Boeing Perspectives on Safe Composite Maintenance Practices
3 Legged Safety Stool
Operators-Boeing-Regulators

Operators
Manufacturer
Regulatory Authorities
Maintainable and Repairable Composites are no “Accident”

- Included as part of the design criteria
- Extensively validated by test and analysis—some unique methods are developed specific to repair
- Documented in the Airplane Maintenance Manual (AMM), Structural Repair Manual (SRM), Maintenance Planning Document (MPD) and Non-Destructive Test Manual as well as ancillary documents such as the Overhaul Manual and Component Maintenance Manuals.
<table>
<thead>
<tr>
<th>Threat</th>
<th>Criteria</th>
<th>Requirement</th>
<th>Notes</th>
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</thead>
<tbody>
<tr>
<td>Small Tool Drop</td>
<td>48 in-lbs normal to surface.</td>
<td>No visible damage&lt;br&gt;No non-visible damage growth for 3 DSOs&lt;br&gt;Accounted for in Ultimate Design Allowables</td>
<td>1” diameter-hemispherical impactor</td>
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<tr>
<td>Large Tool Drop (BVID)-general acreage</td>
<td>Up to 1200 in-lbs or a defined dent depth cut-off (considering relaxation) based on level of visibility as related to the inspection method.</td>
<td>Barely visible damage which may not be found during HMV&lt;br&gt;No damage growth for 3 DSOs with LEF&lt;br&gt;Capable of Ultimate strength</td>
<td>1” diameter-hemispherical impactor</td>
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<tr>
<td>Large Tool Drop (BVID)-repeat impact threat areas (FAR 25.305, AC20-107A)</td>
<td>Consider higher than 1200 in-lbs&lt;br&gt;Consider multiple, superimposed impacts&lt;br&gt;Consider clustered impacts</td>
<td>Barely visible damage which may not be found during HMV&lt;br&gt;No damage growth for 3 DSOs with LEF&lt;br&gt;Capable of Ultimate strength</td>
<td>1” diameter-hemispherical impactor</td>
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<td>Visible Impact Damage (VID) (Damage Tolerance FAR 25-571b)</td>
<td>No energy cut-off</td>
<td>Visible Damage with a high probability to be found during HMV&lt;br&gt;No damage growth for 2 times the planned inspection interval with LEF&lt;br&gt;Capable of residual Limit strength</td>
<td>1” to 4” diameter hemispherical impactor</td>
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<tr>
<td>Runway Debris</td>
<td>0.50-inch dia spherical object @ tangential tire speed.</td>
<td>Ultimate design strength and no detrimental damage growth during DSO, including effect of environment.</td>
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<tr>
<td>Ground Hail ~ Non-Removable Structure</td>
<td>Up to 500 in-lb impact with simulated hail ball.</td>
<td>Ultimate design strength, no moisture intrusion and no detrimental damage growth during DSO.</td>
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<tr>
<td>In-flight Hail</td>
<td>Simulated hail ball up to a specified airspeed.</td>
<td>Ultimate design strength, no moisture intrusion and no detrimental damage growth during DSO for smaller size simulated hail ball. Limit residual strength for larger size simulated hail ball. Hail ball sizes and velocities based on statistical data.</td>
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<tr>
<td>“Failsafety”</td>
<td>The airframe shall be capable of completing a flight during which complete failure of a structural segment, such as a frame or stiffener, with associated skin or web, occurs due to an undefined source.</td>
<td>Analysis, supported by component tests, shall demonstrate that the airframe will sustain required residual strength loadings without failure.</td>
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</table>
Maintenance and Repair data developed using the same overall process as design data

- Numerous test articles ranging from coupons to components have (or will have) repairs of the types planned for the SRM (including bolted, bonded, QCR, etc.) installed on them and will be tested.
- Tests include (but are not limited to): static and fatigue (with and without BVID, with and without environment), Tension, Compression and Combined Loads.

Airplanes

Material Specimens

Elements

Assemblies

Components

Increasing Levels of Complexity
Challenges: Validation to a Common Test Properties Database

- **Standard Material Spec**
- **Industry Process Limits (Suppliers, OEMs, MROs, Airlines)**
- **Decision to Pursue Design Values?**
- **Who will Fund?**
- **OEM Specific Database**
- **Industry Test Matrix**
- **Shared Industry Property Database**
- **Testing**
- **OEM Allowables/analysis methods Development (Proprietary)**
- **Zone Application Areas & Publish In-Service Documents**
- **Info Available to Authorized Users**

- **Suppliers**
- **CACRC/NCAMP**
- **OEMs**
- **End-Users**
Allowables without access to analysis method are generally not usable—and vice-versa.

Testing is both material and process dependent—limiting the OEM ability to approve material substitutions or process variations.

This diagram is a representation of a bearing/bypass strength interaction that may be used for bolted joint design. The data points shown are fictitious and shown only for illustrative purposes.
Complex Bonded Repair Validation Test

OML Scarf

Stringer Replacement

Impact

Lightning Damage
Bolted Repair Validation Testing
Successful Validation of Repair Analysis - static and fatigue
What are the key messages?

Follow the Approved Documentation:

- Composite structures maintenance and repair practices are based on rigorous analysis substantiated and validated by extensive test data.
- Deviations/Omissions/Modifications can have significant, unintended consequences.
What are the key messages?

Follow the Recipe

- Composite repairs require rigid adherence to proper processes and procedures
- Some improper actions do not have detectable effects.
What are the key messages?

- **Training, Training and more Training!!**
  - All folks who come in contact with the airframe need to understand and appreciate how composites differ from metal.
  - Just because you don’t see any indications of damage after an incident cannot be used as a justification to release an aircraft.
  - Only properly trained and/or qualified personnel can/should perform inspections, assessments and repairs of structures.