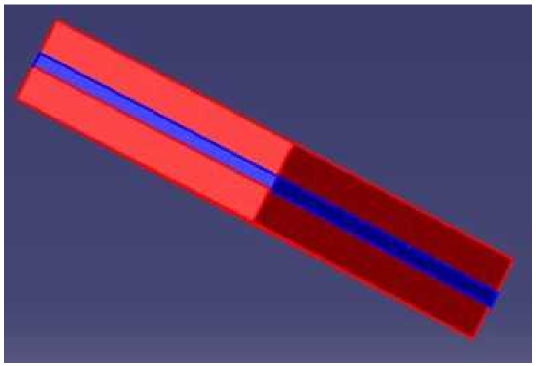
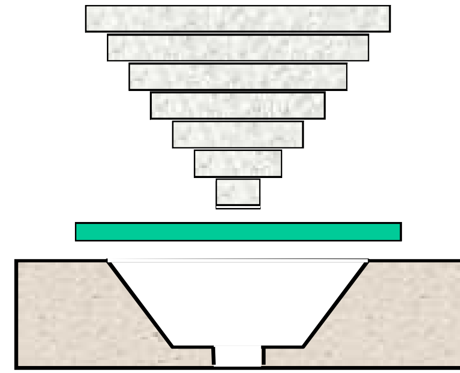
Quantifying the Response of Conventional and Advanced Inspection Methods to Ensure Flaw Detection in Composite Primary Structure

SAND2007-5240C





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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Experiment Planning and Implementation Conducted in Conjunction with:

CACRC Inspection Task Group Members:

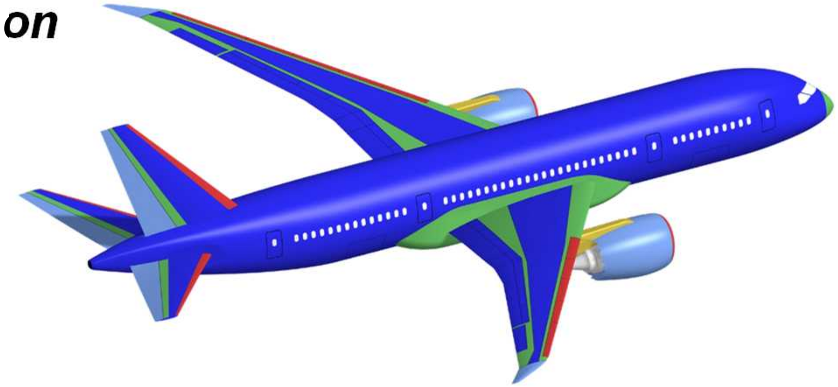
John Hewitt – Airbus (Co-chair)
Jim Hofer - Boeing
Jeff Kollgaard – Boeing
Kirk Rackow - Sandia Labs AANC
Dennis Roach - Sandia Labs AANC (Co-chair)
Glae McDonald - US Airways
Darrell Thornton – UPS
Richard Watkins - Delta Air Lines
Bob Stevens – United Airlines
Eric Bartoletti – American Airlines
Alex Melton - Northwest Airlines
Ana Tocalino – Embraer

Dave Galella, Al Broz, Rusty Jones, Larry Ilcewicz – FAA

Program Motivation - Extensive/increasing use of composites on commercial aircraft and increasing use of NDT to inspect them

Composite Structures on Boeing 787 Aircraft

- Carbon laminate
- Carbon sandwich
- Fiberglass
- Aluminum
- Aluminum/steel/titanium pylons

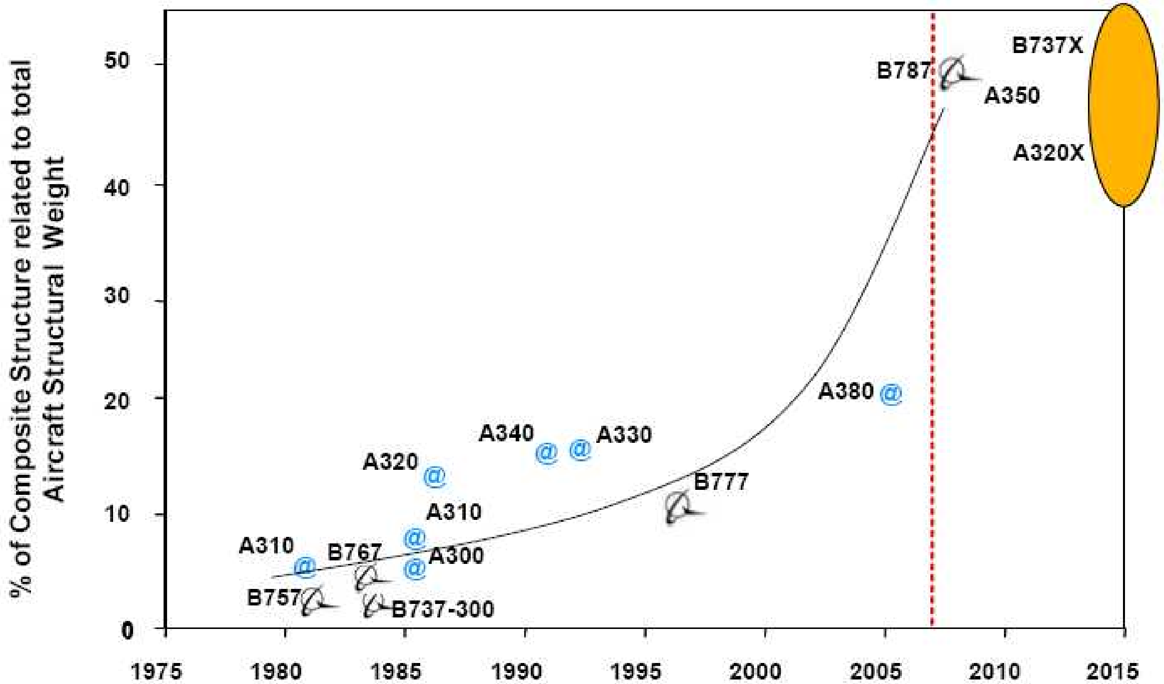


Composite Center Wing Box

A380 Pressure Bulkhead

Program Goals: Assess & Improve Flaw Detection Performance in Composite Laminate Aircraft Structure

Ground Handling Damage



Expansion in Use of Composite Materials in Aircraft Construction

An Experiment to Assess Flaw Detection Performance in Composite Laminate Structures

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).

737 Composite Horiz. Stabilizer

A380 Fuselage Section 19

Flaw Detection in Solid Laminate Composites

Approach

- Statistical design of flaws and other variables affecting NDI - range of types, sizes & depths of flaws
- Study factors influencing inspections including composite materials, flaw profiles, substructures, complex shapes, fasteners, secondary bonds, and environmental conditions
- Blind application of techniques to study hits, misses, false calls, and flaw sizing
- NDI Ref. Stds. prepared to aid experiment

Specimen Design - Flaw Detection in Solid Laminate Composites

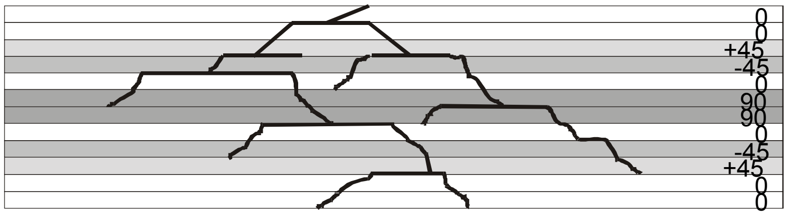
<u>Specimen Types</u> – Solid laminate carbon (12 to 64 plies)

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

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

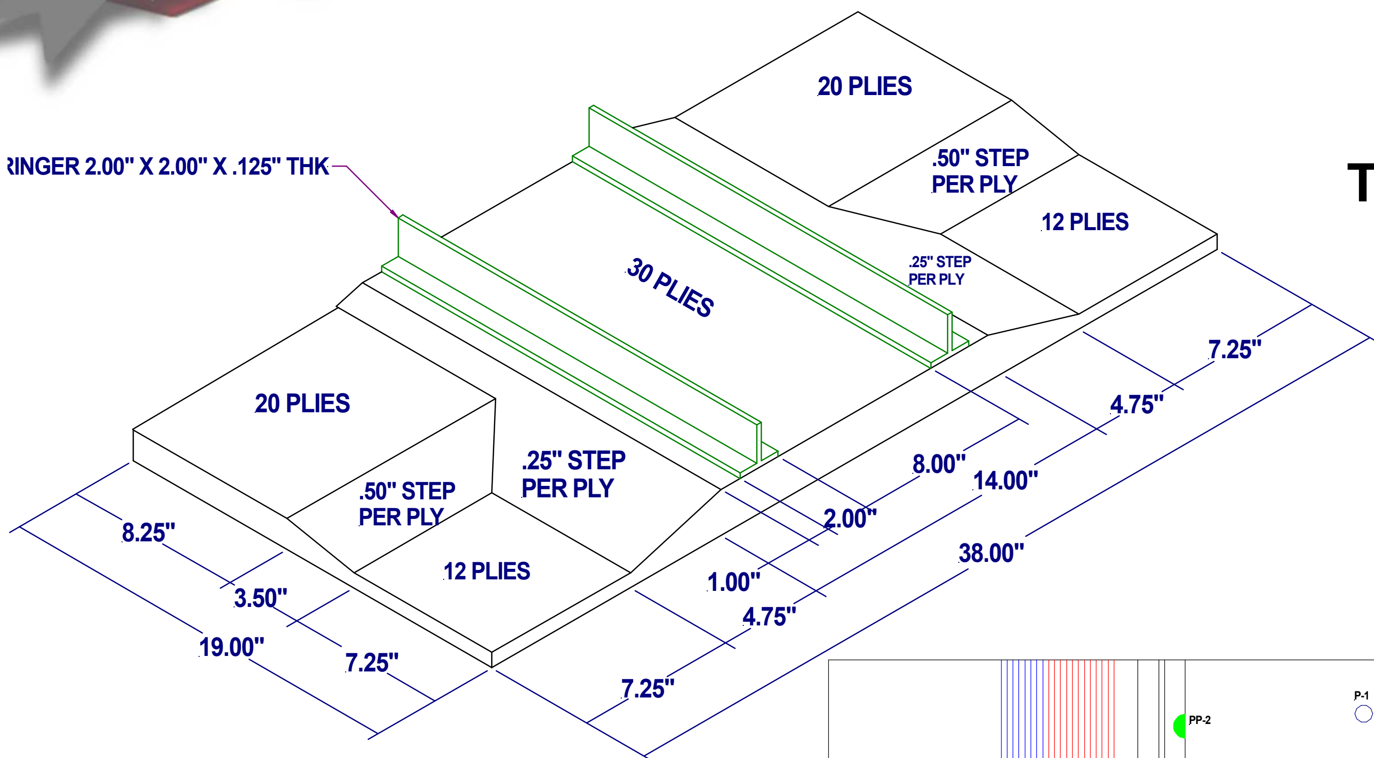
1) interply delaminations ("kissing" and air gap)
2) substructure damage
3) skin-to-stiffener disbonds
4) simulated impact damage

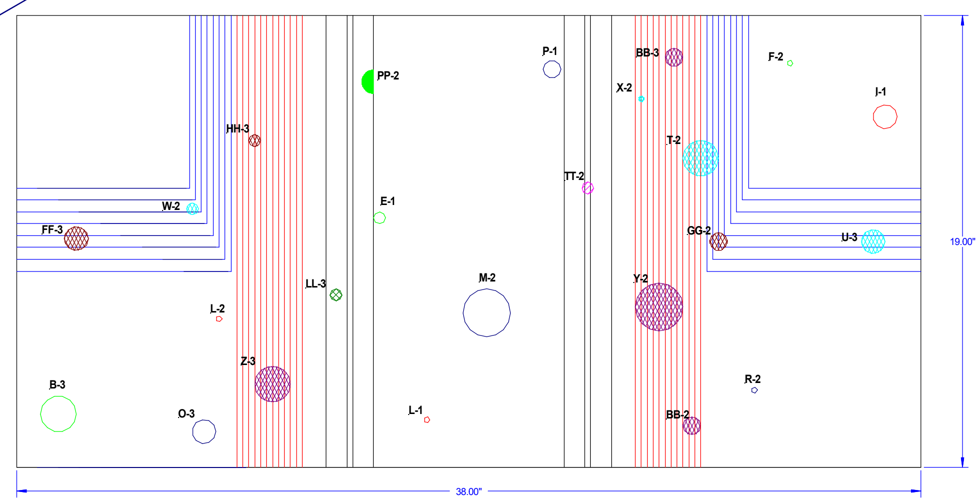
Low Energy Impact



Thick Laminate With Complex Taper

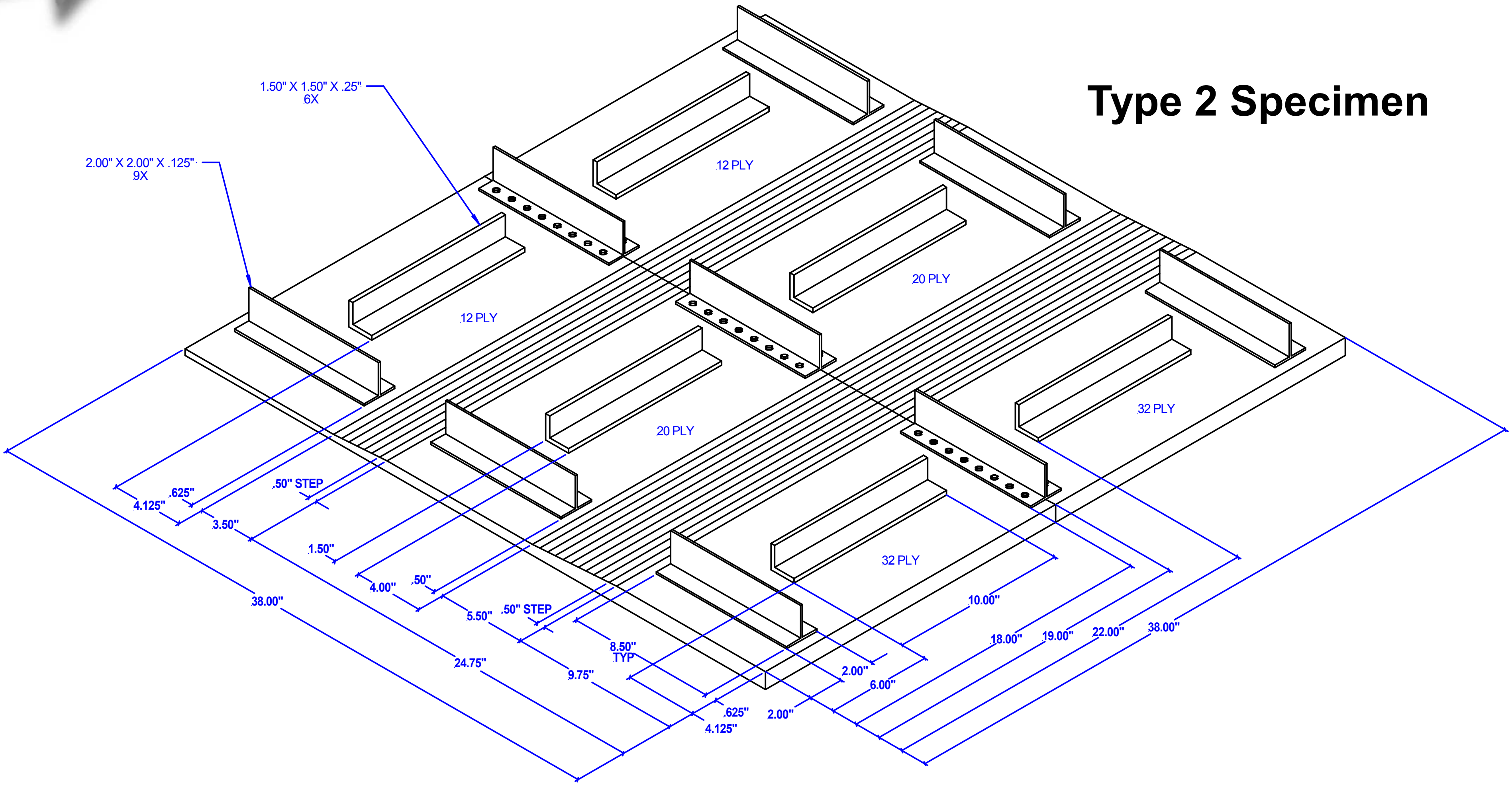
Type I Specimen





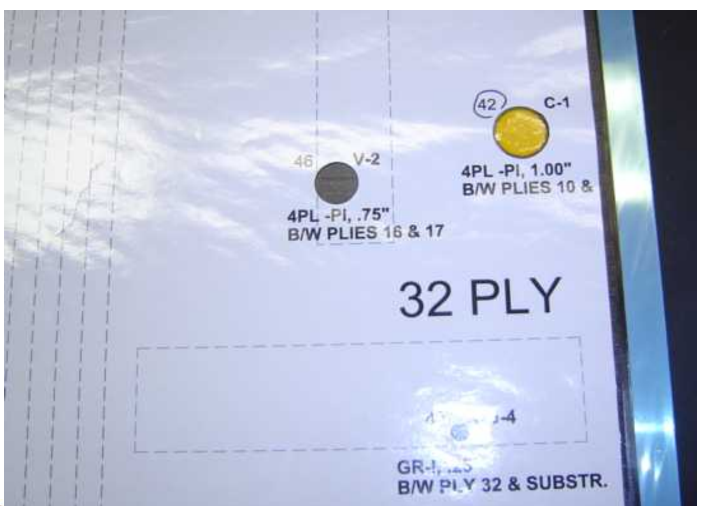
Thick Laminate With Complex Taper

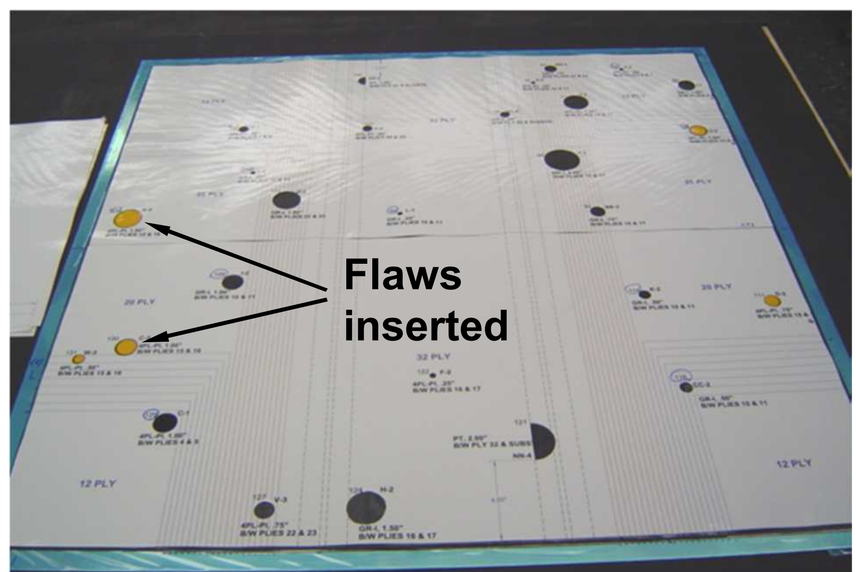
Type 2 Specimen



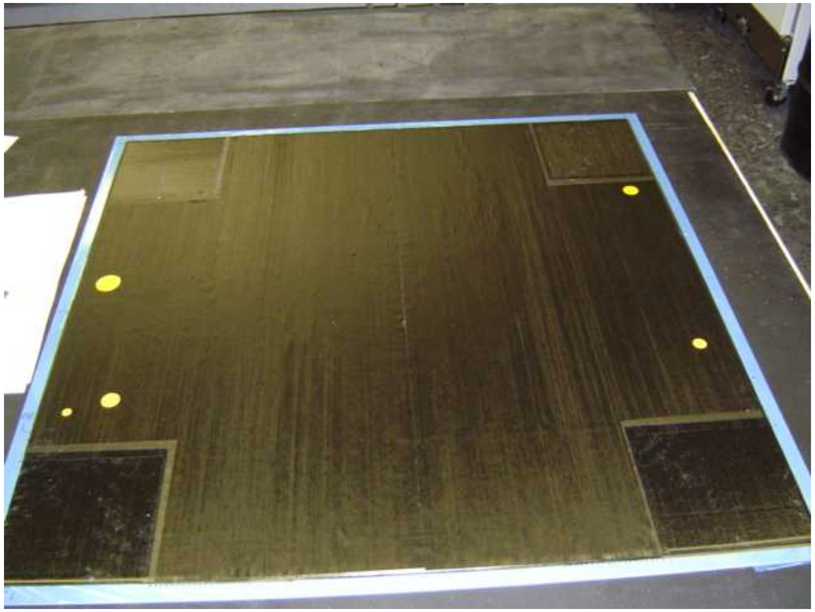
Thick Laminate With Complex Taper - Fabrication

Flaw templates - ensure proper location of flaws

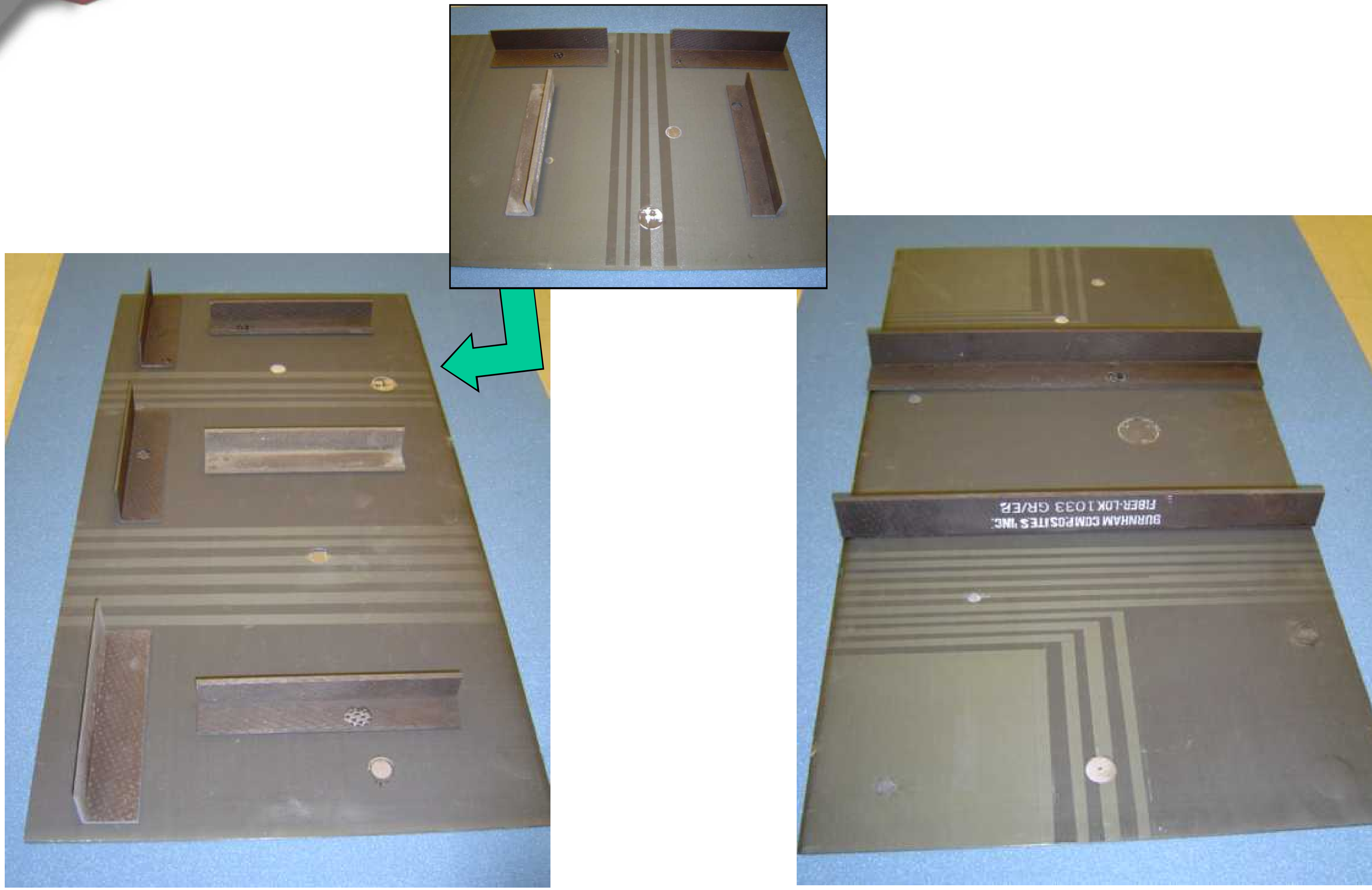




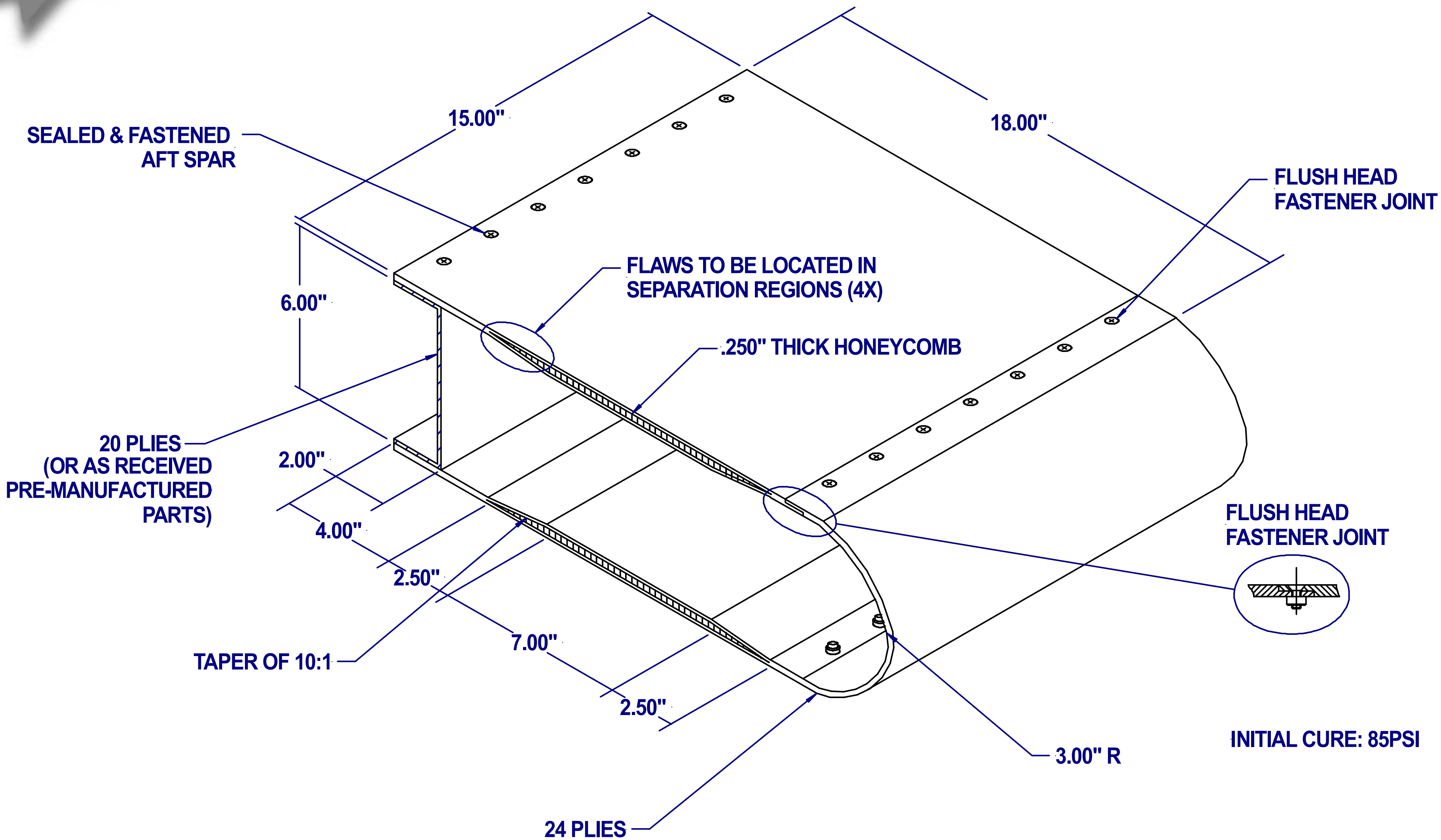
Thick Laminate With Complex Taper - Fabrication



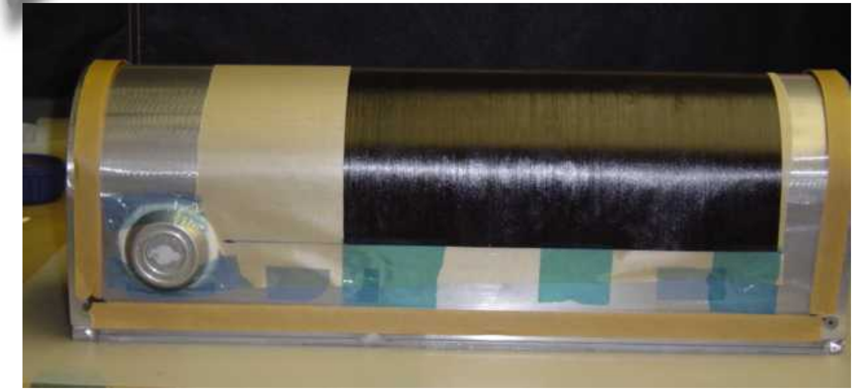
Thick Laminate With Complex Taper - Fabrication

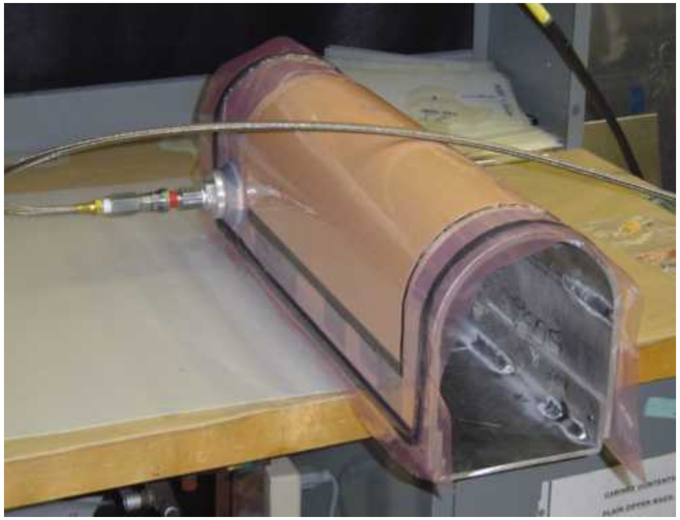


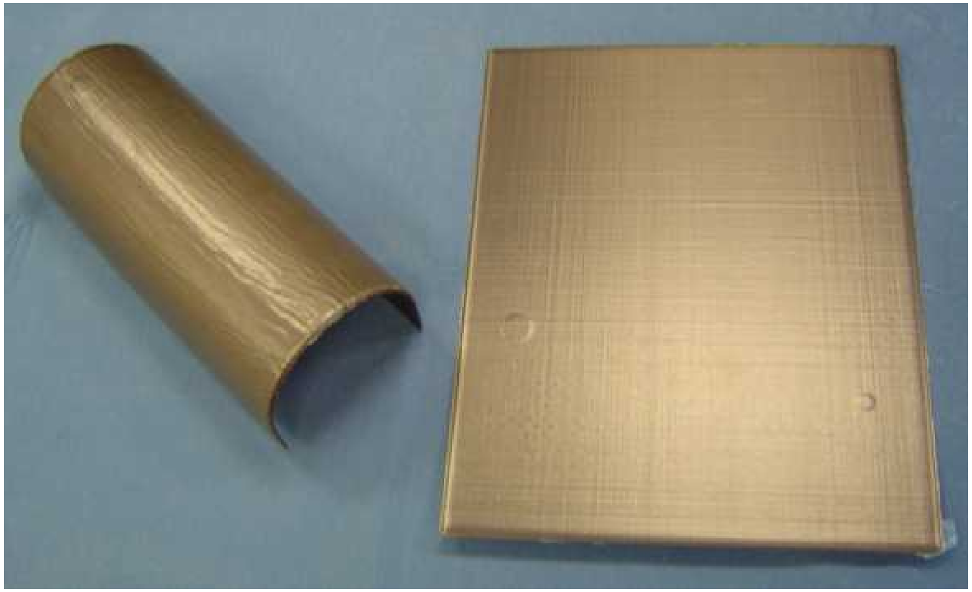
Contoured Test Panel with Honeycomb



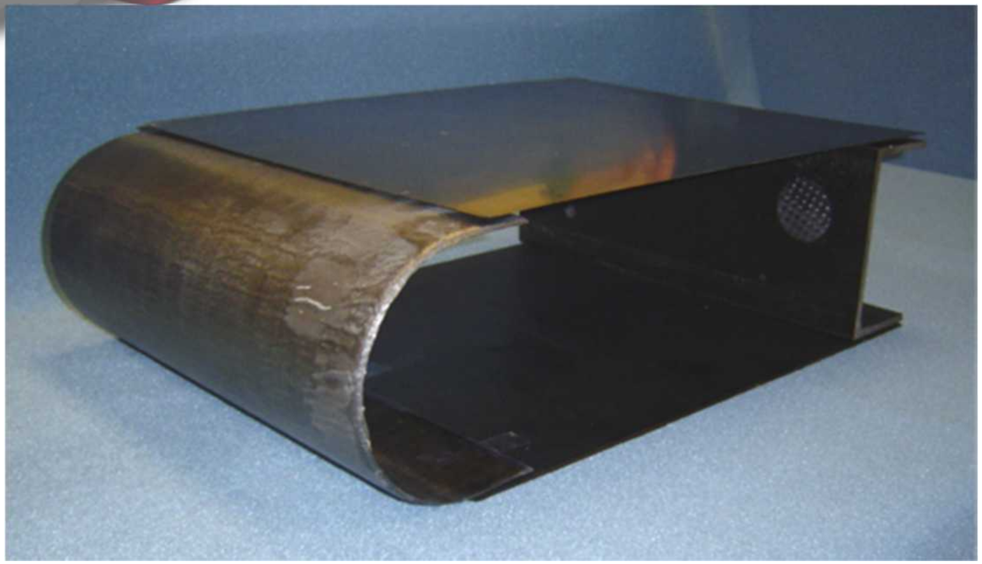
Contoured Test Panel - Fabrication

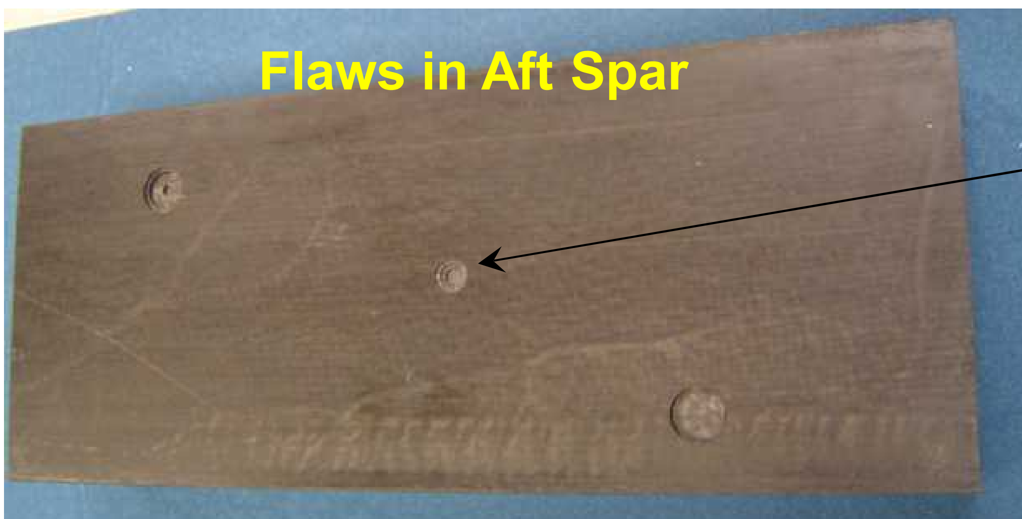






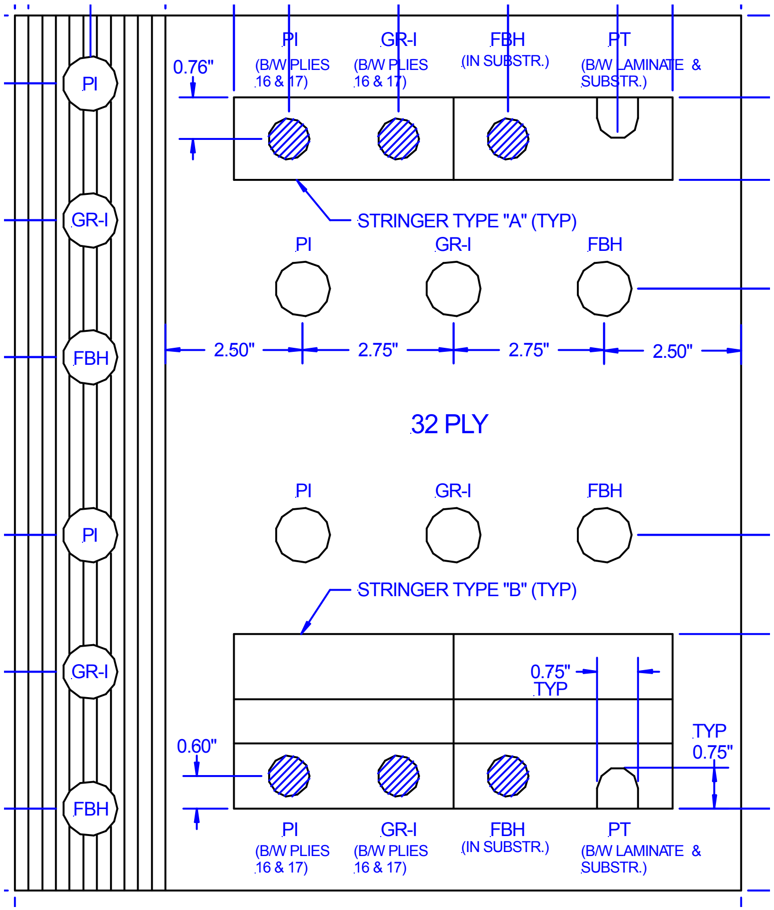
Contoured Test Panel - Fabrication

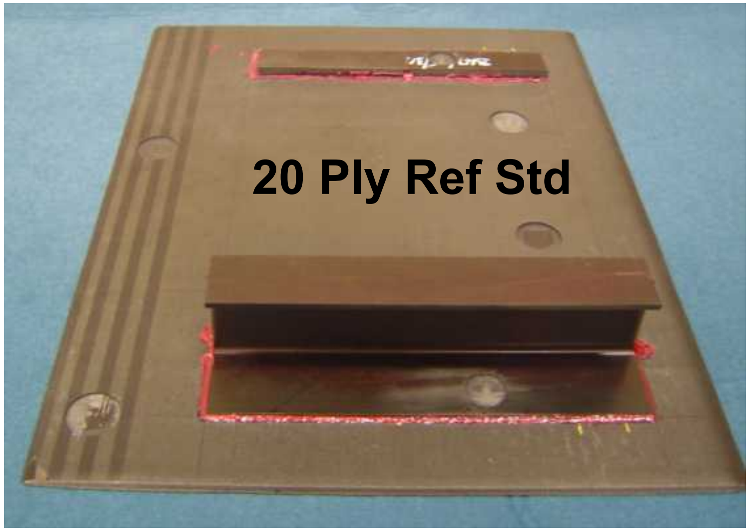




Concentric FBH to Simulate Impact Damage

Reference Standards – Feedback Panels



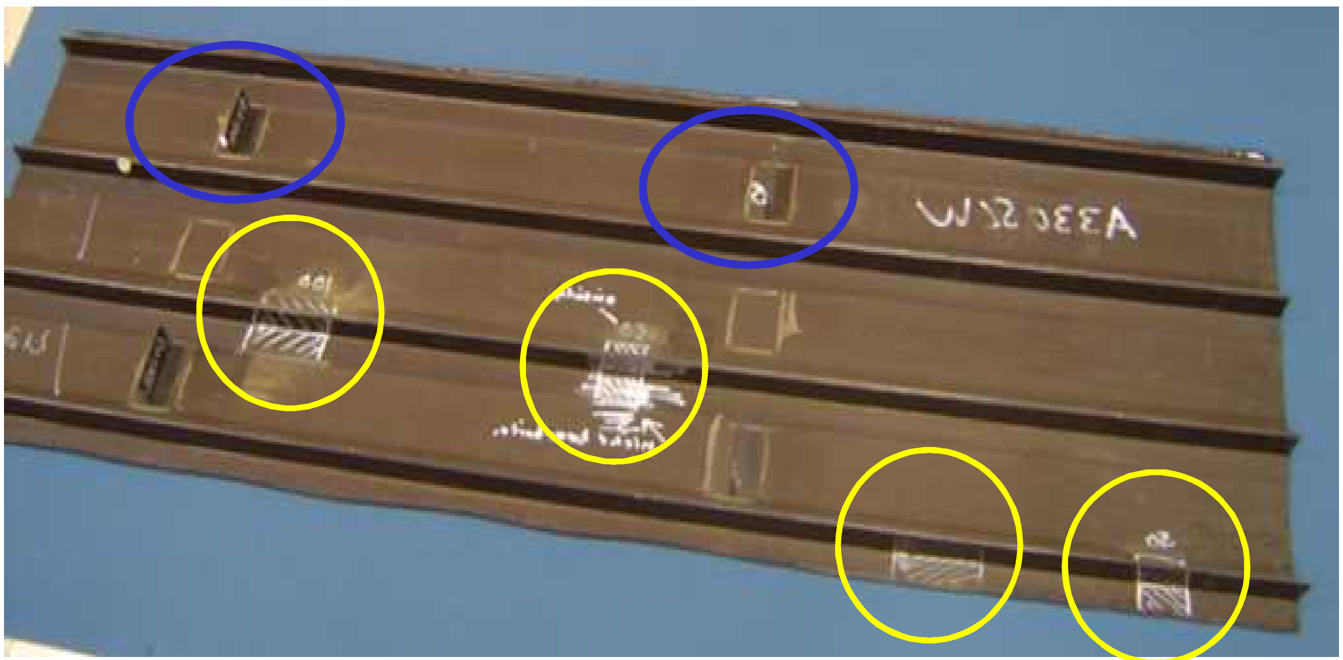


Specimen Set - Flaw Detection in Solid Laminate Composites

Thickness Range: 12 – 64 plies

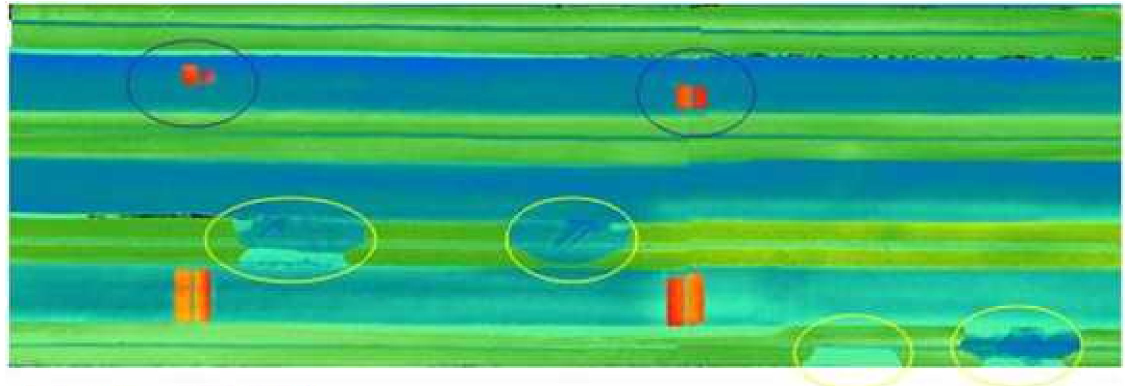
Experiment Design & Implementation

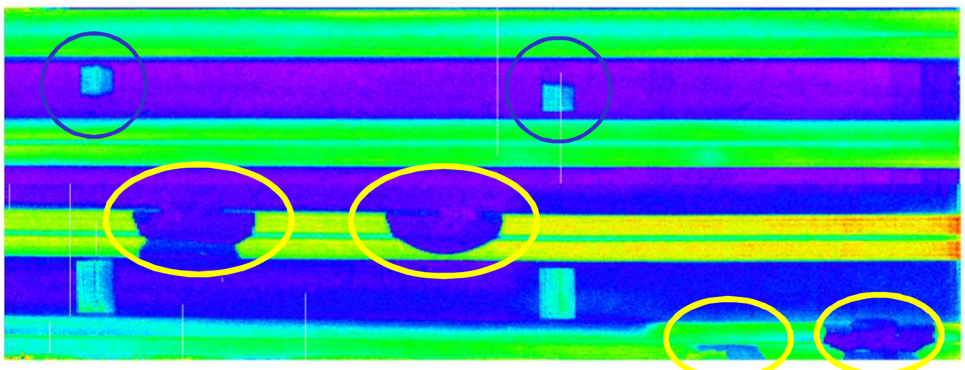
- Surface area & no. of flaws req'd (no. of specimens) vs. time for inspector to complete experiment
  - ➢ Trial inspections on simulated stabilizer by UA inspectors – 2.9 to 3.9 ft.^{2} per hour



Simulated Vertical Stabilizer with Stringers, Rib Sections and Engineered Flaws
Three stringer-to-skin disbonds (yellow)
Two rib to-skin-partial disbonds (blue)

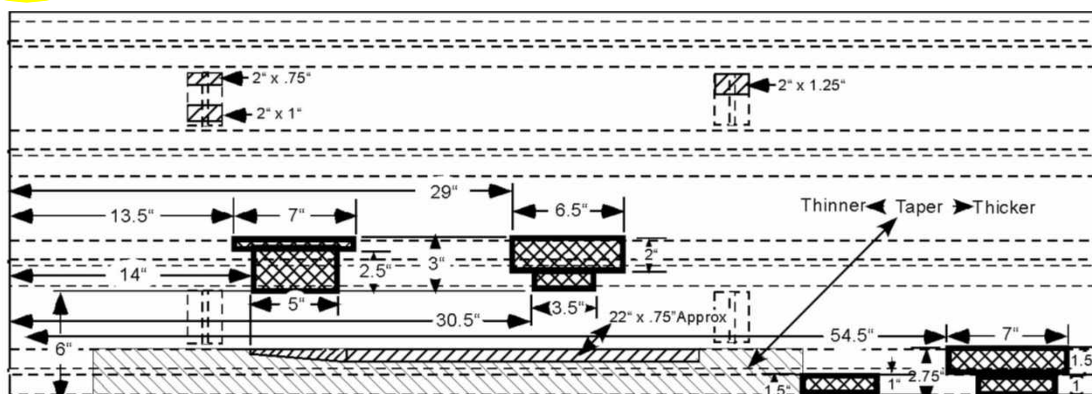
Phased Array UT Inspection of Vertical Stabilizer Specimen





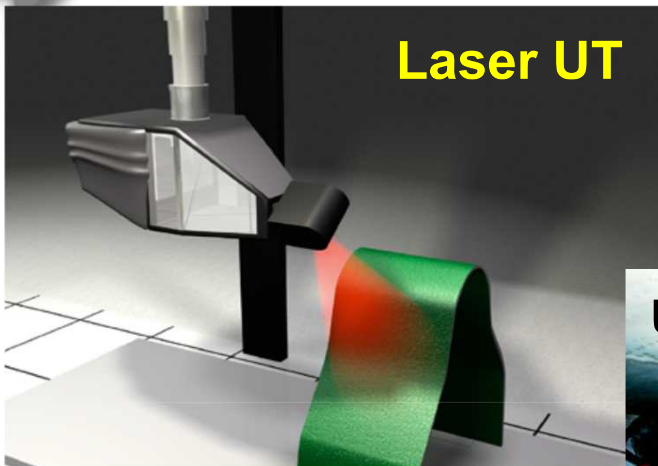
MAUS – Resonance Mode

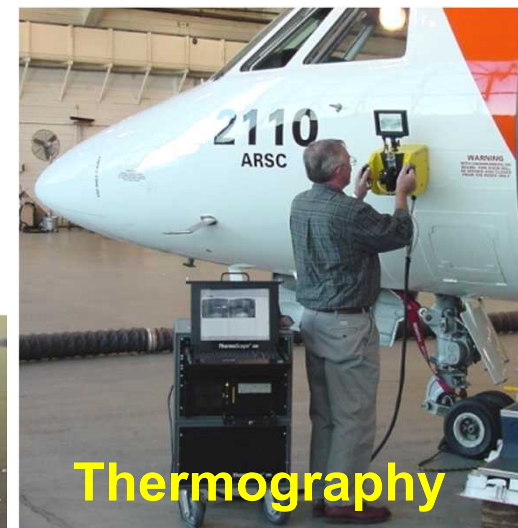
United Airlines inspection with hand-held P-E UT

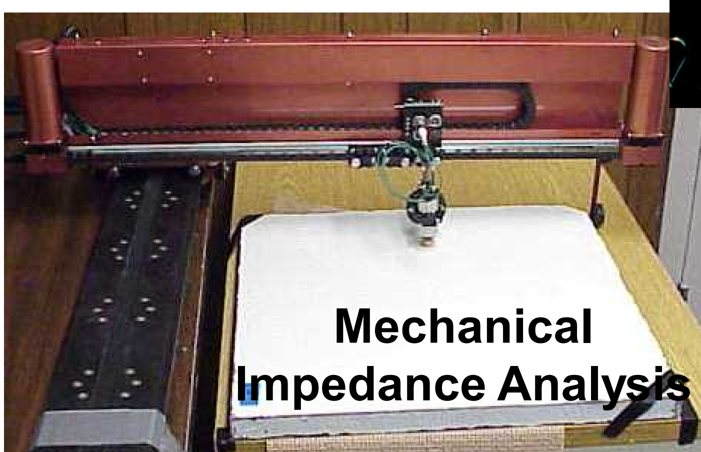


Implementation of Honeycomb Flaw Detection Experiment

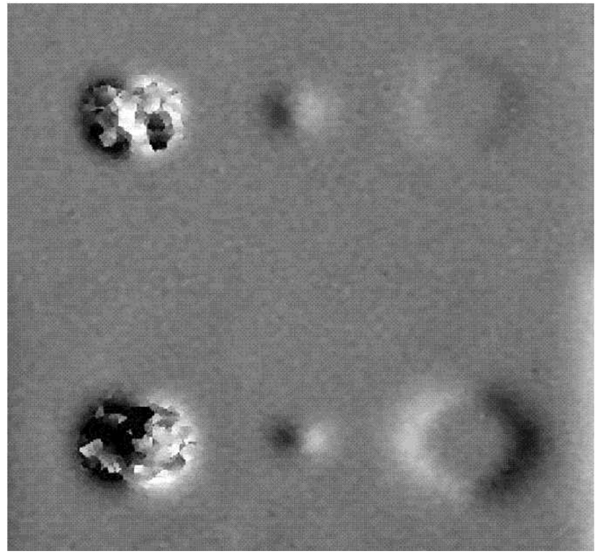
Wide Area and C-Scan Inspection Methods



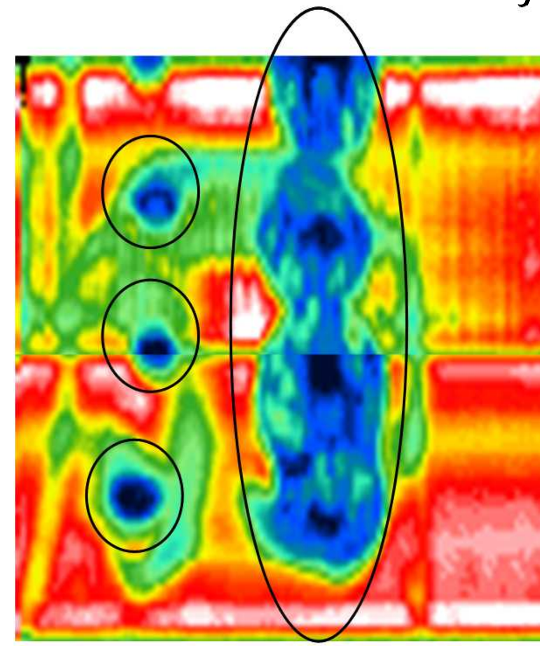




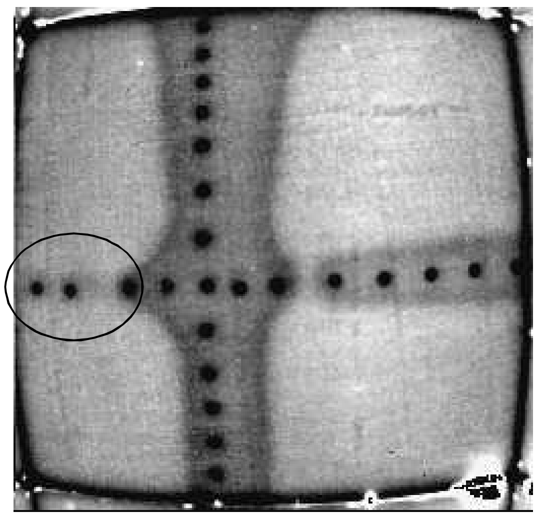
Shearography (LTI) Image

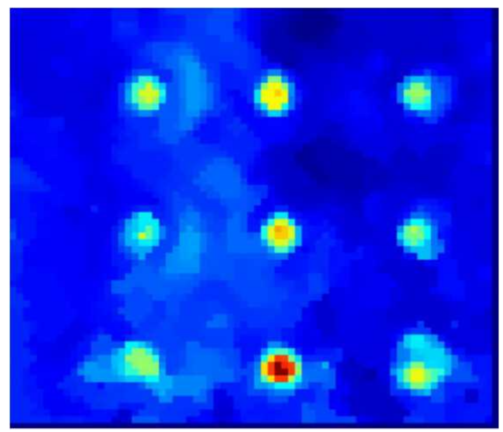


Ultrasonic Wheel Array

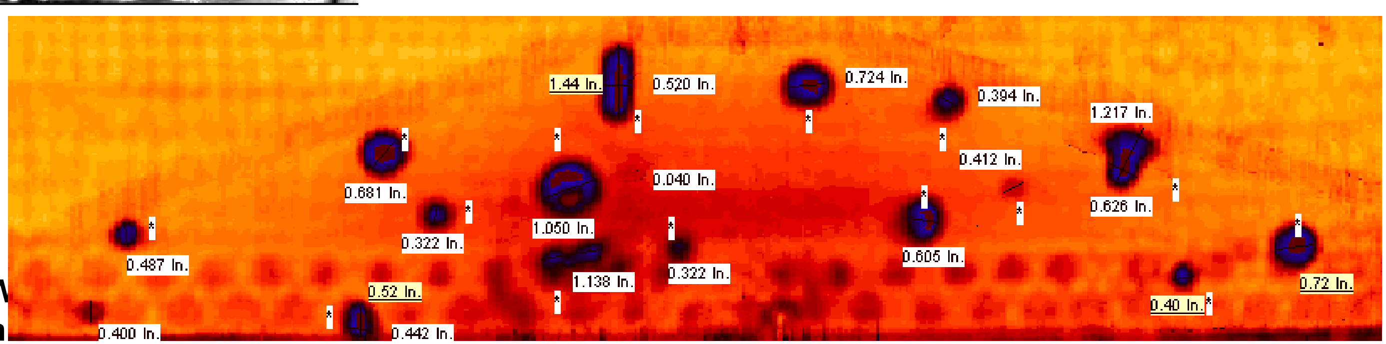


Thermography (TWI) Image



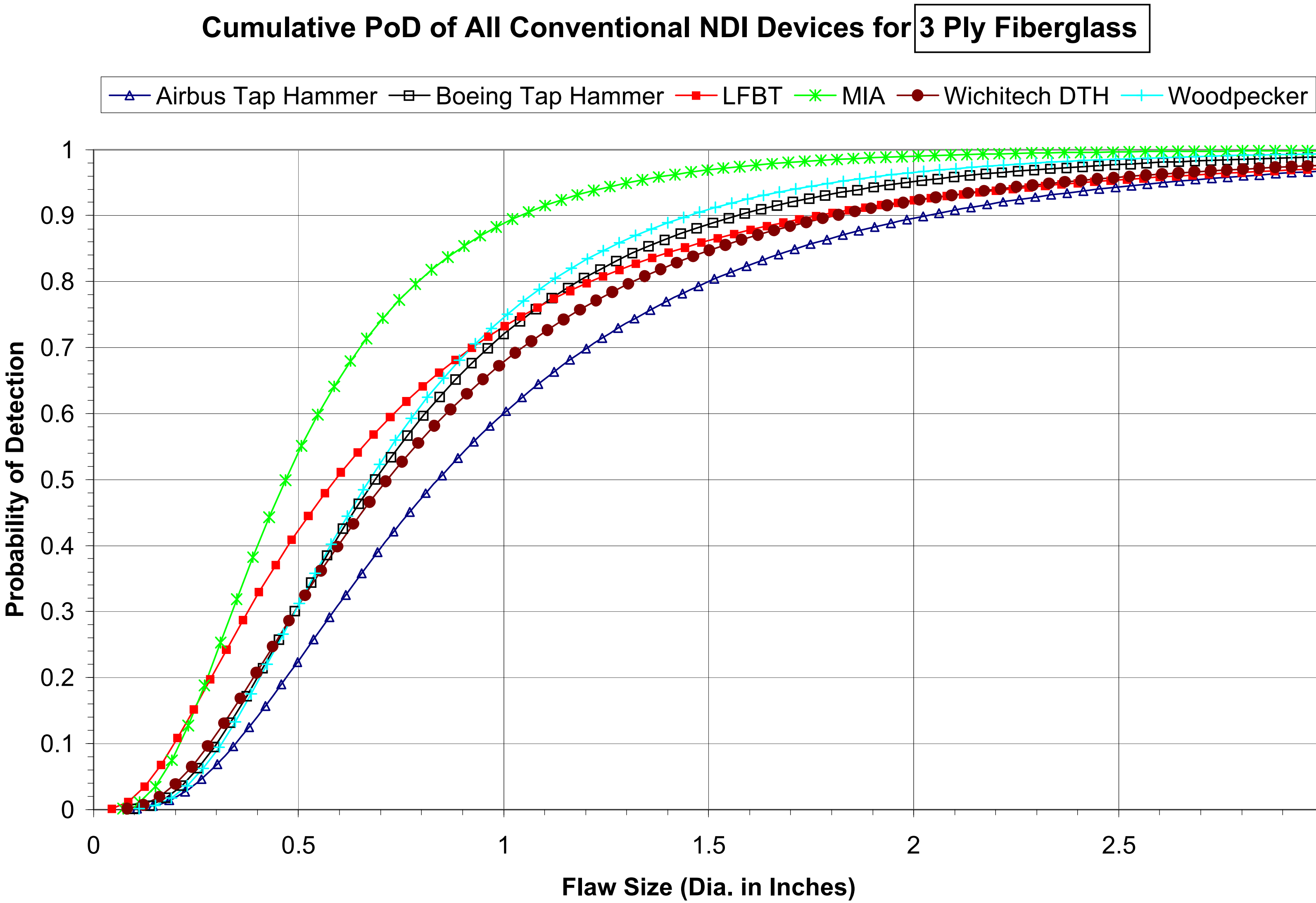


SAM Image



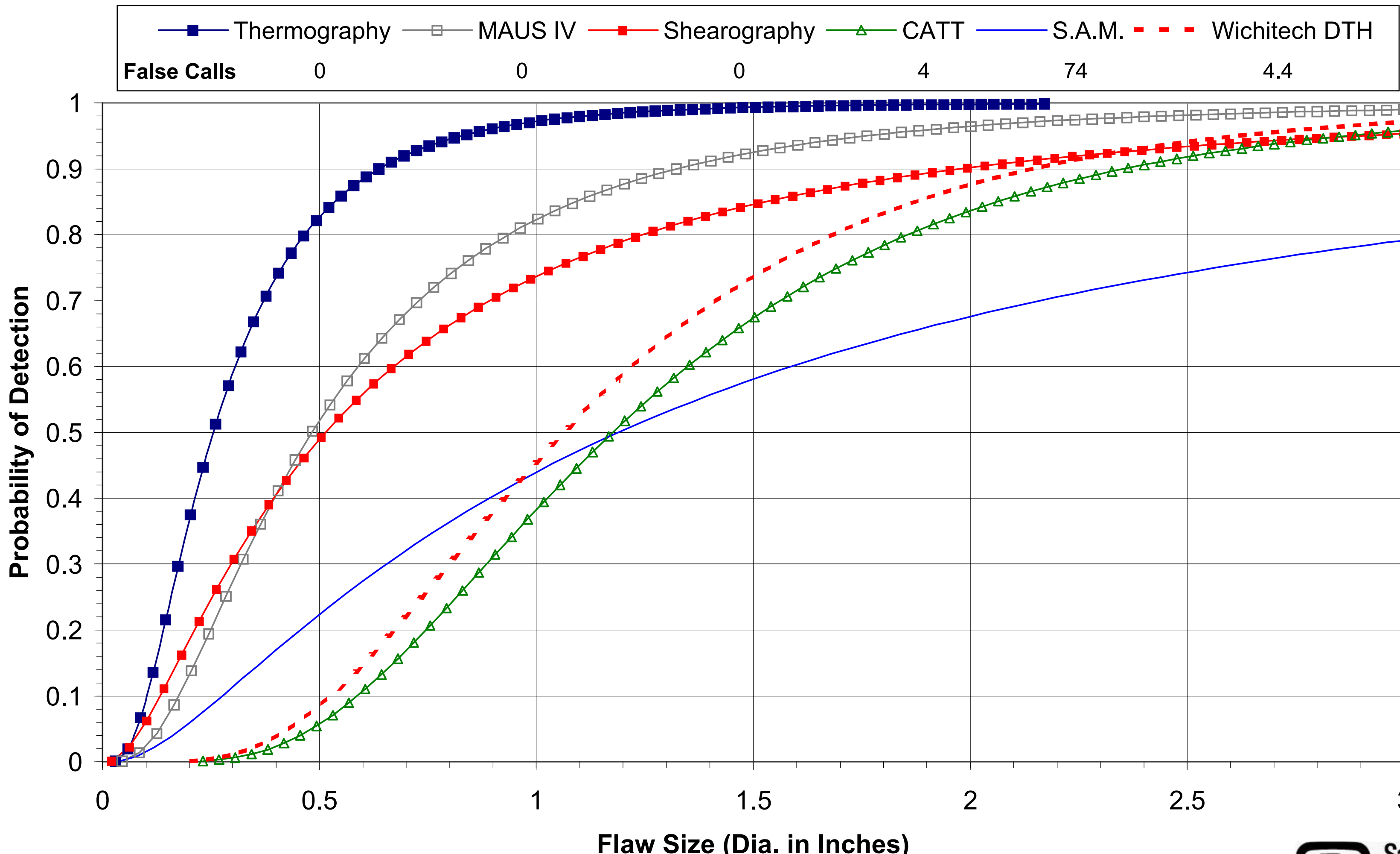
MAUS Image

Sample of Expected Performance Results



Inspection Improvements Via Advanced NDI Techniques

Comparison of Advanced Inspection Techniques with Best Conventional NDI Result on 9 Ply Carbon



An Experiment to Assess Flaw Detection Performance in Composite Laminate Structures

- Experiment design & specimen fabrication competed
- Specimen characterization ongoing
- Experiment protocols being finalized
- Expect to begin running experiment at airline facilities in 2007

- Program will assess flaw detection performance in composite laminate structures
- Results will produce a capability baseline for current NDI techniques
- Program will quantify potential improvements stemming from the application of advanced NDI
- Field testing will address procedural and implementation issues as well

Quantifying the Response of Conventional and Advanced Inspection Methods to Ensure Flaw Detection in Composite Primary Structure

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Federal Aviation Administration

Dennis Roach & Kirk Rackow
FAA Airworthiness Assurance Center
Sandia National Laboratories

Composites have many advantages for use as aircraft structural materials including their high specific strength and stiffness, resistance to damage by fatigue loading and resistance to corrosion. The aircraft industry continues to increase its use of composite materials, most noteworthy in the arena of principle structural elements. This expanded use, coupled with difficulties associated with damage tolerance analysis of composites, has placed greater emphasis on the application of accurate nondestructive inspection (NDI) methods. Traditionally, a few ultrasonic-based inspection methods have been used to inspect solid laminate structures. Recent developments in more advanced NDI techniques have produced a number of new inspection options. Many of these methods can be categorized as wide area techniques that produce two-dimensional flaw maps of the structure. An experiment has been developed to assess the ability of both conventional and advanced NDI techniques to detect voids, disbonds, delaminations, and impact damage in adhesively bonded composite aircraft structures. A series of solid laminate, carbon composite specimens with statistically relevant flaw profiles will be inspected using conventional, hand-held pulse echo UT and resonance, as well as, more sophisticated NDI methods that have recently been introduced to improve sensitivity and repeatability of inspections. Some portions of the testing will be in the form of blind Probability of Detection (PoD) studies while other portions of the testing will determine signal-to-noise ratios from which flaw detection can be inferred. The primary factors affecting flaw detection in laminates are included in this study: material type, flaw profiles, presence of complex geometries like taper and substructure elements, presence of fasteners, secondarily bonded joints, and environmental conditions. One phase of this effort will utilize airline personnel to study PoD in the field and to formulate improvements to existing inspection techniques. After the airline inspectors produce a baseline of current inspection performance, other candidate laminate inspection methods – such as thermography, shearography, scanning pulse-echo UT, ultrasonic spectroscopy, laminography, and phased array UT - will be applied to quantify the improvements achievable through the use of advanced NDI. This paper presents the experiment design used to evaluate applicable inspection techniques and some preliminary results from initial NDI testing.