FAA Inspection Research Activities for Composite Materials

Presented to: The 2006 Composite Damage Tolerance & Maintenance Workshop

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Outline

- **Inspection Systems Research - Background**
- **Technology Validation Projects**
  - Composite Reference Standards
  - Honeycomb Inspection Reliability Study
  - Flaw Detection in Solid Laminates Study
  - Repair of Metal Aircraft Using Composite Patches
- **Inspection Research Needs**
- **NDT Development Projects - Time Permitting**
  - Computer Aided Tap Tester (CATT)
  - Air Coupled Ultrasonic Tester (ACUT)
  - Generic Scanner
  - Thermosonics (Sonic Infrared Imaging)

Aging Aircraft Research Program
8 Research Project Descriptions (RPDs)

Structural Integrity of Commuters (RPD-161)

Structural Response Simulation and Modeling (RPD-515)

Rotorcraft Structural Integrity (RPD-519)

Airborne Data Monitoring Systems (RPD-510)

Mechanical Systems (RPD-672)

Aging Electrical Systems (RPD-673)

Continued Airworthiness of Aircraft Engines (RPD-556)

Inspection Systems Research (RPD-584)

RPD 584 NDI Research Conducted Primarily at CASR and the AANC

Center for Aviation Systems Reliability (CASR)
Managed at Iowa State University
Consisting of ISU, Northwestern, & Wayne State
Established 1990. Re-established as an FAA Center of Excellence in 1997

Airworthiness Assurance NDI Validation Center (AANC)
Albuquerque International Airport
Operated by Sandia National Laboratories
Established 1991
Hangar Dedication in February 1993

Composite Reference Standards

Objective: Develop industry-wide composite reference standards to support damage assessment and post-repair inspection of non-metallic composite structures

Deliverables:

- **Optimized Honeycomb Reference Standard Set**
- **Universal Laminate Standard Set**

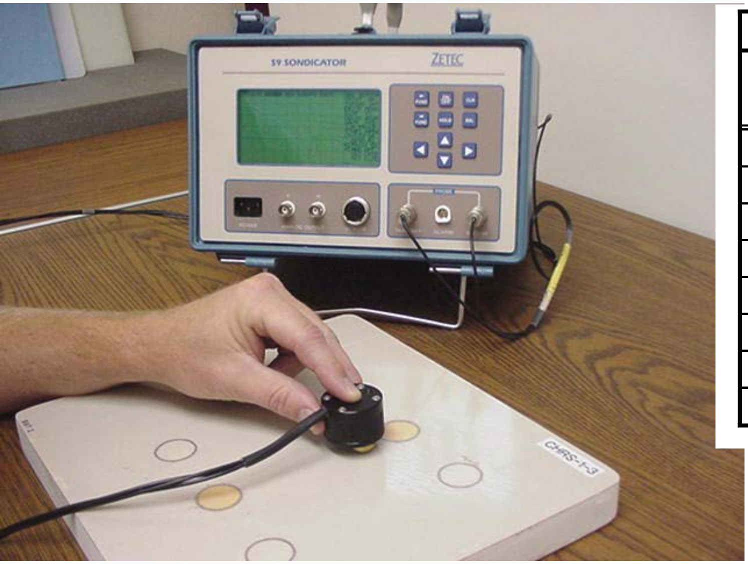
Benefits:

- **Provide a consistent approach to composite inspections**
- **Reduced standard procurement costs**
- **Formal modifications to OEM manuals - harmonized approach by industry**

Worked in collaboration with the CACRC Inspection Task Group

Composite Reference Standards

Honeycomb NDI Reference Standards



Variables Addressed in Prototype Composite Honeycomb Standard Set						
Flaw	**Laminate Type**	**Laminate Thickness**	**Honeycomb Type**	**Honeycomb Thickness**	**Cell Size**	**Cell Density**
Delam.	Carbon	3, 6, 9, 12 plies	Nomex	1"	3/16"	3 lb.
Disbond	Carbon	3, 6, 9, 12 plies	Nomex	1"	3/16"	3 lb.
Delam.	Fiberglass	3, 6, 9, 12 plies	Nomex	1"	3/16"	3 lb.
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- **Skin to Core Disbonds**
- **Delaminations**
- **Potted Core**
- **Core Splice**

Published as Aerospace Recommended Practice 5606: "Composite Honeycomb NDI Reference Standards"

Composite Reference Standards

Solid Laminate NDI Reference Standards

Developed for use with Ultrasonic, Resonance, and Tap Test Methods

G-11 Phenolic found to have similar acoustic properties to both carbon and fiberglass laminates

OEMs working toward adoption of standards via insertion into NDT Manuals

Published as Aerospace Recommended Practice 5605: "Solid Composite Laminate NDI Reference Standards"

Honeycomb Inspection Reliability Study

<u>Objective:</u> To establish industry-wide performance curves that quantify:

1) How well current field inspection techniques reliably find flaws in composite honeycomb structures
   Current Field Methods:
   - Manual Tap Hammers
   - Automated Tappers
   - Low Frequency Bond Testers (LFBT)
   - High Frequency Bond Testers (Resonance)
   - Mechanical Impedance Analysis (MIA)
2) The degree of improvements possible through the integration of more advanced NDI techniques and procedures

<u>Approach:</u> To utilize industry inspectors and a series of composite honeycomb specimens with statistically relevant flaw profiles in a blind test.

Honeycomb Inspection Reliability Study

<u>Specimen Types</u> - modeled after range of construction found on aircraft; carbon graphite & fiberglass skin over Nomex core

<u>Flaw Types</u> - statistically relevant flaw distribution with sizes ranging from 0.2 in.^{2} to 3 in.^{2}

1) interply delaminations
2) skin-to-core air gap disbonds
3) skin-to-core "kissing" disbonds
4) impact damage

<u>Application of NDI</u> - blind tests implemented in aircraft maintenance depots; guideline procedures provided; use of ref. standards to set up equipment

<u>Goal</u>- evaluate performance attributes

1) accuracy & sensitivity (hits, misses, false calls, sizing)
2) versatility, portability, complexity, inspection time (human factors)
3) produce guideline documents to improve inspections
4) introduce advanced NDI where warranted

Honeycomb Inspection Reliability Study

Airlines, 3rd Party Repair Shops and Advanced NDT which participated

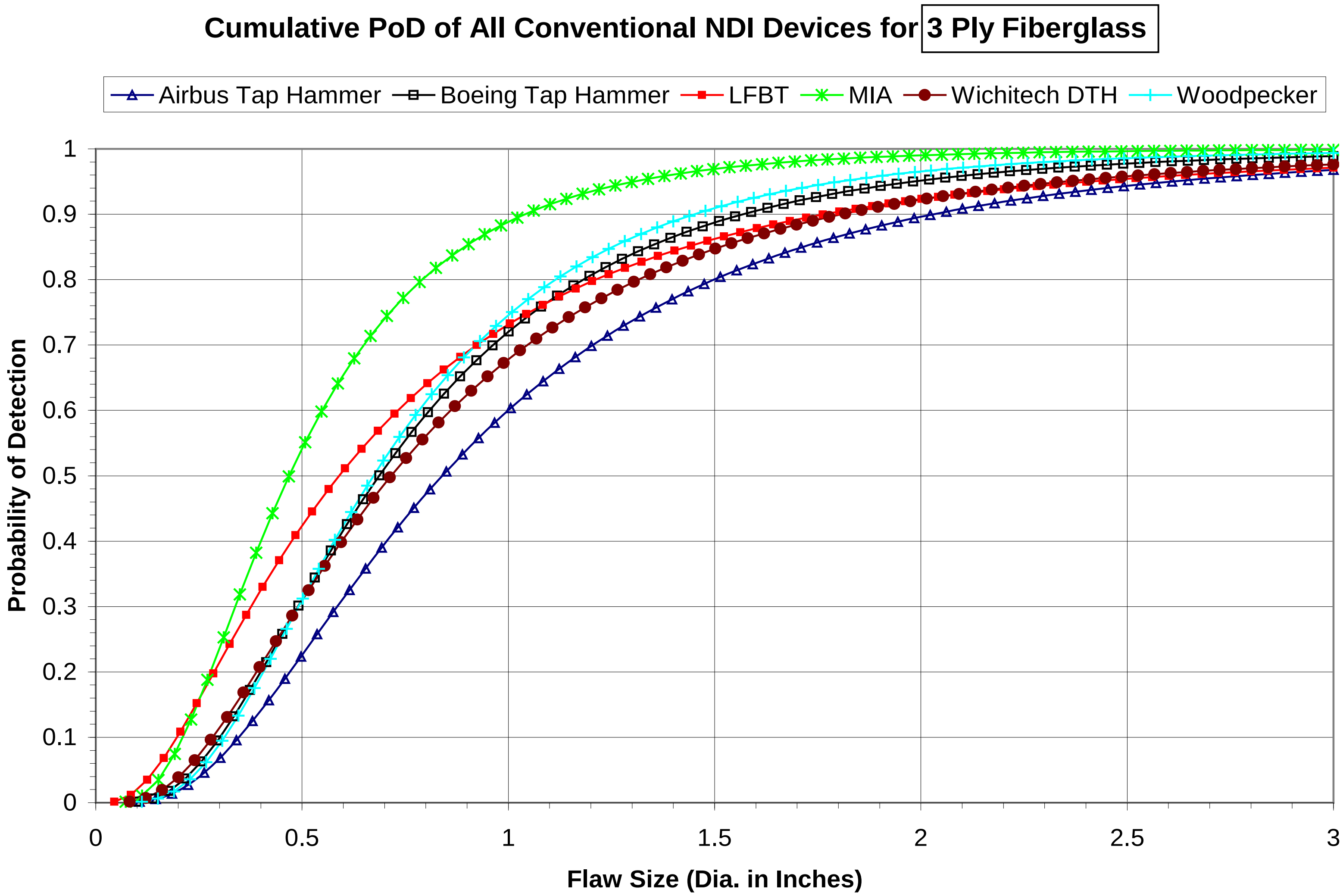
Wichitech (Seattle)
Boeing (Long Beach)
Boeing (Seattle)
Computer Aided Tap Tester (ISU)
Thermal Wave Imaging
Thermosonics
Phased Array Ultrasonics
Shearography
Air Coupled UT
Ultra Image UT Scanner
MAUS MIA & Resonance Scanner
Digital Radiography (Lock.-Martin)

Honeycomb Inspection Reliability Study

Experiment Implementation

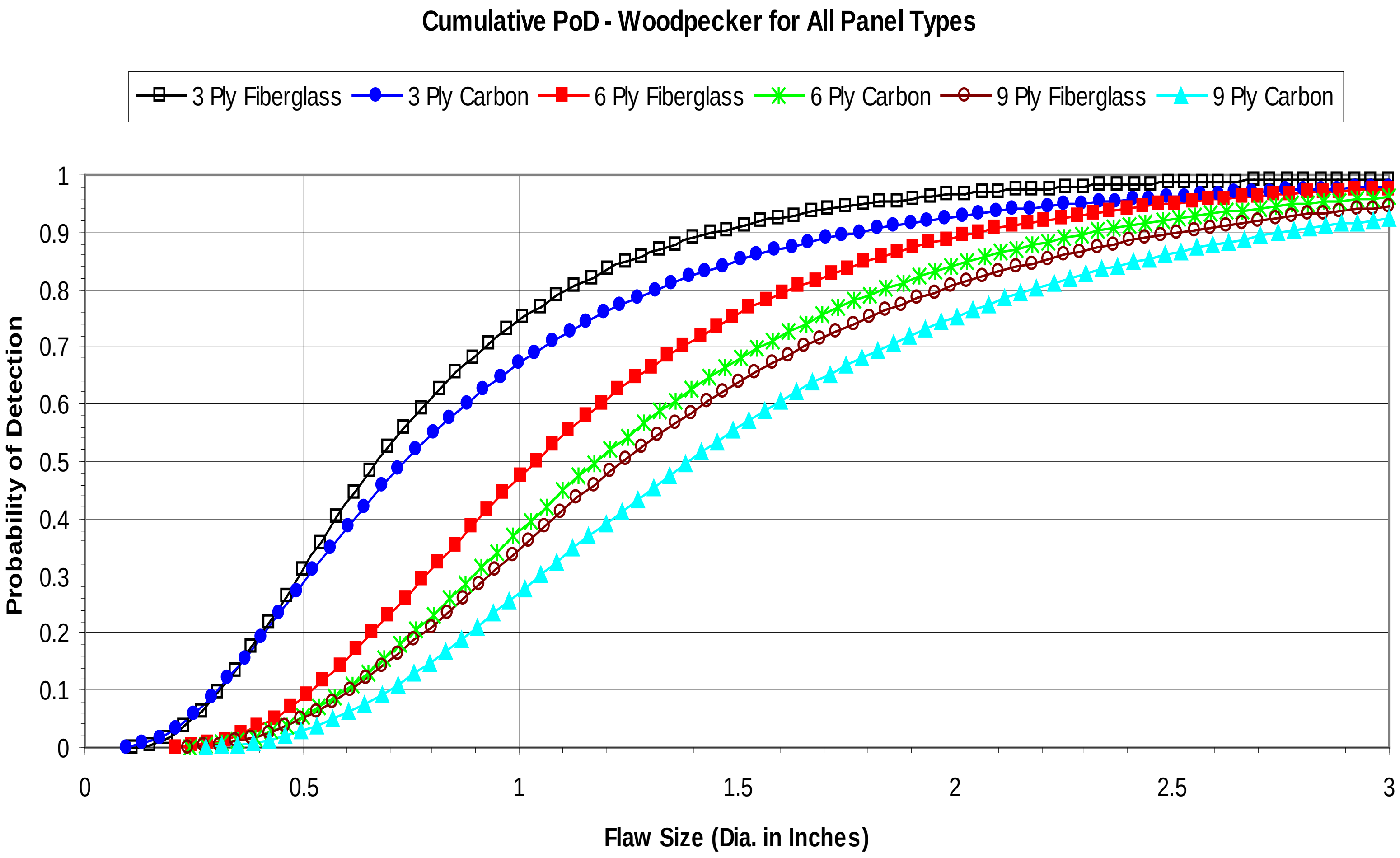
Honeycomb Inspection Reliability Study

Performance of Multiple Devices for A Single Type of Test Specimen



Honeycomb Inspection Reliability Study

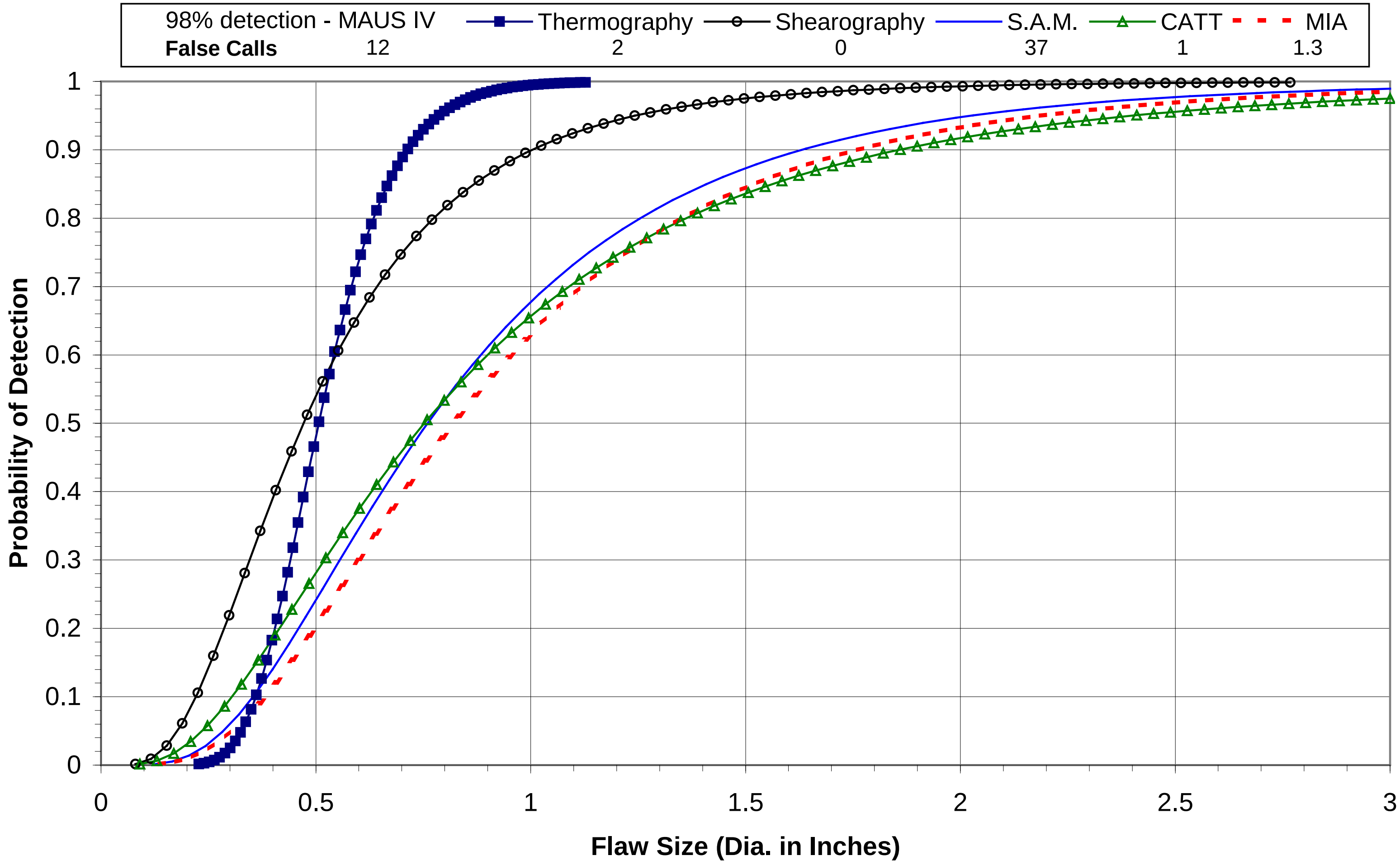
Performance of a Single Device over the range of Test Specimens



Honeycomb Inspection Reliability Study

Inspection Improvements Via Advanced NDI Techniques

Comparison of Advanced Inspection Techniques with Best Conventional NDI Result on 6 Ply Carbon



Honeycomb Inspection Reliability Study

- **Flaw Detection with Conventional NDI**
  - 90% POD is not achieved for 1” dia. flaws; at 9 plies it exceeds 2” dia.
  - POD can improve as inspection time per area increases (up to a limit)
  - False call rate was independent of inspection time
  - External noise affects tap testing
  - Tap testing is difficult above 9 plies; CATT improves on this approach via C-scan
  - Human factors issues (time, attention to detail, proper deployment)
  - Some inspectors marked grids on panel to aid in coverage of inspection area – most inspectors had good coverage; some followed random pattern (find small flaws but miss large ones)
  - Boeing and Airbus inspection procedures were provided but used very little by the inspectors
  - Some Wichitech DTH users would listen for pitch change during inspection then verify by looking at digital readout
  - Difficulty/complexity in deploying LFBT equipment produced large data spread
  - Overall, MIA mode worked well (reliability, repeatability, ease of use)

Honeycomb Inspection Reliability Study

Flaw Detection with More Sophisticated NDI

- Note that NDI techniques evaluated are in different states of maturity
- Improvement in flaw detection ranged from 66% to 72%
- Automated deployment & data presentation/analysis reduces many human factors concerns (100% coverage; flaw recognition on images)
- Allow for more rapid inspections
- If greater sensitivity is needed, NDI methods are available now to address those needs
- MAUS, Thermography (sizing), Shearography all performed well

Composite flaw detection experiment is available for continued testing

Flaw Detection in Solid Laminates

Purpose

- Determine in-service flaw detection capabilities: 1) conventional NDT methods vs. 2) improvements through use of advanced NDT.
- Optimize laminate inspection procedures.
- Compare results from hand-held devices with results from scanning systems (focus on A-scan vs. C-scan and human factors issues in large area coverage).
- Provide additional information on laminate inspections for the "Composite Repair NDT/NDI Handbook" (ARP 5089).

Approach

- Statistical design of flaws and other variables affecting NDI
- Study factors influencing inspections including composite materials, flaw profiles, substructures, complex shapes, fasteners, and secondary bonds
- Blind application of NDT techniques to study hits, misses, false calls, and flaw sizing
- POD and signal-to-noise data gathering

Flaw Detection in Solid Laminates

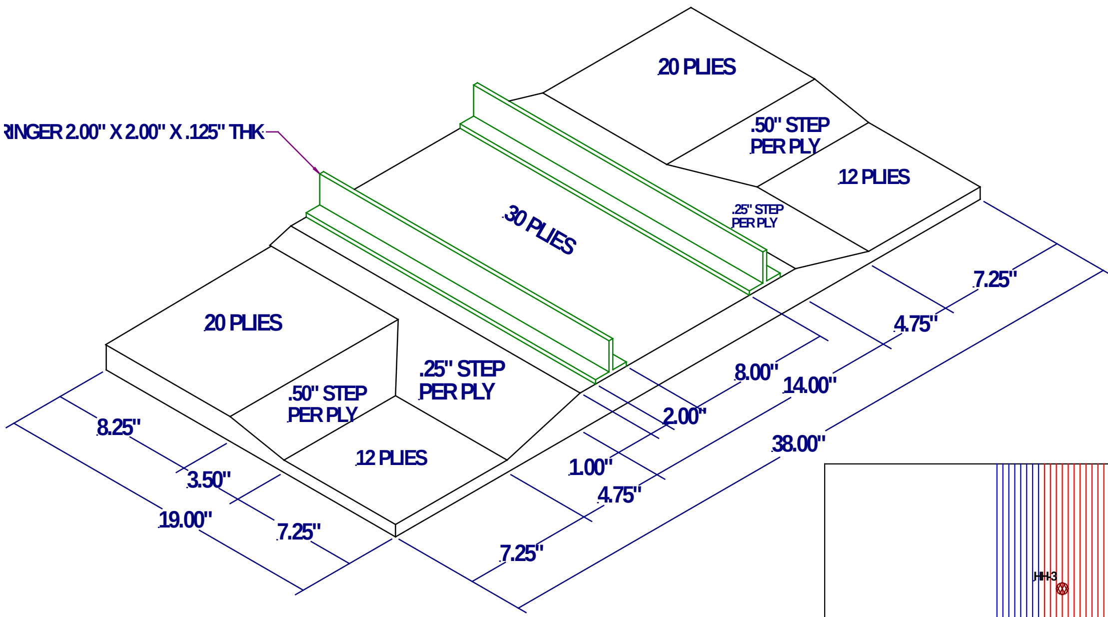
<u>Specimen Types</u> – Solid laminate carbon (12, 20, 24, 32 plies)

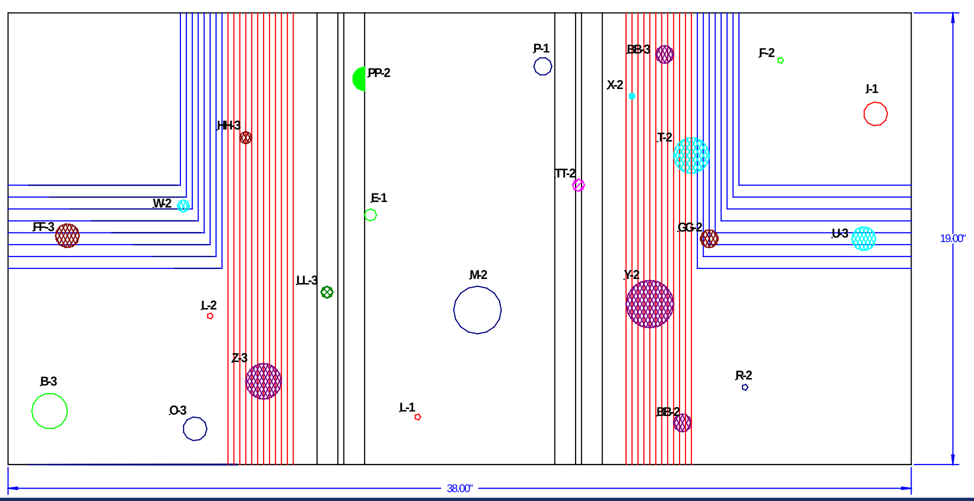
- Contoured and tapered surfaces
- Substructures – stringers, ribs, spars; honeycomb impediment
- Bonded & sealed joints; fasteners
- Large enough to warrant scanners; complex geometry to challenge scanners

<u>Flaw Types</u> - statistically relevant flaw distribution with range of sizes & depths (near front & back surfaces; in taper regions)

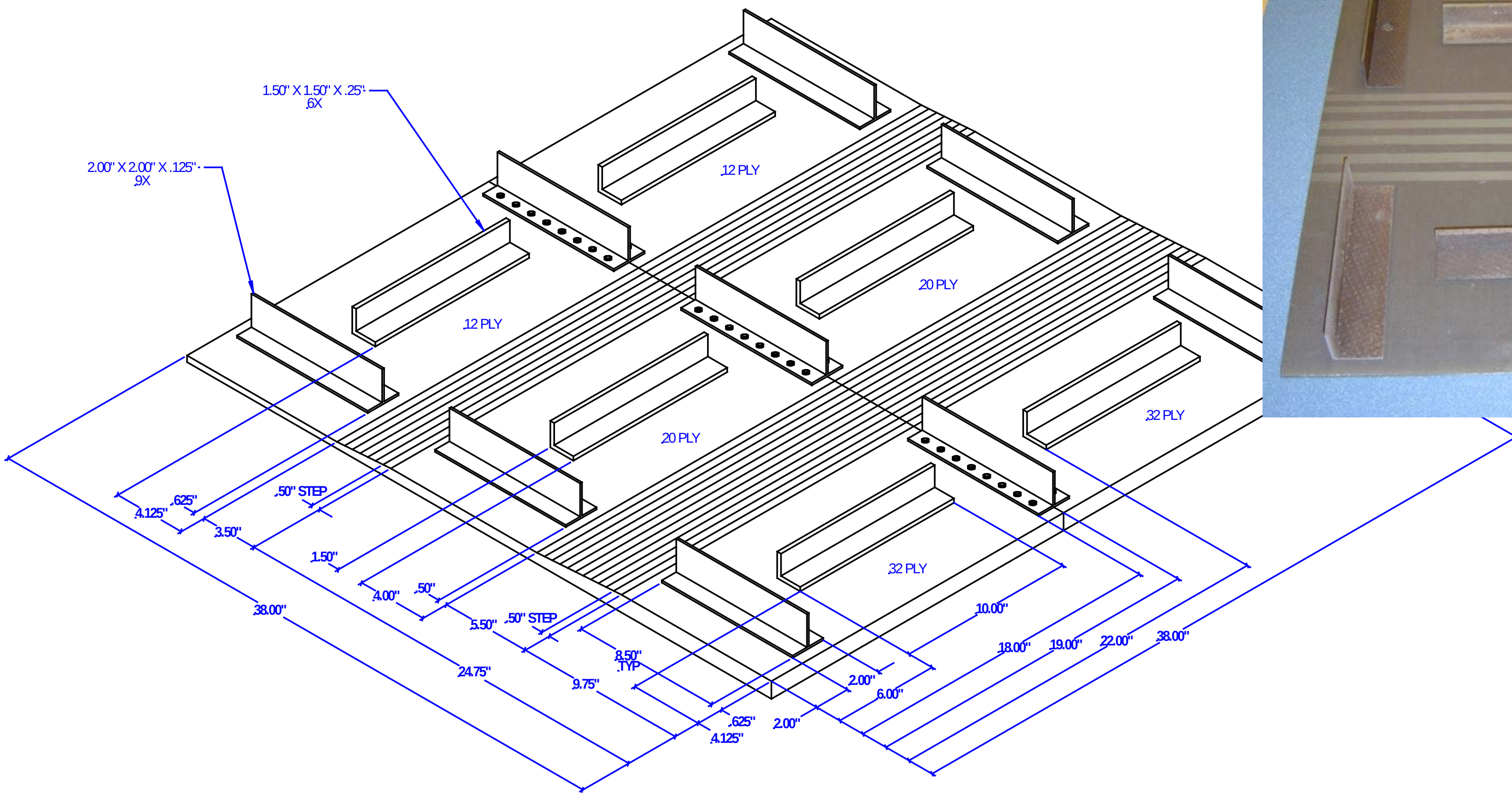
1) interply delaminations ("kissing" and air gap)
2) substructure damage
3) skin-to-stiffener disbonds
4) simulated impact damage

Flaw Detection in Solid Laminates

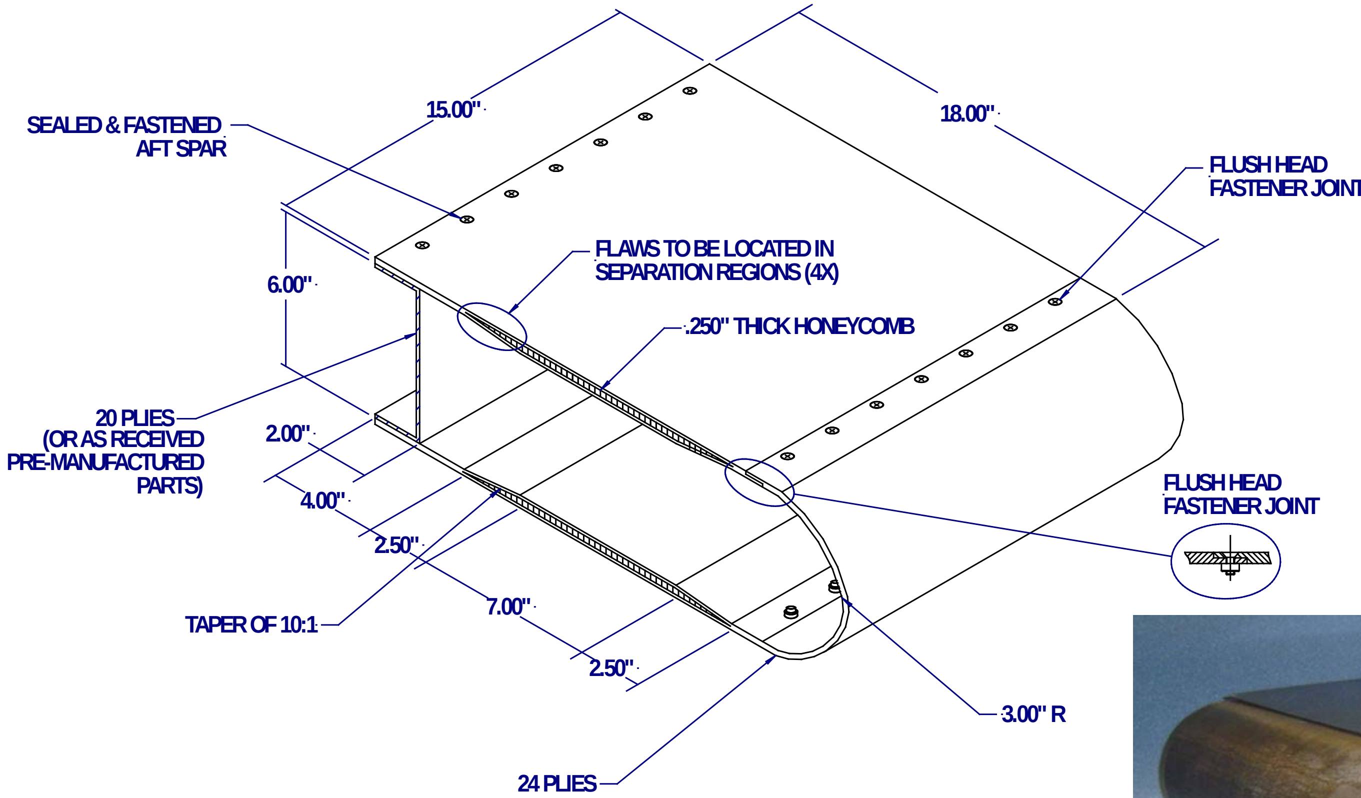


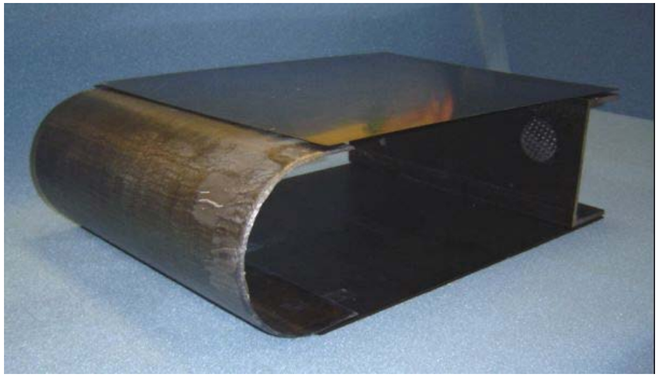


Flaw Detection in Solid Laminates



Flaw Detection in Solid Laminates





Repair of Metal Aircraft Using Composite Doublers


Delta Air Lines L-1011


Fed Ex DC-10

<u>GOALS & BENEFITS</u>:

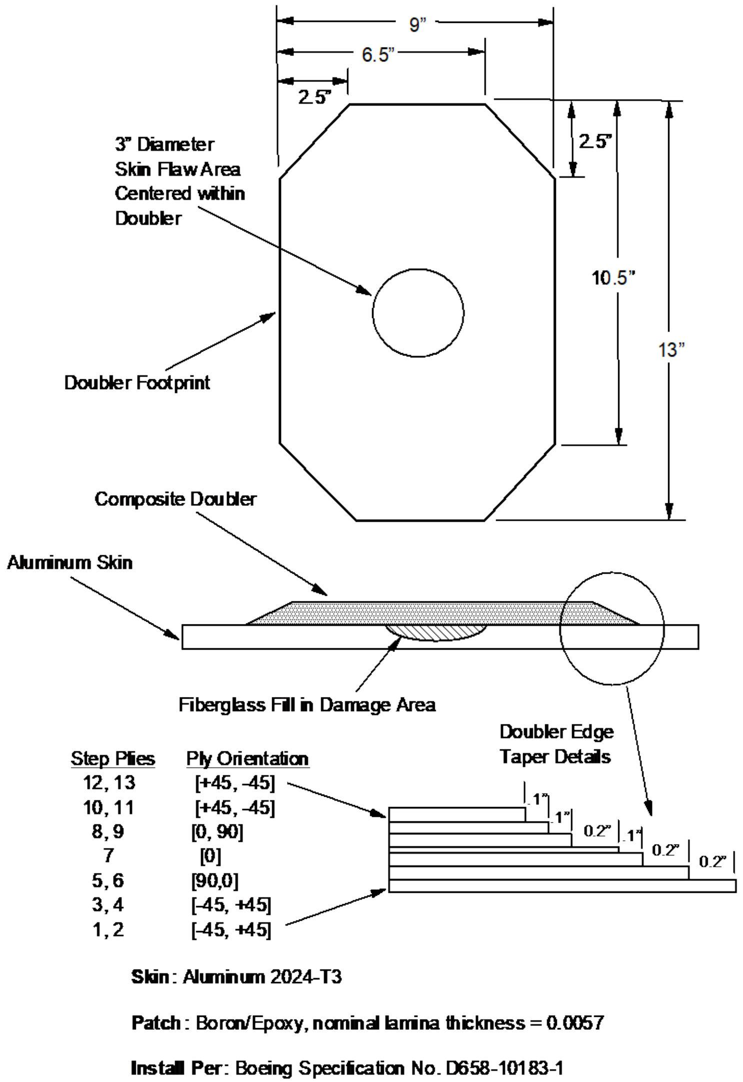
- **Perform comprehensive development & validation of composite doubler technology**
- **Streamline design-to-installation process to make technology viable for wide scale use**
- **Program recognizes the value of composite doublers and the need to safely integrate their use into aircraft maintenance facilities**

Repair of Metal Aircraft Using Composite Doublers

Patches designed to repair damage corresponding to 1”, 3”, and 5” diameter damage

Repair Applications

- Gouges
- Dents
- Lightning strike
- Impact skin damage
- Corrosion grind-outs in skin



Repair of Metal Aircraft Using Composite Doublers

Installation and Inspection Training Classes held at FedEx

PACS annodize surface prep

Laying up plies for doubler on clean tool

NDI using pitch-catch ultrasonic technique

Applying doubler to cleaned surface

Cured composite doubler

Repair of Metal Aircraft Using Composite Doublers

- Doubler design & analysis approved (8110-3)
- Pilot Program completed
    - 7 Repairs on 6 DC-10/MD-11 aircraft
- BMS completed & approved (8110-3)
- NDT Manual revised to include doubler inspection procedures
- SRMs revised for all Boeing Long Beach models
- Composite doubler design, installation, & inspection training courses (Abaris) in process
- Tech Transfer Workshop at AANC - Planning for 2007

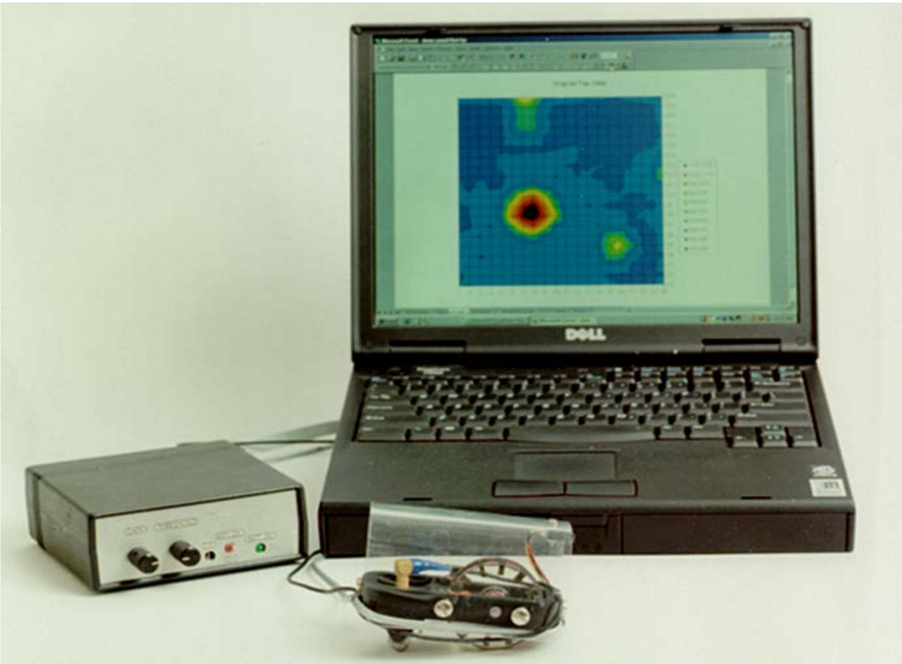
Inspection Research Needs

1. Enhance visual inspection schemes for detecting critical composite defects and damage.
2. Perform reliability studies for visual detection of impact damage ranging in size from barely visible to that which lowers residual strength to critical levels (below ultimate load and above limit load) for a range of impact threats.
3. Review current curriculums and manufacturers suggested training programs to make recommendations for updating Part 147 with regard to composites.

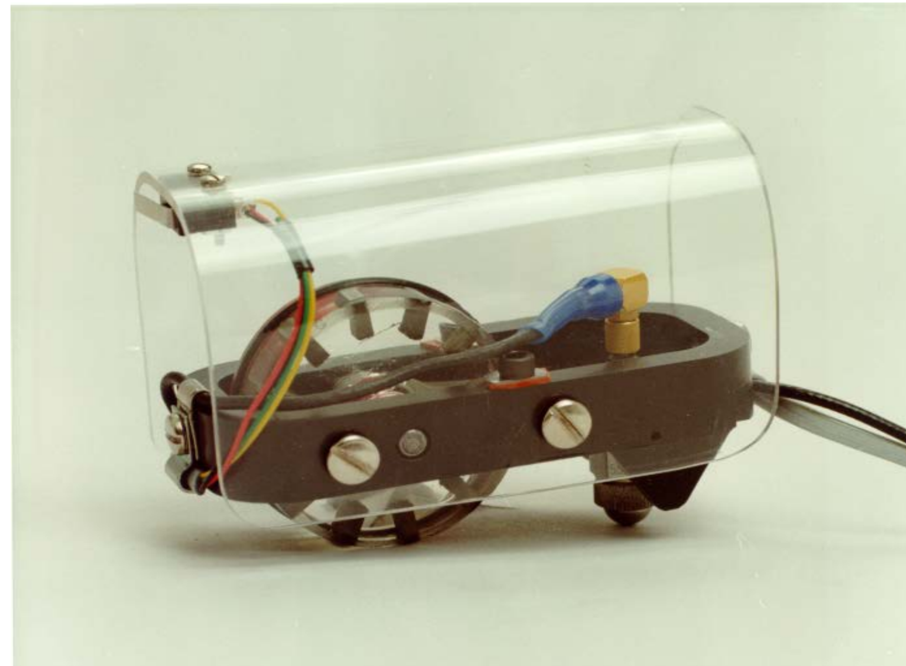
Inspection Research Needs

4. Evaluate advanced NDI methods and their reliability for factory and field applications to composite problems (defect or damage detection, characterization, repair, or process control.)
5. Identify NDI methods to measure key characteristics of critical composite damage that can be used to reliably assess structural integrity (residual strength and resistance to repeated load).
6. Evaluate advanced NDI methods for their ability to measure the structural integrity of adhesive bonds.

Computer Aided Tap Tester

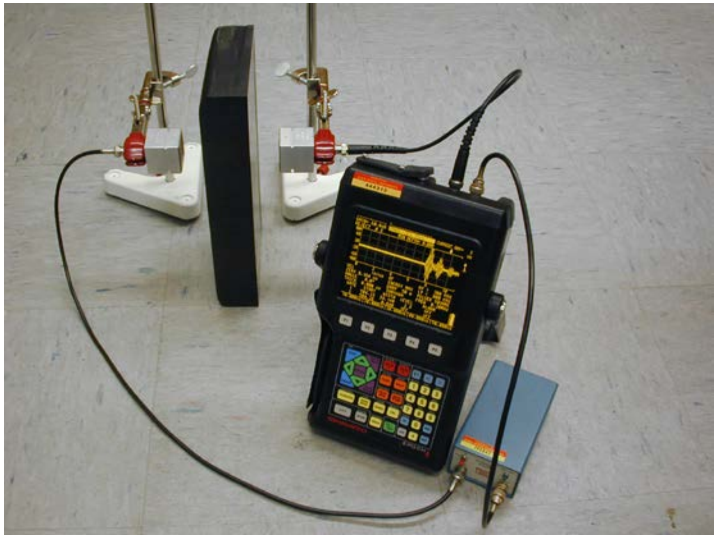


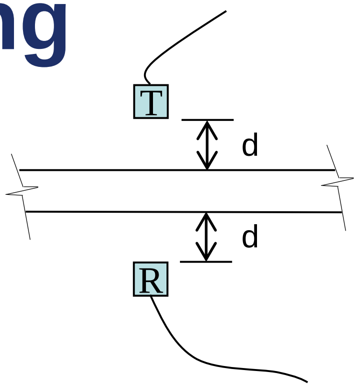
The CATT System



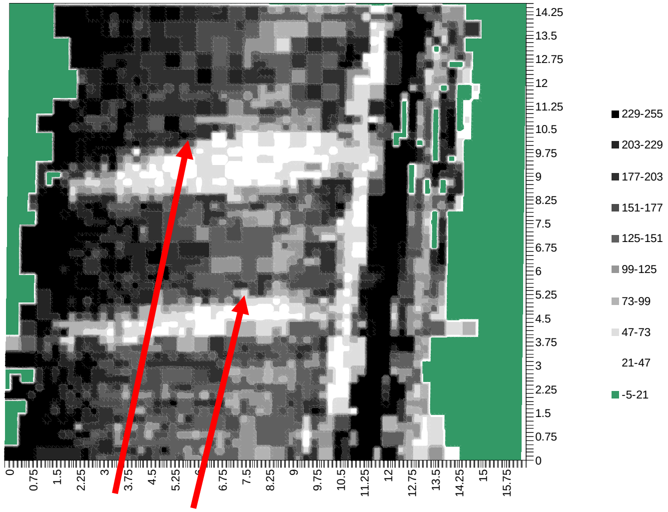
Magnetic Tapper

Air Coupled Ultrasonic Testing





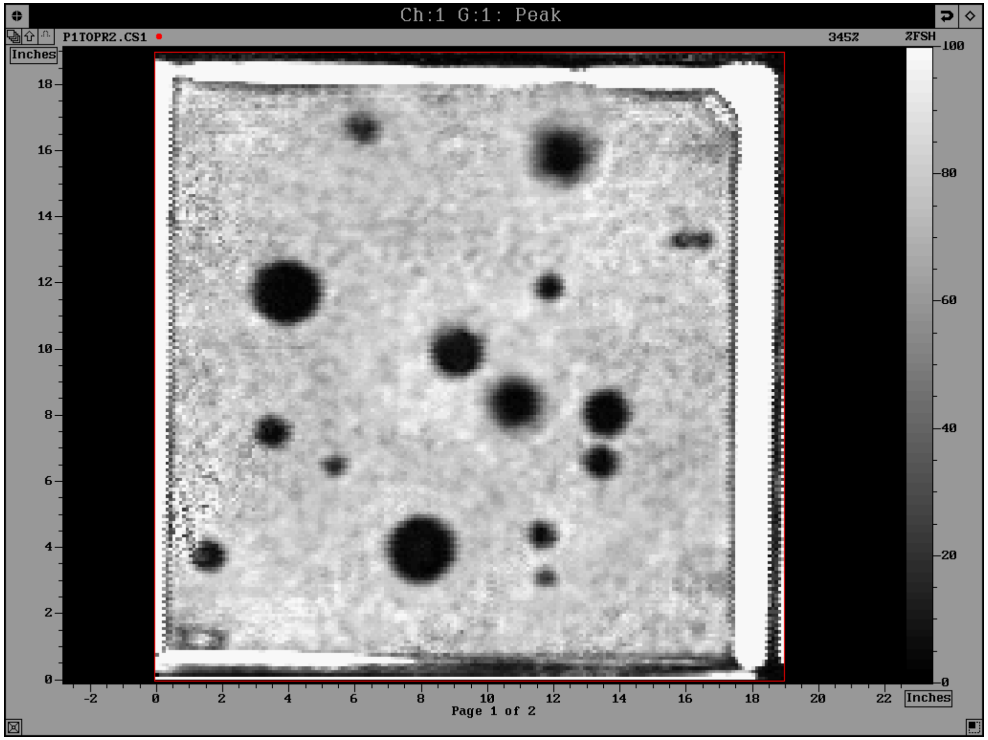
Stand-off d ~ 1”



Damaged Areas

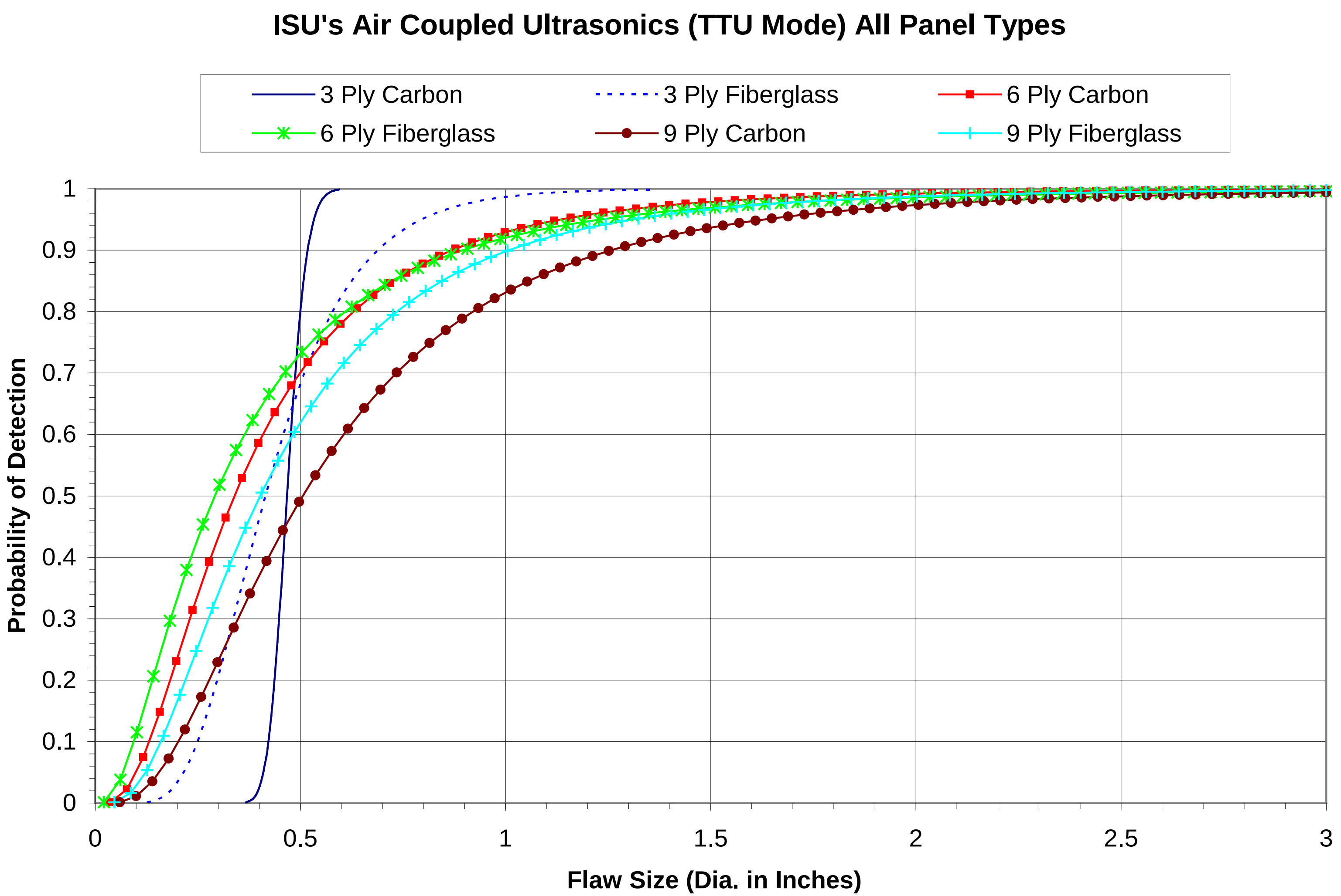
Air Coupled Ultrasonic Testing

Blind Test of Flaws in Honeycomb Sandwich by Air Coupled UT



Through transmission scan using 120 kHz unfocused transducers.

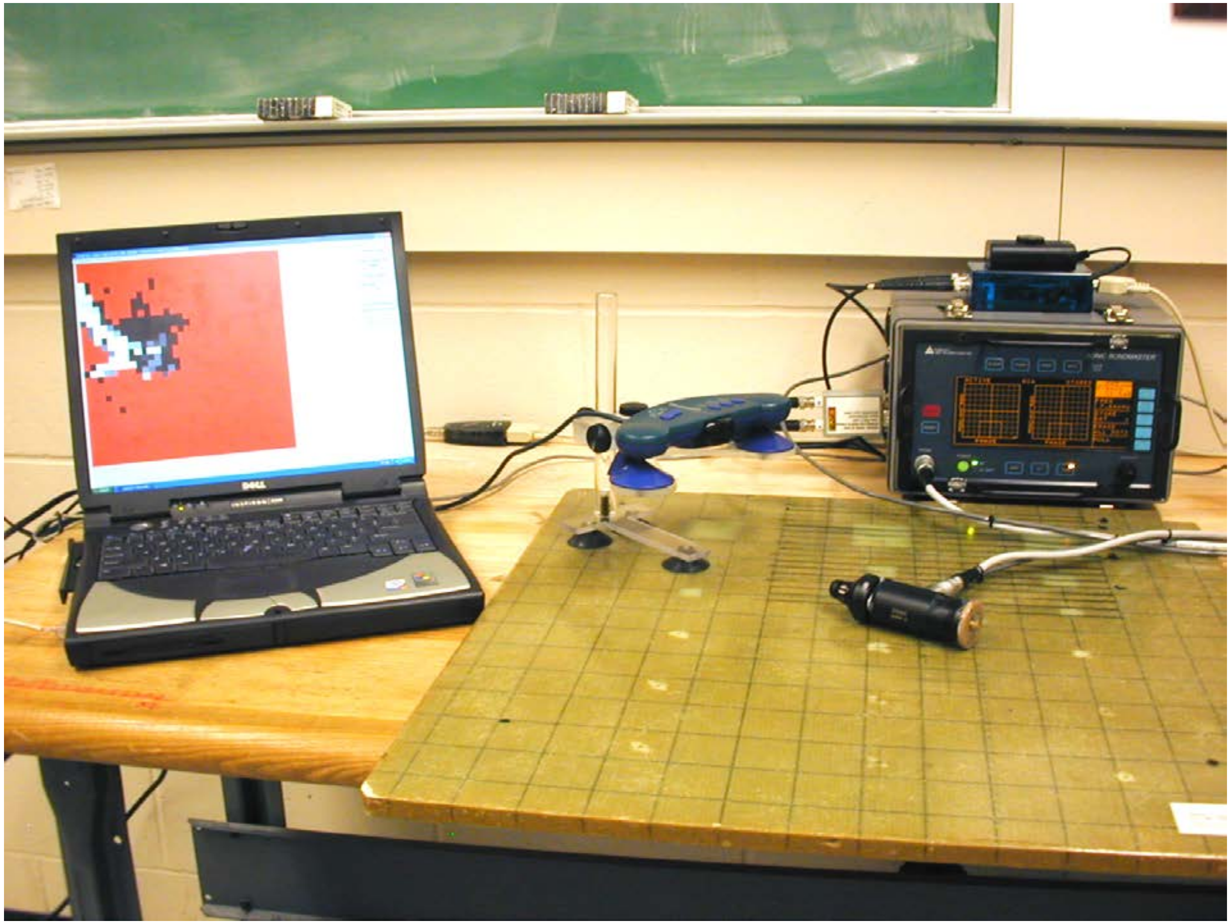
Air Coupled Ultrasonic Testing



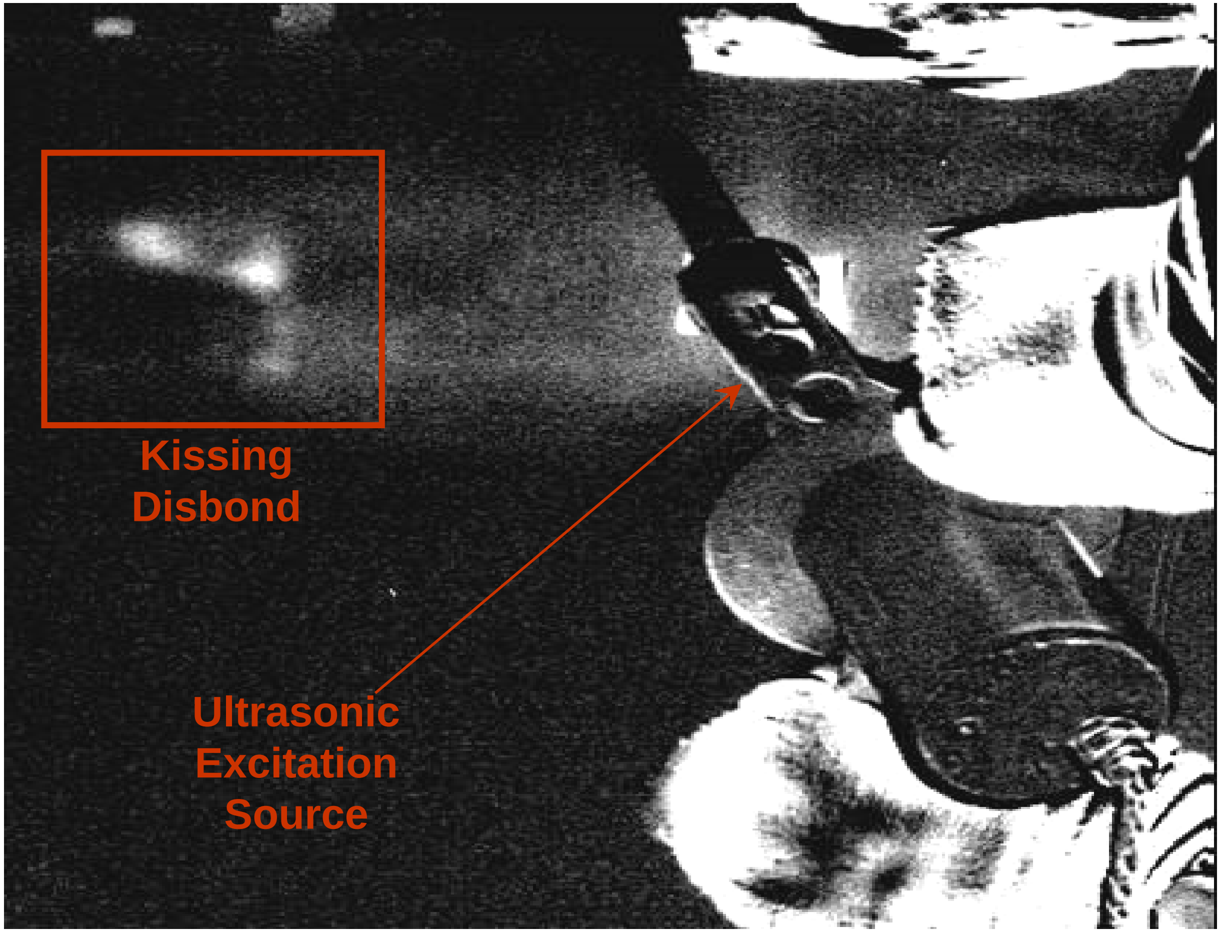
Generic Scanner

- Developed by ISU
- Mating conventional field NDT with simple & cheap position encoders and a lap top PC to generate inexpensive C-scans.
- To date Gen-Scan mated to various off the shelf NDT for MIA, PE UT, Resonance, and Automated Tappers.

Generic Scanner



Thermosonics – Sonic IR



Sonic Infrared