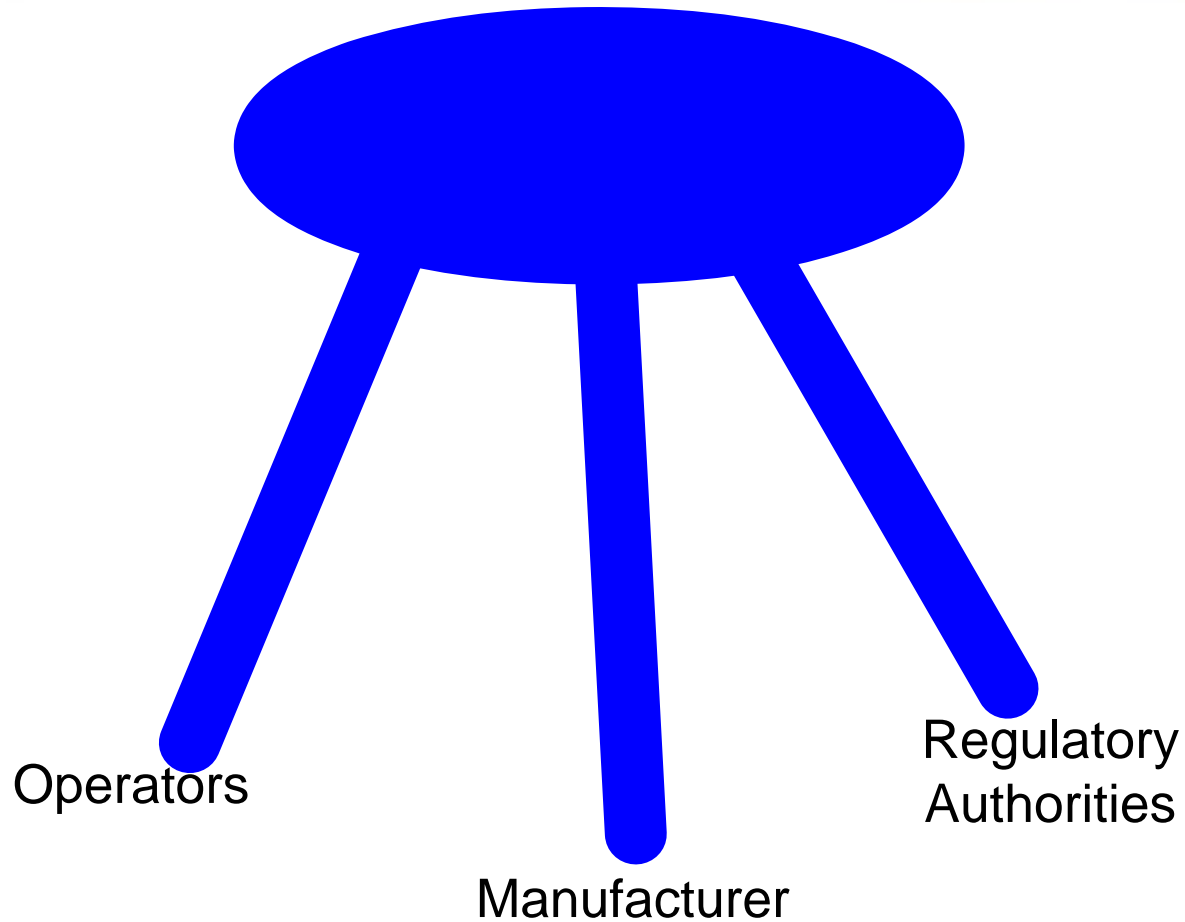


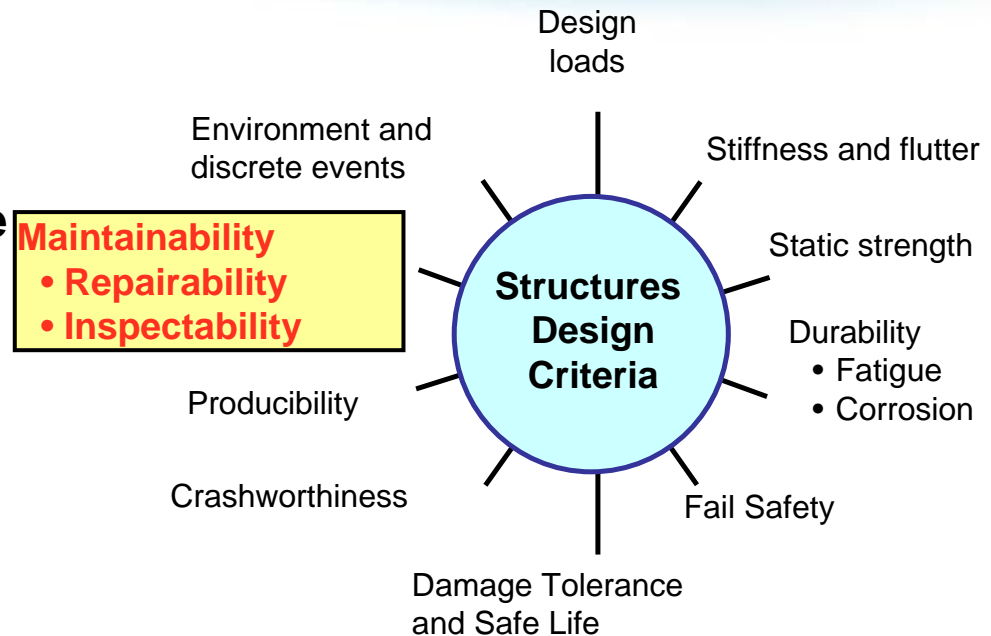
Boeing Perspectives on Safe Composite Maintenance Practices

3 Legged Safety Stool Operators-Boeing-Regulators



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.



Sample Damage Tolerance Criteria-Impact

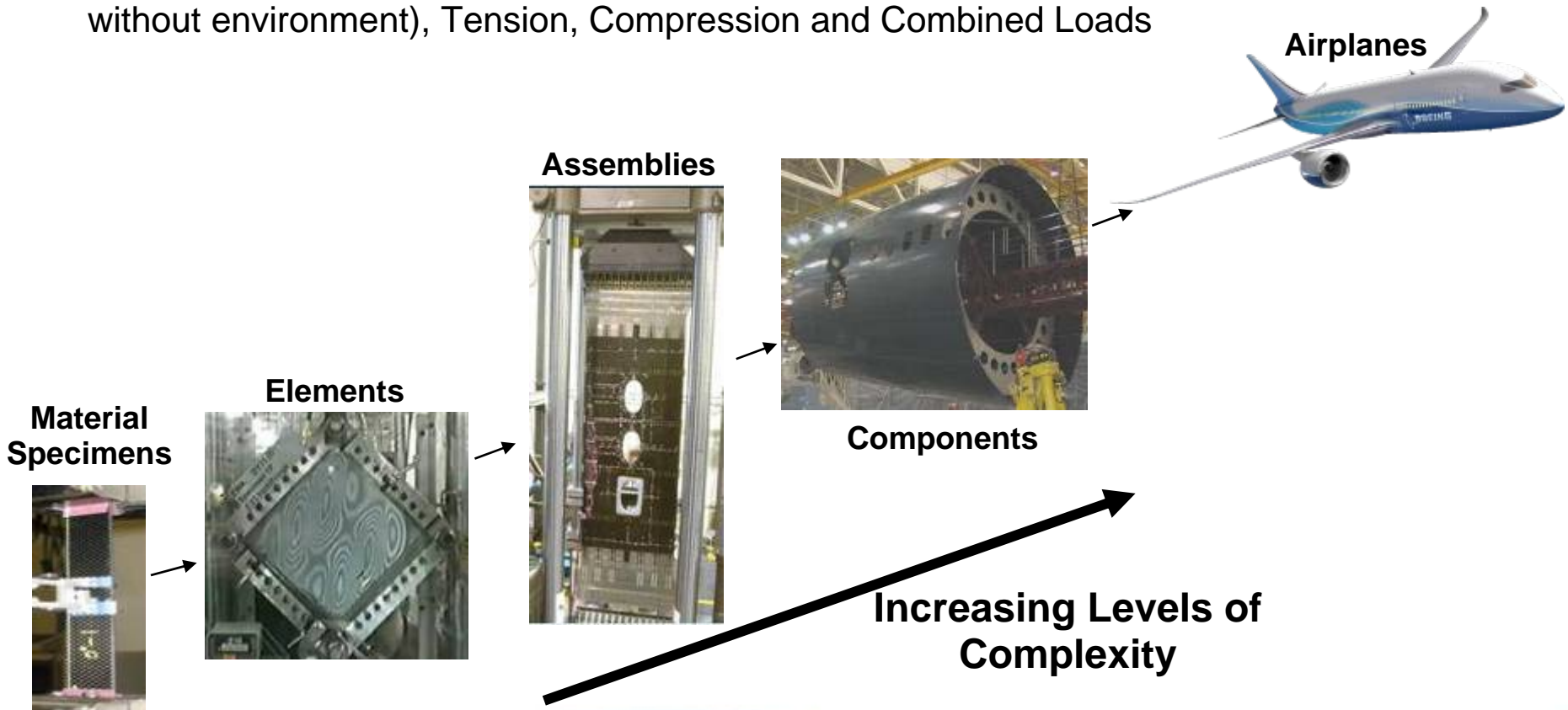
Threat	Criteria	Requirement	Notes
Small Tool Drop	48 in-lbs normal to surface.	No visible damage No non-visible damage growth for 3 DSOs Accounted for in Ultimate Design Allowables	1" diameter-hemispherical impactor
Large Tool Drop (BVID)-general acreage (FAR 25.305, AC20-107A)	Up to 1200 in-lbs or a defined dent depth cut-off (considering relaxation) based on level of visibility as related to the inspection method.	Barely visible damage which may not be found during HMV No damage growth for 3 DSOs with LEF Capable of Ultimate strength	1" diameter-hemispherical impactor
Large Tool Drop (BVID)-repeat impact threat areas (FAR 25.305, AC20-107A)	Consider higher than 1200 in-lbs Consider multiple, superimposed impacts Consider clustered impacts	Barely visible damage which may not be found during HMV No damage growth for 3 DSOs with LEF Capable of Ultimate strength	1" diameter-hemispherical impactor
Visible Impact Damage (VID) (Damage Tolerance FAR 25-571b)	No energy cut-off	Visible Damage with a high probability to be found during HMV No damage growth for 2 times the planned inspection interval with LEF Capable of residual Limit strength	1" to 4" diameter hemispherical impactor

Sample Damage Tolerance Criteria-Impact

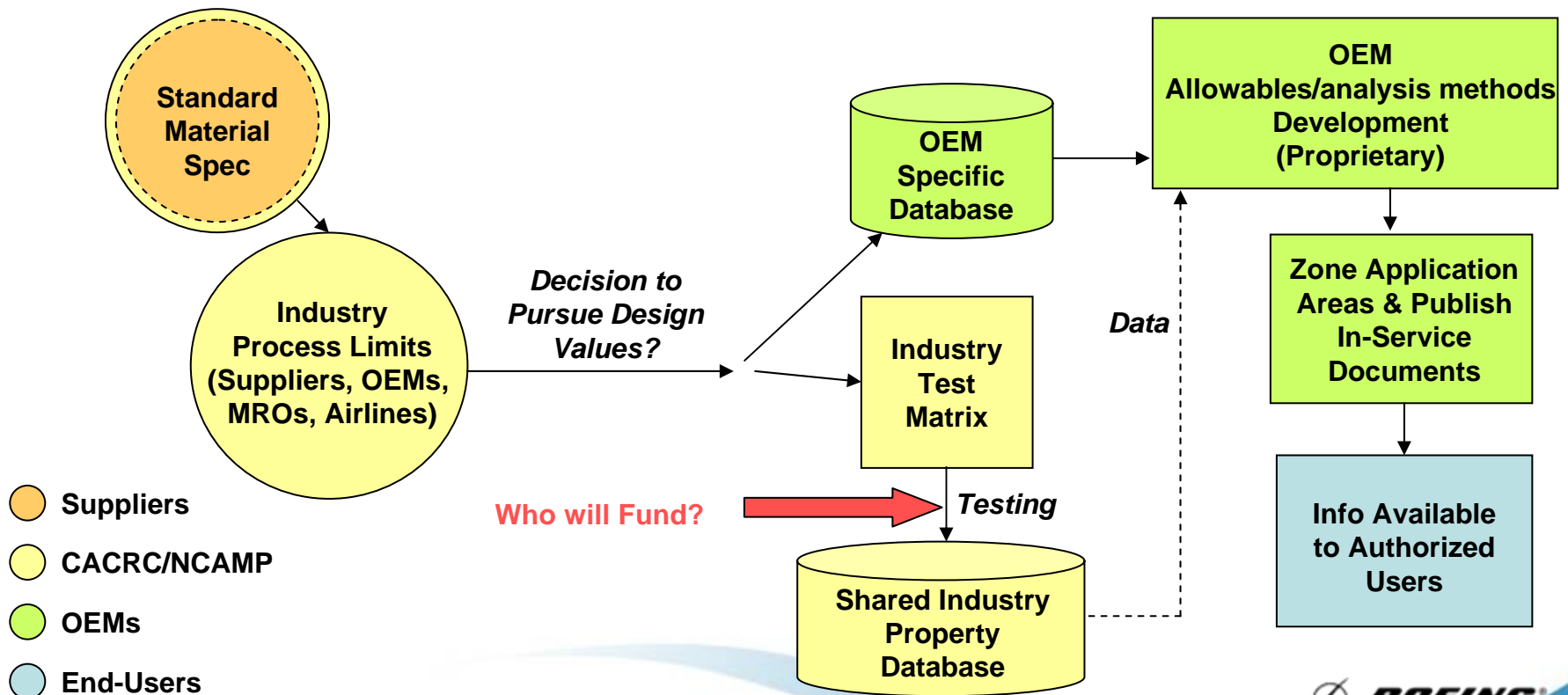
Threat	Criteria	Requirement
Runway Debris	0.50-inch dia spherical object @ tangential tire speed.	Ultimate design strength and no detrimental damage growth during DSO, including effect of environment
Ground Hail ~ Non-Removable Structure	Up to 500 in-lb impact with simulated hail ball.	Ultimate design strength, no moisture intrusion and no detrimental damage growth during DSO.
In-flight Hail	Simulated hail ball up to a specified airspeed.	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.
"Failsafety"	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.	Analysis, supported by component tests, shall demonstrate that the airframe will sustain required residual strength loadings without failure.

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



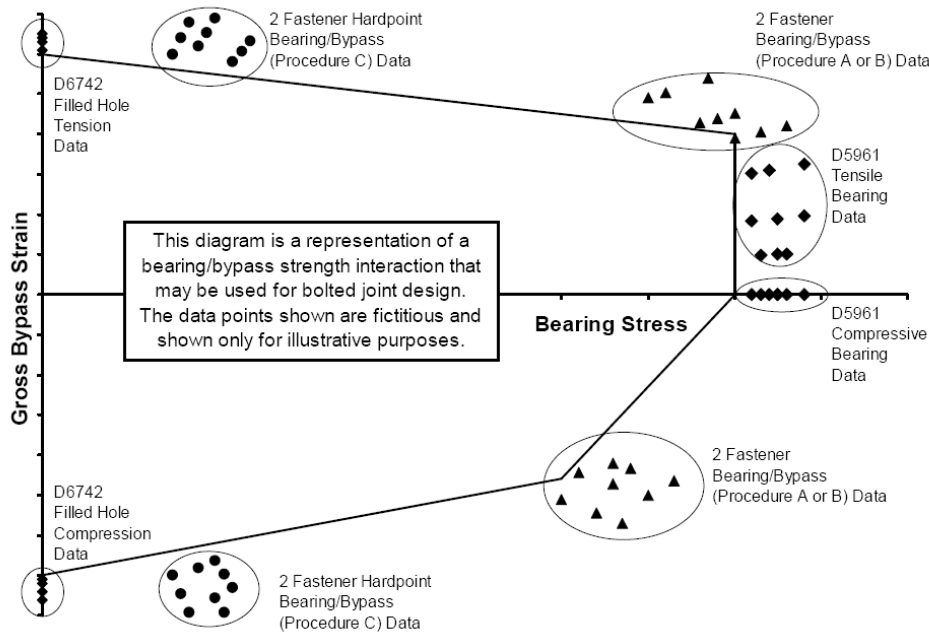
Challenges: Validation to a Common Test Properties Database



Design Allowables-Analysis Methods are Interrelated

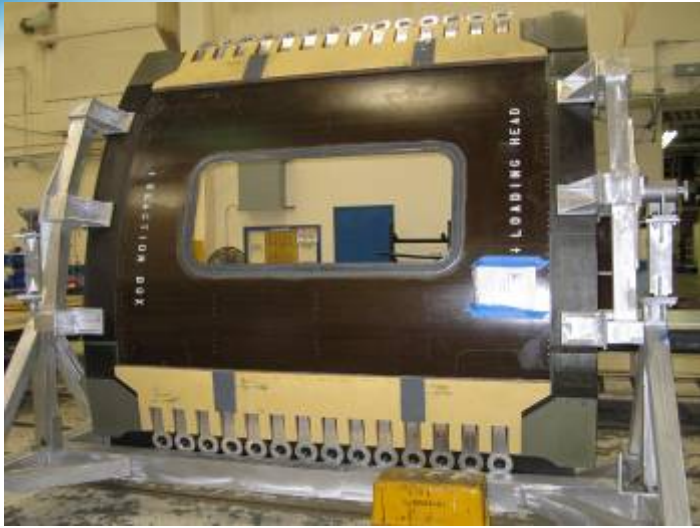
Allowables without access to analysis method are generally not usable-and vice-versa

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

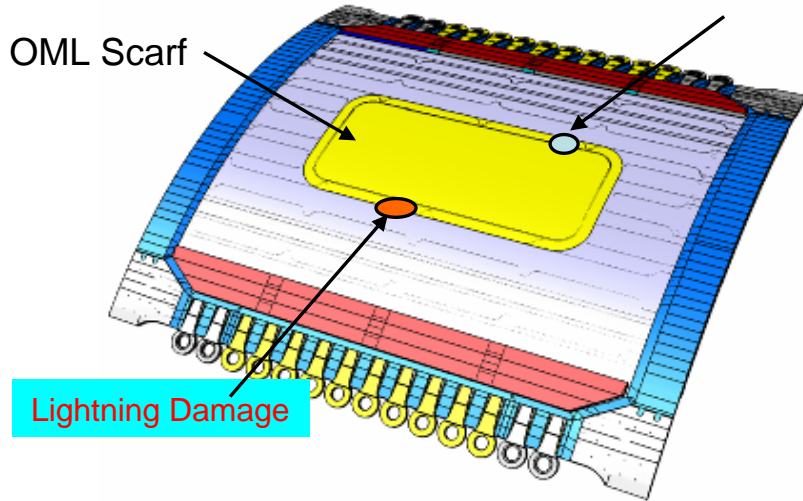


ASTM D 7248 Bearing-Bypass Tests

Complex Bonded Repair Validation Test

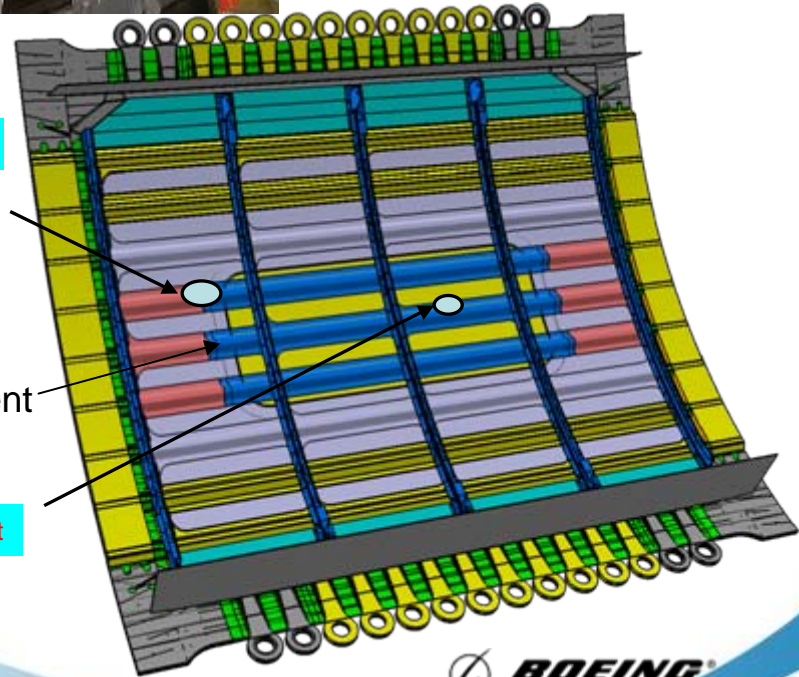


Impact



OML Scarf

Lightning Damage

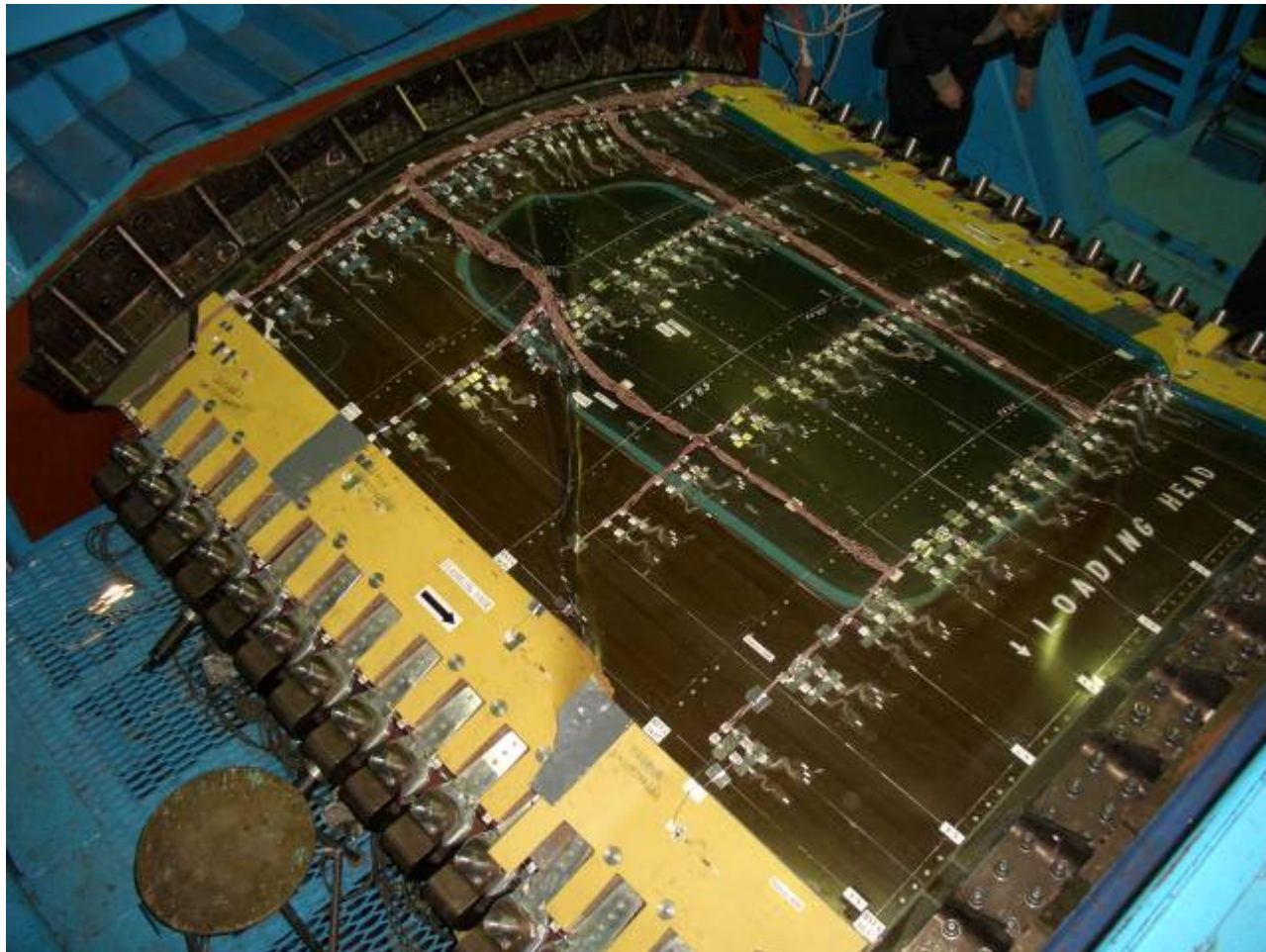


Impact

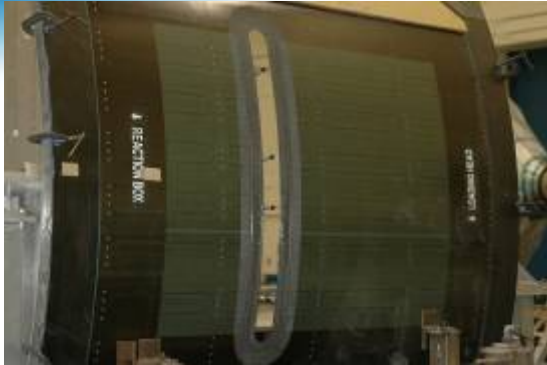
Stringer Replacement

Impact

Complex Bonded Repair Validation Test

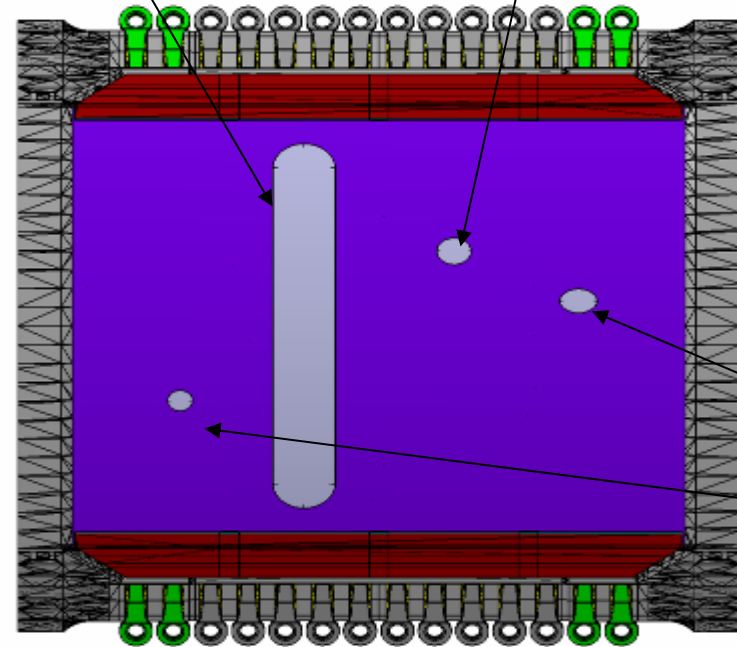
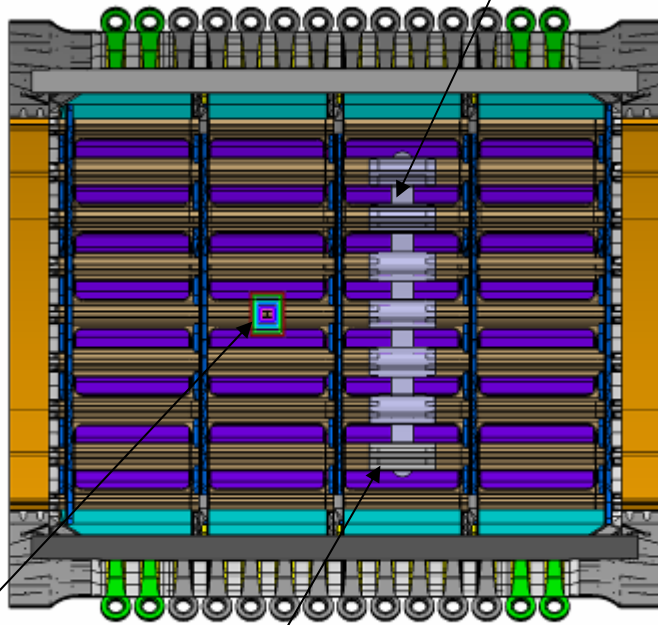


Complex Bonded Repair and Alternate Repair Testing



Skin Repair

Wet lay-up Repair



QCR

Wet Lay-up Repair

Stringer Repair

Stringer Repair

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