Following Slides were Given at Noon on 7/20/06 (to recap FAA Damage Tolerance and Maintenance Workshop to that time)
# Categories of Damage & Defect Considerations for Primary Composite Aircraft Structures

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples (not inclusive of all damage types)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category 1:</strong> Allowable damage that may go undetected by scheduled or directed field inspection (or allowable manufacturing defects)</td>
<td>BVID, minor environmental degradation, scratches, gouges and allowable mfg. defects that must retain ultimate load for the specified life</td>
</tr>
<tr>
<td><strong>Category 2:</strong> Damage detected by scheduled or directed field inspection @ specified intervals <em>(repair scenario)</em></td>
<td>VID (ranging small to large), deep gouges, mfg. defects/mistakes, major local heat or environmental degradation that must retain limit load until found</td>
</tr>
<tr>
<td><strong>Category 3:</strong> Obvious damage detected within a few flights by operations focal <em>(repair scenario)</em></td>
<td>Damage obvious to operations in a “walk-around” inspection or due to loss of form/fit/function that must retain limit load until found by operations</td>
</tr>
<tr>
<td><strong>Category 4:</strong> Discrete source damage known by pilot to limit flight maneuvers <em>(repair scenario)</em></td>
<td>Damage in flight from events that are obvious to pilot (rotor burst, bird-strike, lightning, exploding gear tires, severe in-flight hail)</td>
</tr>
<tr>
<td><strong>Category 5:</strong> Severe damage created by anomalous ground or flight events <em>(repair scenario)</em></td>
<td>Damage occurring due to rare service events or to an extent beyond that considered in design, which must be reported by operations for immediate action</td>
</tr>
</tbody>
</table>
Categories of Damage

**Category 1**: Allowable damage that may go undetected by scheduled or directed field inspection (or allowable manufacturing defects)

**Category 2**: Damage detected by scheduled or directed field inspection at specified intervals (repair scenario)

- **Exterior Skin Damage**
- **Interior Blade stringer Damage**

X-sec of BVID at Skin Impact Site

1.5 Factor of Safety

~ Maximum load per lifetime

Increasing Damage Severity

- Allowable Damage Limit (ADL)
- Critical Damage Threshold (CDT)

Category 1

Category 2

X-sec of BVID Impact at Flange to Skin Transition

FAA Composite Damage Tolerance & Maintenance Workshop (July 19-21, 2006)
**Categories of Damage**

**Category 3**: Obvious damage detected within a few flights by operations focal (repair scenario)

**Category 4**: Discrete source damage known by pilot to limit flight maneuvers (repair scenario)

- **Category 3**: Obvious damage detected within a few flights by operations focal (repair scenario)
  - **Lost Bonded Repair Patch**
  - **Accidental Damage to Lower Fuselage**

- **Category 4**: Discrete source damage known by pilot to limit flight maneuvers (repair scenario)
  - **Severe Rudder Lightning Damage**
  - **Rotor Disk Cut Through the Aircraft Fuselage Belly and Wing Center Section to Reach Opposite Engine**

**Allowable Damage Limit (ADL)**

**Critical Damage Threshold (CDT)**

- **Ultimate**: Maximum load per lifetime
- **Design Load Level**: Continued safe flight
Categories of Damage

Category 5: Severe damage created by anomalous ground or flight events (repair scenario)

- Birdstrike (flock)
- Birdstrike (big bird)
- Maintenance Jacking Incident
- Propeller Mishap
Safety Concerns for Composite Airframe Structures

• Unanticipated accidental damage threats that are not covered by design criteria
  – Damage that can’t be found with maintenance inspection procedures and lowering structural capability below URS
  – Damage that is not obvious and lowering structural capability to near LRS
• Environmental damage developing/growing with time
• Systematic structural bonding process problems that are not localized or contained to limited aircraft
• Severe damage occurring in flight, incl. take-off & landing, without knowledge of flight crew (overloads)
Safety Concerns for Composite Airframe Structures, continued

• Repeated service loads outside the design envelop
• Severe damage occurring on ground without proper reaction by operations personnel (e.g., ground vehicle collision, work stand impact, engine run-up/runway debris)
• Severe damage occurring in flight without immediate detection by operations personnel on the ground (e.g., in-flight breakaway & impact by secondary structure)
• Application of unsubstantiated repair designs and processes by field personnel
  – Repairs and/or damage outside approved data sources
  – Unqualified engineers, technicians and/or inspectors
Recap of Some Key Points from 7/19 (PM) and 7/20 (AM) Workshop

• Large category 3 damage is of a magnitude that growth can occur (i.e., reliance on operations for detection)
• More similarities than differences between Boeing and Airbus approaches to design criteria and substantiation
• Best practices for bridging gap for repair substantiation
  – Type Cert. can never be complete – must iterate w. field data
  – Minimize iterations by early repair process development and tests/analyses for the largest damage imagined
• Repair substantiation of primary structure includes static, stiffness/flutter, fatigue and damage tolerance
  – One reason why Boeing/Airbus/EASA/FAA WG was stating that major non-SRM repair requires OEM involvement
Recap of Some Key Points from 7/19 (PM) and 7/20 (AM) Workshop

• Integration of multiple disciplines is essential to safety
• No-growth, growth, and arrested growth options for DT substantiation will likely depend on design detail, defect/damage type and loading (failure mode)
• Some apparent problems with the “operations end of safety net” were given in Case Studies of large “category 5” damage that saw flight time
• “Analysis without testing is almost as bad as testing without analysis” - Promising analysis methods exist!
  – Engineering approaches for predicting both RS & fatigue
  – Progressive damage analyses of complex failure modes in configured sandwich and stiffened skin composite structure
Recap of Some Key Points from 7/19 (PM) and 7/20 (AM) Workshop

- Improperly performed bonded repairs can yield category 2 or 3 damages that are difficult to detect
- Some field NDI limits in detecting full extent of damage
- Fluid contamination (e.g., skydrol) of bonded joints may have complex, time-related degradation mechanisms
- Test “worst-case" manufacturing defects & field damage cases “to find out how bad it can get”
  Experienced Engineer that has lived his life on (over) the edge
- Limited fatigue data can be used to justify LEF=1.15 from Northrop Report (more rigor may yield lower LEF)
Recap of Some Key Points from 7/19 (PM) and 7/20 (AM) Workshop

• WSU R&D on structural test protocol welcomes industry input to define large scale substantiation of inspection, repair fatigue, damage tolerance and static strength
  – Evaluation of multiple hot spots allow statistical evaluations from a single test

Considering the fun of being FAA Program Manager for these large scale tests it may be time for a certain individual to postpone retirement for a couple years