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Reliability of Emerging NDI for Metal Airplane Fuselage Structural Integrity

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FAA Airworthiness Assurance NDI Validation Center (AANC)

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FAA Airworthiness Assurance Nondestructive Inspection Validation Center - AANC

- Initiated in 1988 under the Aviation Safety Act & opened in 1991.
- Offers a mechanism to evaluate, develop, and transfer aircraft inspection technologies to market.
- Operated by Sandia National Laboratories for the FAA Office of Aviation Safety (AVS).
- Funded primarily through the William J Hughes Technical Center.
- AANC partners with industry, academia, and other government agencies.

B737-200
Visual Inspection
Test Bed

DC-9-10 Corrosion
Test Bed

B727-200 MSD
Test Bed

FAA William J. Hughes
Technical Center

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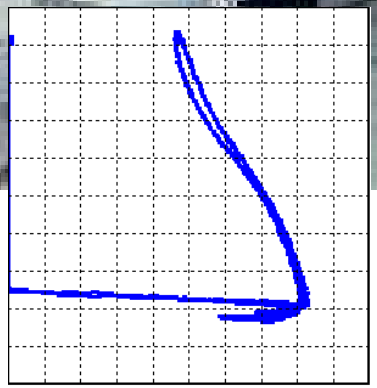
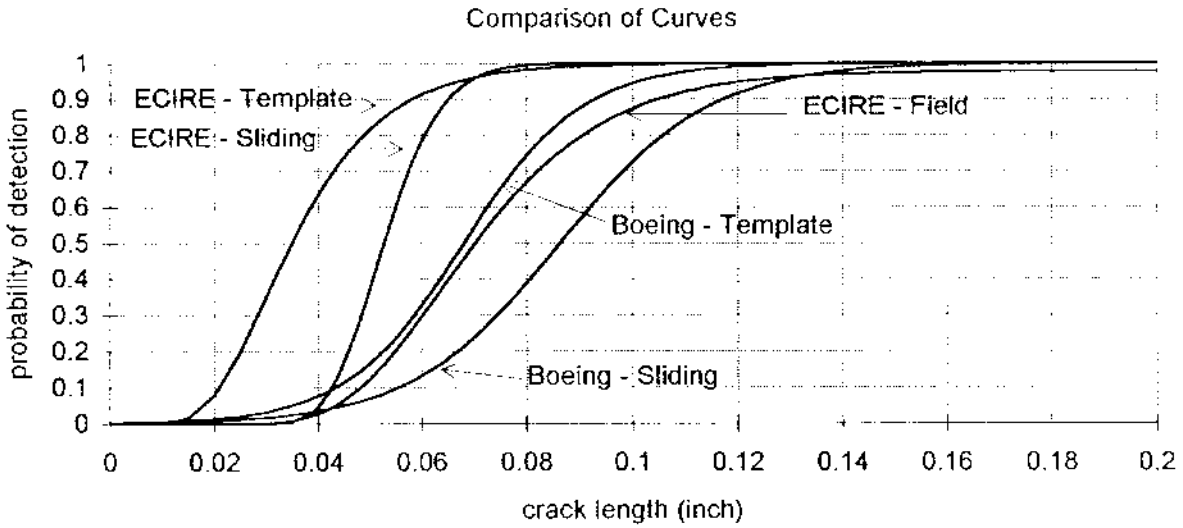
Eddy Current Inspection Reliability Study Mid 1990's



Eddy Current Defect Signal

Benchmark study that quantified inspection reliabilities for fuselage surface crack detection by several conventional methods.



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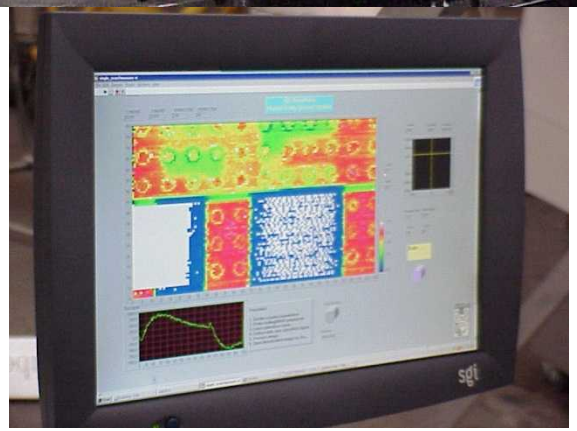
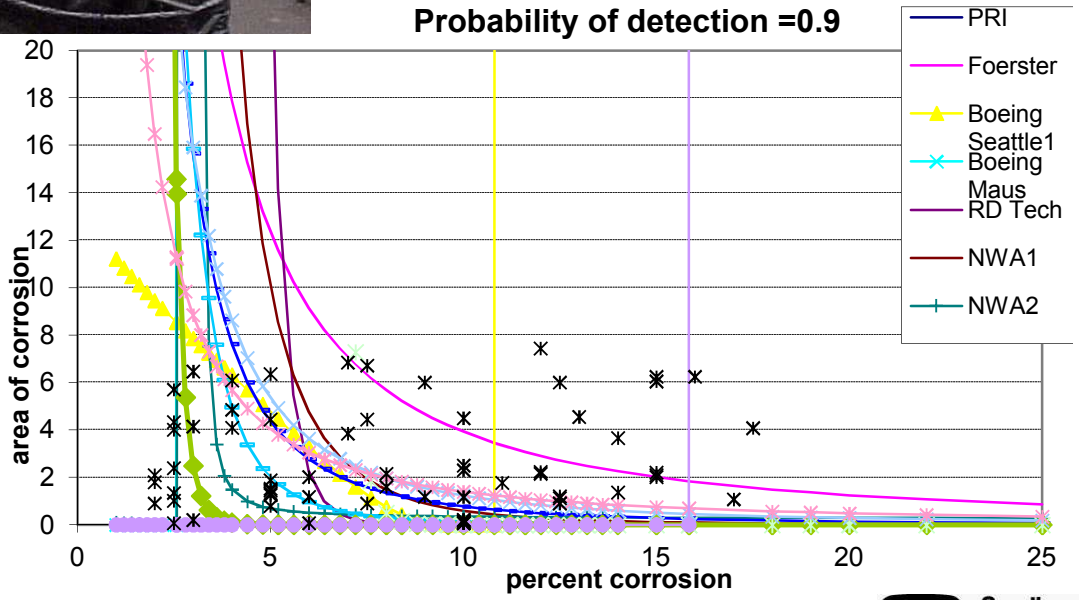
Lap Joint Hidden Corrosion Detection Study
Late 1990's

Validated inspections for conventional and emerging corrosion detection methods.



Inspection C-scan Image



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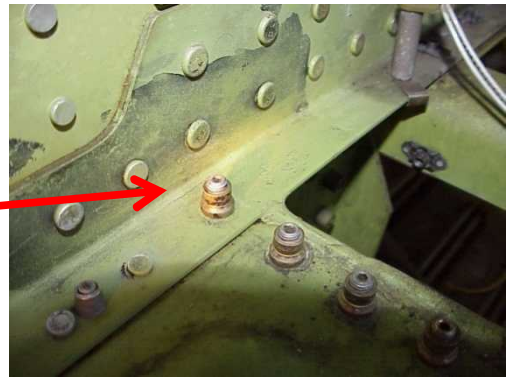
Visual Inspection Reliability Project
Late 1990's

Detailed visual inspection of 737 floor beams using a flashlight and mirror.



Floor Beam Crack

FAA William J. Hughes Technical Center

- This study confirmed that it is possible to change inspection performance strategies and results through the design of the work instructions.
- The effect on reliability for the more specific job cards is primarily in increasing the chances of alerted flaws being found.
- Thus it is important to maintain strong communication between engineering groups and inspection groups so that inspectors are alerted to known defect information.

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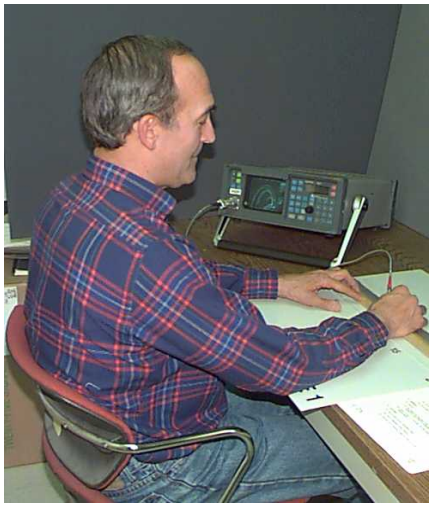
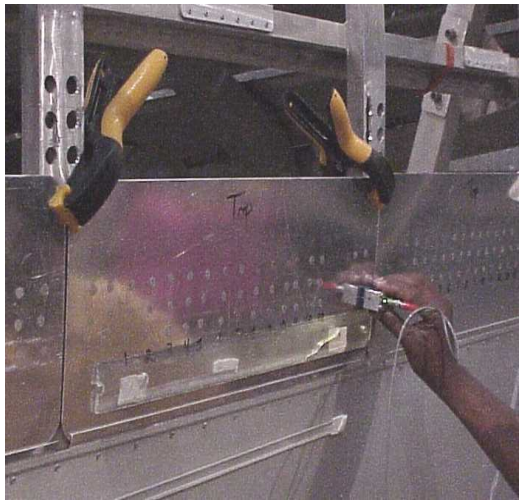
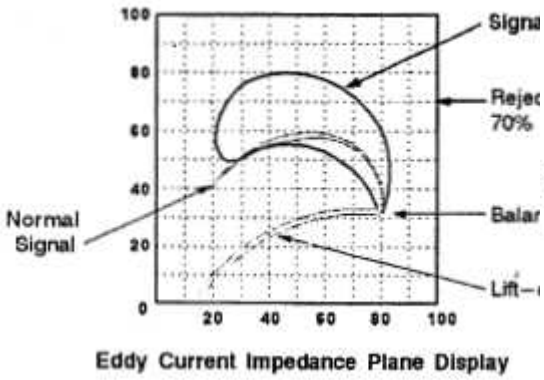
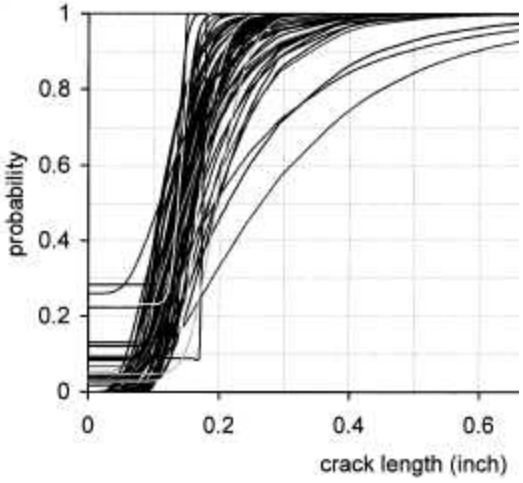
Inner Layer Crack Detection Studies
1999 - 2002









- Assessed inspections for conventional lap joint lower rivet row crack detection.
- This study demonstrated that often inspectors do not achieve assumed reliability.
- Several methods identified that provided $POD_{0.9}$ values lower than Boeing assumed value of 0.200” (detection range from 0.220” to 0.300”)
- Dual frequency inspections have been implemented due to two kinds of rivets known to have been used.

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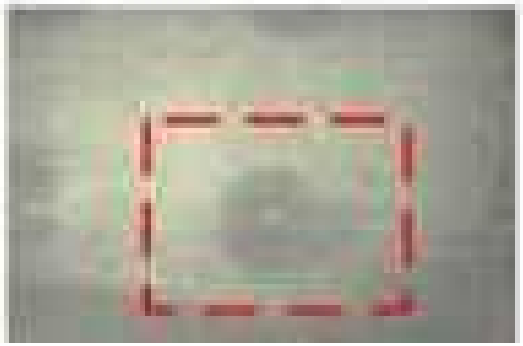
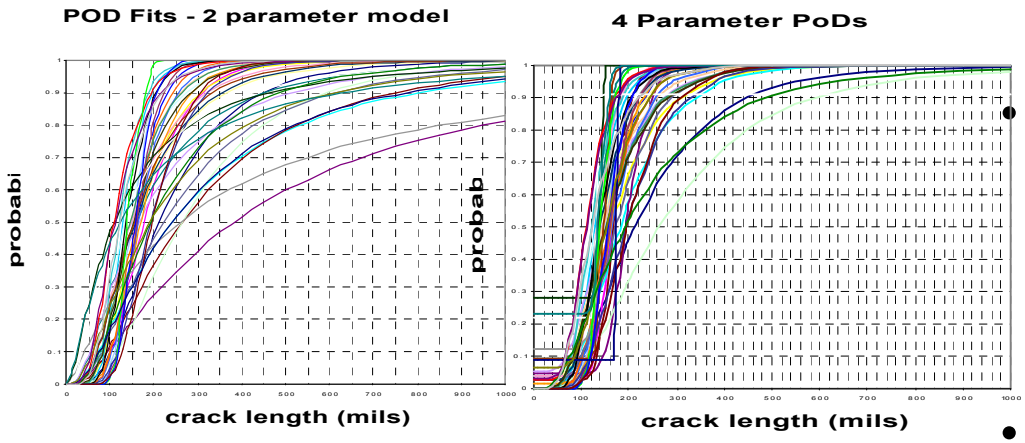
Delta/FAA/AANC 727 Teardown, Fatigue & Inspection Reliability Studies – 2003



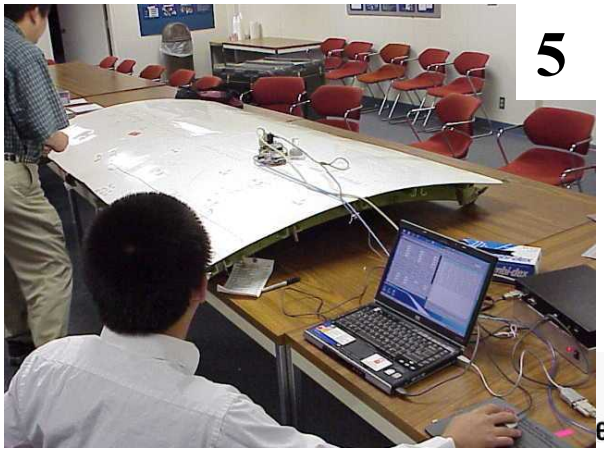


- Use of retired 727 lap joint structure with post-inspection characterization of multi-site fatigue cracking (similar to 737).
- 19 new, unproven techniques in various stages of development assessed.
- Assessment methods utilized models that account for multiple flaws and more factors that can influence detection.
- NDT Report Cards generated.

Widespread Fatigue Damage Inspection Reliability Studies – Mid to Late 2000's

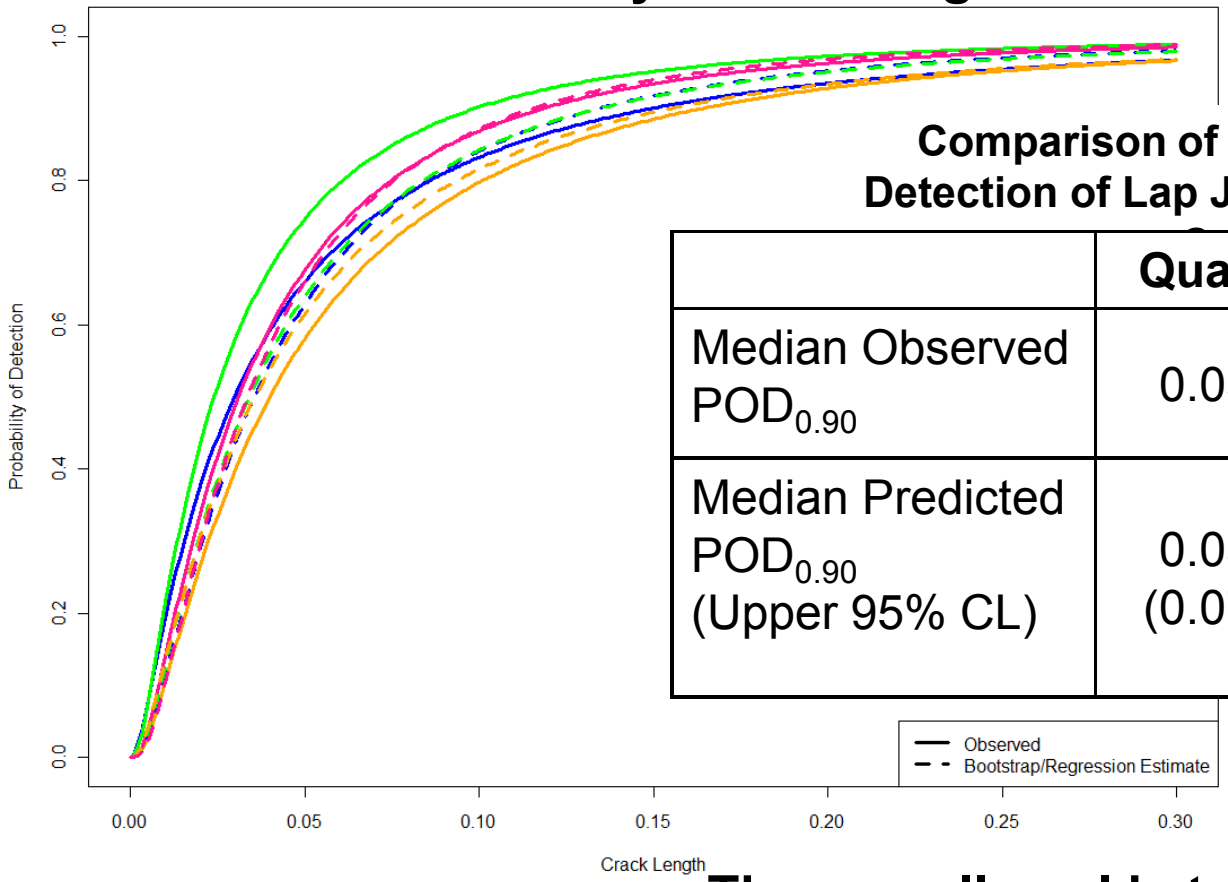
Use of retired structure with characterized multi-site fatigue cracking for Comparison of Emerging NDI Technologies not available during Delta/FAA/AANC study. Led to MAPOD studies.

1. Inspect
2. Disassemble
3. Characterize
4. Reassemble
5. Re-inspect & Perform PODs



Model Assisted Probability of Detection Validation for Lap Joint Multi Site Damage Detection - 2011

MAPOD offers the potential for faster, less expensive reliability studies to generate POD data.



Comparison of Observed and Predicted Detection of Lap Joint Multi-Site Fatigue

	Quad 2	Quad 3	Quad 4
Median Observed $POD_{0.90}$	0.039	0.088	0.162
Median Predicted $POD_{0.90}$ (Upper 95% CL)	0.039 (0.071)	0.088 (0.156)	0.155 (0.258)

The overall goal is to use MAPOD methods for assessing large area metal and composite inspection methods.

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Proposed Research for Metal Airplane Nondestructive Inspection at the AANC

- Comparative POD studies to detect Chem-Milled Edge Cracking in Boeing Airplanes (737 & 757)
  - Quantify detection reliability based on “Ill Behaved” cracks.
  - Provide regulators with data to adjust inspection intervals.
- Scribe Line Crack Probability of Detection Studies
  - Quantify detection reliability based on “Ill Behaved” cracks.
  - Provide regulators with data to adjust inspection intervals.
- Develop rivet quality inspections and correlate to early onset of multi-site damage cracking in lap joints.
  - Provide operators with predictive tools to anticipate early lap joint cracking.
  - Particularly useful for inspection of all hand rivet lap joints.
    - B737 Classics
    - Next Generation B737’s with skin panel replacements
- Structural Health Monitoring development partnership with the FAA and Delta Air Lines Enabling Technologies.

Issues with Inspection of Metal Airplanes

- **The Aging Airplane Program conducted by the FAA has resolved many age related fatigue issues.**
  - **However, better inspections methods continue to evolve as technology (particularly computational capabilities) improves.**
  - **More importantly, there are service/repair related issues that must be addressed as airplanes are operated to Limits of Validity mandated by the Widespread Fatigue Damage Rule.**
    - **Inspections of hand riveted repaired structure and large modifications such as crown skin replacements.**
    - **Any structure that was hand riveted during repair or modification where poor riveting quality could exist.**
- **Since most of the US commercial fleet is still made of metal, the AANC recommends a continuing research program to address inspections of metal airplanes.**