

F-15 WWR 2025

JENTEK Eddy Current Array Inspections and Field Portable Systems

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Hans Foelsche,
Taylor Simon
jenteksensors.com

Highest Performance Crack Detection Capability



Air calibration per ASTM E2338
ECM Notch Sizes:
length 0.06 0.04 0.03 0.02 0.015 in.
depth x0.03 x0.02 x0.015 x0.01 x0.0075 in.



"The Leader in Eddy Current Testing Performance."

*...Introducing new
field hardened jETi for
bolt-hole and other NDT*



- MWM-Array eddy current technology and systems
- Bolt-Hole inspection for challenging holes
- Surface-breaking cracks on complex surfaces
- Sub-surface cracks on curved/variable thickness structures
- Detection of cracks at fasteners

jET[®]

JENTEK Eddy Current Array Tester

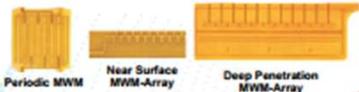
With conformable MWM-Array technology

- **BEST** detection and characterization performance
- **VERY LOW** false indication rates
- **REDUCED** surface preparation
- **NOW** in a small, convenient and lightweight package that fits your budget!
- **Engine Components Inspection**
 - Blades, disks, IBRs, holes, etc.
- **NDT of Complex Structures**
 - Surface breaking and subsurface cracks
 - Hidden corrosion
- **Coating Characterization** without need for expensive custom calibration standards
- **Complex Shaped Surfaces**
 - Firtree slots in engine disks, fillets in aircraft structures, etc.
- **Materials/Process Quality Characterization**



MWM-Array

jET weighs less than 1 lb.



JENTEK GridStation advanced eddy current inspection systems have been called "the gold standard" of inspections at U.S. Navy Depots.



Highest Performance Crack Detection Capability

Air calibration per ASTM E2338
ECM Notch Size:
length 0.06 0.04 0.03 0.02 0.015 in.
depth 0.03 0.02 0.015 0.01 0.0075 in.



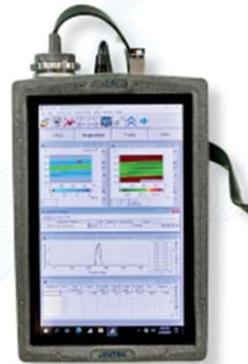
"The Leader in Eddy Current Testing Performance."

jETi[™]

with MWM-Array Technology

"The Leader in Eddy Current Testing Performance."

- **NDT of Complex Structures**
 - Surface breaking and subsurface cracks
 - Hidden corrosion
- **Bolt hole inspection multi-material stack-ups**
- **Coating Characterization** without need for expensive custom calibration standards
- **Materials/Process Quality Characterization**



jETi for Bolt Hole



MWM-Array Bolt Hole Mandrel

Air calibration and crack detection (ASTM E2338; E2884)

GS9000[™]

"The Leader in Eddy Current Testing Performance."

FULLY PARALLEL IMPEDANCE INSTRUMENTS

19, 39, 79-channel, and larger configurations available



SPECIFICATIONS

- ✓ Rapid wide area scanning
- ✓ 19, 39, and 79 channel MWM-Arrays
- ✓ Battery packs for portable operation
- ✓ System configuration up to 396-channels +
- ✓ Surface and sub-surface crack detection, corrosion imaging, coating characterization, and material property mapping



±45° MWM-Arrays

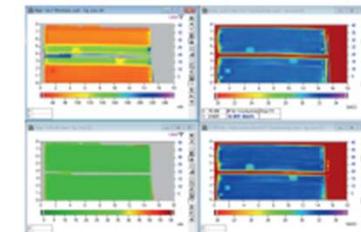


GS9000 for Weld Inspection/ Crack Detection

GS9000 for Automated Internal Surface Tube and Pipe Scanner



- ✓ 39-channel GS9000 MWM-Array
- ✓ Helical Scan Path
- ✓ 1ft/min Scan Time
- ✓ Crack Detection
- ✓ Coating Characterization
- ✓ Conductivity and Thickness
- ✓ Coated-Uncoated Tubes
- ✓ 120-180mm Diameter Range



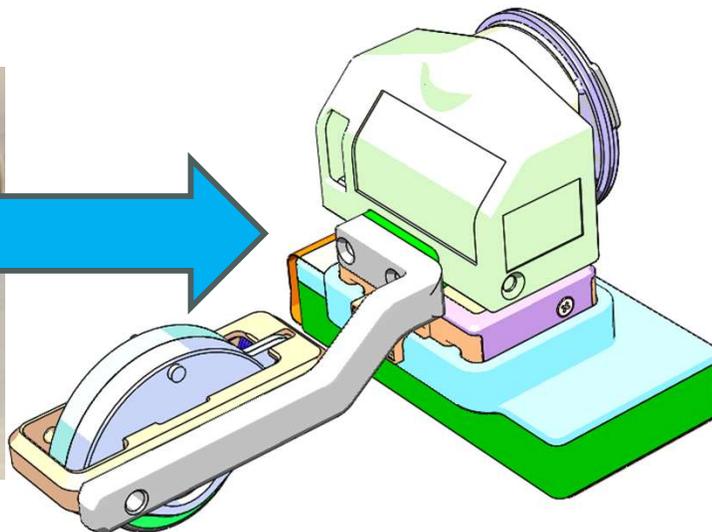
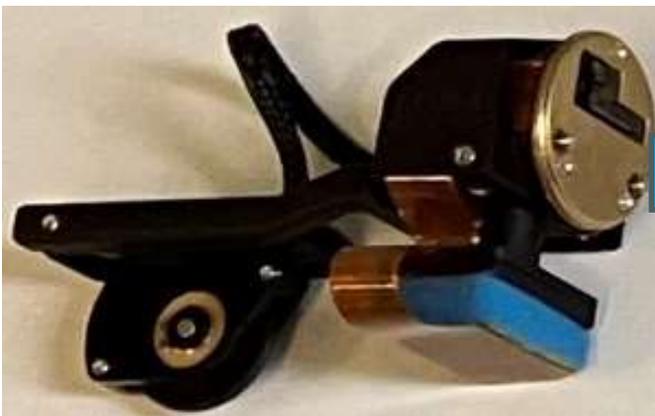
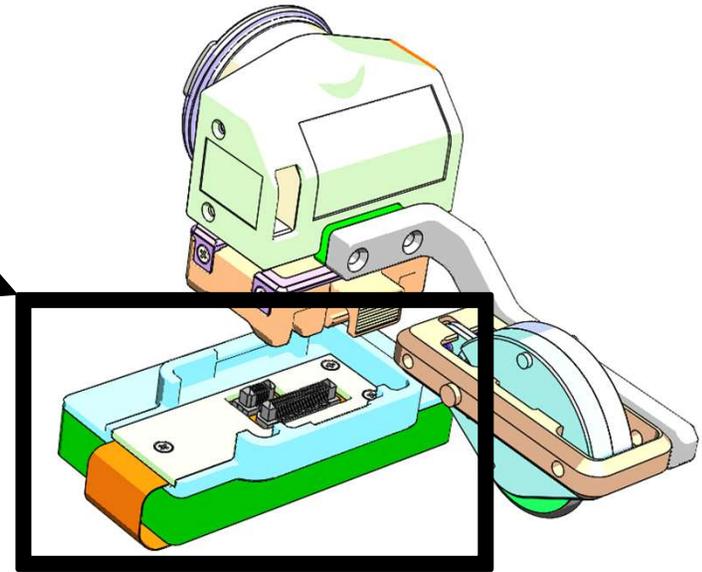
Corrosion Loss Imaging



GS9000 for Corrosion Imaging

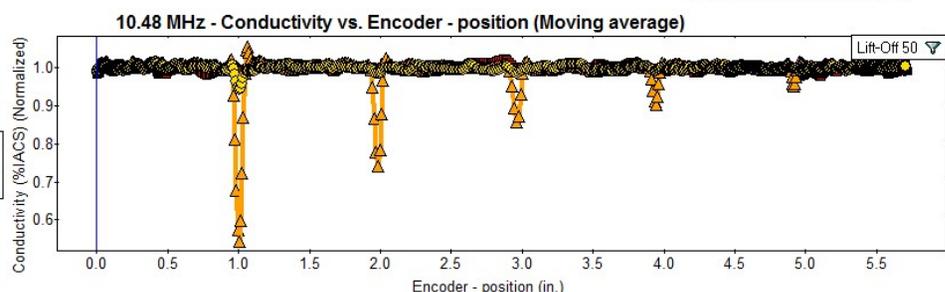
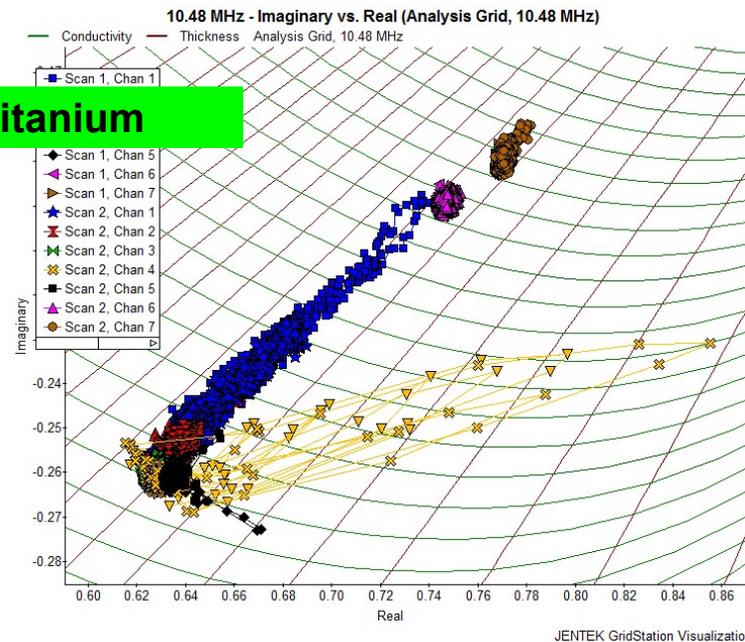
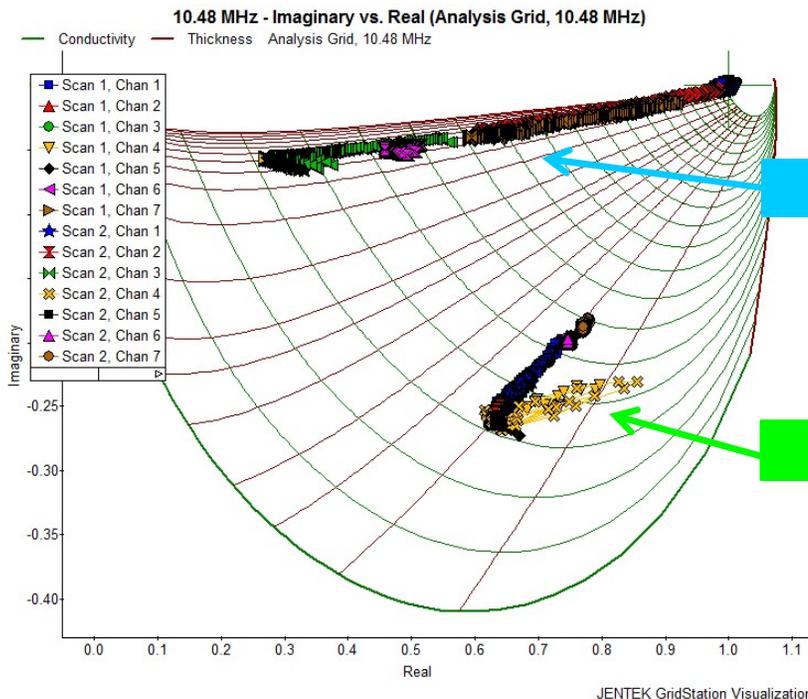
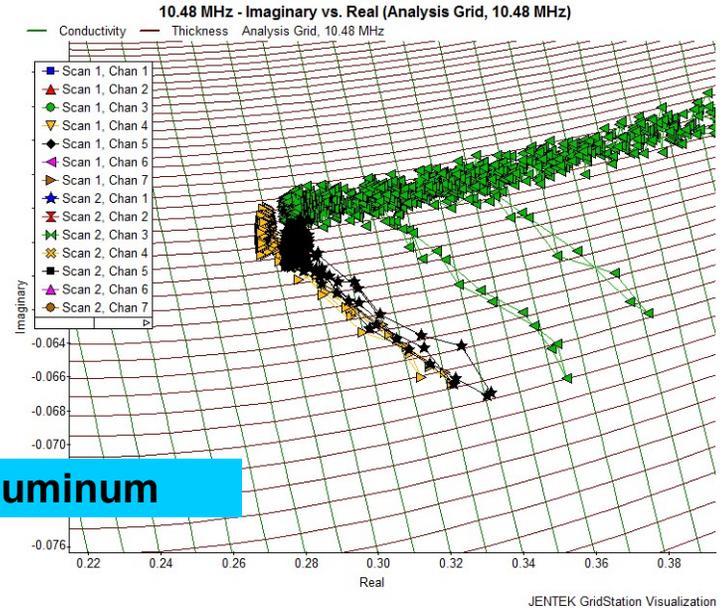
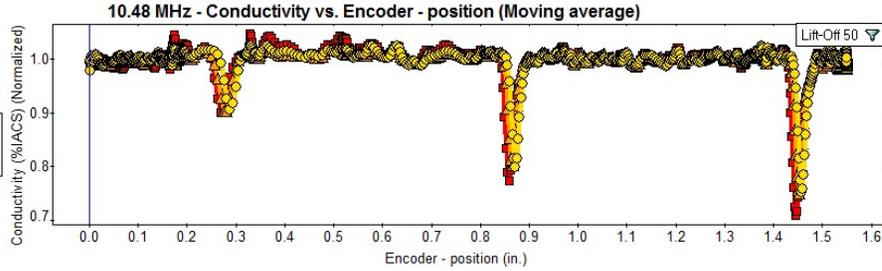
Right Angle Scanner

- 7-channel jET scanner
- Quick-release sensor cartridges for rapid sensor swap and cost reduction



Automatic Correction for Part Conductivity (and Temperature)

Aluminum Alloy Standard



Titanium Alloy Fillet Sample

Surface Crack Detection at fillets with MWM-Arrays



Liftoff & coverage verification

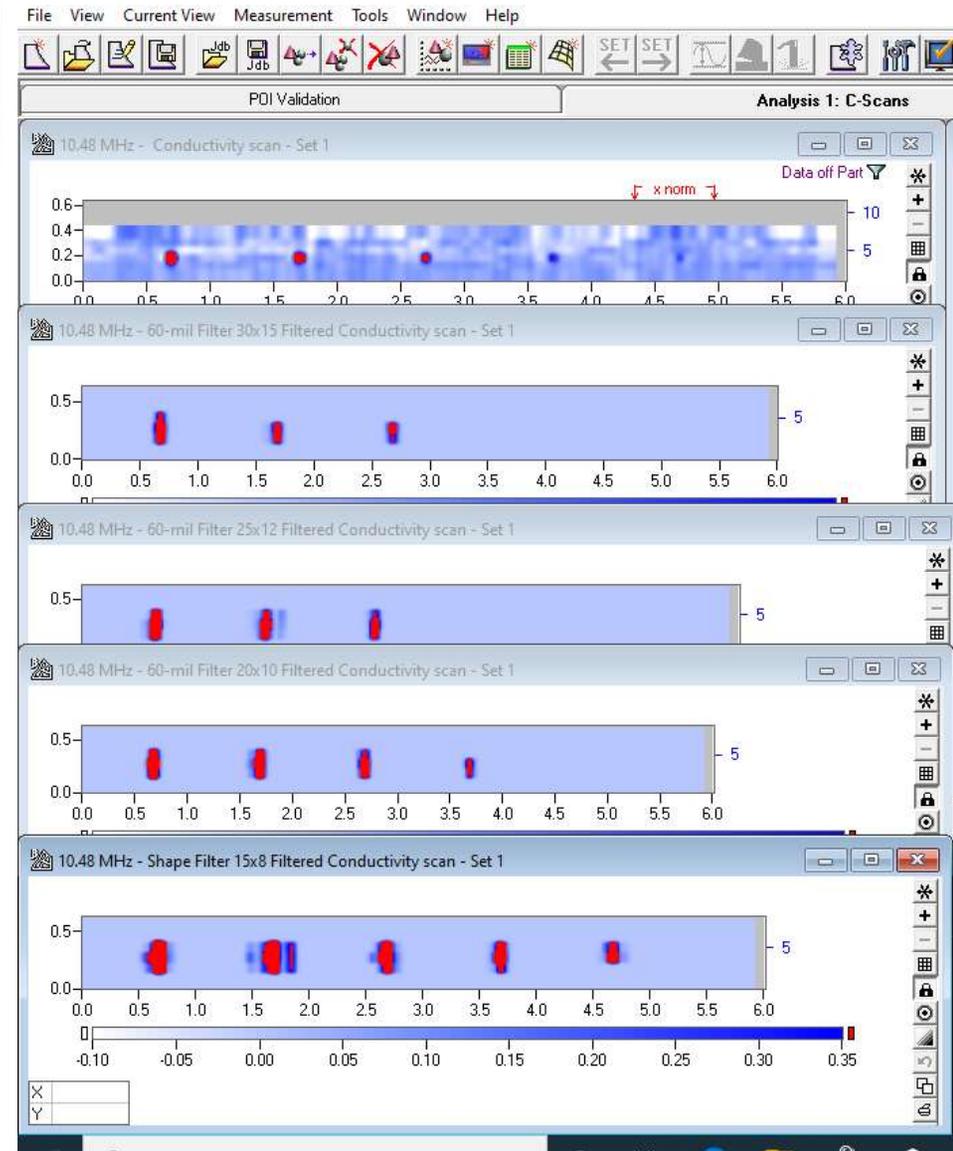


Six EDM notches at fillet

Depths 0.030, 0.020, 0.015, 0.010, 0.007 in.

Filtered by size

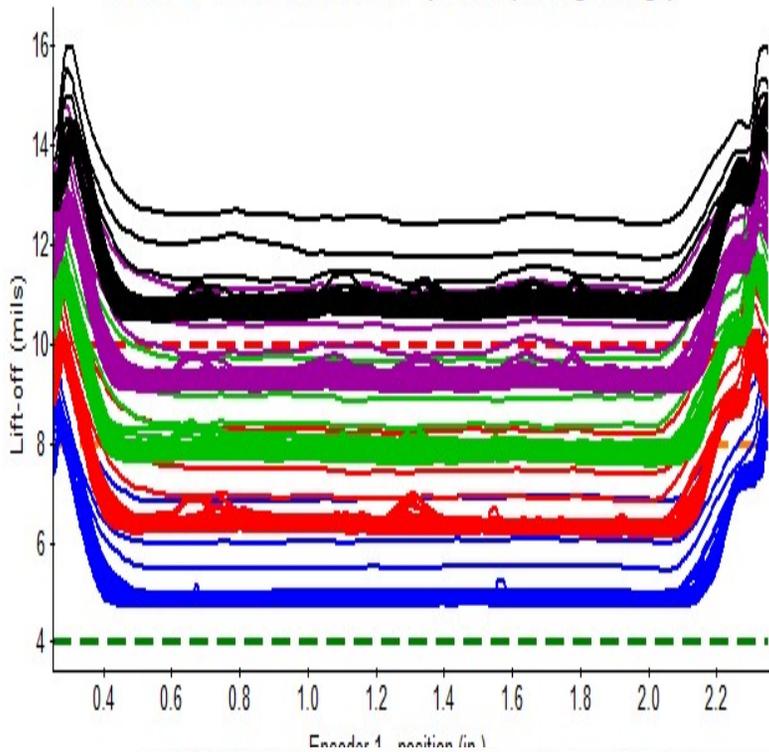
All detected, with “air calibration”



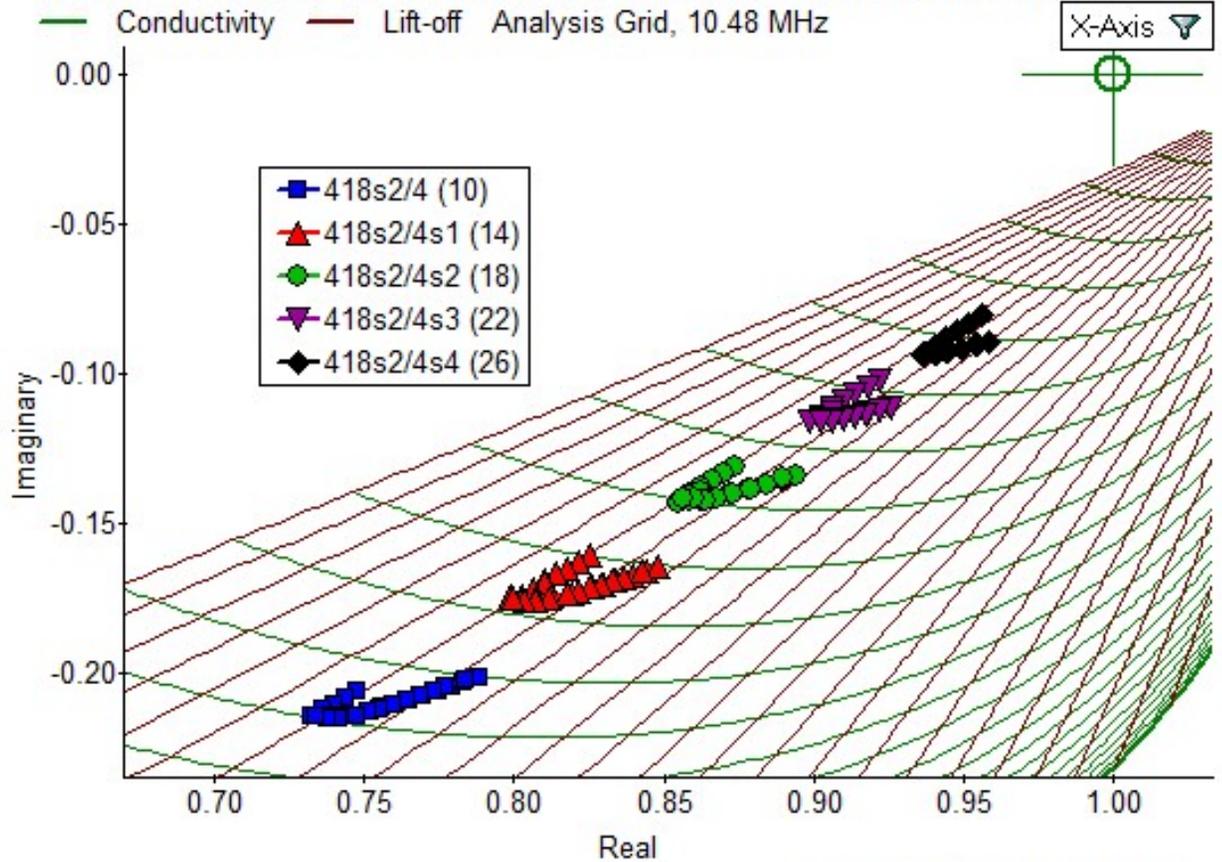
Unfiltered (top) and Filtered C-Scans

Automatic Rescaling of Crack Response with Lift-off

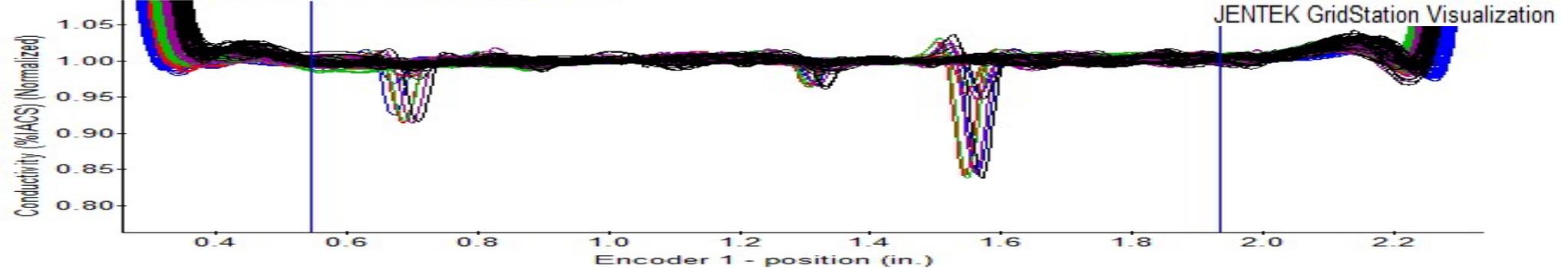
10.48 MHz - Lift-off vs. Encoder 1 - position (Moving average)



10.48 MHz, Chan 19 - Imaginary vs. Real (Analysis Grid, 10.48 MHz)



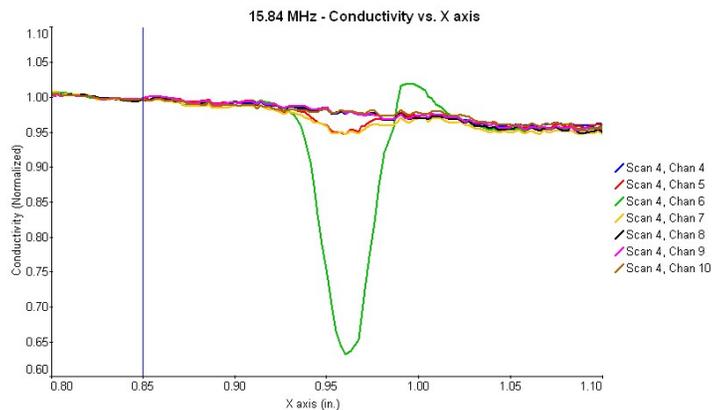
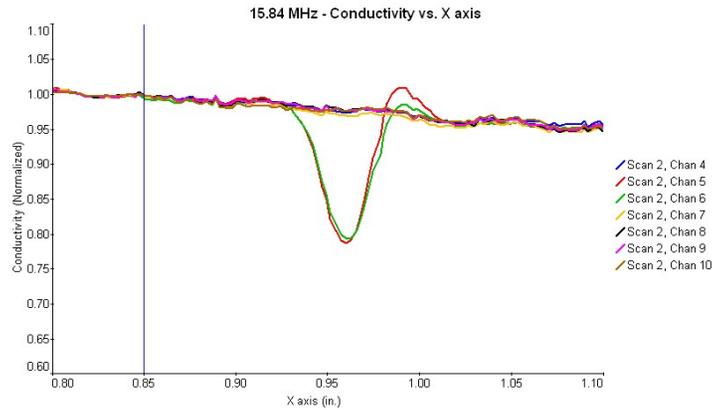
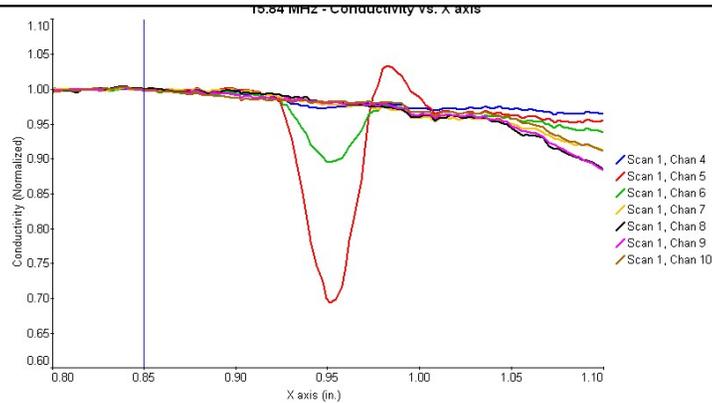
10.48 MHz - Conductivity v



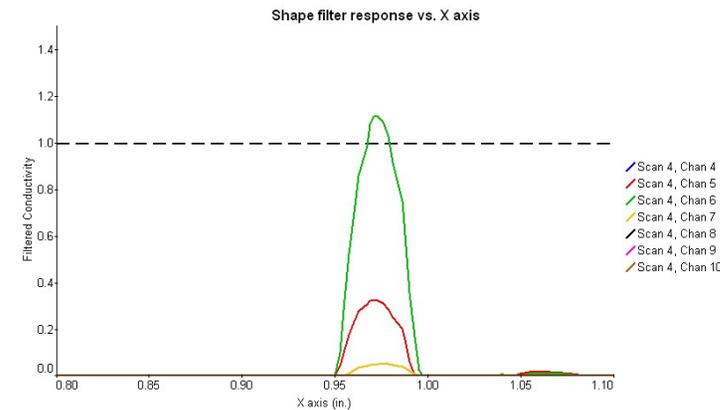
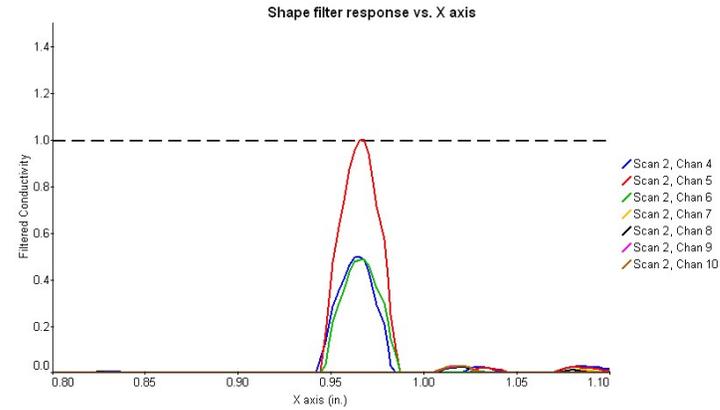
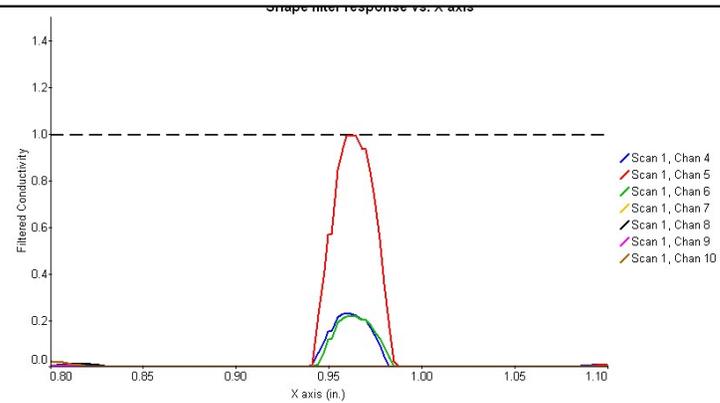
Automatic Rescaling of Crack Response with Position within Array

Varying Transverse Position

Unfiltered Crack Response

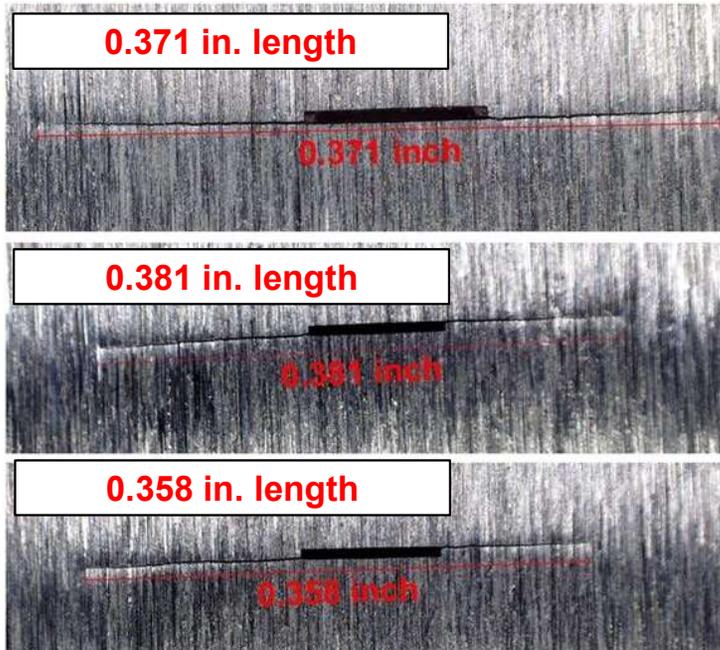


Filtered Crack Response

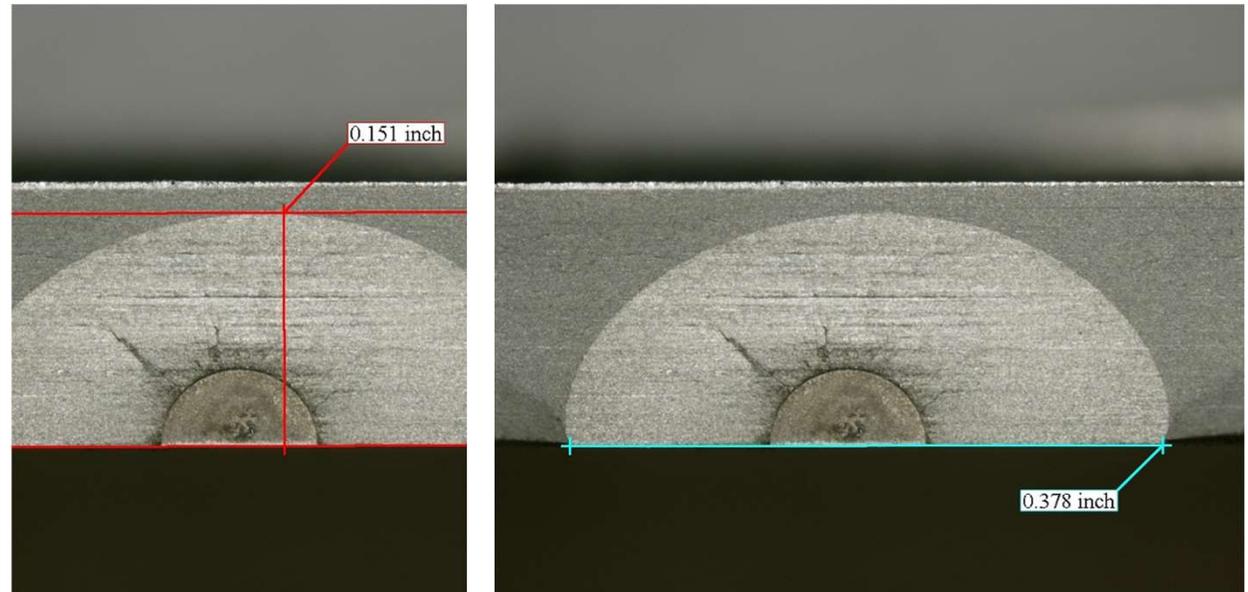


- Air Force funded POD study
- Fractography for largest defect shown below
- Real crack generated with starter EDM notch

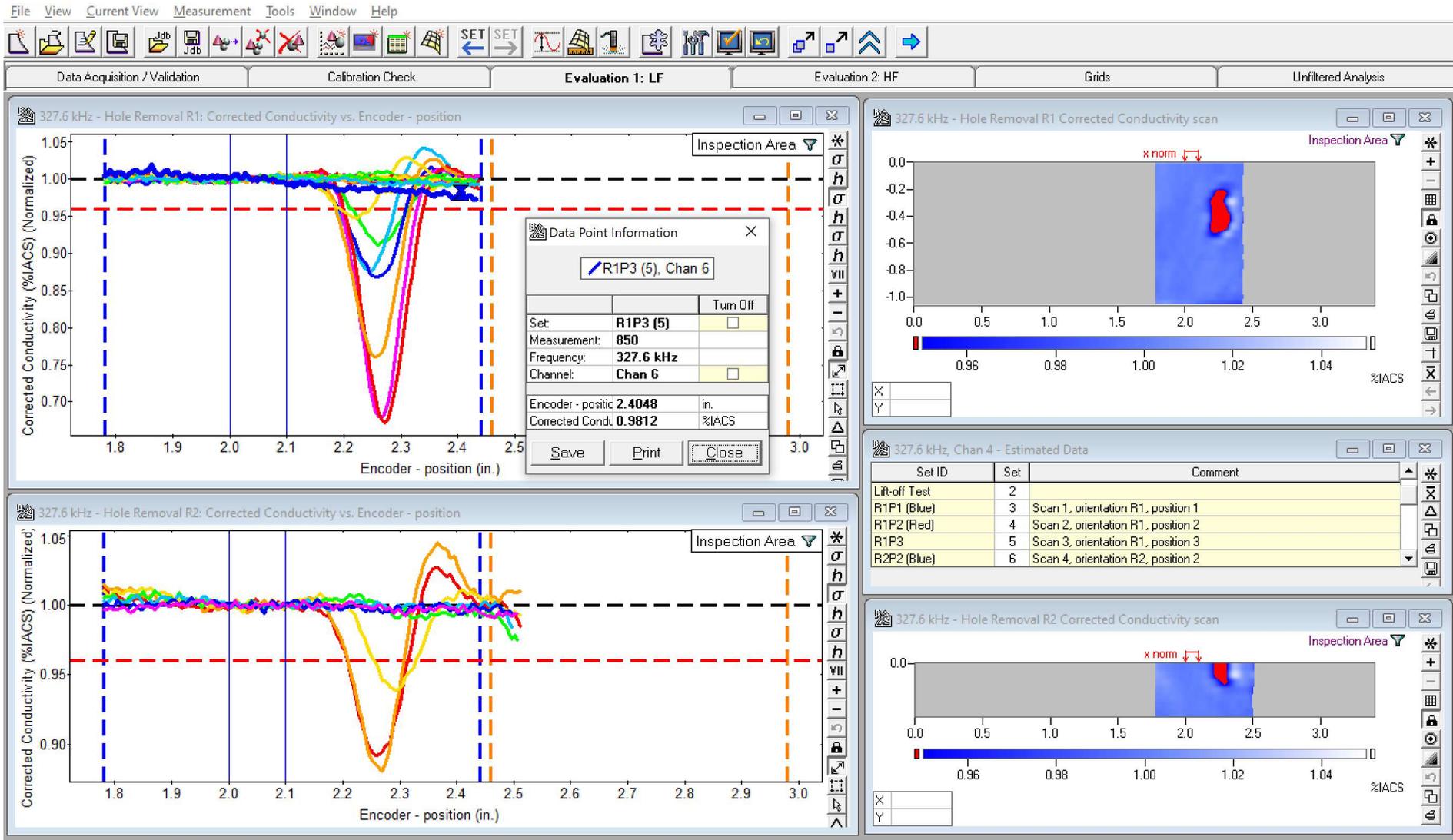
Crack length measurement
Specimens 1, 2, 3



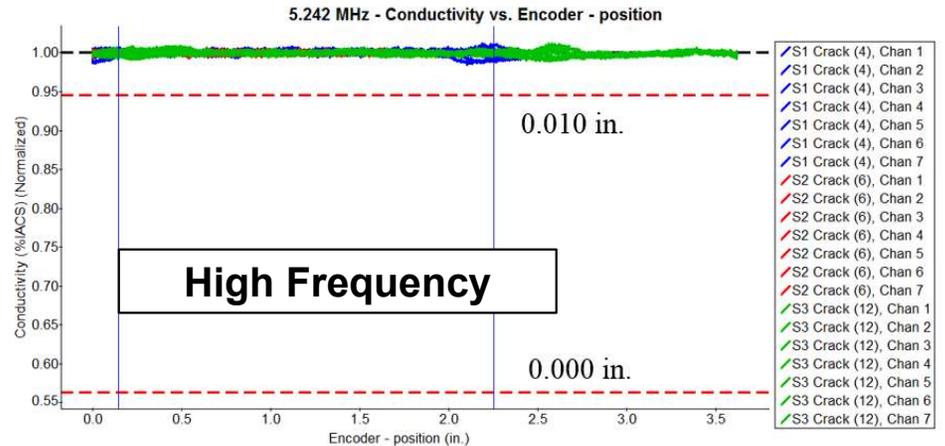
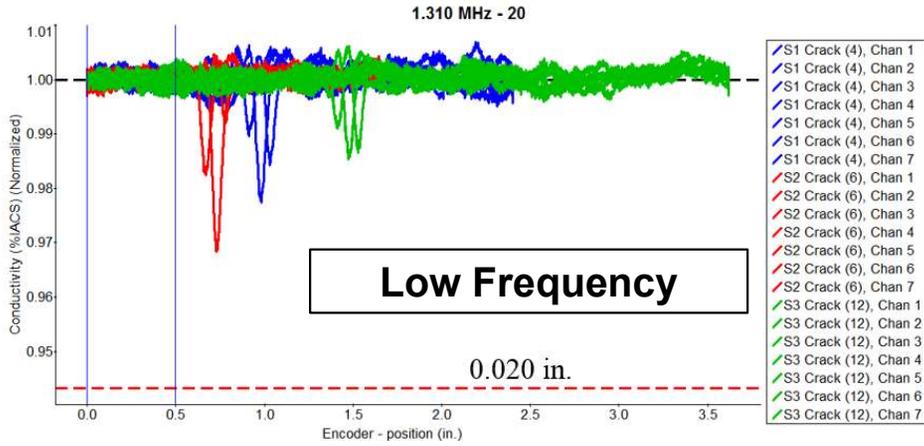
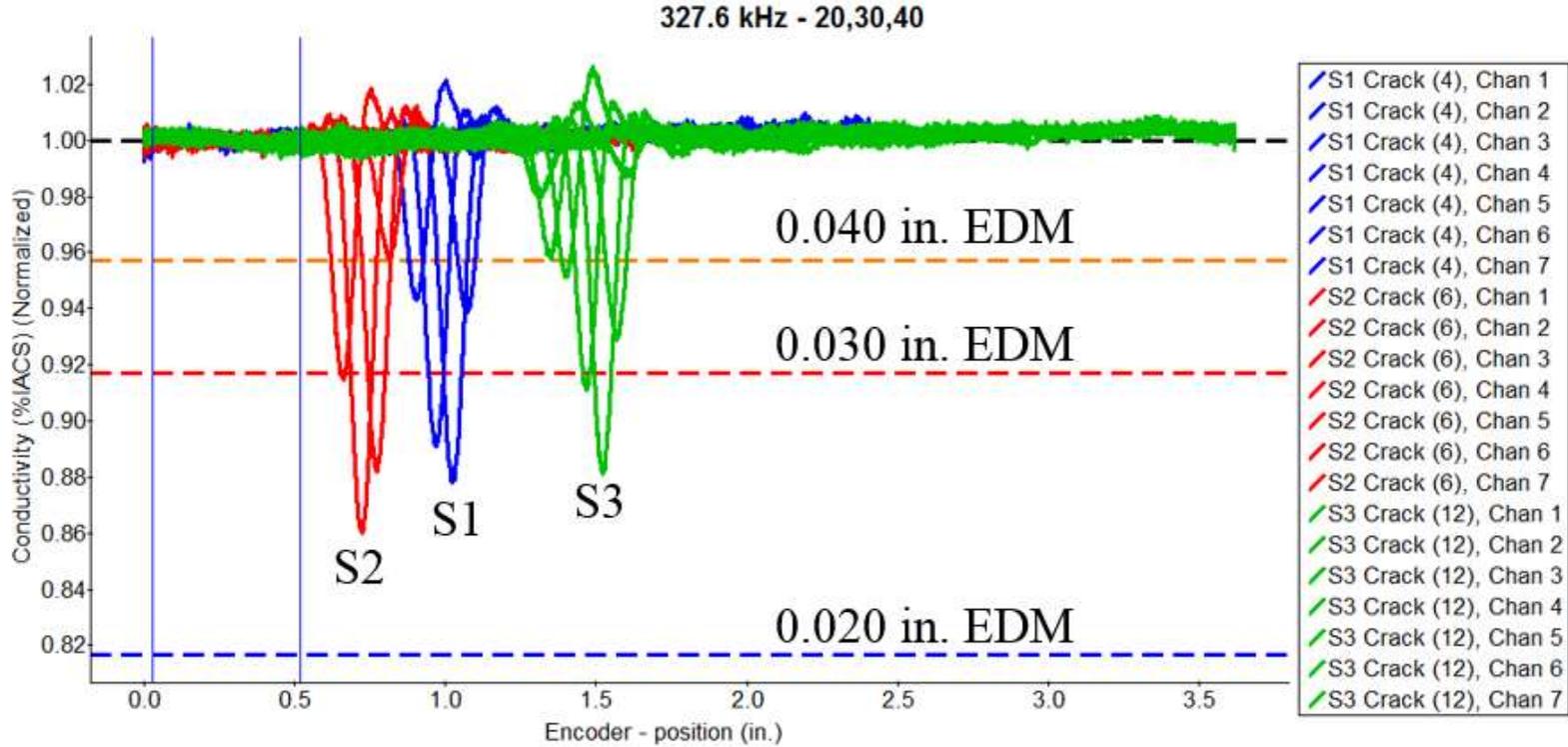
Destructive analysis of Specimen 2
Specimen thickness measured at 0.168 in.



Sub-surface Real Crack Response

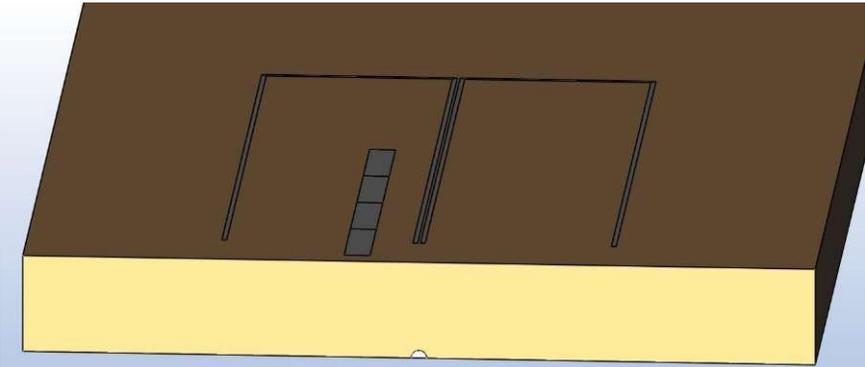


Sub-surface Real Crack vs. EDM Notch Responses

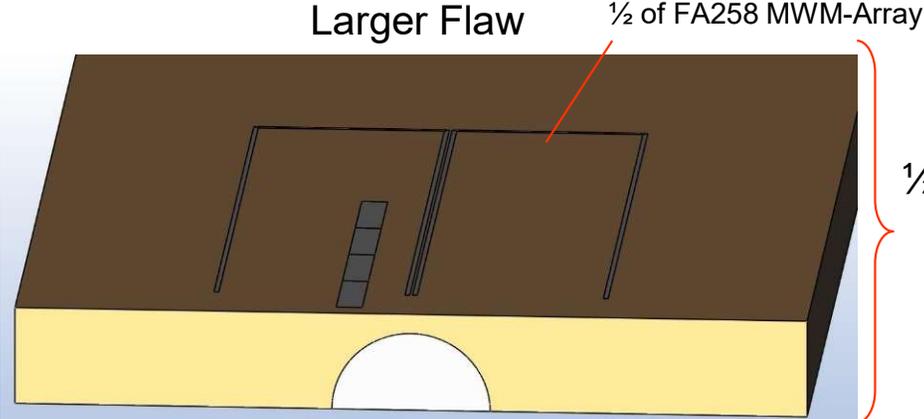


Subsurface crack modeling

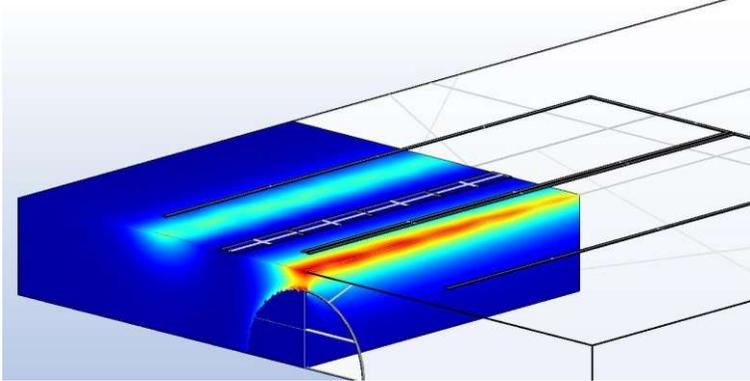
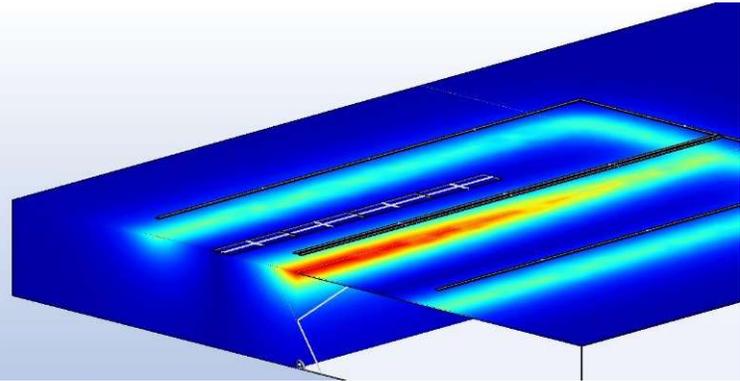
Smaller Flaw



Larger Flaw

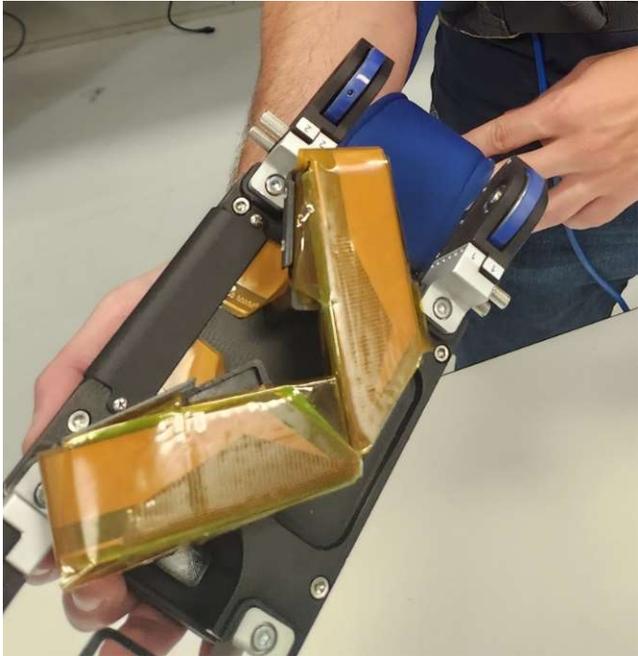


1/2 of physical geometry (using symmetry)



Induced current density contour plots [100 kHz; 0.05 in. lift-off; 0.4 in. long larger notch]

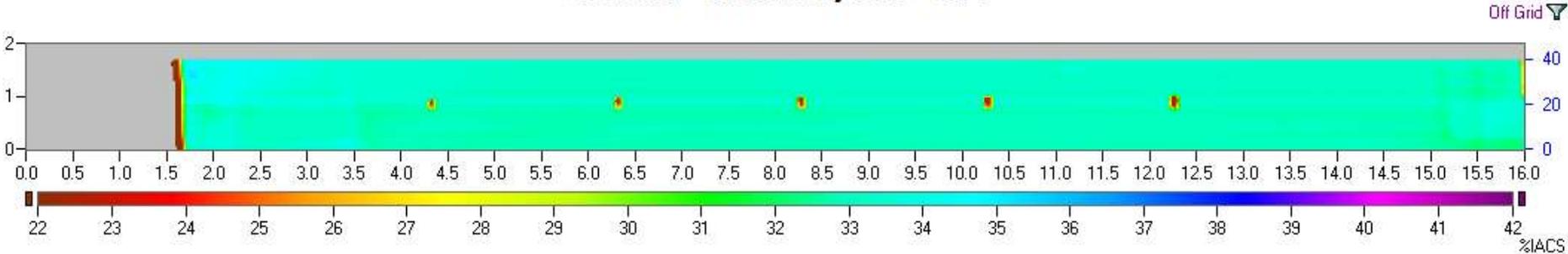
GS9000 Surface-Breaking Crack Detection



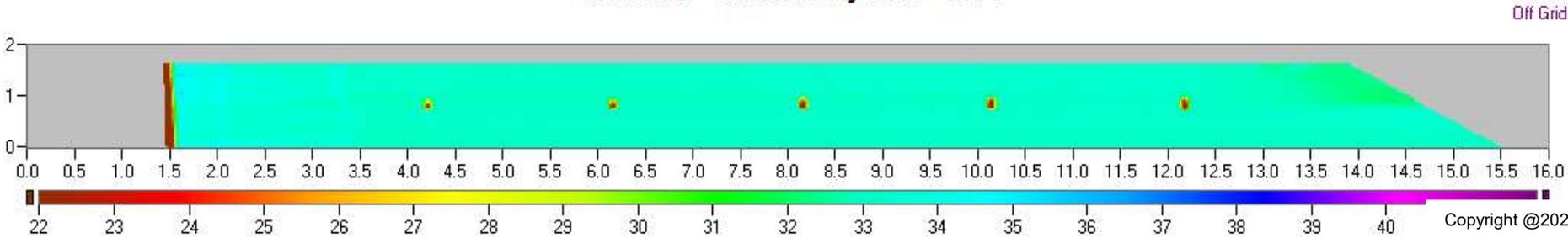
- 79-channel MWM-Array
- Simultaneous $\pm 45^\circ$ scan for improved defect detection



655.3 kHz - Conductivity scan - Set 4

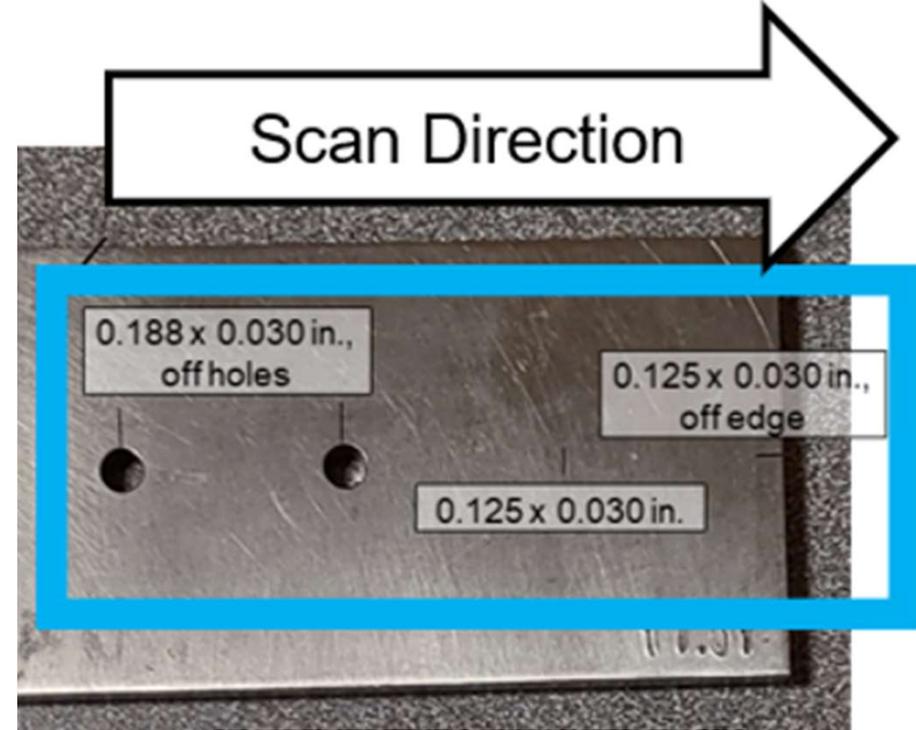


655.3 kHz - Conductivity scan - Set 4



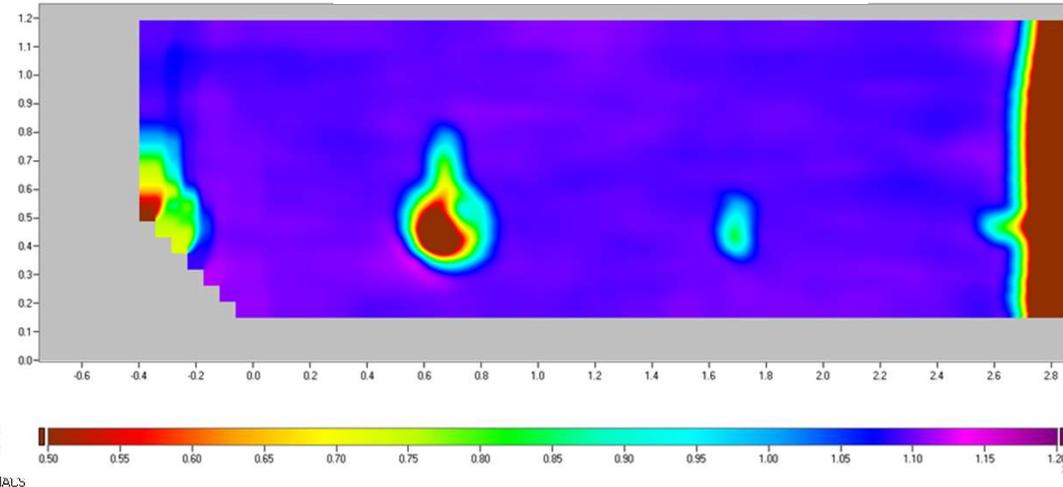
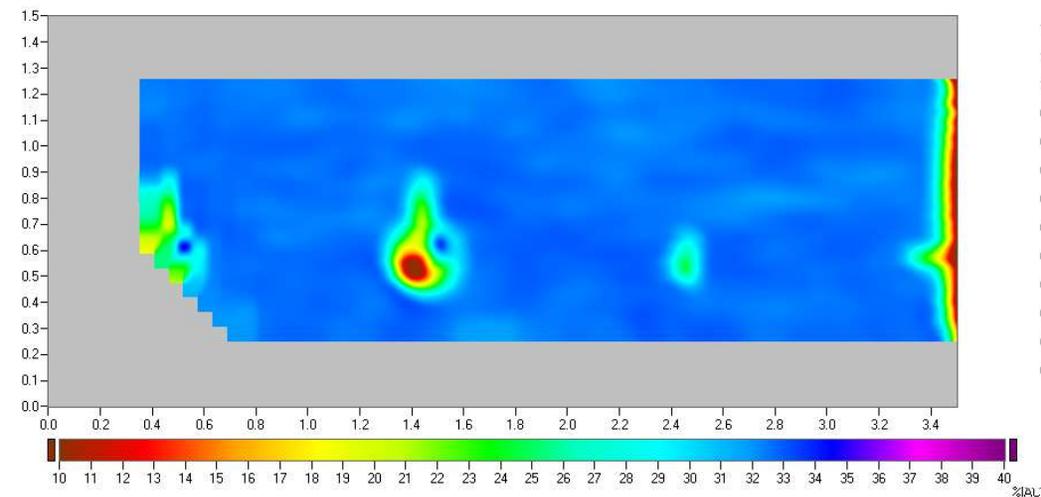
Surface Cracks at Holes, Away from Holes, at Edges

- GS9000 39-channel $\pm 45^\circ$ scans
- DAC GSET (Douglas A/C standard)
- 1mm sense element pitch
- 1.1 inch scan width (27.5mm)
- Approx. 1 inch/sec scan speed



Aluminum, 1.3 MHz

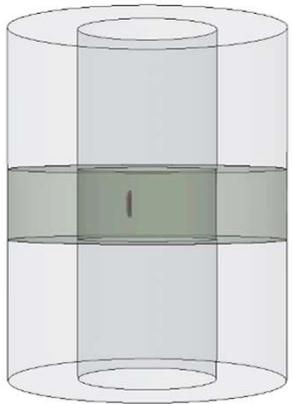
Titanium, 10 MHz



jETi Bolt-Hole Inspection System



Example Result: 3 Layer Stack-up (50 x 25 mil; mid-wall flaw) 16

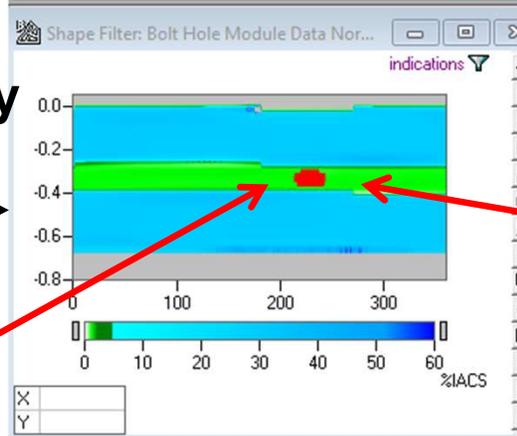


Automatic Reporting

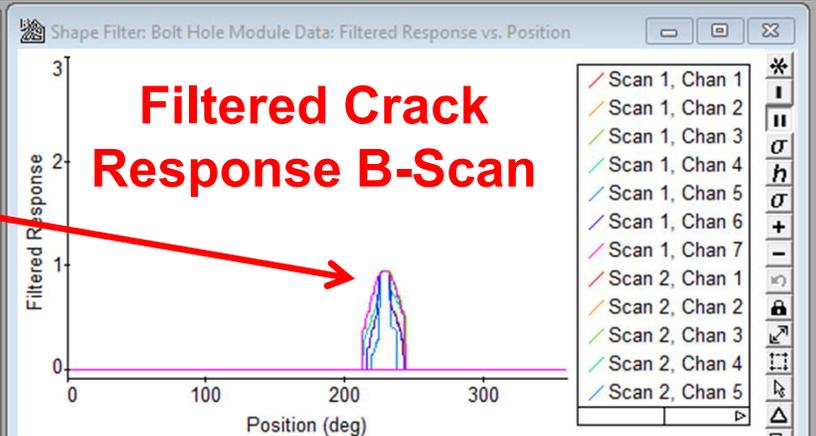


Indication	Peak Response	Layer	X Center (deg)	Y Center (in.)	X Peak (deg)	Y Peak (in.)	Set	Channel
1	0.9492	2.000	229.9	-0.3300	228.6	-0.3194	4.000	4.000
2								
3								
4								
5								

Conductivity C-Scan

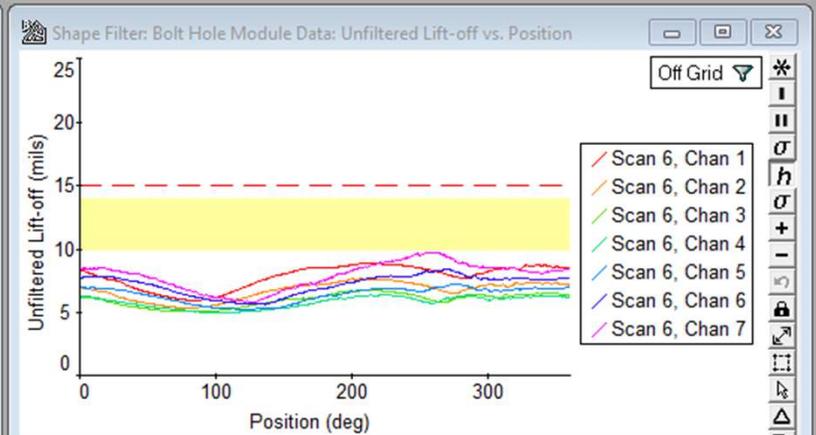
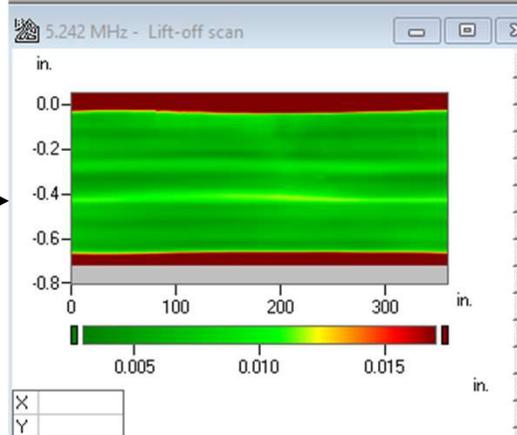


0.050 in. x
0.025 in.



Filtered Crack Response B-Scan

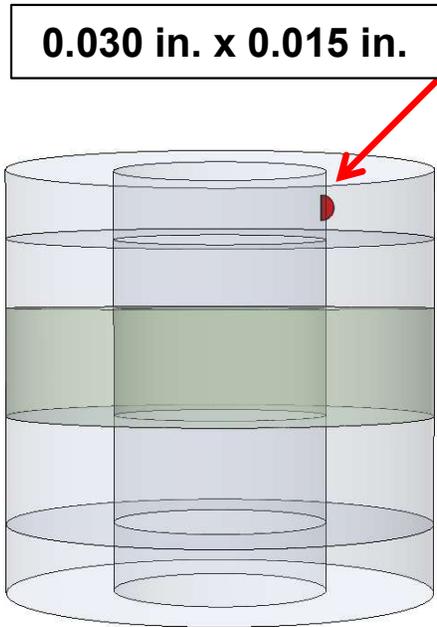
Lift-off C-Scan



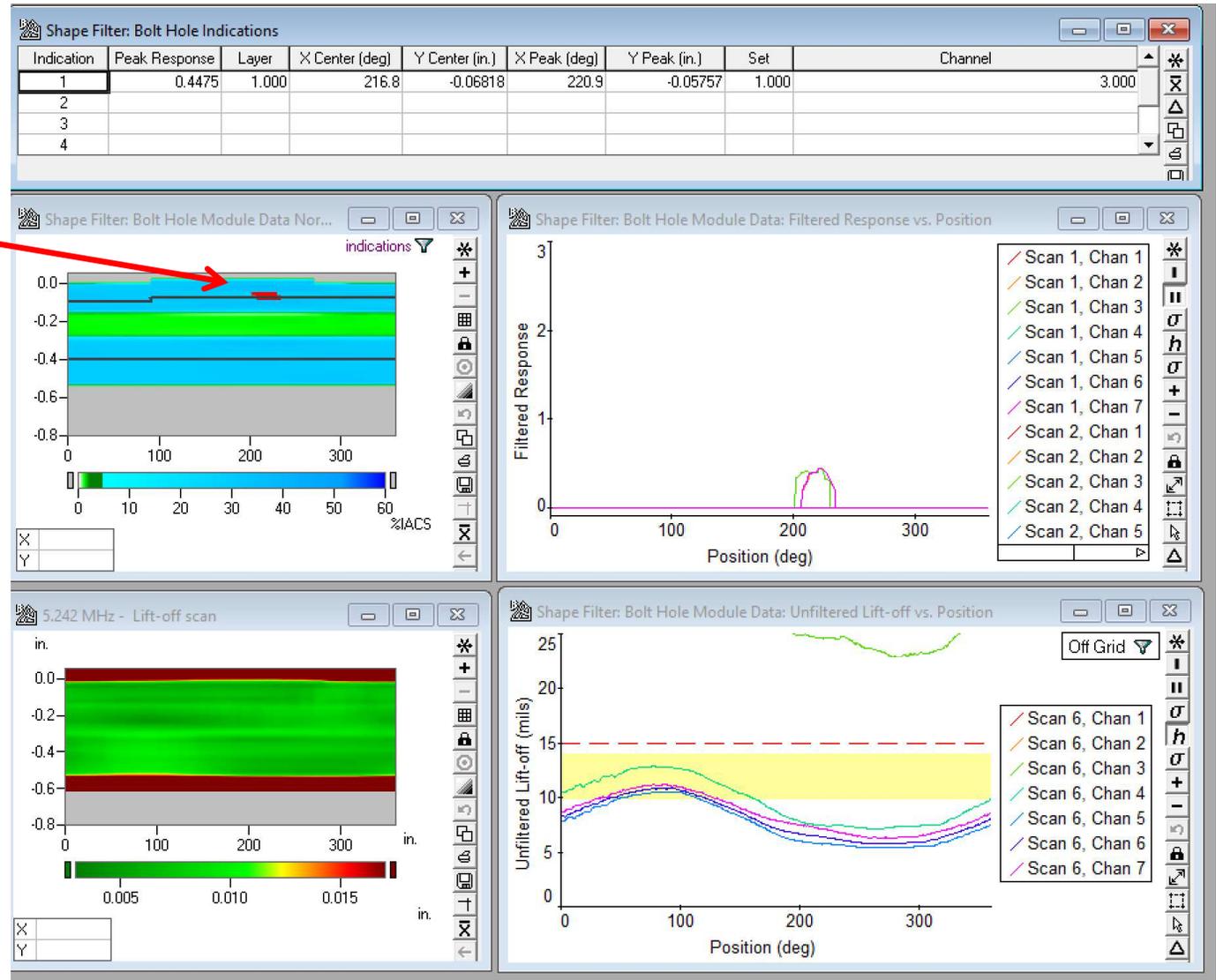
Lift-off B-Scan



Study Specimen 1701 Hole 3 (30 x 15 mil; mid-wall flaw)



- Aluminum
- Aluminum
- Titanium
- Aluminum
- Aluminum



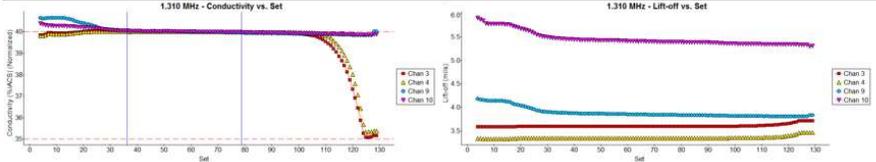
Real Crack Specimen Fabrication

Material	Thickness (in)	Hole Diameter (in)
6061-T6	0.125	¼ (0.250)

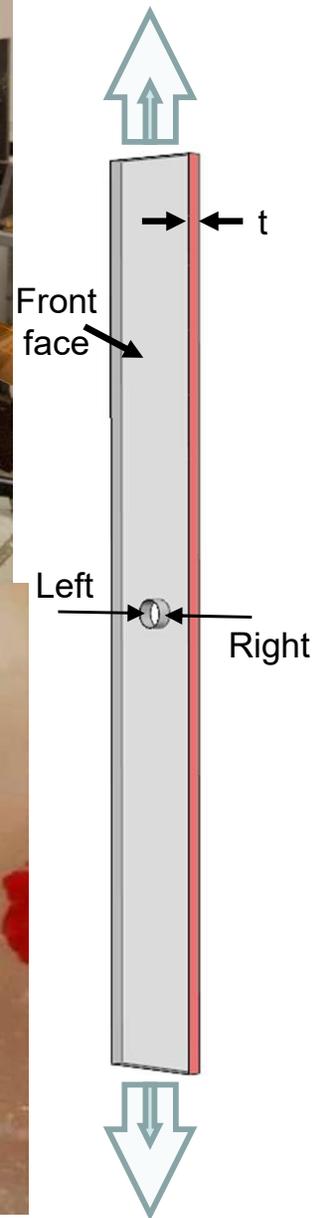
Note: Conductivity measurements are **NOT** consistent with 6061-T6

Maximum Load (lbs)	Minimum Load (lbs)	Frequency (Typical)	Max. # Cycles
3000	300	25Hz	19,773

Left		Right	
Length in Hole (in)	Length on Surface (in)	Length in Hole (in)	Length on Surface (in)
0.000	0.000	0.044	0.018



Sample 1



Photos of front and back face for measurement of crack length on surface
(back shown)

Replicas of left (9 o'clock) and right (3 o'clock) sides for measurement of crack length in hole

No crack left side

0.044 inch crack right side

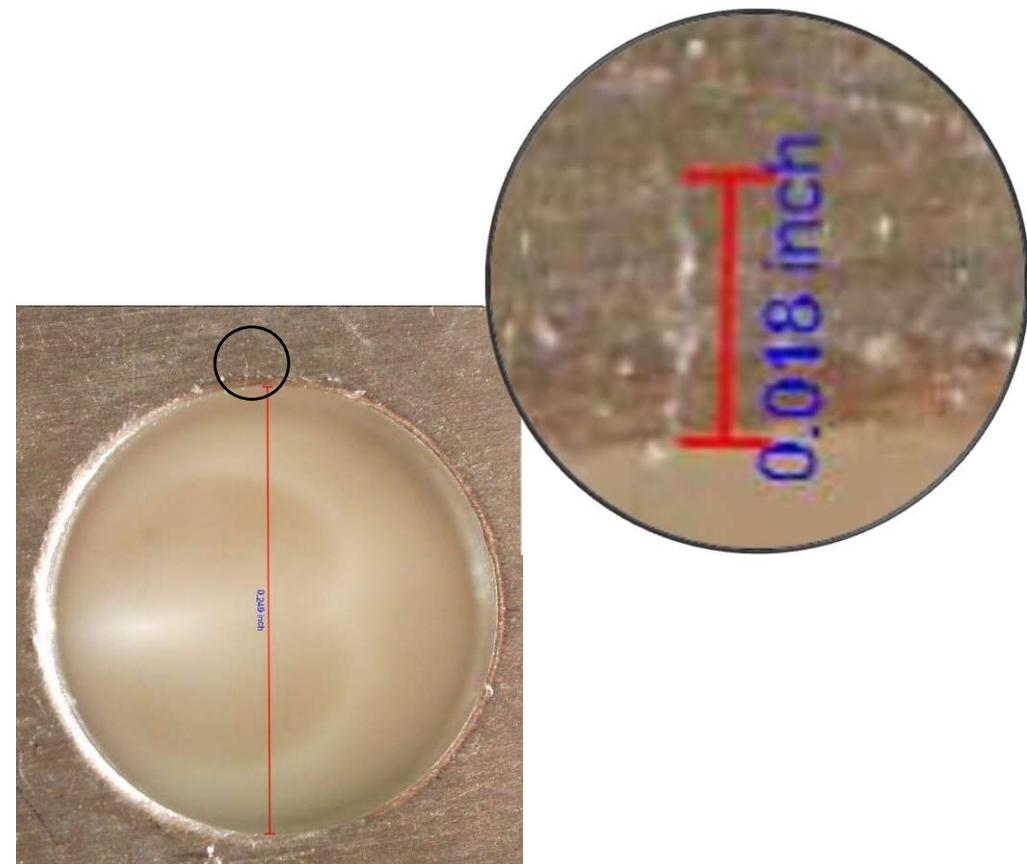
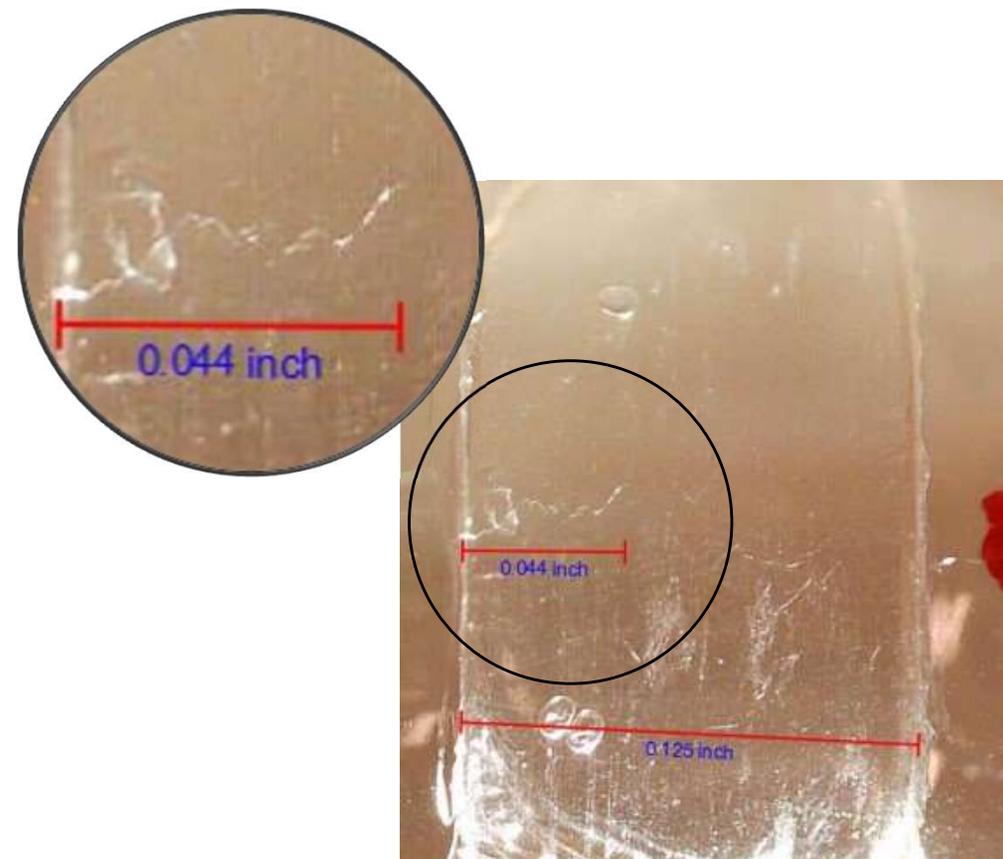
0.044 inch

0.125 inch

Real Crack Specimen 1

- ¼ in. hole; Al alloy
- Left inside: No defect
- Right inside: 0.044 in. corner crack (0.018 in. external surface crack)

Note the jagged nature of real cracks



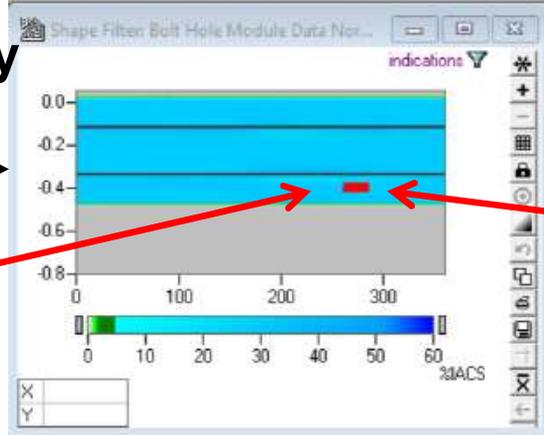
Real Crack Specimen 1 – (44 x 18 mil; corner crack)

Automatic Reporting

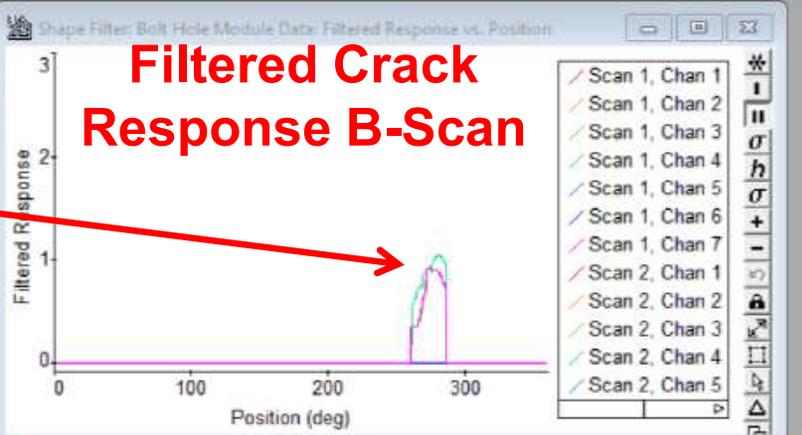


Indication	Peak Response	Layer	X Center (deg)	Y Center (in.)	X Peak (deg)	Y Peak (in.)	Set	Channel
1	1.042	3.000	273.5	-0.3980	280.1	-0.3824	5.000	4.000
2								
3								
4								
5								

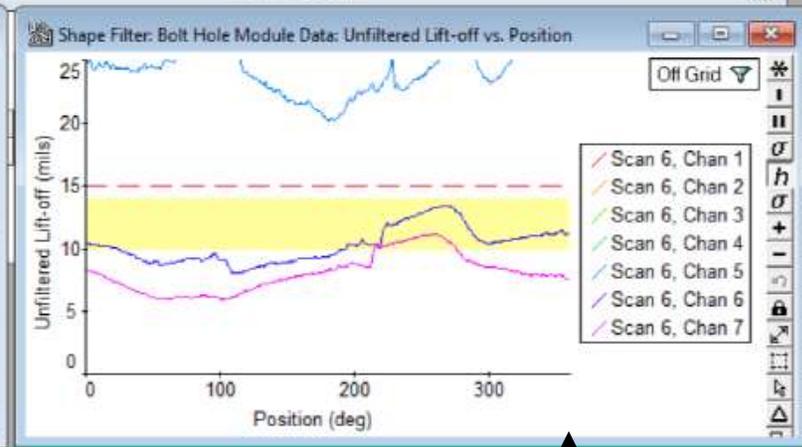
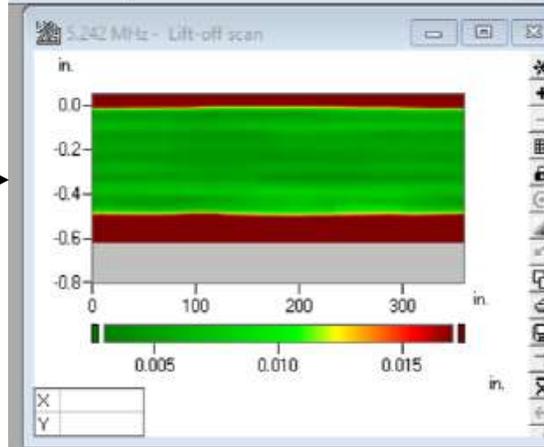
Conductivity C-Scan



0.044 in. x 0.018 in.



Lift-off C-Scan

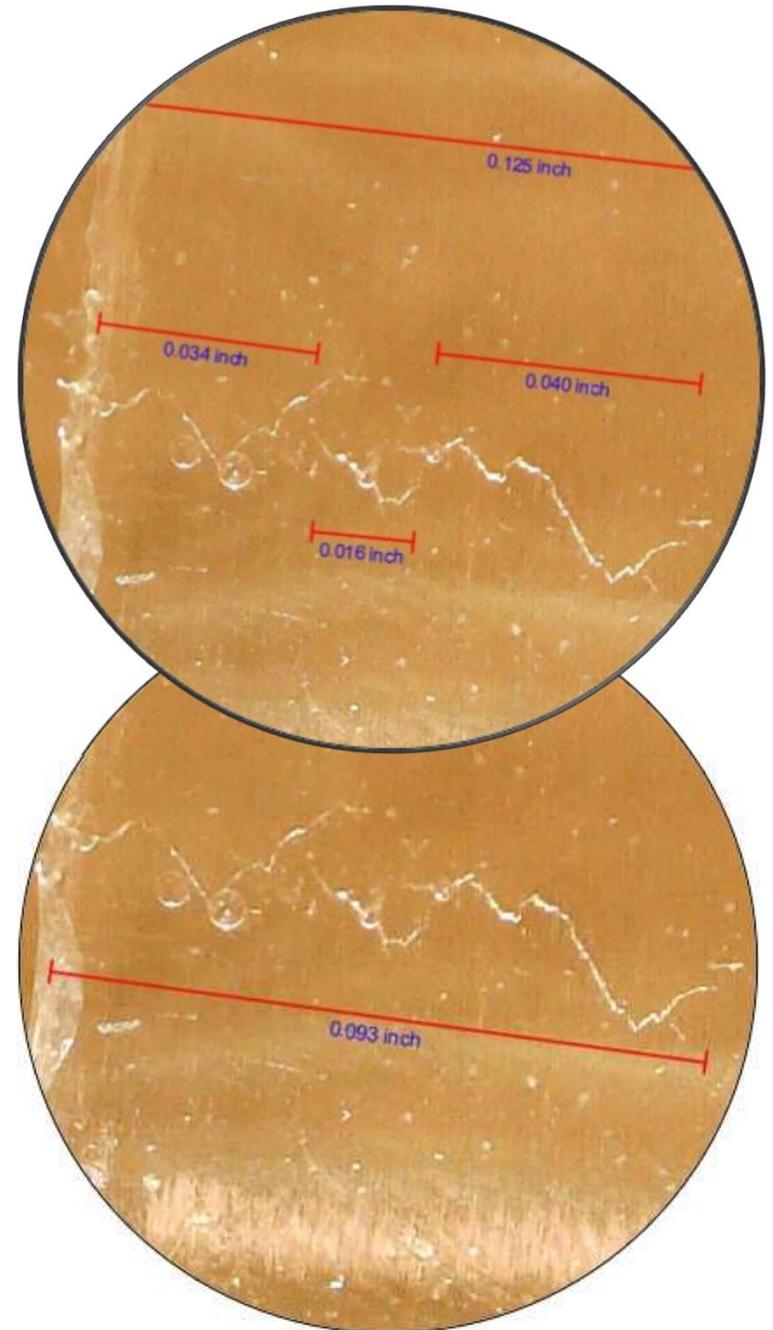
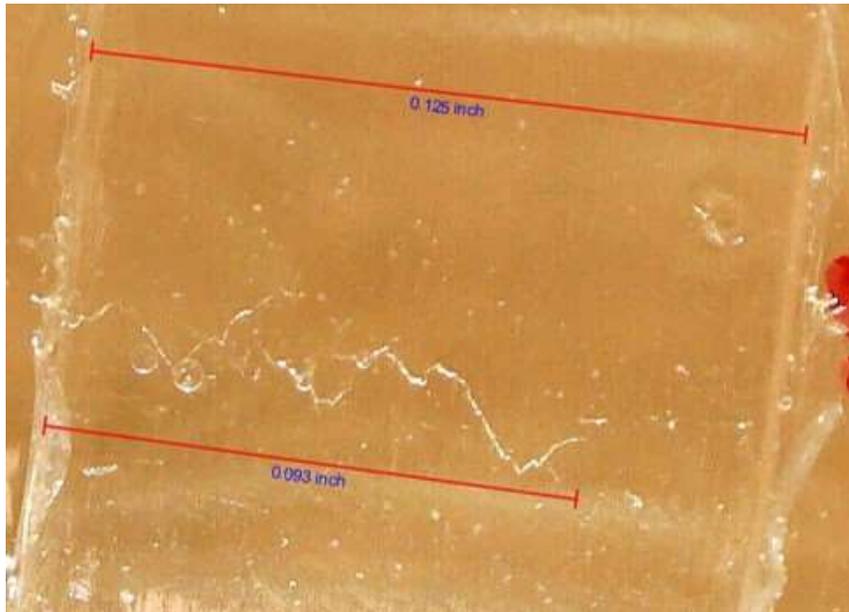


Lift-off B-Scan

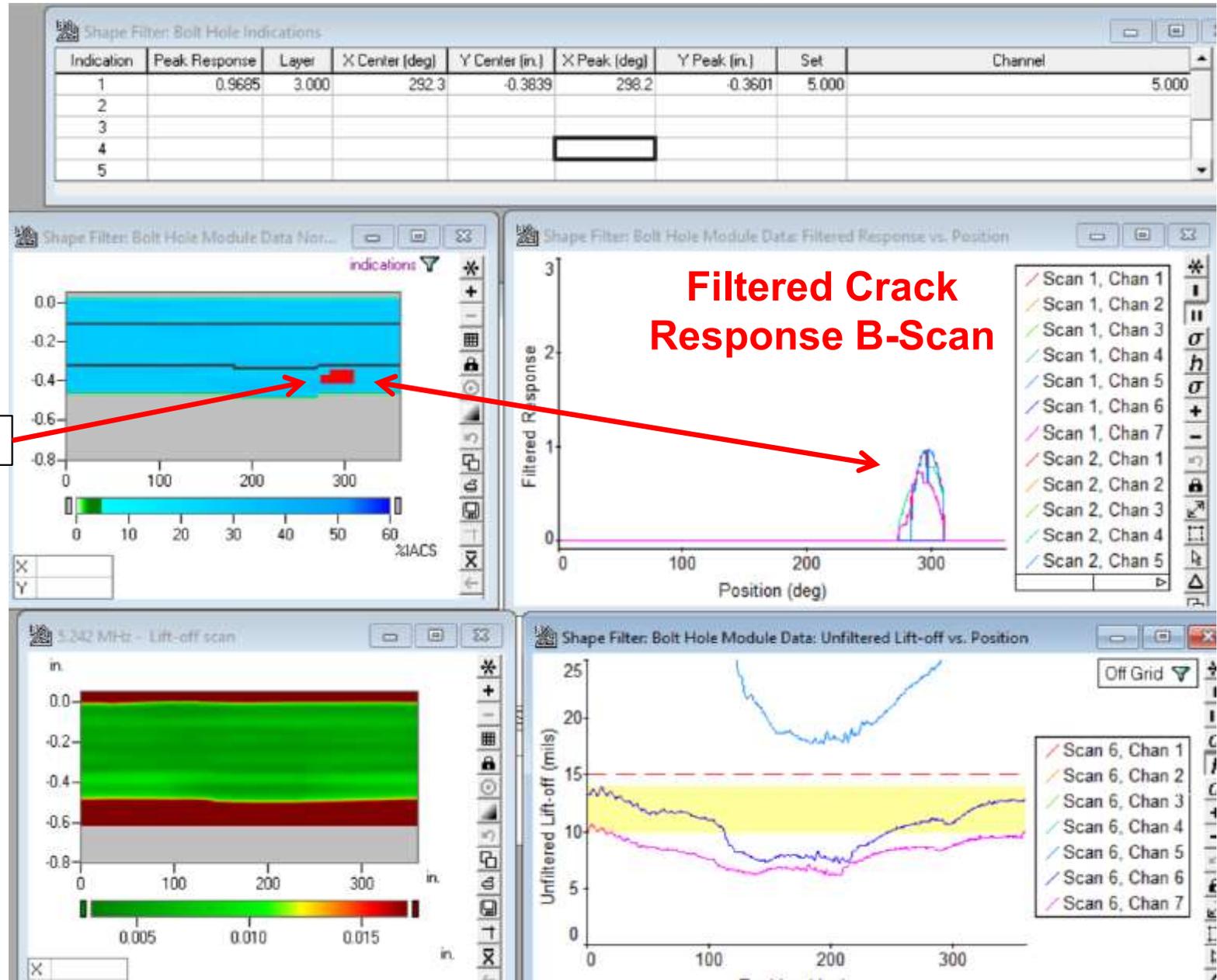


Real Crack Specimen 2

- ¼ in. hole; Al alloy
- Left inside: No defect
- Right inside: 0.093 in. crack near edge (no external surface crack visible)
- Appears to be three nearly coalesced cracks of lengths 0.040 in., 0.016 in., and 0.034 in.

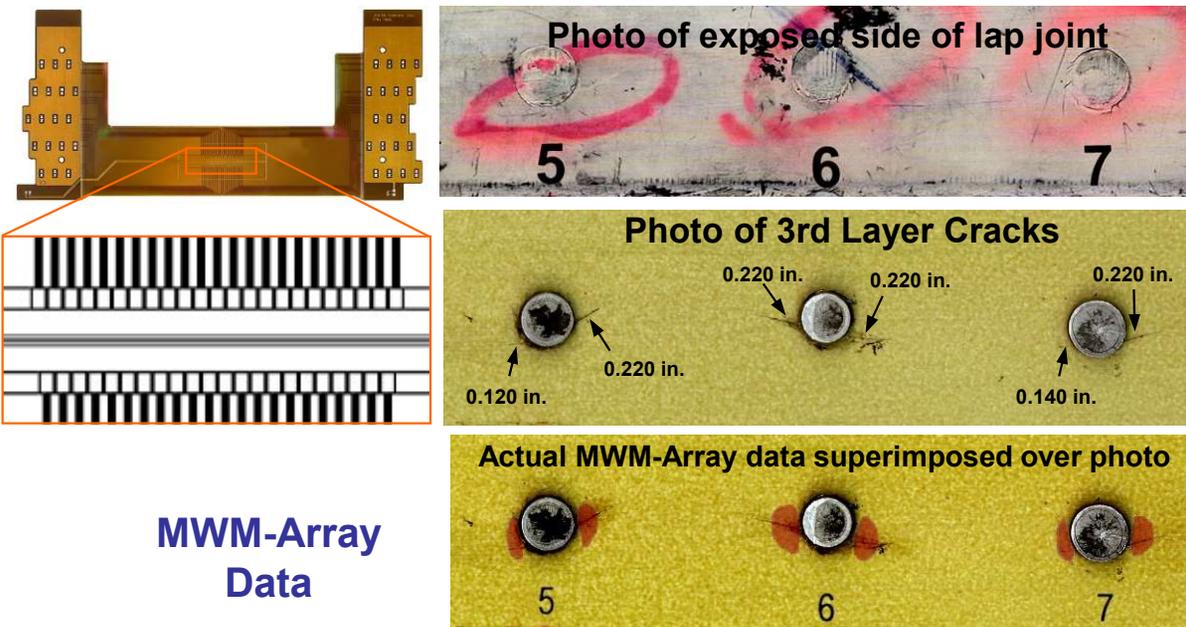


Real Crack Specimen 2 – (93 mil mid-bore/coalesced)



Example: Subsurface Cracks Near Fasteners

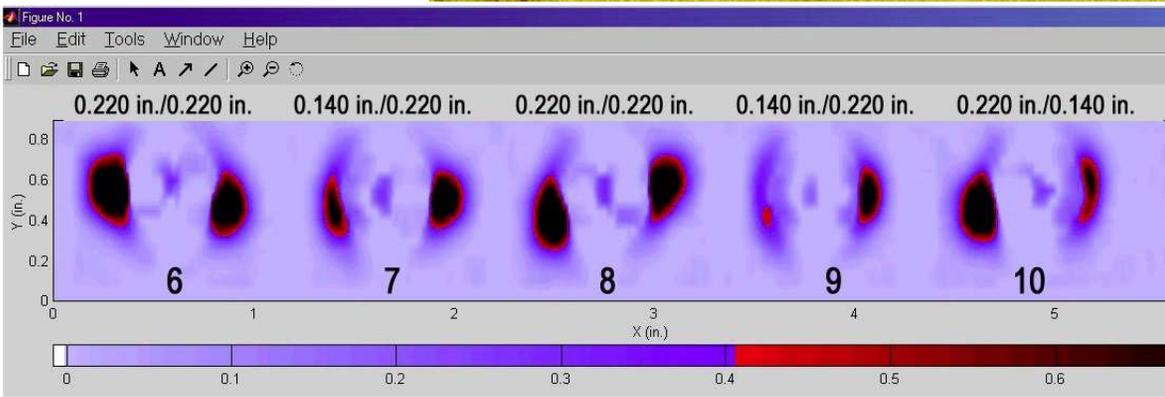
- For the FAA in ~2003 JENTEK participated in a performance study for the Probability of Detection (POD) of 2nd layer cracks in lapjoints for 727 aircraft. JENTEK had the best POD performance in the initial blind tests.
- Representative response images are shown below for a single pass of a sensor array across the fasteners. These scans were very slow but demonstrated excellent detection capability for the multiple crack sites; the current program would extend this work to accommodate a variety of fastener types and increase speed.



**MWM-Array
Data**



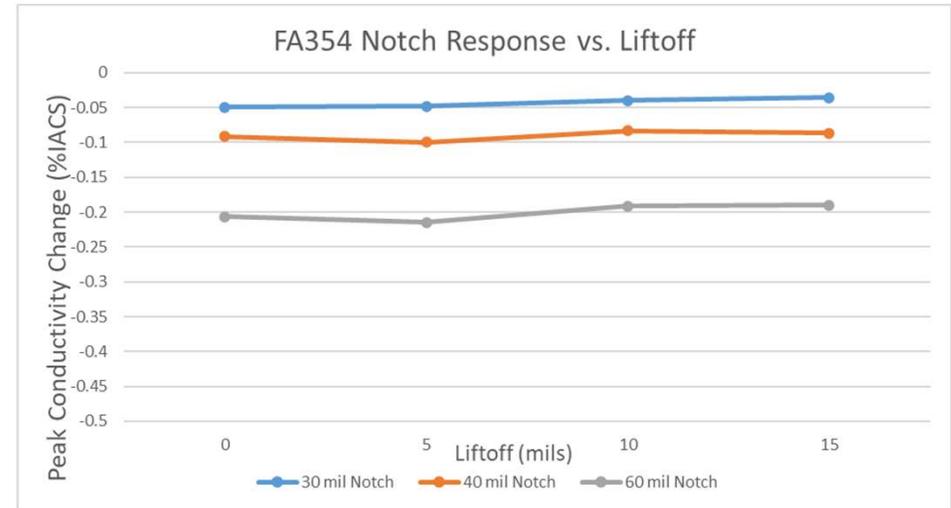
FAA System Training



Improved Lift-off Tolerance

Benefits

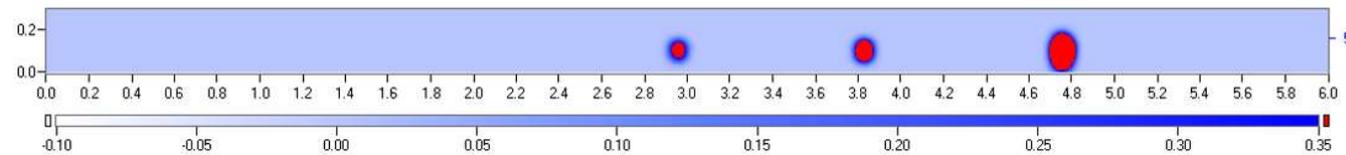
- Reduced false indications
- Less surface preparation required
- Inspection through paint
- Use of thicker protective coatings on the sensor to improve durability



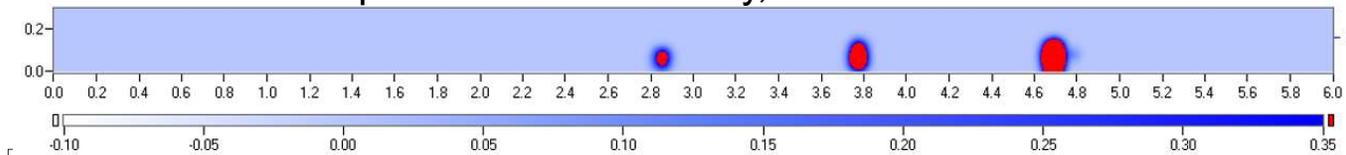
Sample Notch Sizes

Fillet	Angle
15x8	45
20x10	35
30x15	55
40x20	45
60x30	35

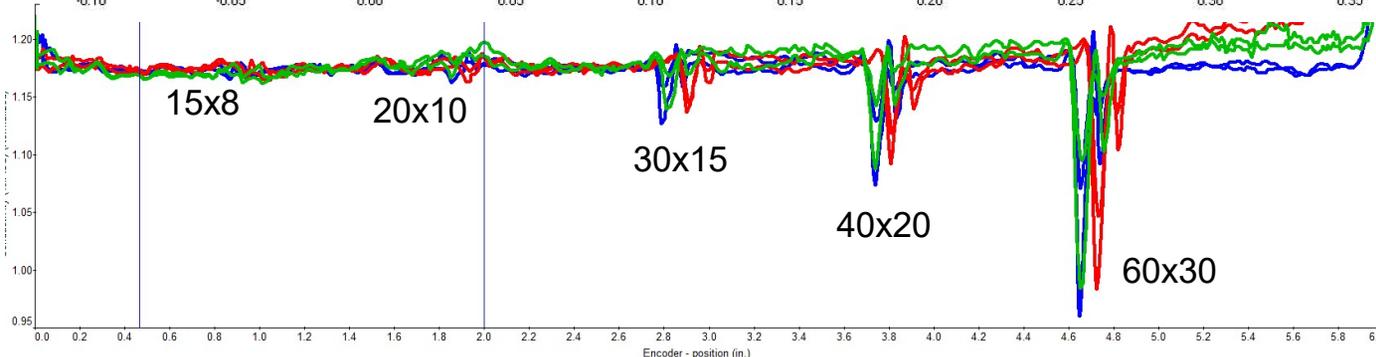
30 mil shape filtered conductivity, no added lift-off



30 mil shape filtered conductivity, 15 mils added lift-off



- 5 mils Liftoff Added (2) (9), Chan 3
- 5 mils Liftoff Added (2) (9), Chan 4
- 10 mils Liftoff Added (1) (13), Chan 3
- 10 mils Liftoff Added (1) (13), Chan 4
- 15 mils Liftoff Added (2) (19), Chan 3
- 15 mils Liftoff Added (2) (19), Chan 4



- **MWM-Array crack detection for bolt-holes and complex structures:**
 - Air calibration (ASTM E2338; ASTM E2884)
 - Three frequencies simultaneously
 - All sensing elements simultaneously (fully parallel)
 - Automatic crack response rescaling for liftoff
 - Automatic rescaling for defects between channels
 - Surface and sub-surface crack detection
- **Additional applications include: detection of cracks at fasteners, corrosion imaging, coating characterization, and in-process layer-by-layer sensing for additive manufacturing**