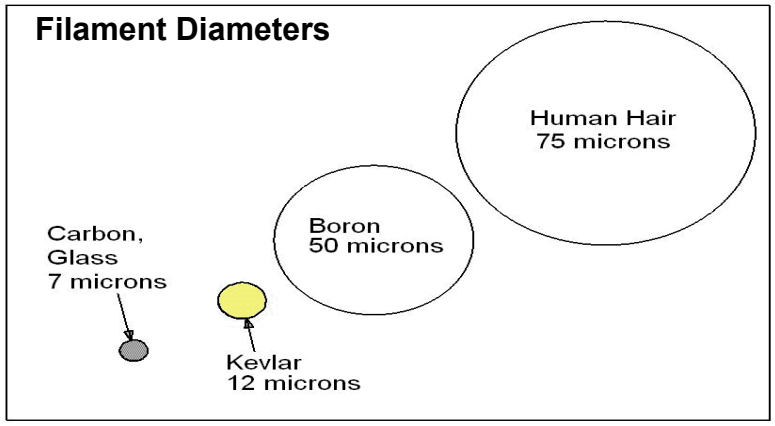
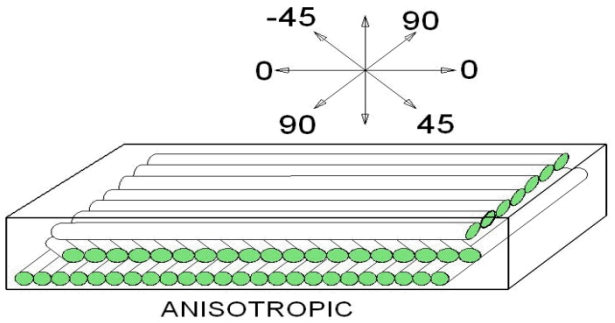
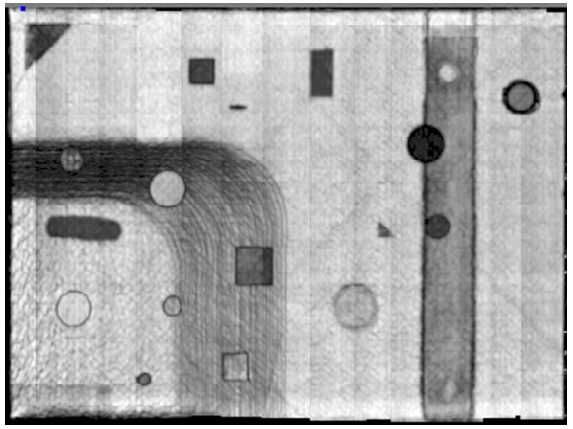
FAA Composite Inspector Training Course to Enhance Proficiency and Improve Reliability

SAND2015-8333C

Airlines for America NDT – September 2015







David Westlund,
Rusty Jones
FAA

Stephen Neidigk, Dennis Roach,
Tom Rice, Randy Duvall
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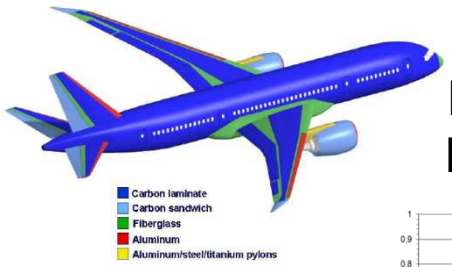
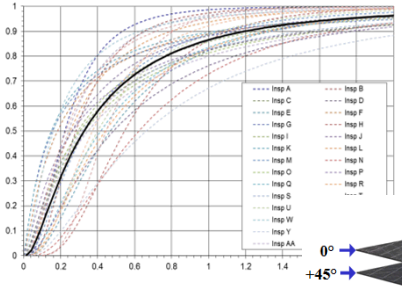
FAA Airworthiness Assurance Center

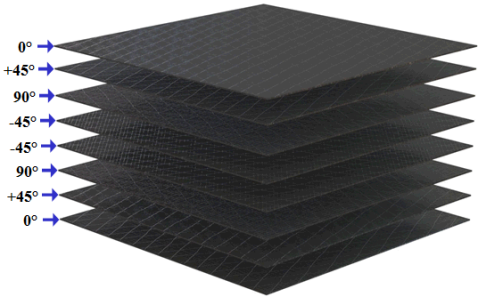
Presentation Overview



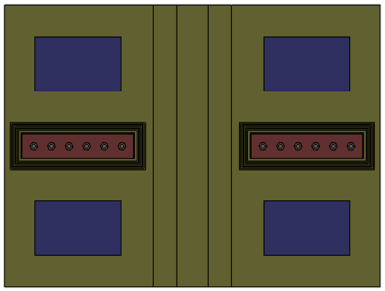
Introduction and Background
POD Experiment



Motivation



Class Modules and
Objectives



NDI Proficiency
Specimen Set

Industry Workshop

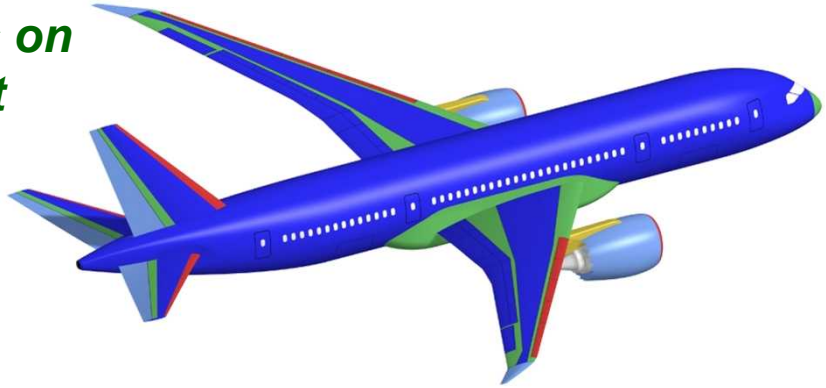
Path Forward

Motivation for Composite NDI Training Class

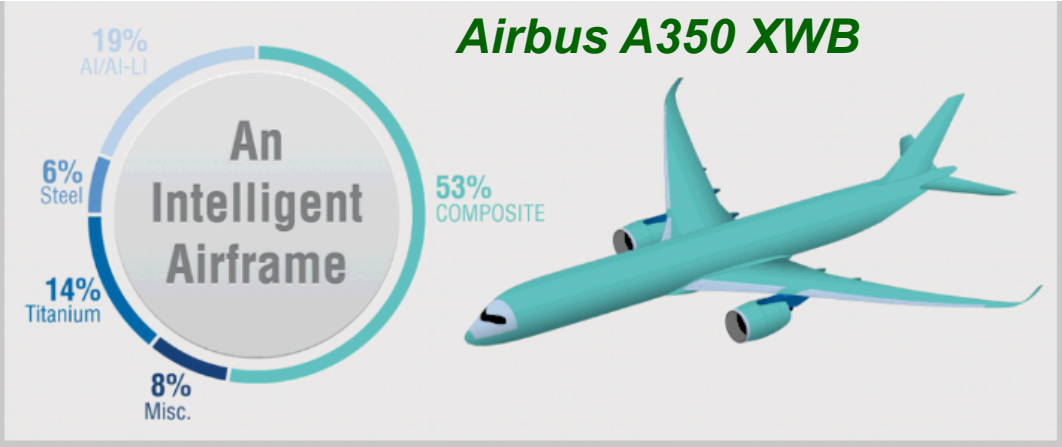
Motivation - Extensive/increasing use of solid laminate composites on commercial aircraft and need for inspectors to maintain a level of proficiency via training and hands-on practice.

Composite Structures on Boeing 787 Aircraft

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



Airbus A350 XWB



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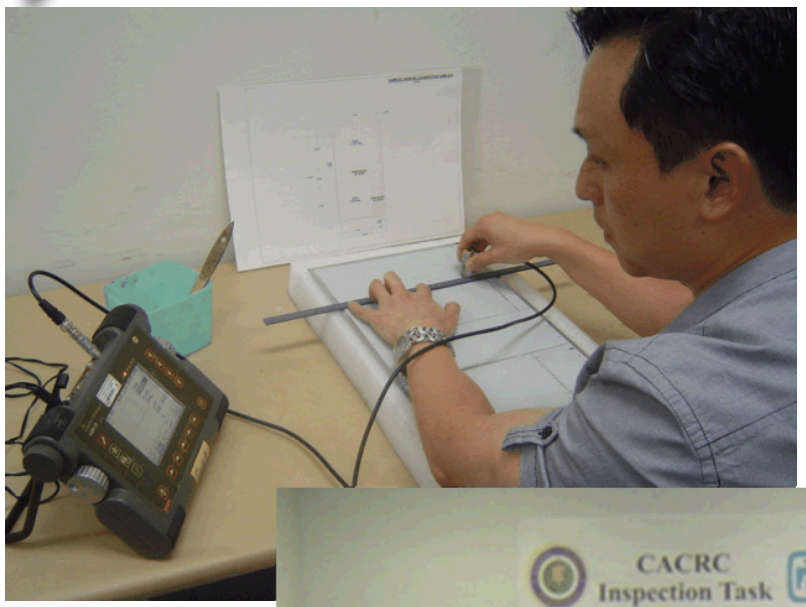
Solid Laminate Flaw Detection Experiment Implementation



Probability of Detection (POD) Experiment

PODs calculated for overall laminate, by thickness family, by substructure effects, by complex geometry effects, by flaw types, etc.

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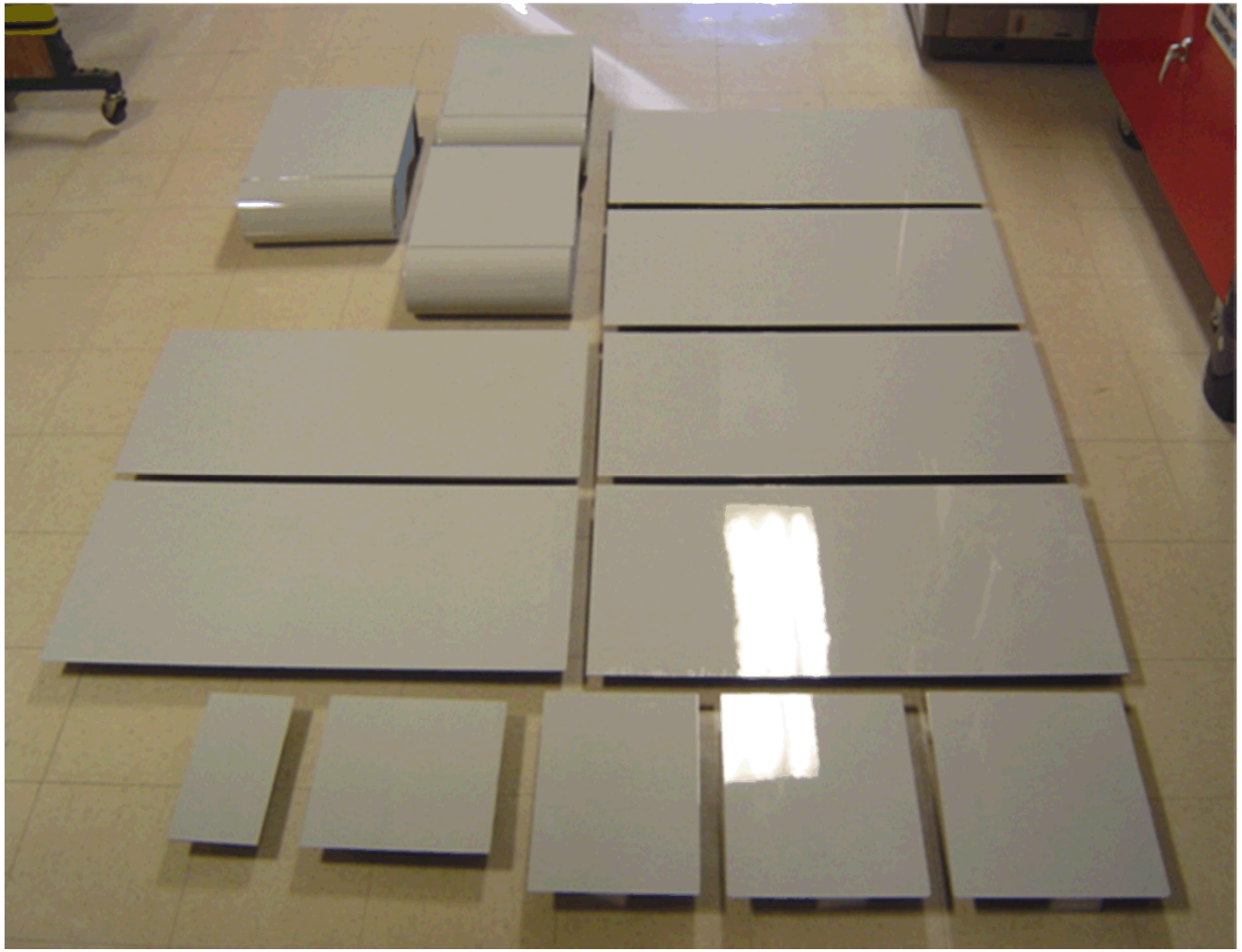
Specimen Set - Flaw Detection in Solid Laminate Composites



Thickness Range: 12 – 64 plies

Simple Tapers

Complex tapers

Substructure Flaws

Curved Surfaces

Array of flaw types

NDI Ref. Stds.

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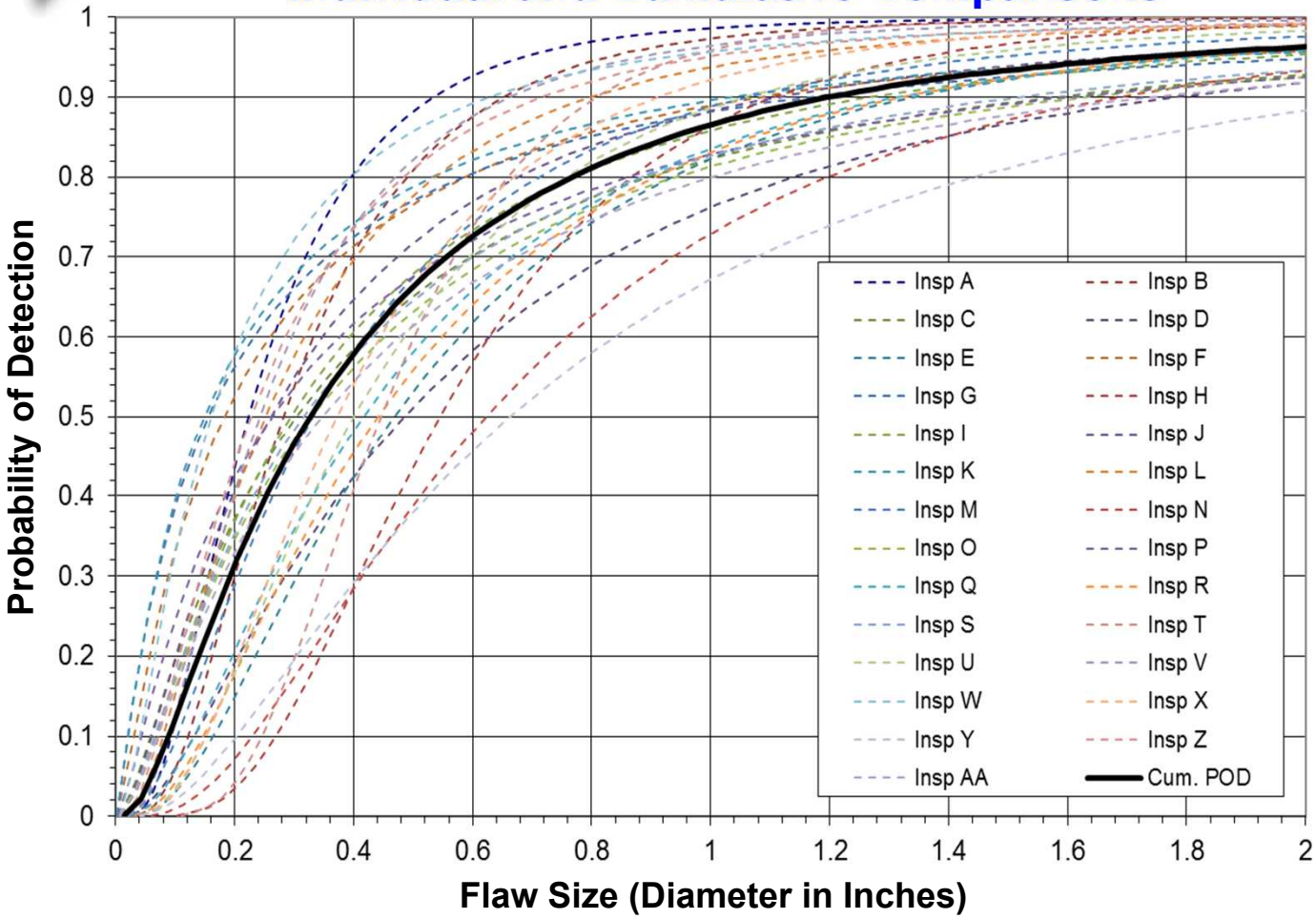
POD Curves for 12-20 Ply Solid Laminate Family

Individual and Cumulative Comparisons



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.

False Calls: Constant thickness = 0.4/inspector
Complex Geometry = 4.0/inspector
34 ft.^{2} inspection area

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Recommendations – How to move inspections from "average" to "good" to "outstanding"

- Increased exposure to representative composite inspections – common industry NDI Proficiency Specimens
- Increased, focused composite NDI training
- Use of NDI and composite shop apprenticeships (OJT, awareness training, formal/uniform use of this tool)
- Enhanced NDI procedures – deployment, signal interpretation, clear schematics showing structural configuration
  - Follow procedures
- Use of inspection coverage aids should be required
- Divide large area inspections into a number of smaller regions
- Reiteration of best practices & use of NDI apprenticeships
- Guidance on addressing complex geometry challenges
- Prepare additional industry guidance to address training, use of NDI Reference and Proficiency specimens, procedures, composite construction awareness

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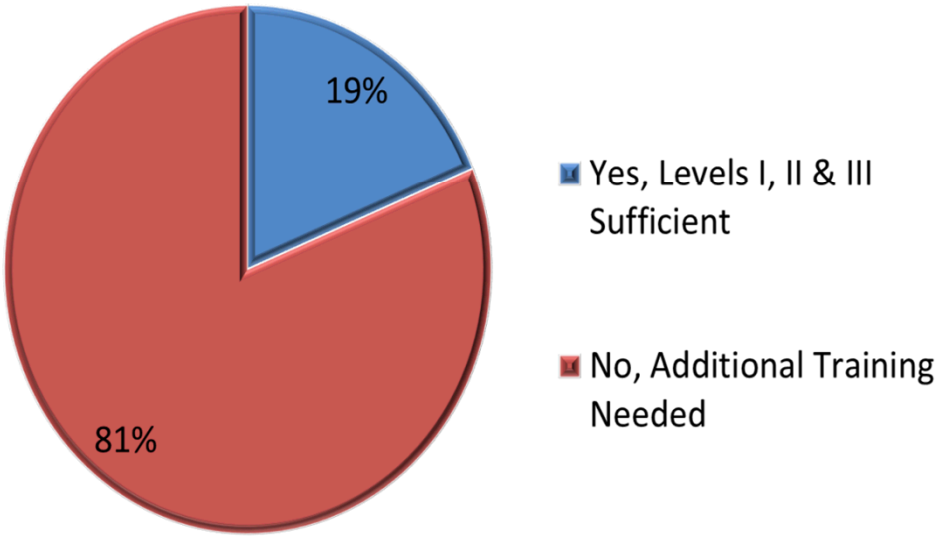
Survey of Industry Composite NDI Training

Question 16 - In your opinion, do Level I, II, and III training/qualifications provide the necessary expertise for both metal and composite NDI or should additional training take place for composite inspections?

Airline and MRO NDI Survey

Composite NDI Training Survey Participants	
Company	**Completed Survey**
AAR-ASI (Indy)	Yes
American Airlines (Tulsa)	Yes
Aviation Technical Services, Inc (Seattle)	Yes
Delta Air Lines (Atlanta)	Yes
Delta Air Lines (MN)	Yes
FedEx (Indy)	Yes
FedEx (Los Angeles)	Yes
Goodrich Aerostructures (Chula Vista)	Yes
Kalitta Air LLC (Michigan)	Yes
Rohr Aero Services LLC (Alabama)	Yes
Southwest Airlines (TX)	Yes
Timco (Georgia)	Yes
United Airlines (Houston)	Yes
United Airlines (San Fran.)	Yes
UPS (KY)	Yes
US Airways (PA)	Yes



Only 25% of responders currently have special composite NDI training in place

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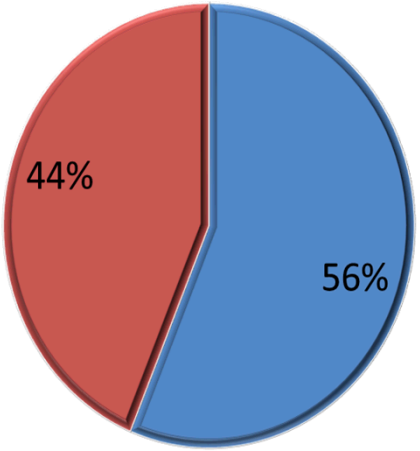
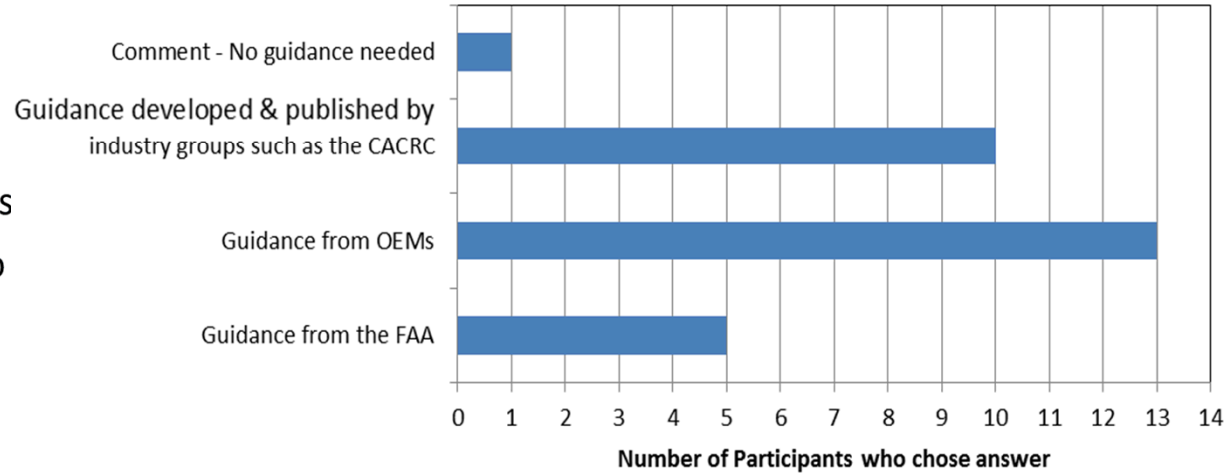
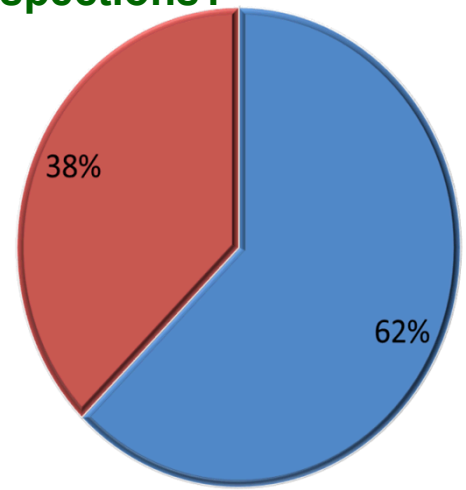
Question 21 - In what areas is additional guidance needed to help ensure comprehensive composite training programs for the aviation industry?





Question 15 - If experience level is a factor in determining qualification to perform certain inspections, do you use some sort of apprentice program to expose newer inspectors to such inspections?



Question 5 – Do inspectors also receive general composite training to understand composite materials, plies, lay-ups, scarfed repairs, composite design, composite processing, etc.?

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Composite NDI Training Class - Drivers

- Extensive/increasing use of composites on commercial aircraft
- Solid Laminate Flaw Detection Experiment (Probability of Detection) produced recommendations for improving the performance of current inspection practices – key recommendation was to enhance an inspector's training
- NDI Survey– support for additional guidance and training
- Identified need for specific training that specifically addresses composite inspection
  - Unique challenges associated with composites
  - Additional routine exposure to composite laminate inspections

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Composite Laminate NDI Training Class

Class Definition – General Training Content

- Summary of typical structural configurations from NDI perspective - schematics showing structural configuration
- Present NDI challenges and means to address them
- Field issues –NDI common errors; human factors concerns, deployment, lessons learned
- Inspection cases – typical and unique (unexpected) demands; review of inspection processes and issues/problems from the field (input from operators)
- Use of NDI Proficiency Specimens - usage processes/modes for feedback & learning
- Hands-on portion of class – designed exercises, selection of equipment, highlight lessons learned with lab exercises

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Composite Laminate NDI Training Class

Class Definition – General Training Content (cont.)

- **Target Class Length** – 2 days (1/2 classroom, 1/2 hands-on)
- **Format** – stand-alone course but assumption is min of Level I student
- Instructor modifies for specific needs

Goal of training is to enhance aircraft safety & optimize aircraft utilization by improving NDI flaw detection performance in composite aircraft structure.

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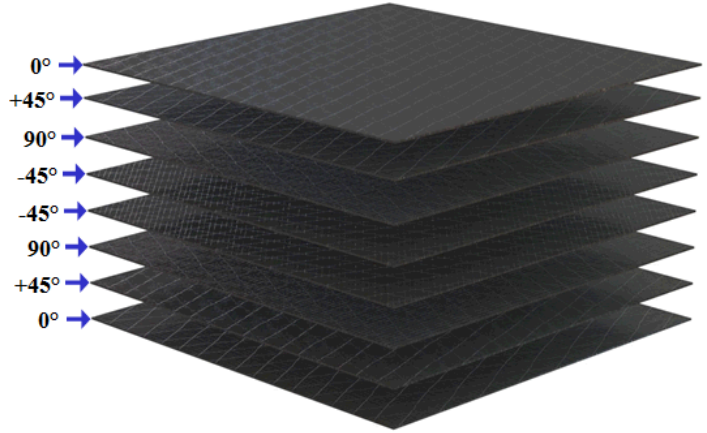
Composite Laminate NDI Training Class

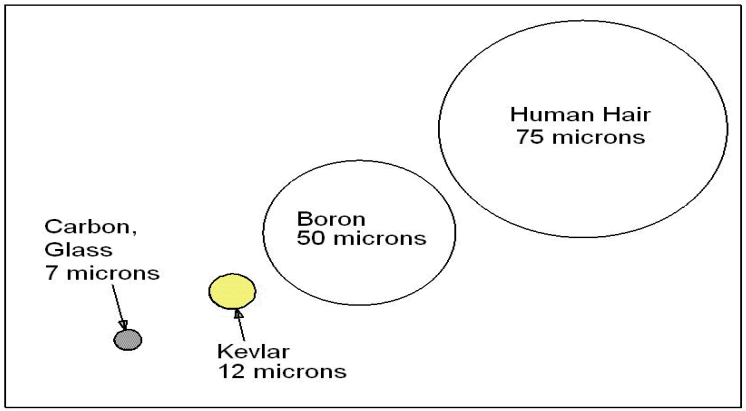
Class Modules

1. Introduction, Motivation, Objectives & Expected Outcome from Class
2. Composite Awareness – Materials, Design, Fabrication and Use
3. Composite NDI – Theory and Practice
4. Special Cases - Challenges & Lessons Learned
5. NDI Proficiency Specimens
6. Composite NDI – Hands-On Exercises

2. Composite Awareness – Materials, Design, Fabrication and Use



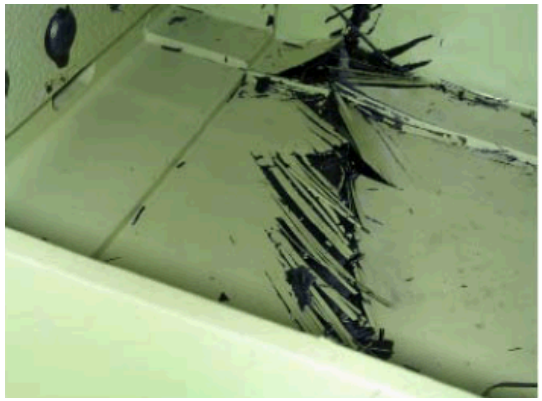
What are Composites?



Common Materials used

Autoclave and VARTM Processing

Types of Damage



Introduction to Repairs

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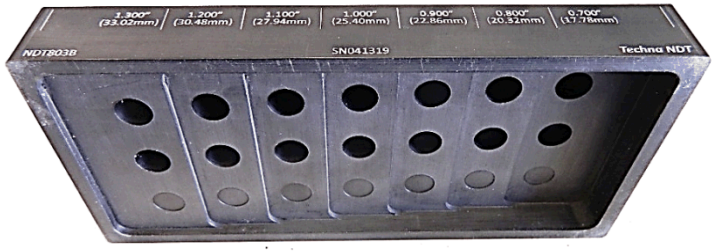
3. Composite NDI – Theory and Practice

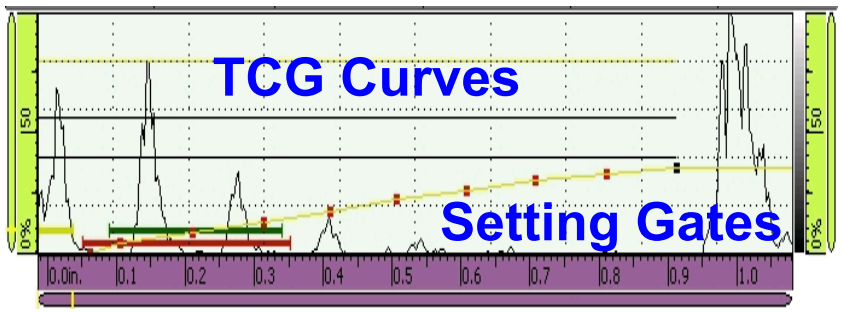
- Visual inspection of composites
- Basic ultrasonic inspection theory
- Ultrasonic deployment and options
- Ultrasonic equipment set up
- Mapping damage
- Ultrasonic signals from normal and damaged structure
- Solid laminate inspection methods and sample results



Reference Standards

Transducers and Delay Lines

Sample Procedures



Deployment Options

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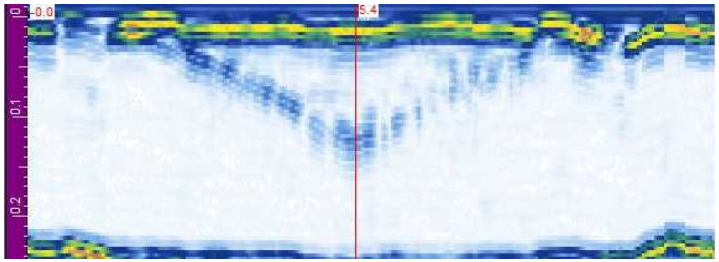
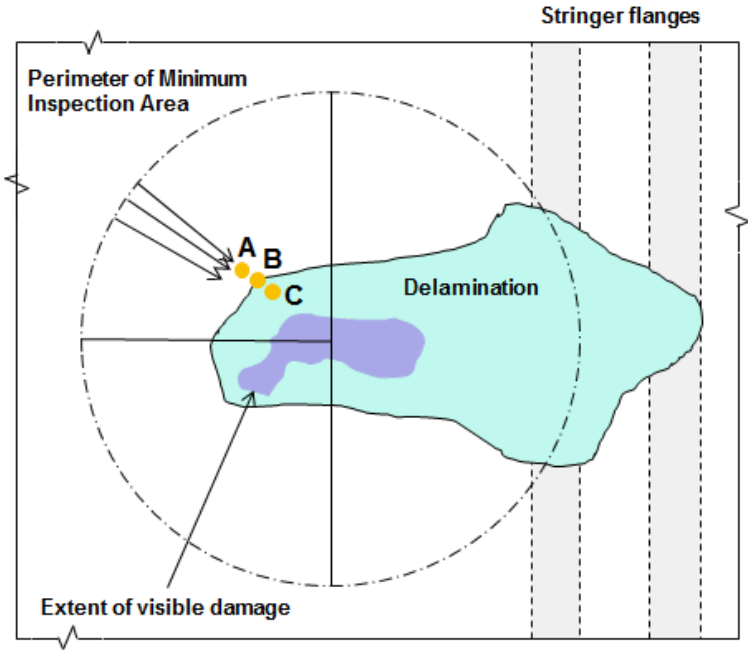
3. Composite NDI – Theory and Practice

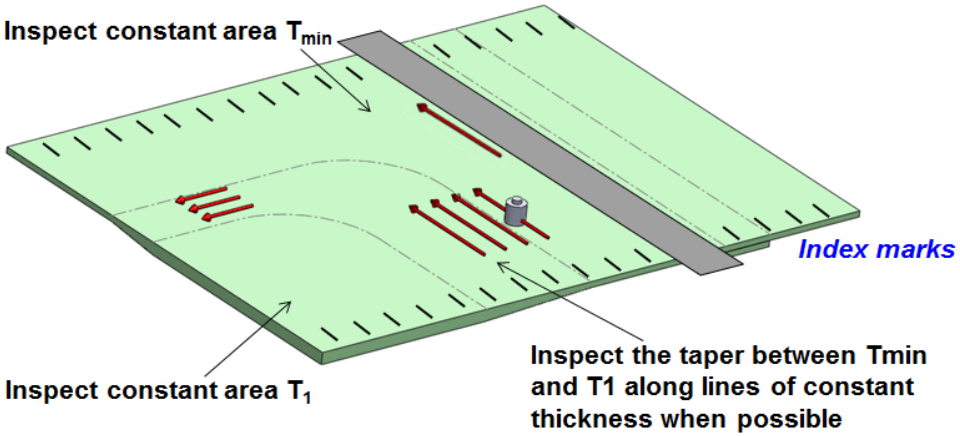


A-Scan, B-Scan, C- Scan

"Go" / "No-Go" Devices



Sizing Damge



Scan Indexing, Tapers and Substructure

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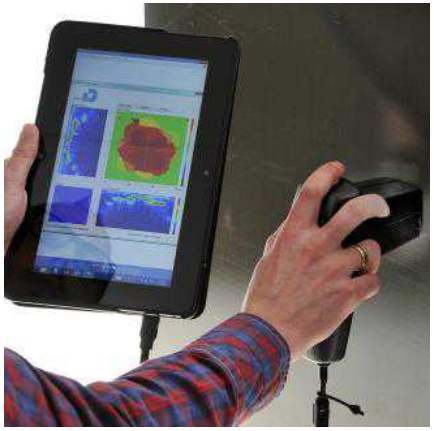
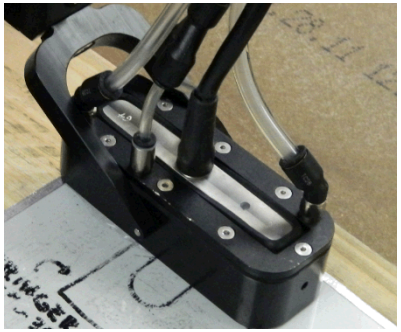
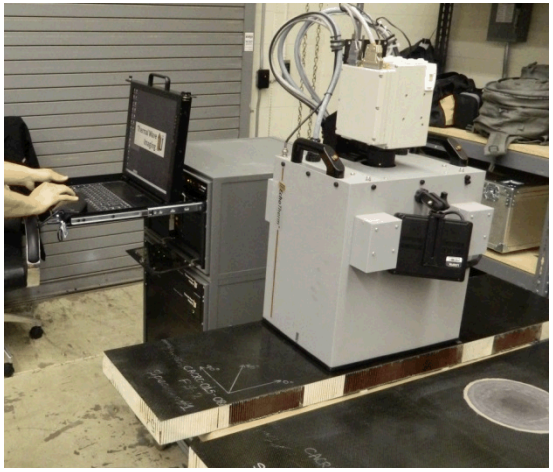
3. Composite NDI – Theory and Practice

Brief introduction and sample results from:

- Various phased array systems
- CT Scanning
- DolphiCam
- Thermography
- Roller Probes
- LaserUT
- Digital Acoustic Video







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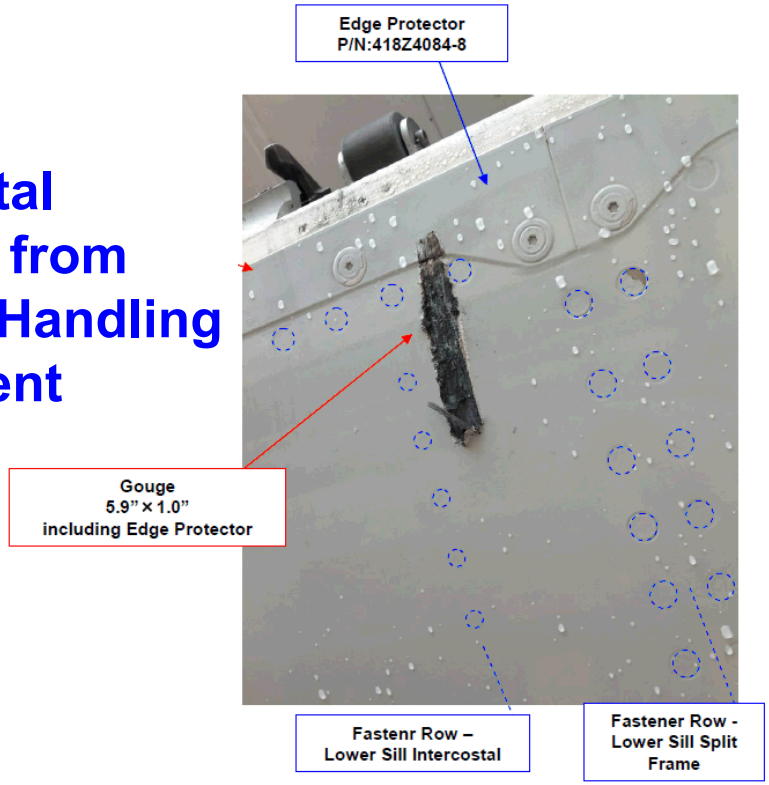
4. Special Cases – Challenges & Lessons Learned

- Read and Follow the Procedures
- Embrace New Technology – It Can Be Helpful
- Composite Damage Tolerance is Good – NDI will Tell
- Follow OEM Documentation

Accidental Damage from Ground Handling Equipment



Lightning Strike Damage

5. NDI Proficiency Specimens

Initial design guidelines were assembled at the 1st (August 2014) project kick-off meeting with industry partners and the FAA.

- ***Thickness, materials, flaw types, structural configurations etc.***

Development Considerations:

- Support hands-on training exercises
- Support recurrent training and composite NDI exposure
- Can be used in "blind mode" to demonstrate inspector proficiency
- Multiple flaw profiles and configurations designed so that end users can put together a set that fits their specific training and budget needs
  - All lessons and teaching points will be encompassed in a limited number of panel configurations (minimize cost)
- Specimen geometry designed for ease of construction

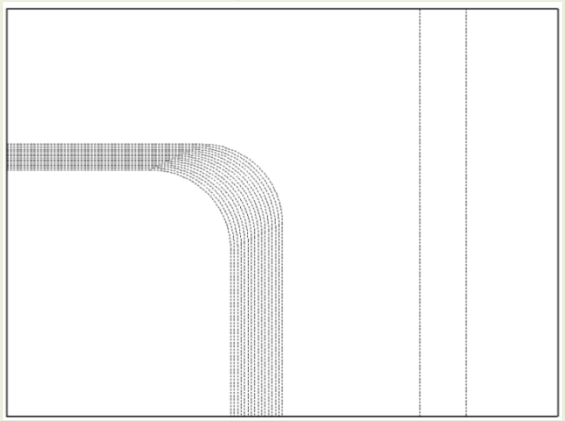
5. NDI Proficiency Specimens

Panel Configuration Summary - 10 total panels

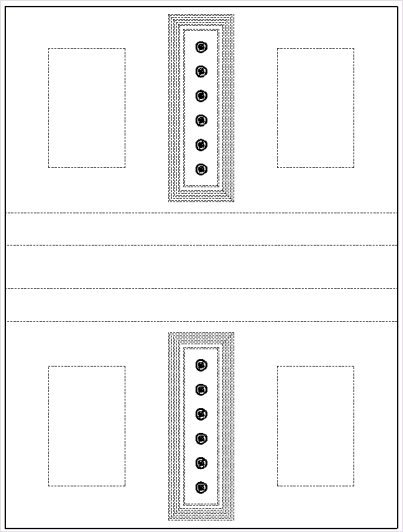
- 3 variations of configuration 1 panel
- 2 variations of configuration 2 panel
- 3 configuration 3 panels
- 2 repair panels

Panel Configuration	Structure	Test Specimen	Primary Variation
Configuration 1	24"x18" Panel with complex taper (10:1 and 20:1) and secondary bond	1a	Standard configuration 1
		1b	Additional Secondary bond and more subtle flaws (different flaw profile)
		1c	Additional thickness (up to 64 plies) and different flaw profile
Configuration 2	24"x18" Panel with pads, fasteners, co-cured bonds, sealant, sound dampers	2a	Standard configuration 2
		2b	Different flaw profile
Configuration 3	16 ply solid lamiante skin	3a	Standard configuration 3
		3b	Subtle impact
		3c	Large impact
Repair Panel Configuration	20 Ply solid laminate parent material	Rep. Panel 1	Standard repair panel
		Rep. Panel 2	Different flaw profile

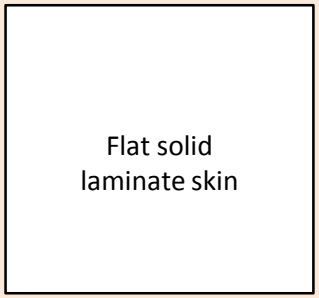
Configuration 1



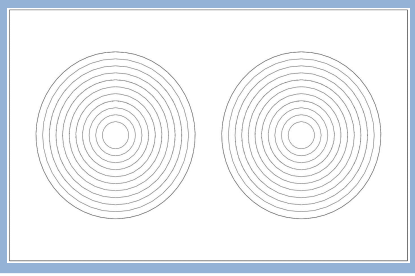
Configuration 2



Configuration 3



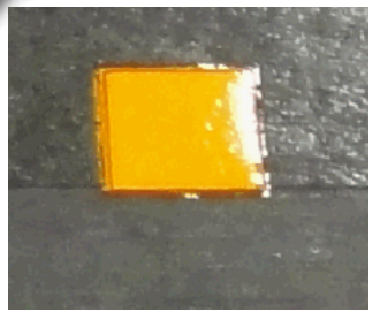
Repair Panel Configuration



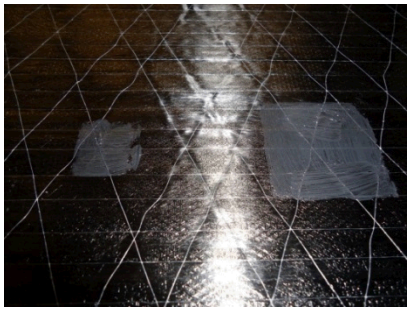
5. NDI Proficiency Specimens

Example Engineered Flaws in Proficiency Specimens

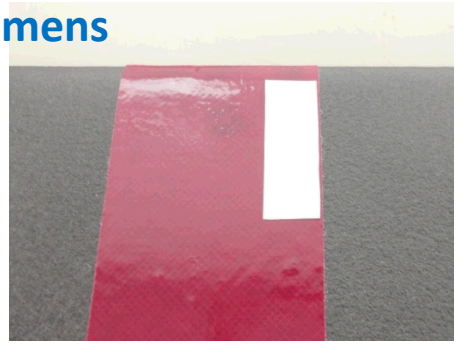
Embedded in the panels



Pillow insert
***Delamination**

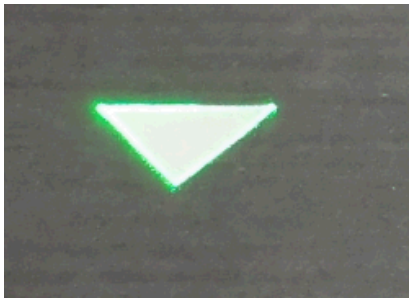


Grease
***Contamination**

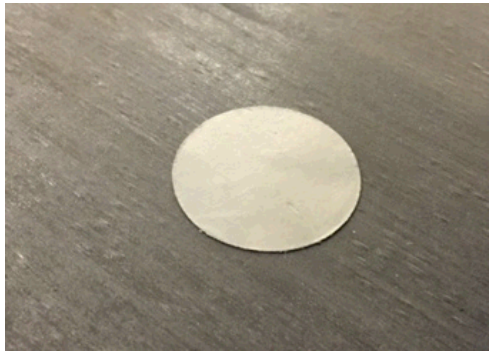


Paper Backing in the bond line
***Foreign object damage**

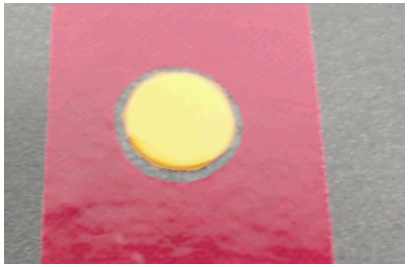
Carbospheres
***Localized porosity**



Paper backing in the laminate
***Foreign object damage**



Grafoil insert
***Tight delamination**



Pillow insert in the bond line
***Disbond**

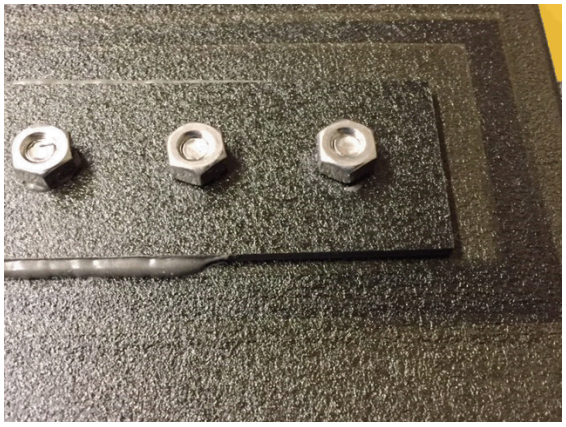
5. NDI Proficiency Specimens

Example Engineered Flaws in Proficiency Specimens

Added to the panels after fabrication

Concentric flat bottom holes
***Impact damage**

Flat bottom holes
***Significant delamination**



Missing Sealant

Grinder Cut
***Cracked or broken substructure**

Grinder Disk Grove
***Gouge or deep scratch**

Sealant
***Raised material, not a flaw**

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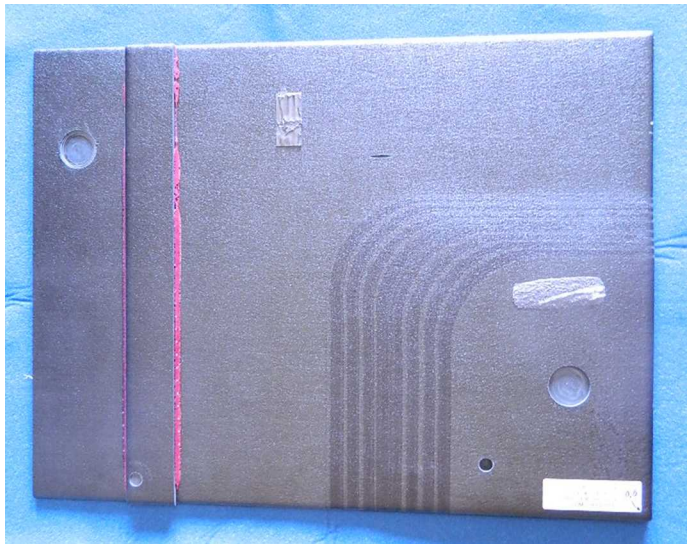
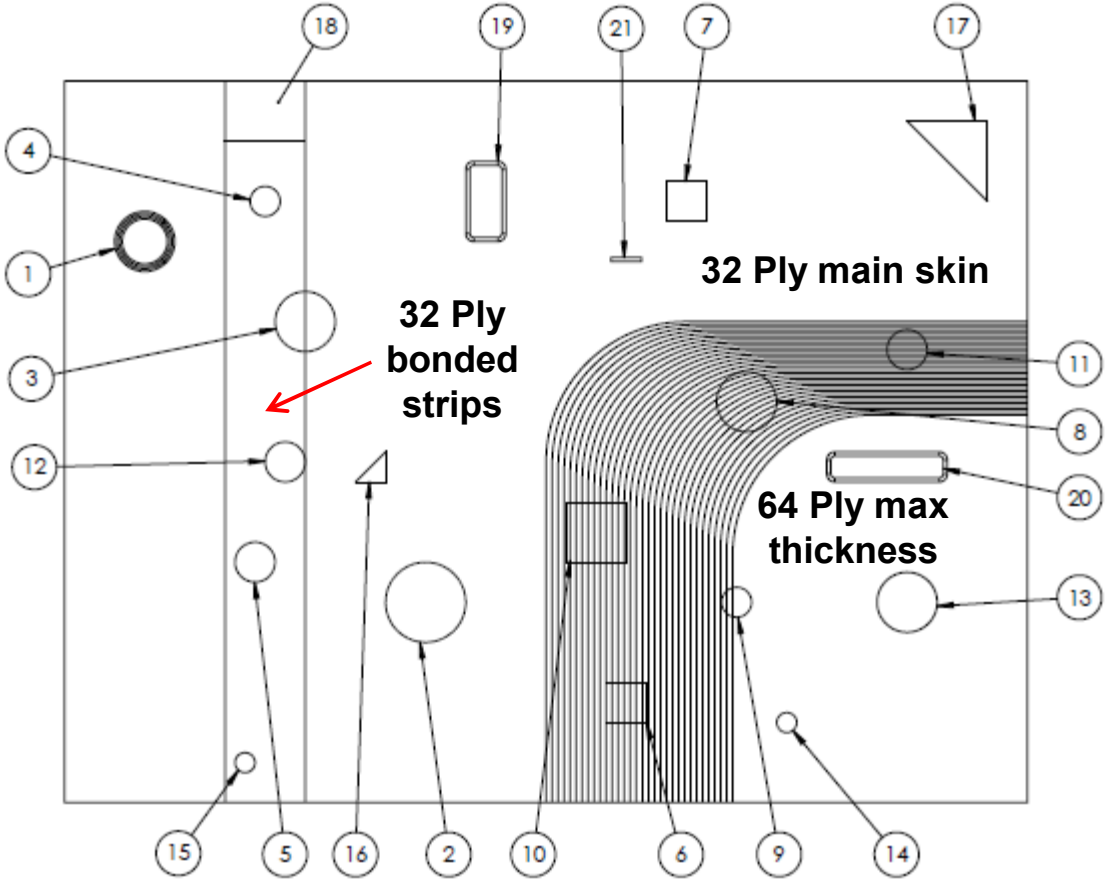
5. NDI Proficiency Specimens

Specimen Design 1c – Flaw Profile

Structure: *Thick Specimen* - Taper (10:1 and 20:1) and secondary bond





Fabrication support from *NORDAM Interiors and Structures*

Darryl Graham and Jeff Harper

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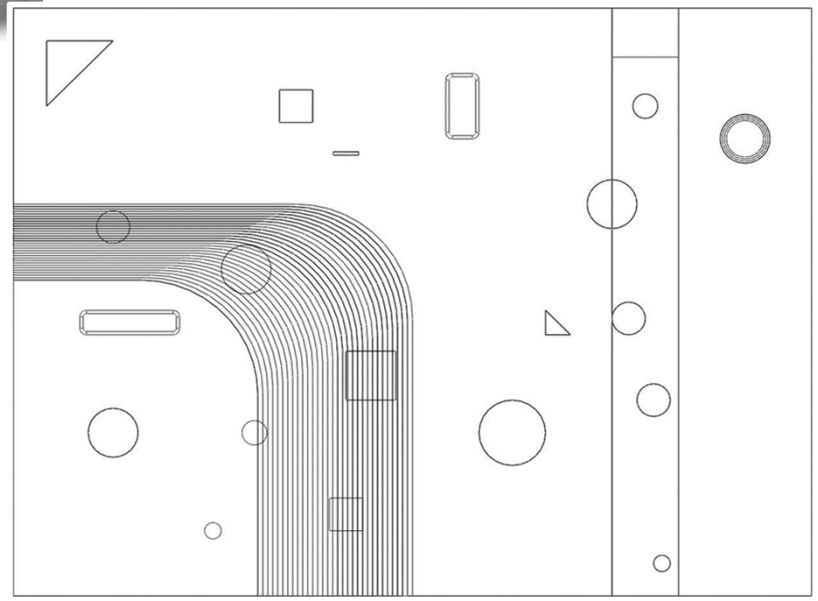
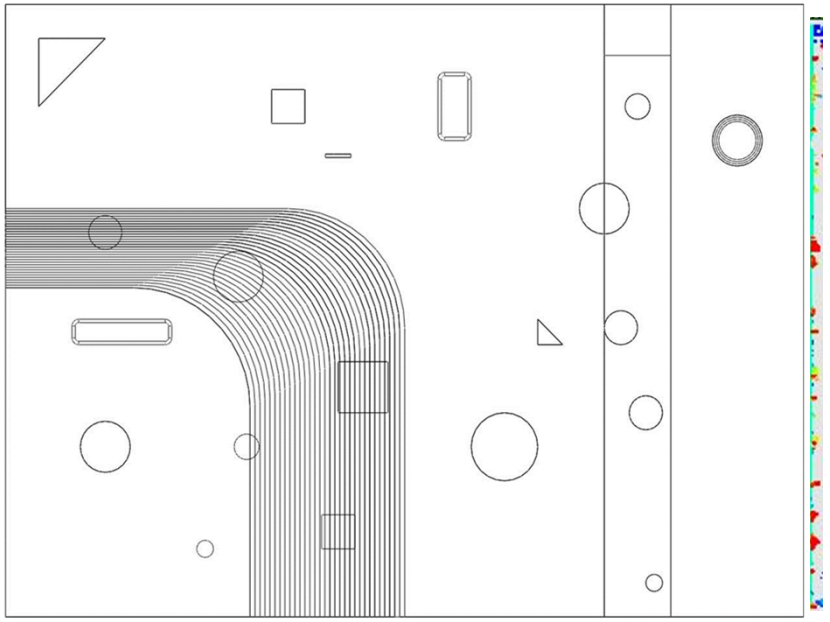
5. NDI Proficiency Specimens

OmniScan 3.5L64 (3.5 MHz)

Specimen 1c - Inspection

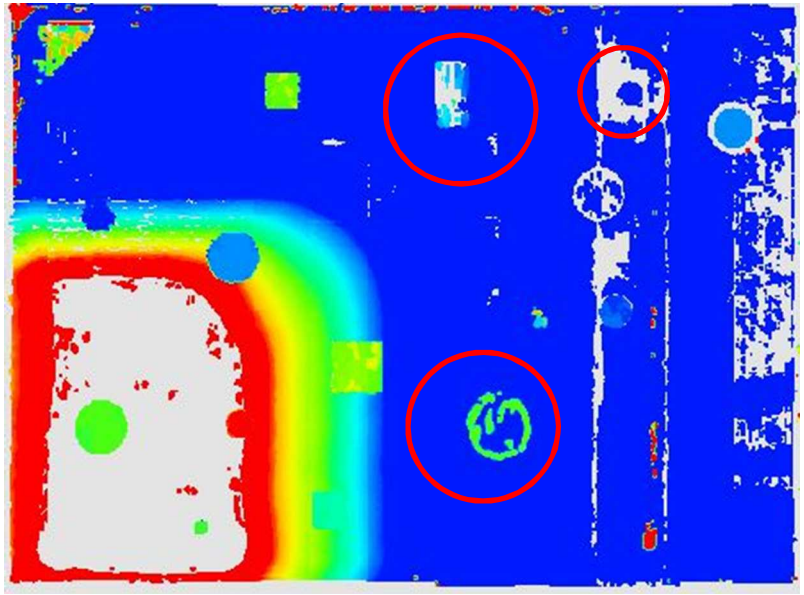


Amplitude



TOF

Thickness:
0.240-0.480”
64 Ply



Note: Images post processed in TomoView analysis. Some flaws didn’t show until further analysis as shown with a red circle.

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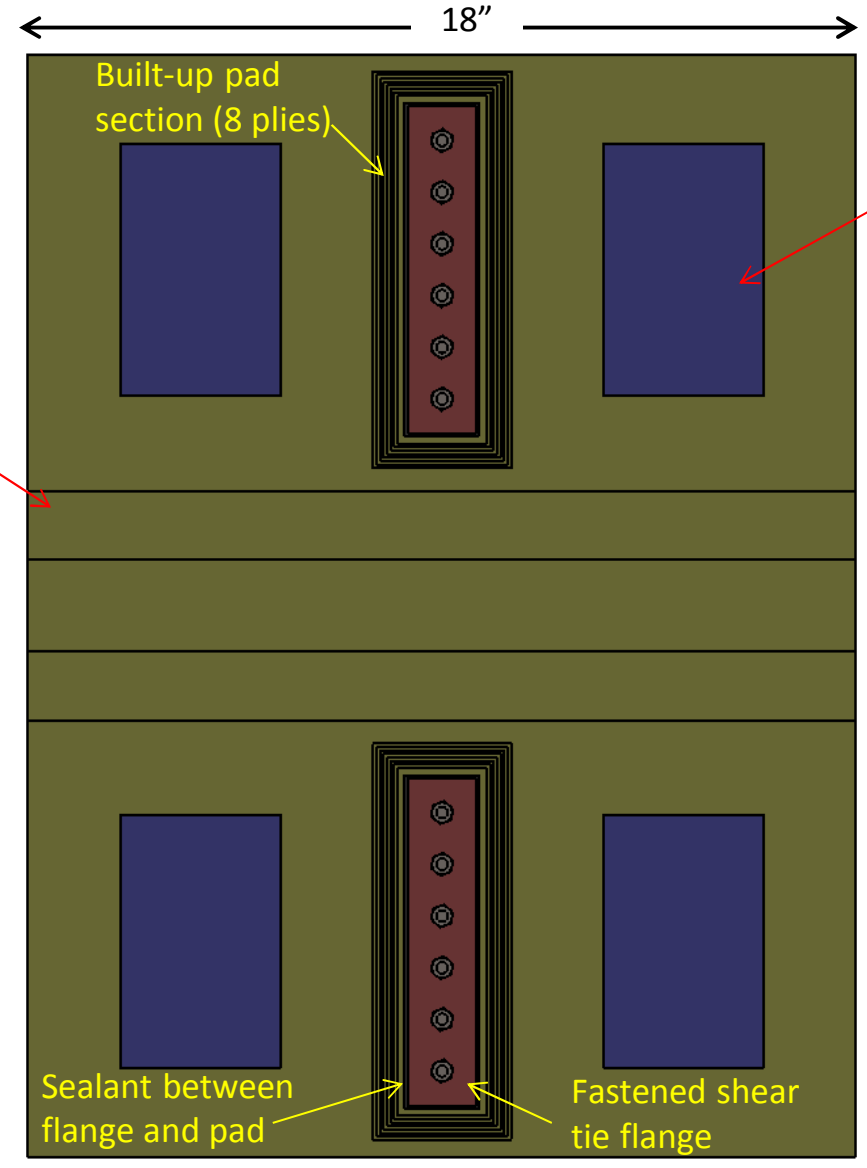
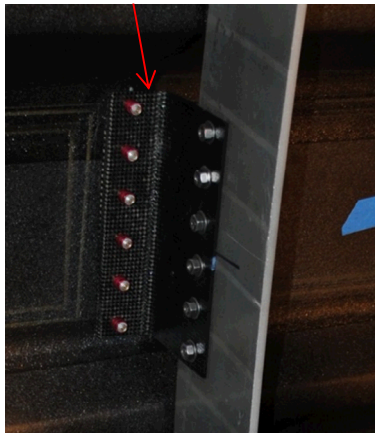
5. NDI Proficiency Specimens

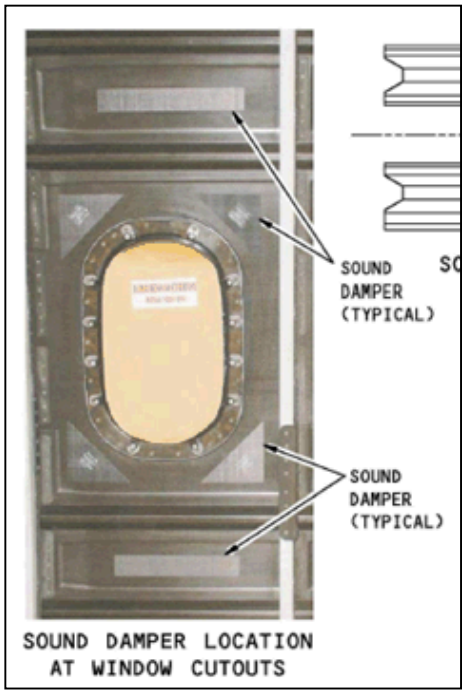
Configuration Design 2 – Description Continued

Structure: Uniform thickness skin, pads, fastened shear tie flanges, co-cured stiffeners, sealant



Shear tie flange





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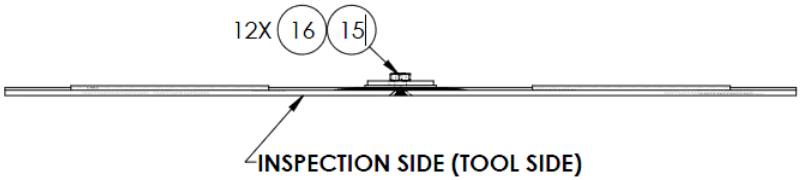
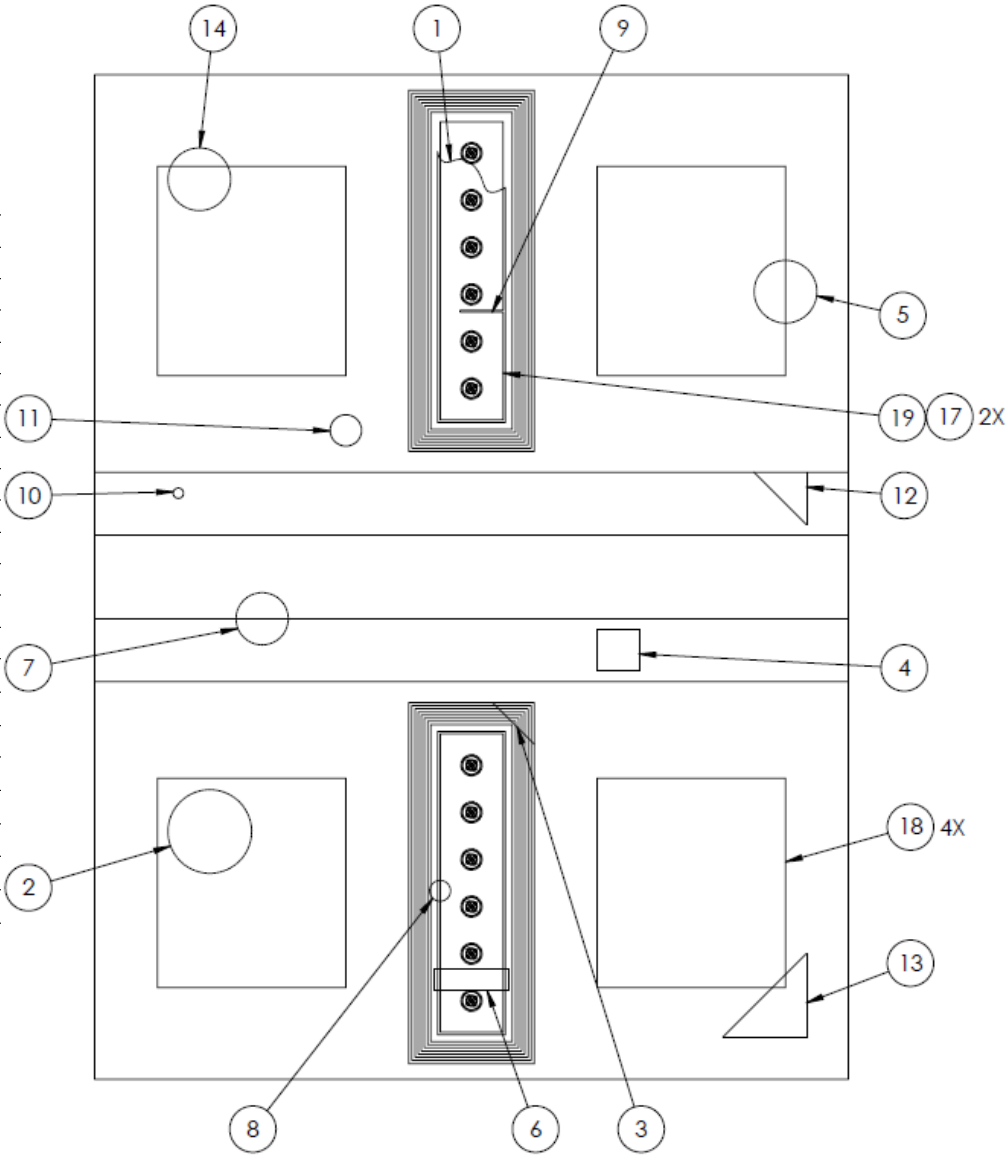
5. NDI Proficiency Specimens

Specimen Design 2a – Flaw Profile

ITEM #	FLAW TYPE	SIZE	PLY LAYER
1	MISSING SEALANT	AS SHOWN	BTN PLY 8 & SHEAR TIE FLANGE
2	PILLOW INSERT	∅2.00	BTN PLY 16 & SOUND DAMPER
3	PILLOW INSERT	1.00 X 1.00	BTN LAM PLY 16 & ST PAD PLY 1
4	PILLOW INSERT	1.00 X 1.00	BTN PLY 2 & 3 OF STIFFENER
5	PILLOW INSERT	∅1.50	BTN PLY 4 & 5 (25%)
6	PILLOW INSERT	1.75 X 0.50	BTN PLY 4 & 5 OF ST PAD
7	PILLOW INSERT	∅1.25	BTN PLY 8 & 9 (50%)
8	PILLOW INSERT	∅0.50	BTN PLY 6 & 7 OF ST PAD
9	DREMEL CUT	~0.05 X 1.00	SHEAR TIE FLANGE AS SHOWN
10	FLAT BOTTOMED HOLE	∅0.25	0.015" ↧ (BTN PLIES 6 & 7)
11	FLAT BOTTOMED HOLE	∅0.75	0.030" ↧ (BTN PLIES 12 & 13)
12	PREPREG BACKING	1.25 x 1.25	BTN PLY 16 & STIFFENER PLY 1
13	PREPREG BACKING	2.00 X 2.00	BTN PLY 8 & 9 (50%)
14	GREASE	∅1.50	BTN PLY 8 & 9 (50%)
ITEM #	DESCRIPTION	QUANTITY	DESIGNATION
15	FLAT HEAD BOLT	12	100° FL HD, 1/4-20UNC-2A X 0.500
16	HEX NUT	12	1/4-20UNC-2B
17	SHEAR TIE FLANGE	2	SEE SHEAR TIE FLANGE DRAWING
18	SOUND DAMPER	4	4.5" X 5.0" SMACSONIC PADS
19	SEALANT	AS NEEDED	





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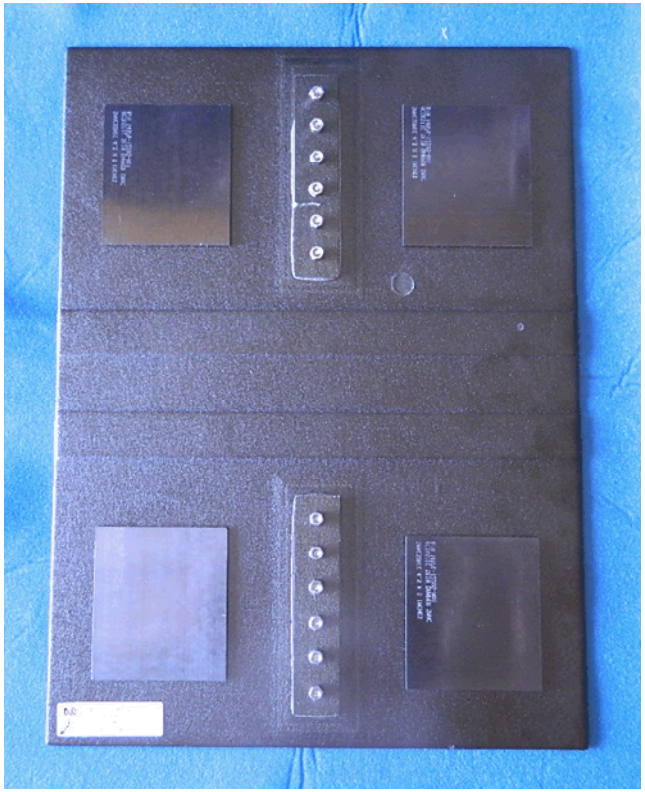
5. NDI Proficiency Specimens

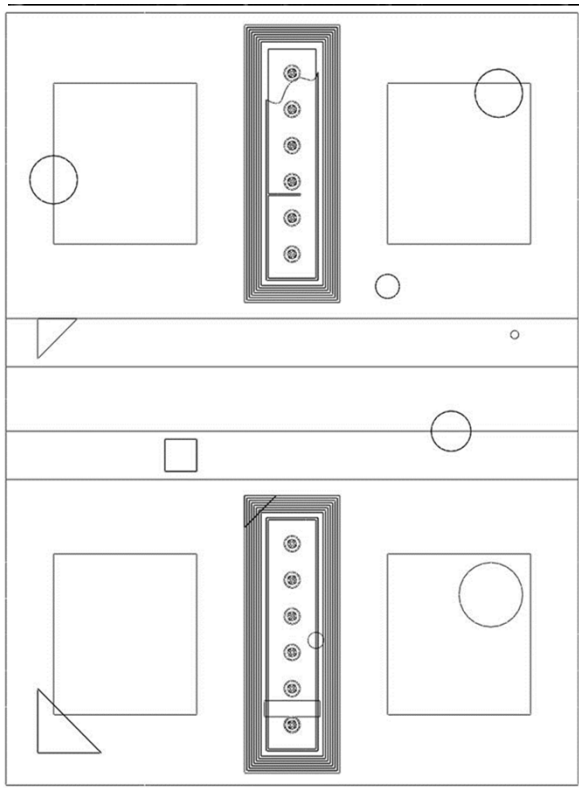
Configuration Design 2a – Inspection Results

Structure: Uniform thickness skin, pads, fastened shear tie flanges, co-cured stiffeners, sealant

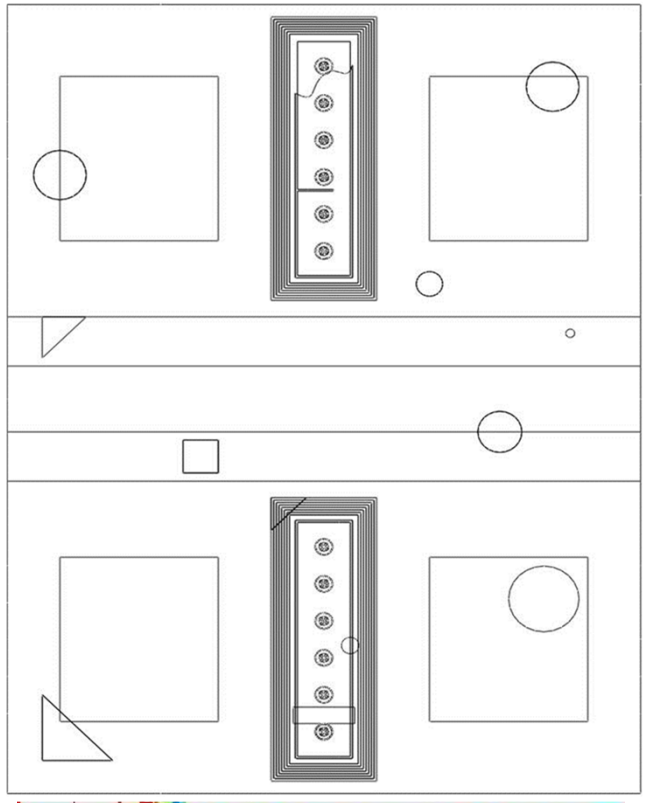
OmniScan 3.5L64 (3.5 MHz)



Back



Amplitude



TOF

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Industry Review Workshop – August 2015

- Presented class materials from the Composite Inspector Training course at an industry review workshop hosted by the AANC at Delta Air Lines maintenance depot in Atlanta.
- The prototype class and proficiency specimens were presented.
- 35 participants representing airlines, cargo carriers, MROs, aircraft manufacturers and regulators from as far as Japan, Germany and Holland participated in the review of course materials.

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Update and Path Forward

- Complete course module development by end of FY16
- Finish Proficiency Specimen fabrication in collaboration with NORDAM
- Develop additional, specific hands-on exercises using the proficiency specimens
- Conduct “dry run” of class with an airline
- Work with the FAA to determine best methods for course content dissemination to airlines
  - Complete course description - SAE Aerospace Information Report (AIR)
  - Adoption and modification by Airlines, MOR’s
  - Possible course deployment by 3rd party agency

Questions?

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