CONTINUED DEPLOYMENT OF FAA-AANC NDI TEST SPECIMEN LIBRARY

Presented to: A4A NDT Forum

By: Paul Swindell, Danielle Stephens and Dennis Roach

Date: Sept 18, 2024

Airworthiness Assurance NDI Validation Center (AANC)
A Unique FAA Facility

Albuquerque International Airport
Operated for the FAA by Sandia National Laboratories
Dedicated in February 1993

AANC Role and Services

- NDI Inspection Validation, technology transfer, and deployment
- Ongoing comparisons of conventional & emerging NDI technologies
- Develop and perform NDI reliability studies
- Rapid response to airworthiness issues
- Perform structured validation experiments
- Consult on maintenance technique applications
- Support development of new technology
- Provide access to other resources within SNL

SAMPLES OF PAST AANC PROJECTS

Industry wide NDI Reference Standards
NDI Assessment: Honeycomb Structures
NDI Assessment: Solid Laminate Structures
Composite Heat, UV, and Fluid Ingress Damage
Composite Repairs and Porosity
Composite NDI Training and NDI Proficiency Specimens

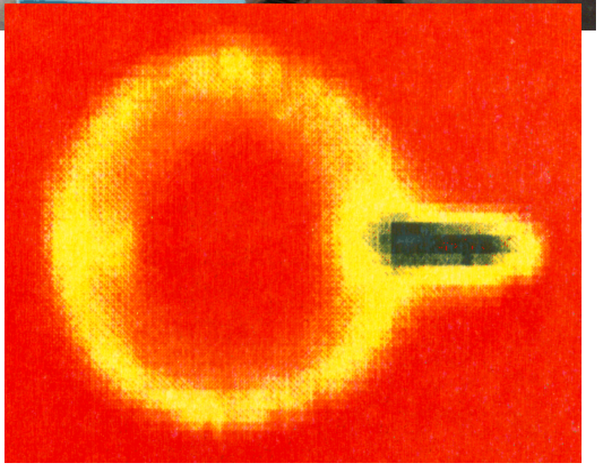
Visual Inspection Reliability
NDI Capability Characterization
NDI Structured Experiments (POD)

- Surface Cracks
- Faying Surface Corrosion
- Interlayer Crack Detection Program
- Composite Laminate Flaw Detection Program
- Composite Honeycomb Flaw Detection Program

Pulsed Eddy Current
Liquid Penetrant Technology
Composite Inspection & Reference Standards
Structural Health Monitoring Research/Mock Certification

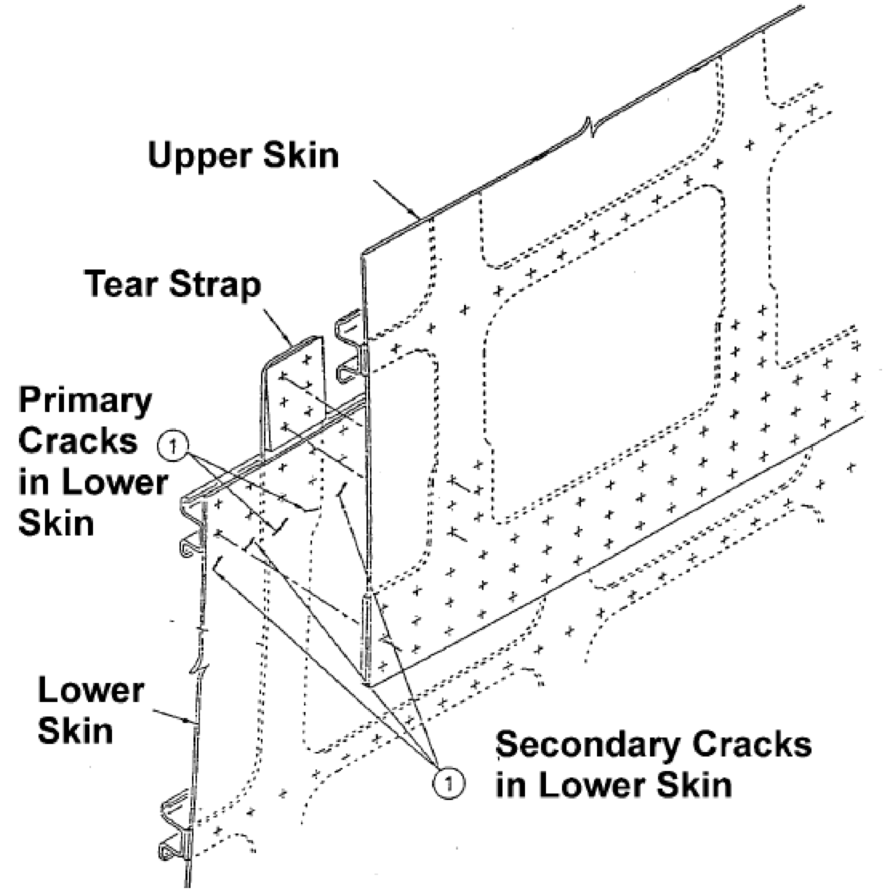
Eddy Current Inspection Reliability Experiment

- Evaluated the performance of conventional eddy current devices at aircraft maintenance depots to detect fuselage cracks, circa 1995
- Demonstrated the need for better imaging capabilities to interpret eddy current measurements
- Led to developing new imaging technologies which will allow operators with less expertise to use the technology
- Supports AD 91-06-06 (terminating action) & subsequent Boeing Alert SB 737-53A1224 (AD 99-04-22)



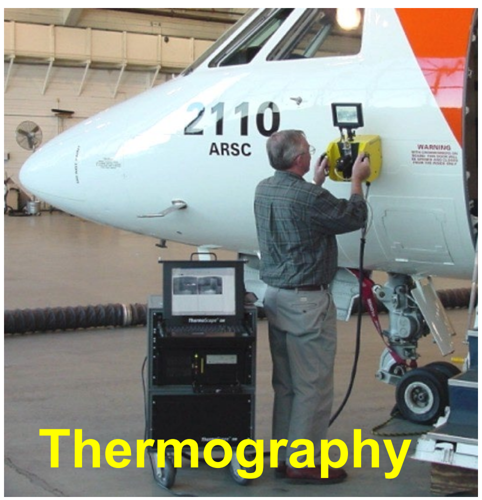
Eddy current imaging technology for crack length measurement

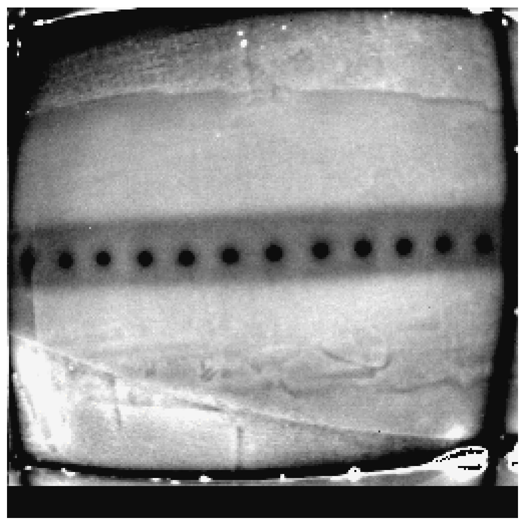
Interlayer (Low Frequency) Eddy Current



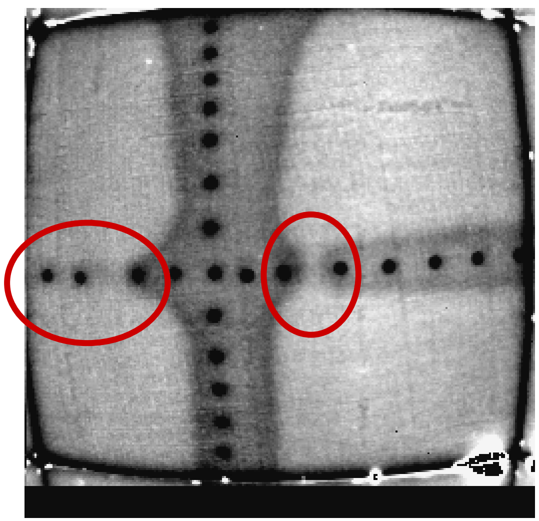
Fuselage Inspection Using Pulsed Thermography

- Improved corrosion & disbond detection
- Developed in partnership with (CASR) Wayne State Univ., Boeing and Northwest Airlines
- Boeing-approved method (NDI Manual revision) for fuselage disbond detection; addresses AD for over 2000 aircraft





Bonded Doubler

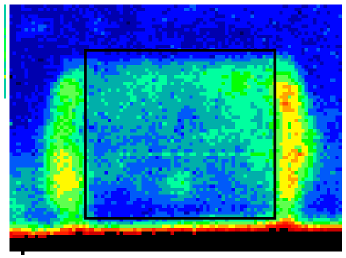


Disbonded Doubler

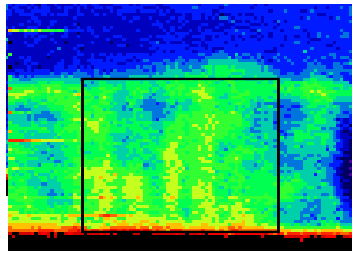
Pulse-Echo Ultrasonic Quantification of Weak Bonds

MAUS P-E UT scans produced by gating on Peak 3

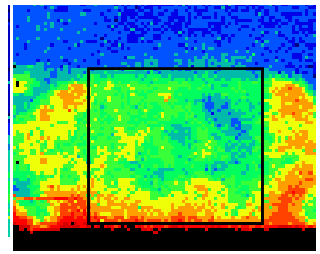
T-GRE-100-05-15F-E
10%



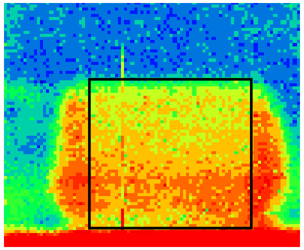
T-PWD-25-15F-E
30%



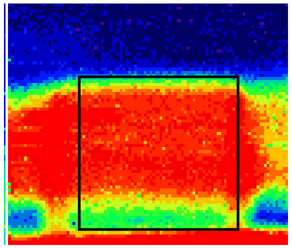
T-PWD-10-15F-E
50%



T-MO-RE-MS-50-12F-E
70%

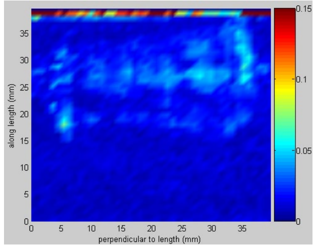


T-PRI-11F-E
100%

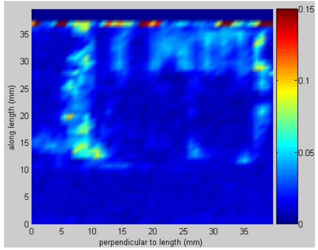


Omniscan P-E UT scans produced from the ratios between peak 2 and peak 3 for each point on the specimen.

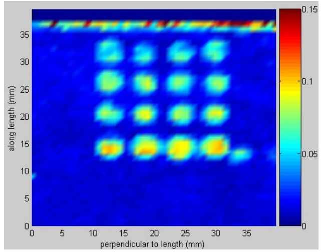
T-GRE-100-05-21F-G
10%



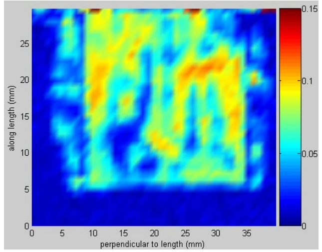
T-GRE-100-02-21F-G
30%



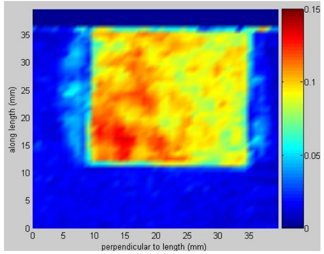
T-SC-25-17F-G
50%



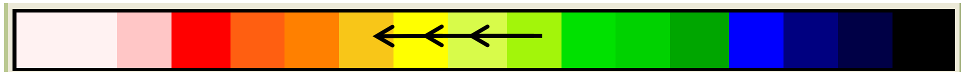
T-GRE-100-01-21F-G
70%



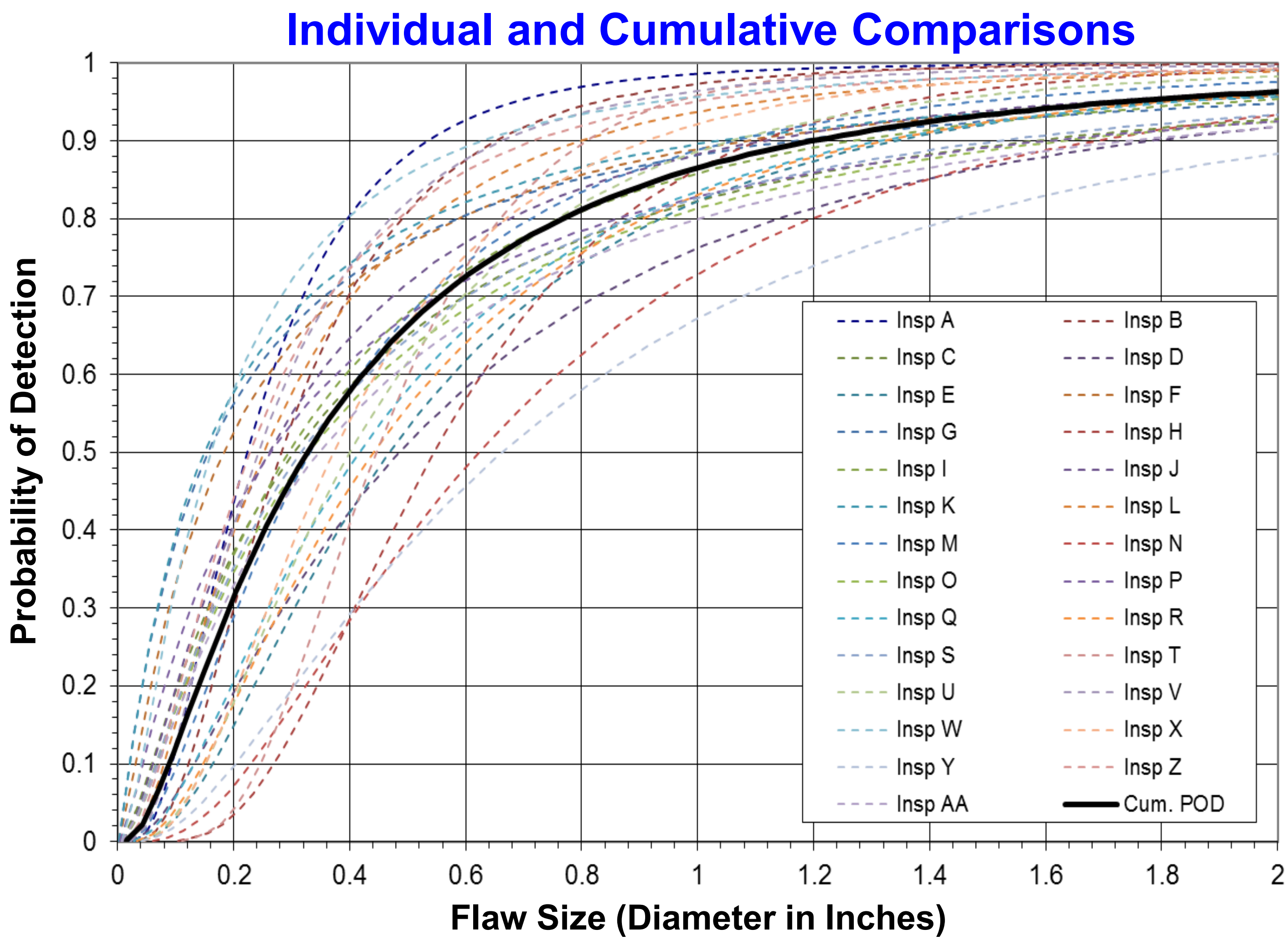
T-PRI-7F-G
100%



Stronger Bonds **Weaker Bonds**



POD Curves for 12-20 Ply Solid Laminate Family



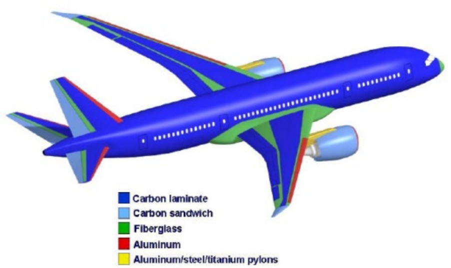
Overall:
$POD_{[90/95]}$ = 1.29" dia.

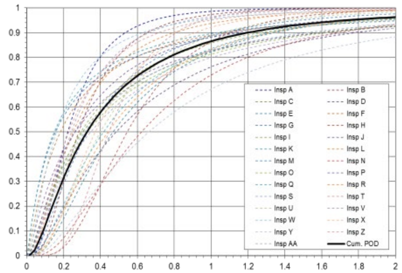
Constant Thickness (12, 20, 28 plies):
$POD_{[90/95]}$ = 0.86" dia.

Complex Geometry (tapered, curved, substructure, fasteners, honeycomb):
$POD_{[90/95]}$ = 1.49" dia.

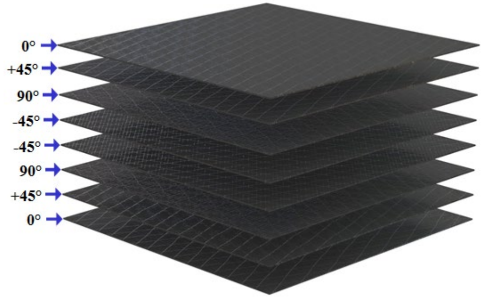
FAA Composite Inspector Training Course to Enhance Proficiency and Improve Reliability

Objective - The Composite NDI Training class will be used by airlines and MROs to enhance an inspector's preparation and training by focusing on the unique challenges associated with composite laminate inspections

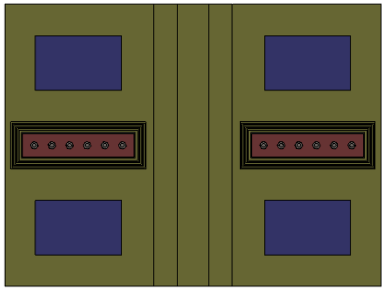




Motivation/Background POD Experiment



Class Modules and Objectives



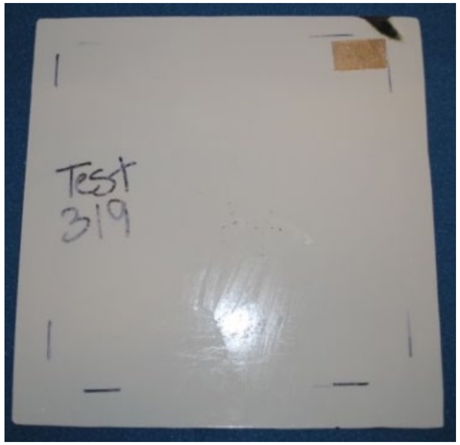
NDI Proficiency Specimen Set

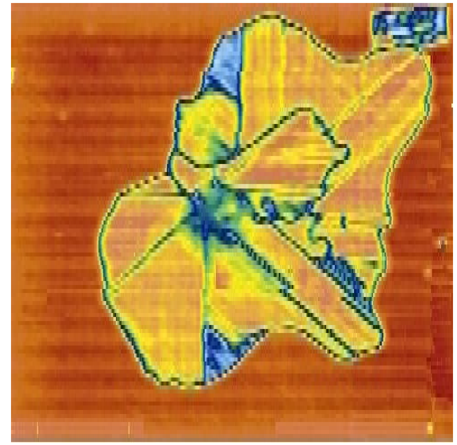
Industry Workshops & Initial Class Implementation

Inspection Challenge – Hidden Impact Damage

Internal delamination from ice impact

Extent of visible damage $44\ in^2$ Delamination





Programs/Partnerships

DC-9 Tee Cap
Northwestern University
Northwest Airlines
Douglas Aircraft
SAIC UltraImage

ECIRE
United Airlines
American Airlines
US Air
Alaska Airlines
etc

Corrosion Inspection Experiment
Boeing Commercial Aircraft
NRC Canada
CASR
etc

Engine Bearing Cleaning
GE Engines
Lewis Corporation
MRC Bearings

Halon Bottle Tester
Air Transport Association
Walter Kidde
Pacific Scientific
Physical Acoustics

Thermal Wave Imaging
Wayne State University
Northwest Airlines
Boeing Commercial Aircraft

Boron Epoxy Repairs
Douglas Aircraft
Lockheed Martin
Delta Air Lines
Federal Express
Textron
Wright Labs

MOI for Corrosion Inspection
Boeing Commercial Aircraft
United Airlines
Physical Research Inc.

Published Reports

- Roach, D., Rice, T. “Performance Evaluation of Comparative Vacuum Monitoring and Piezoelectric Sensors for Structural Health Monitoring of Rotorcraft Components,” Dept of Energy SAND2021-7984, July 2021.
- Roach, D., Rice, T. “Application and Certification of Comparative Vacuum Monitoring Sensors for Structural Health Monitoring of 737 Wing Box Fittings,” Dept of Energy SAND2020-9184, September 2020.
- Roach, D., Rice, T., Ely, R., “Probability of Detection Study to Determine Inspection Method and Assess Subsurface Crack Detection in E1 and E2 Wing Joints,” Dept of Energy SAND Report SAND2019-6476, June 2019.
- Neidigk, S., Roach, D., Rice, T. “FAA Composite Inspector Training Course to Enhance Proficiency and Improve Reliability,” Dept. of Transportation Report DOT/FAA/TC-18/12, June 2019.
- Ely, R., Roach, D., Falls, J., Montoya, G., Newton, C., Rice, T., “Analysis of Sensors for a Drone- Deployed Wind Turbine Blade Nondestructive Inspection System,” Dept of Energy SAND Report SAND2019-3933, April 2019.
- Neidigk, S., Roach, D., Duvall, R., Rice, T. “Detection and Characterization of Hail Impact Damage in Carbon Fiber Aircraft Structures,” Dept. of Transportation Report DOT/FAA/TC-16/8, September 2017.
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- Roach, D., Rackow. K., “A Quantitative Assessment of Conventional and Advanced NDI Techniques for Detecting Flaws in Composite Honeycomb Aircraft Structures,” Dept. of Transportation Report DOT/FAA/TC-15/63, January 2017.
- Roach, D., Rice, T., “A Quantitative Assessment of Advanced Nondestructive Inspection Techniques for Detecting Flaws in Composite Laminate Aircraft Structures,” US Dept. of Transportation Report DOT/FAA/TC-15/4, March 2016.
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- Roach, D., Rice, T., “A Quantitative Assessment of Conventional NDI Techniques for Detecting Flaws in Composite Laminate Aircraft Structures,” Dept of Transportation Report DOT/FAA/AR-13/23, May 2013.
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Published Reports

- Roach, D., DeLong, W., Rackow, K., Yepez, E., Reedy, D., White, S., "Use of Composite Materials, Health Monitoring, and Self-Healing Concepts to Refurbish Our Civil and Military Infrastructure," *Dept of Energy SAND Report SAND2007-5547*, September 2007.
- Roach, D., and Rackow, K., "Development and Validation of Bonded Composite Doubler Repairs for Commercial Aircraft," *Dept of Energy SAND Report SAND2007-4088*, July 2007.
- Roach, D., Walkington, P. and Rackow, K., "Pulse-Echo Ultrasonic Inspection System for In-Situ Nondestructive Inspection of Space Shuttle RCC Heat Shields," *Dept of Energy SAND Report SAND2005-3429*, June 2005.
- Roach, D., and Rackow, K., "Development of Bonded Composite Doublers for the Repair of Oil Recovery Equipment," *Dept of Energy SAND Report SAND2005-3195*, June 2005.
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- Roach, D.P., "Damage Tolerance Assessment of Bonded Composite Doubler Repairs for Commercial Aircraft Applications," Sandia National Laboratories/ *Dept. of Energy Report No. SAND98-1016* , August 1998.
- Roach, D., Walkington, P., "Development and Validation of Nondestructive Inspection Techniques for Composite Doubler Repairs on Commercial Aircraft", Sandia National Laboratories/ *Dept. of Energy Report No. SAND98-1014*, May 1998.
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- Jeong, D.Y., Roach, D.P., Canha, J., Brewer, J., Flournoy, T., "Strain Fields in Boeing 737 Fuselage Lap Splices: Field and Laboratory Measurements with Analytical Correlations", Dept. of Transportation Report No. DOT/FAA/CT-95/25, June 1995.
- Beattie, A., Dahlke, L., Gieske, J., Hansche, B., Phipps, G., Roach, D., Shagam, R., and Thompson, K., "Emerging Nondestructive Inspection for Aging Aircraft", Dept. of Transportation Report No. DOT/FAA/CT-94/11, October 1994.
- Roach, D., Beattie, A., Dahlke, L., Gieske, J., Hansche, B., Phipps, G., Shagam, R., and Thompson, K., "Emerging Nondestructive Inspection Methods for Aging Aircraft"; Dept. of Energy SAND Report 92-2732, March 1994; Dept. of Transportation Report No. DOT/FAA/CT-94/11, October 1994.
- Spencer, F., Borgonovi, G., Roach, D., Schurman, D., Smith, R.; "Reliability Assessment at Airline Inspection Facilities, Volume I: A Generic Protocol for Inspection Reliability Experiments"; Dept. of Transportation Report, DOT/FAA/CT-92/12-I, March 1993.

2024 Status:

FAA Contract ended, AANC Closed

AANC specimen library, equipment and other assets arrived at FAA Tech Center NJ late 2023

Performing Inventory

Developing process/procedures for assets

Inventory: Metal and composite structure that are representative of actual aircraft structure and contain characterized flaws, Feedback Specimens, POD Experiments

Material will be available for Industry Use

- **Test NDI new equipment**
- **Industry NDI training**
- **POD Experiments**

Loaned weak bond and other composite specimens to Kratos (paper at 2024 A4A Forum)

Bell Helicopter interested in Composite POD experiment

AANC Test Specimen Library

Test Specimen Library

Confirmed

composite bonded doubler
Rotorcraft test specimens
EC Inspection Reliability POD Set
Corrosion POD set
Interlayer Crack POD Experiment
Wing crack POD
Solid Composite Laminate POD
Honeycomb POD
Assorted composite laminate NDI specimens
Honeycomb NDI specimens
Composite Impact NDI specimens
NDI ref stds/composite corrosion NDI specimens
composite weak bond specimens (USCAR)

scarfed composite specimen
FTIR and NASA contamination
composite honeycomb impact damage
Cessna wing crack specimen
Bell damage detection/Robinson accident
microcrack specimens for penetrant/mag particle
Rotor CVM and PZT specimens
PZT specimens
Embraer PZT specimens
NDT reference standards-cracks and thickness metals
Composite specimens

Unconfirmed

Large A/C control surfaces
Large skin/structure panels
Robinson rotorcraft blades
787 composite panels with impact damage
Honeycomb panels
Skin panels with substructure
Assorted aircraft components
ECIRE frames POD experiment
ECIRE bolt hole POD experiment
cases of POD experiments
Engine Ti and Inconel specimens
NDT reference standards-composite

Rotorcraft compostite Hub/composite doublers
Lap splice with corrosion
Goodrich hidden tire damage
NASA shuttle heat shield

Composite Laminate POD Experiment

Thickness Range:
12 – 64 plies

Simple Tapers

Complex tapers

Substructure Flaws

Curved Surfaces

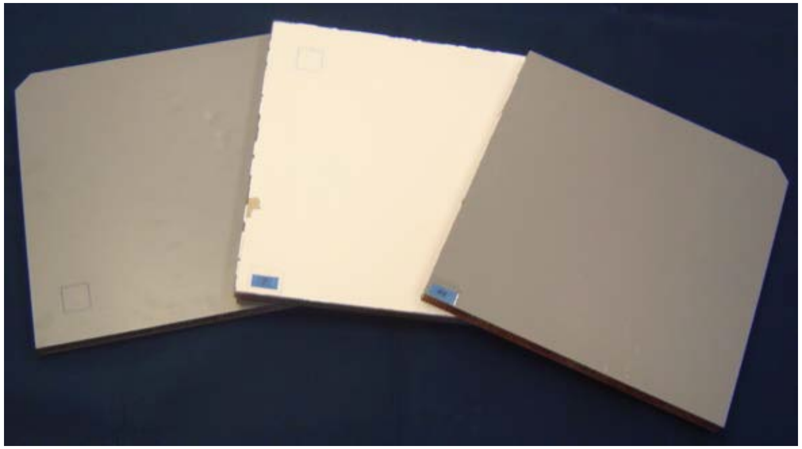
Array of flaw types

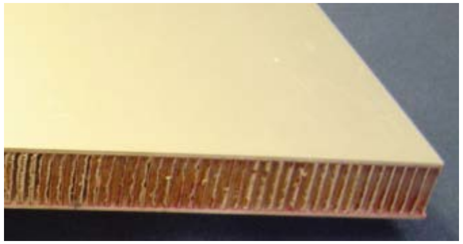
NDI Ref. Stds.

Inspection Area: 46 $ft.^2$

Number of Flaws: 202

Composite Honeycomb test specimens





Qty 6 of each: 3, 6 and 9 ply carbon and fiberglass skins (18 total panels of each skin)

PILLOW INSERTS
TEFLON INSERTS
BRASS SHIMS
POTTED CORE
CORE SPLICE
MACHINED CORE DISBONDS
PULL TAB

FAA AANC Small Panels For NDI Validation Studies

Allows quantitative assessments of NDI Methods

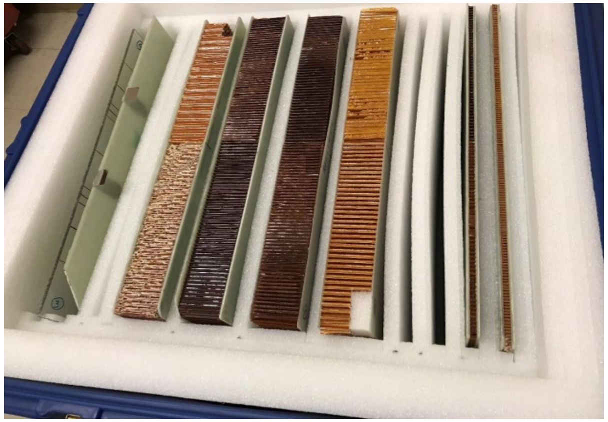
Small Crack/WFD Panels

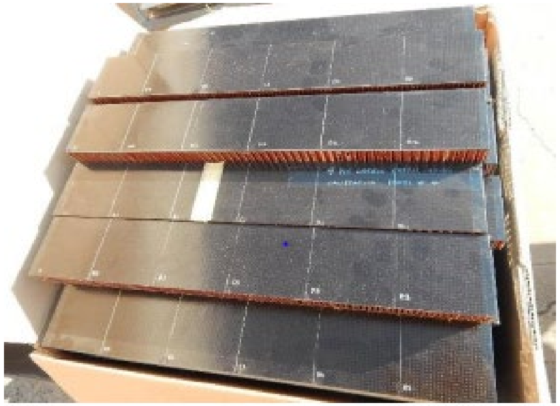
Solid Laminates

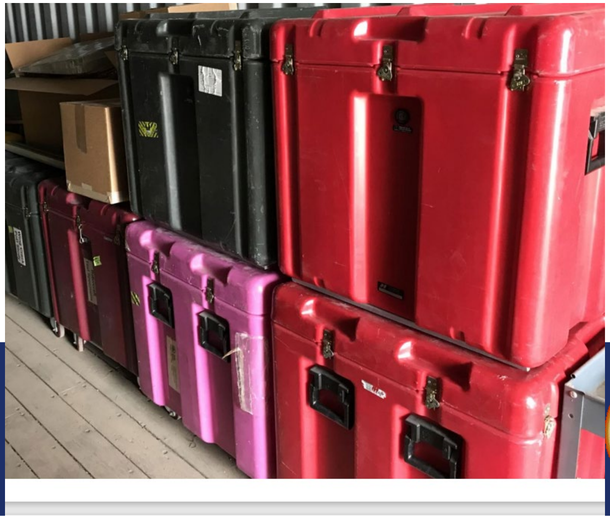
Lap Joint Corrosion

Composite Honeycomb


Wing Crack
PoD Study







Specimen Loans:

- ➢ FAA pays to ship to/Borrower pays to ship back to FAA
- ➢ Period of loan: 90 days
- ➢ Share data with FAA

POD Experiments:

Prefer tests to be completed at FAA Tech Center

Pay for statistical analysis, test oversight

If test not on site, pay for test oversight (incl travel)

Contact Danielle Stephens or Paul Swindell/Dennis Roach

Contact info chart 24

Conclusions

Although AANC no longer open, the material and equipment have been recovered by the FAA, we won't be able to replace the full capability of the AANC (lack of personnel and funding)

The FAA is offering the use of the various feedback specimens and POD experiments to the NDI industry

We hope to figure a way to keep Dennis Roach involved

We are still inventorying the material to understand what we have and with a visit from Dennis, we plan to complete the task soon. The specimens/experiments are valued at several million dollars and too valuable to dispose of them.

Please contact Danielle, Dennis or myself if you more information or use of the AANC material

QUESTIONS?

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Dennis Roach
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FAA NDI SURVEY

- The FAA is developing a research requirement for use of advanced NDI for emerging structural technologies. We need to define this research and would like to use the aviation industry to help aid in this definition process. We would like the Airlines for America (A4A) NDT Forum community help in this effort.

Inspection Challenges of Emerging Structural Technologies

- Automated drone inspection with camera or other sensors to inspect large area of aircraft skin for dents, cracks, corrosion, and methods of characterizing images (AI/ML for image analysis and damage characterization)

- Industry benchmarking survey to identify other emerging inspection technologies are currently being pursued by industry for both traditional and advanced materials and structures.

- Provide guidance and training to prepare the FAA and industry for the implementation of these materials and technologies

- Goal: promote certification efficiencies and mitigate potential risk factors of the application of emerging materials, structures, and inspection technologies

POC

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- Paul Swindell paul.e-ctr.Swindell@faa.gov 732-581-1987

Questions?