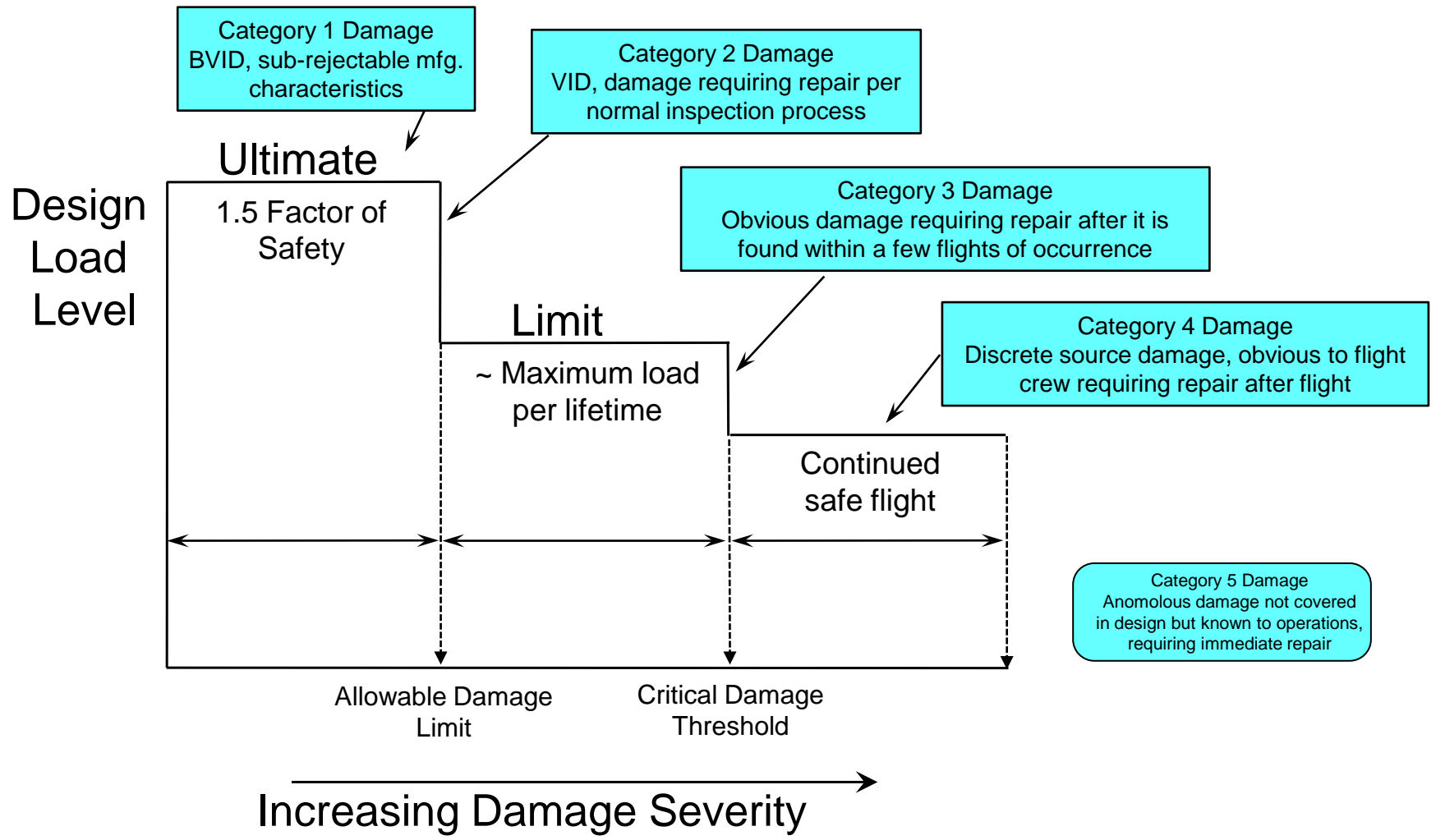
- Portions of upper skin ply tows peeling horizontal stabilizer multi-spar main box
- Erosion is due to air flow over an upstanding edge
  - Concavity of aerodynamic sealant

## Final Action

- Revised sealant definition of gap between main box and leading edge with stricter flushness requirements
- Added Ti foil to forward skin edge
- Service Bulletins B787-55-0003-01 and 55-0004 released 27/2/15 with retrofit instructions.



# Damage Categories – AC20-107





# Impact Damage - Boeing Design Philosophy

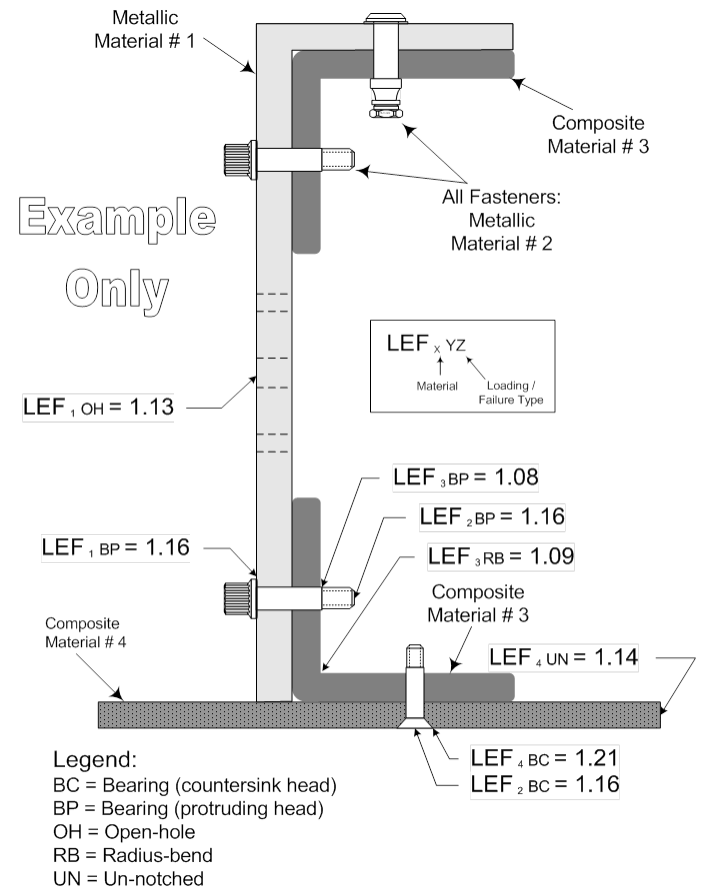
- **Boeing evaluates structural performance accounting for various damage states**
  - **Barely visible impact damage**
  - **Visible impact damage**
    - damage ranges from clearly visible during planned inspection performed by trained personnel to visible during normal walk around performed by un-trained personnel
  - **Discrete source damage**
    - Bird impact and Small fragment damage up to large rotor burst type damage
  - **Boeing fail-safe design philosophy**
    - Design using redundant load paths and evaluate residual strength with any member cut
  
- **Design structure using the “no growth” / arrested growth philosophy**
  - **Impact damage is included in the structural test building block**
    - Configured element, sub-component, component tests
  - **Demonstrate no “detrimental” damage growth through fatigue testing**
    - Life of product for BVID
    - Two inspection intervals for VID
  - **Demonstrate appropriate residual strength at the conclusion of fatigue life**
    - Ultimate load for BVID
    - Limit load for VID

# Approach to Basic Maintenance

- **Characterize material and general construction sensitivity to damage**
  - thin skin honeycomb, thick skin honeycomb, solid laminate
  - Assign a robustness rating based on service experience
- **Assess exposure to environmental or accidental damage**
  - **Assess likelihood of occurrence and sensitivity to damage for both accidental and environmental sources**
  - **Accidental damage sources**
    - ground and cargo handling equipment, maintenance traffic, passenger traffic, hail, runway debris, fluid spillage (oil, acid, water, etc), incident (bird strike, lightning strike, etc)
  - **Environmental damage sources**
    - UV light, moisture, fluids, heat, etc.
- **Develop a combined rating for the structure based on construction and exposure to accidental/environmental damage**
  - A low score would indicate that inspection intervals should be frequent whereas a high score would indicate a robust design or protected region where inspection intervals could be much greater.

# Example LEF in Configured Structure

- Configured structure can contain many different details with different LEFs
- How do you perform test to efficiently address appropriately?
- Conservatively use highest value
- Use a weighted average value
- Split testing between multiple tests



# Flight with Known Damage

## ■ Metallic Primary Structure

- The airplane is currently at a remote operating base where insufficient technical or maintenance resources are available to perform a repair.
- The cracked structure is capable of meeting limit and ultimate load conditions as specified in 14 CFR 25.305.
- The adjacent structure has been inspected and is free of cracks or other damage.
- The affected structure is not subject to any AD.
- The crack tips have been stop-drilled (stop-drilling is not considered a repair). Approval shall not be granted for cracks not stop-drilled.
- This approval is time limited

## ■ Composite Structure

- Damage to composite structure will typically consist of delaminations, surface scratches, gouges or penetrations with associated local delaminations.
- It is customary during repair to prepare the damaged area by cleaning it up sufficiently to allow repair. It is not always necessary to remove all damage and in some cases this helps to facilitate the repair e.g. bolted repairs. This is acceptable as long as the remaining damage will not detrimentally grow in service and the repaired state maintains ultimate load capability.
- Delaminations are not considered active cracks if it is known that they will not detrimentally grow in service and that the structure maintains ultimate load capability.
- Sufficient engineering evidence must exist to support this determination.