ASNT | LEARN.

GROW YOUR KNOWLEDGE. GROW YOUR CAREER.

Welcome!
"NDT Applications" Webinar Series

December 16, 2021

Host: Flynn Spears

Alban NDE

SPONSORED BY Arcadia Aerospace Industries, LLC

www.arcadiaaerospace.com

asnt.org / learn

“Acoustography NDE and Its Use for UT of Aerospace Composites”

Presenters:

Jaswinder (Jas) S. Sandhu, SANTEC SYSTEMS, INC.

Ramona Bergó Soto, Arcadia Aerospace Industries, LLC.

Dr. Jaswinder “Jas” Singh Sandhu

Founder and Owner

Santec Systems Inc.

Ramona Bergó Soto

Materials Specialist & Quality Manager

Arcadia Aerospace Industries, L.L.C.

SANTEC SYSTEMS INC.

Arcadia Aerospace INDUSTRIES, LLC

Acknowledgement

This work was supported in part by:

US Army Research Laboratory

Contract: W911QX-16-C0027

Army Project Lead: Mr. Charles J. Pergantis

Agenda

1. Introduction
2. PART 1

    2.1 Quick review of traditional of UT methods

    2.2 Fundamental Principles of Acoustography NDE method

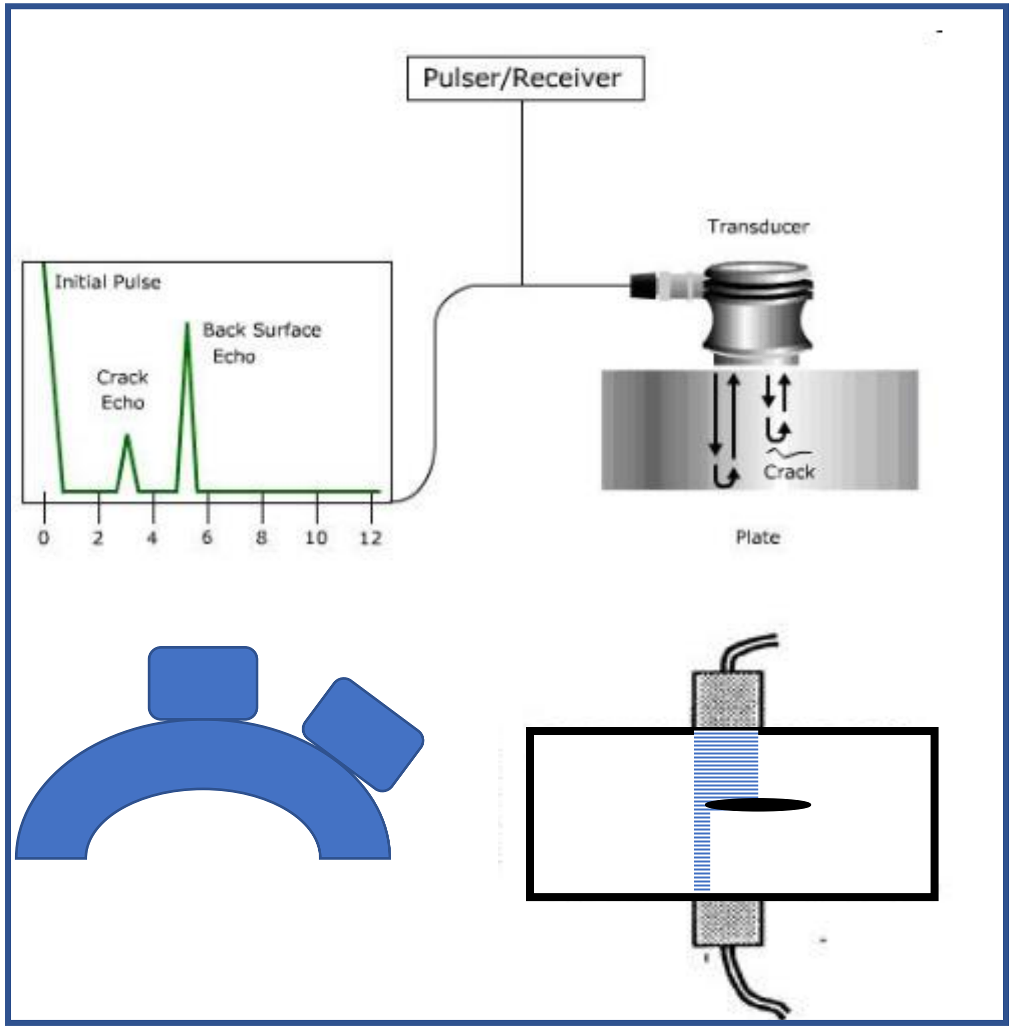
3. PART 2: Case Study- "UT of Small Composite Parts"

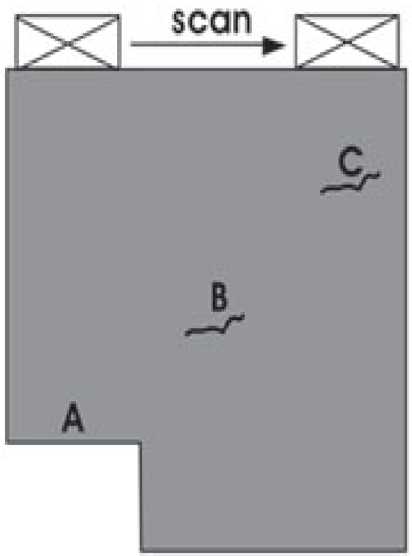
Introduction

- Acoustography NDE
  - Alternative to the traditional point-by-point UT
  - like radiography, uses **large area ultrasound detector screen (**AO sensor) to form instant “x-ray like” ultrasound images
- Acoustography NDE Principles (Part 1):
  - Physical Principles;
  - Geometrical & Contrast resolution;
  - Ultrasonic Inspection Process.
- Acoustography NDE of “small” Composites- Case Study (Part 2):
  - “Small” composite UT Challenges.
  - Acoustography NDE Solution.

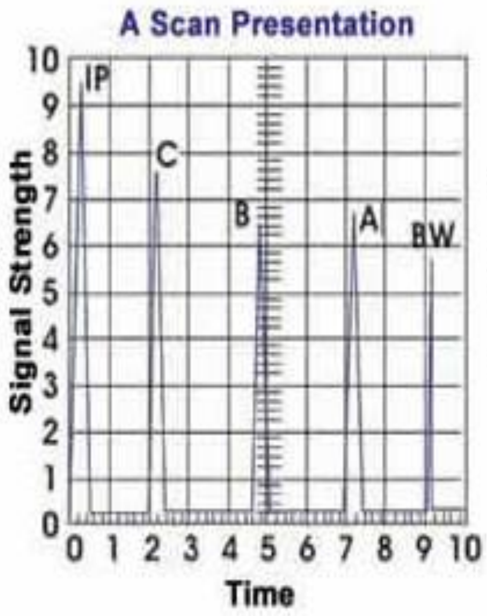
PART 1
Acoustography NDE Principles
by
Jaswinder S. (Jas) Sandhu
Santec Systems, Inc.

Traditional UT Method

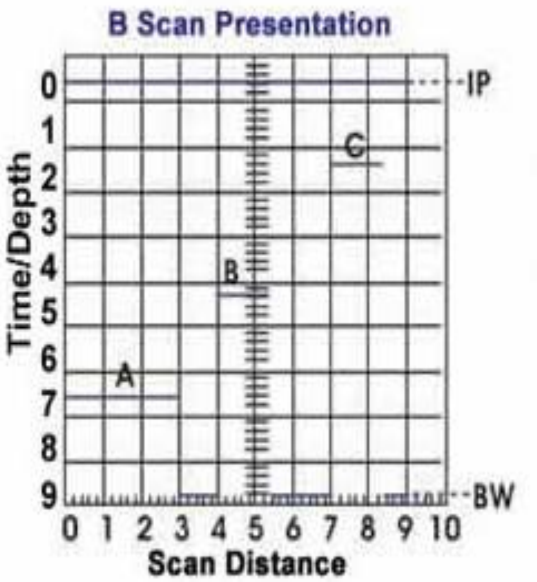




Transducer scanned

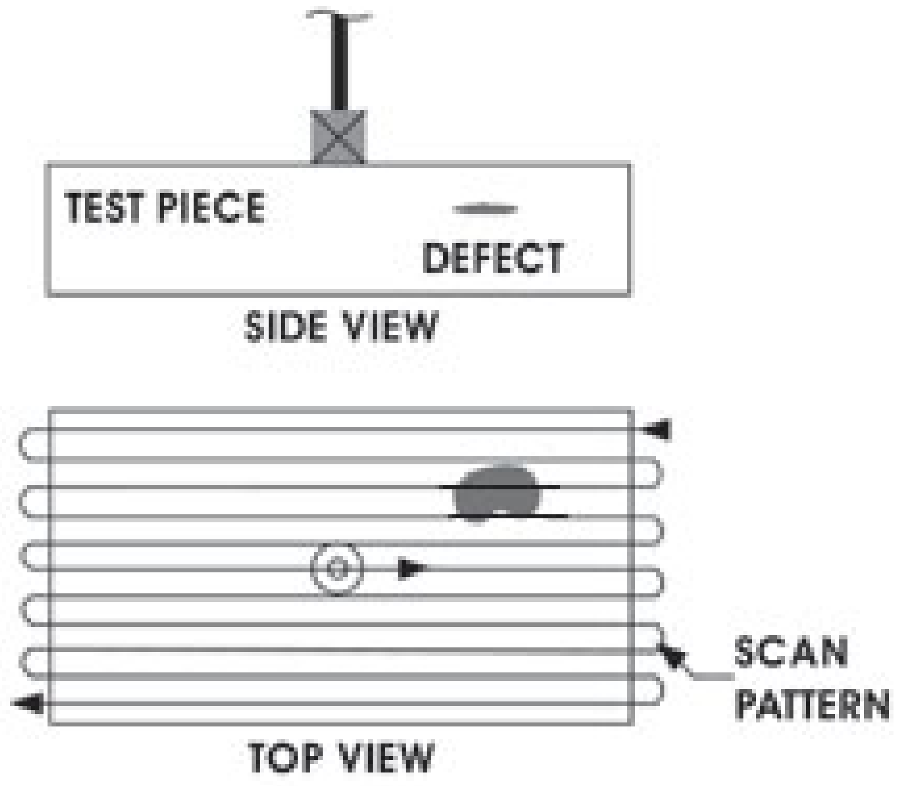


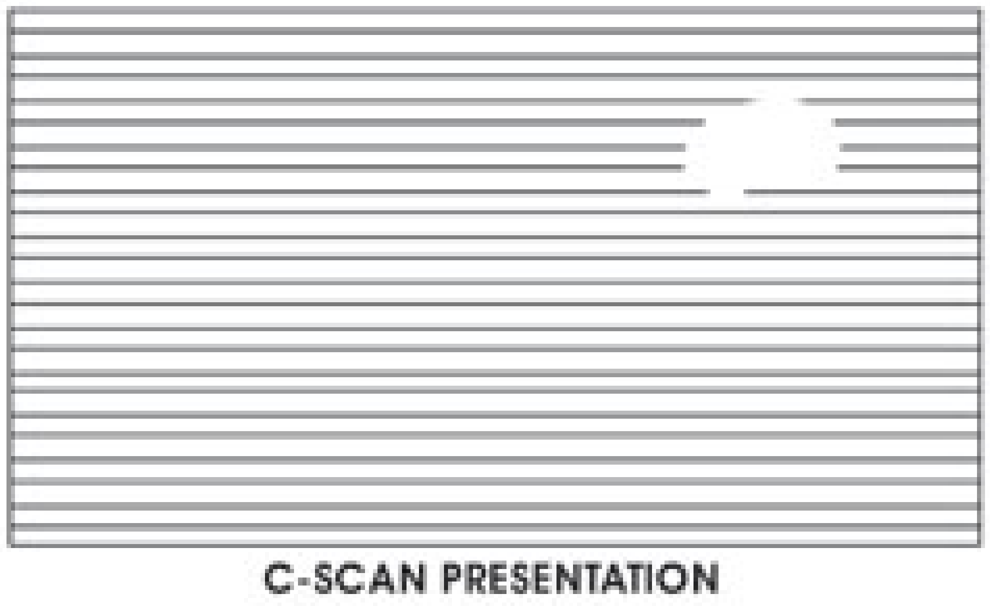
A-Scan showing IP and echoes from A,B,C & BW



B-scan showing echo travel time (cross-sectional view)

UT Methods – C-Scan Data Presentation

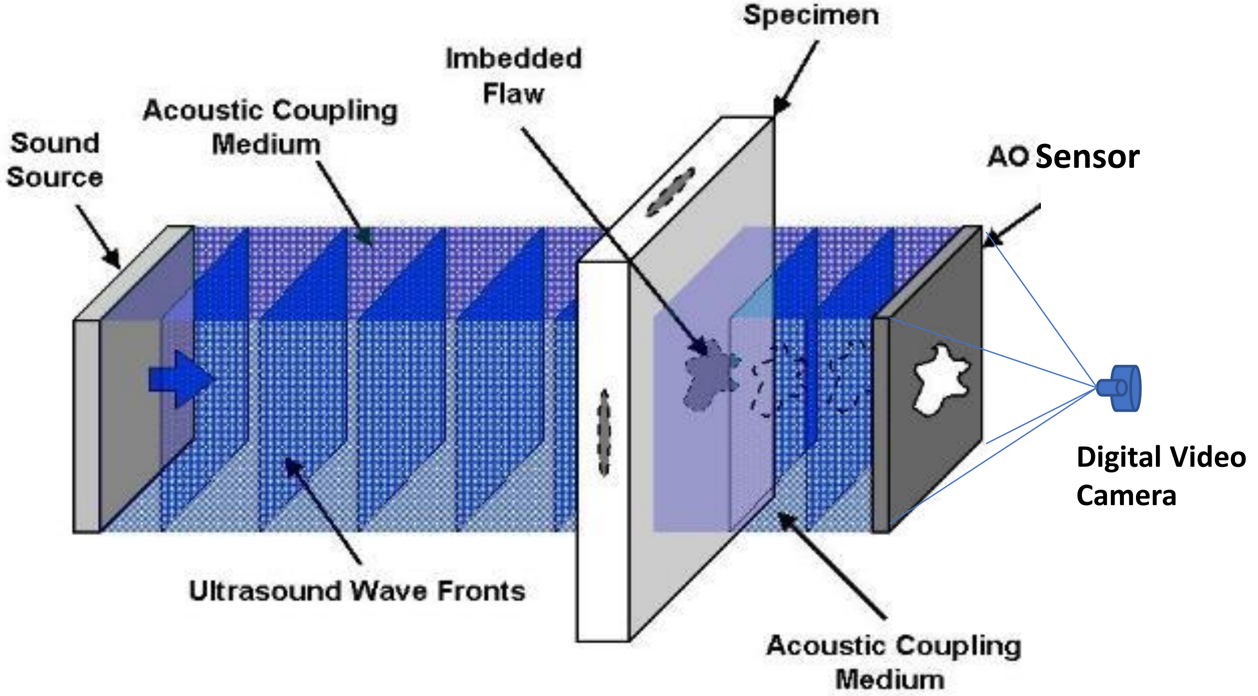




Transducer scanned point-by-point in pulse-echo mode

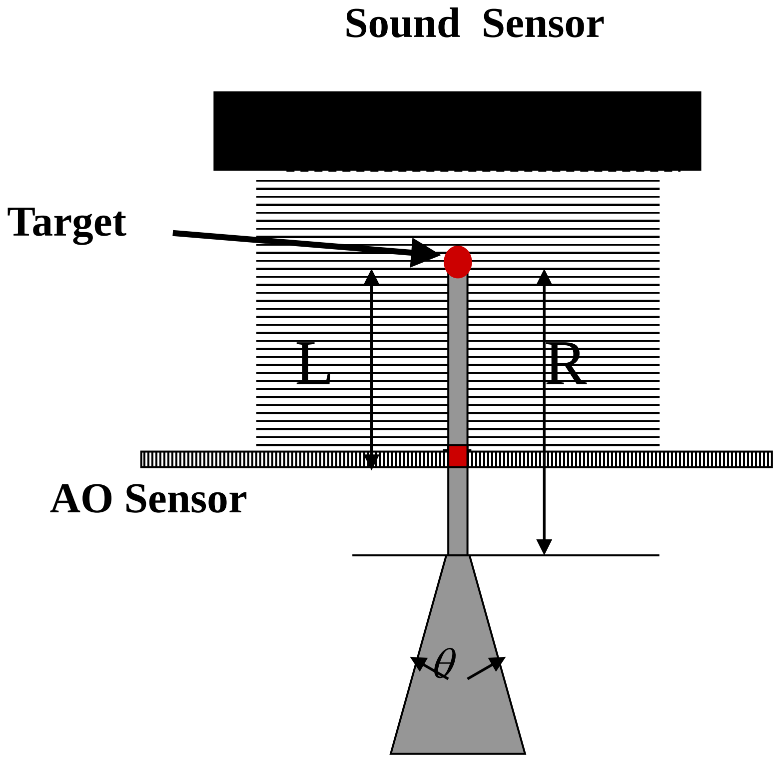
C-Scan is a 2D image of the scanned area, lateral resolution depends on Transducer indexing steps.

Acoustography NDE – Image Formation Principle



1. Sound Source (Transducer) illuminates Test Specimen with Ultrasound Waves.
2. Ultrasound Waves are “Differentially Attenuated” as they propagate through the Test Specimen and cast an “X-ray like” 2D Ultrasound image on the AO Sensor (Detector Screen).
3. AO Sensor converts the 2D Ultrasound image into corresponding visual image.
4. Digital video camera acquires the 2D visual image on the AO Sensor for computer storage and image enhancement.

Acoustography NDE – Geometrical Resolution



Near Field Diffraction Length (Ref. 1)

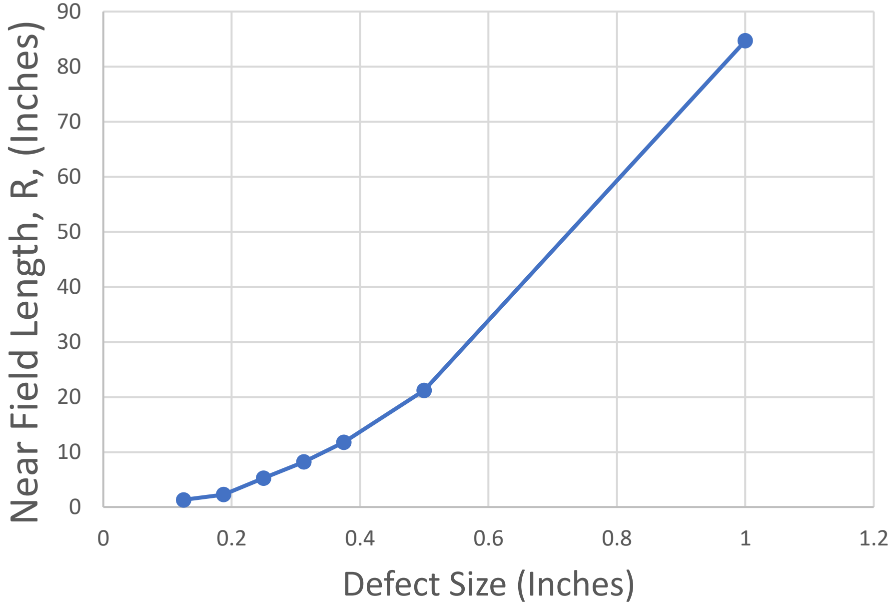
$$R = D^2/\lambda$$

D= Target (Defect) Diameter
λ = wavelength in medium

Beam Divergence Angle (Ref.2)

$$\mathrm{Sin}(\theta/2) \sim \lambda/D$$

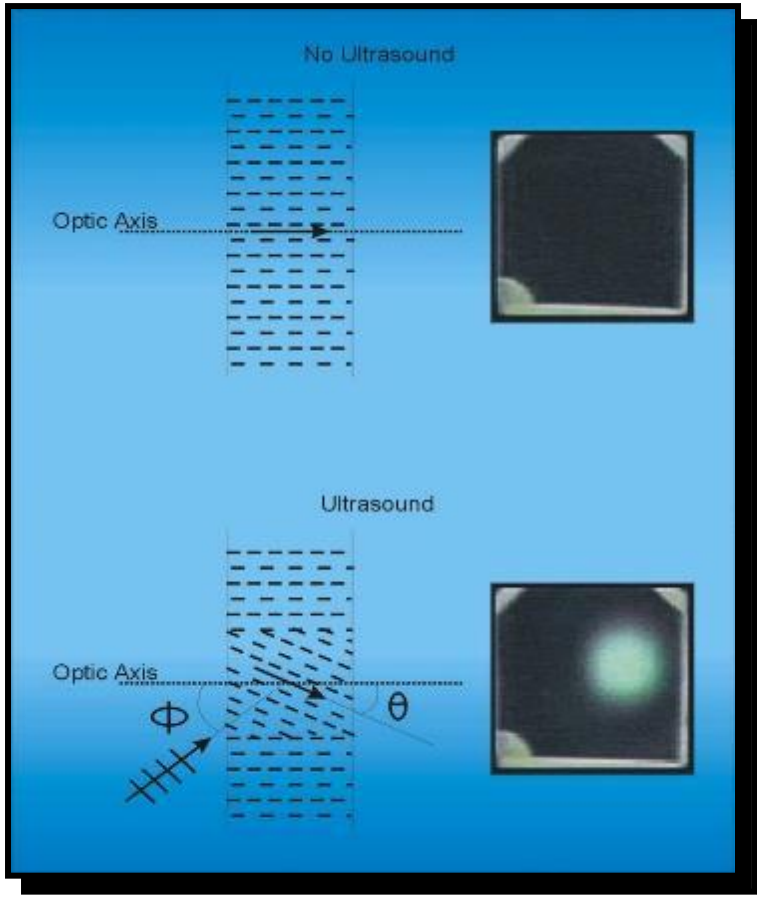
- L<R - Defect Shape recognizable
- L>R -Defect Shape deteriorates

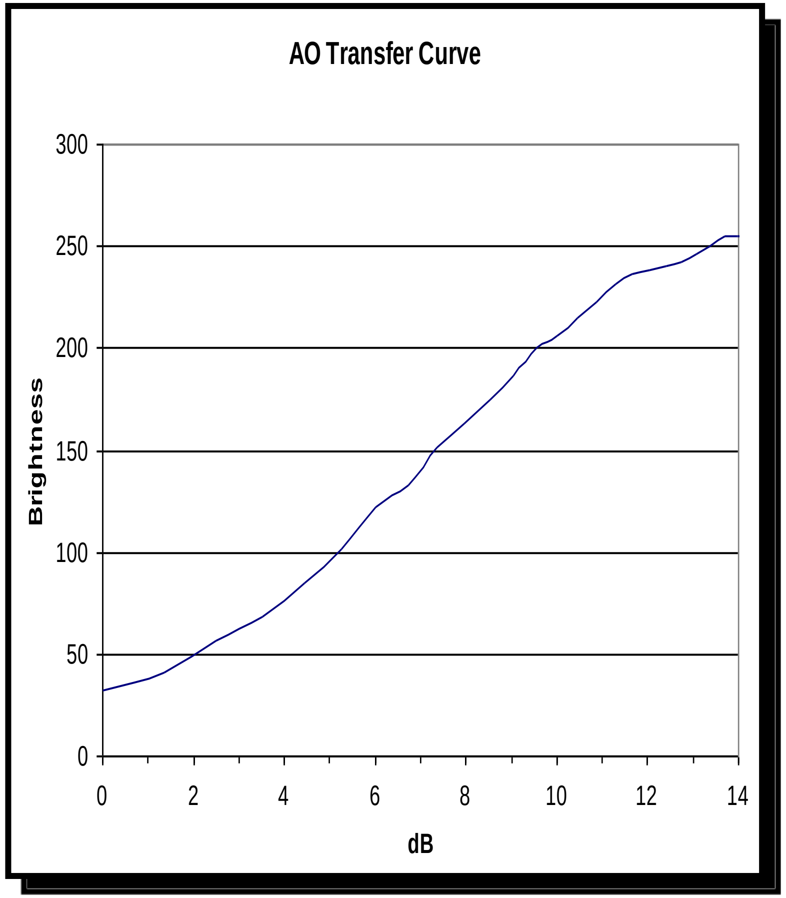


Ref. 1- Hecht, "Optics," 2nd Ed., Pub. Addison Wesley, 1987, pp. 396.
Ref. 2-ASNT, NDT Handbook, 2nd Ed., Vo. 7 "Ultrasonic Testing,"pp831.

Acoustography NDE – AO Sensor (Detector Screen)

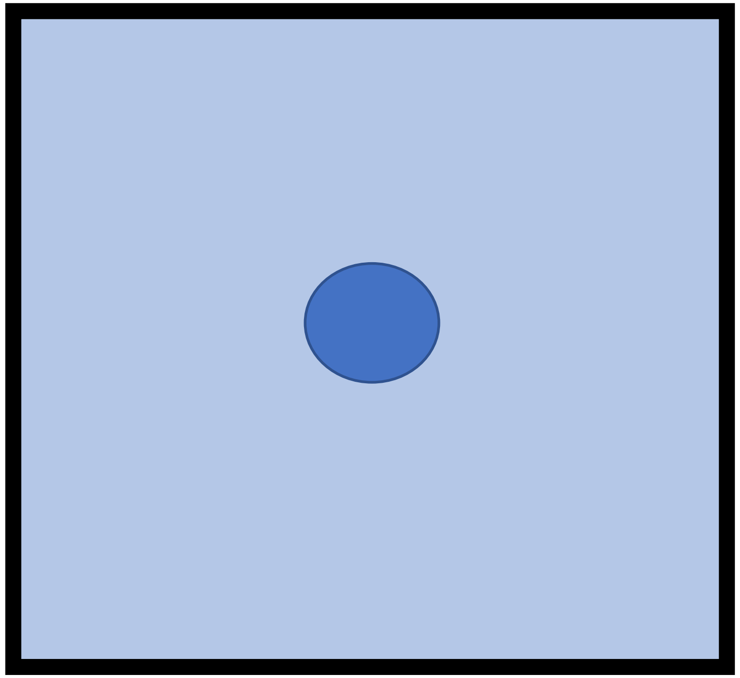
How it Works & Contrast Resolution



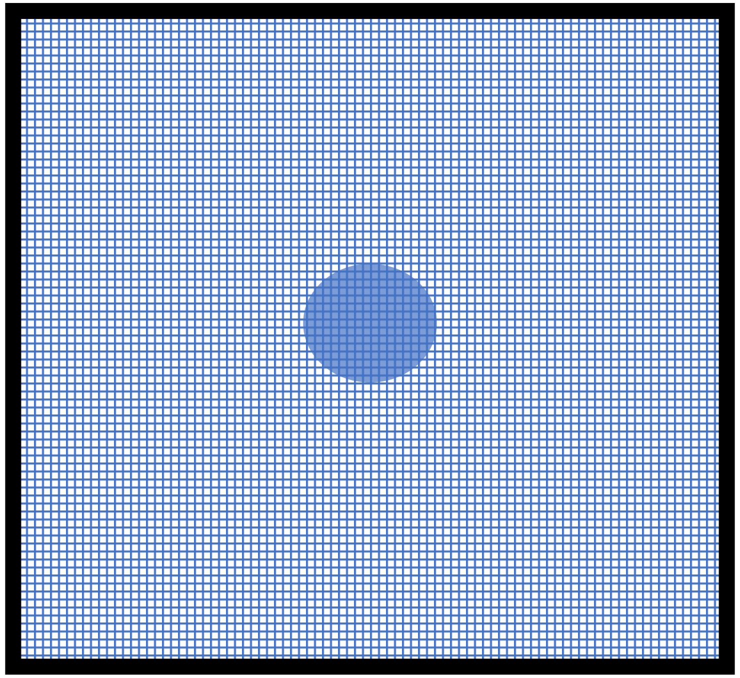


1. Acousto-Optic (AO) Sensor contains a layer of proprietary LC material that shows a brightness change when exposed to ultrasound.
2. Brightness level is related to the Ultrasound level; see AO transfer curve.
3. Differential Attenuation between flaw and normal area is converted to a visual (optical) image according to the AO transfer curve.
4. Digital video camera acquires the image formed on the AO Sensor for computer storage and image enhancement.

Acoustography NDE – AO Sensor (Detector Screen) Pixel/Lateral Resolution



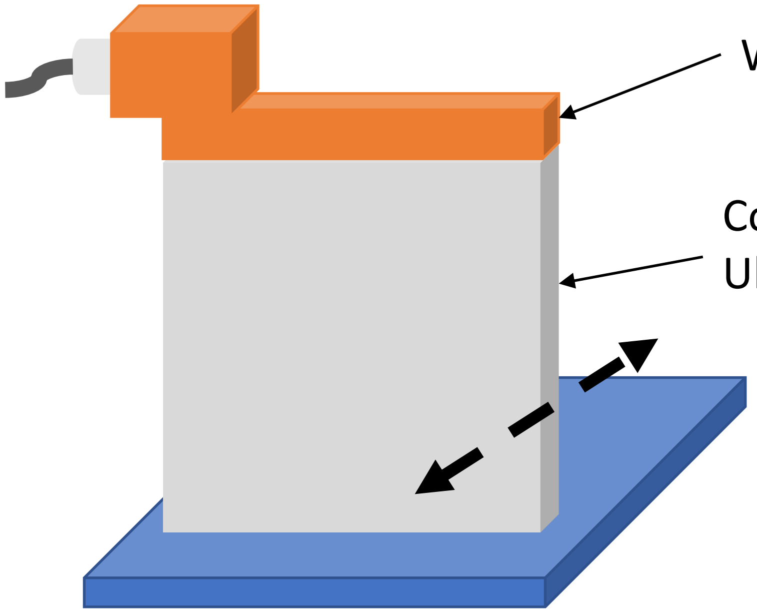
AO Sensor Resolution: Photographic Film like because LC layer detector molecules are ~20 Angstrom in size



When viewed by Digital Camera, AO Sensor resolution depends on pixel resolution of the Digital camera (See Table).

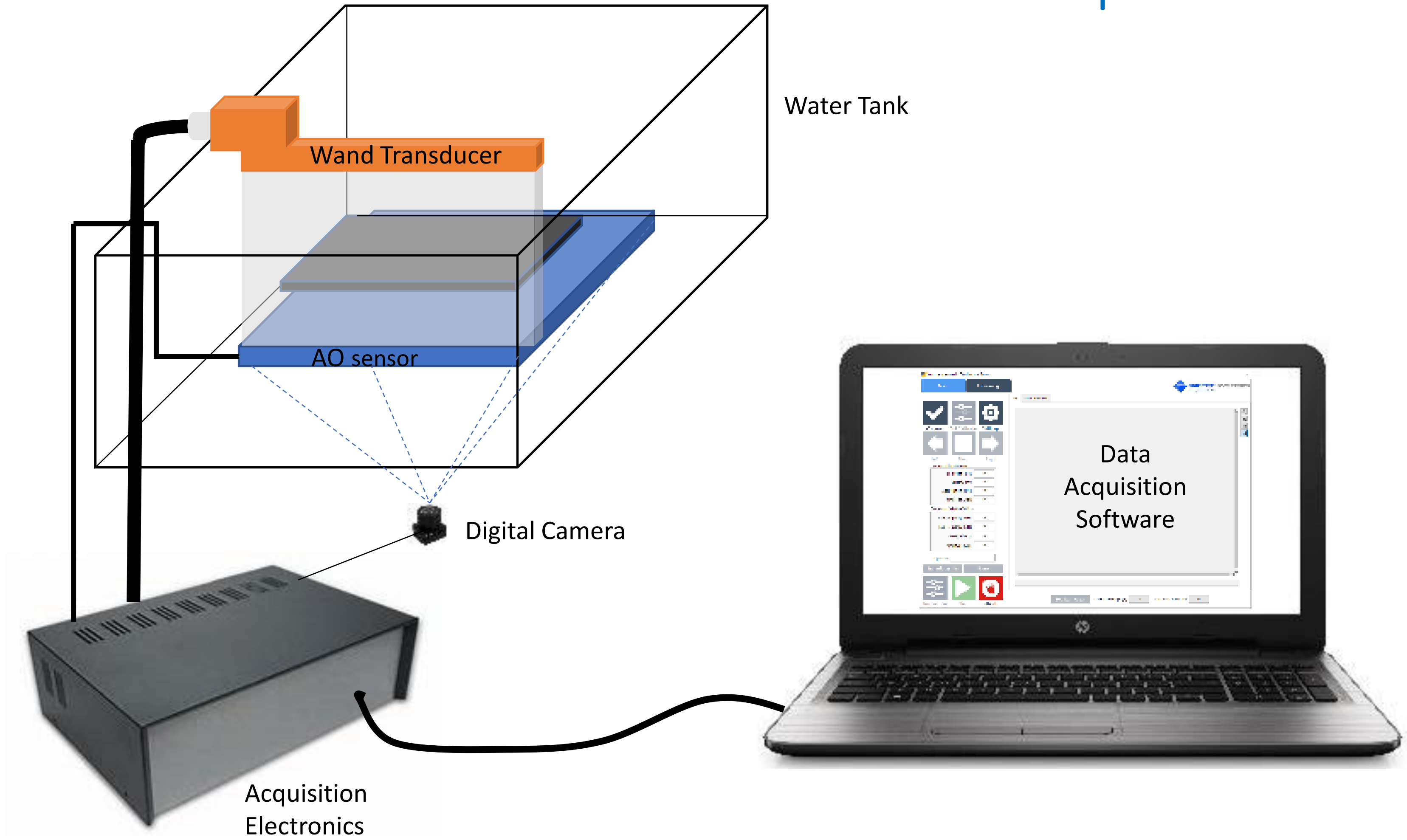
AO Sensor Image Area	Resolution with 1216x912 Camera (1Megapixel)
6”x6” (152mm x152mm)	0.0065 to 0.005 in/pixel (0.166 to 0.125 mm/pixel)
12”x12” (305mmx305mm)	0.013 to 0.01 in/pixel (0.332 to 0.25 mm/pixel)

Acoustography NDE – Sound Source
Wand Transducer



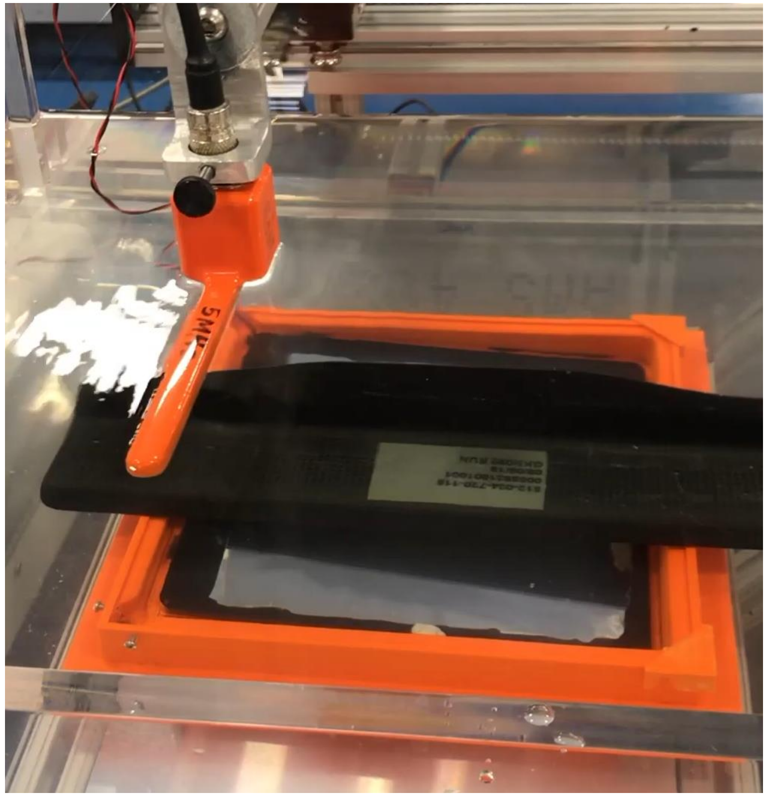
1. Wand transducer radiates a collimated, rectangular ultrasound beam.
2. Transducer is swept across the AO sensor width to generate images.
3. Image on the AO sensor is continuously acquired by a digital camera as the Wand transducer sweeps across AO sensor.

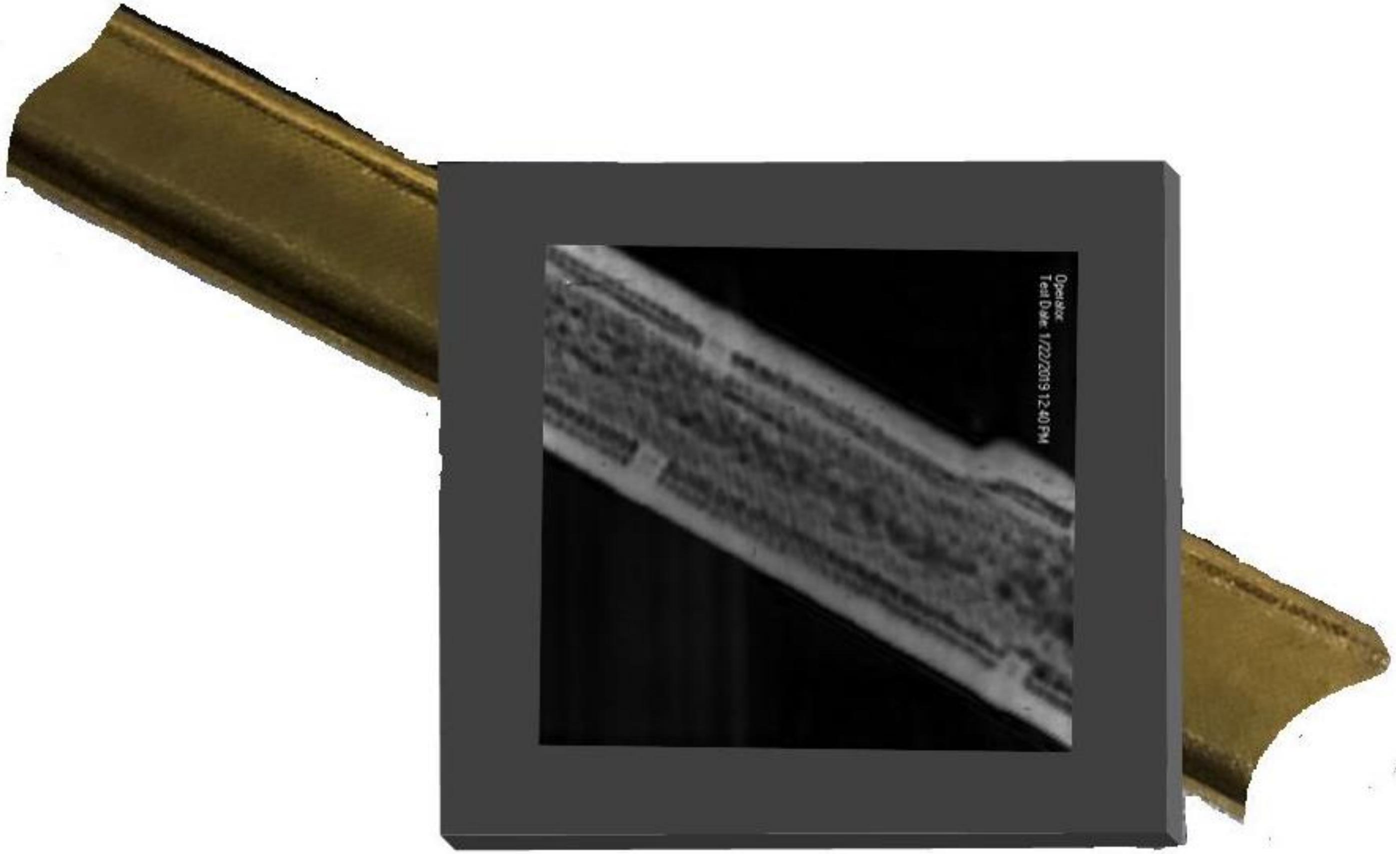
Acoustography NDE – Inspection Process
Data Acquisition



1. Test Part is held above the AO sensor.
2. Wand transducer is powered on and swept across the test part by DAS (Data Acquisition Software).
3. DAS acquires image generated on the AO sensor with a Digital camera.
4. AO sensor reset using an E-field for next part or area to be imaged.
5. Steps 1 through 4 repeated until entire part has been imaged.

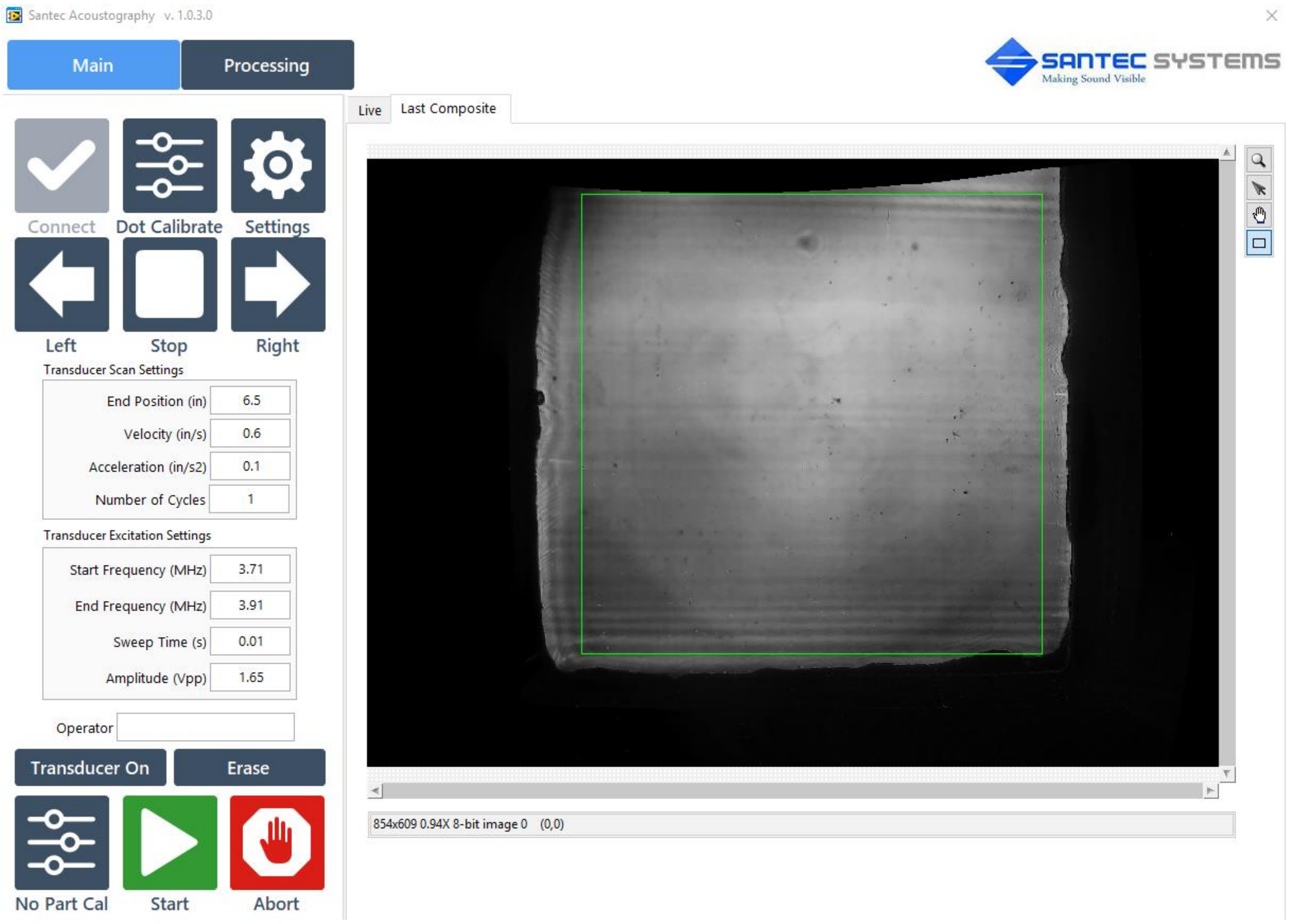
Acoustography NDE – Instant Ultrasound Image generated on AO Sensor (Detector Screen)





Acoustography NDE - Data Acquisition & Analyses-User Interface

Main Menu

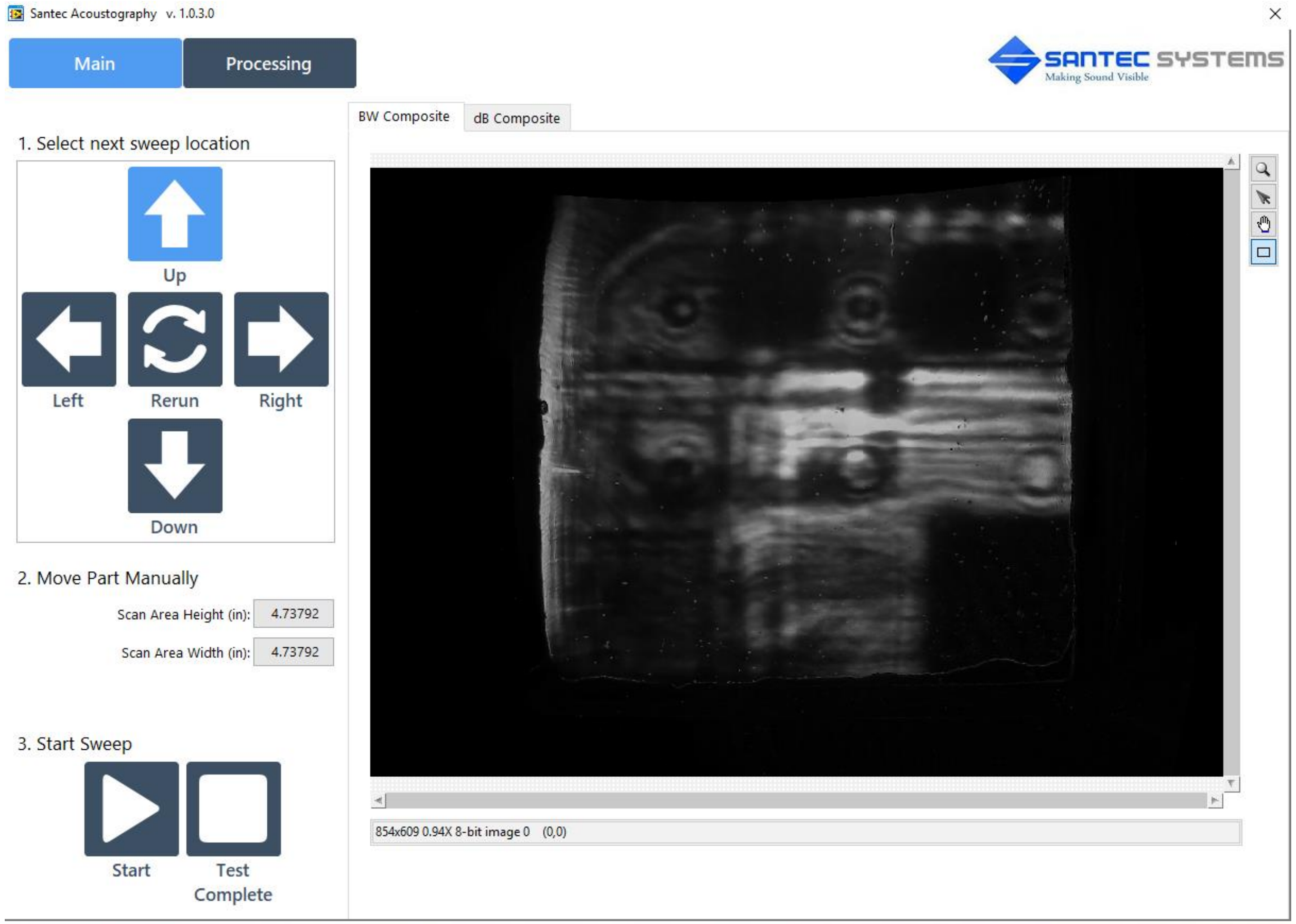


Main Menu

Allows operator to input all the test parameters, e.g. Wand transducer frequency, power, sweep limits, sweep speed, etc.

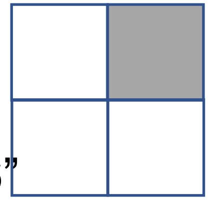
Acoustography NDE - Data Acquisition & Analyses – User Interface

Second Menu

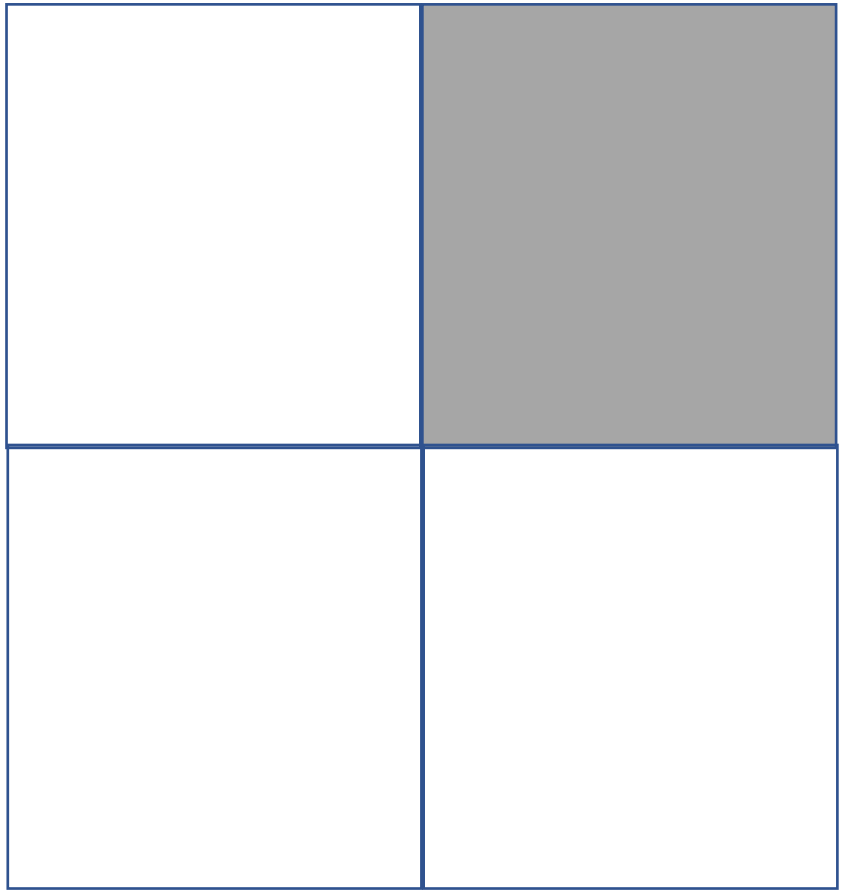


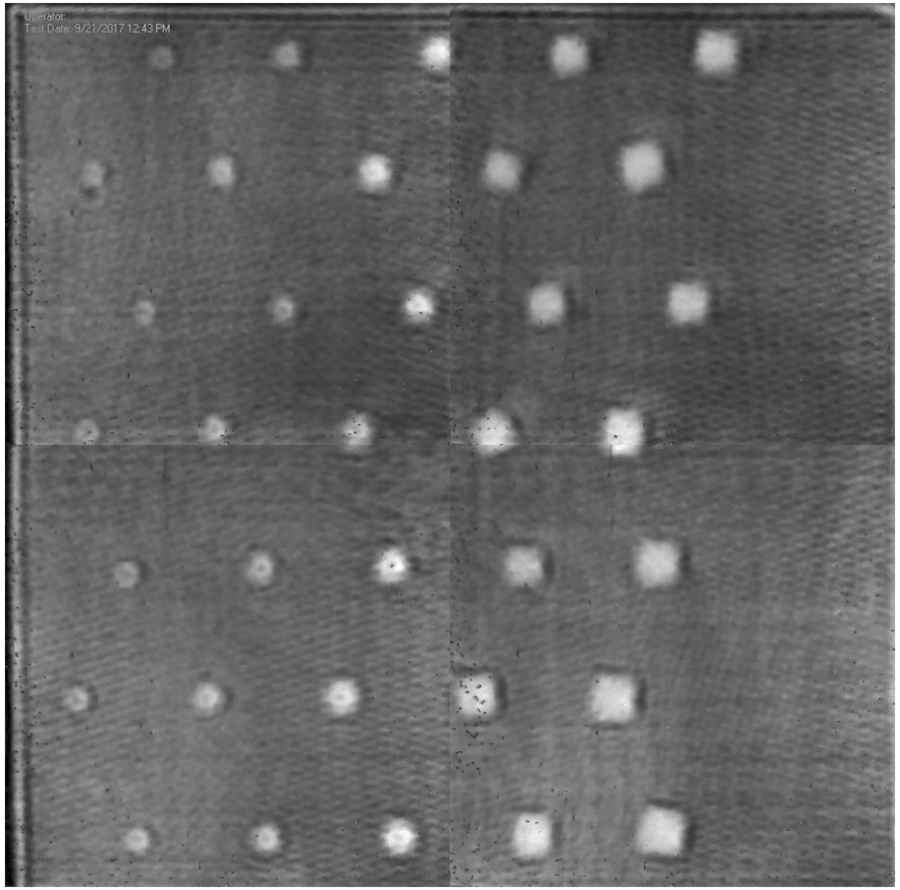
Second Menu

1. Shows the acquired image, which is processed using SSI Algorithms and various other tools.
2. Images can be stitched contiguously, by moving the part in 6” indexing steps; 6”x6” images stitched in a Matrix (See Next Slide).

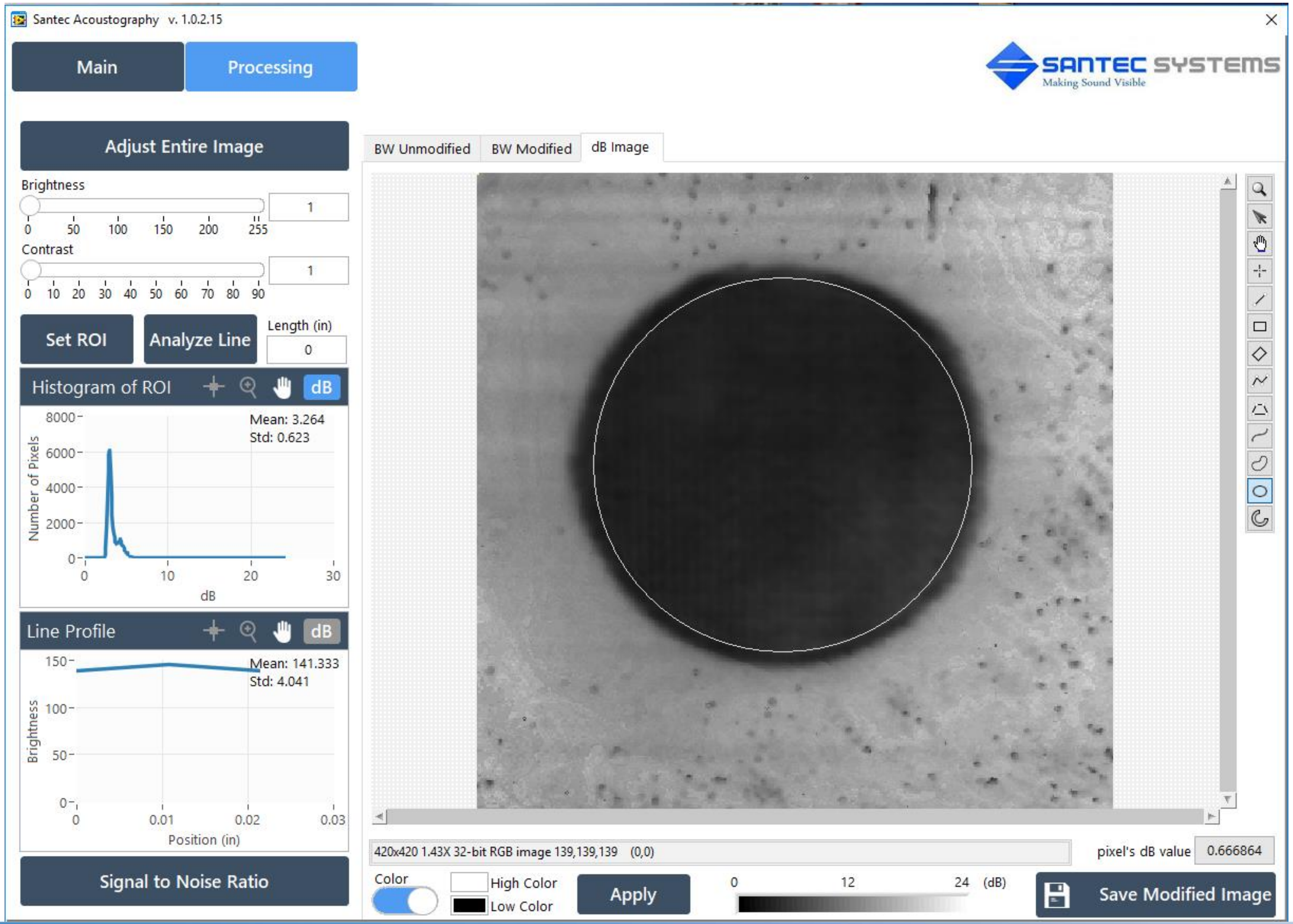


Acoustography NDE - Data Acquisition & Analyses – User Interface
Second Menu - Example of Stitched Image





Acoustography NDE - Data Acquisition & Analyses – User Interface
Third Menu



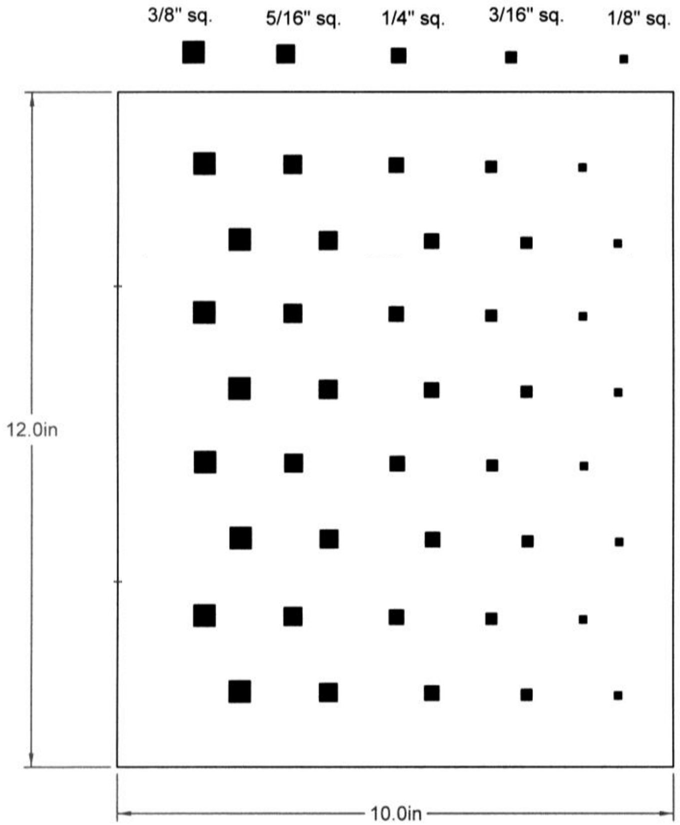
Third Menu

1. Allows operator to convert images into quantitative dB images, color coded or gray scale.

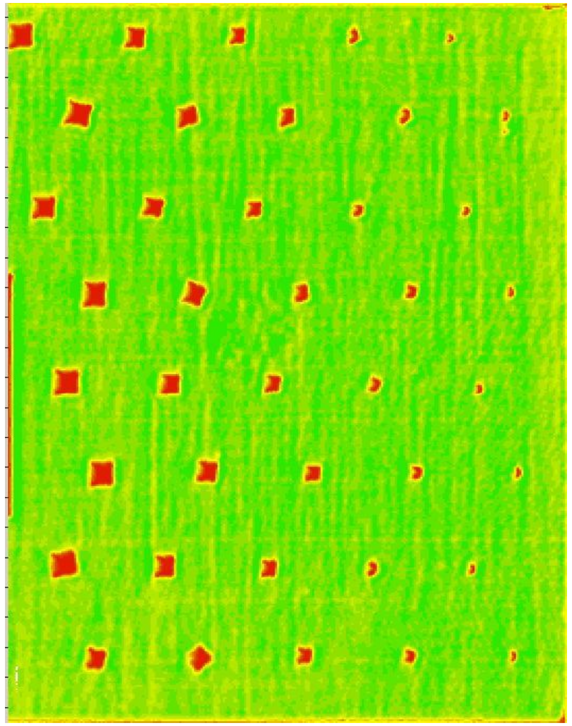
2. Measurements and analyses can be performed, e.g. SNR, dB variation, thresholding, etc.

Acoustograhpy NDE - High Resolution & Detection Sensitivity
NDE of 1/8" Thick Aerospace Flat Panel Standard

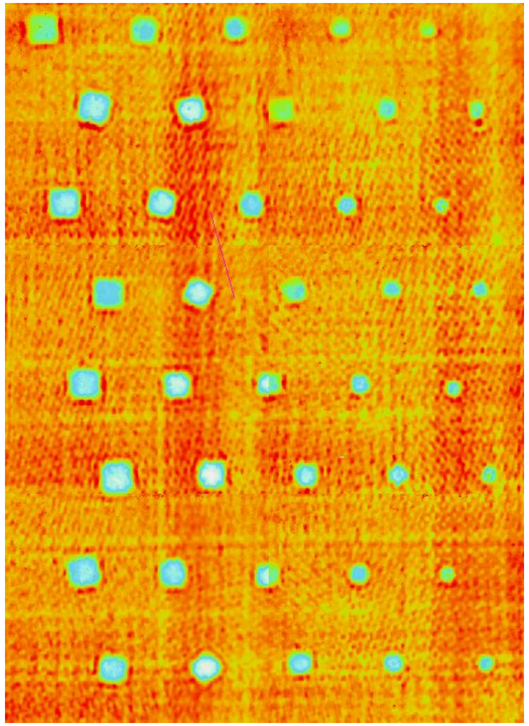
1/8" thick
Graphite/Epoxy Panel
with Embedded Defects



Defect Map

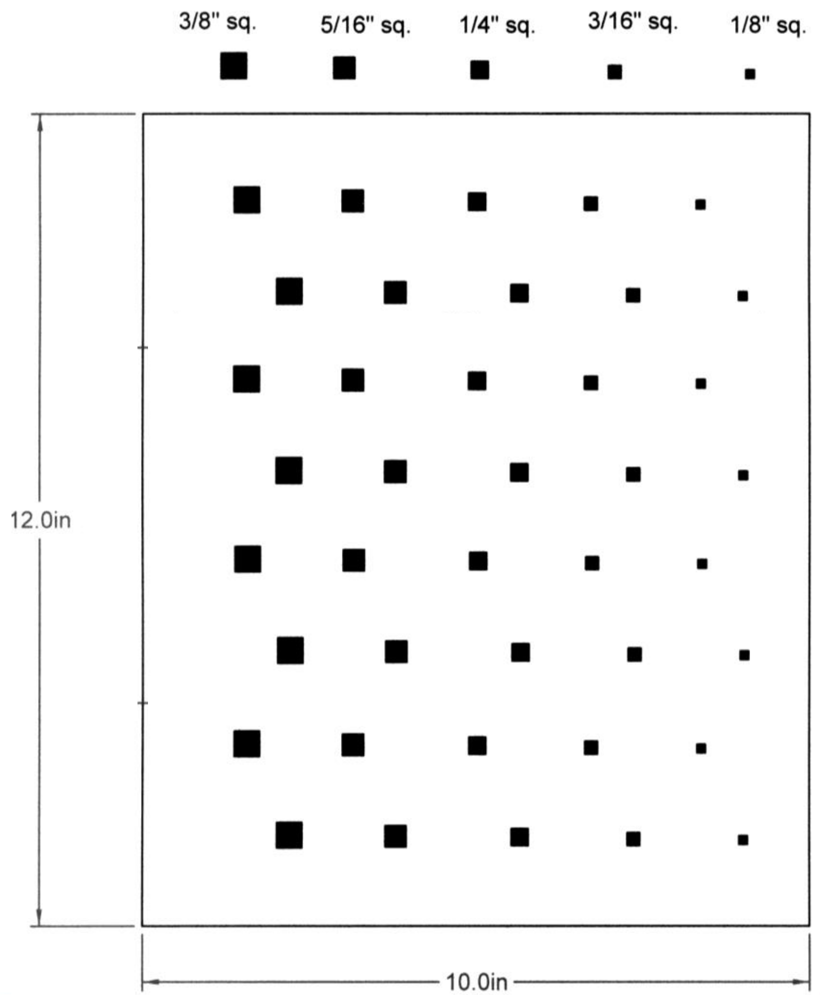


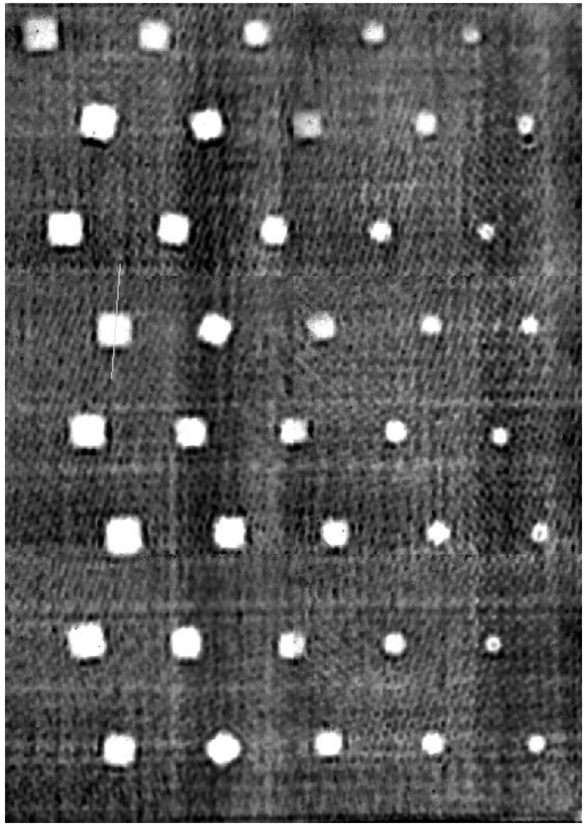
C-scan performed with
0.5" dia., flat, 5 MHz
Transducer

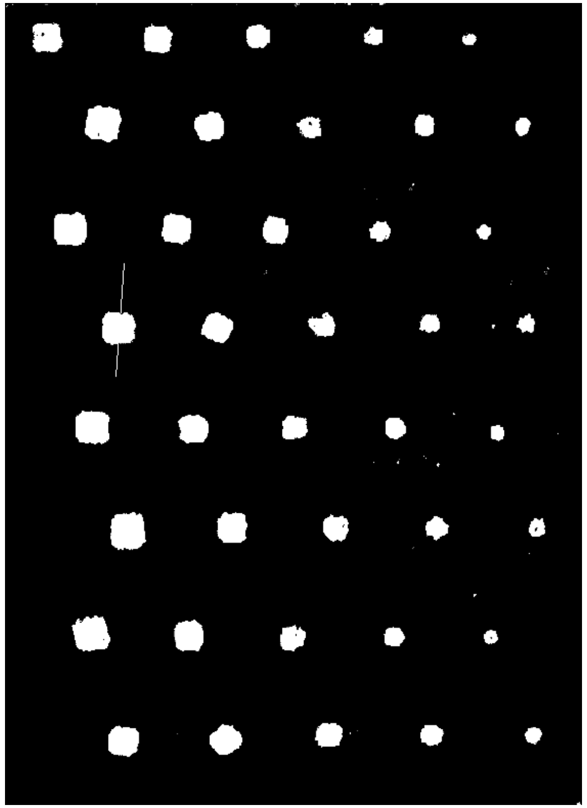


Acoustography Image
produced on AO sensor,
5MHz Wand Transducer

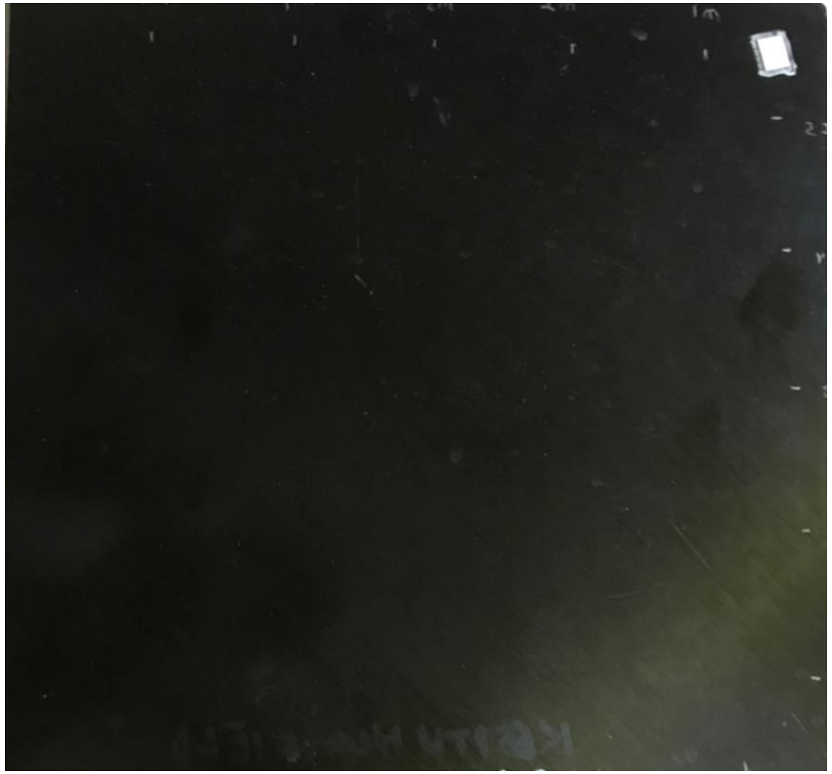
Detection Sensitivity (Thresholding)



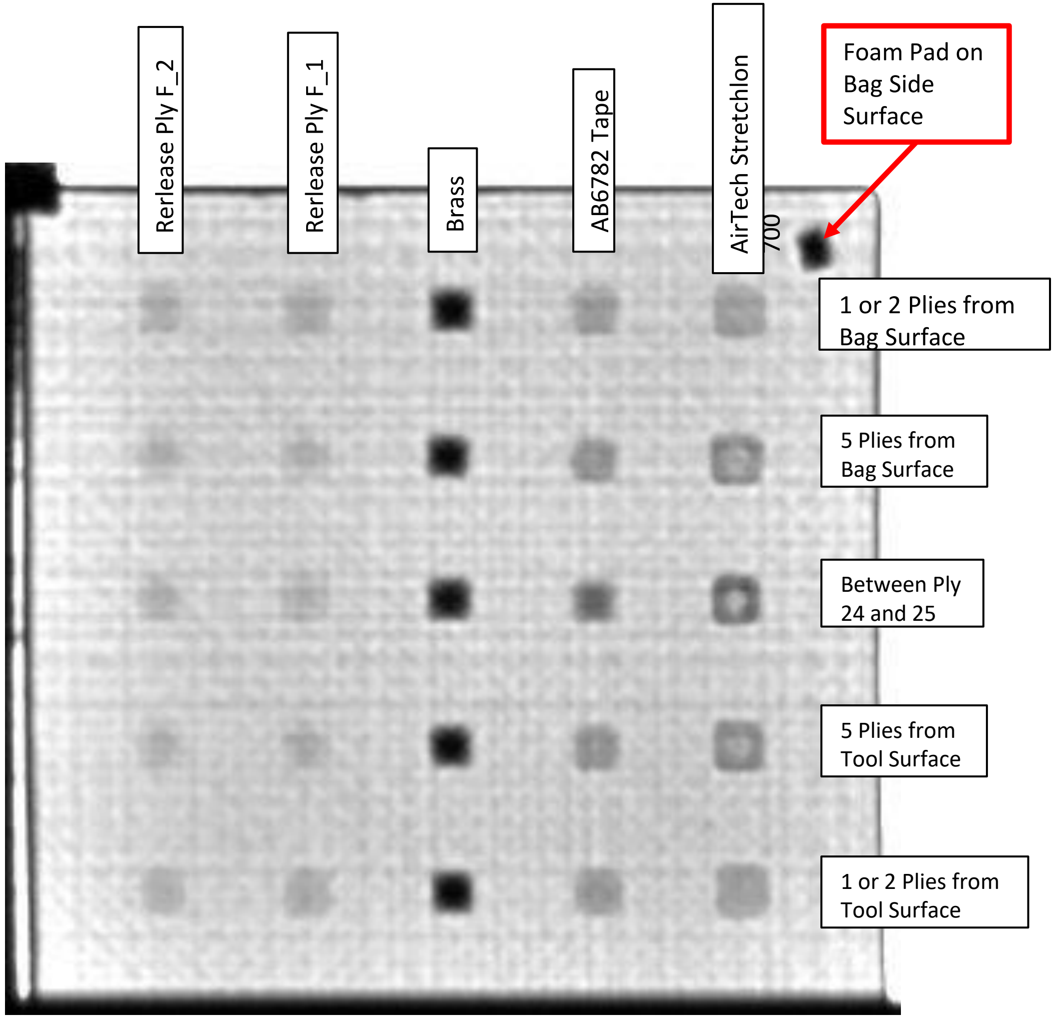




NDE of 0.4” Thick Aerospace Flat Panel Standard Through Transmission Ultrasonic Scan

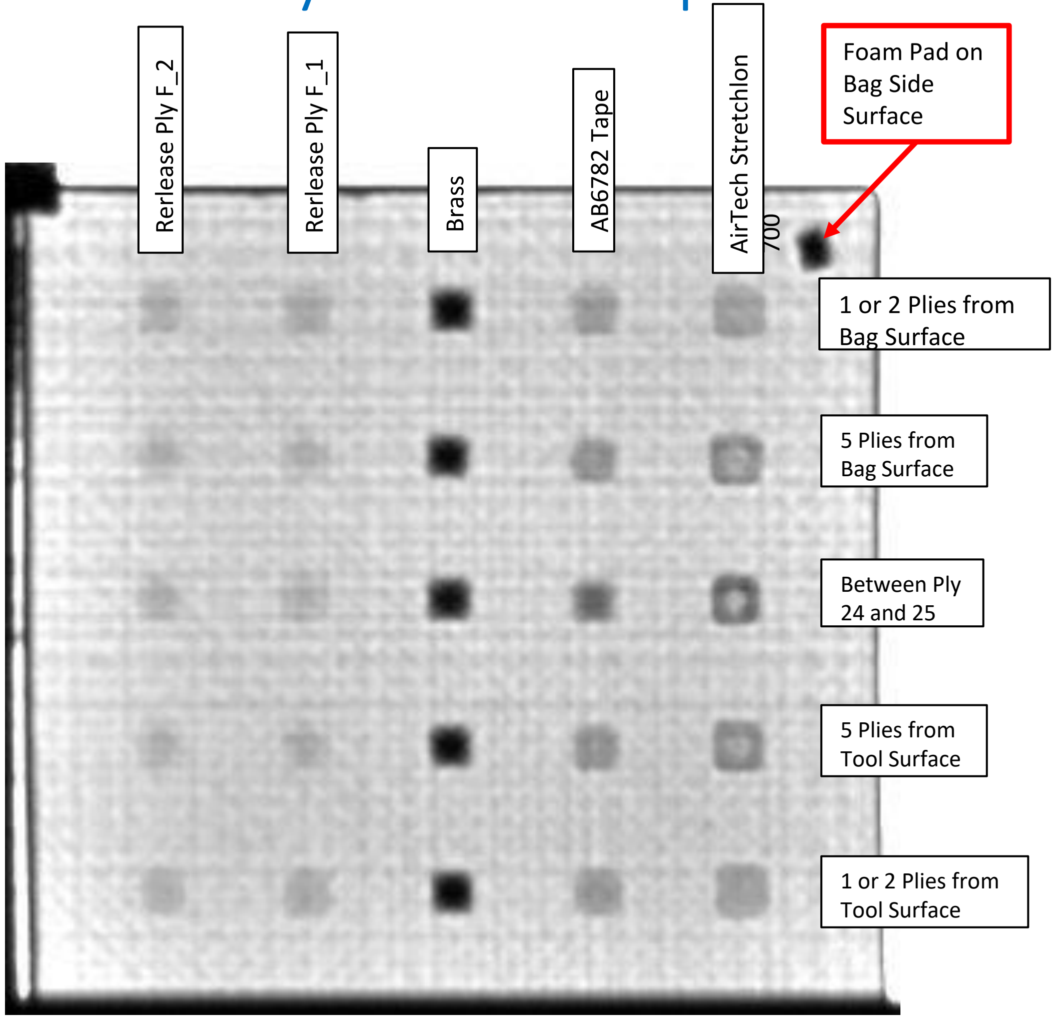


0.4” thick Graphite/Epoxy Panel with Various Manufacturing Embedded Defects

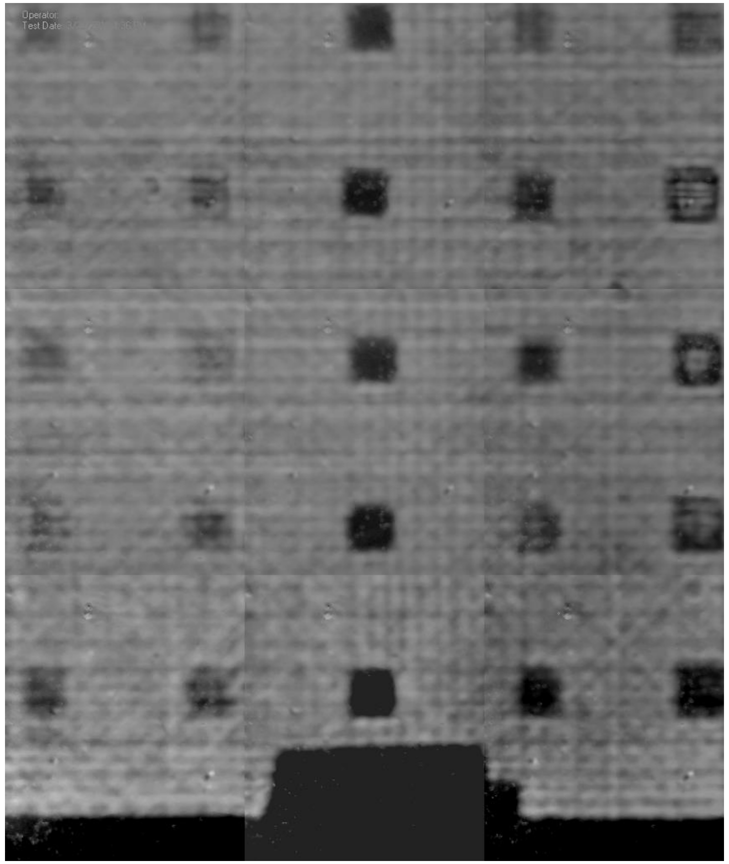


Point-by-point UT @ 5MHz, unfocused TX with 0.25”diameter

Side-by-Side Comparison of TTU C-Scan and Acoustography NDE

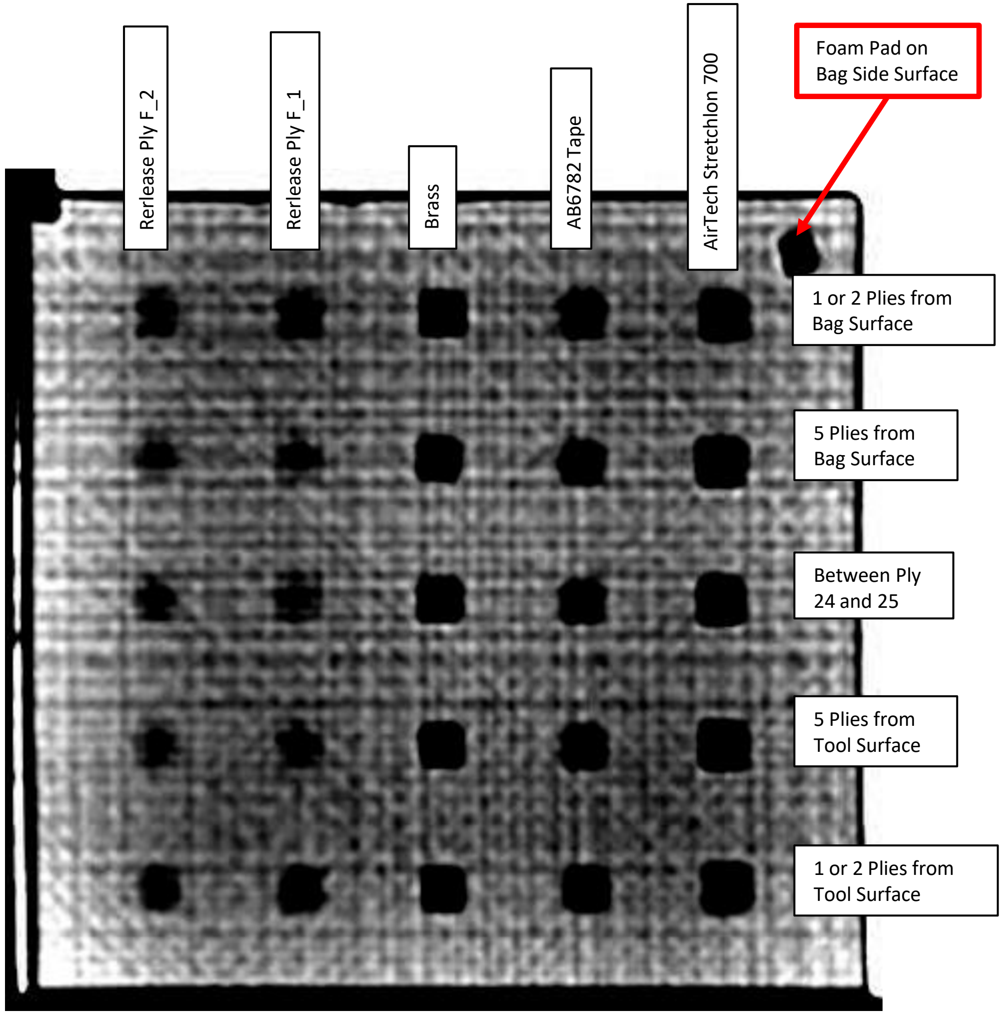


Point-by-point TTU C-Scan @ 5MHz, unfocused TX with 0.25”diameter

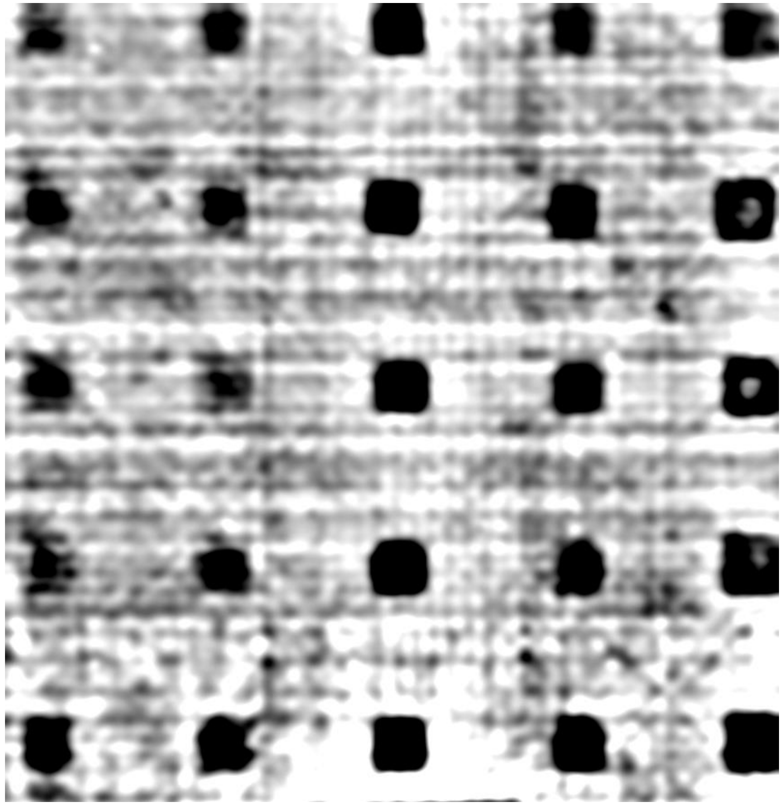


Acoustography NDE @ 5MHz, unfocused 6”x0.5” Wand TX

Acoustography NDE vs. C-Scan Enhanced



C-Scan - Contrast Enhanced



Acoustography Image – FFT Band Pass filter and Contrast Enhanced.

PART 2

UT of “Small Composites Parts”

by

Ramona Borgo Soto

Arcadia Aerospace Industries

UT of “Small Composites Parts” - The Problem

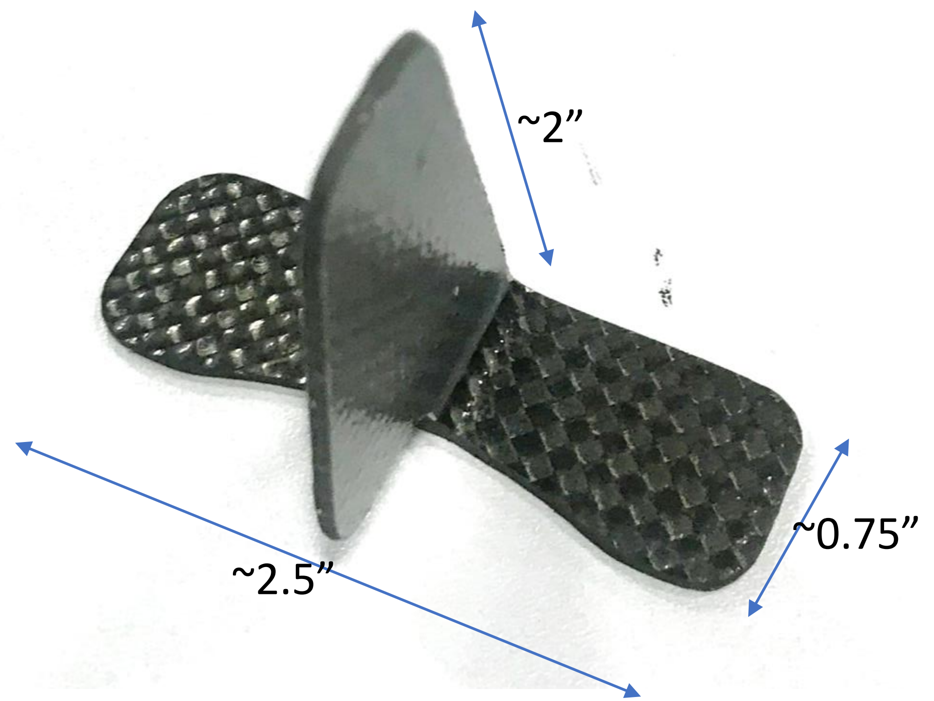
- UT of Small composite parts such as T-shaped Clips, L-shaped Clips, U-shaped Longerons, etc., which range in size from a few inches to 1ft or so, is usually performed through <u>manual hand-scanning</u> of a small ¼” diameter ultrasound probe, point-by-point, over the entire part area.

- This process is:
  1) Labor-intensive
  2) Inefficient
  3) Subjective
  4) Less reliable
  5) Provides no image of the flaw

UT of "Small Composites Parts" - The Problem

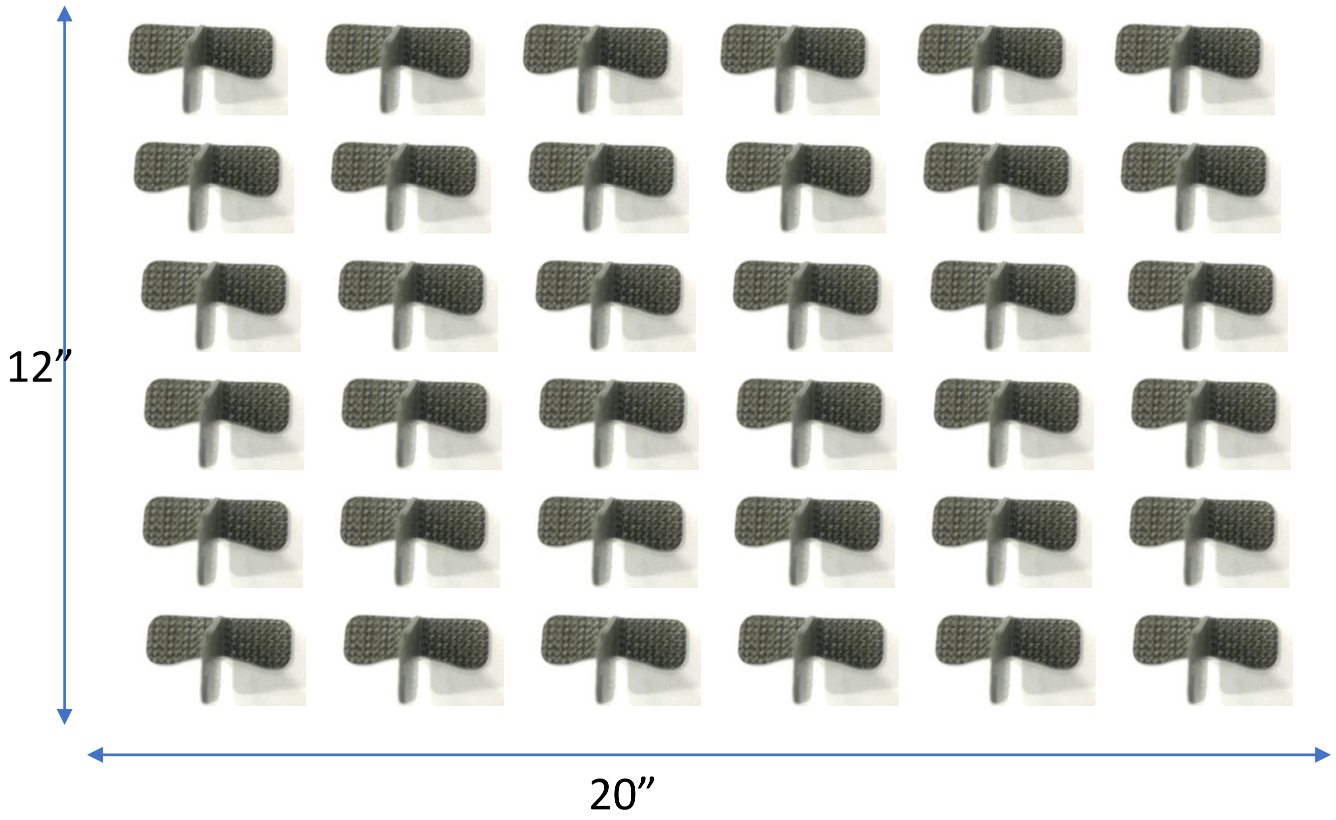
- Traditional point-by-point C-scan can be slow.
- Automated UT equipment with multi-axes gantry or robot is too expensive, and not practical for small parts.
- Phase Array UT could provide a faster solution but requires extensive operator training.

Case Study:
Candidate "Small Composite Part" Selected



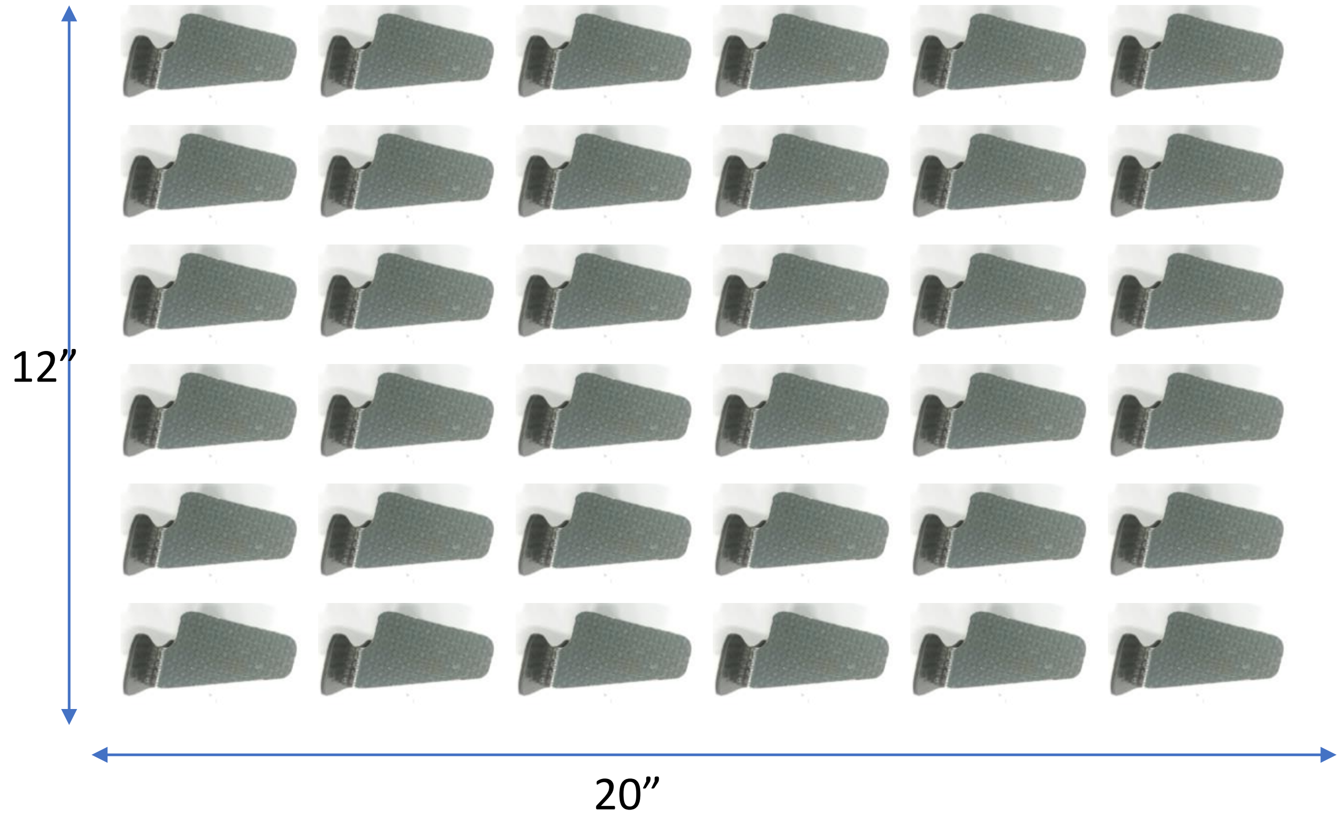
- This part is produced in a batch (30-40 clips)
- Currently each part is tested manually by scanning areas with a ¼" probe.

Case Study: Traditional C-Scan (2 Scans needed)
1st Scan – Clip Base



C-Scan of 12”x20” (304mm x 508mm) Envelope			
Scan Speed	3in/s (76mm/s)	6in/s (152mm/s)	12in/s (305mm/s)
Indexing Steps	0.04 in (1mm)	0.04 in (1mm)	0.04 in (1mm)
Time for 1Pass (12”)	4 sec	2 sec	1 sec
Passes Required for Full Coverage	508	508	508
1st Scan Time	2032s (34 min)	1016s (17 min)	508s (8.5 min)

Case Study: Traditional C-Scan (2 Scans needed)
2nd Scan – Clip Vertical (Web)

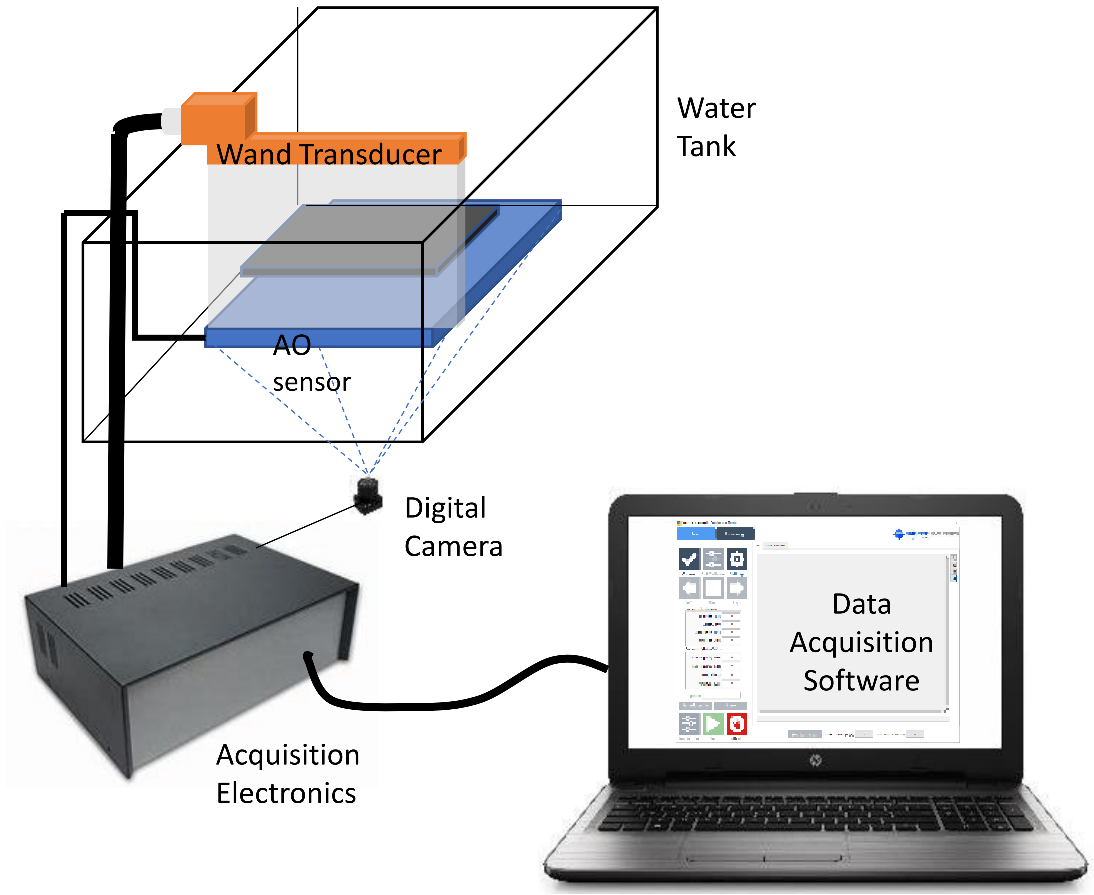


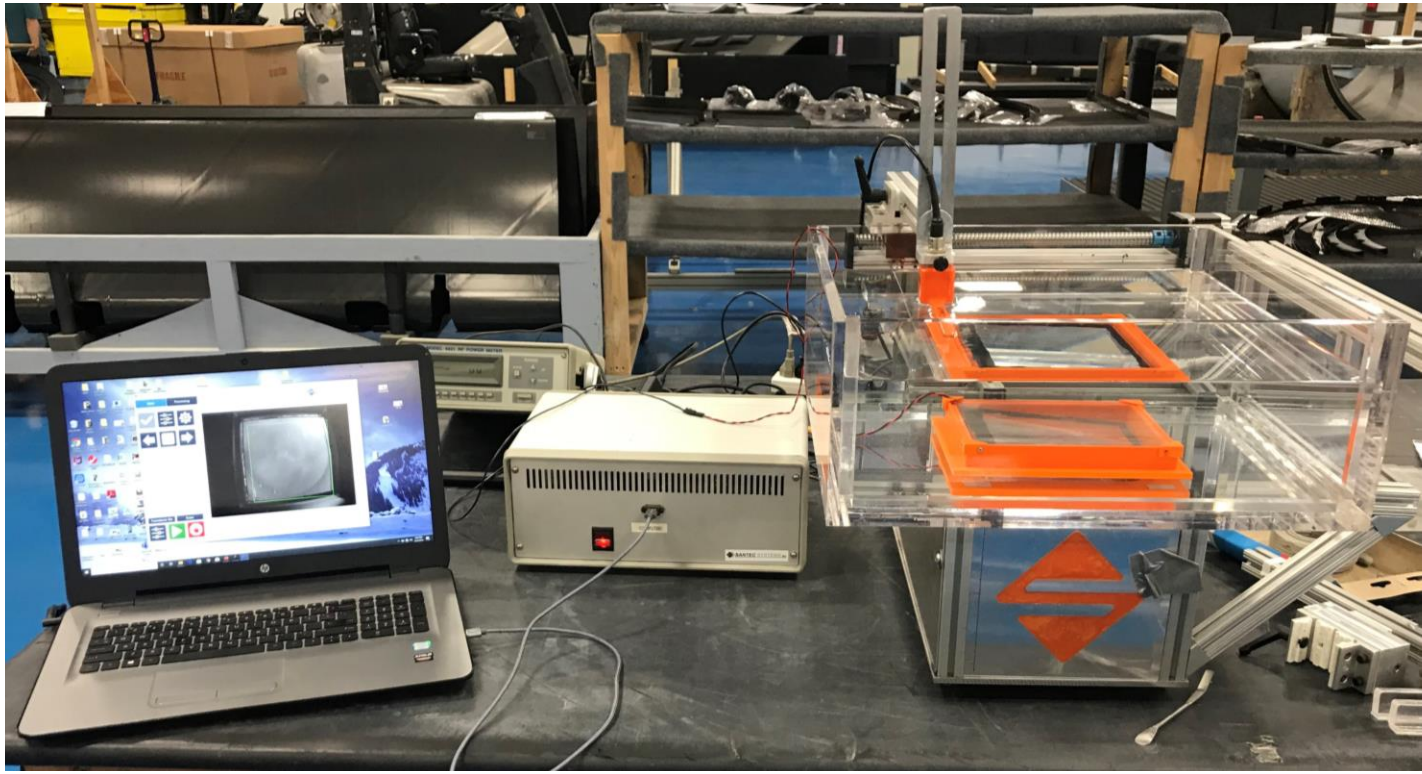
C-Scan of 12”x20” (304mm x 508mm) Envelope			
Scan Speed	3in/s (76mm/s)	6in/s (152mm/s)	12in/s (305mm/s)
Indexing Steps	0.04 in (1mm)	0.04 in (1mm)	0.04 in (1mm)
Time for 1Pass (12”)	4 sec	2 sec	1 sec
Passes Required for Full Coverage	508	508	508
2nd Scan Time	2032s (34 min)	1016s (17 min)	508s (8.5 min)
Scan Time (1st+2nd)	**68 min**	**34 min**	**17 min**

Case Study: Manual Hand Scan

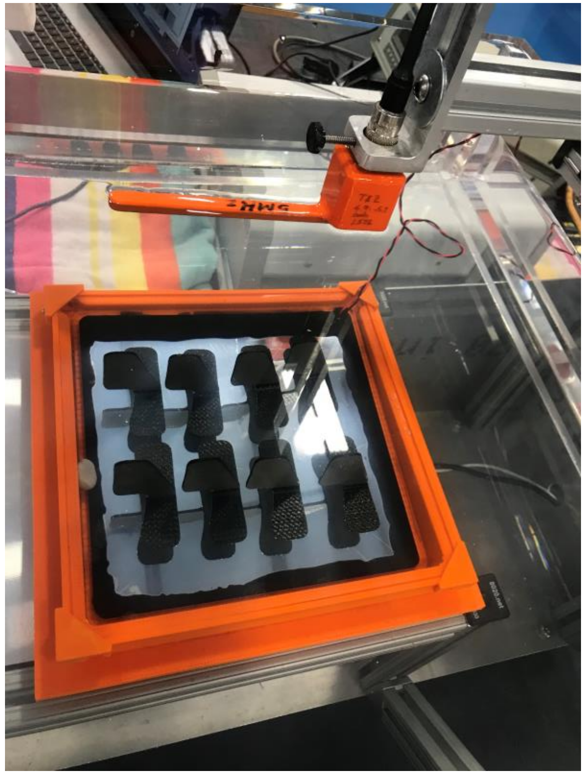
- Manual hand-scanning is performed with a small ¼” diameter ultrasound probe, point-by-point, over the entire part area.
- Operator looks for flaw echo signal between the Front and Back Surface on the A-scan Display.
- Acceptable / Rejectable testing decision made by operator based in his training/experience
- No C-scan type image, no way to review the results in the future.
- No historical file to compare after part has been in service or some damage occurs.

Case Study: Acoustography NDE System Used for UT of Clip Part

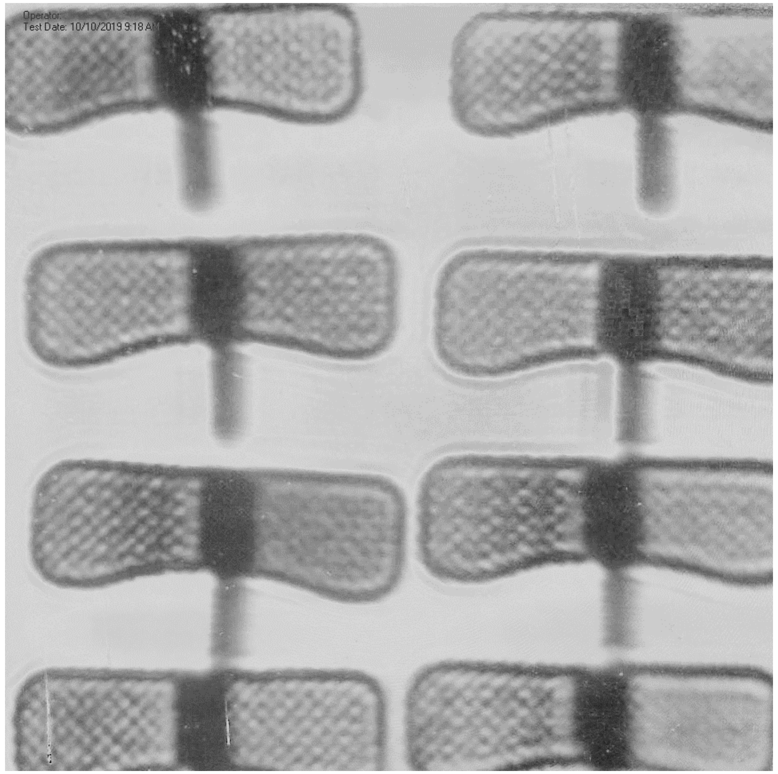




Case Study: Acoustography UT



Scan Setup

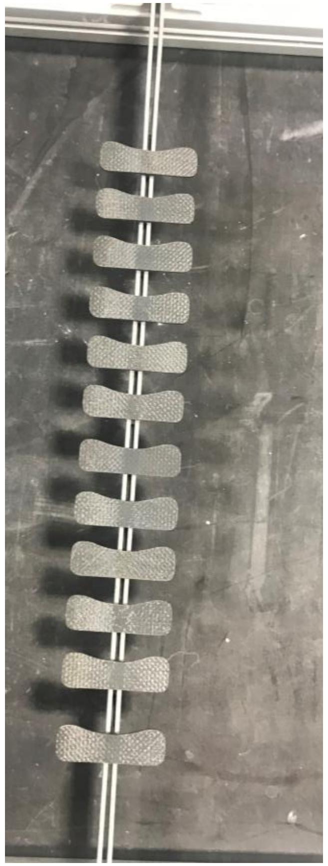


UT Image produced in seconds

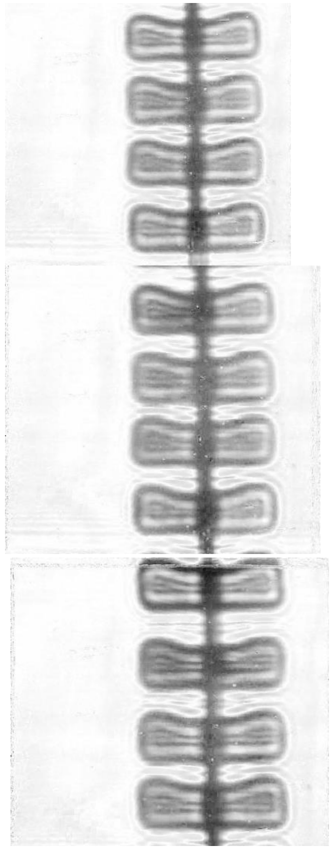
1. Initially, multiple test parts were placed on the cover plate over the AO sensor, as shown in Scan Setup.
2. Wand Transducer was swept across the AO sensor (~6”x6” area).
3. Ultrasonic image of multiple test parts appear in <u>just seconds!!</u>

Case Study: Acoustography UT - Clip Study
1st Scan – Clip Base

12 loaded clips –for base imaging



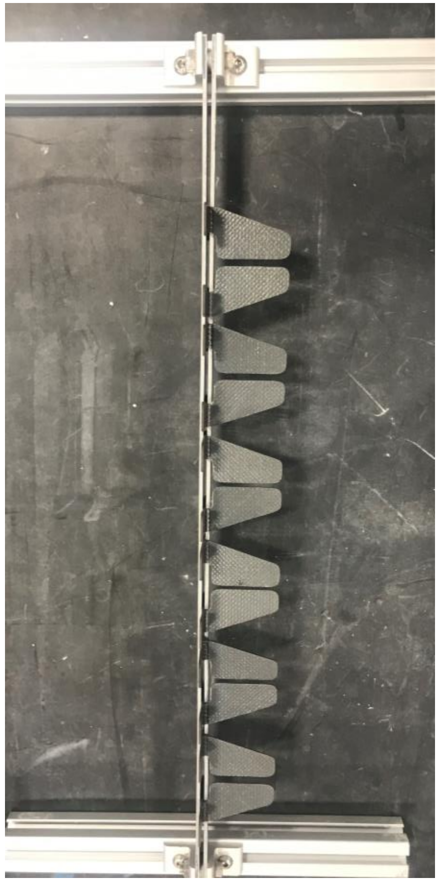
Acoustography UT of Base of 12 Clips



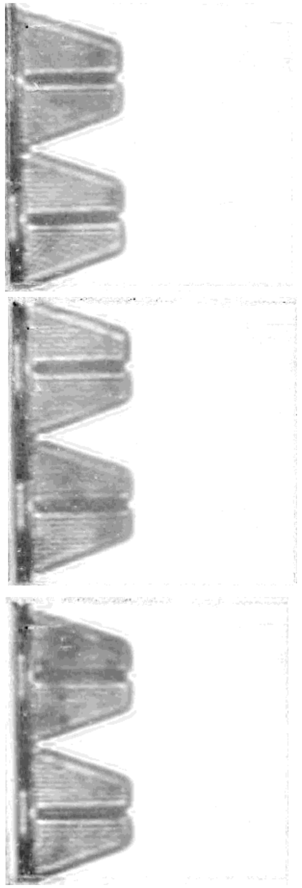
1. A simple Jig designed to hold Clips.
2. 12 clips were loaded as shown (1st image from left).
3. 3 image shots were needed to image 12 Clips bases (2nd image from left).
4. At ~10 seconds/Image Shot, 1st Scan inspection time was about <u>30 seconds!</u>

Case Study: Acoustography UT - 12 Clip Study
2nd Scan – Clip Vertical

12 loaded clips –for base imaging



Acoustography UT of Base of 12 Clips



1. Clips were removed, rotated 90° and reloaded, as shown.
2. 3 image shots were needed to image 12 Clips verticals (2nd image from left).
3. At ~10 seconds/Image Shot, 2nd Scan time was also ~ 30 seconds!
4. Scan Time (1st + 2nd) ~ 60 seconds
5. For 36 Clips Scan Time was 180! seconds (~3min).

Comparison

Hand Scan	
¼” Diameter Probe	~1in/s (25mm/s)
Index	Continuous Sweeping
Inspection time	20-25 mins

This process is:
1) Labor-intensive
2) Inefficient
3) Subjective
4) Less reliable
5) Provides no image of the flaw.

C-Scan			
Scan Speed	3in/s (76mm/s)	6in/s (152mm/s)	12in/s (305mm/s)
Index Steps	0.04 in (1mm)	0.04 in (1mm)	0.04 in (1mm)
Inspection Time	**68 min**	**34 min**	**17 min**

This Process is:
1) Reliable
2) Provides image of the flaw.

(inspection of a set of 36 units of composite clips)

Acoustography	
Wand TX Sweep Speed	~1in/s (25mm/s)
Index	N/A
Inspection time	~3mins!

This Process is:
1) Reliable
2) Provides image of the flaw
3) 5-20x FASTER THAN C-scan
4) >5X FASTER THAN HAND-SCAN

Summary

- **Acoustography NDE** can provide **reliable** UT of Composites, with **images** that are **comparable** to **high quality** point-by-point **C-scan**.
- **Acoustography NDE** method can be **much faster** than point-by-point **C-scan** for "small" composite parts; **5-20x faster** as demonstrated by the Case Study.
- **Acoustography NDE** is more that **5X faster than current Manual hand-scan** UT inspection which is: 1) Labor-intensive; 2) Inefficient; 3) Subjective; 4) Less reliable; 5) provides no image of the flaw.
- Unlike Manual hand-scan, **Acoustography** provides a high-resolution **C-scan type image** that can be **archived** and **reviewed**; for future comparison after part has been in service or some damage occurs.

Additional Questions?

Contact:

Dr. Jaswinder “Jas” Singh Sandhu
j-sandhu@santecsystems.com
www.santecsystems.com

Ramona Bergó Soto
ramona.bergosoto@arcadiaaerospace.com
www.arcadiaaerospace.com

Flynn Spears
flynn@albannde.com

Thank you for participating!

The American Society for Nondestructive Testing
1711 Arlingate Lane
Columbus, Ohio 43228-0518

(614) 274-6003 | (800) 222-2768
www.asnt.org

ASNT … Creating a Safer World!®