Reliability of Emerging NDI for Metal Airplane Fuselage Structural Integrity

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Sandia National Laboratories
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's 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

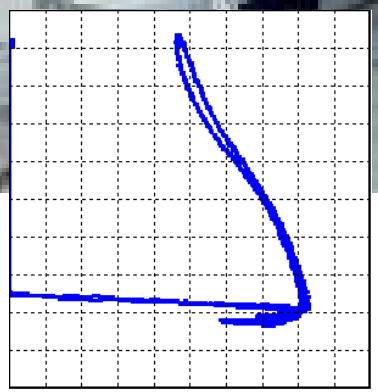
B727-200 MSD
Test Bed

FAA William J. Hughes
Technical Center

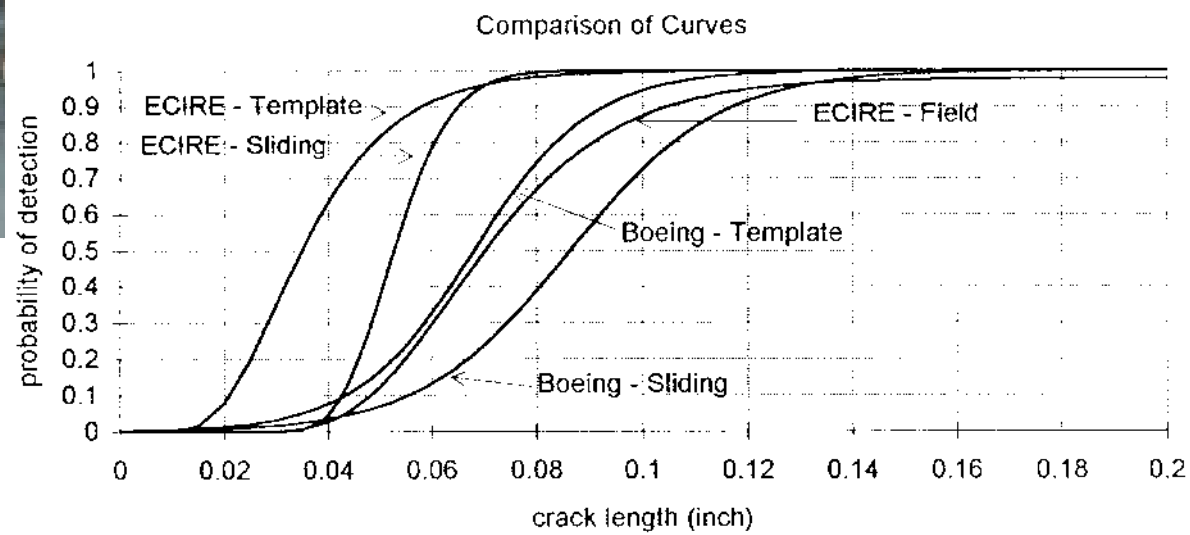
Sandia
National
Laboratories

Eddy Current Inspection Reliability Study
Mid 1990s

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

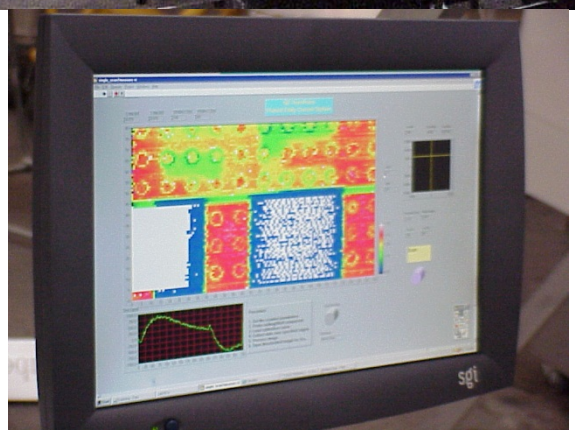


Eddy Current Defect Signal

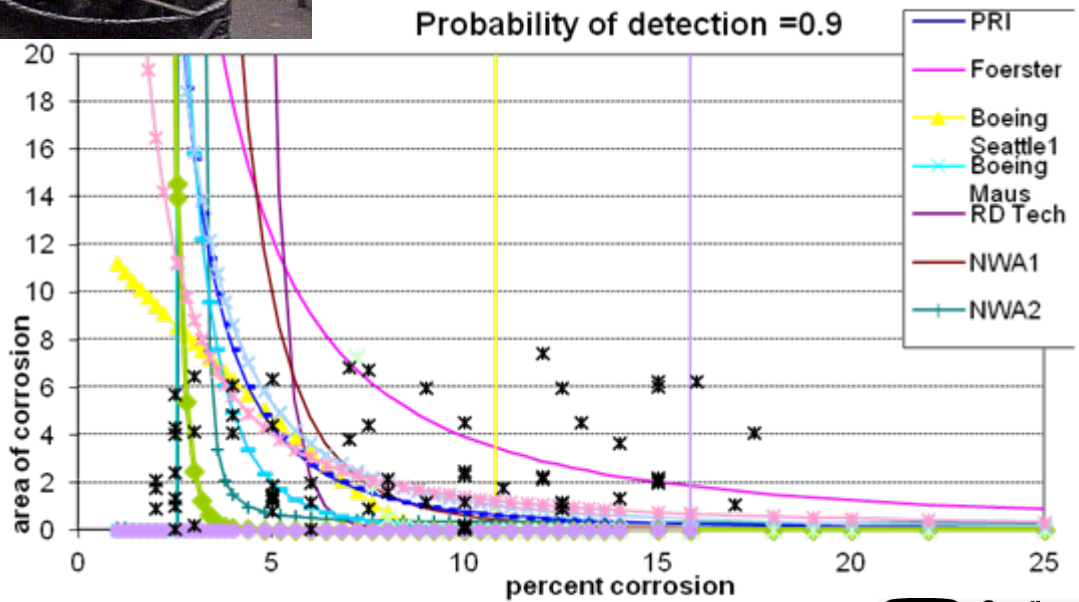


Lap Joint Hidden Corrosion Detection Study Late 1990s

Validated inspections for conventional and emerging corrosion detection methods.



Inspection C-scan Image



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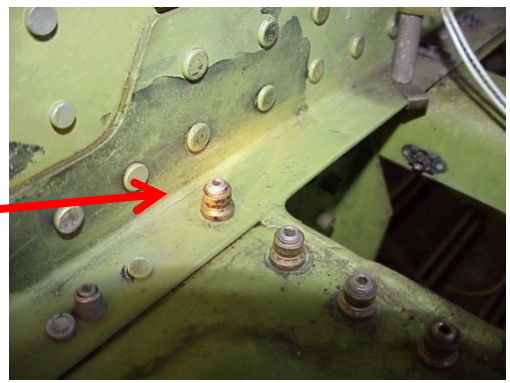
Visual Inspection Reliability Project
Late 1990s

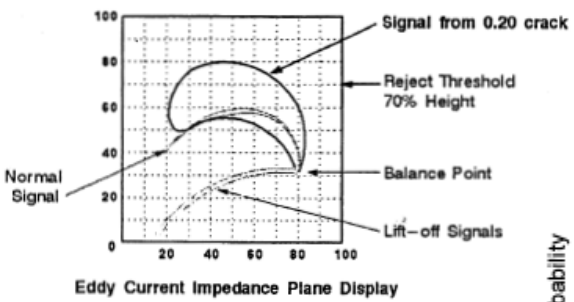
Detailed visual inspection of 737 floor beams using a flashlight and mirror.

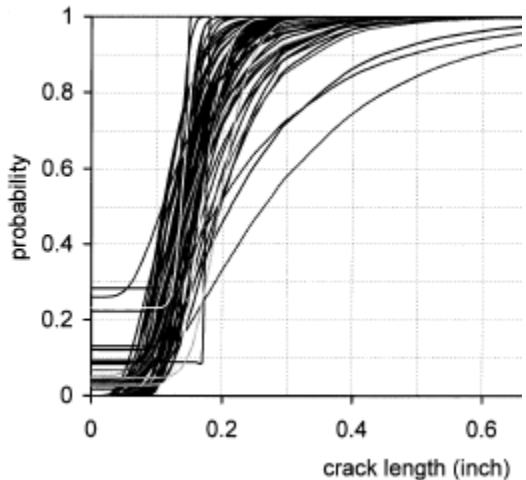
Floor Beam Crack



- 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.

Inner Layer Crack Detection Studies
1999 - 2002





- Assessed inspections for conventional lap joint lower rivet row crack detection.
- This study demonstrated that often inspectors achieved $POD_{0.9}$ values lower than Boeing assumed value of 0.200” (detection range from 0.220” to 0.300”)
- Boeing made changes to the inspection procedure because of these results.
- More recently, dual frequency inspections have been implemented due to two kinds of rivets known to have been used. POD is pending.

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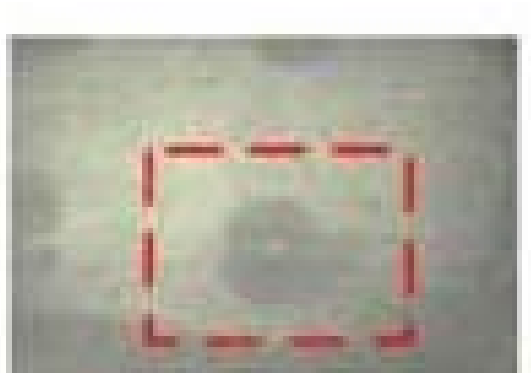
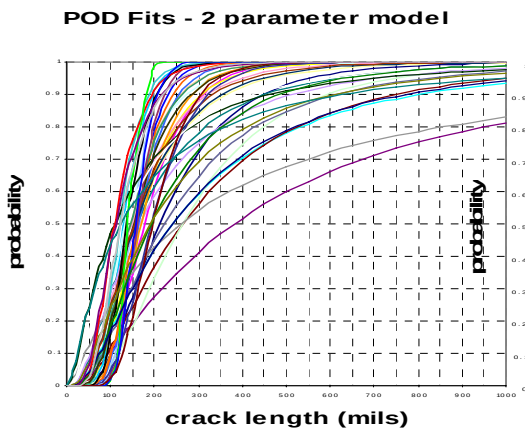
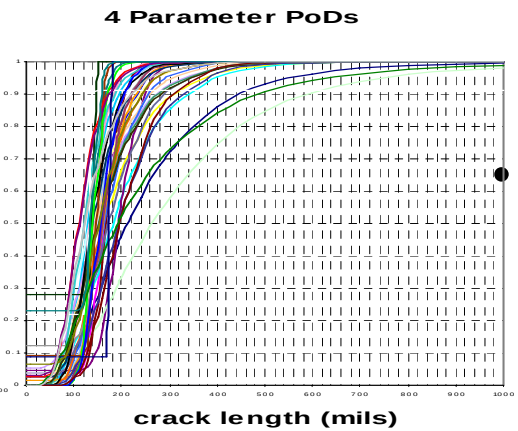
Delta/FAA/AANC 727 Teardown, Fatigue & Inspection Reliability Studies – 2003







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, along with conventional methods. Assessment methods utilized models that account for multiple flaws and more factors that can influence detection.

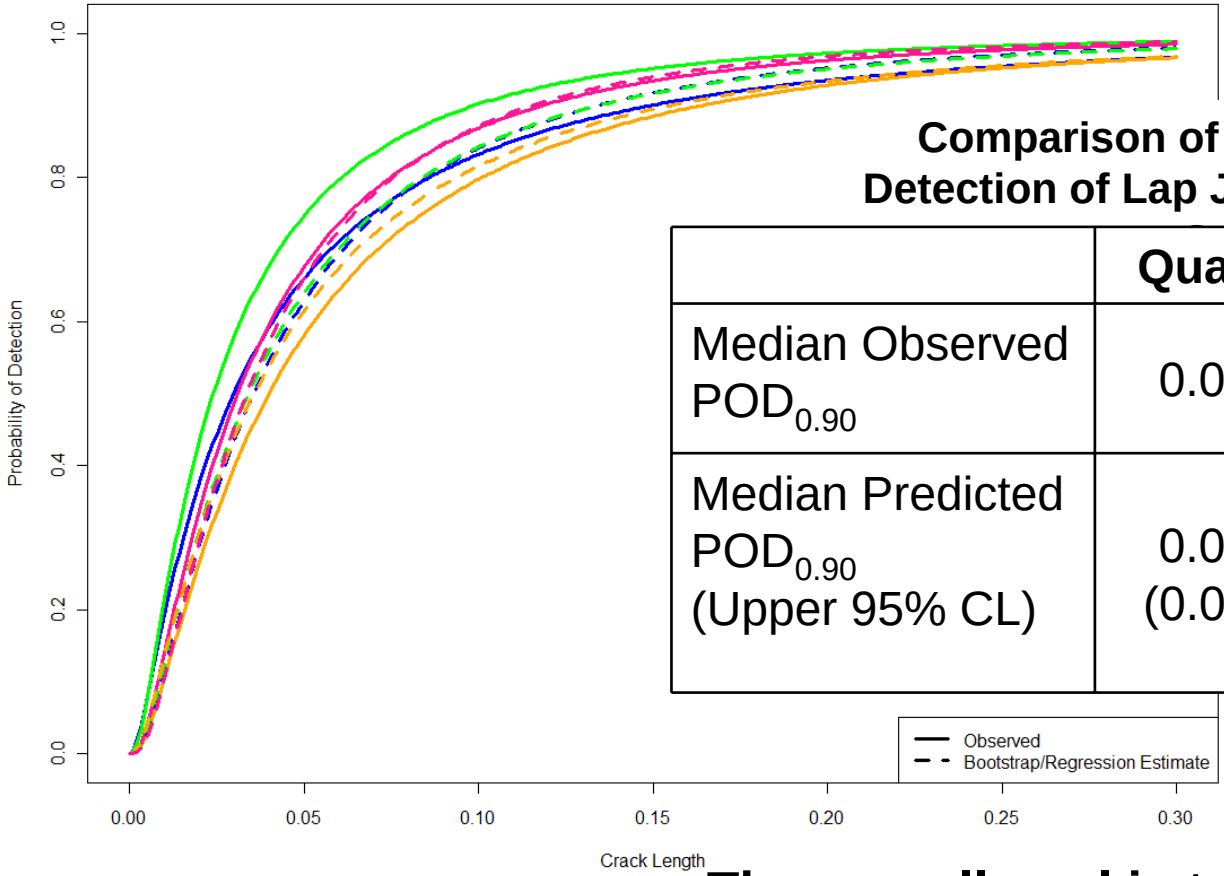
Widespread Fatigue Damage Inspection Reliability Studies – Mid to Late 2000s

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.

Summary of Research for Metal Airplane Nondestructive Inspection at the AANC

- The prior 8 projects detail only some of the NDI research performed at the AANC under FAA direction. Several other projects were completed that are not listed here.
- The personnel, facilities and process, and most of the airplane defect test specimens used for various NDI evaluations, are still in place at Sandia National Laboratories to respond to future R&D as requested by the FAA, or other organizations.
- Sandia leverages limited funds from several programs to enhance the overall effectiveness of the AANC (e.g. US CAR project and wind energy inspection research).
- The AANC is a resource the FAA utilizes to provide proactive R&D into inspection of all types of transport airplanes (metallic and composite).

Issues with Inspection of Metal Airplanes

- **The Aging Airplane Program conducted by the FAA has resolved many age-related fatigue cracking issues through multiple new rules (e.g. WFD Rule).**
  - **However, better inspection methods continue to evolve as technology (particularly computational capabilities) improves.**
- **The FAA, through participation with multiple industry groups, is proactive in identifying potential fleet-wide structural degradation issues that can be safely managed by the use of inspection and subsequent repair.**
- **Thus, NDI research continues to be an important component of an overall approach to ensuring the safety of the flying public.**