Safe Composite Repairs – Substantiation Linking Repair Test Data to Observed Fleet Performance

FAA Workshop for Composite Damage Tolerance and Maintenance
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SPIRIT AEROSYSTEMS™

- **Spirit Nacelle Composites Safe Repair Substantiation**

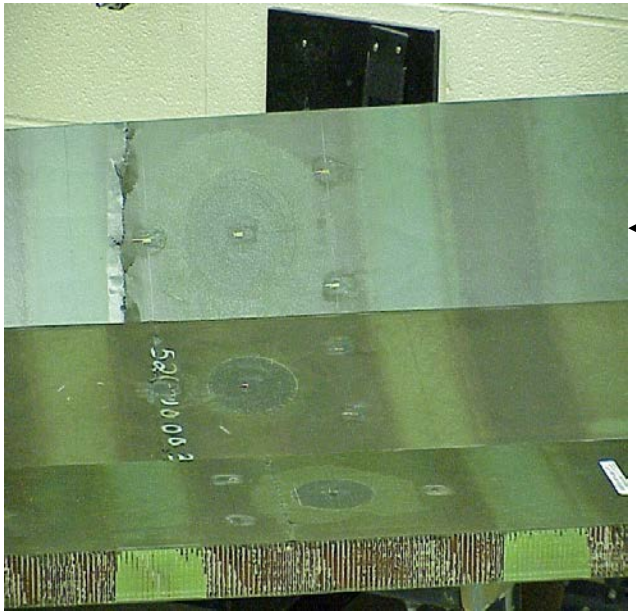
* Test Coupon Data – Substantiates Capacity
* Service Related Repair Experiences – Substantiates Performance
  - Start Bleed Duct Repair Kit
  - Large Trans-Sleeve Repair Kits
  - Inner Wall Overheat Repair Efforts
  - Large Inner Wall Compliance Repair Kits
* Summary and Closing
  - Conclusions of Experiences Linked to Repair Substantiation
  - Recommendation

Preparation for Repair Efforts Required Substantive Data

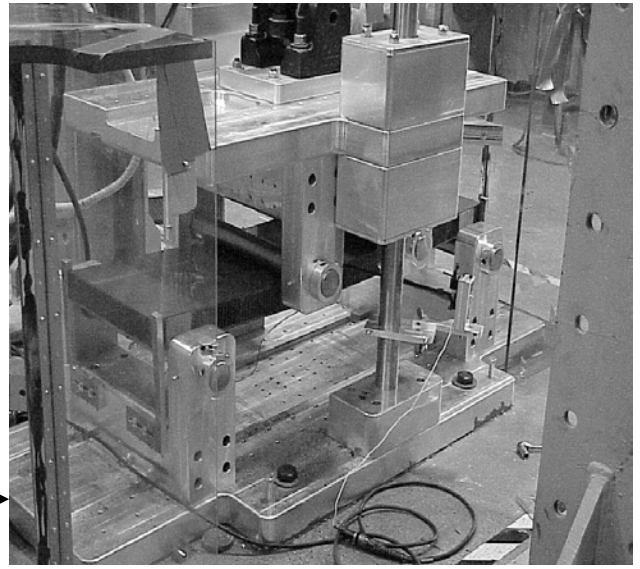
- Prepared Test Plan Based on Available Information
- Outlined Large Matrix of Potential Coupons
- Performed Testing and Documented Results
- Data Showed Structural Response was Acceptable
- Alternate Materials from Substrate Were Tested

Tension

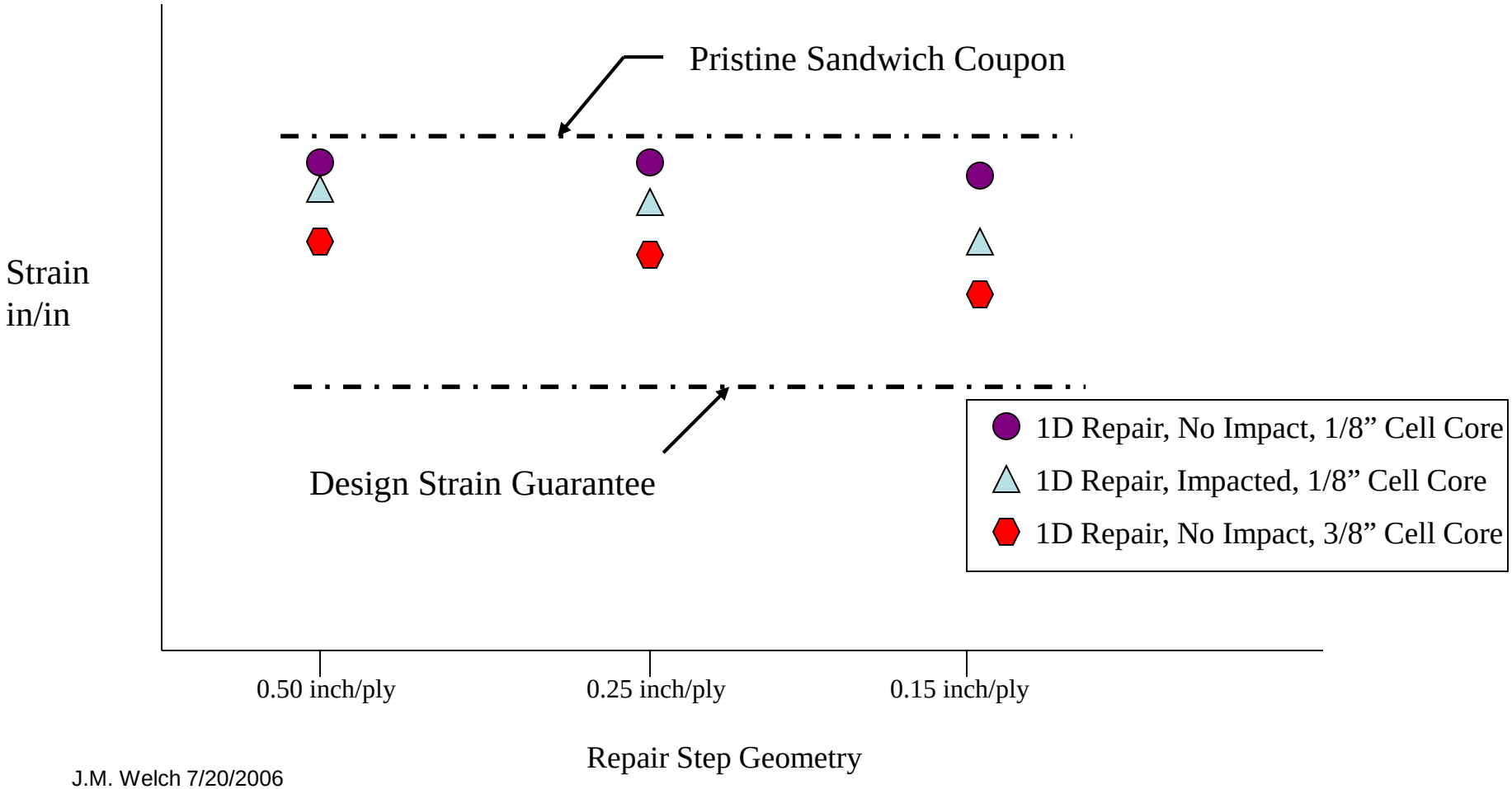
Compression



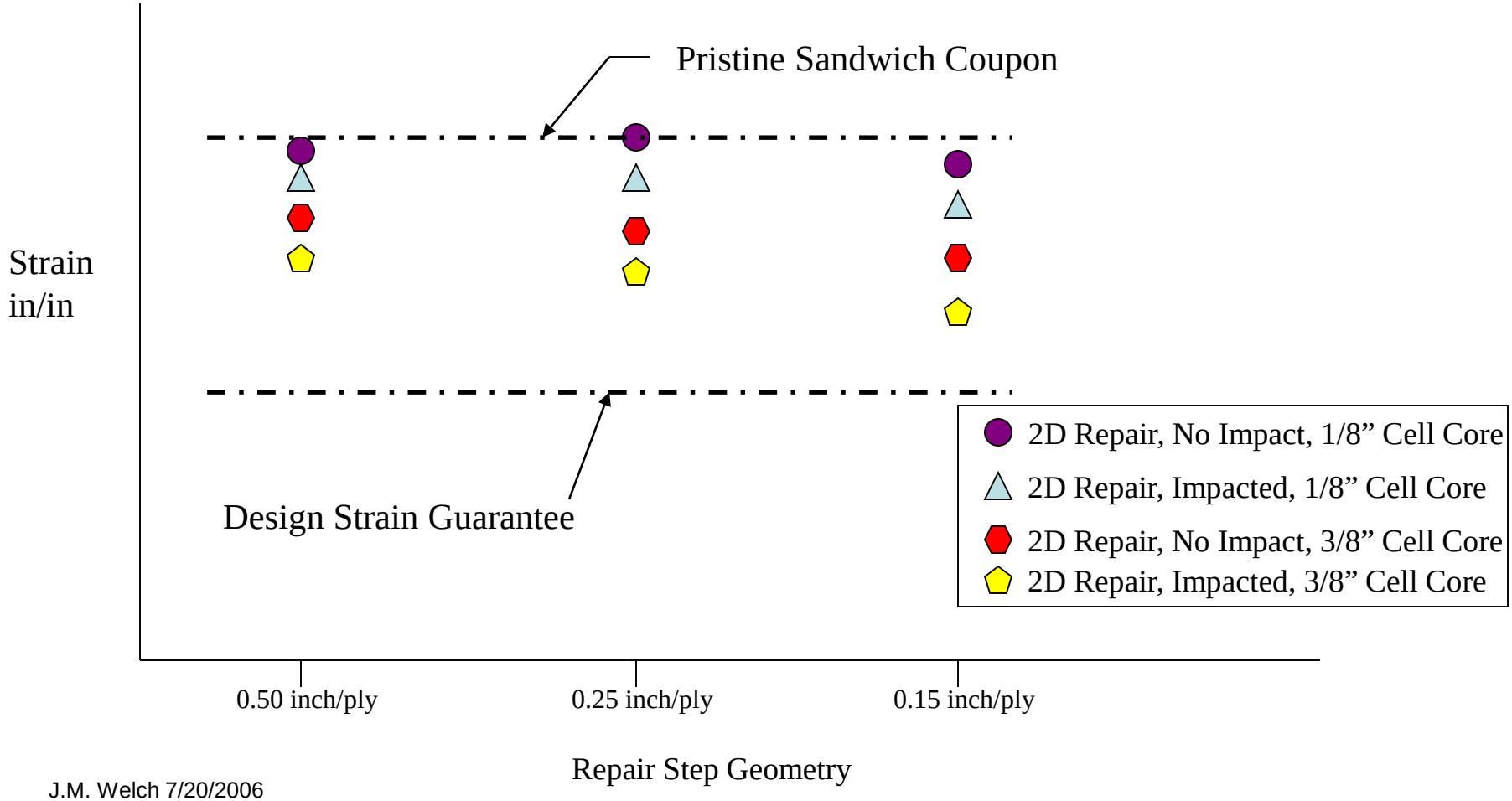
Large Beam Bending



Example - Tension



Example - Tension



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Realization of Performing Repair Required Mobile Solutions

Hardware Size and Scale not able to be easily shipped.

Difficulty in Shipping for Domestic Carriers was amplified for Foreign Carriers.

Time for Repair had to be minimized to reduce risk.

Unable to rely on available spares – repair must succeed.

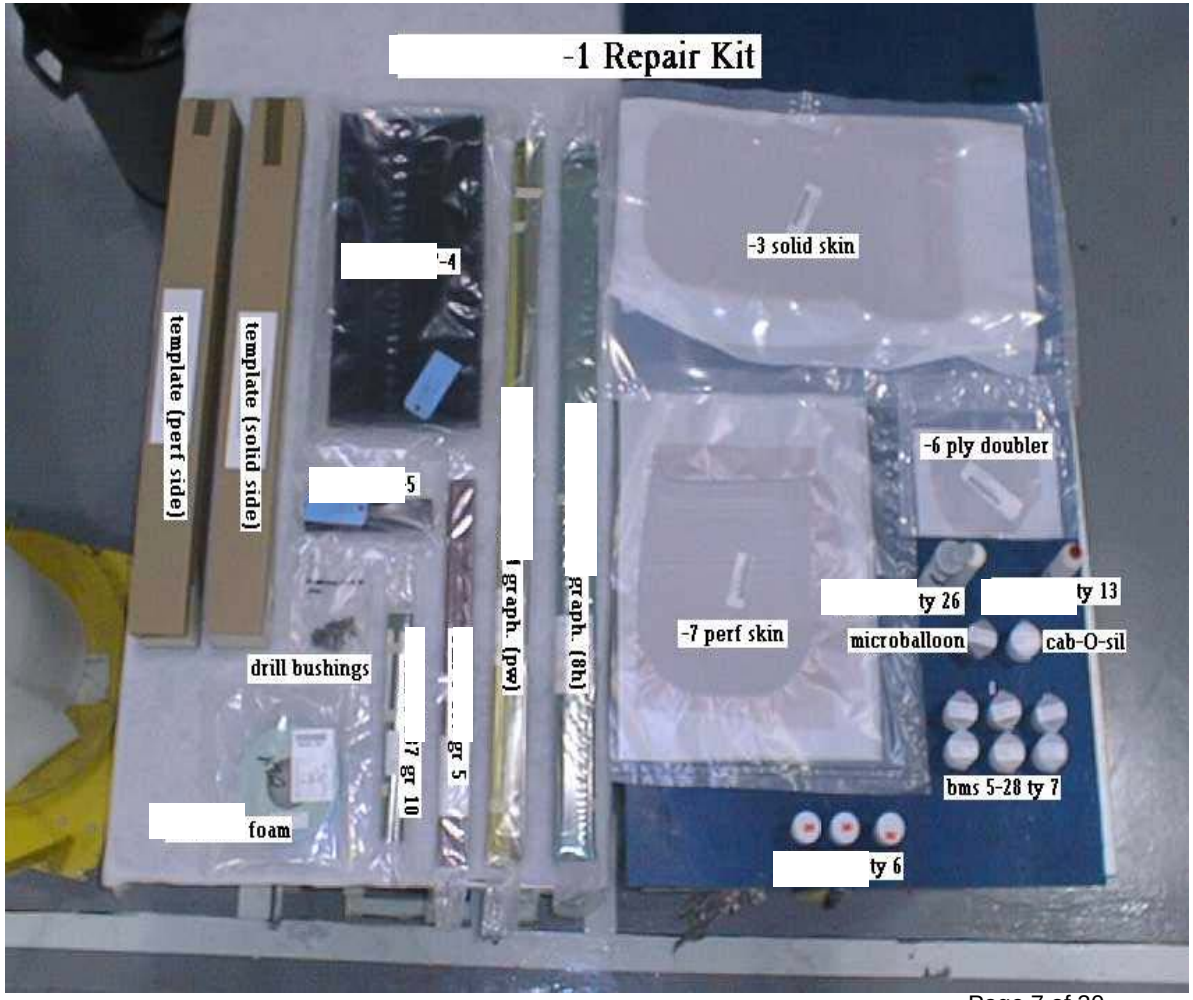
Equipment and Logistics, Materials and Processes, all had to become “mobile”.

Thrust Reverser Inner Wall Damage from Start Bleed Duct

- **Bleed Valve Failure Repair Kit.**
- **All necessary components to perform repair**
- **Accompanied by detail repair instructions**
- **Maintenance center estimated 30-45 days for effort.**

Accomplished repair on 3 units - took 5, 4, and 3 days respectively.

- **Provided 8110, carrier provided 8130.**



Thrust Reverser Inner Wall Damage from Bleed Duct

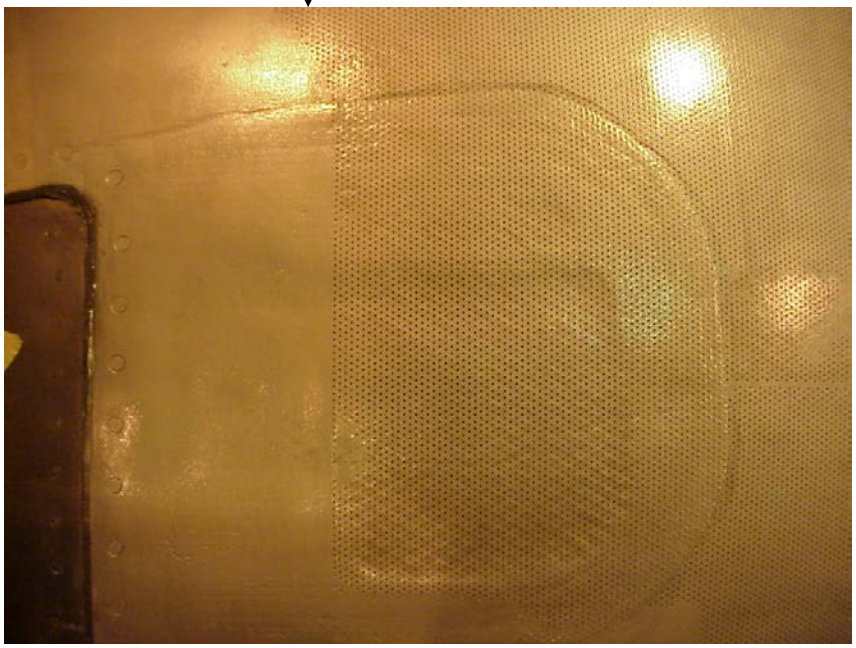
Consolidated Repair Patch being placed

Cured Repair Patch

Thrust Reverser Inner Wall Damage from Bleed Duct

Restored Perforations

Final Painted Repair



3 Units
Repair Area = 7 sq ft
Exceeding 8000 cycles, 50000 hours (oldest)
First performed circa 1997
Was thought to be largest we would ever see

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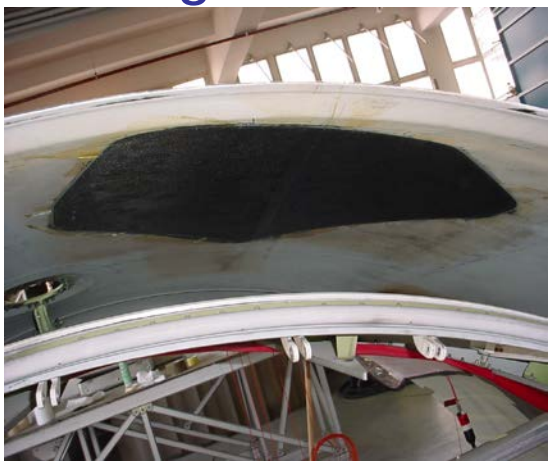
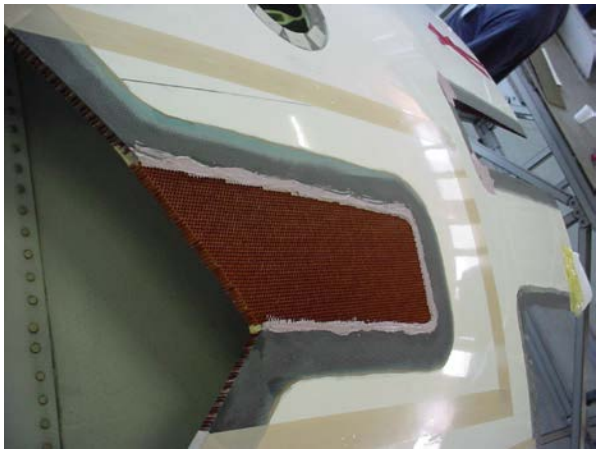
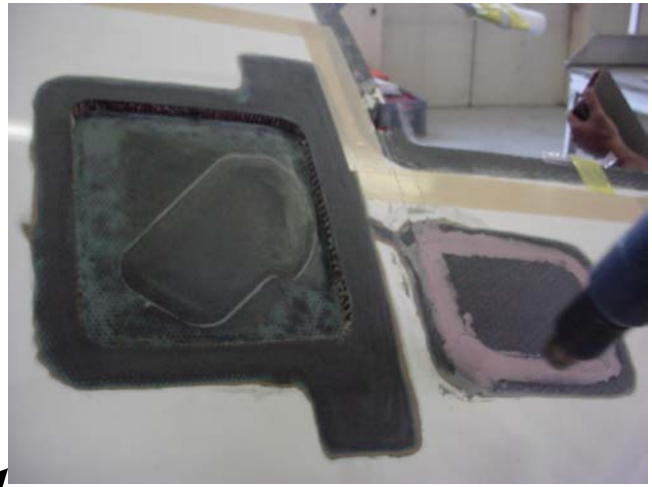
Large Area Trans-Sleeve Repair

- Trans-Sleeve Repair Kit, for foreign carrier
- All necessary components to perform repair
- Accompanied by detail repair instructions
- Hardware had been out of commission for over 1 year.
- Accomplished repair on 1 unit – took 10 days.
- Provided 8110, carrier provided 8130.

Large Area Trans-Sleeve Repair







Through Penetration

Several Stages of Core Repair

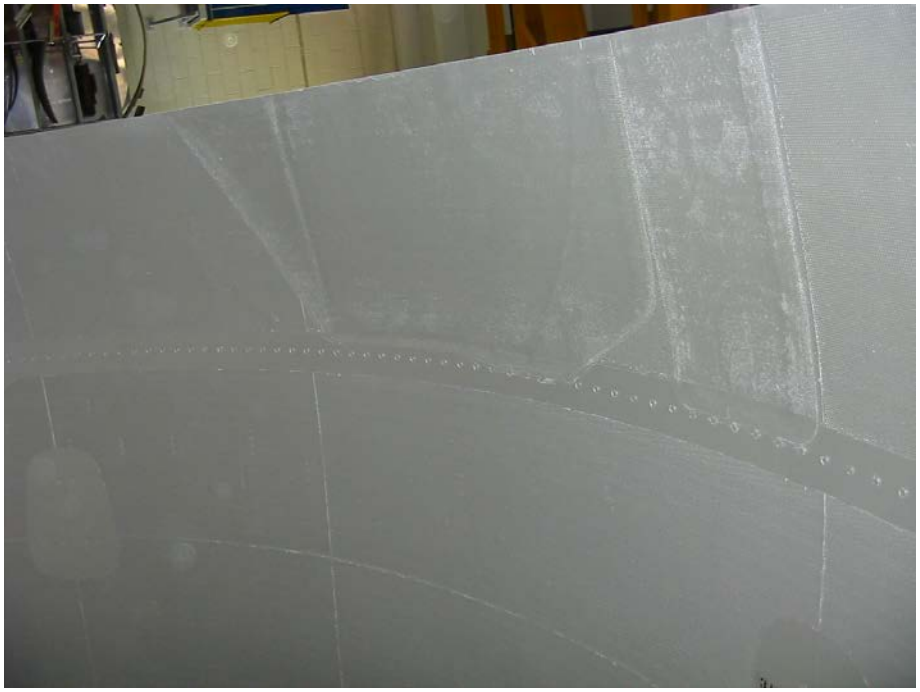
Innovative “Cavity” Repair

Perforate Restored

Large Area Trans-Sleeve Repair

- **Trans-Sleeve Repair Kit – completed prior to paint**

Large Area Trans-Sleeve Repair



1 Unit
Repair Performed on site at Foreign Carrier
Repair Area = 25 sq ft
6000 cycles, 48000 hours
Performed circa 2001
“Certainly” this was largest we would ever see

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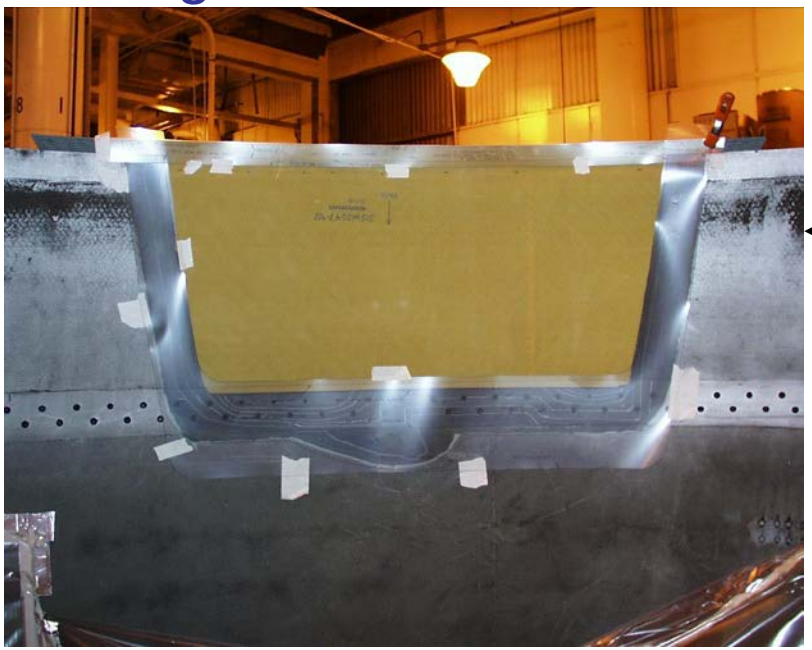
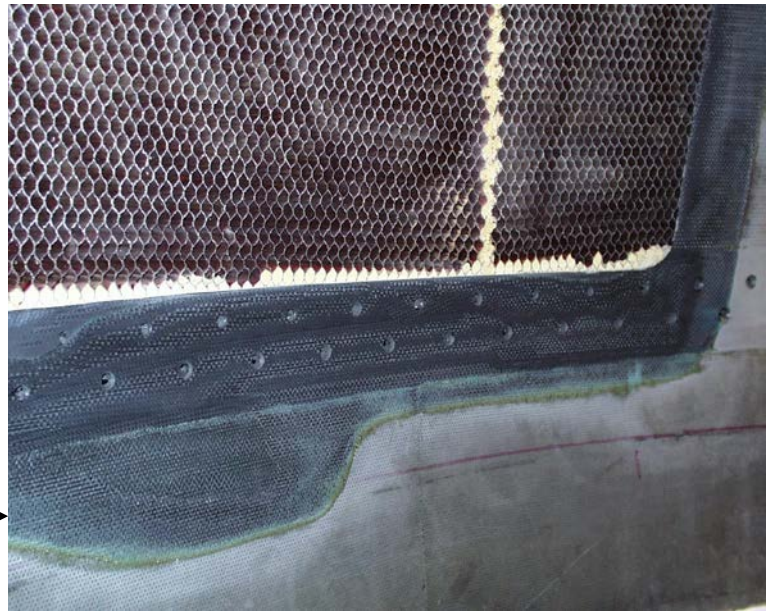
Large Area Trans-Sleeve Repair - Collaborative



Carrier Provided Dimensions-
We provided Everything else
Including mylars for Indexing



Core Replaced and
Taper Sanding Complete

Large Area Trans-Sleeve Repair

Solid Side Replaced

Core Replaced

Perforate Restored

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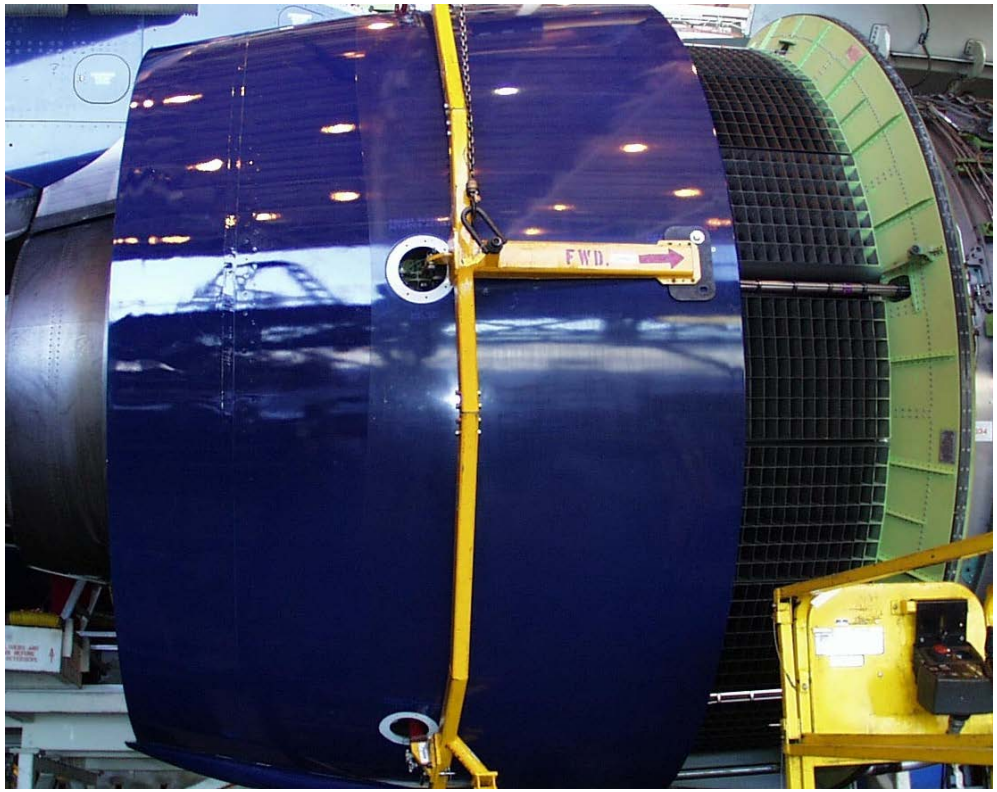
Large Area Trans-Sleeve Repair

- **Trans-Sleeve Repair Kit – completed**
- **Provided 8100, carrier provided 8130**



1 Unit
Repair Performed by Carrier
Kit Provided on Contract
Repair Area = 15 sq ft
1500 cycles, 16000 hours
Performed circa 2001

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Thrust Reverser Inner Wall Damage from Overheat Issues

Overheat Damage at Blanket Seam

- Provided 8100
- Carrier provided 8130

Taper Sand

Bonded Repair

Thrust Reverser Inner Wall Damage from Overheat Issues

Taper Sand

Overheat Damage at Blanket Seam

24 Units
Repairs Performed on-site with “Carriers” as Tech Assist
Repair Area = 1 to 5 sq ft
6000 cycles, 32000 hours (oldest)
Performed circa 2002,2003,2004

Bonded Repair

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Large Inner Wall Repair for Compliance

Necessary Tooling to get T/R into Repair Position

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Large Inner Wall Repair for Compliance

Special “Tent” for Facility Request

Core Removed

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Large Inner Wall Repair for Compliance

Core Replaced

NDI, Prior to Core Replacement

Doublers Replaced

Large Inner Wall Repair for Compliance

Doublers Replaced

Final Taper Sanding

Fwd & Mid Kits Applied

Large Inner Wall Repair for Compliance

Fwd & Mid Kit Cured

Aft Kit Applied

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Large Inner Wall Repair for Compliance

Compliance Repair Kit Complete

NDI Being Performed

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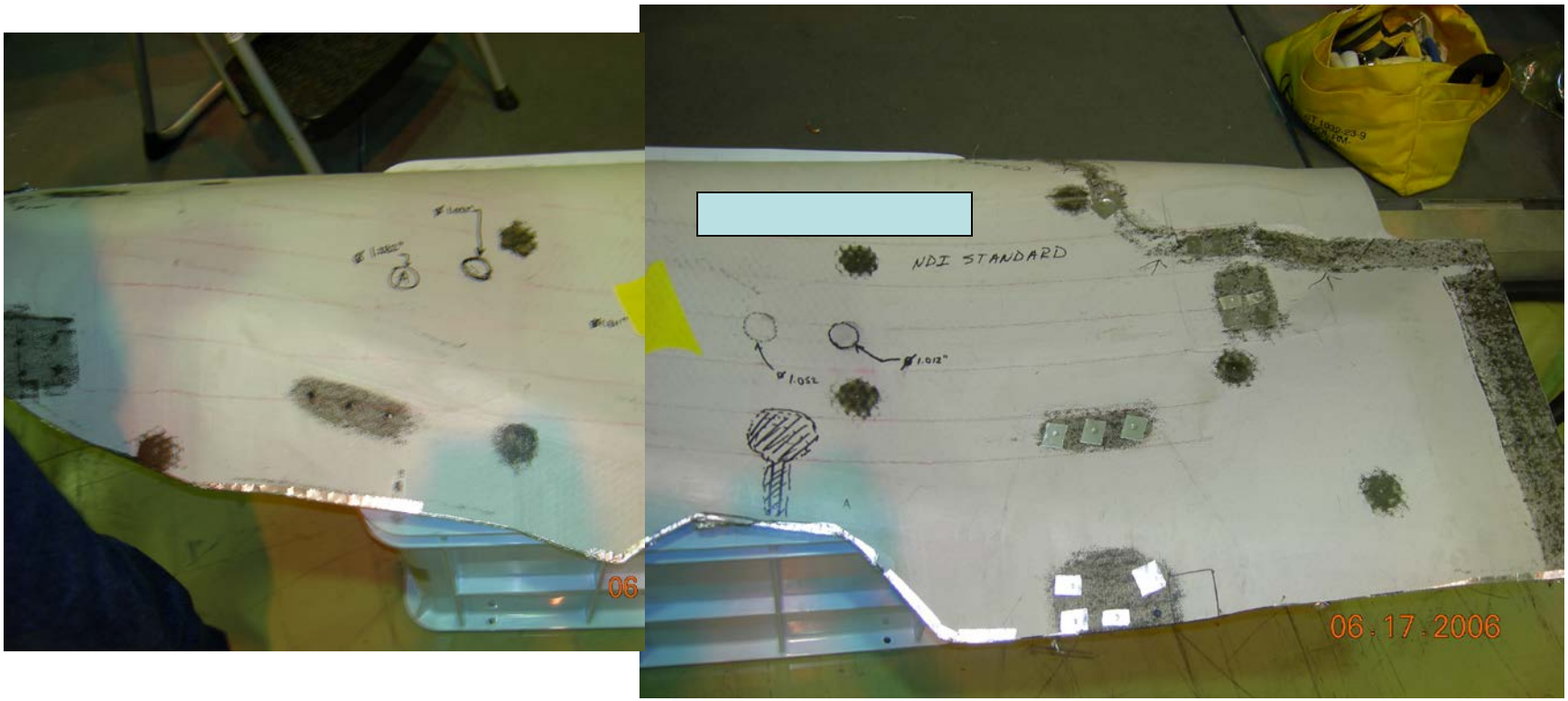
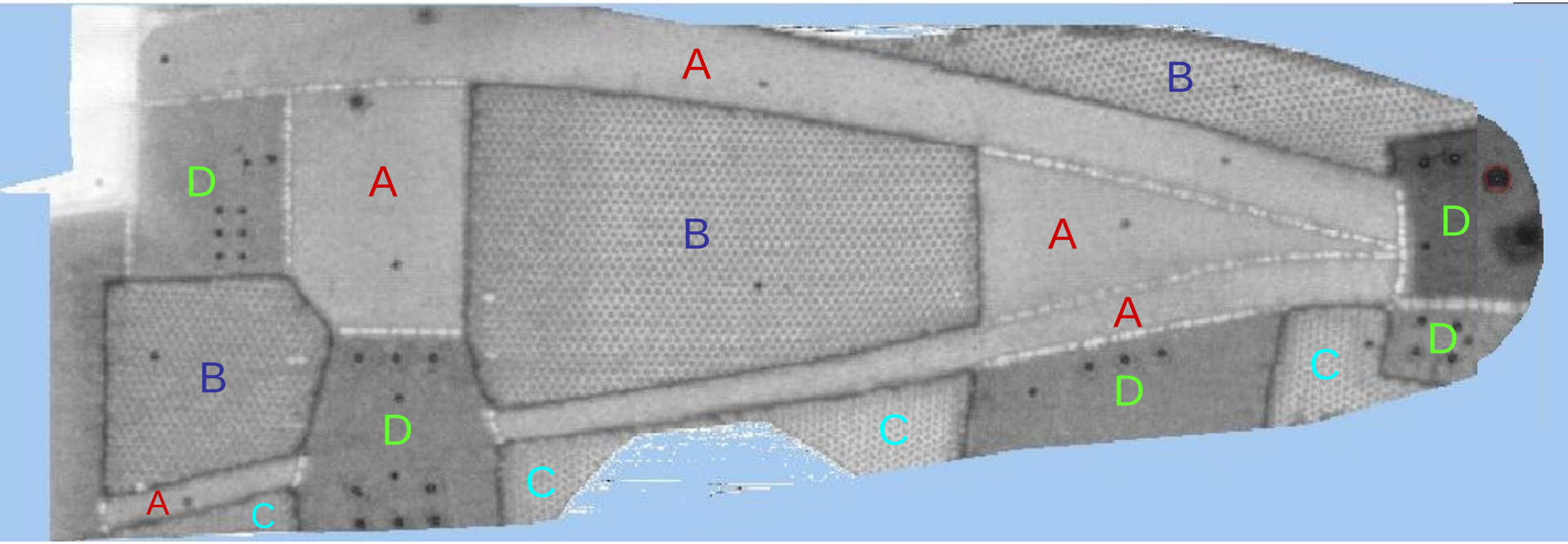
Large Inner Wall Repair for Compliance



NDI Standard on-site

Large Inner Wall Repair for Compliance



Details and Inclusions Were validated using several types of NDT methods – TTU shown

LAMINATE THICKNESS

A – 6 Ply
B – 6 Ply
C – 6 Ply
D – 14 Ply

NDI Plan required standard Containing all details of the Panel, and potential voids

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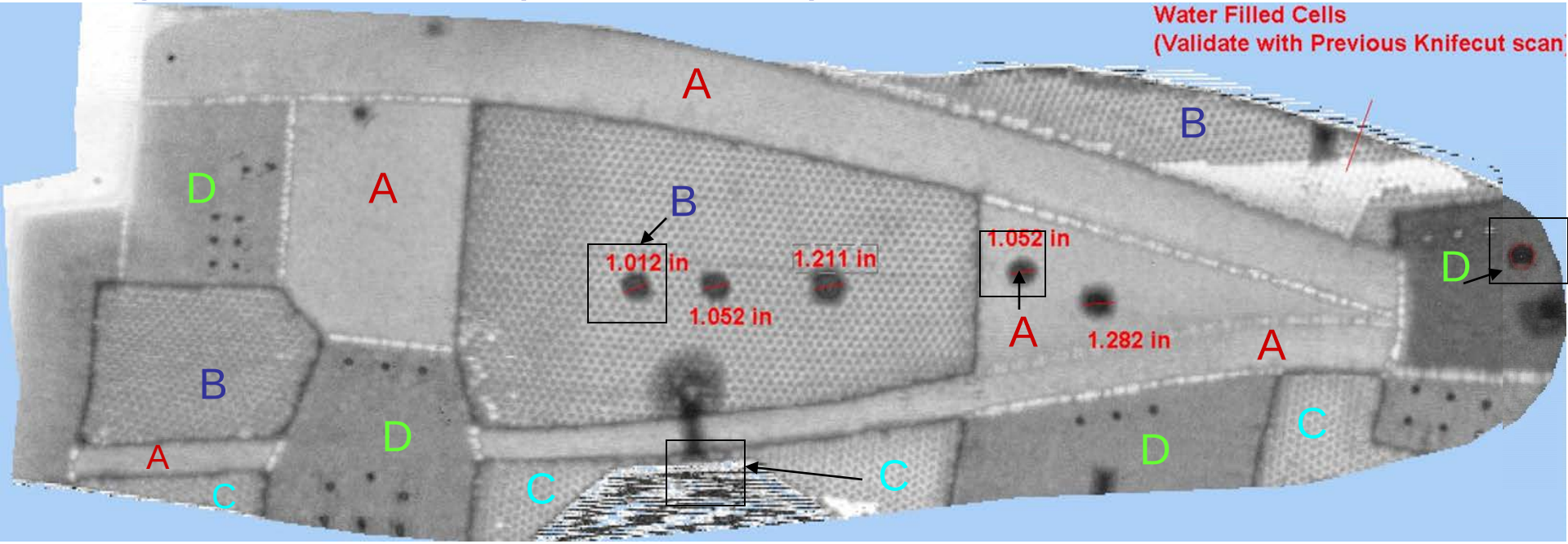
Large Inner Wall Repair for Compliance



Details and Inclusions Were validated using several types of NDT methods – TTU shown

CORE TYPES

A – Dense Aluminum

B – Double-Slotted Aluminum

C – Single-Slotted Aluminum

D – Grade 16 "High Dense"

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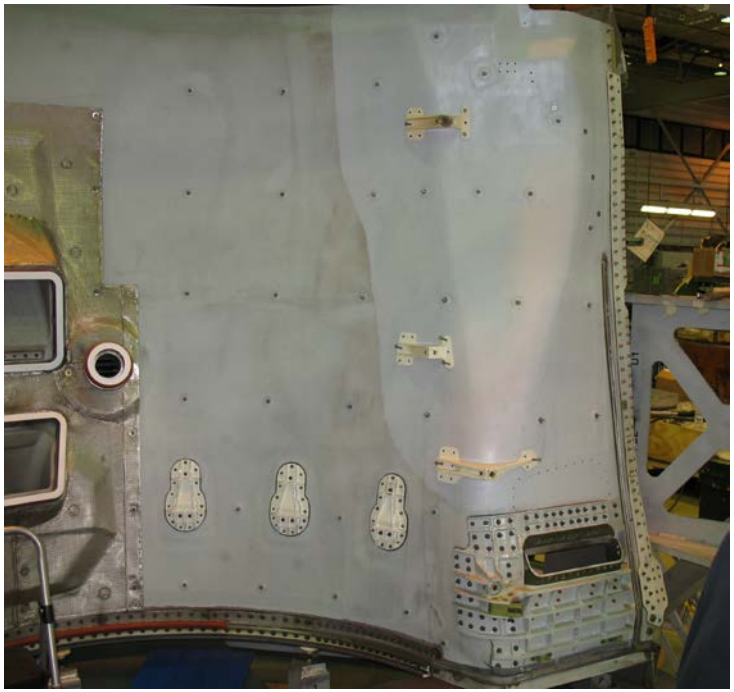
Large Inner Wall Repair for Compliance



- **Inner Wall Repair Kit – completed**
- **Provided 8100, 8130**

72 Units to comply, 4 complete
Repairs Performed on-site for “Carriers”
Repair Area = 33 and 35 sq ft (LH & RH)
Just returned to service
Performed 6/9 thru 6/22, 2006

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Conclusions – Substantiation Data supporting Repair Performance

- **The substantiated test data created to support repair efforts has served its intended purpose. All test coupons supporting repair configurations were complied.**
- **Performance of repair kits to date has been as expected – capable.**
- **Noted performance and fleet experiences from repair kits applied and flying, for a significant amount of time, indicate that testing supports application for repair efforts.**
- **Inclusive, Pre-consolidated (with pressure) repair patches perform the best in our experiences.**
- **Structural testing must be supplemented with a capable NDI plan.**
- **The environment available for processing in the field may need to be artificially supplemented, i.e. "tents", de-humidifiers, extensive cleaning, etc. Solvents and fluids will be present, so to ensure the data supporting the repair is not hindered, these considerations must be addressed – preferably in the test matrix.**
- **Total heat transfer must be considered and planned for, so as to support the data and processes being sponsored . This means power requirements become fundamental to larger repairs.**

Recommendation – Preparing for Large Scale Composite Repair

- **First, it has to be at least recognized, that all sizes and locations that might be damaged, will. Our experiences have shown that we underestimated the potential, and eventual, larger damage/repair sizes required to support a composite, commercial nacelle.**
- **The role of logistics is large –Mobility is key and response to a damage event that will leave an airplane out of service has to be practiced and swift. Electrical requirements to support necessary wattage for large scale repairs has to be provided.**
- **Environmental issues may have to be manipulated to guarantee a capable repair.**
- **There will be a need to repair with materials other than the OEM substrate.**
- **Recommend that bonded kits be pre-plied, pre-oriented, and pre-consolidated prior to being shipped on-site so that the greatest ability to preserve strength is guaranteed. This drives a secondary requirement that suppliers, other than the OEM, would need to be "qualified" to lay-up, orient, Quality Assure, and consolidate potential repair kits. Designated Centers of Excellence, perhaps?**
- **Potential Repair "Centers of Excellence"(?) entities must have available test data from industry, or supply their own data to correlate to their repairs to guarantee large scale capability.**
- **"Qualifying" repair entities should be required to include successful "proof-of-concept" work prior to carrying out the actual, large scale, composite repair.**

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