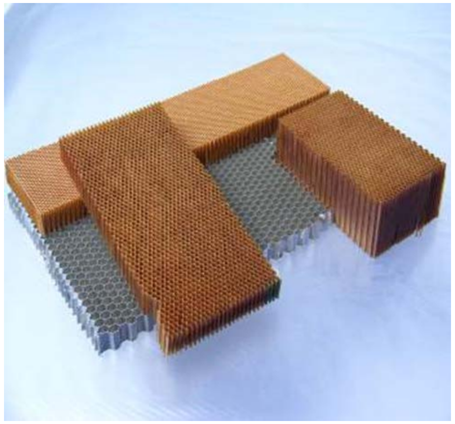
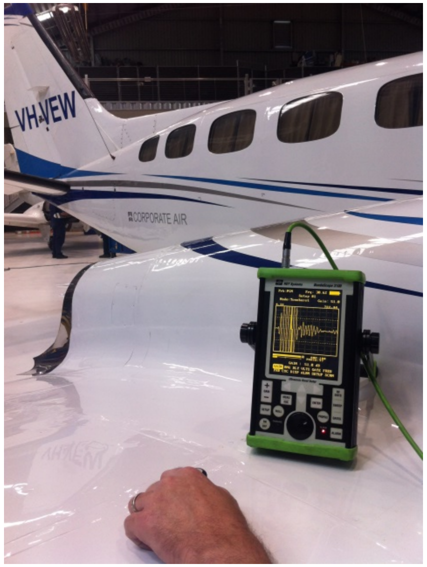
Imaging Bond Testing





Dr Matt Crompton

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NOVA INSTRUMENTS

Introduction

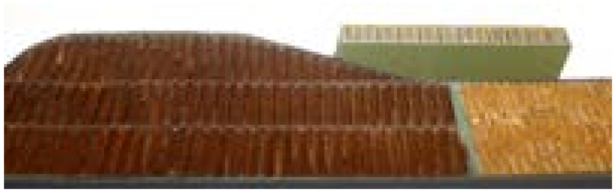
- Use of composites and adhesively-bonded structures has increased in the aerospace, automotive and marine industries for strength and weight saving
- The integrity of the bonds is critical for the performance of the structure and existing technologies are not suitable for most inspections
- Conventional inspection techniques can be of limited use because of the multiple glue lines and attenuative materials inherent in the lay-up.
- Bond Testing has different modes of operation to successfully inspect a wide range of materials and combinations used in multi-layered bonded structures and modern composites

Typical Material Combinations

- Bonded Structures
  - Aluminum to Aluminum
  - Carbon to Carbon

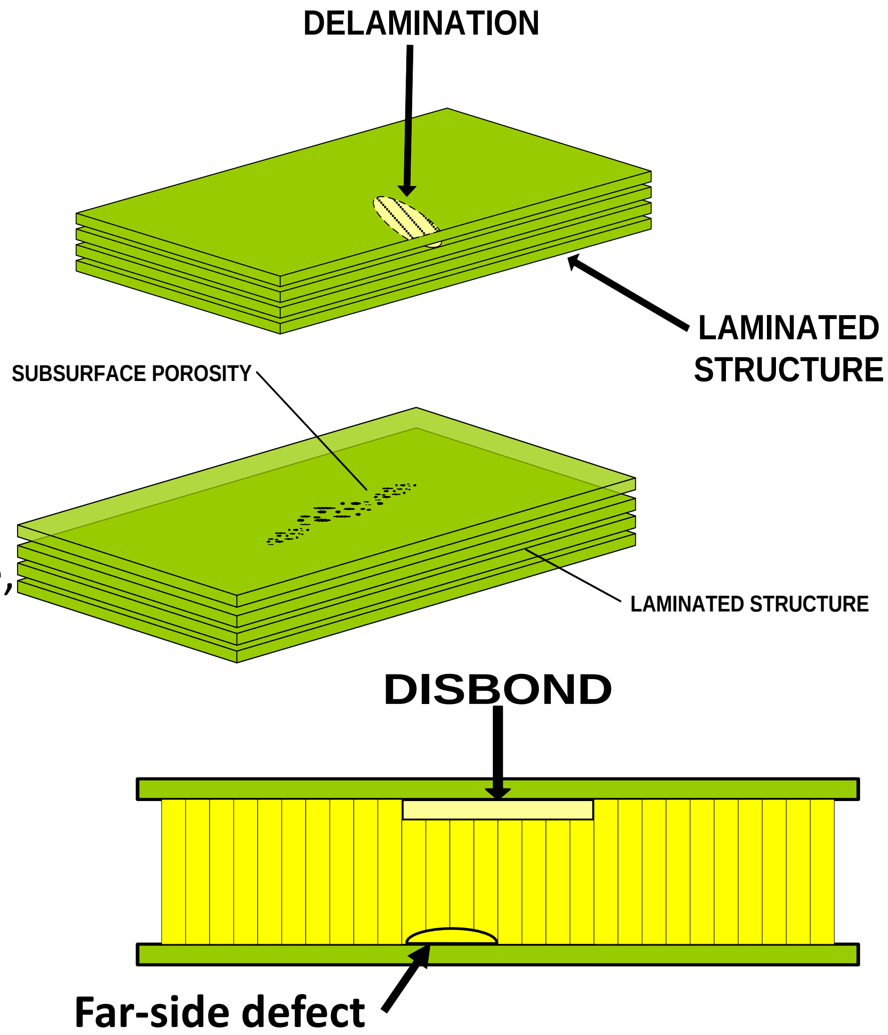
- Monolithic Composite
  - Carbon
  - Graphite
  - Glass

- Sandwich Construction
  - Aluminum skins
  - Carbon skins
  - Glass fiber skins
  - Nomex, Rohacell core
  - Various honeycombs



Detectable Flaws

- Bonded Structures
  - Disbonds, unbonds, foreign objects
- Monolithic Composites
  - Delaminations, impact damage, foreign objects, porosity
- Sandwich Construction
  - Disbonds, unbonds, impact damage, crushed-core, foreign objects, porosity, delaminations, far-side defects
- Repair validation



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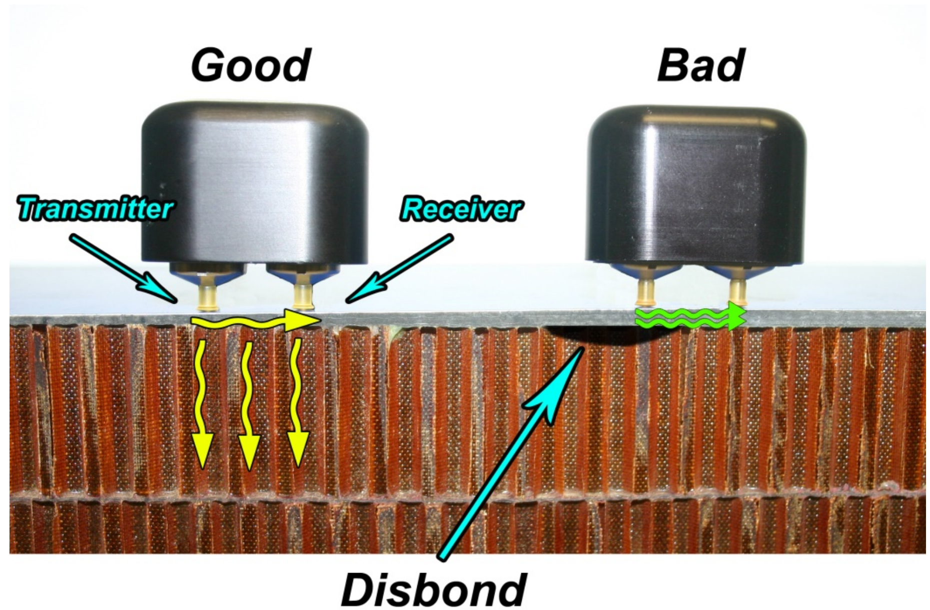
Pitch-Catch Mode

- Probe consists of a transmitter and receiver element on separate tips
- Transmitter 'pitches' a burst of acoustic energy that propagates into the test part. Receiver 'catches' the sound.



- Bonded condition- Sound waves propagate across the skin, with significant attenuation into the core
- Disbonded condition- Little attenuation into the core giving higher amplitude at receiver

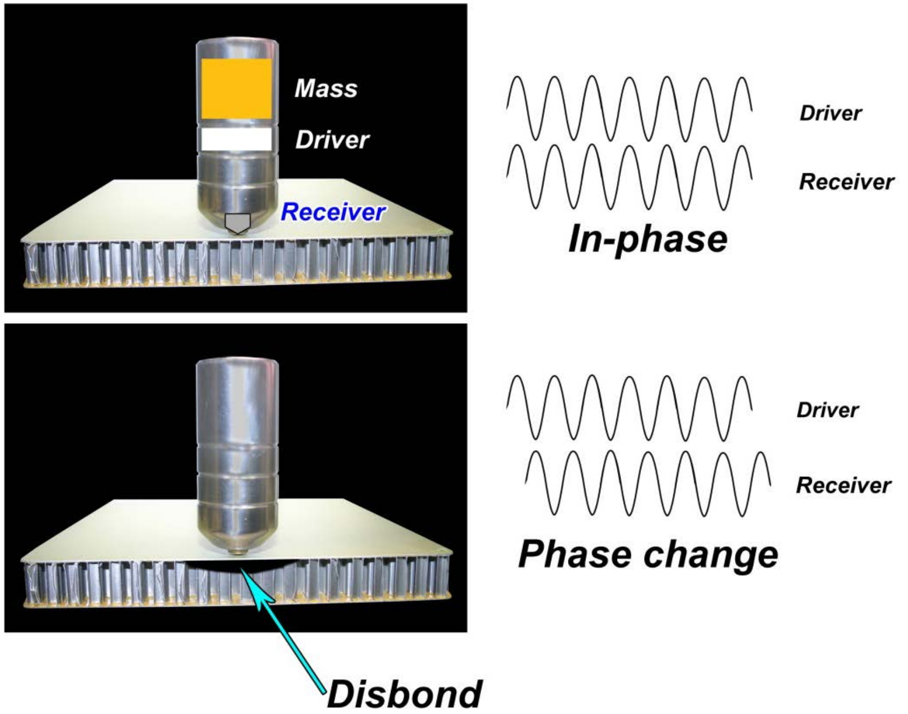
➢ Easy calibration and no couplant is required, fast, high penetration

Frequency Range = 10kHz-40kHz

Mechanical Impedance (MIA) Mode

- Probe consists of driver and receiver elements coupled in series with a single probe tip.
- The loading of receiver element, in the tip, is related to the stiffness of the test part
- When the system is ‘nulled’, the driver and receiver elements vibrate together with the same phase and amplitude
- As the receiving element moves to a disbonded area, which is weaker, the phase and amplitude of the signals change

➢ No couplant, accurately locates defects, works on stiff, irregular & curved surfaces



Frequency Range 4kHz-30kHz

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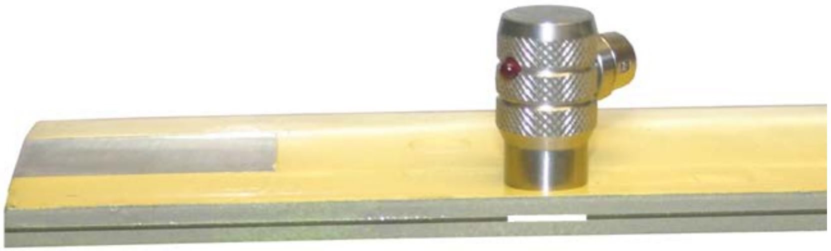
Resonance Mode



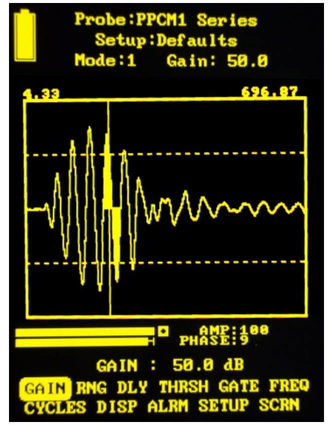
- Probe consists of an ultrasonic contact probe driven at its resonance frequency
- The instrument automatically selects the resonance frequency of the probe in air by sweeping over the frequency range and locating the phase null.
- On contact with the test part, the material damping reduces the amplitude of the signal and changes the resonant frequency. This reference condition can be nulled out. A disbond changes the acoustic impedance of the material, changing the phase and amplitude. The phase is related to depth of the defect in multi-layered structures.
- Higher frequency probes are used for better resolution and thinner parts. Thicker parts require lower frequency probes

➢ Requires couplant, best for laminates, high penetration, can determine layer that defect resides in.

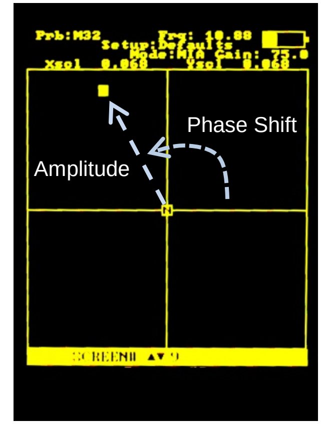
Frequency Range 18kHz-370kHz

Traditional Bond Testing

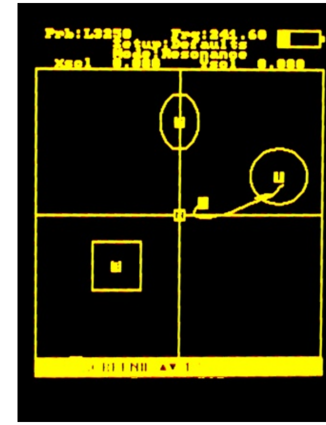
Bondascope 3100



RF mode



Impedance plane



Gating

- **Single point measurement**
- **Hard to understand**
- **Not always possible to distinguish between signal and noise**
- **Inspector can miss defects easily**
- **Can be slow**
- **No digital archive**

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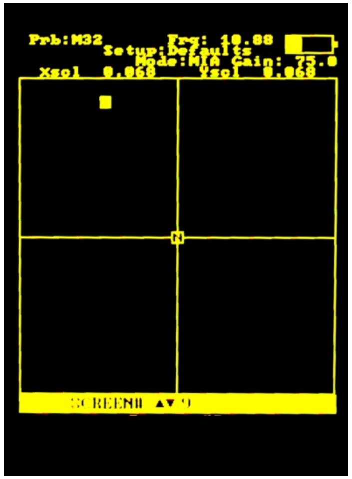
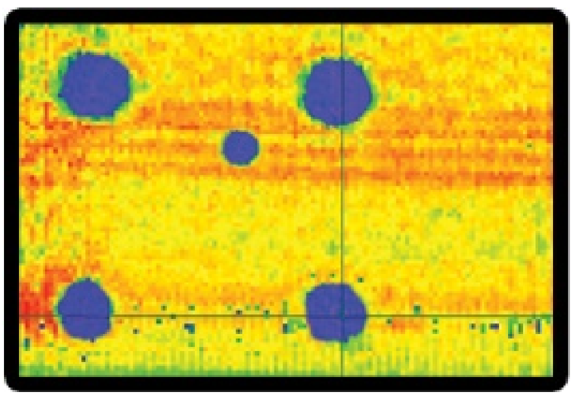
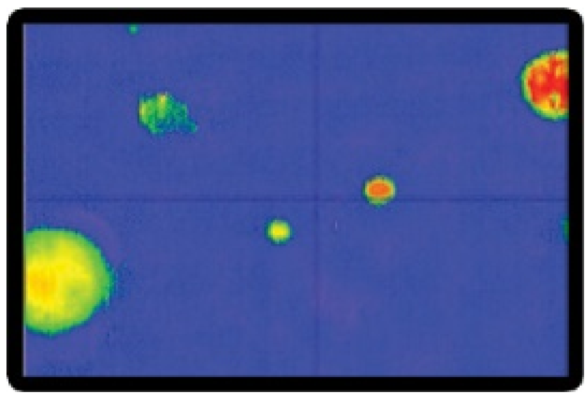
Why does the bond testing market need imaging?



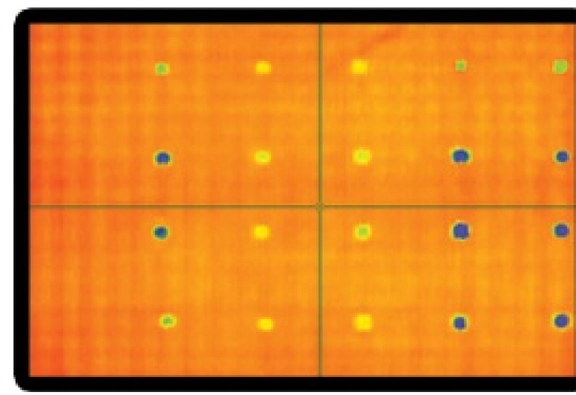
- Easy to understand
- Increased probability of detection
- 100% coverage, no mistakes
- Automatic or manual scans
- Digital Archiving of results
- Faster and more reliable



Pitch-Catch



MIA



Resonance

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What is the BondHub?

- Integrated PC and scanner motor driver
- Dedicated imaging and analysis software
- Reads phase and amplitude output from Bondascope (or equivalent device)
- Defines scan area, speed, resolution
- Plots C-scan image, with live gating/ filters
- Full analysis software, 3D rendering, export

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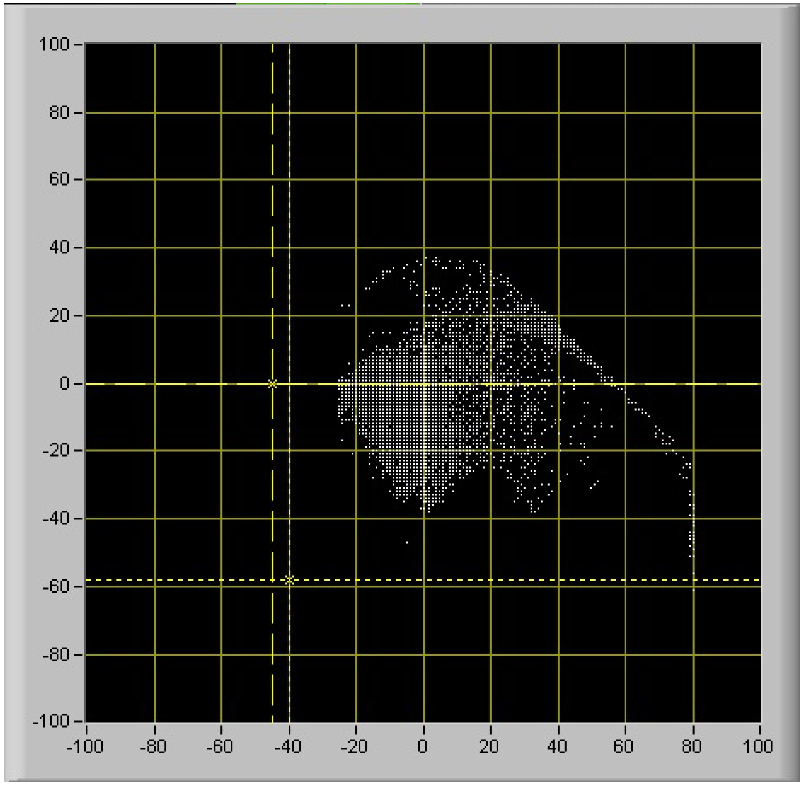
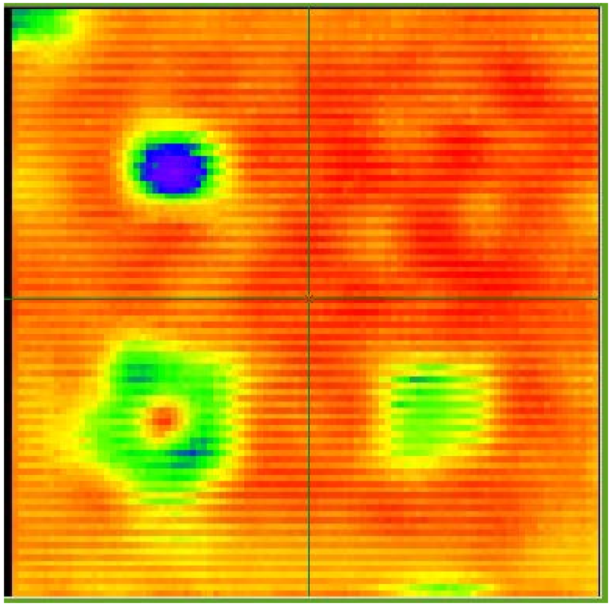
New inspections now possible

- Marine Glass Fiber/ foam core
- 3/16” skin, chopped mat, 0/90^{o} and 45^{o} lay-up
- UT cannot penetrate, Resonance and P/C failed
- MIA measures an out-of-plane stiffness



Impedance plane
scatter plot



Amplitude showing
skin-core disbonds

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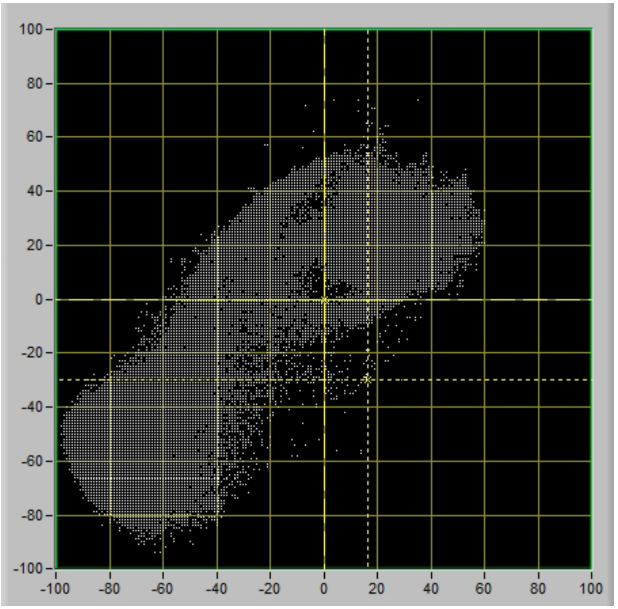
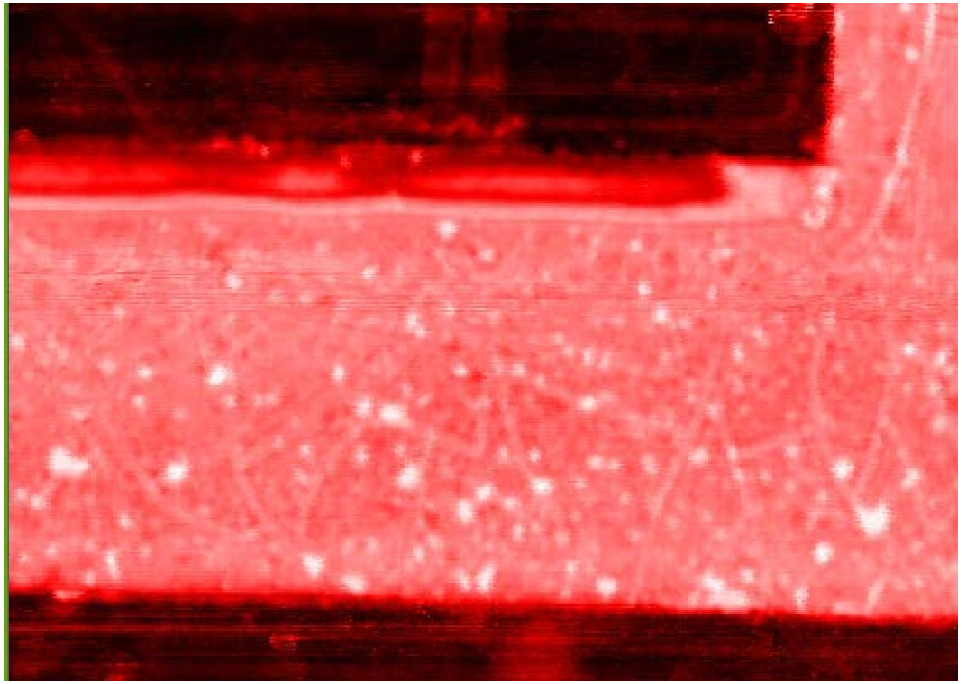
Panel courtesy of Arcadia Aerospace

Cracks and voids in adhesive bond line

- Bonded carbon laminates
- Resonance inspection of adhesive glue line- showing cracks and voids in the adhesive through the carbon skin.
- Vertical cracks represent a few pixel shift, not possible to detect manually





X-component- impedance plane

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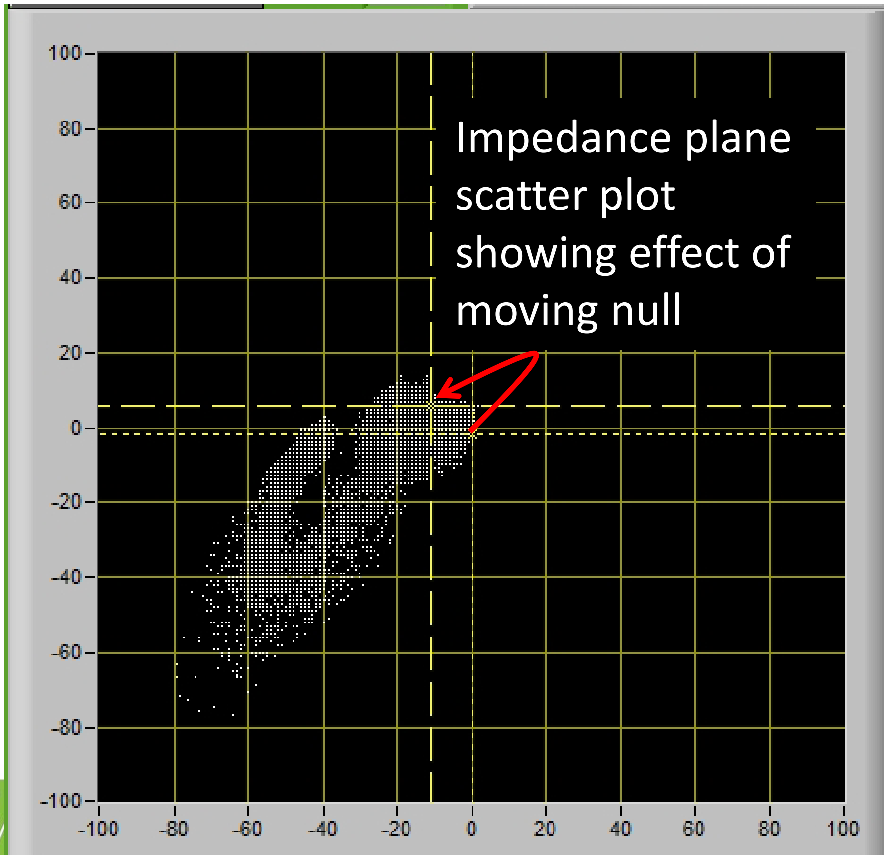
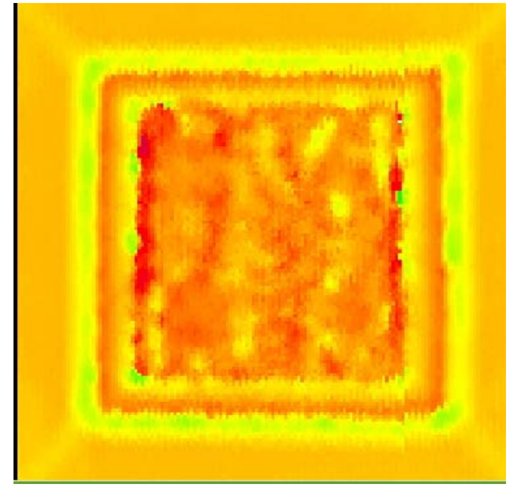
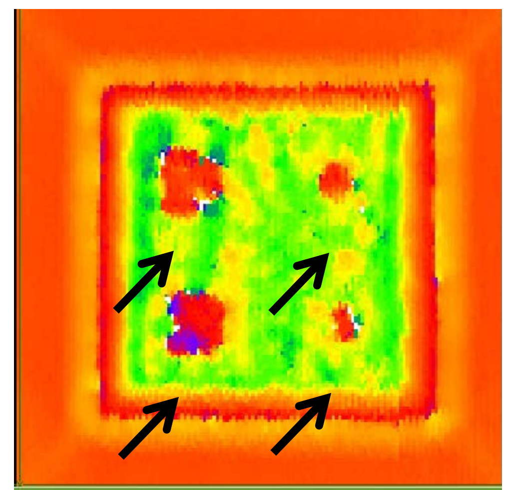
Increased Probability of detection

- Carbon skin/ honeycomb sandwich panel
- Near and far-side defects skin-core disbonds
- Cannot see all defects in x,y or amplitude
- 110kHz resonance mode, phase display





Phase, with instrument null point

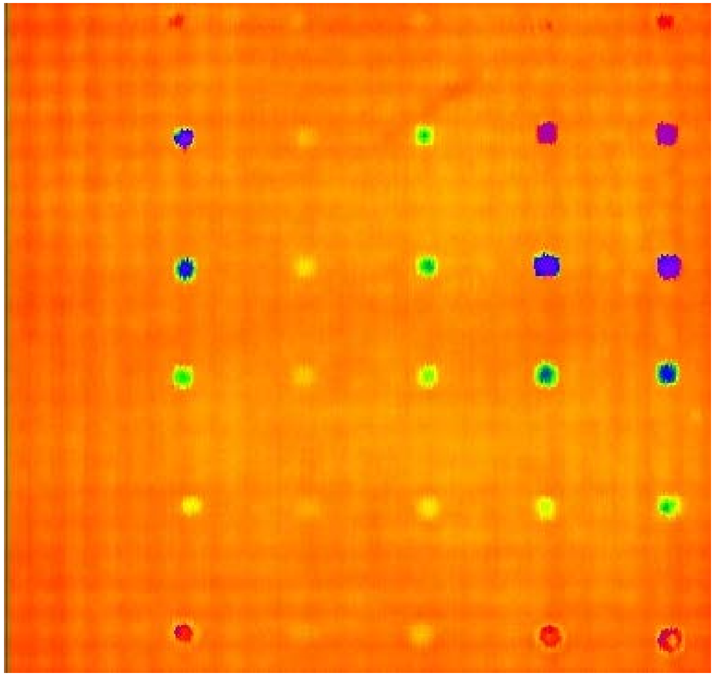


Phase, with adjusted null point

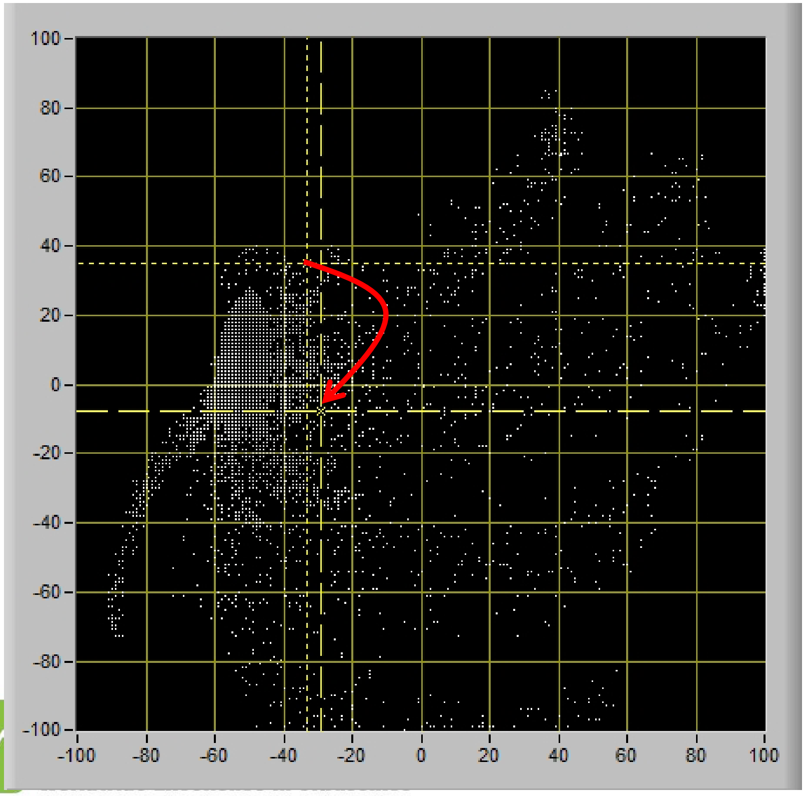
Panel courtesy of R-CON NDT

Composite Reference Standard

- Aerospace Composite laminate Reference Standard
- 30 ply with brass foil, Armalon, release ply F, poly backing material, pressure sensitive tape inserts at different depths. (BAC5578 Inserts)
- 2 plies from near surface to 2 plies from far surface
- 110kHz resonance mode (compromise)



Phase display

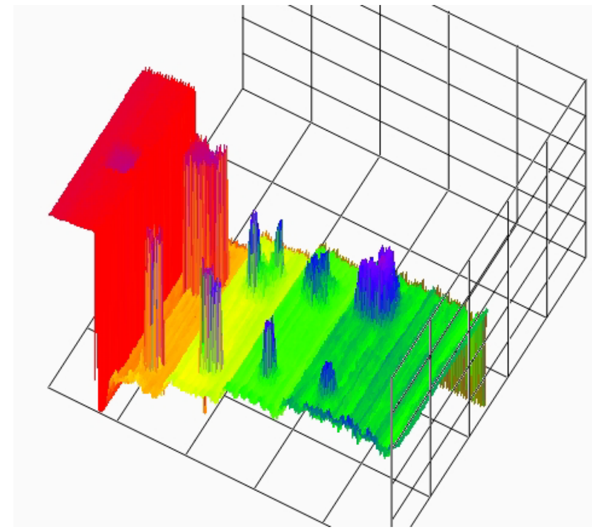


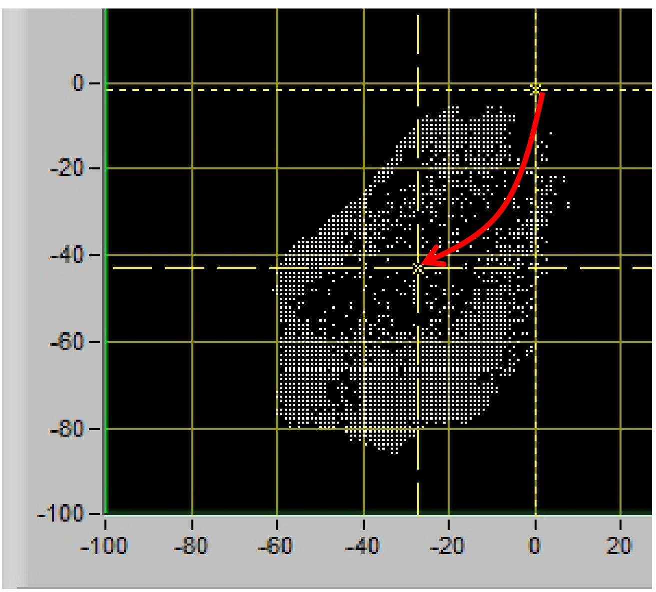
Impedance plane scatter plot with adjusted null

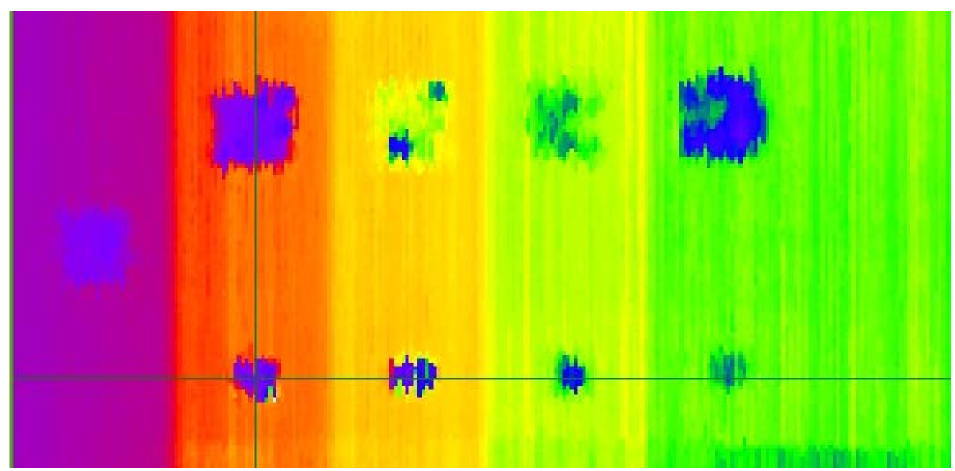
Panel courtesy of Arcadia Aerospace

Composite Step block

- Resonance inspection of carbon laminate step block with inserts.
- Thickness range- 0.014” – 0.070”
- Both the change of thickness and defects affect phase and amplitude







Phase display

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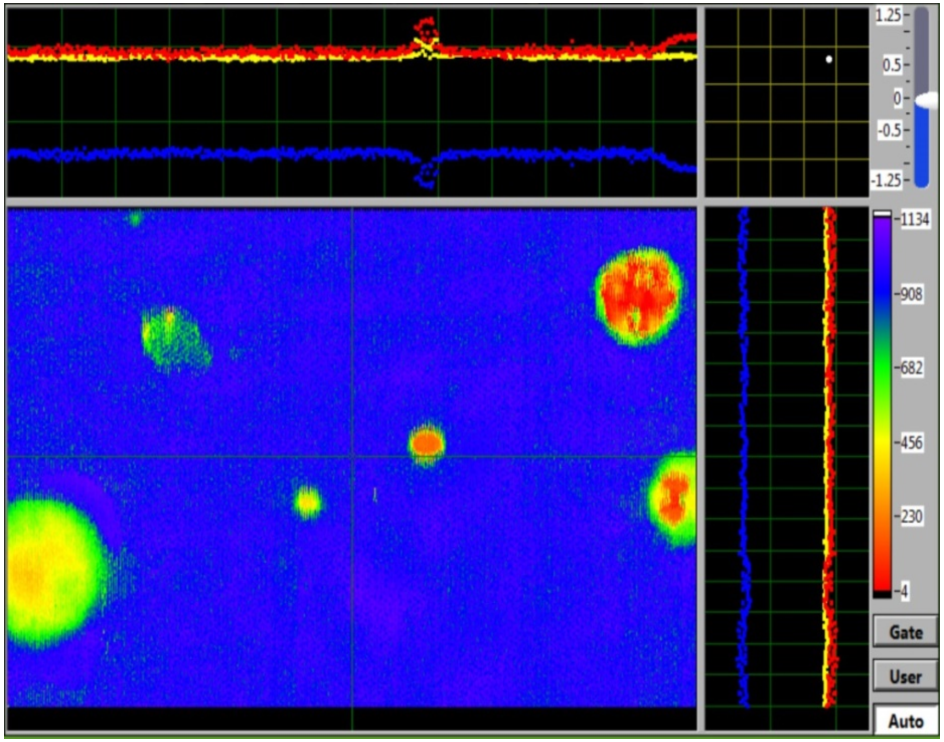
Panel courtesy of R-CON NDT

Carbon skin / Aluminum honeycomb

- Satellite panel- a carbon skin, aluminum honeycomb
- Dry coupled MIA mode
- Crushed core, disbonds, far-side defects and more



Amplitude display

Mode Selection Guide

Requirement	Pitch-Catch	Mechanical Impedance (MIA)	Resonance
Couplant required for testing	No	No	Yes
Surface geometry	Flat or curved to >1" radius	Flat or curved to <1" radius	Flat or slightly curved
Typical minimum detectable flaw size	>0.5" (12.7mm)	>0.25" (6.4mm)	>0.25" (6.4mm)
Flaw Depth determination in multi-layered bonding	No	No	Yes
Far-side flaws or core damage on sandwich constructions	Best	Poor	Fair
Applications			
Metal to metal bonded skins (Disbonds)	Fair	Good	Best
Multi-layer carbon laminate (Delaminations, voids, porosity)	Fair	Poor	Best
Metal skin to metal honeycomb (Disbonds, crushed core)	Good	Good	Good
Carbon skin to metal or Nomex™ honeycomb (Disbonds, delaminations crushed core)	Best	Good	Good
Carbon skin to foam core (Disbonds, delaminations)	Best	Good	Fair
Multi-core sandwich structures (Inter-core disbonds, core damage)	Best	Poor	Fair
Bonded Stiffeners (Disbonds)	Good	Poor	Good
Glass fiber skin to foam or wood core (Disbonds, delaminations)	Best	Poor	Good
Perforated metal skin to honeycomb core, used for acoustic liners (Disbonds)	Good	Good	Poor
Carbon-Carbon, used for heat shields (Delaminations)	Best	Poor	Poor
Carbon or Glass reinforced pipes or pressure vessels (Disbonds, delaminations	Good	Poor	Poor
Carbon Overwrapped Pressure Vessels (COPV) (Disbonds, delaminations)	Good	Poor	Poor
Composite Repair Validation (Disbonds, delaminations)	Best	Poor	Good

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Conclusions

- Increased use of multi-layered bonded structures and composites leading to demand for alternate testing method- Conventional ultrasonics has limited capability through multiple bondlines, composites with porosity and sandwich structures.
- Ultrasonic bond testing runs at a lower frequency with a range of operational modes, 2 of which are dry-coupled, that are customized for different material combinations, defect types and constructions.
- **Imaging bond testing** provides a powerful enhancement to conventional bond testing with C-scan imaging and analysis software providing:
  - a digital archive of results
  - an increased probability of detection
  - A new solution to previously ‘non-inspectable’ parts
  - 100% coverage with a faster and more reliable scan