“Safe” Composite Repairs ~ Substantiation Database Framework

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Presentation Objective

- Discussion Of Considerations Which Drive The Definition of “Sufficient” Data To Evidence A “Safe” Repair

- I’m Not Really Offering Anything That Isn’t Already Known

- Only Summarizing Key Points To Prompt Discussion
How Do We Meet “Safe”

• With Respect To Structural Repair, Safety Can Be Met A Number Of Ways
  – Repair Failure = No Effect On Flight Safety
    • Example: Superficial Repair On Non-Structural Component
  – Repair Failure = “Safe” Impact On Flight Safety
    • Repair Or Replacement Of Component Necessary But No Impact On Continued Safe Flight
  – Repair Failure = Unacceptable
• Each Of These Defines A Unique Set Of Substantiation Data Requirements
What Are The Broad Questions?

• Is Repair Itself Strong Enough?
• Is Attachment To Airframe Strong Enough?
• Was The Repair Performed Per The Expectations Of The Supporting Design/Analysis?
  – Fabrication Process Well Documented?
  – Critical Aspects Of Fabrication Process Understood and Addressed With Mitigation Plans?
  – Process Compatible With On-Site Equipment and Training?
  – Repair Work Environment Conducive To Success?
  – Quality Of End Product Adequately Assessed?
What Data Is Required For Answers?

• No Single Definition Exists
• Comprehensiveness Of Required Database Is “Repair Scenario” Dependent
  – Database Requirements Range From “Minimal” To “Comprehensive”
    • Minimal For Aesthetic Repair On “Non-Structural” Component
    • Generally, Less Comprehensive For Repairs On Secondary Structure Than For Repairs On Primary Structure
    • Database Coverage “Very” Comprehensive For “Permanent Structural” Repairs
Substantiation Data ~ Considerations

• Questions Defining Database Composition To Support A Given Repair Substantiation Scenario
  – What Are Consequences of Repair Failure?
  – Is Repair On Primary Structure or Secondary Structure?
  – Is Repair In Critical or Non-Critical Area?
  – Is Repair Permanent or Temporary?
  – Does Database Substantiate A “One Off” Repair? Or General Repair Method For Broad Application?
  – Is Repair Bonded Or Bolted?
  – Is Repair Material Same As Airframe Material?
  – Is Repair Process Established or Novel?
  – What Level Of Inspections Can Be Performed?
  – Are Analysis Methods Mature?
Substantiation Data ~ Considerations

• Other Considerations Driving Data Req.’s
  – Environment In Which Repair Will Be Performed
  – Equipment Available On-Site To Perform Repair
  – Training and Education Of Repair Technicians
  – Does Sufficient Understanding of Repair Process Variability and Robustness Exist?
  – What Are Necessary “In Process” Inspection Requirements?
  – What Are Necessary Post Cure Inspection Requirements?
Notional Example Scenario #1

• Repair Description

*Note: Example of scenario requiring VERY comprehensive database req’s.*

– Generally Applied Repair Method
– Flush Bonded Repair (“Scarf”)
– Stringer Stiffened Solid Laminate Structure
– Permanent
– Primary Structure Applications
– Structurally Critical Areas
– Repair Material Not Same As Airframe Material
– Individual Applications To Be Substantiated By Analysis


**Notional Example Scenario #1**

- **Permanent Flush Bonded Repair To Primary Structure In Structurally Critical Area**
  - Potential Requirements of Substantiation Database
    - Mechanical Properties For Repair Material and Adhesive
      - Requires Demonstration Of Material Compatibilities and Equivalency
    - Satisfactory Ultimate Static Strength Capability
      - All Relevant Combined Loading Modes and Environments
    - Satisfactory Resilience To Sustained Load
    - Satisfactory Durability and Residual Strength
    - Sufficient Damage Tolerance Relative To Airframe Design Req’s
    - Repair Damages Propagate In “Controlled” Fashion
    - Airframe Architecture “Contains” Repair Damage Growth
    - Proven Analysis Method OR Rationale Supporting Position That Existence Of Repair Does Not Reduce Original Margin of Safety
Notional Example Scenario #1

- **Notional** Build-Up Of Test Date For “General Use” Repair Method (Not “One-Off”)

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### Notional Example Scenario #1

**Width At Each Level = Test Article Count**

- **Barrel Level Test**
  - Combined Load
  - Tension ~ Flat
  - Compression ~ Curved

- **Element Level Tests**
  - Tens.
  - Comp.
  - Flex.

- **Sub-Element Level Tests (Combined Joints)**
  - Patch Materials: E’s, G’s, N’s (Analysis Inputs), and Mechanical Strengths
  - Adhesives: E, G, Stress vs. Strain (Analysis Input), Mechanical Strengths
  - Joints: Scarf Lap Joints, Lap Joints

**Note:**
- Coupon Quantity Dictated By:
  1) Number of Skin Gages?
  2) Number of Stiffener Types
  3) Number of Stiffener Gages
  4) Number of Skin/Stiffnr Combos

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**Final Substantiation**

- Evaluate Damage Containment
- Evaluate Damage Tolerance and Propagation
- Assess Failure Criteria & Proc. Variability
- Develop Failure Criteria
Notional Example Scenario #2

• Repair Description
  – “One Off” Application
    • One Time Unique Repair
  – Flush Bonded Repair ("Scarf")
  – Sandwich Structure
  – Permanent
  – Secondary Structure Application
  – Structurally Critical Areas
  – Repair Material Same As Airframe Material
  – Unique Application Substantiated By Analysis And Supported By “Point Test” Data
  – Unique Fabrication Process ("Kit” Repair)
Notional Example Scenario #2

• Substantiation Data Requirements
  – “One Off” Application
    • Data Required Is Limited To The Specific Configuration (Laminate Gage, Core, etc…)
  – Repair Material = Airframe Material
    • Mechanical Properties of Patch and Adhesives Materials Must Be Available Or Must Be Developed, But Fundamental Compatibilities Not An Issue
      – Note: Final Mechanical Properties Reduced From Test Data Must Be Consistent With Airframe Design Requirements
Notional Example Scenario #2

• Substantiation Data Requirements
  – Application Substantiated By Analysis And Supported By “Point Test” Data
    • Need “Joint Performance” Data
    • Demonstrate Life Capability
    • Demonstrate or Characterize Damage Tolerance
    • Document Analytical/Qualitative Assessment Of Ramifications Of Failure and Fail Safe Philosophy
Notional Example Scenario #2

- **Substantiation Data Requirements**
  - **Unique Fabrication Process ("Kit" Repair)**
    - Document Process “Fit With” On-Site Repair Environment and Equipment
    - Document Proof of Concept Tests For Fabrication Process Variability and Robustness
    - Document “In Process” Inspection Requirements
    - Document Post-Cure Inspection Technique and Inspection Standards
    - Document Structural Test Data For Correlation With Analysis Demonstrating Capability (Configurations, Load Modes, Env.’s)
Repair Substantiation

• Hand Off To JW For Specific Case Histories