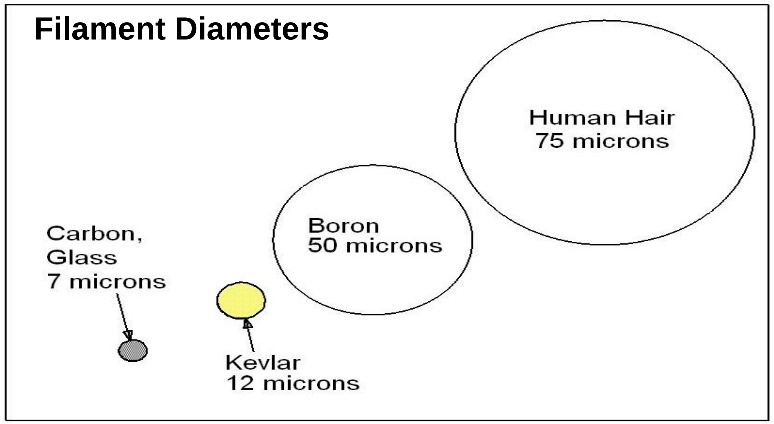
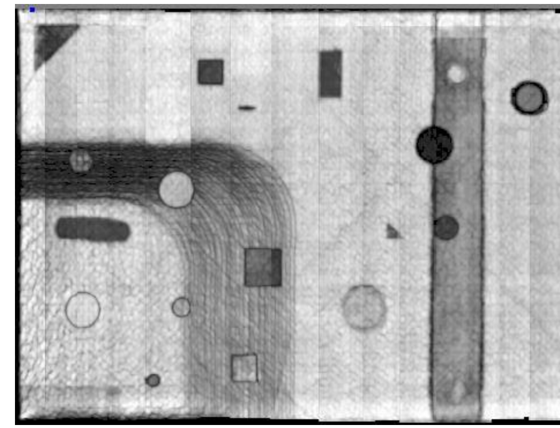
A Composite NDI Training Course to Address the Growing Need for Composite Laminate Inspections

Airlines for America NDT – September 2016





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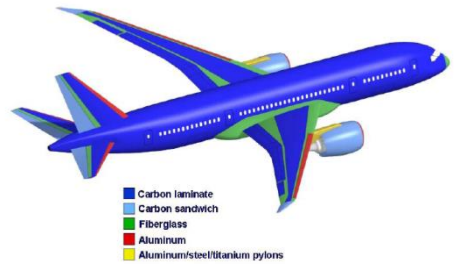
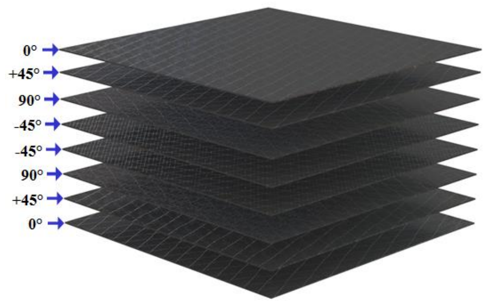
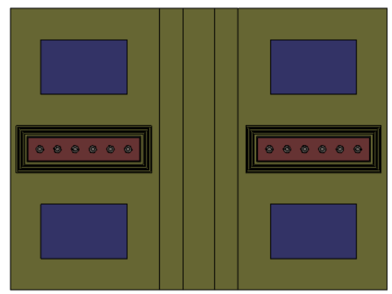
Presentation Overview



Introduction and Background



Class Modules and Objectives



Hands-On Training and Proficiency Specimen Set

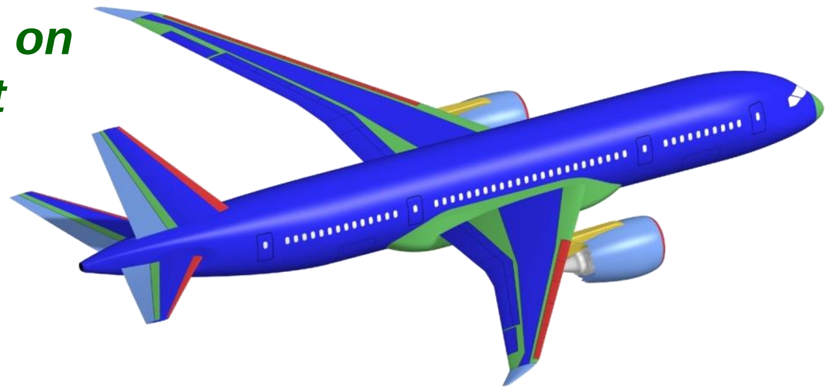
First Deployment of the Composite NDI Training Class

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.

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

Composite Structures on Boeing 787 Aircraft



altairenlighten.com

Motivation for Composite NDI Training Class

Boeing 787

1,161 Ordered
455 Delivered
All Nippon Airways – 83, 50
United – 49, 30
American – 42, 17
Delta – 18, 0

Airbus A350

810 Ordered
36 Delivered
Qatar Airways – 80, 10
United – 35, 0
American – 22, 0
Delta – 25, 0

"Boeing 787: Orders and Deliveries (updated monthly)". The Boeing Company. August 31, 2016. Retrieved September 8, 2016

http://www.airbus.com/company/market/orders-deliveries/

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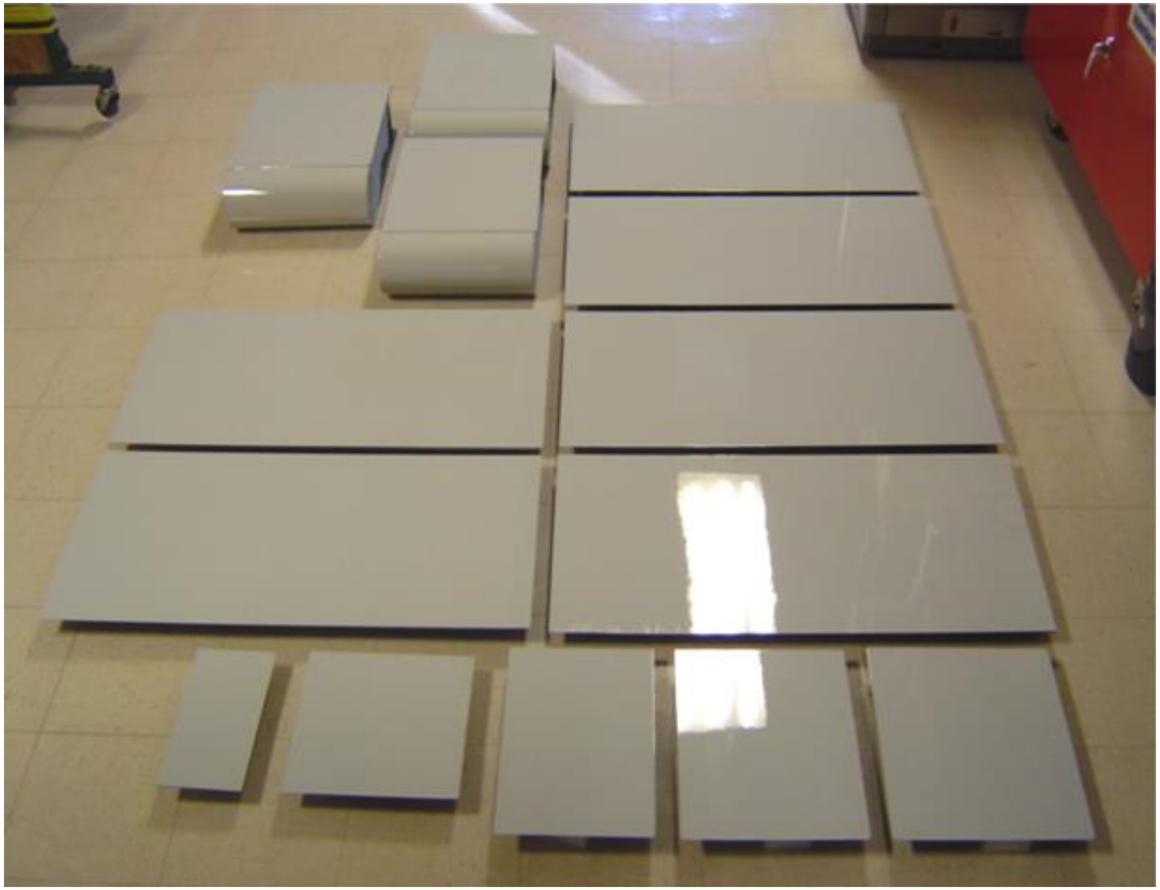
Solid Laminate Flaw Detection Experiment

Probability of Detection (POD) Experiment



Thickness Range:
12 – 64 plies

Simple Tapers

Complex tapers

Substructure Flaws

Curved Surfaces

Array of flaw types

Evaluate the performance of conventional ultrasonic inspection methods for flaw detection in solid laminate structures. 70 inspectors from 14 airlines participated.

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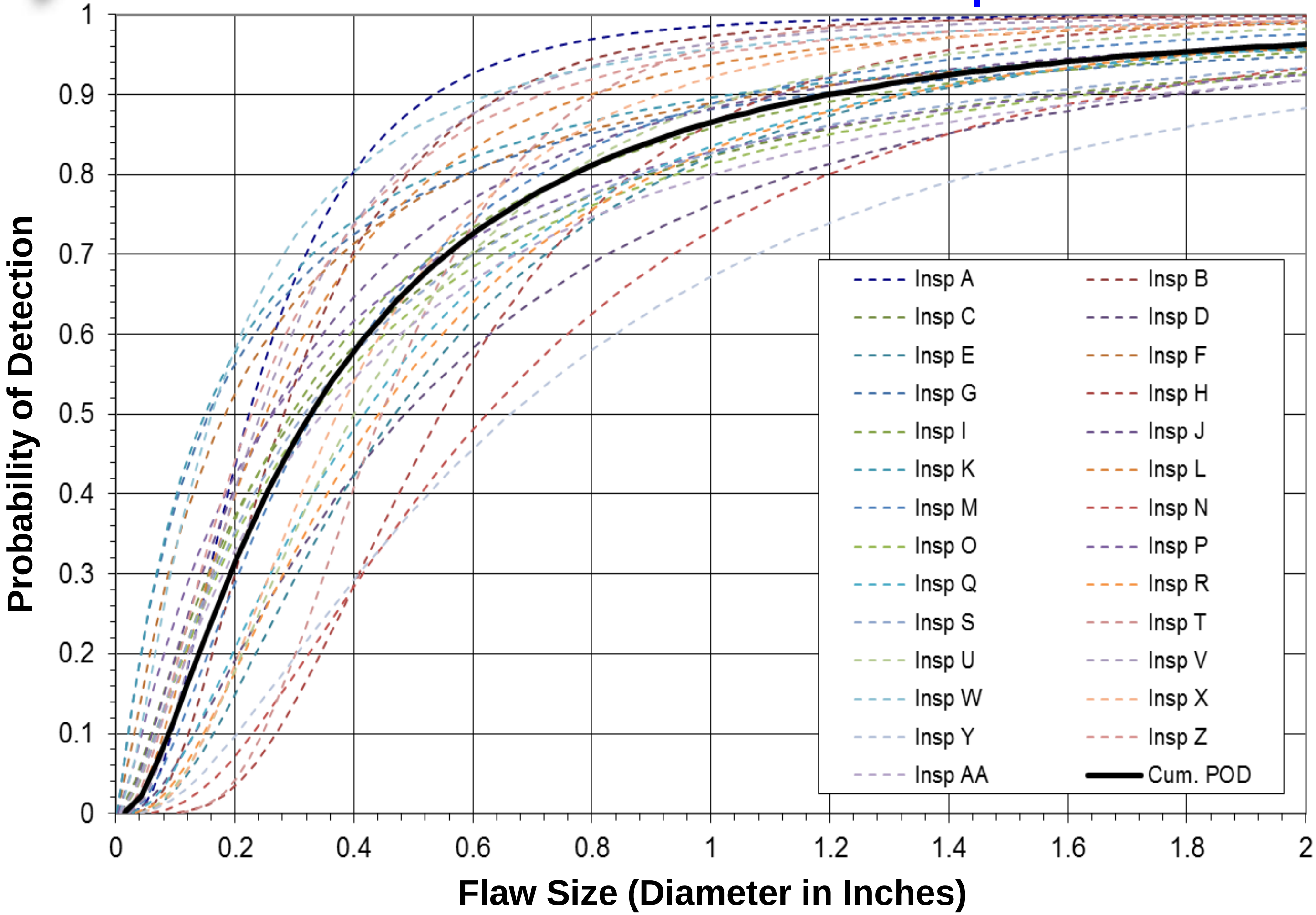
POD Curves for 12-20 Ply Solid Laminate Family

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

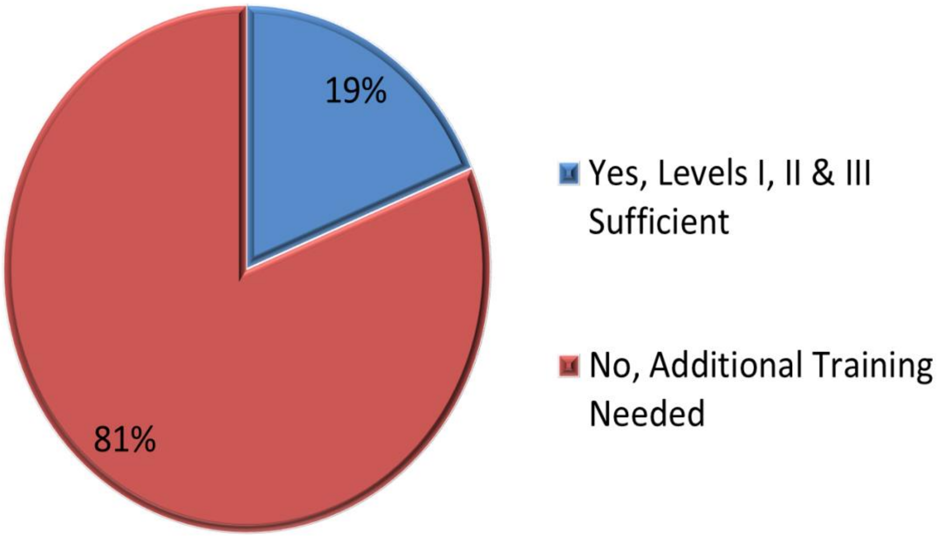
Composite NDI Training Survey

In addition to the POD experiment, a Composite NDI Training Survey was conducted.

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

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

The POD experiment and NDI Training Survey led to several key recommendations resulting in the Composite Inspector Training Class.

- **Increased exposure to representative composite inspections – common industry NDI Proficiency Specimens**
- **Increased, focused composite NDI training**
- **Enhanced NDI procedures – deployment, signal interpretation, clear schematics showing structural configuration**
  - **Use of inspection coverage aids**
  - **Divide large area inspections into a number of smaller regions**
  - **Follow procedures**
- **Identified need for specific training that specifically addresses composite inspection**
  - **Unique challenges associated with composites**
  - **Additional routine exposure to composite laminate inspections**

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 minimum of Level I student
- Instructor modifies for specific needs

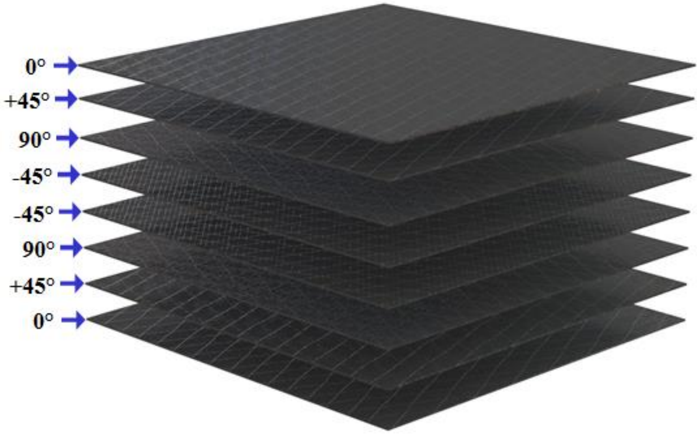
Goal of training is to enhance aircraft safety & optimize aircraft utilization by improving NDI flaw detection performance in composite aircraft structure.

Composite Laminate NDI Training Class

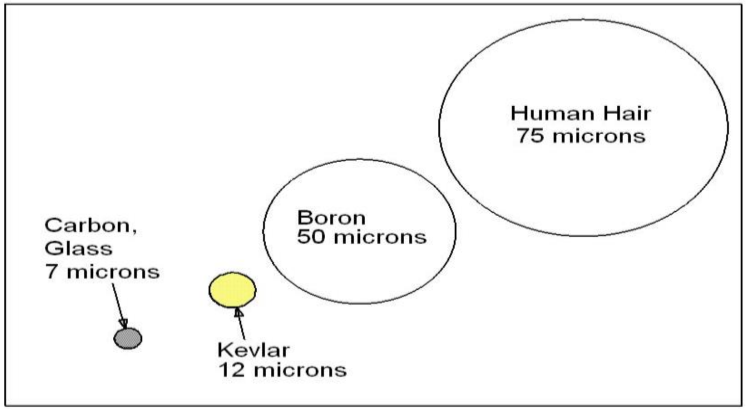
Class Modules

1. Introduction, 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. Hands-On Exercises

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



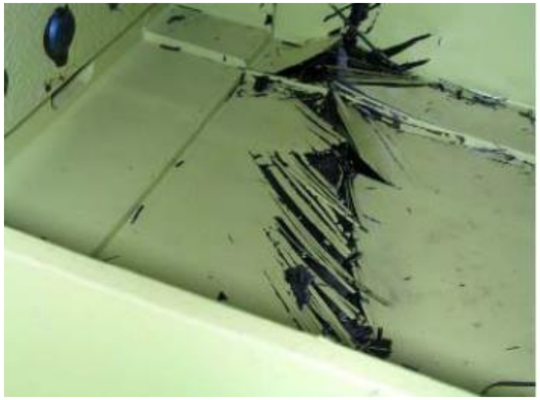
What are Composites?



Common Materials used

Autoclave and VARTM Processing

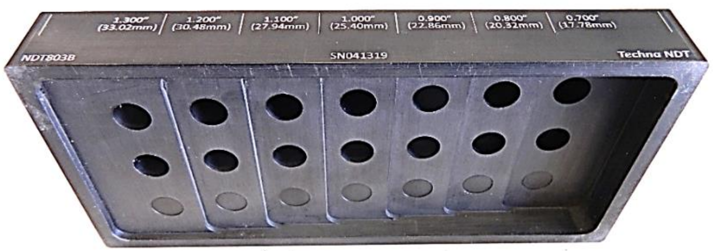
Types of Damage



Introduction to Repairs

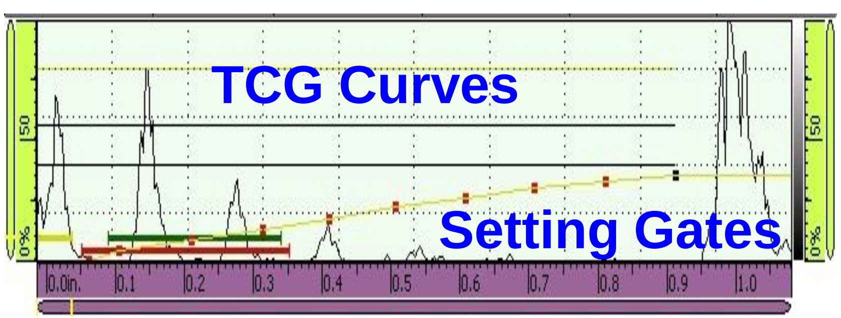
3. Composite NDI – Theory and Practice

- 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
- Phased array inspection
    - C-Scan generation
- Solid laminate inspection methods and sample results



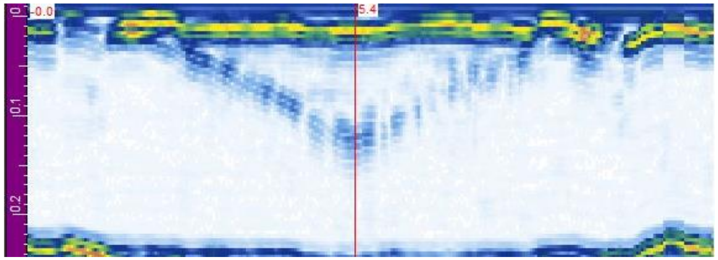
Reference Standards

Transducers and Delay Lines



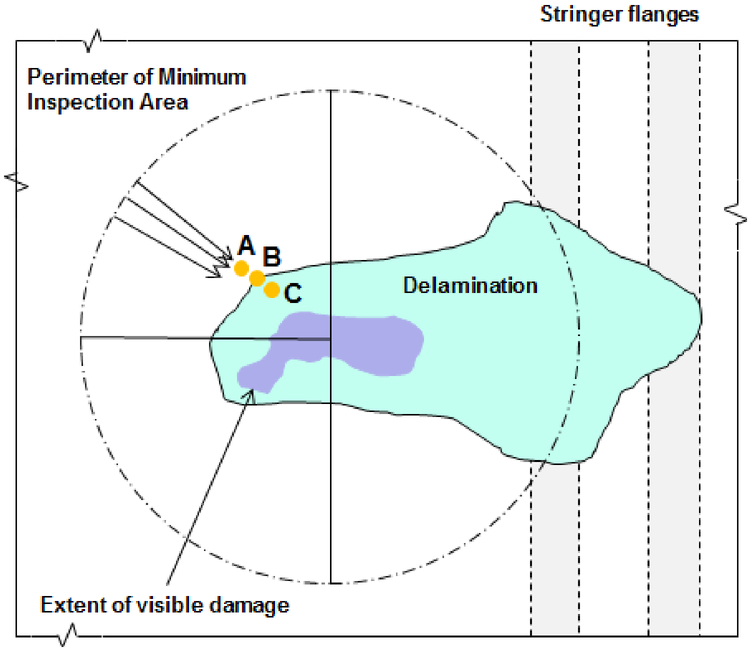
Deployment Options

3. Composite NDI – Theory and Practice

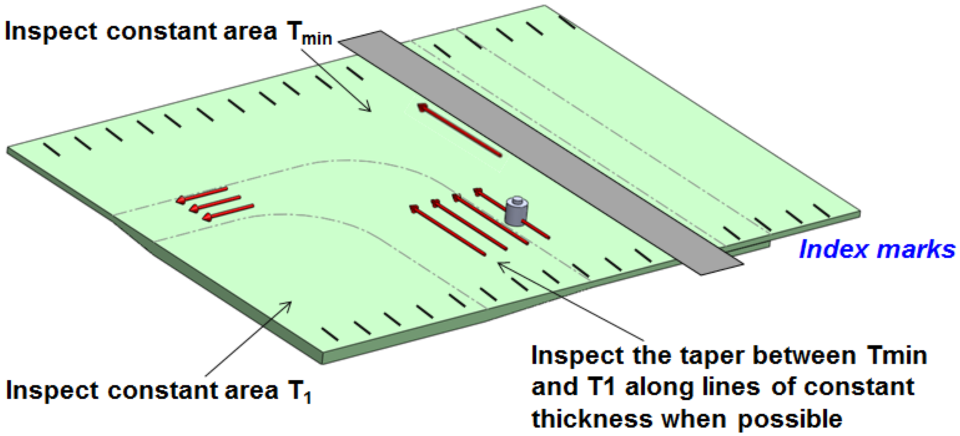


A-Scan, B-Scan, C-Scan

“Go” / “No-Go” Devices



Sizing Damge



Scan Indexing, Tapers and Substructure

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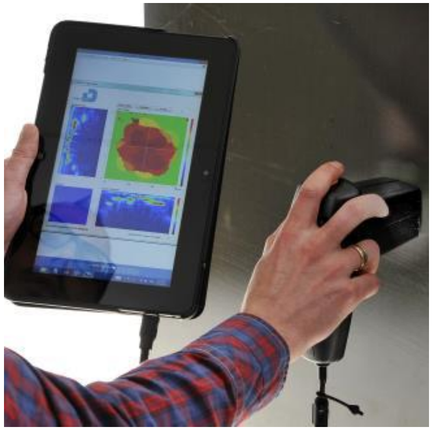
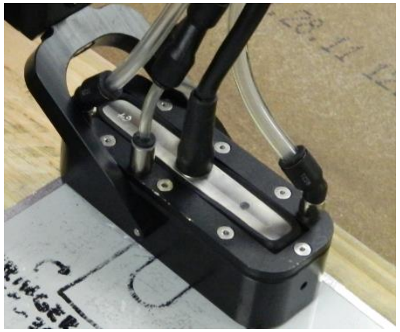
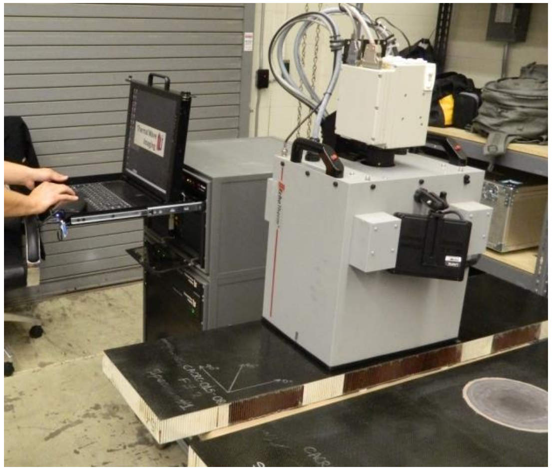
3. Composite NDI – Theory and Practice

Brief introduction and sample results from:

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







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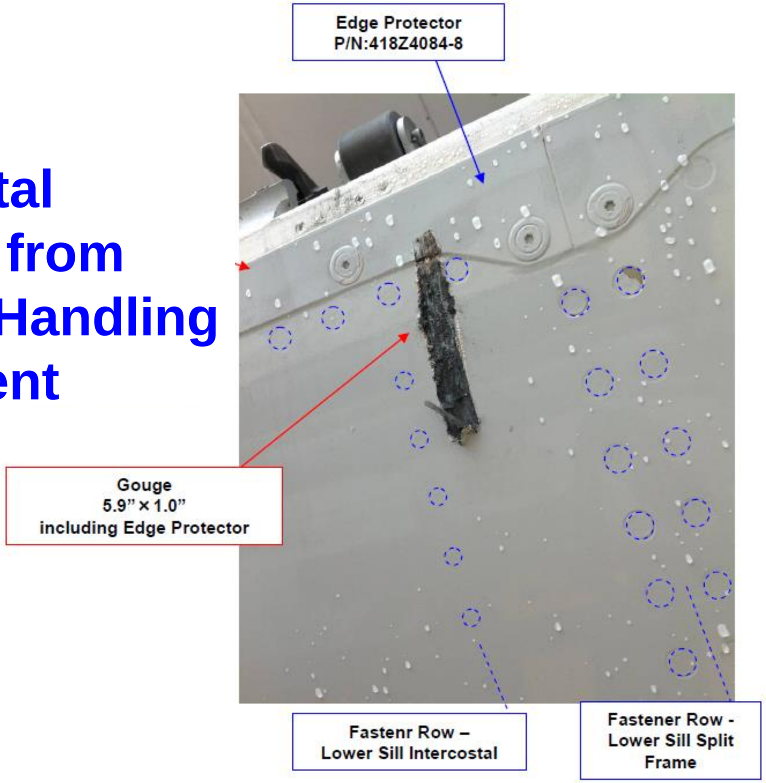
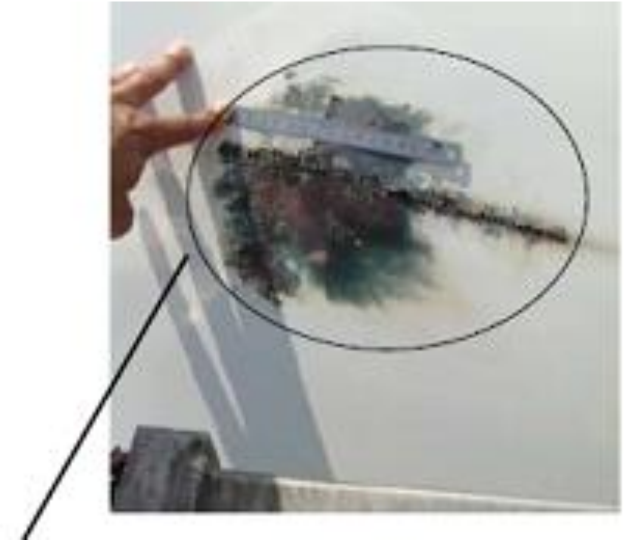
4. Special Cases – Challenges & Lessons Learned

- Examples of operational damage and field inspection results
- Read and Follow the Procedures
  - *Caution using saved settings*
- Embrace New Technology – It Can Be Helpful
- 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 needs and budget**
- **All lessons and teaching points will be encompassed in a limited number of panel configurations (minimize cost)**
- **Specimen geometry designed for ease of construction**

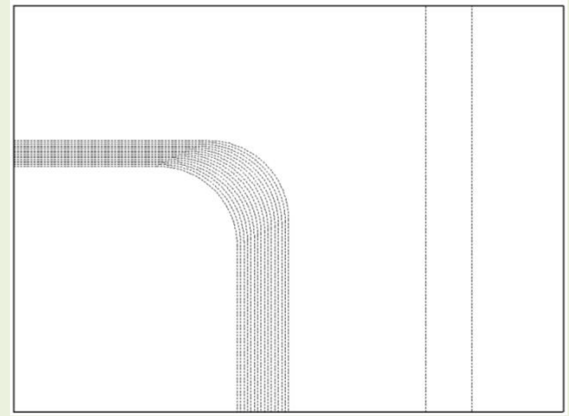
5. NDI Proficiency Specimens

Panel Configuration Summary - 8 total panels

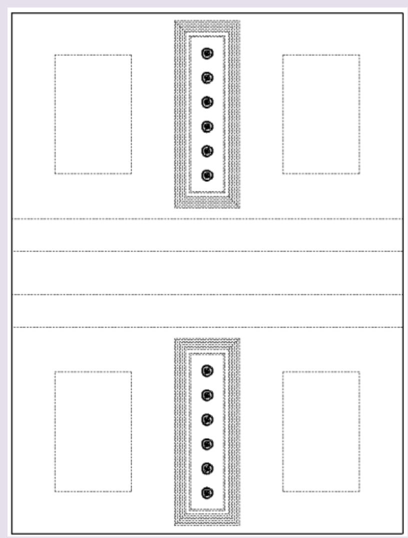
- Configuration 1 - 3 variations
- Configuration 2 - 2 variations
- Configuration 3 - 3 variations

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

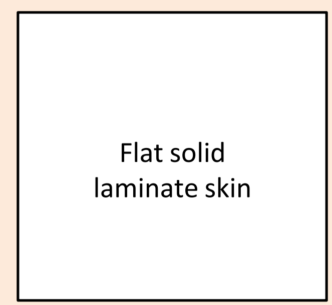
Configuration 1



Configuration 2



Configuration 3



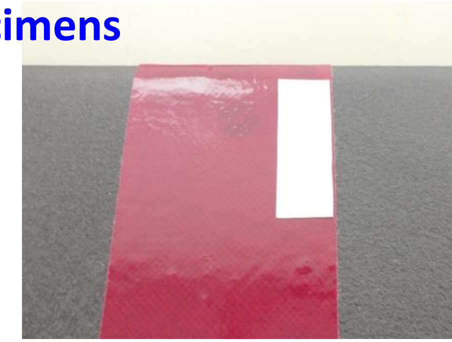
5. NDI Proficiency Specimens

Example Engineered Flaws in Proficiency Specimens

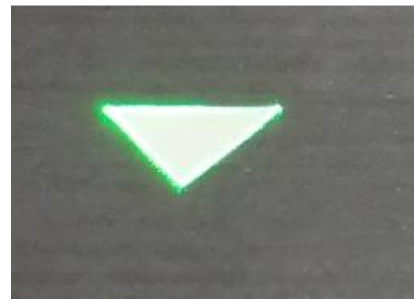
Embedded in the panels

Pillow insert
***Delamination**

Grease
***Contamination**

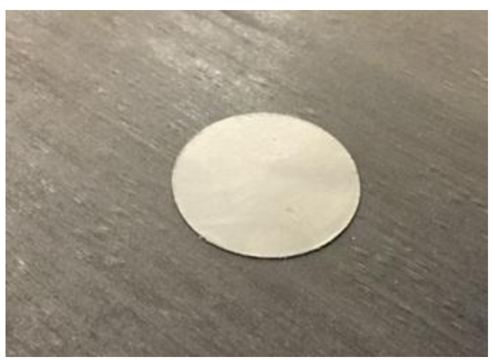


Paper Backing in the bond line
***Foreign object damage**

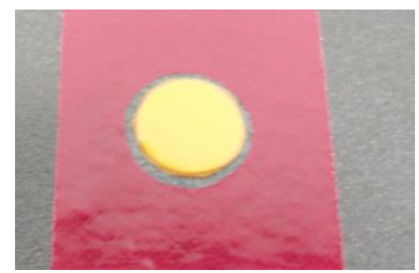


Paper backing in the laminate
***Foreign object damage**

Carbospheres
***Localized porosity**



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**

Grinder Cut
***Cracked or broken substructure**

Flat bottom holes
***Significant delamination**

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

Missing Sealant

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

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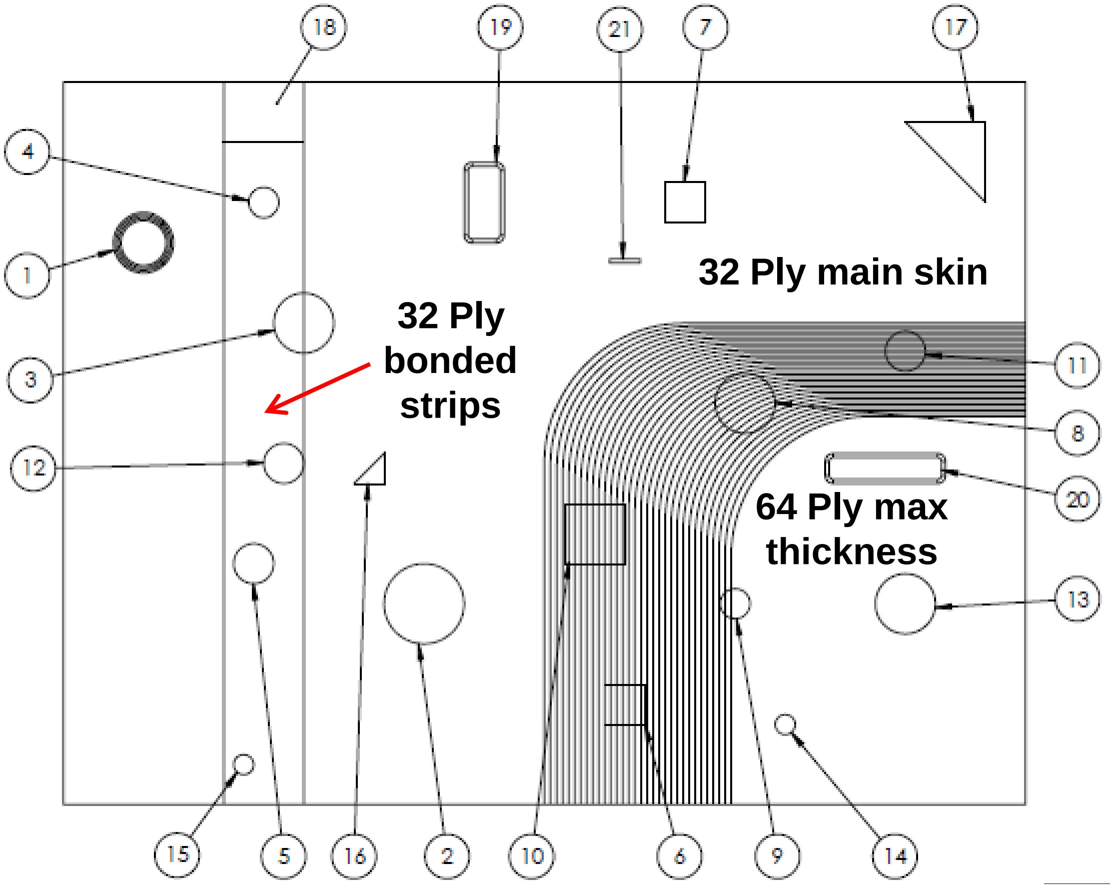
5. NDI Proficiency Specimens

Specimen Design 1c – Flaw Profile

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



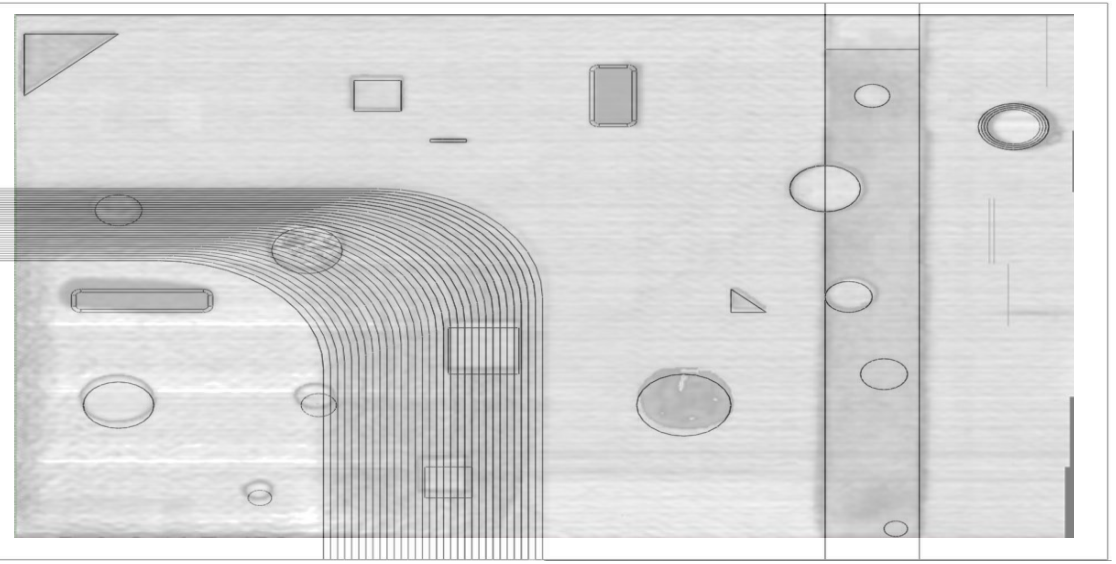
Fabrication support from *NORDAM Interiors and Structures*

Darryl Graham and Jeff Harper

5. NDI Proficiency Specimens

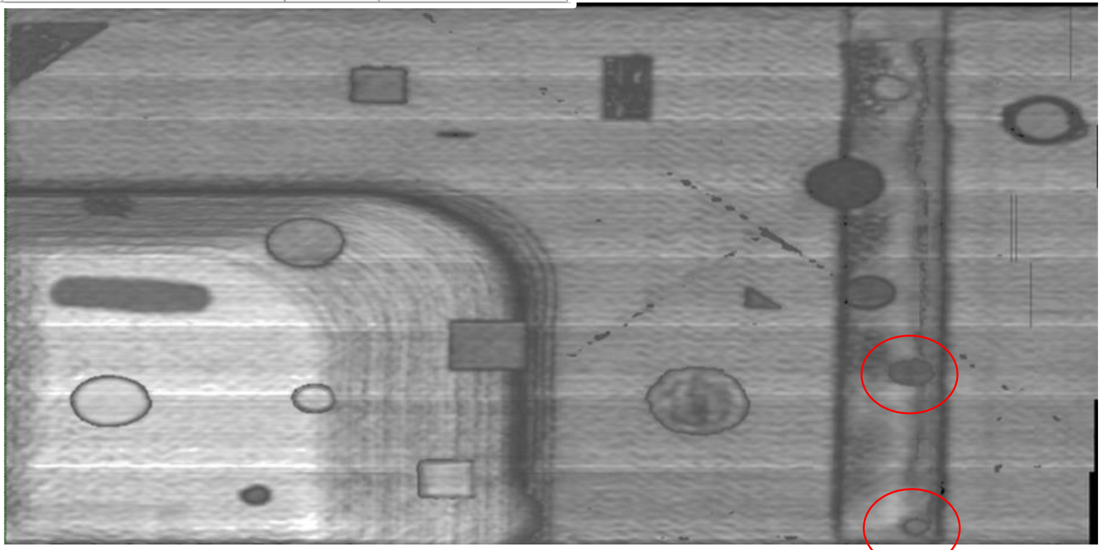
Specimen 1c – Inspection Results

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

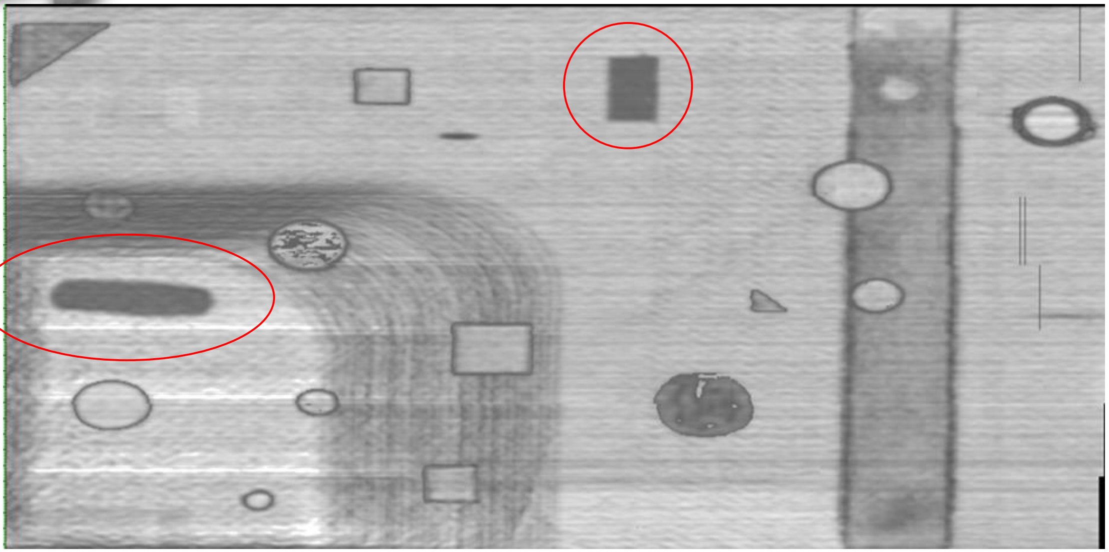


Teaching Points:

Follow procedures to set proper gates and detect second layer defects

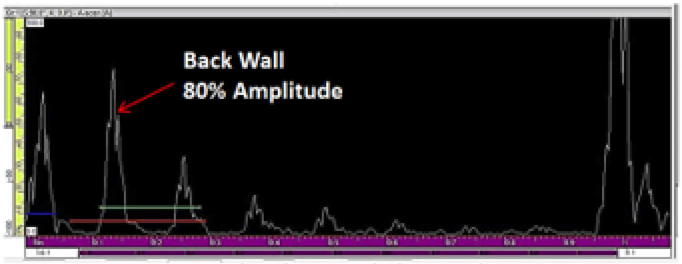


5. NDI Proficiency Specimens

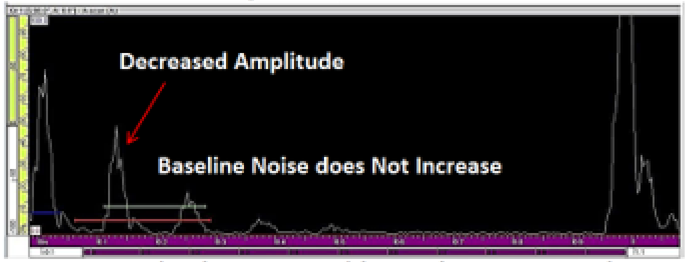


Teaching Points:

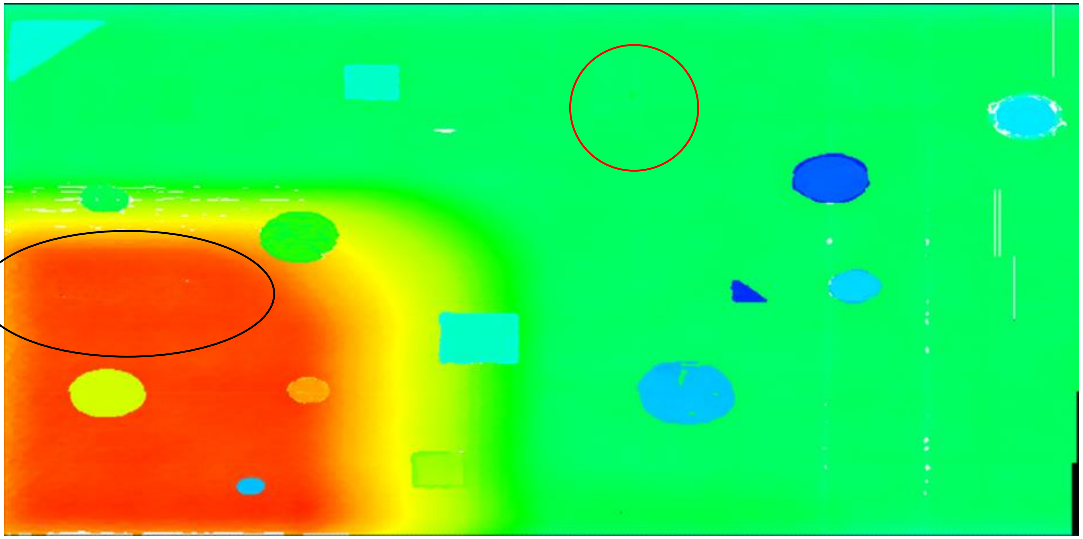
- **Defect detection using PA can require combination of Amp., TOF and A-Scan.**
- **dB drop criteria**



A-Scan Signal over Pristine Laminate



A-Scan Signal over Area With Sound Damper or Sealant



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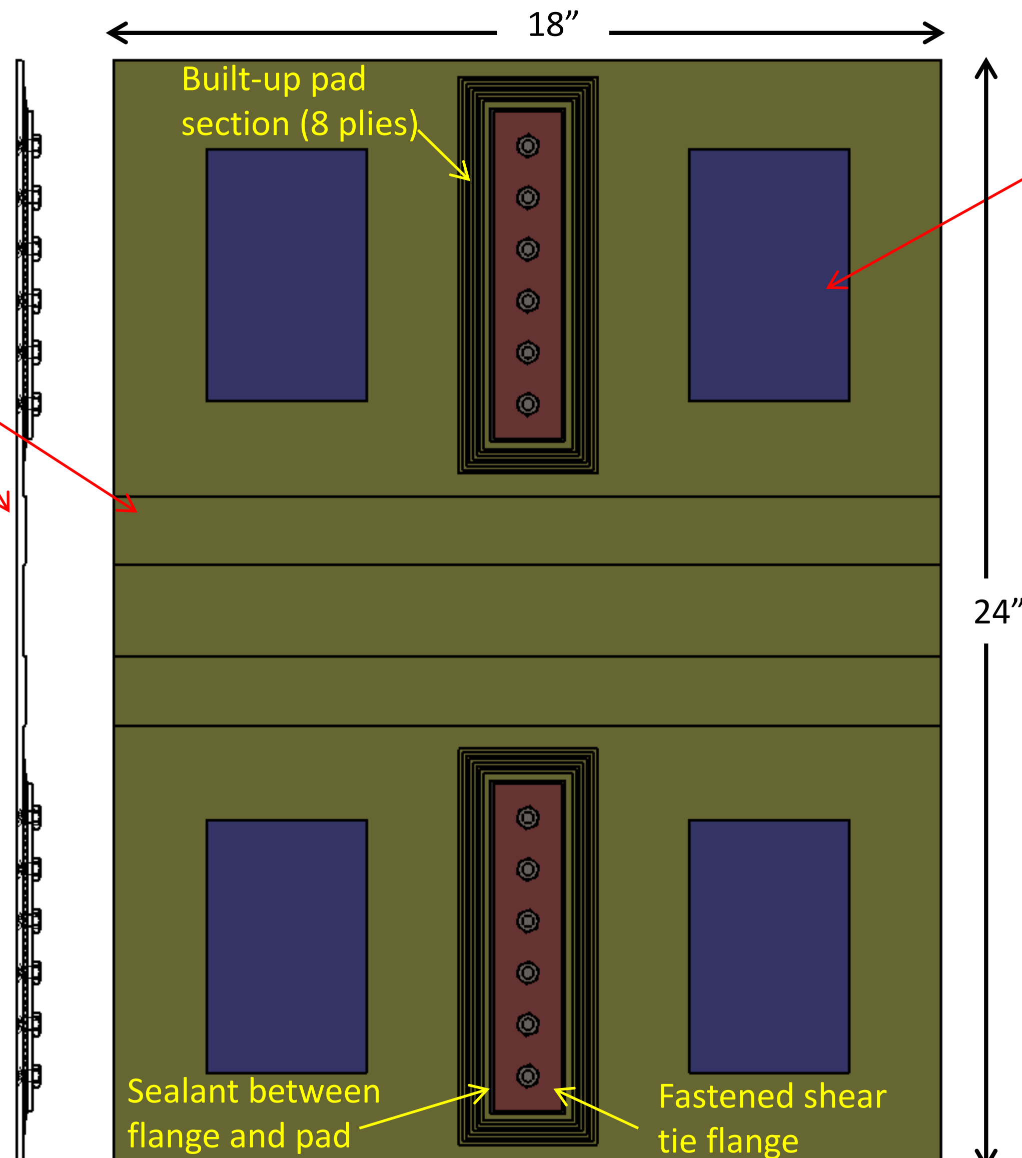
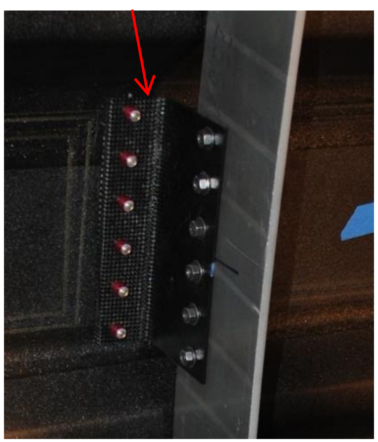
5. NDI Proficiency Specimens

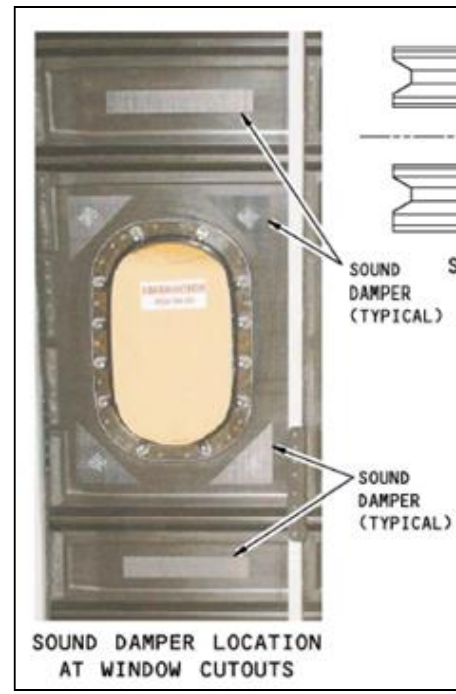
Configuration 2

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



Shear tie flange





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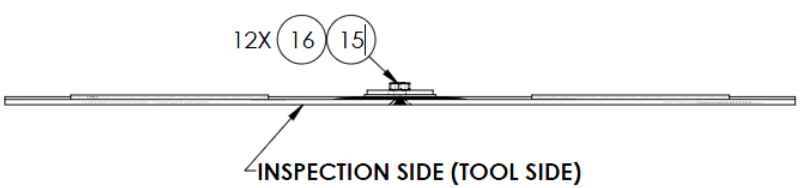
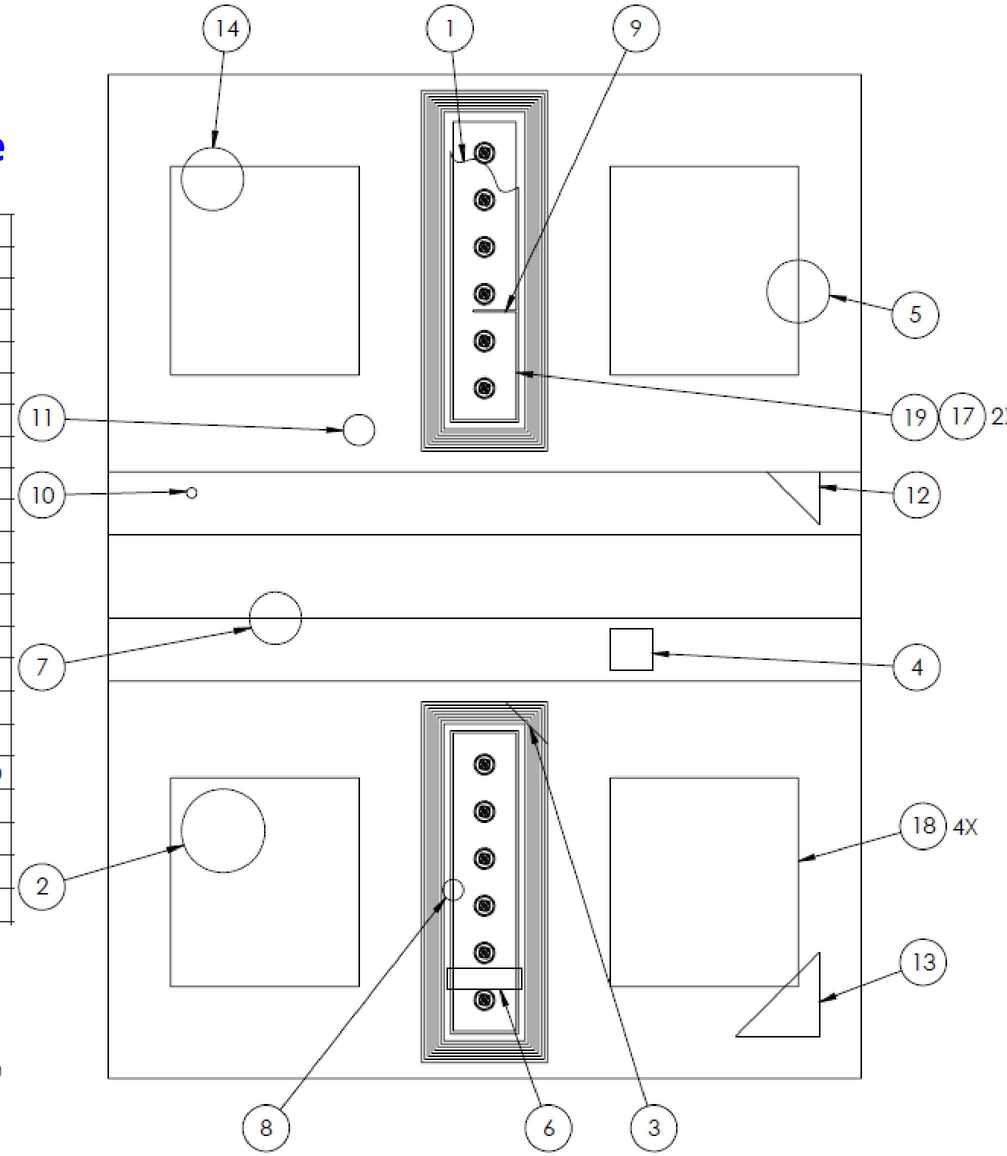
5. NDI Proficiency Specimens

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	





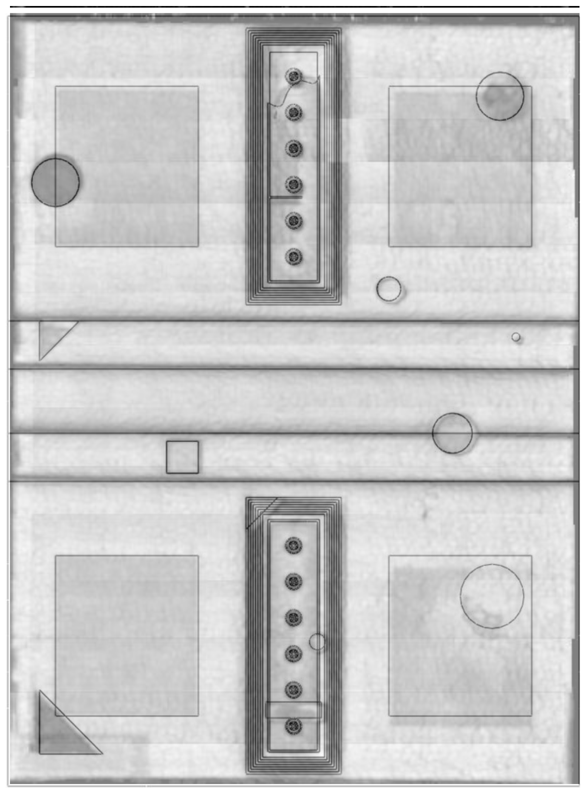
5. NDI Proficiency Specimens

Specimen 2a – Inspection Results

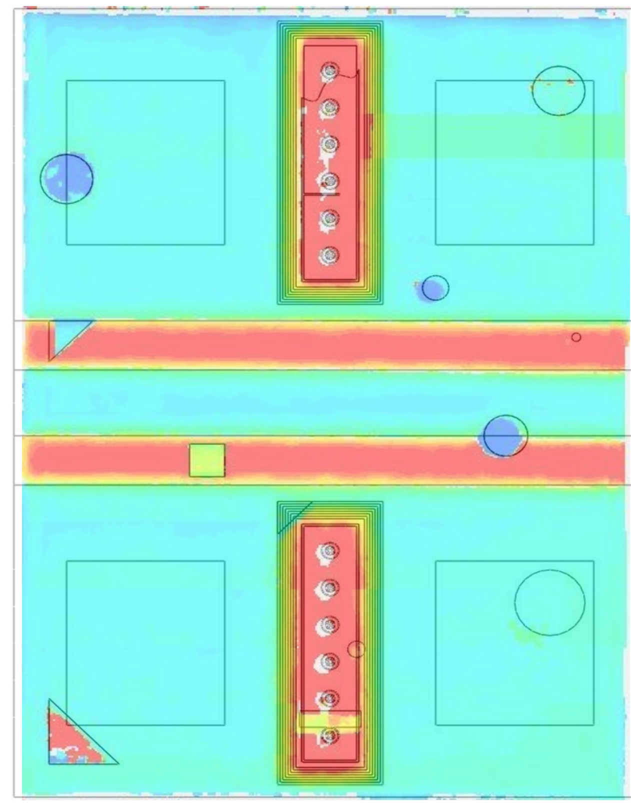
Structure: Uniform thickness skin, pads, fastened shear tie flanges, co-cured stiffeners, sealant

OmniScan 3.5L64 (3.5 MHz)

Back



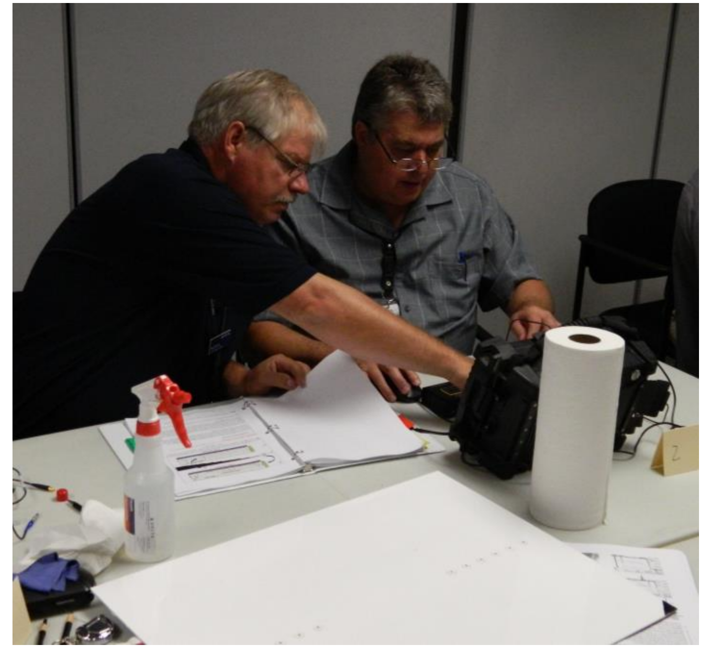
Amplitude



TOF

6. Hands-On Exercises

A-Scan Exercises	Panels
General A-Scan Inspection Procedure	All panels
1 - Calibration - Set Material Velocity and TCG Curve	Ref Std
2 - Mark substructure on surface	1a,1b,1c,2a,2b
3 - Defect detection in uniform thickness skin	1a,1b,1c,3a,3b,3c
4 - Defect detection in tapered skin	1a,1b,1c
5 - Inspection of bonded substructure	1a,1b,1c
6 - Inspection of co-cured substructure	2a,2b
7 - Defect detection around other aircraft elements	2a,2b



PA Exercises	Panels
General C-Scan Inspection Procedure	All panels
1 - PA Calibration	Ref Std
2 - Set up TCG Curve	ST8872
3 - Setting gates	All panels
4 - Analyzing C-Scan results	All panels

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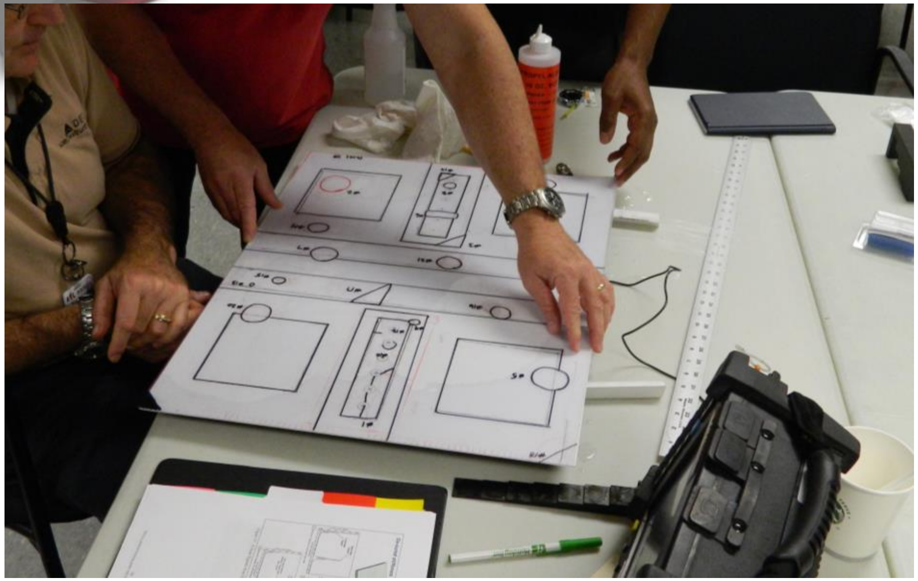
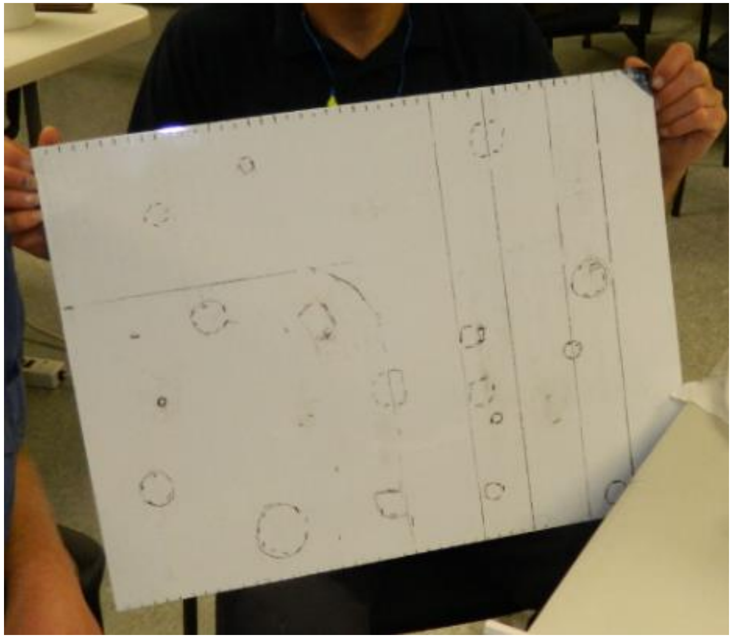
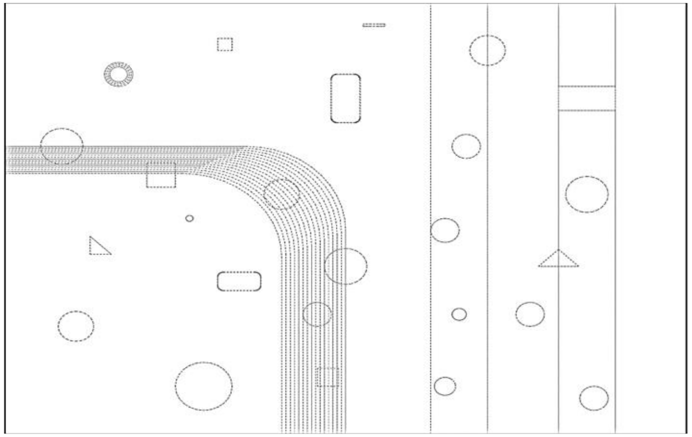
6. Hands-On Exercises





- Students follow inspection procedure and exercises to conduct inspections on the Proficiency Specimens
- Templates are used to check inspection results
- Immediate instructor feedback to identify hits, misses and false calls
- Markings on panel are compared to C-Scan inspection results



First Deployment of the Composite NDI Training Class - July 2016

- Conducted the class at Delta Air Lines
- 20 inspectors, engineers, and FAA participants
- Presented the full class and conducted hands-on exercises using the Proficiency Specimens

Feedback from the first class deployment:

- Helpful background on composite materials and NDI refresher
- TCG, inspection over acoustic tiles, C-Scan data analysis, set up and calibration of phased array transducer, new appreciation for setup files, immediate hit/miss feedback
- Comfort level increased

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Outcome and Path Forward

- Development of NDI training class is complete
- Successful completion of first class deployment with an airline
- Class will provide:
    - A general understanding of composite materials
    - An in-depth understanding of the nondestructive testing methods used to inspect carbon fiber parts
    - An overall inspection proficiency on composite aircraft parts made up of a variety of structural configurations
- Airlines/users customize for their particular needs

In the process of making the class materials available to the public:

- Class modules
- Proficiency specimen drawings and specifications
- Generalized A-Scan and C-Scan inspection procedures
- Hands-on exercises
- Grading and instructor materials

Questions?

If you are interested in obtaining the Composite Inspector Training materials, contact me:

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