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Welcome!
"NDT Applications" Webinar Series

February 11, 2021

Host: Toni Bailey

Owner, TB3 NDT Consulting LLC

asnt.org / learn

“Using Eddy Current Arrays to Augment MT and PT”

Guest speaker:

Nicholas Cardillo, Zetec Inc.

Nicholas Cardillo

Sales Engineering Director (ECT), Zetec Inc.

Conventional Surface Inspection Techniques

- For decades, well-established standards such as the:
  - **ASNT** International
  - American Society of Mechanical Engineers **ASME**
  - International Standards Organization **ISO**

- Determine the appropriate Surface-Breaking Defect Inspection methods, such as:
  - Magnetic particle testing (**MT**)
  - Liquid penetrant testing (**PT**)
  - Eddy current testing (**ECT**)

- To inspect all kinds of metallic components from different assets.

Magnetic Particle Testing (MT)

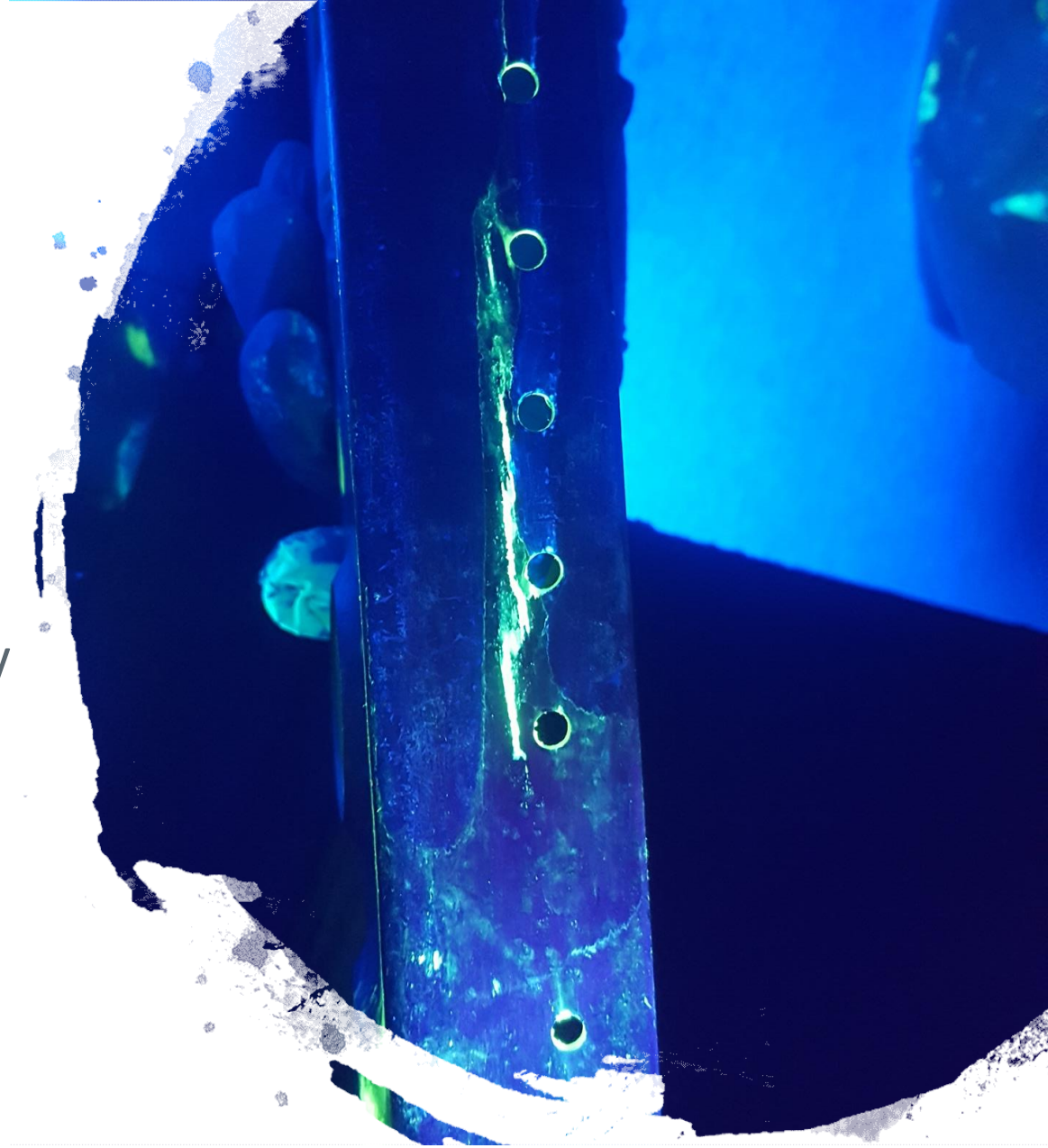
- Surface and shallow subsurface in ferrous materials
- Magnetic field is applied to the part
- Discontinuities in the material allow the magnetic flux to leak
- Dry or wet ferrous particles are applied to a part
- Particles are attracted to the flux leakage and will form around the discontinuity

Magnetic Particle Testing (MT)

Pros	Cons
✓ Easy to use	X Pre- & post-surface cleaning required
✓ Minimum certification required	X Needs electrical power supply
✓ Quick indication detection	X No depth sizing
✓ Low-cost inspection	X No recording data capabilities
✓ Not affected by the inspection zone size	X Limited on thick paint/coatings
✓ Works on different kinds of ferrous material	X Limited on nonferrous material
✓ Effective on complex geometries	X May require large footprint

Liquid or Dry Penetrant Testing (PT)

- Surface-breaking in nonporous materials
- Applied penetrant is drawn into the surface-breaking defects
- Defects become visible from the dye or under UV light

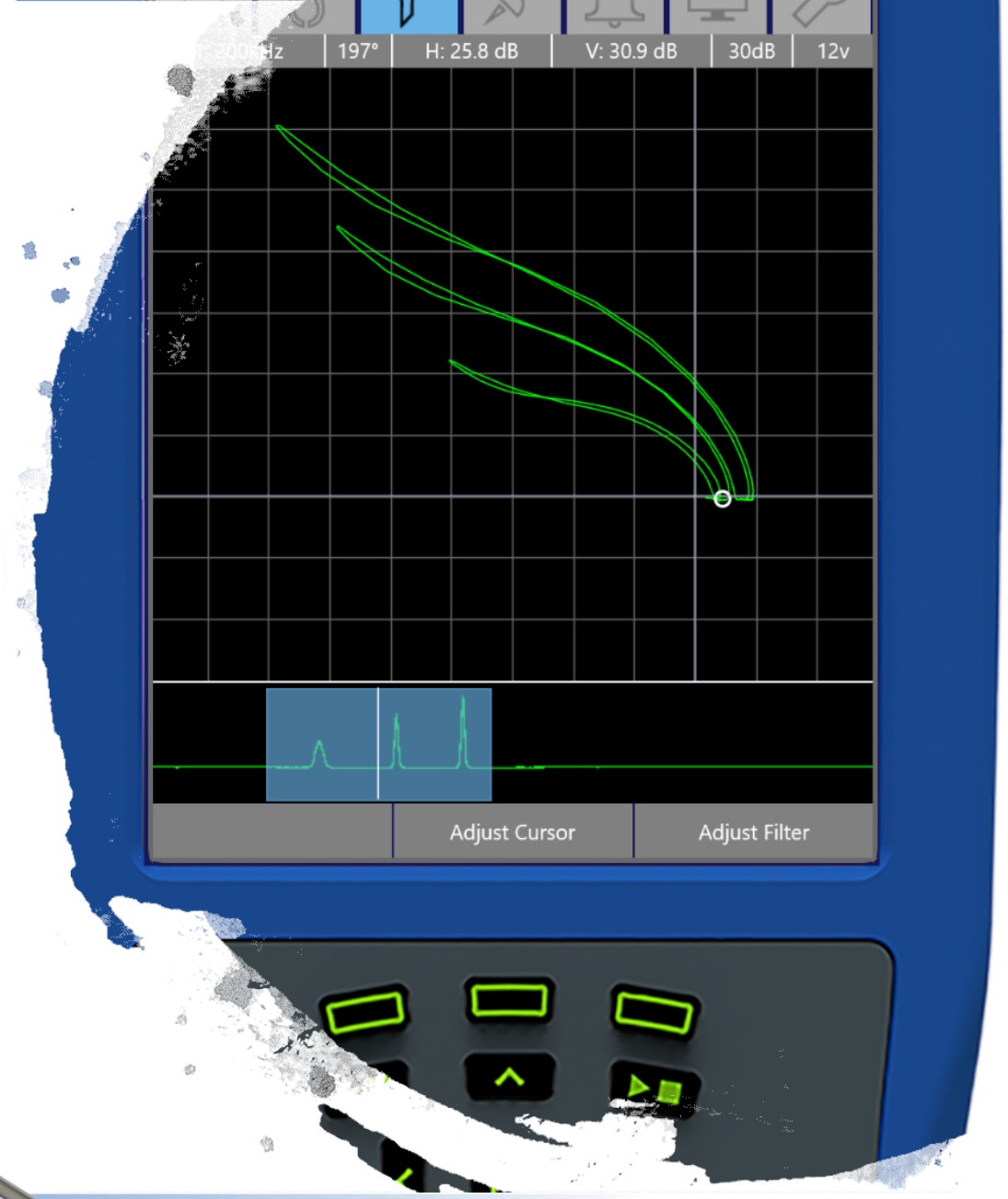


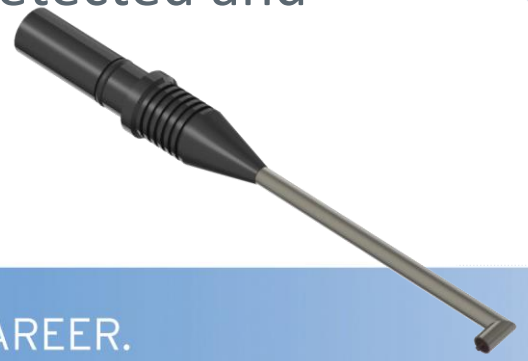
Liquid Penetrant Testing (PT)

Pros	Cons
✓ Easy to use	X Pre- & post-surface cleaning required
✓ Minimum certification required	X Limited on nonporous surface
✓ Show small surface-breaking defects	X No depth sizing
✓ Low-cost inspection	X No recording data capabilities
✓ Not affected by the inspection zone size	X Limited sensitivity on rough surfaces
✓ Works on many types of materials	X Chemical product handling
	X May require large footprint

Eddy Current Testing (ECT)

- Surface-breaking in ferrous, surface and sub-surface in nonferrous metals
- Conductive metals
- Magnetic field from ECT probe induces small eddy currents in metal
- Discontinuities disturb the flow of eddy currents
- The “change” of current flow is detected and measured by instrumentation



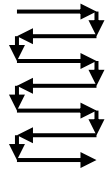


Eddy Current Testing

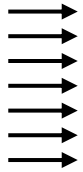
Pros	Cons
✓ Sensitive to surface and subsurface defects	X Affected by magnetic permeability variations
✓ Capable of detection through multilayered structures	X Only effective on conductive materials
✓ Can detect through thin nonconductive surface coatings	X Careful acquisition technique
✓ Little pre-cleaning necessary	X Signal interpretation requires skill
✓ Data can be recorded	X Requires ECT instrumentation ($)

Eddy Current Array (ECA)

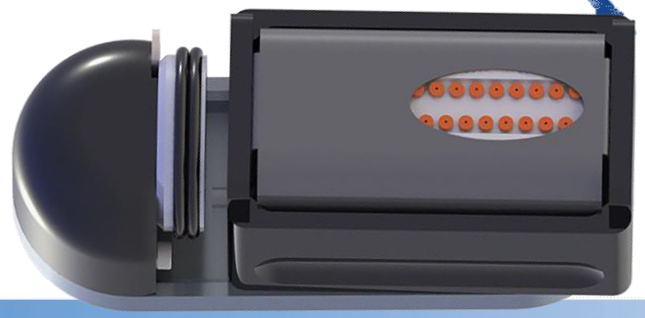
- Series of single ECT coils arranged in a single probe working as one
- One large probe as compared to a small, single-coil probe
- Coils are multiplexed to get specific data from each coil
- Individual coil data is combined in software to create 2D and 3D C-scan imaging

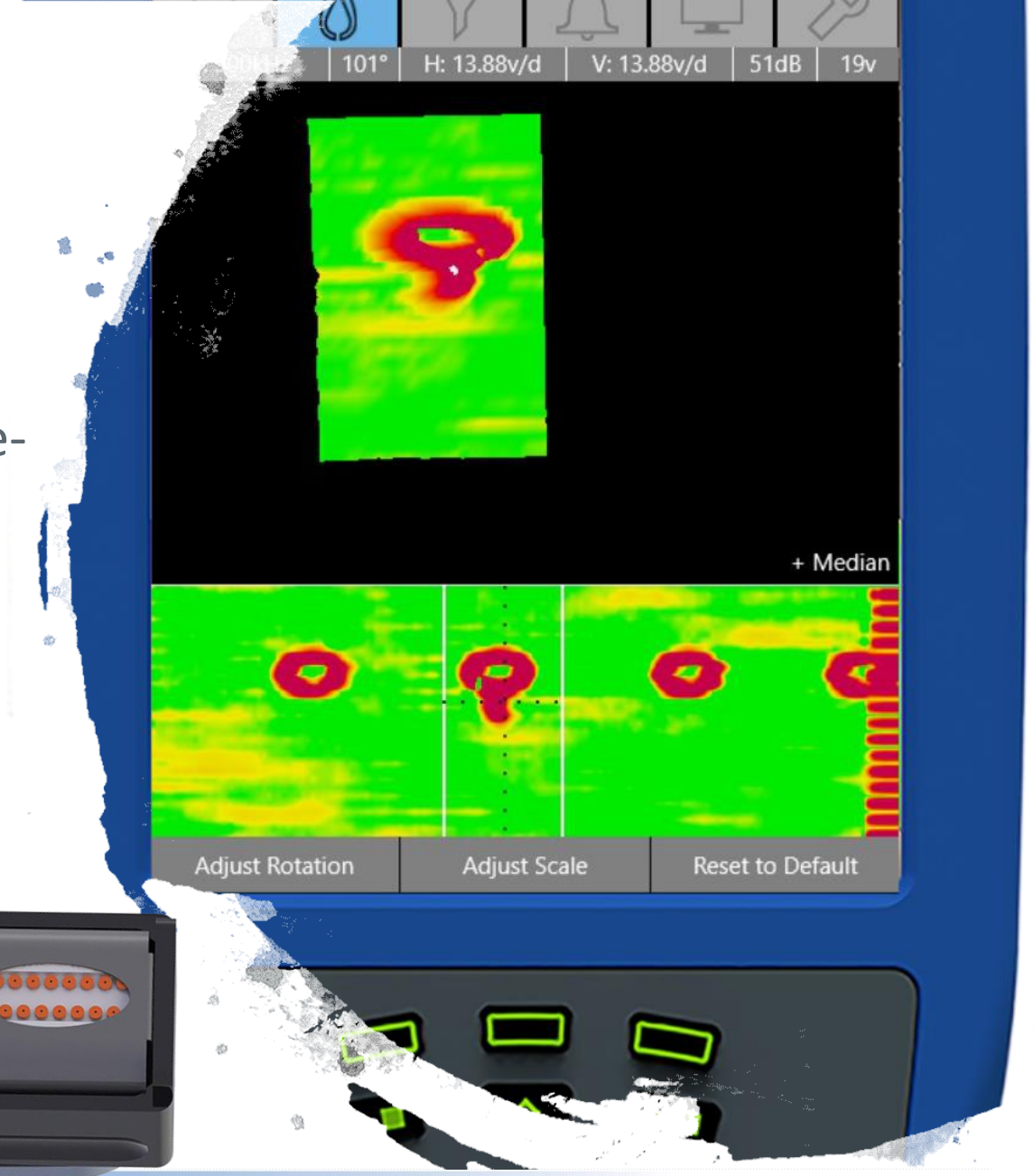


Single coil: slow



n coils: n times faster

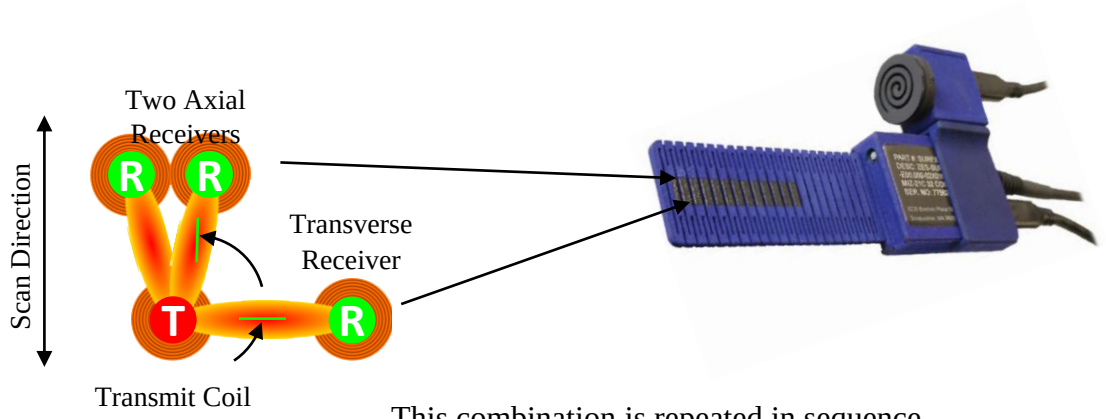




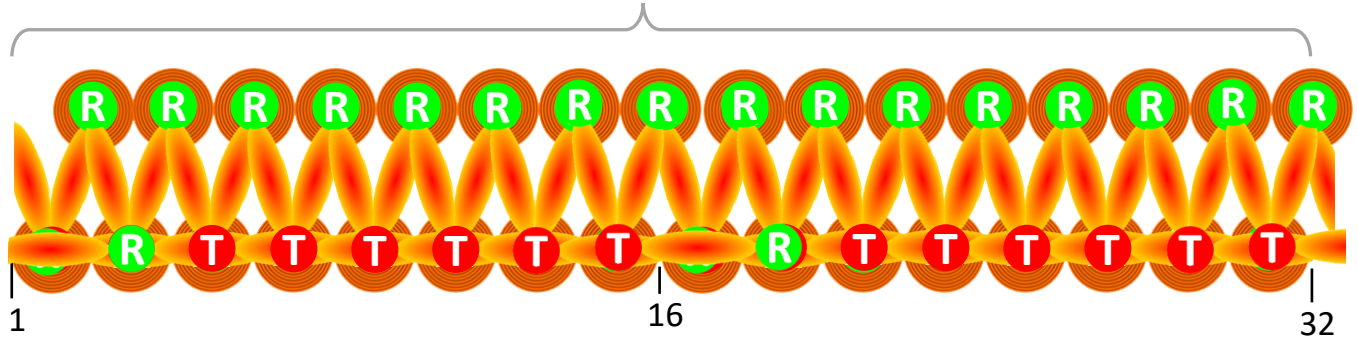
Eddy Current Array

Pros	Cons
✓ Higher sensitivity on surface and subsurface defects	X Affected by magnetic permeability variations
✓ Higher POD	X Only effective on conductive materials
✓ Faster inspection	X Operator dependent
✓ Wider coverage in a single-pass (higher resolution)	X Signal interpretation requires skill
✓ Recording data for optional post-analysis and historical trending	X Higher upfront cost ($$)
✓ Small footprint	

How Does it Work?

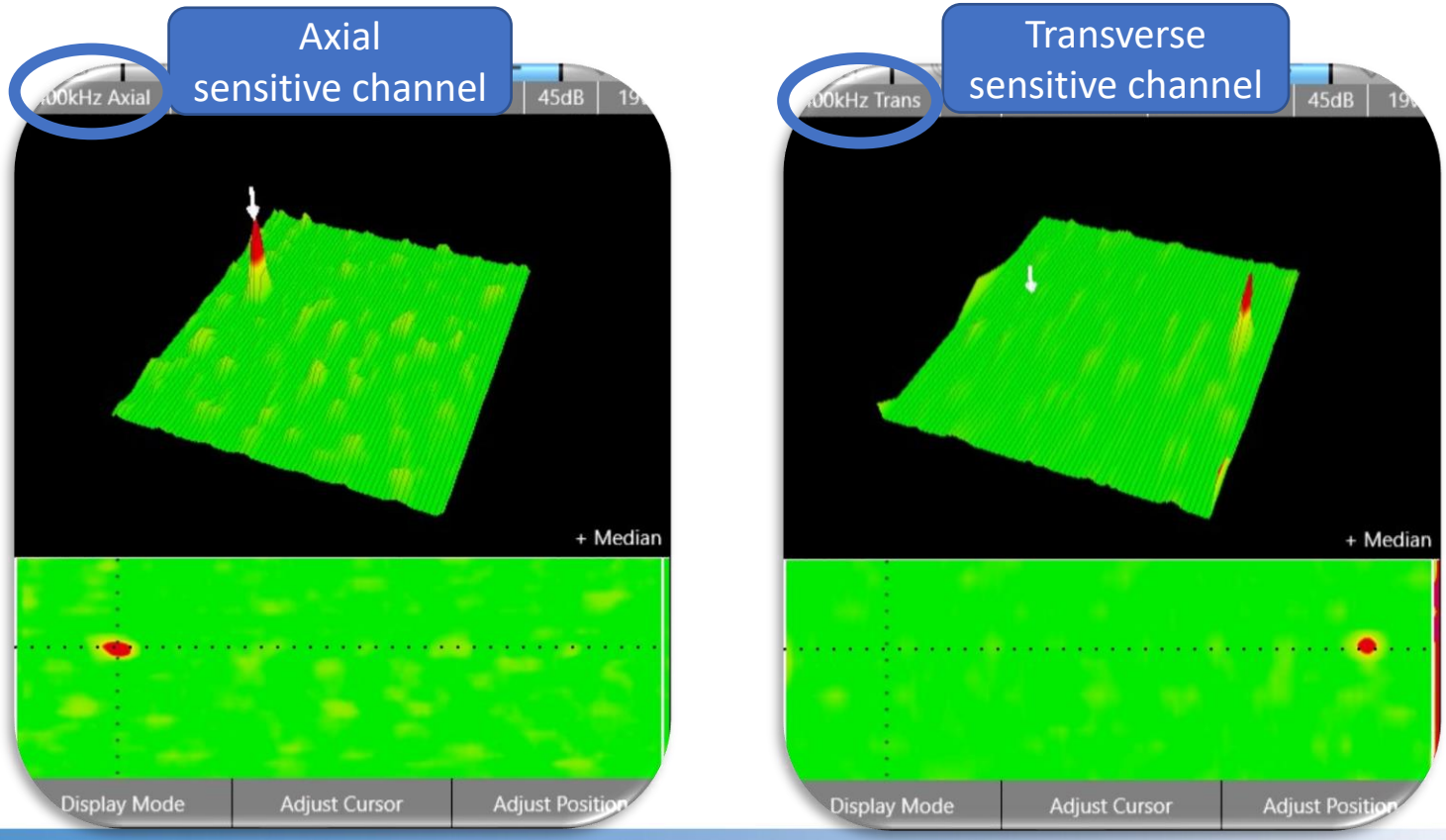


This combination is repeated in sequence across the array of coils in the probe



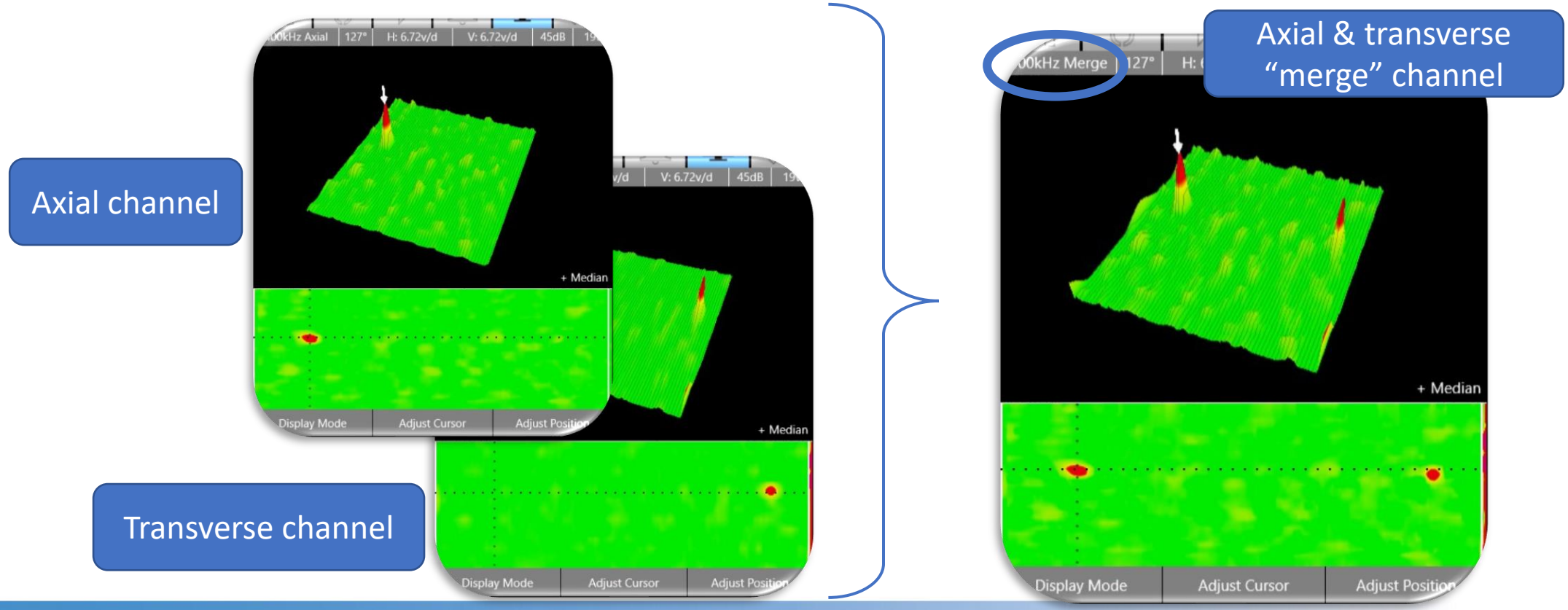
Easy to Analyze

- Ability to have separate axial and transverse sensitive channels



Merge Channel

- Channels can be combined into a single “merged” channel
  - Allows for fast data screening for 360° coverage



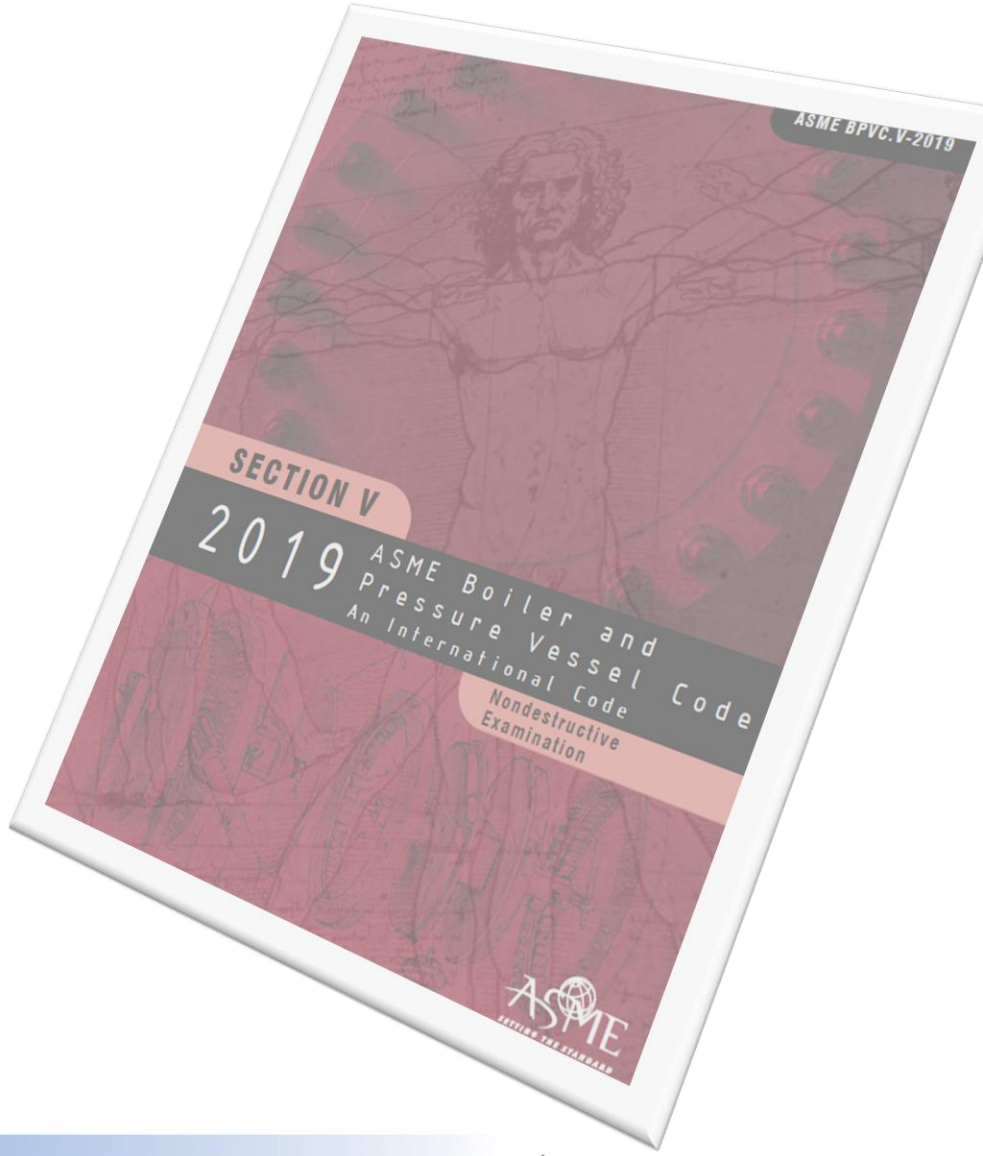
ASME Code Adoption

- 2019 ASME Section V, Article 8
- New appendices for ECA:
  - Appendix IX:

    “Eddy current array (ECA) examination of ferromagnetic and nonferromagnetic ***MATERIALS*** for the detection of surface-breaking flaws”

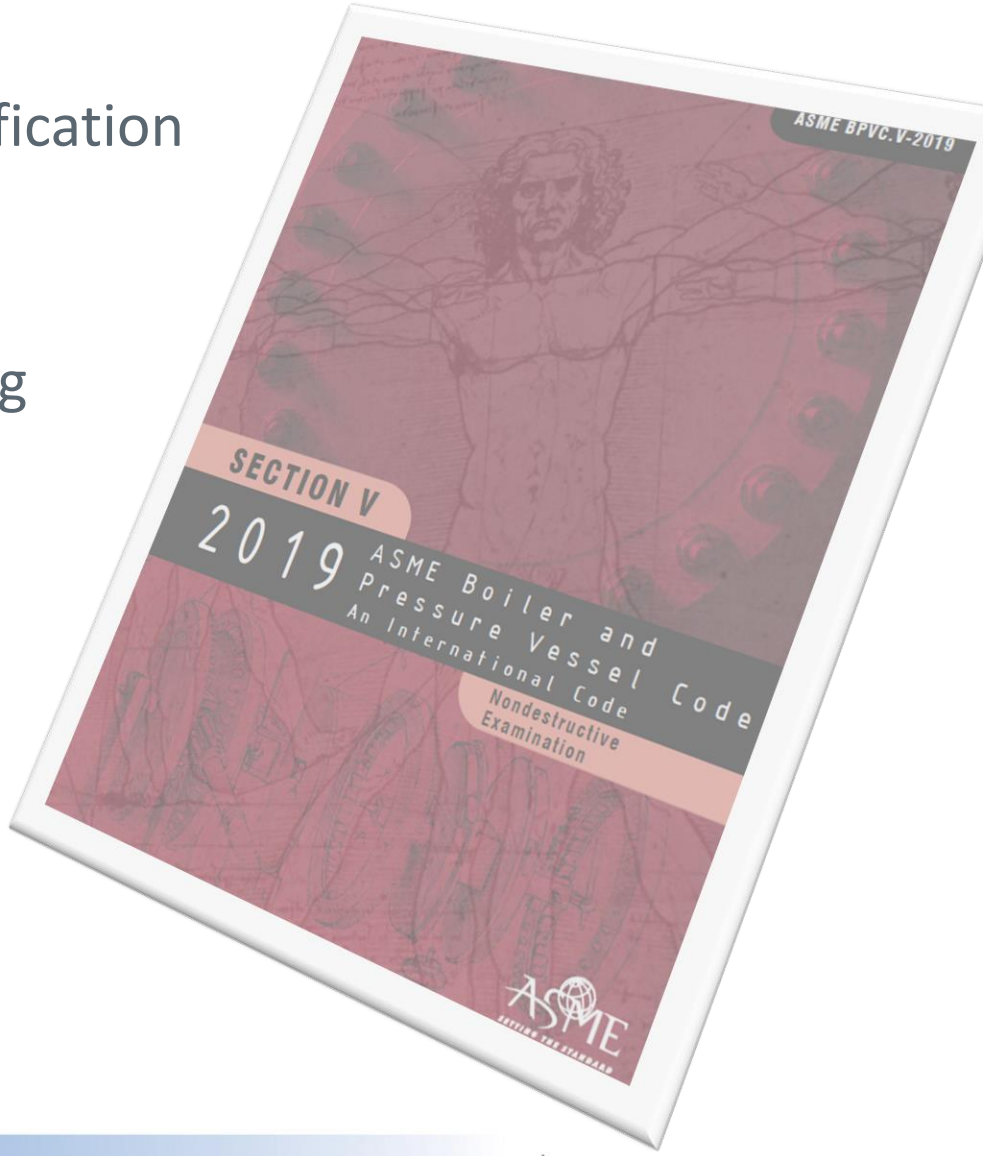
  - Appendix X:

    “Eddy current array (ECA) examination of ferromagnetic and nonferromagnetic ***WELDS*** for the detection of surface-breaking flaws”



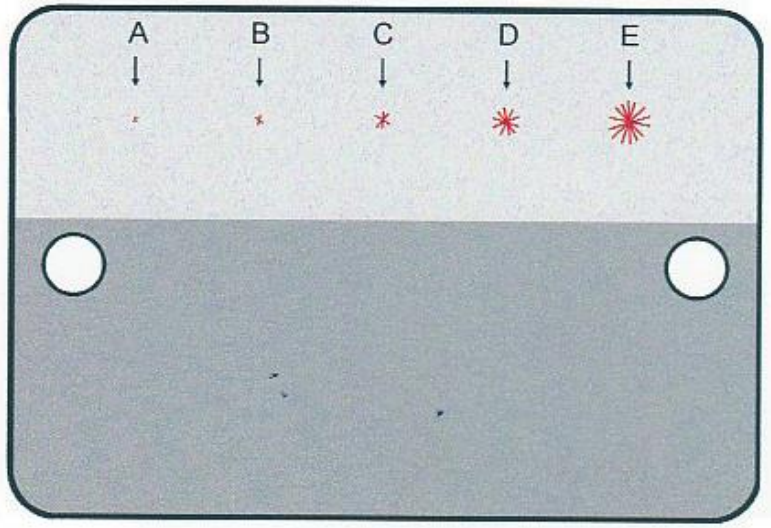
ASME Code Adoption

- General Requirements – Procedure and personnel qualification
- Equipment – Instrument, probes, standards
- Application reqs. – Speed, coated surface, data screening
- Technique – Essential variables, color palette, channels
- Calibration – Equipment and system
- Examination - Acquisition
- Evaluation - Analysis
- Documentation - Reporting



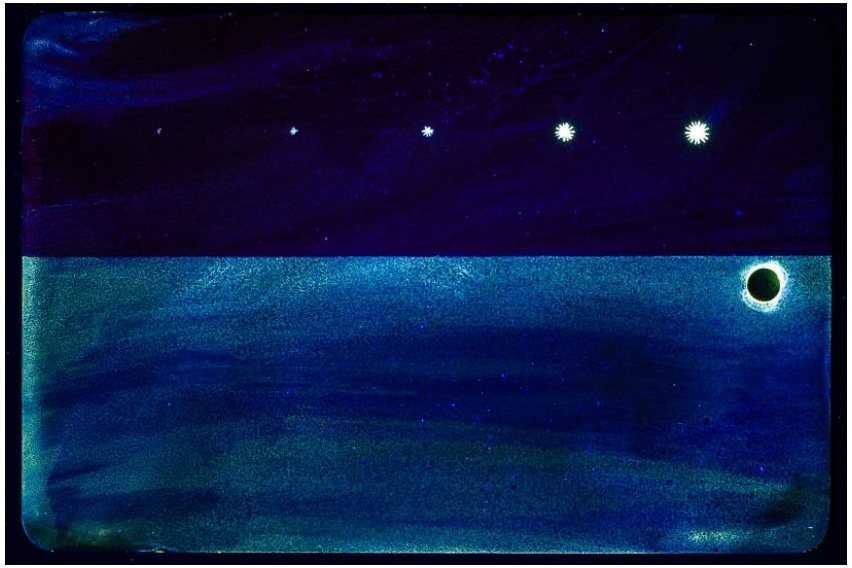
TAM Panel

- Test panels are used to test system's overall performance
  - Known as TAM Panels
  - Also known as Sherwin or Magnaflux Test Panels
- Stainless steel 0.25 cm thick, 15 cm wide, 10 cm tall
- Strip of chrome plating has five variable size crack centers
- Other half has an oxide grit-blasted surface to monitor background fluorescence



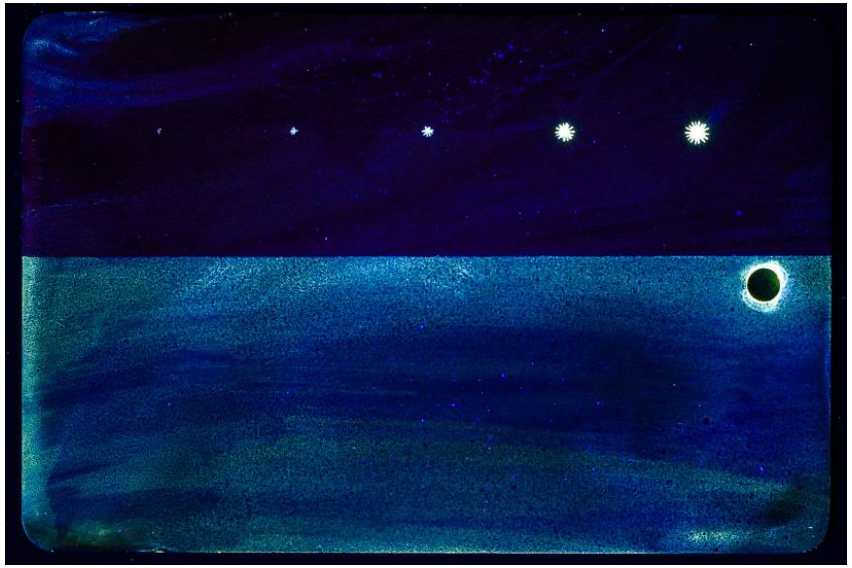
TAM Panel Example

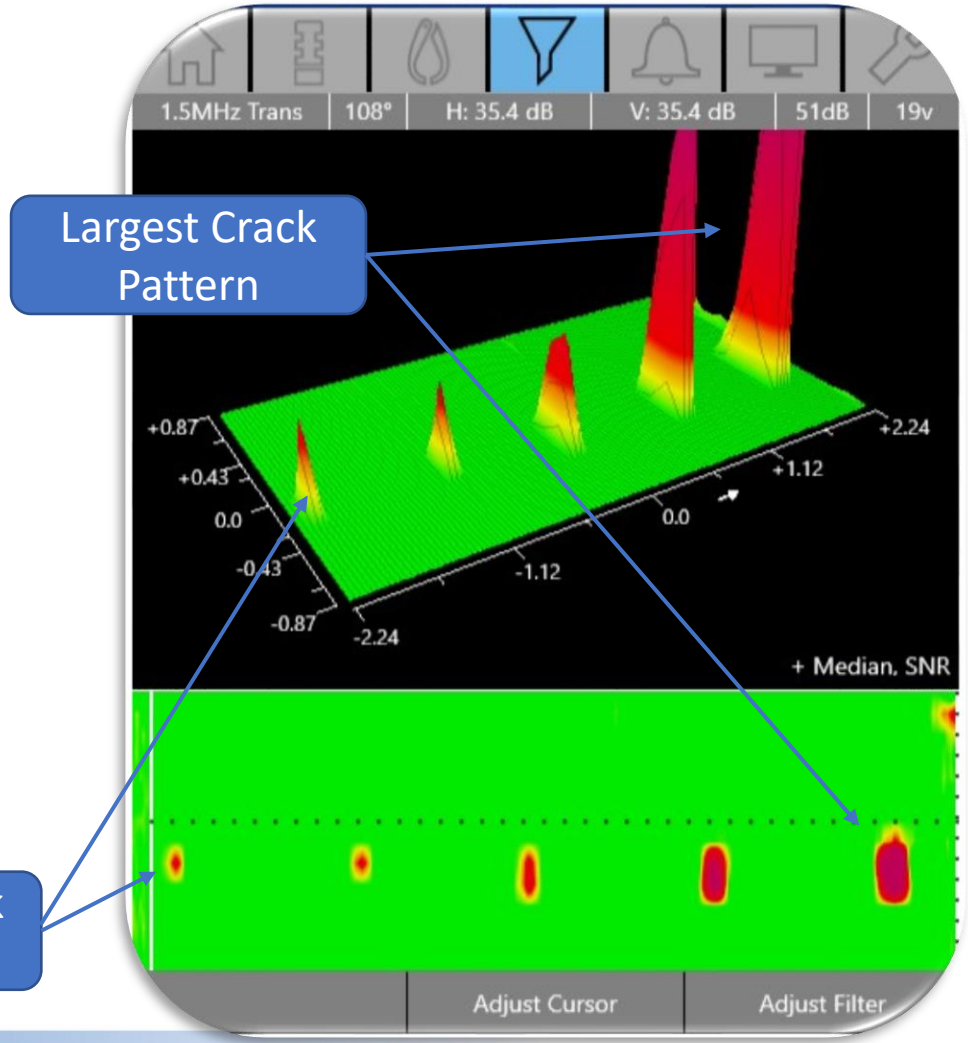
- Largest crack pattern is readily visible with low-sensitivity penetrant materials
- Smallest crack pattern is visible with high-sensitivity penetrant materials
- Can require more than one penetrant type to cover the full inspection
- This also translates to field testing limitations and POD



TAM Panel Using ECA

- Largest crack pattern is clearly visible
- Smallest crack pattern is also visible with a high POD
- Only one scan is needed to cover the full inspection
- This translates to field testing capability of detection

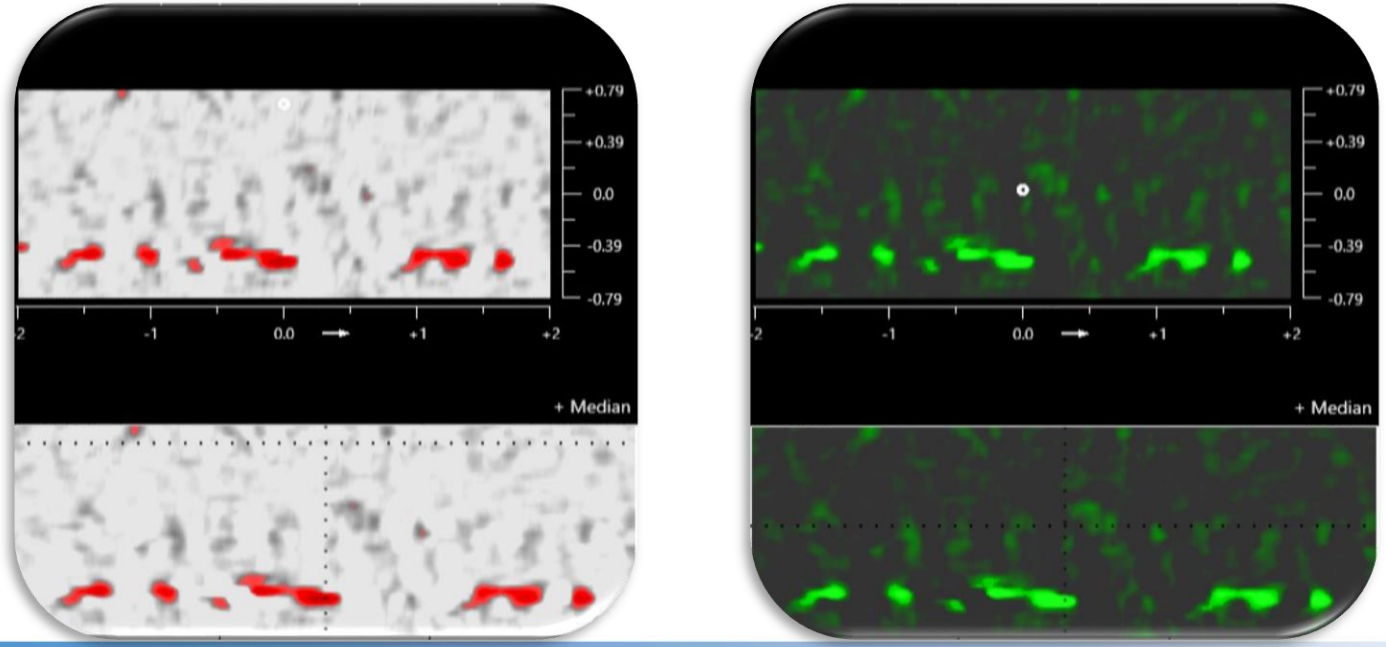


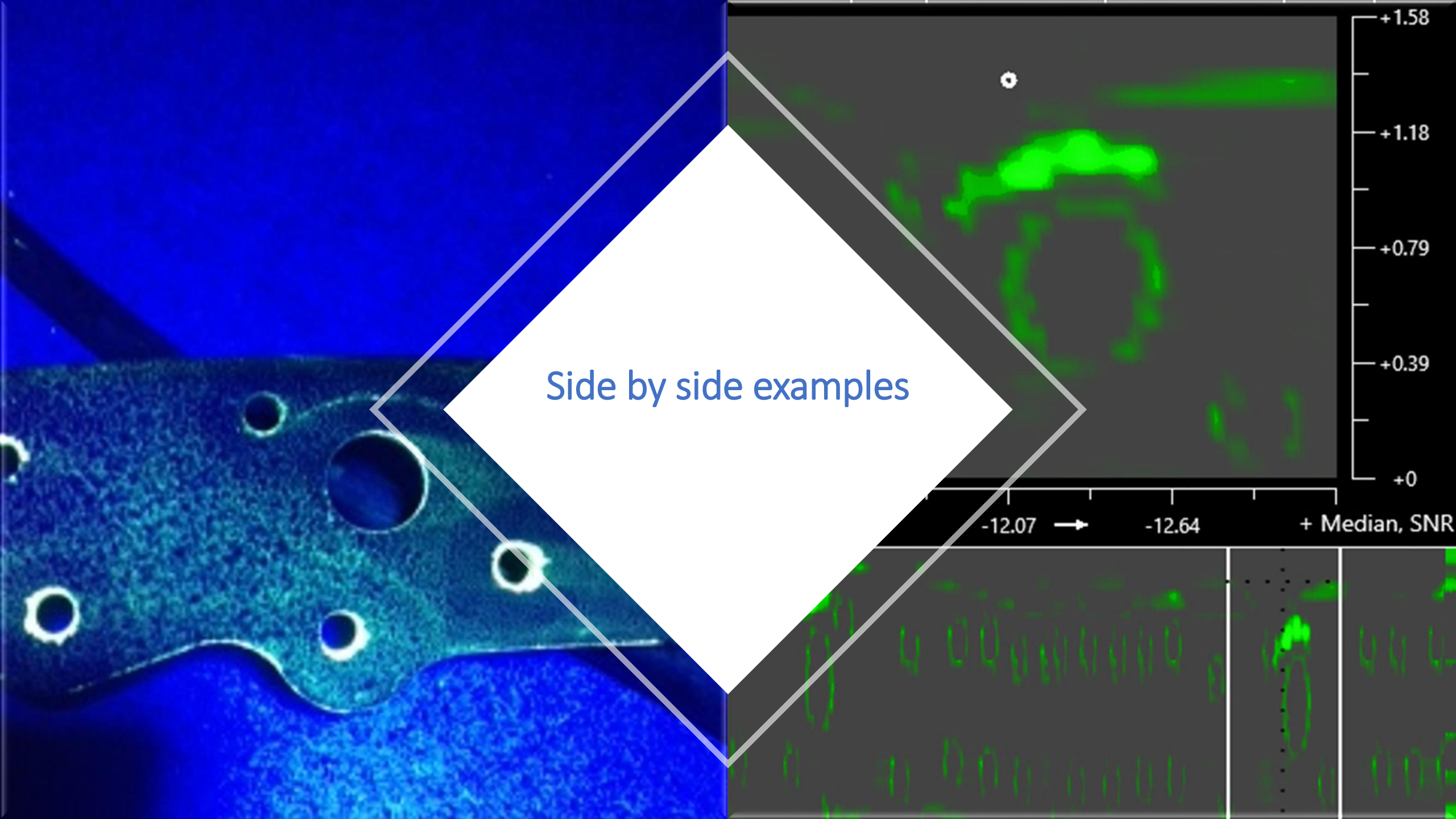


PT & MT Familiarity

- Custom palette options give the user the ability to produce a large variety shading color schemes using variations of red, gray, green, blue, and purple.

- Thresholds can be assigned to designate which voltage breaks in the color gradient occur. This can be used to highlight flaws of interest and downplay other signals.

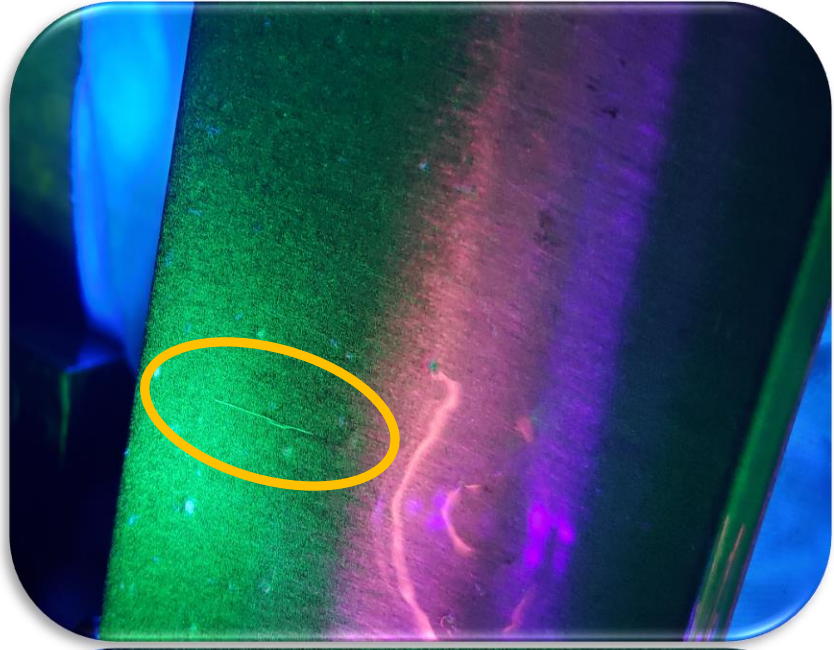


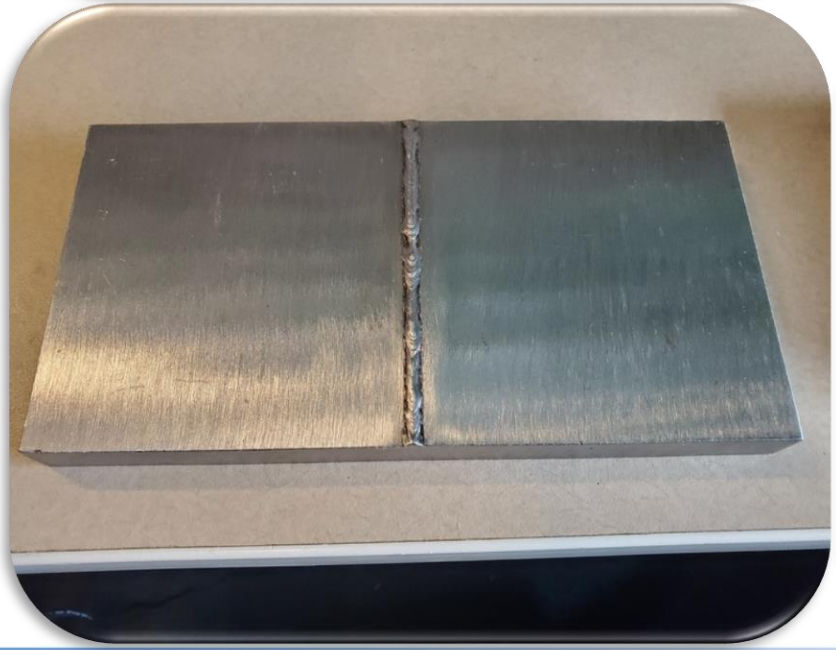


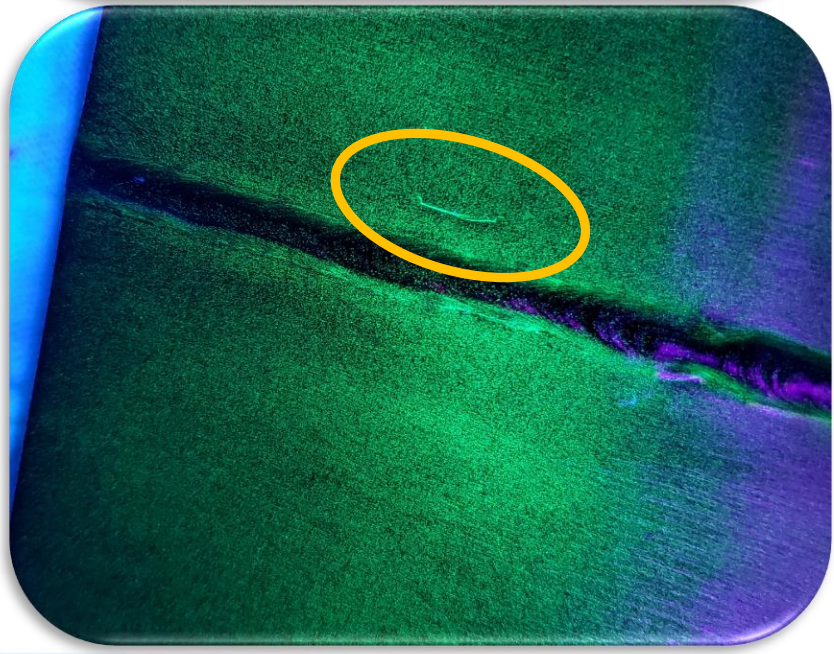
Side by side examples

Carbon Steel Weld

- Base metal crack
- Base metal root crack
- Wet fluorescent particle

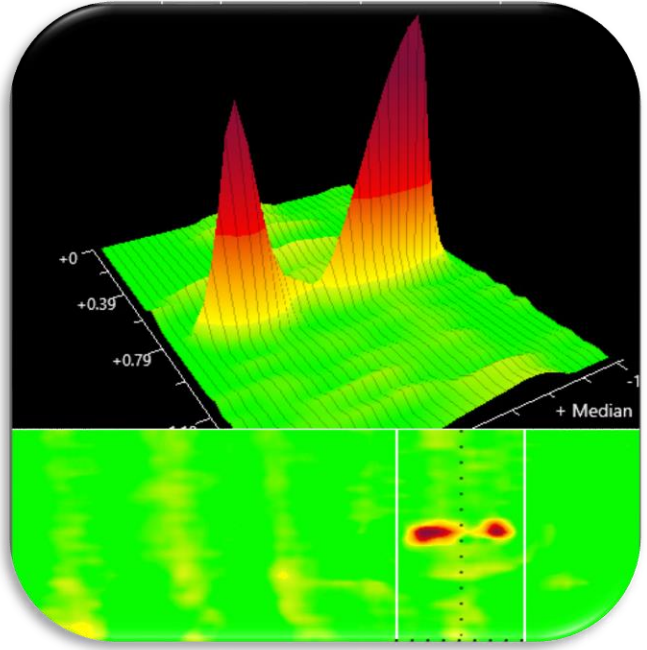


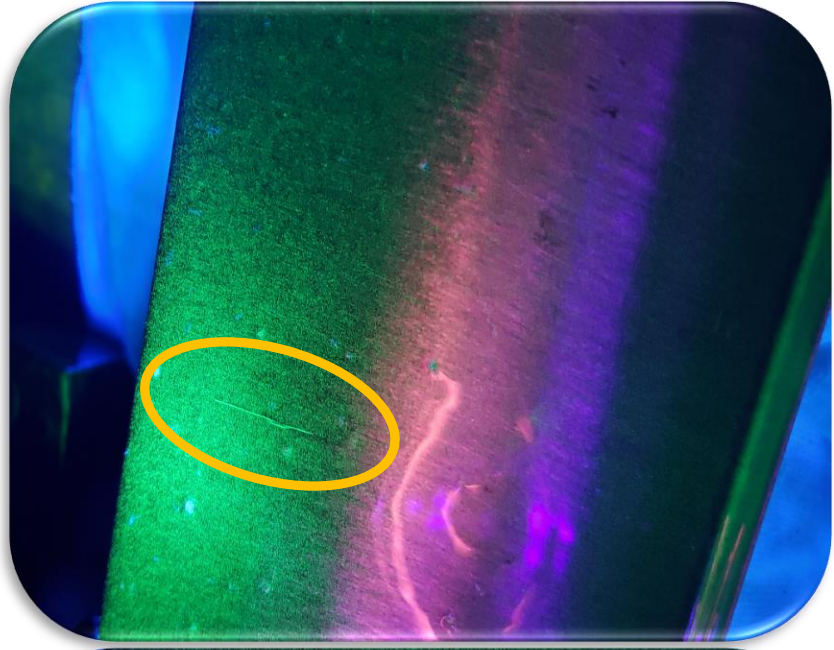


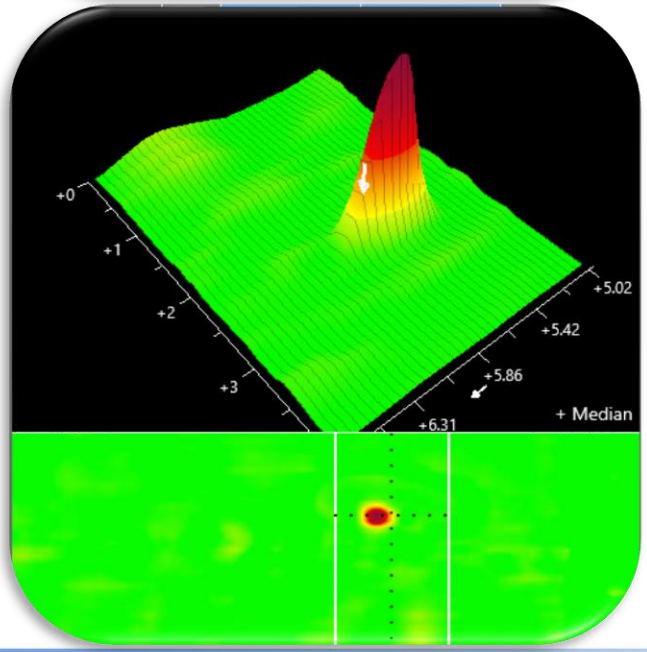


ECA Results

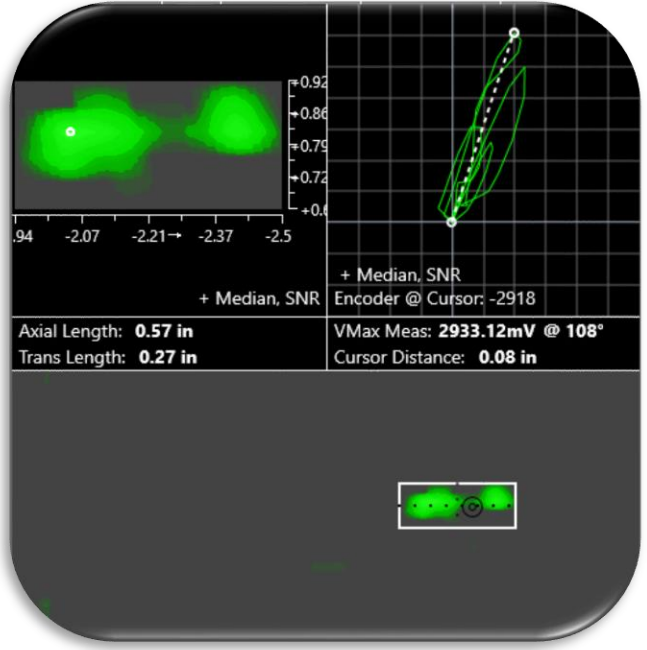
- Great detectability
- Excellent SNR

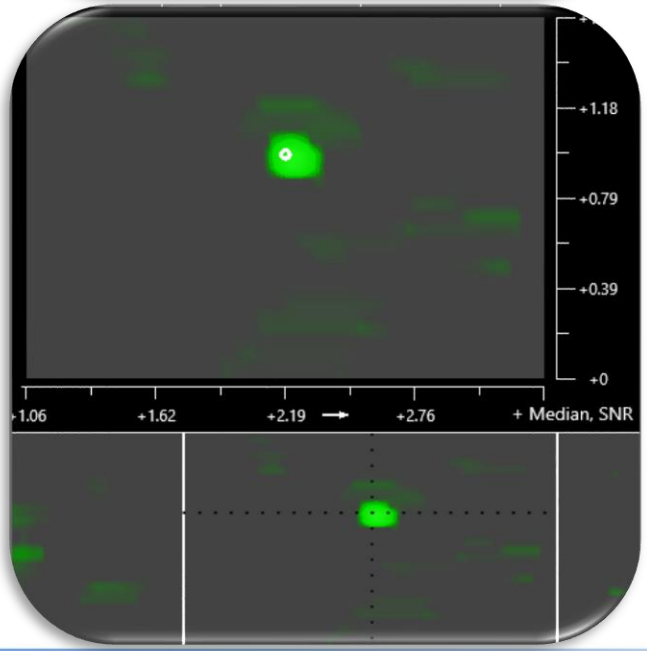






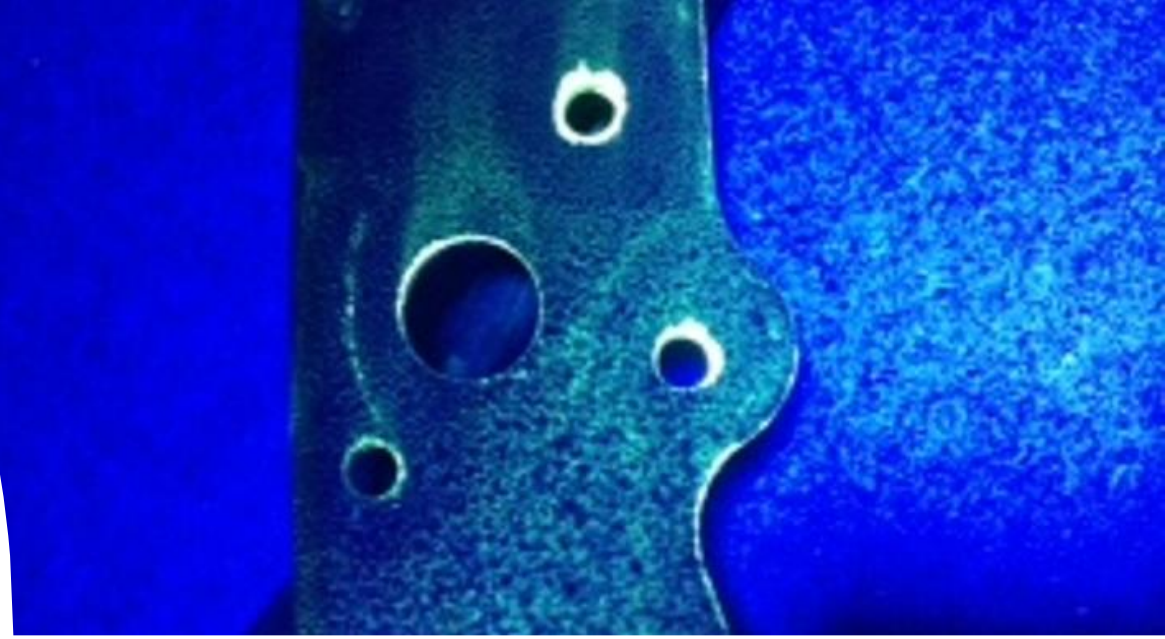
MT-Like Palette



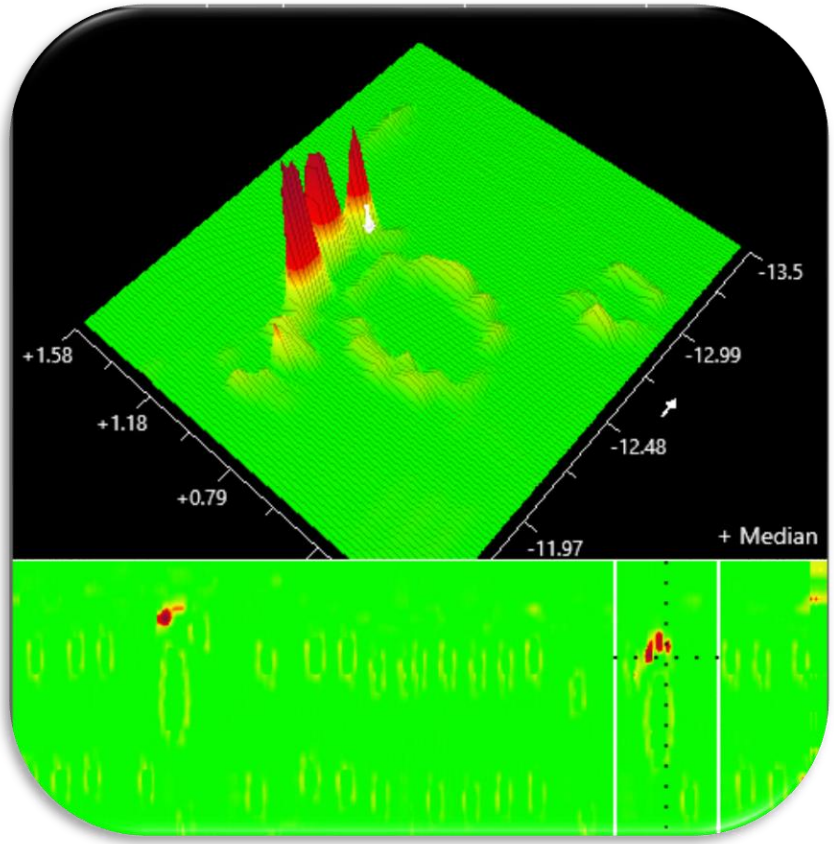


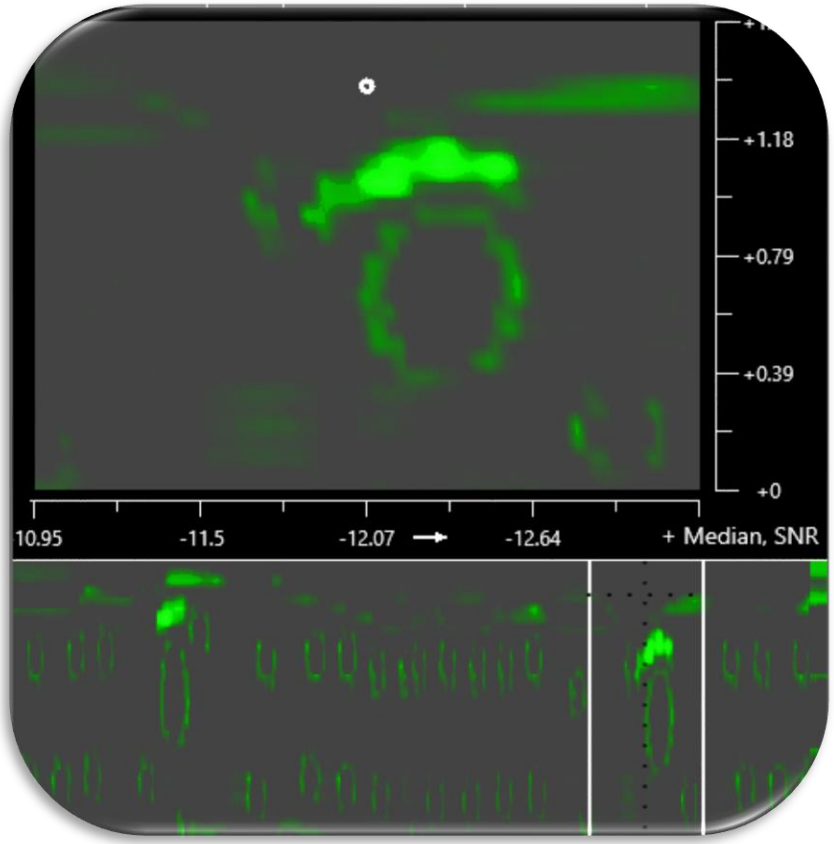
Aluminum

- Aircraft stringer
- Wrought
- Stress crack
- Fluorescent dye



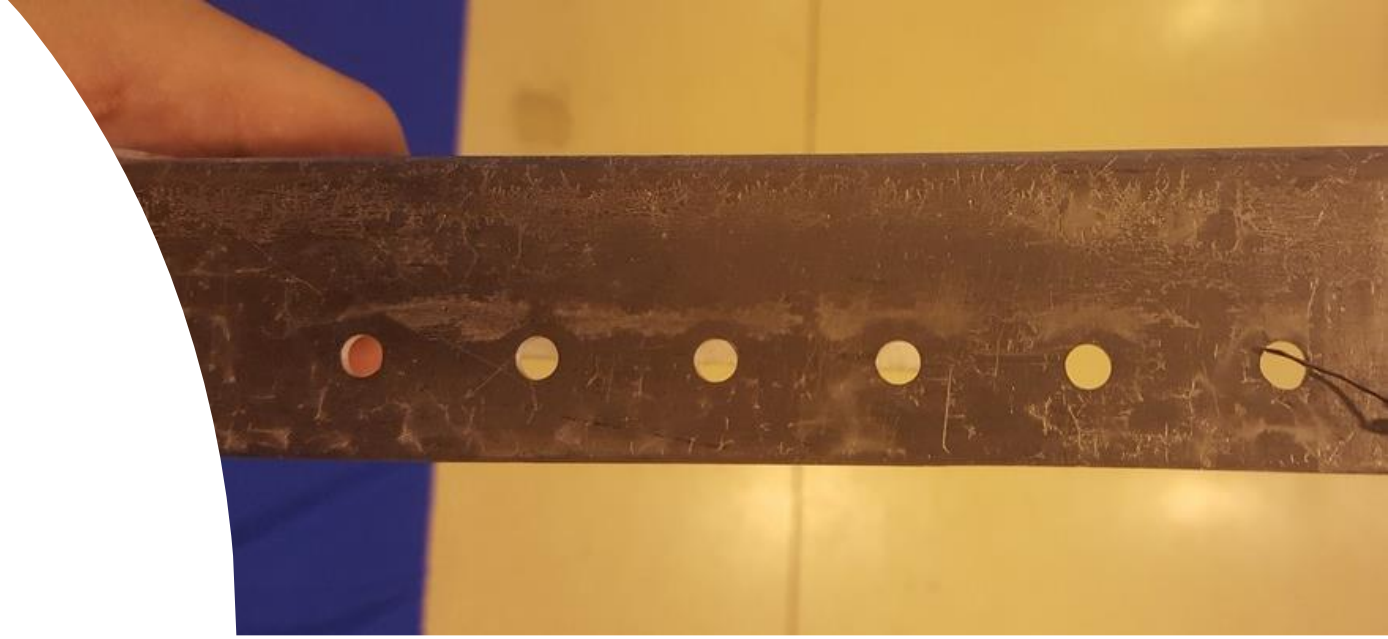
Stress Crack



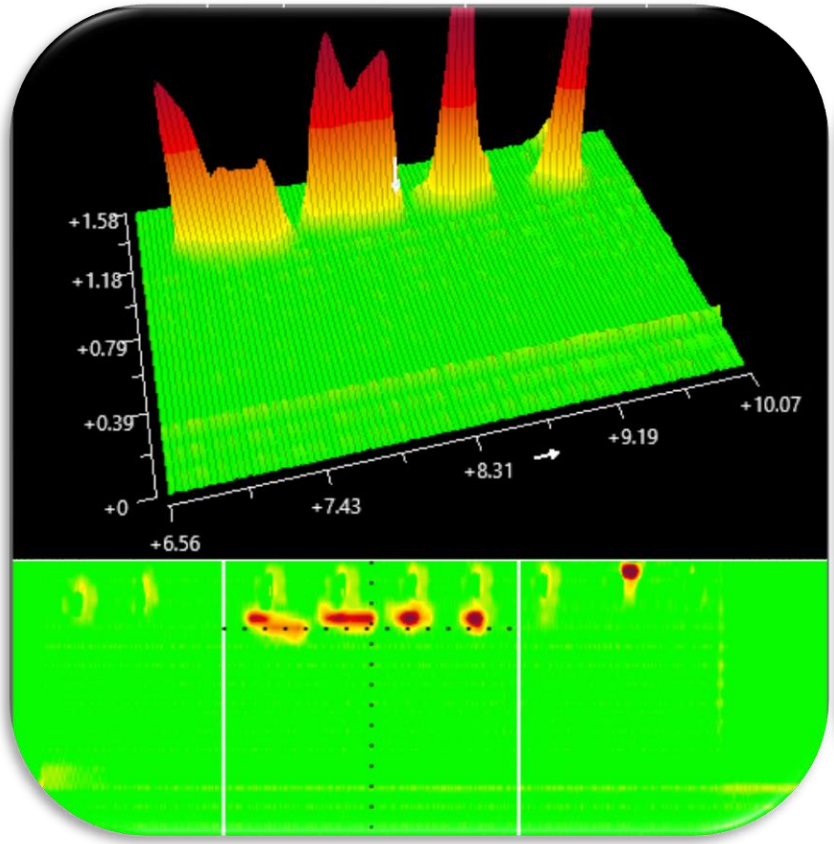


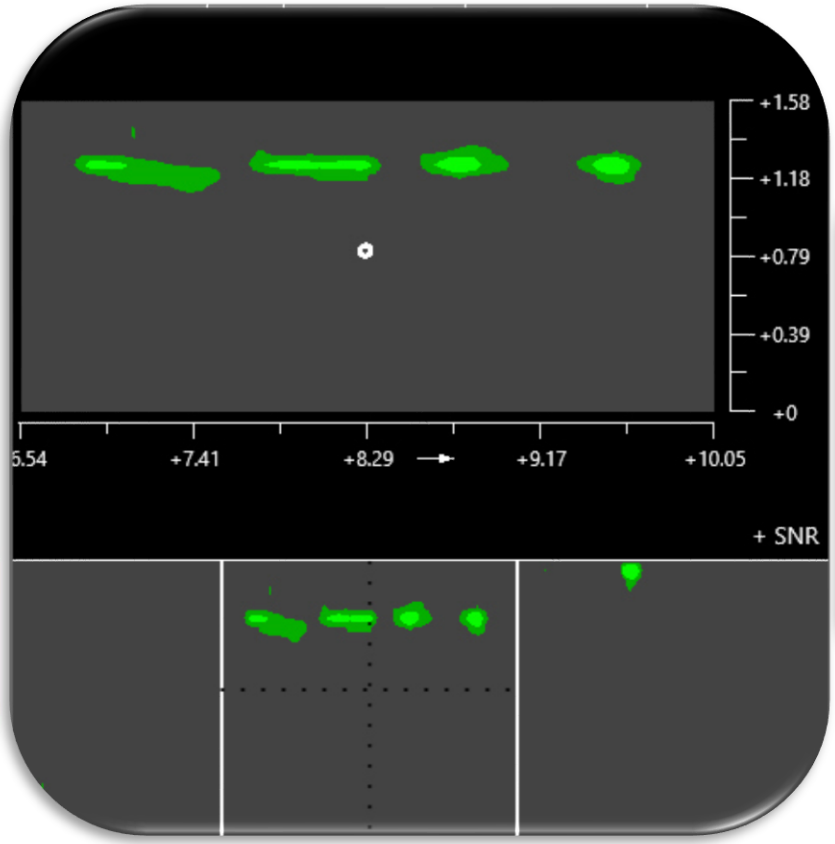
Aluminum

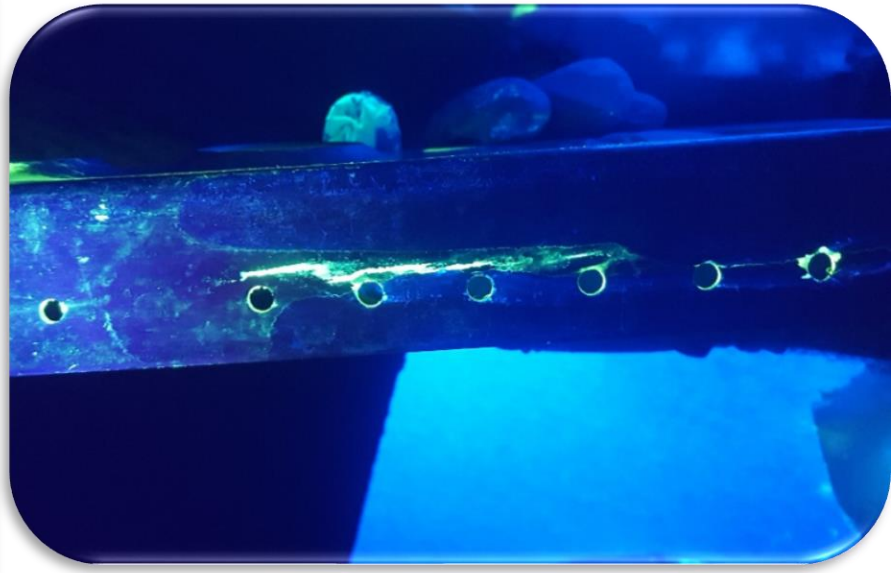
- Aircraft stringer
- Wrought
- Long crack between holes
- Fluorescent dye



Long Axial Crack





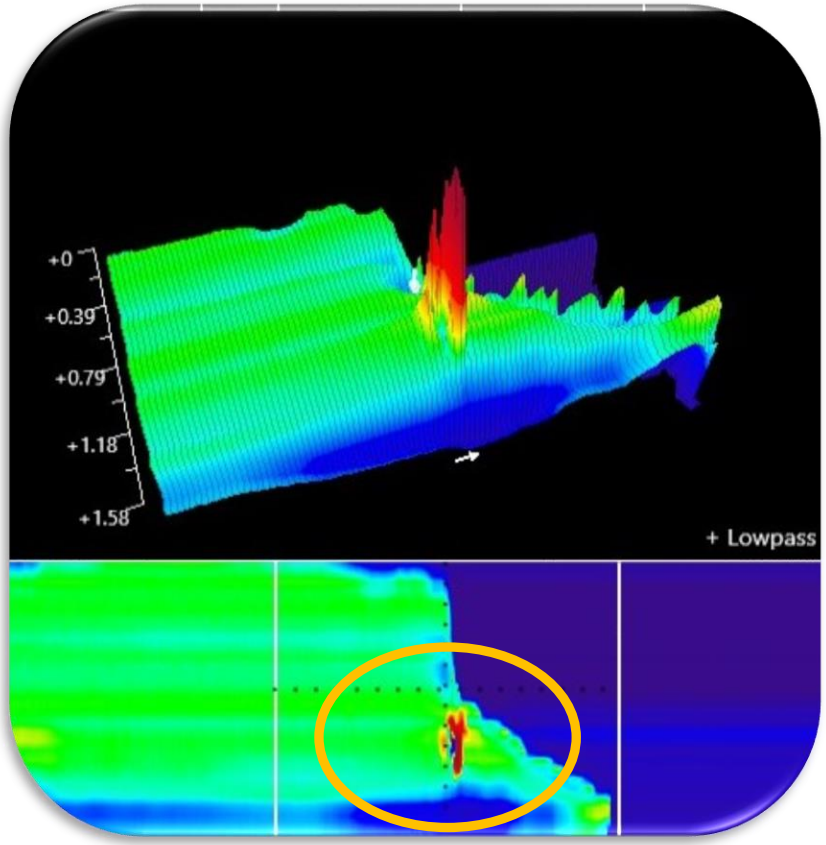


Aluminum

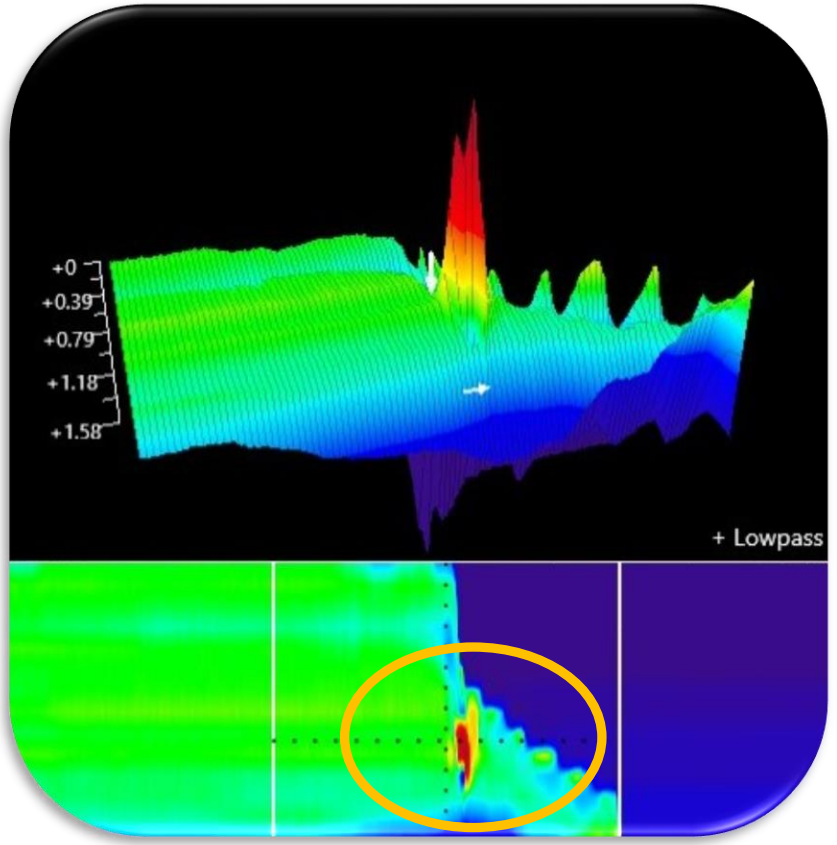
- Wing spar
- Wrought
- Corrosion & cracking
- Visual

Corrosion

Both channels have like indications => Corrosion



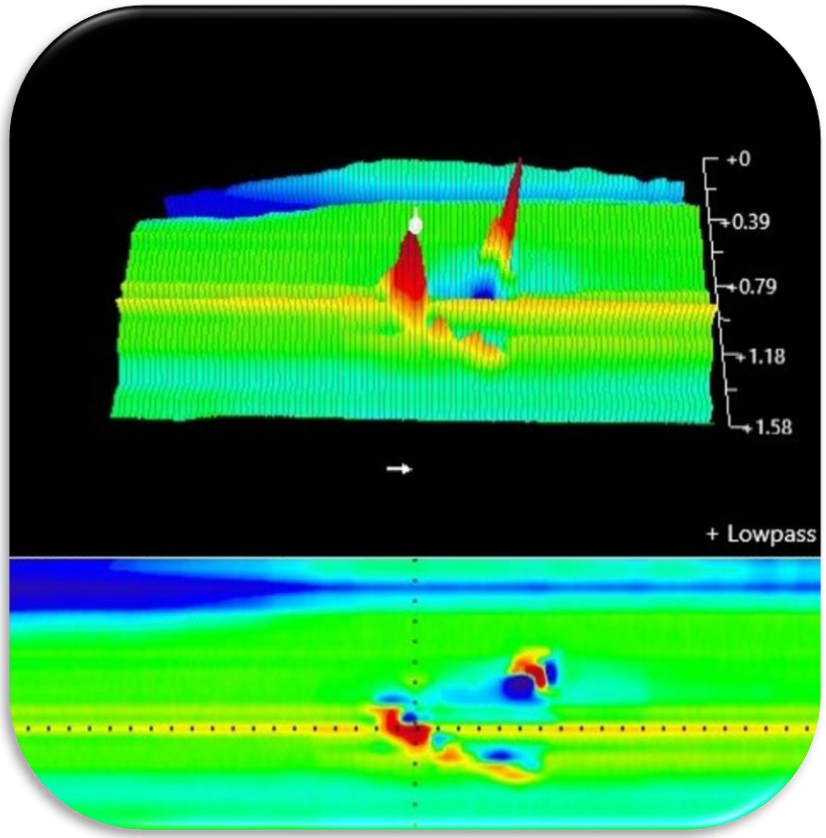
Axial Channel



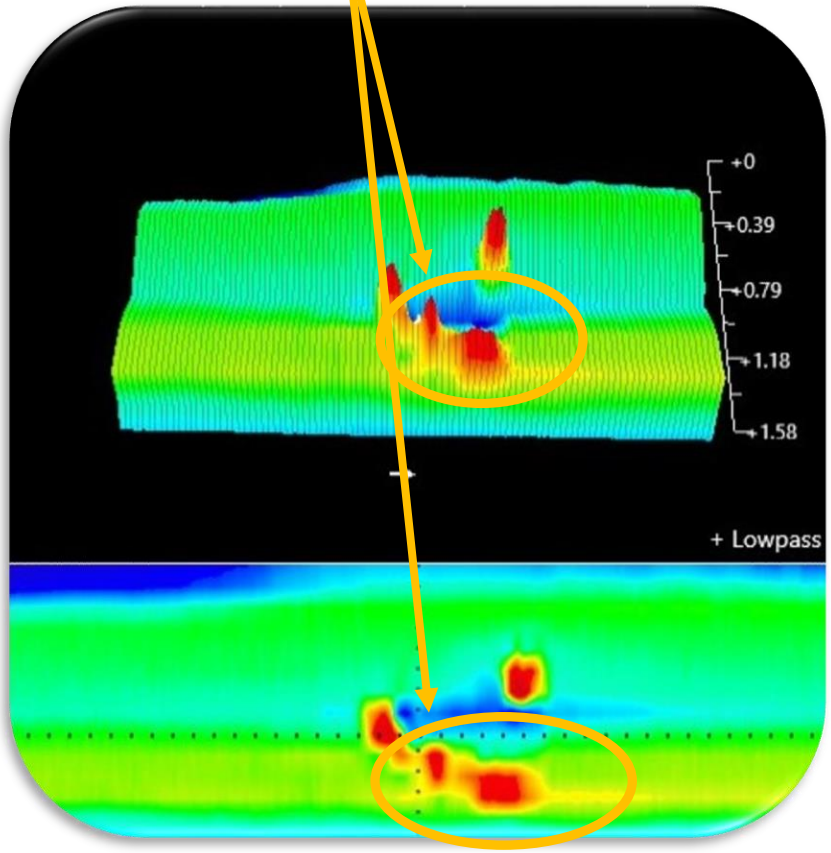
Transverse Channel

Corrosion and Transverse Cracks

Transverse cracking in corrosion



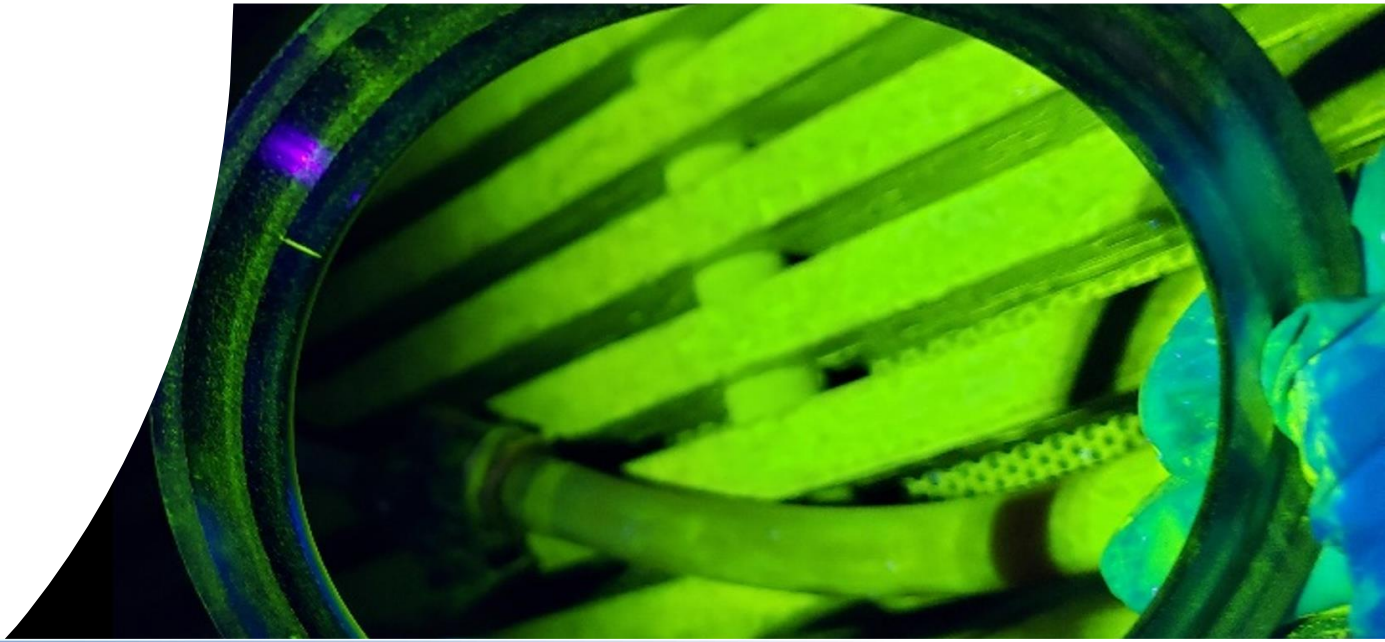
Axial Channel



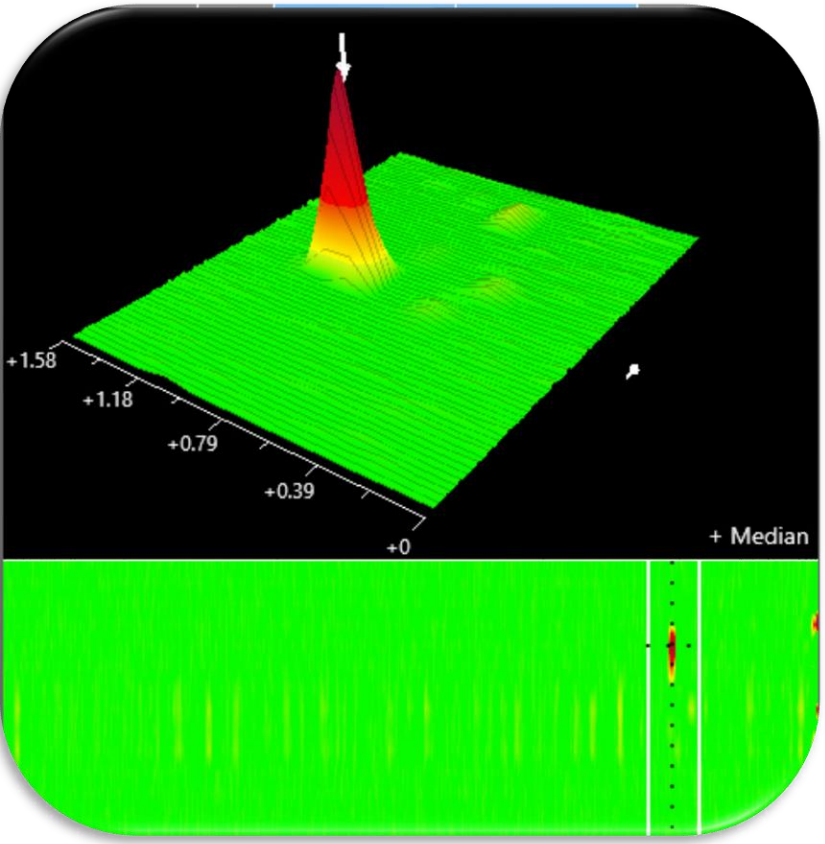
Transverse Channel

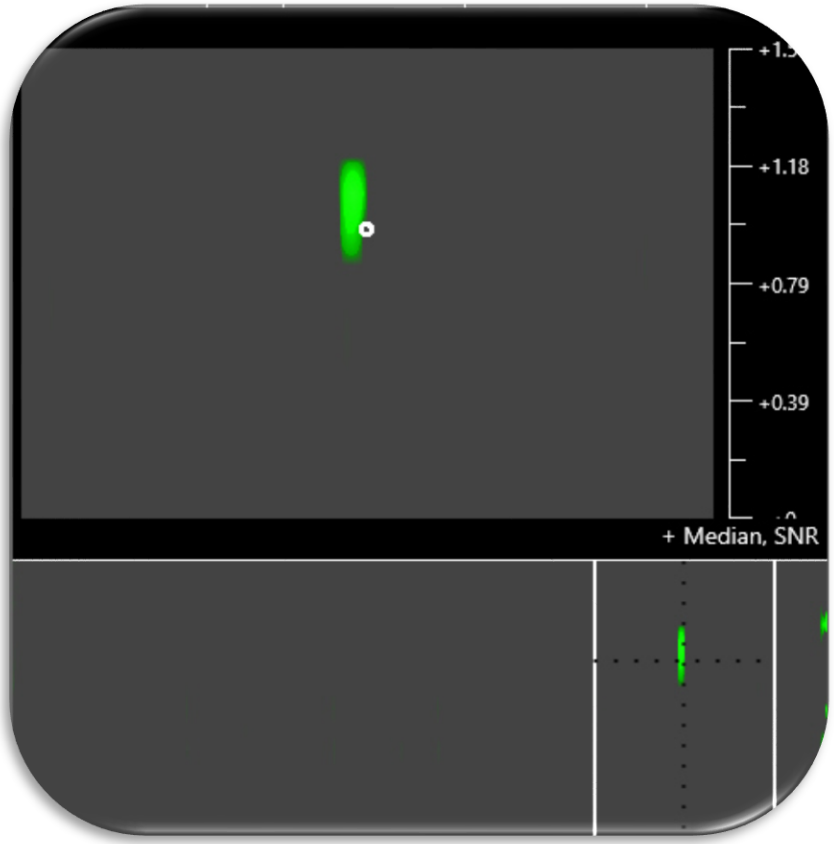
Stainless Steel

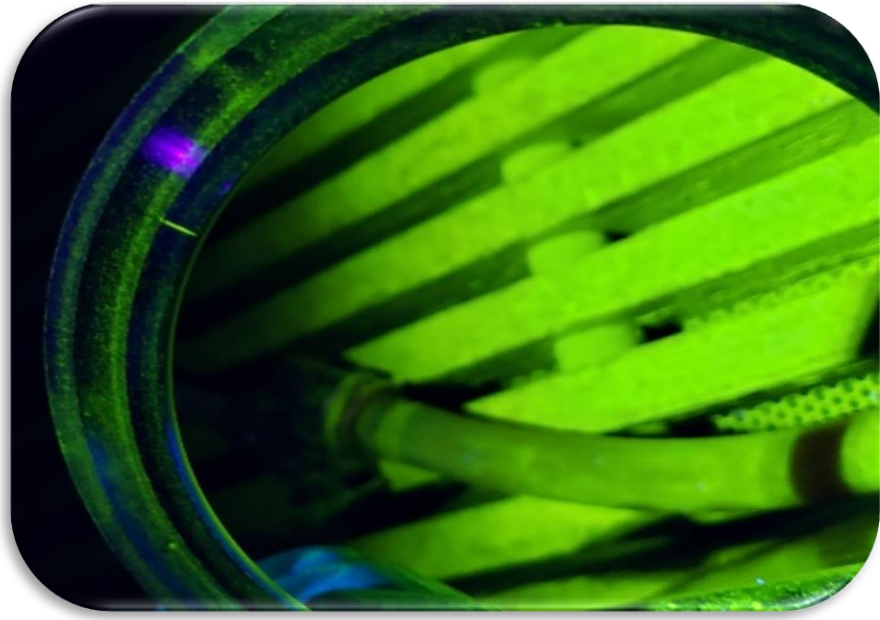
- Engine ring
- Forged & rolled
- Machine tear
- Wet fluorescent particle



Machine Tear

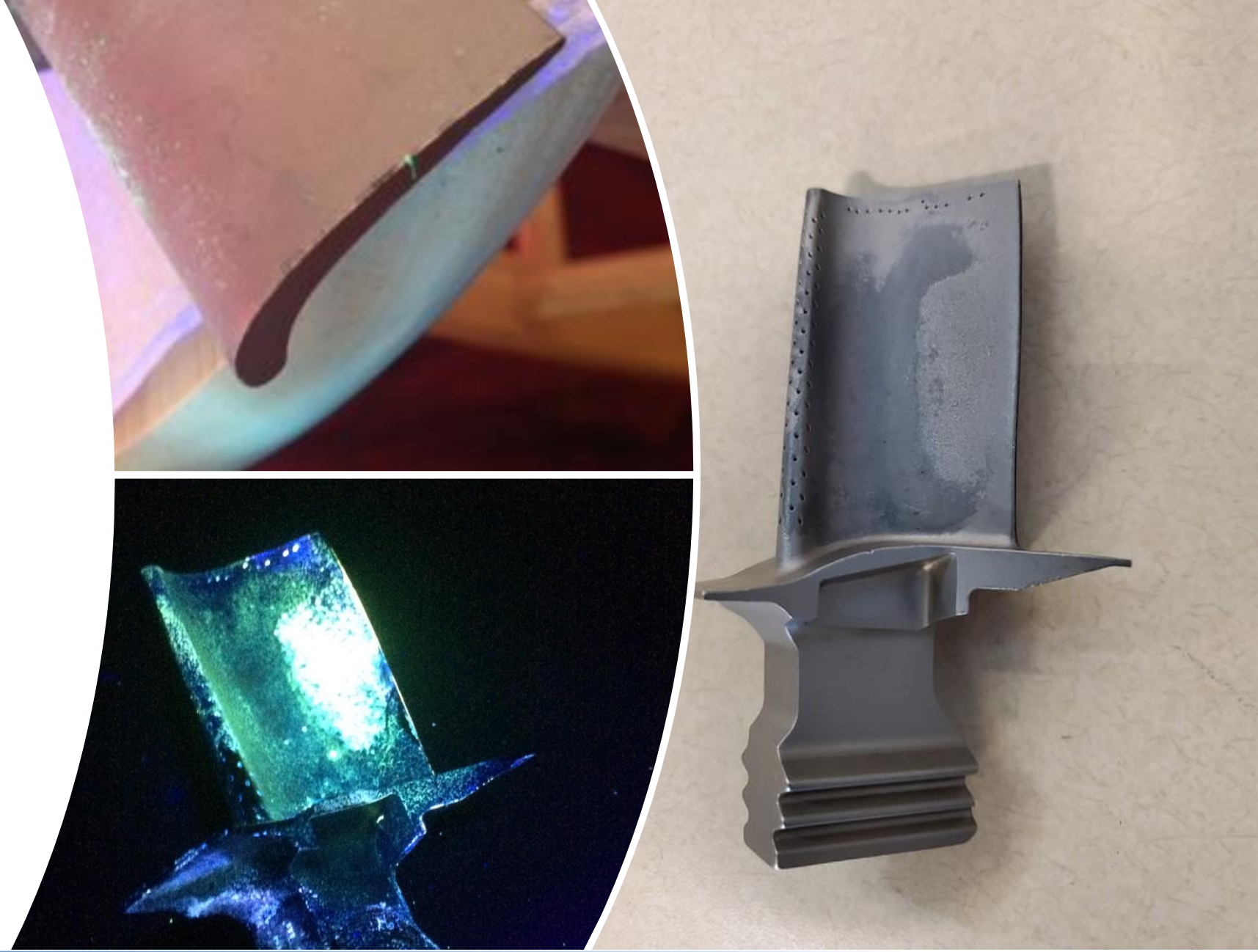




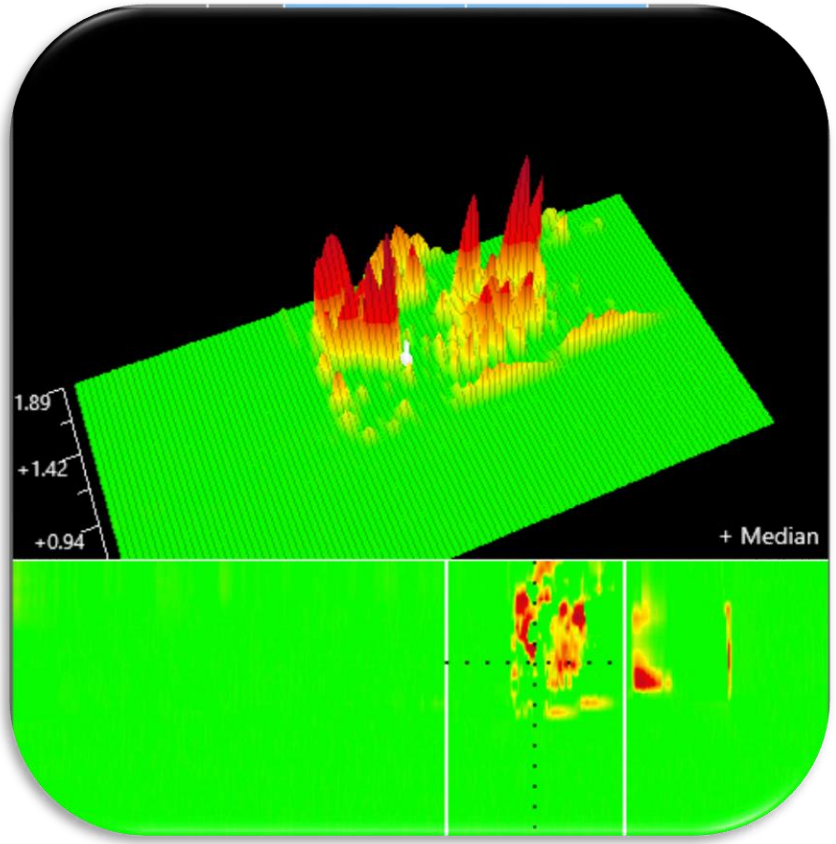


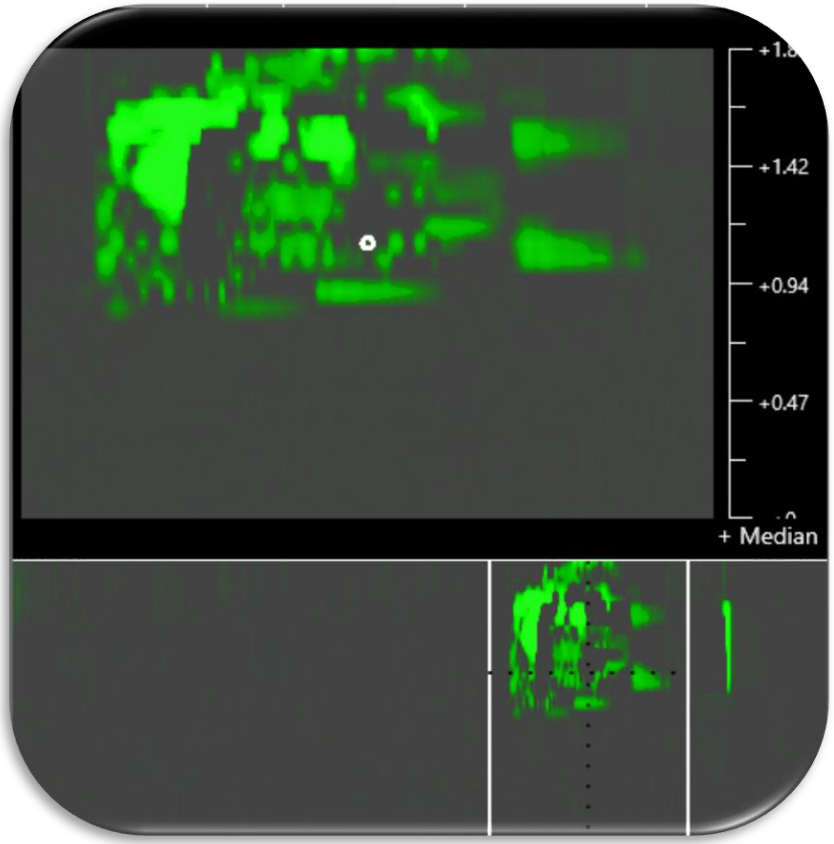
Titanium

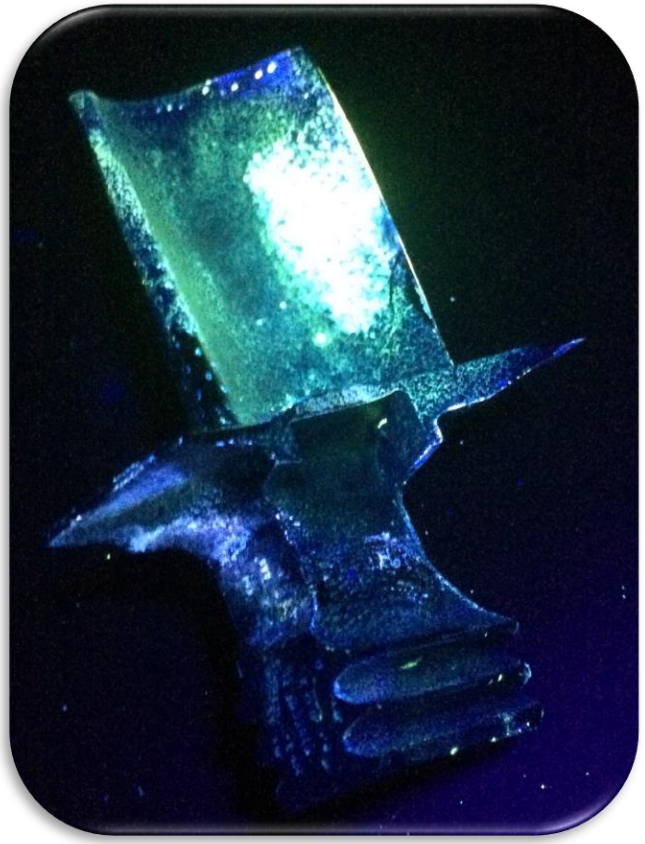
- Small engine blade
- Cast & weld
- Tip crack
- Porosity on pressure side
- Fluorescent dye



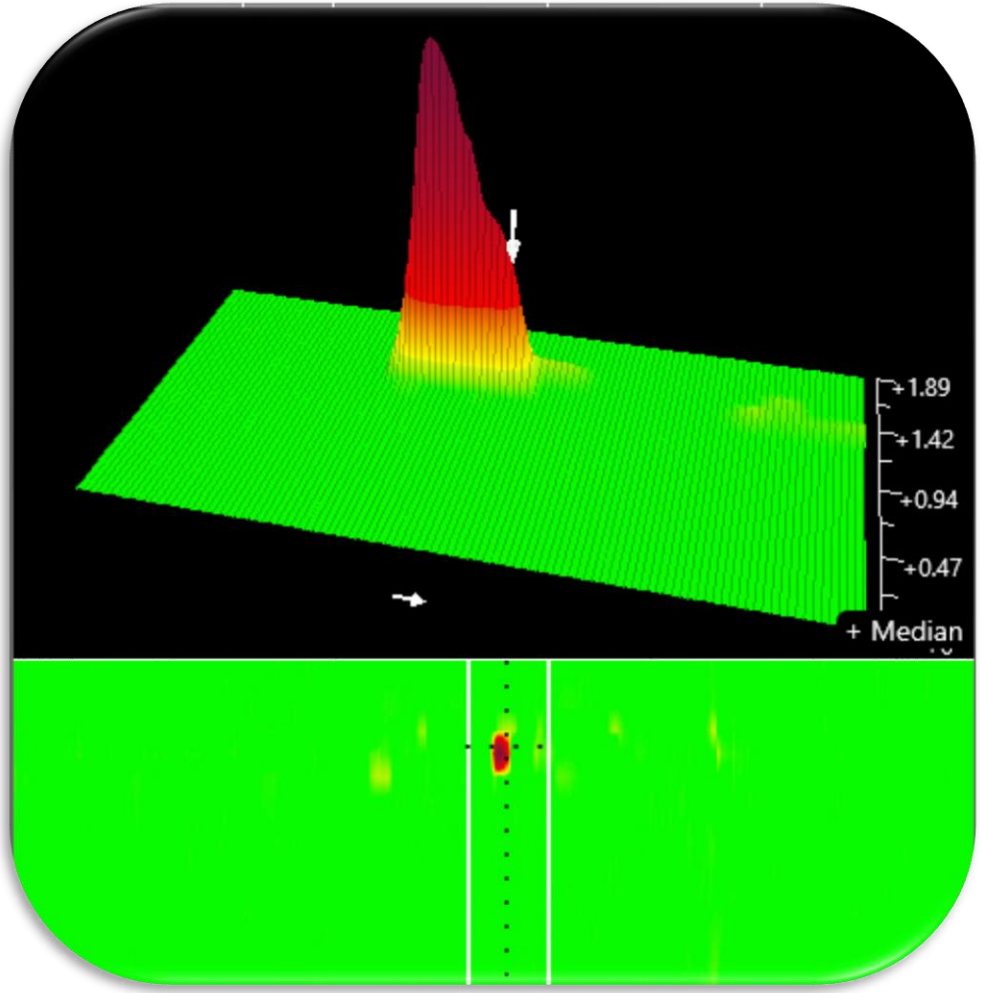
Porosity

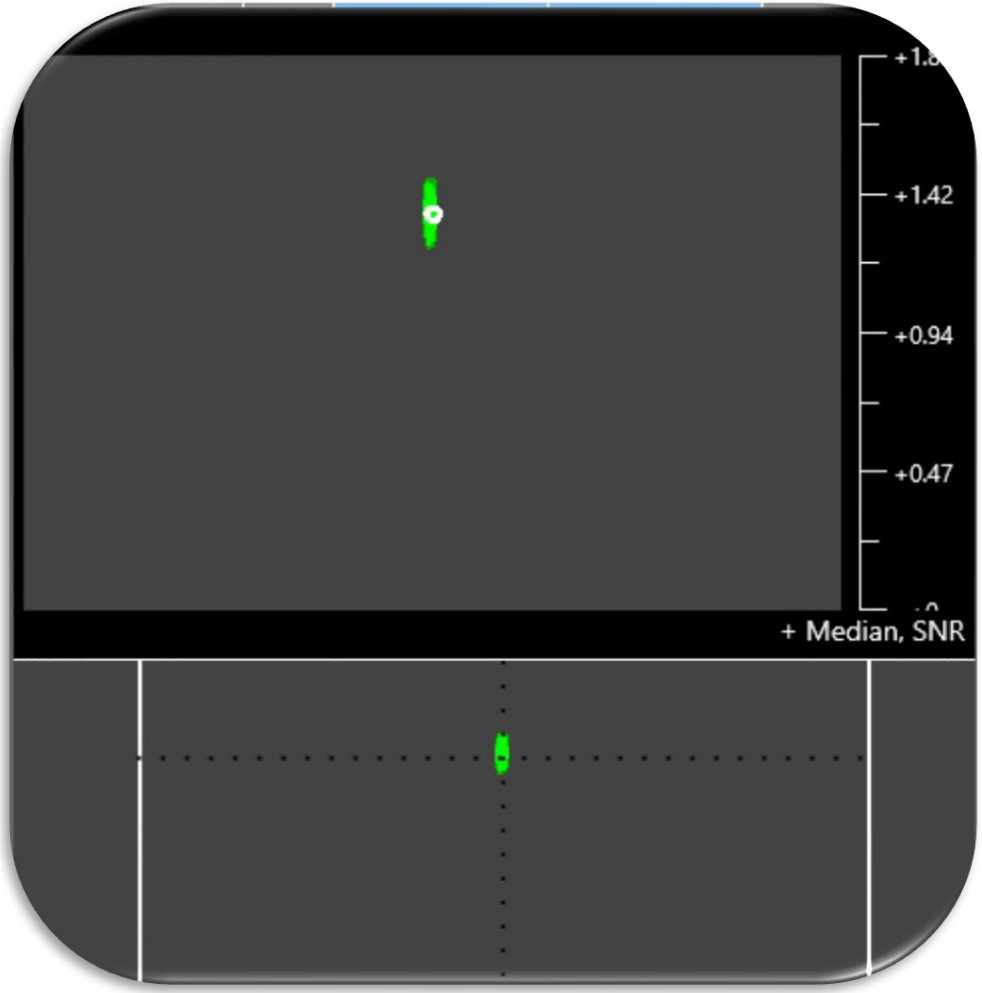


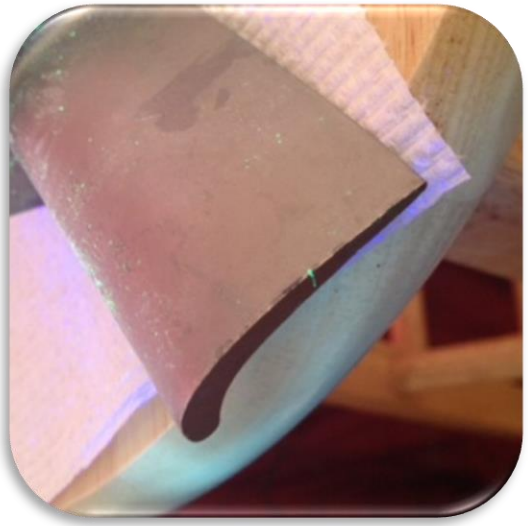




Tip Crack

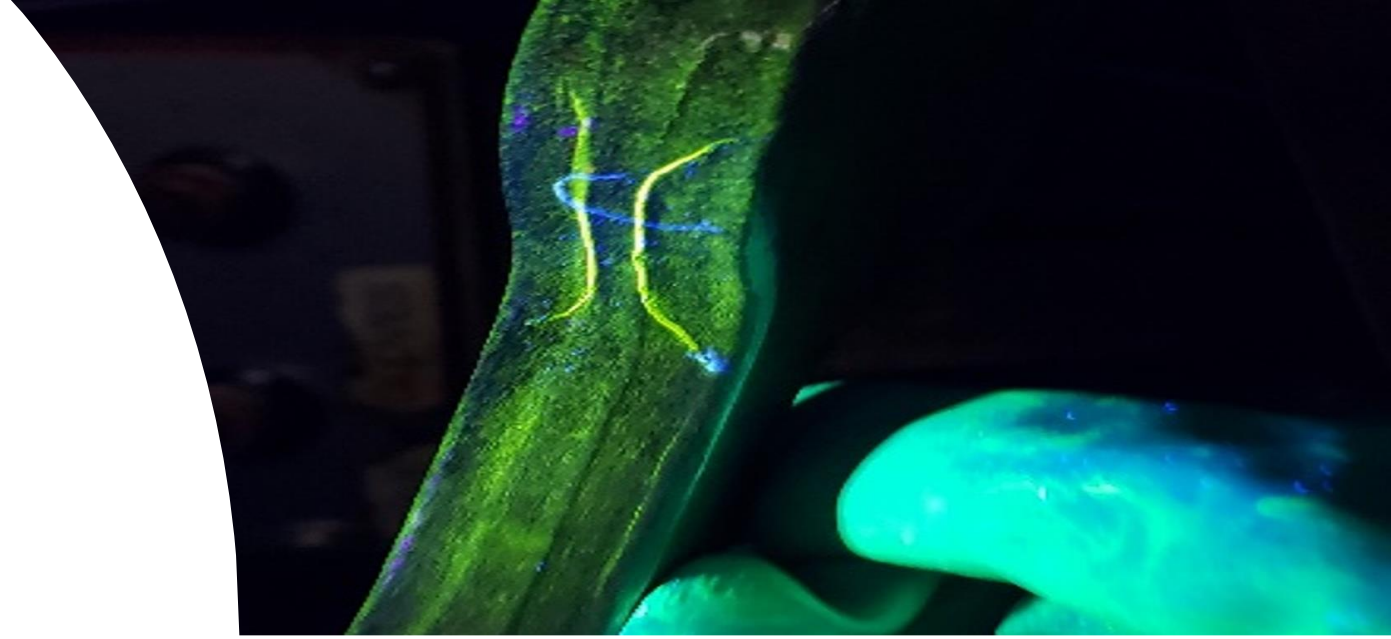




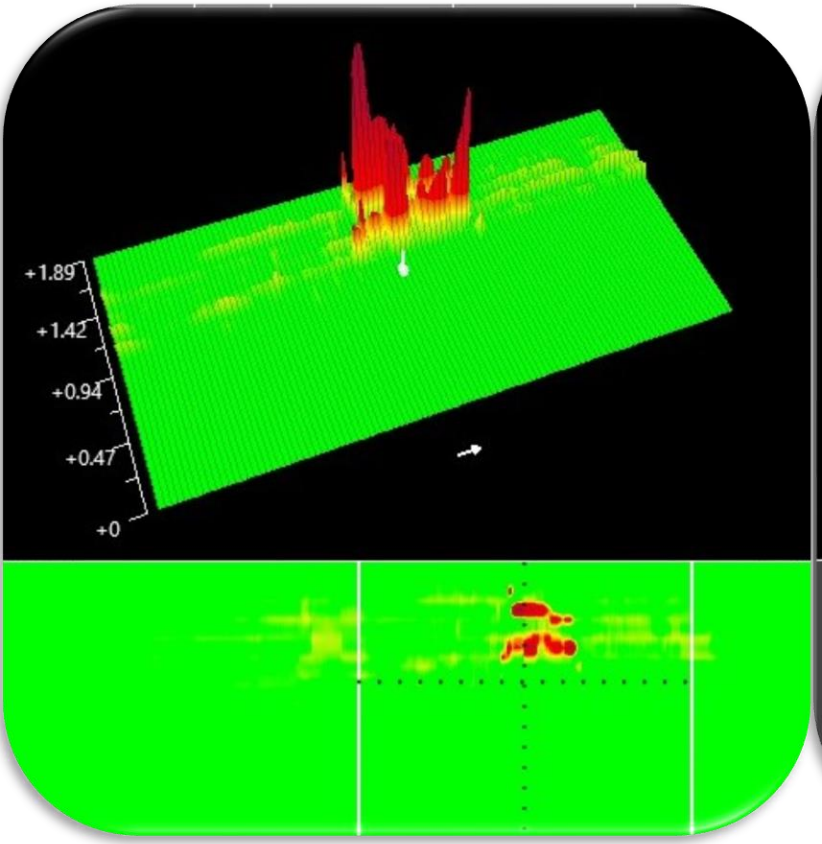


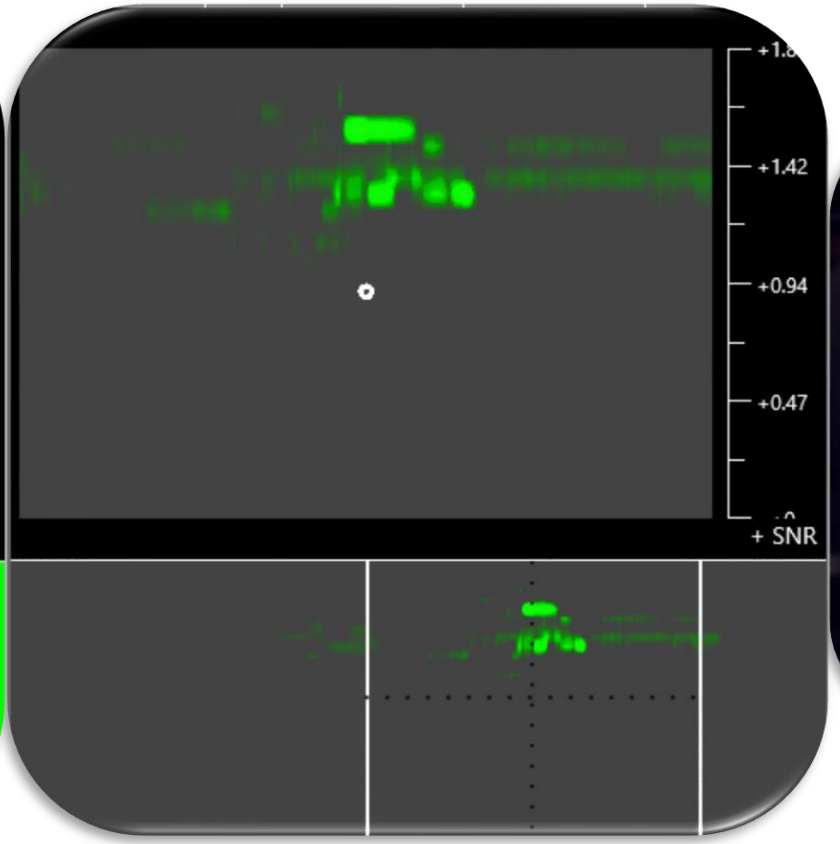
Mild Steel

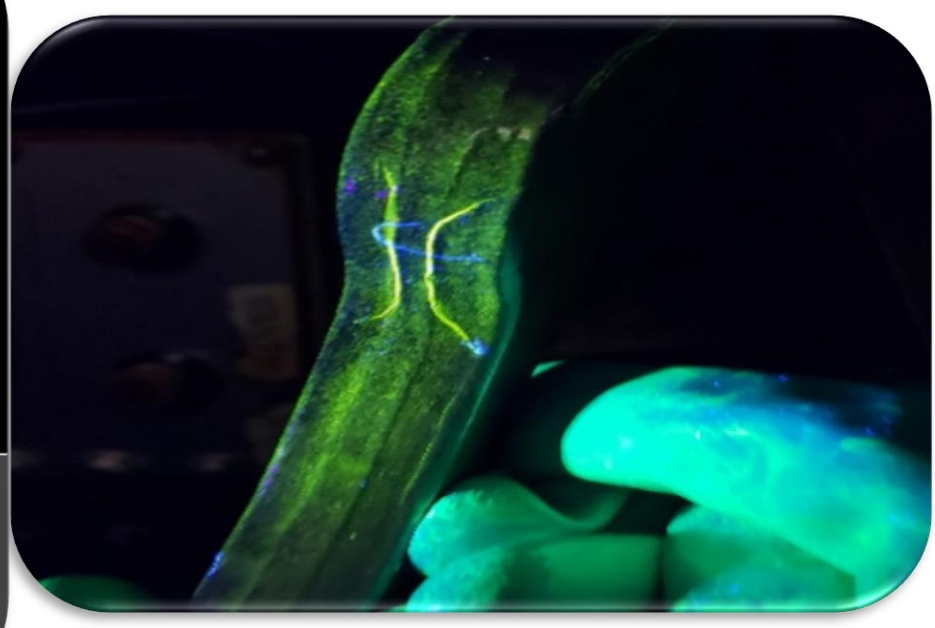
- Aircraft latch
- Forged & rolled
- Forge laps
- Wet fluorescent particle



Forging Laps

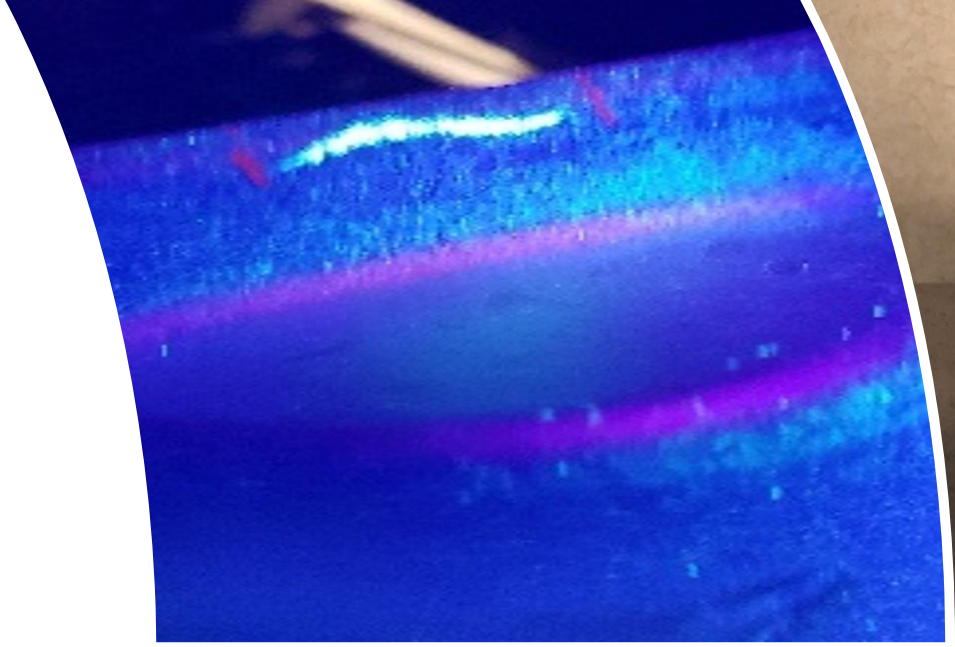


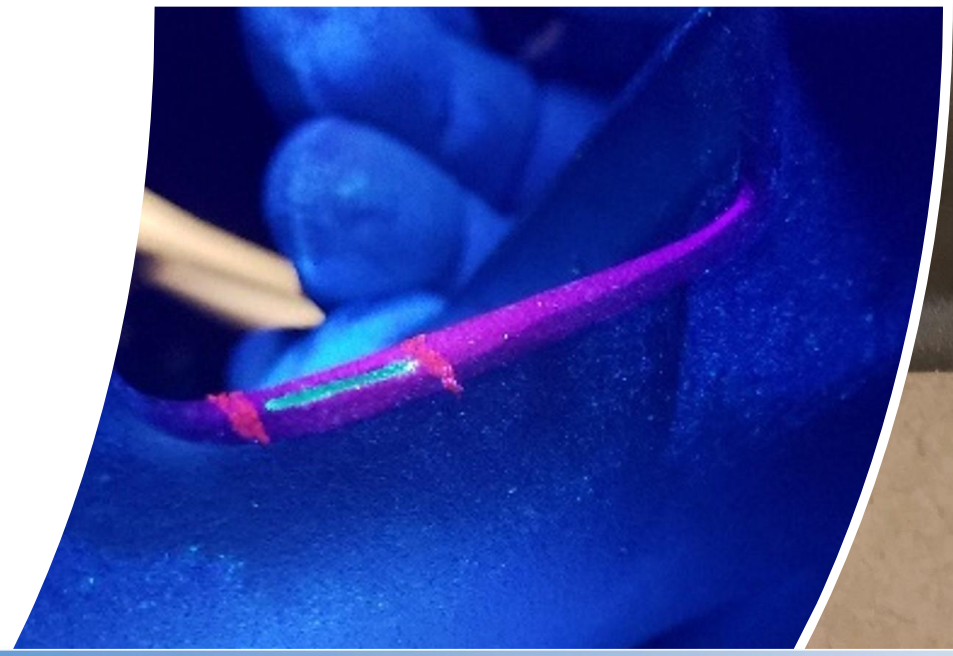


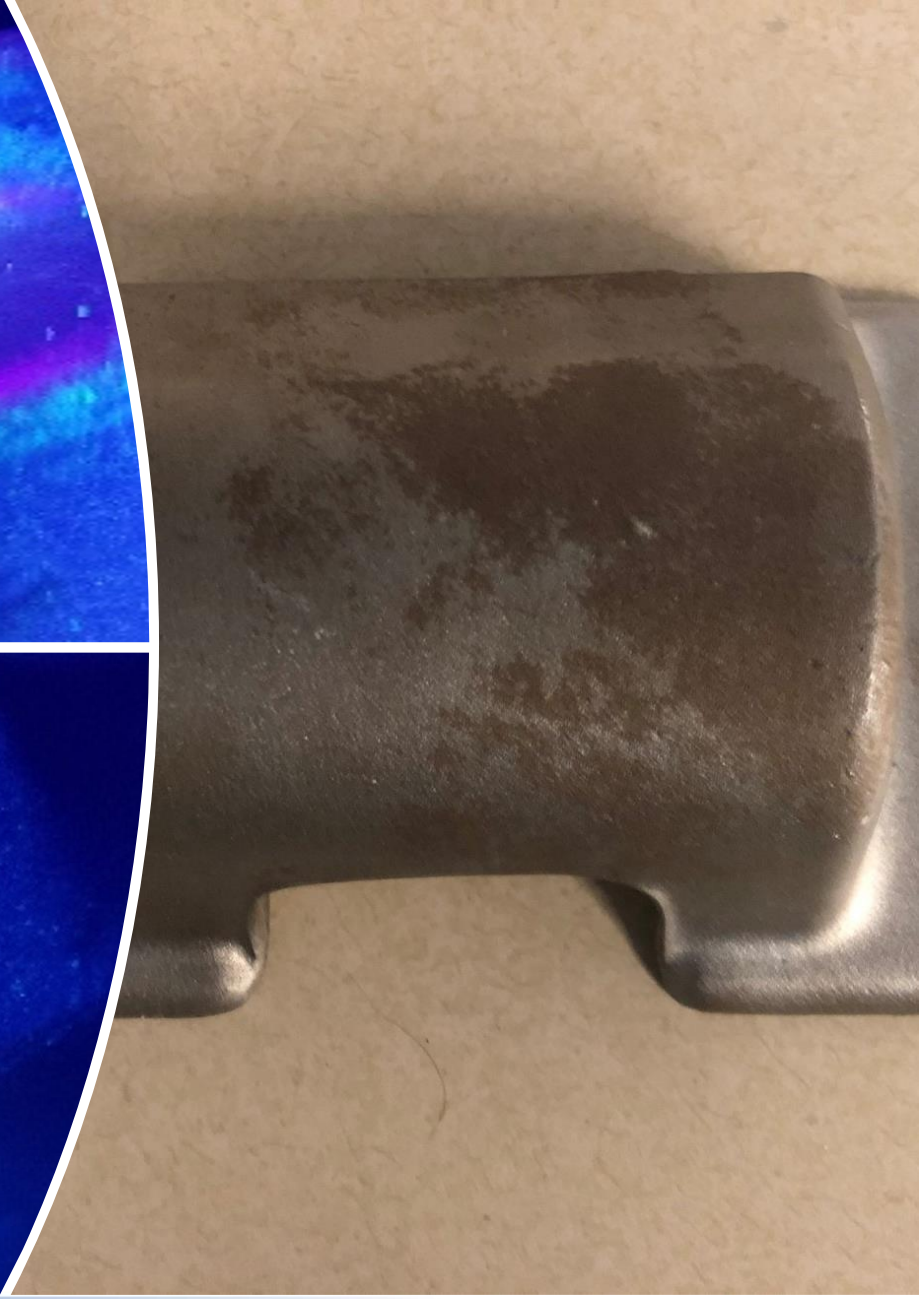


Inconel 718

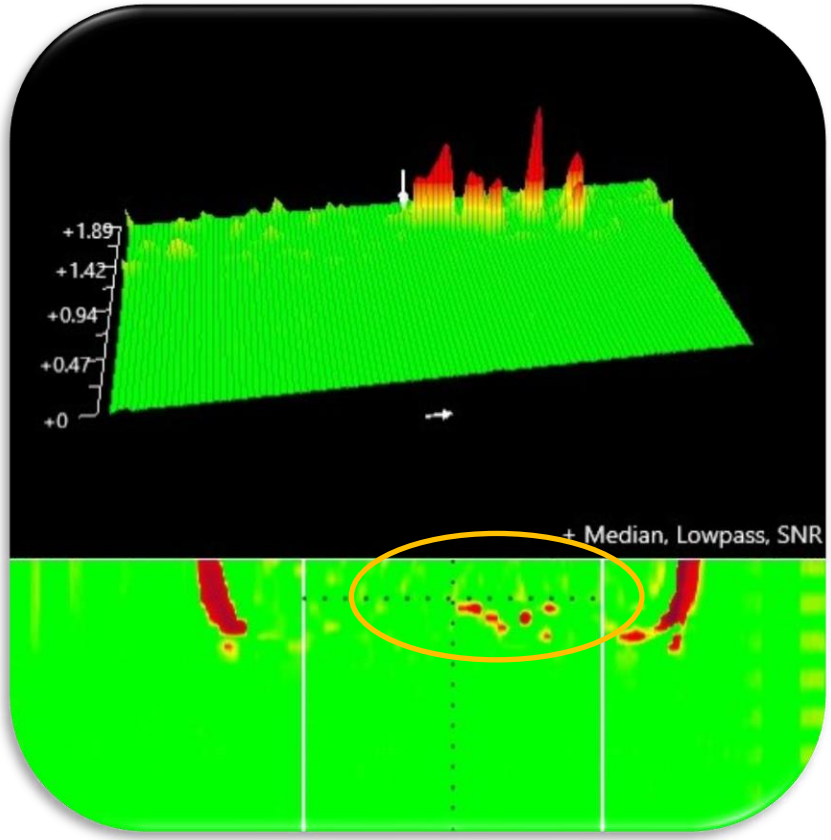
- Wrought forging
- Forging lap
- Forging burst
- Fluorescent dye

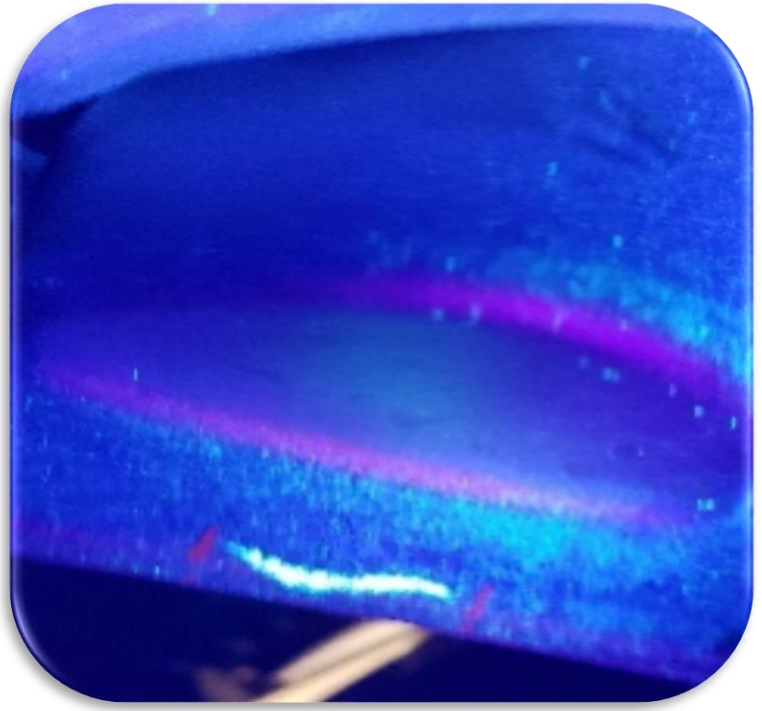




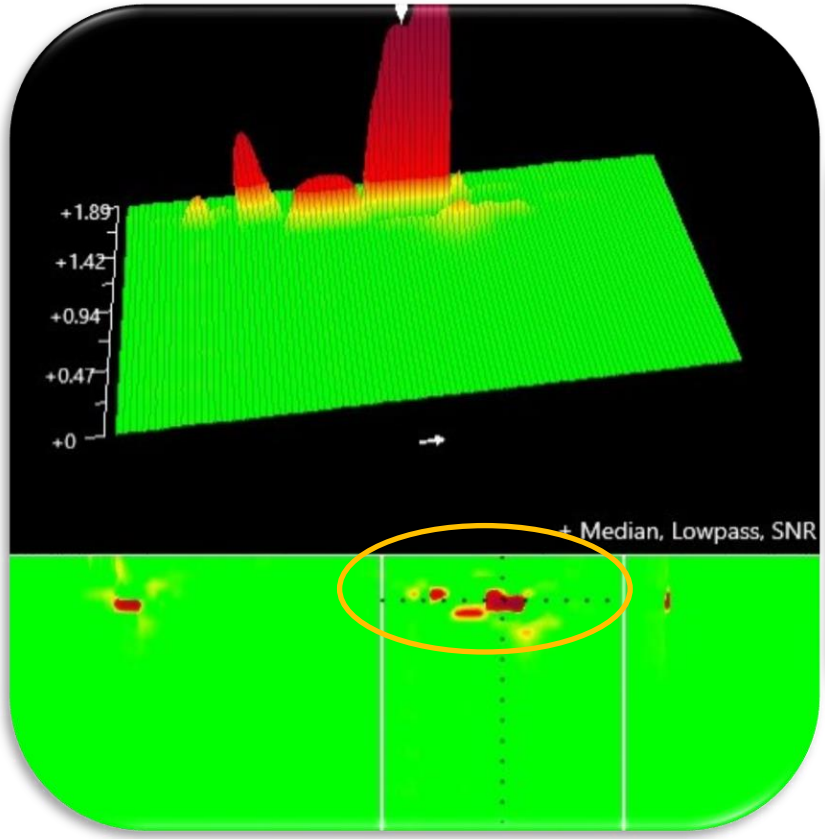


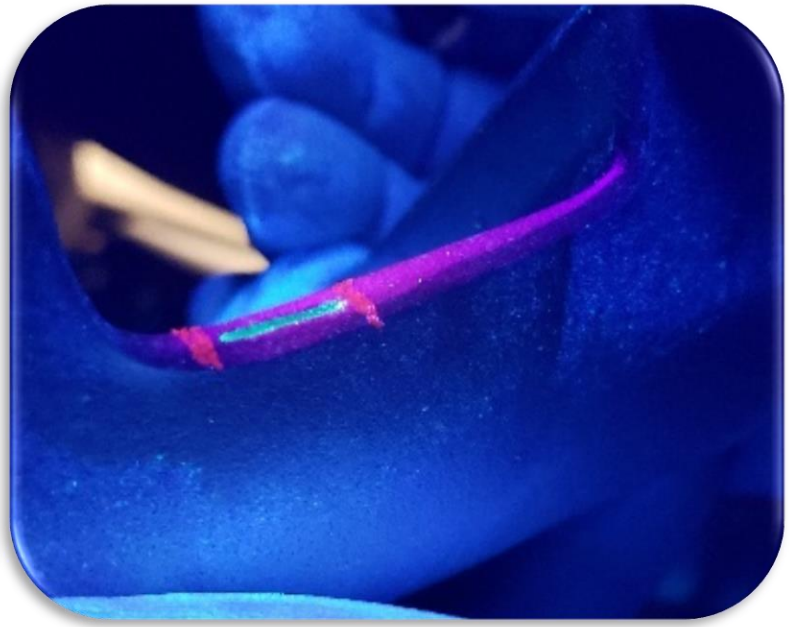
Forging Lap





Forging Burst

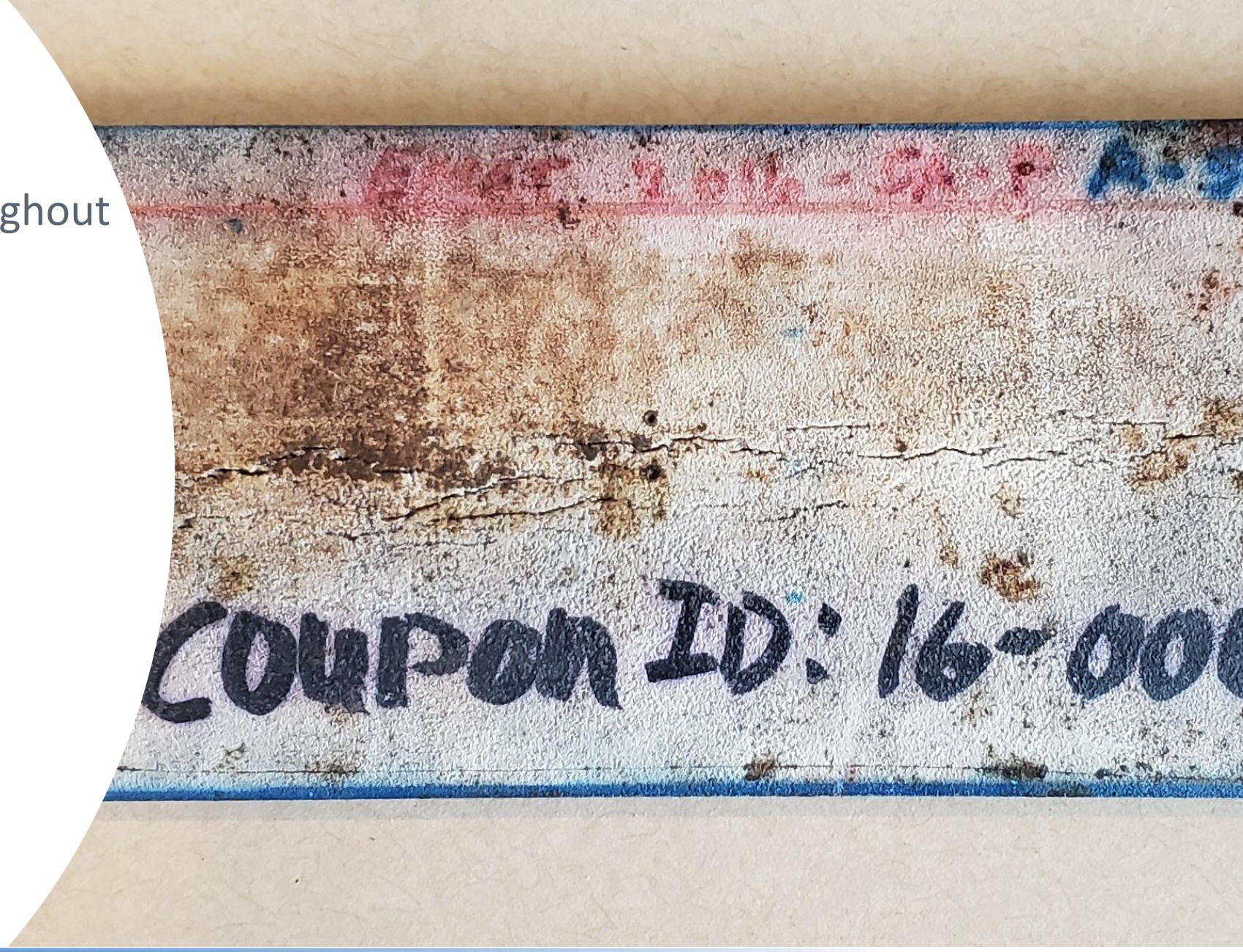




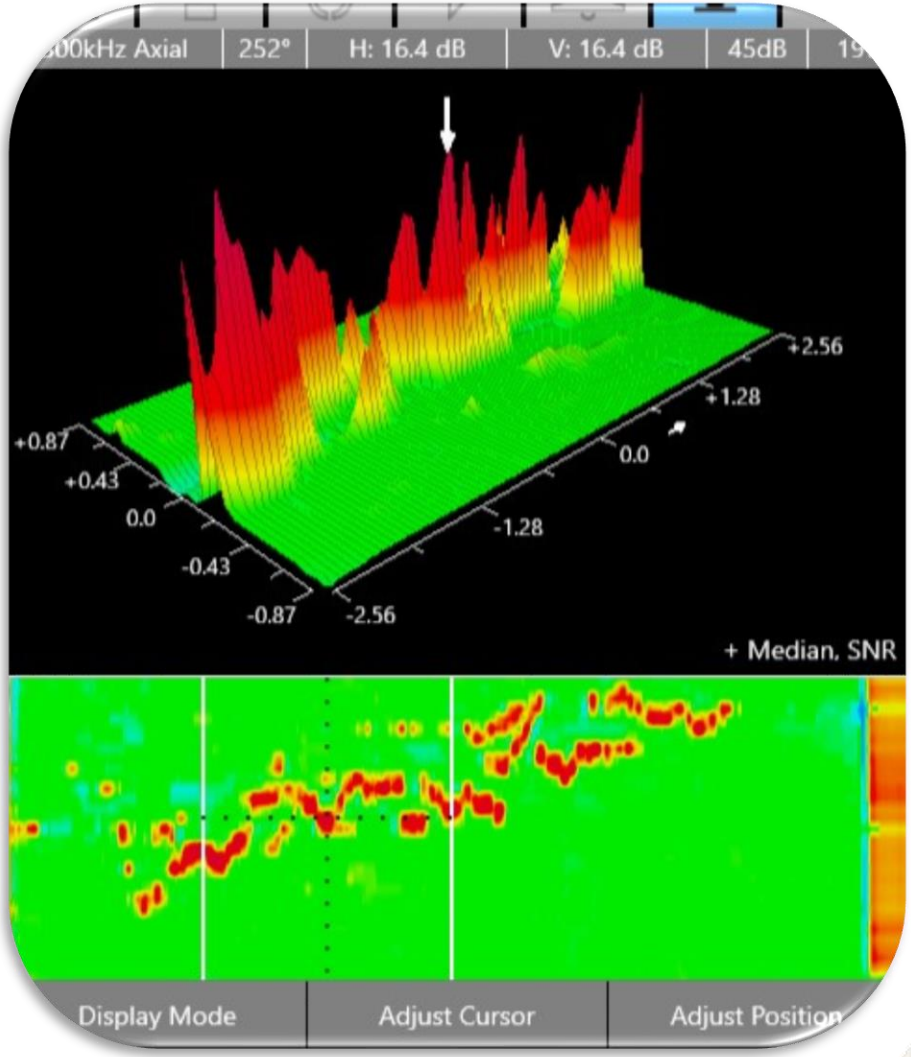
ECA Applications

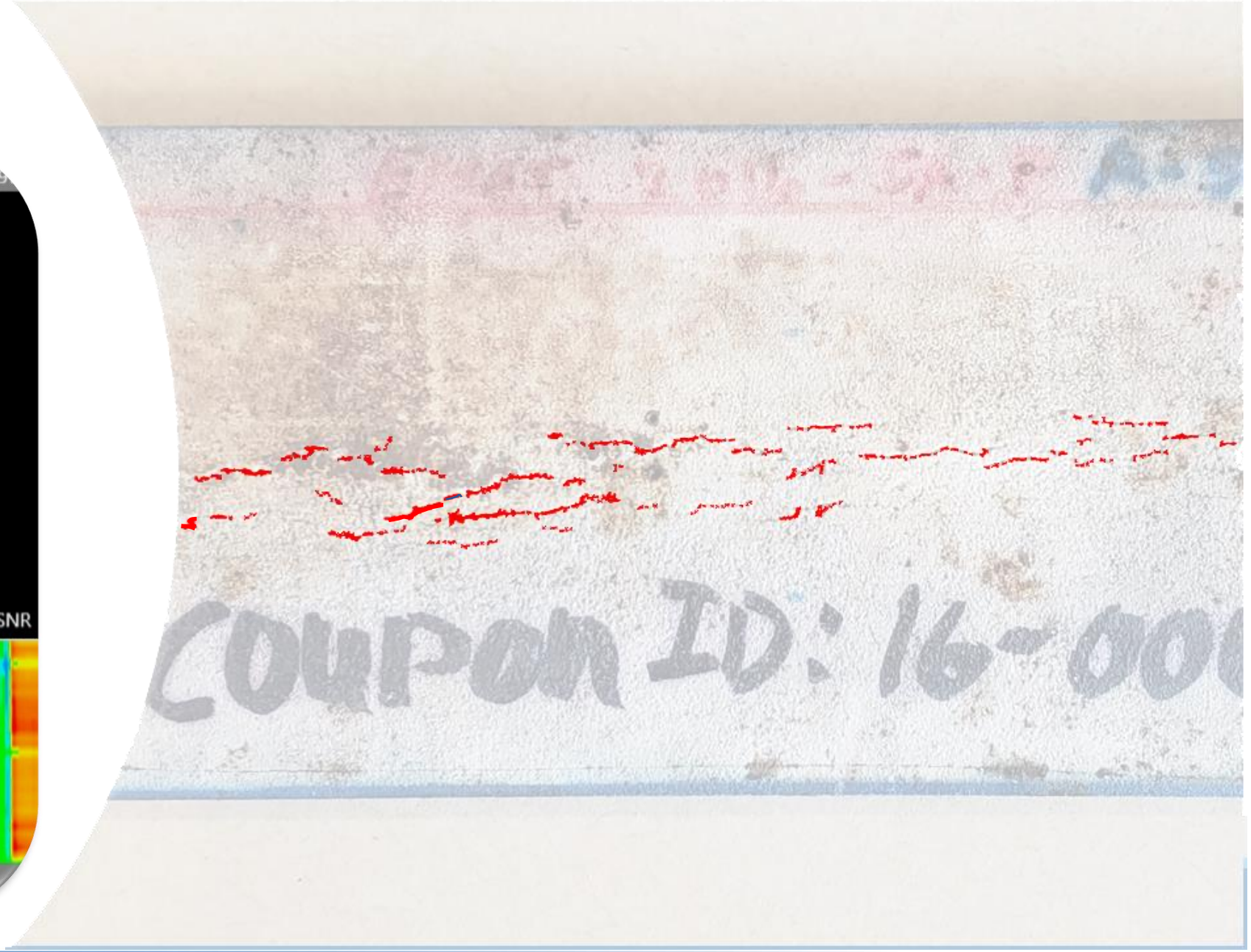
SCC in Carbon Steel

- Widespread corrosion throughout
- Significant axial cracking

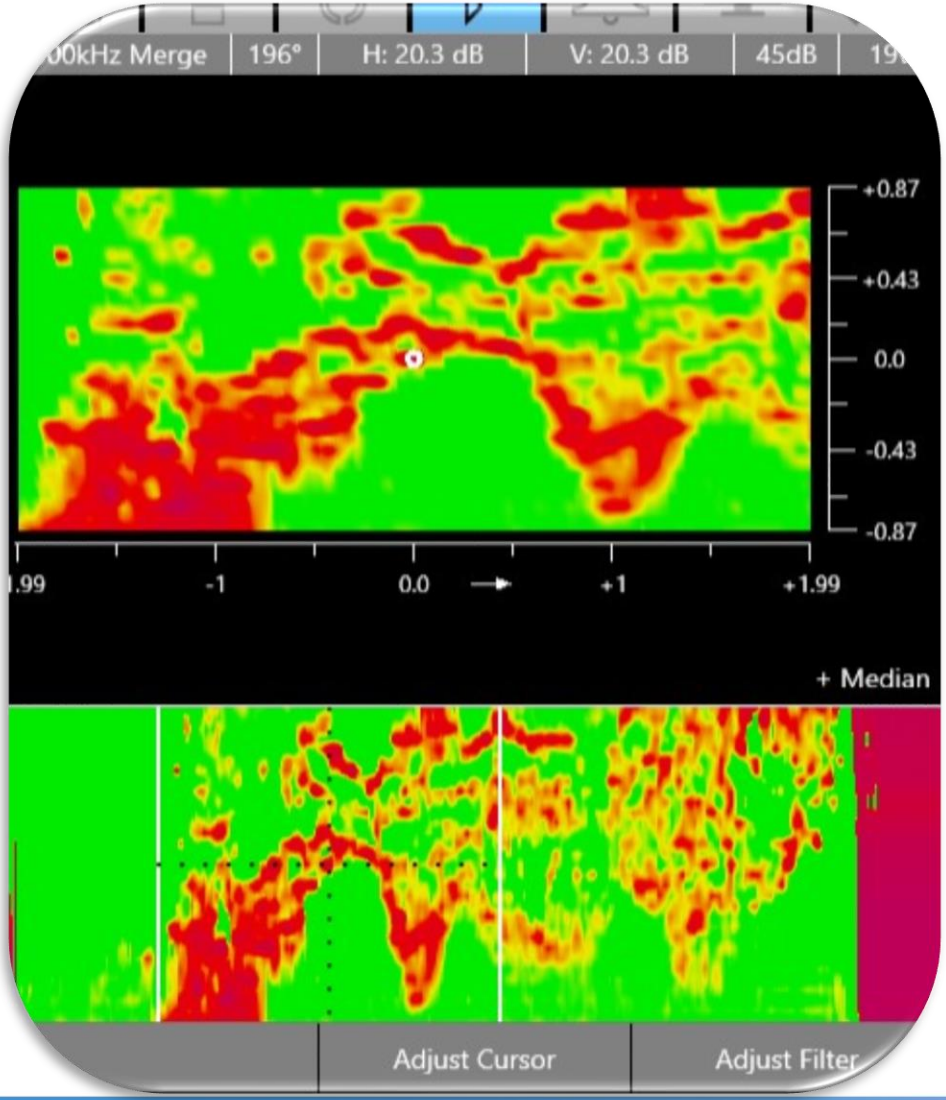


SCC in Carbon Steel





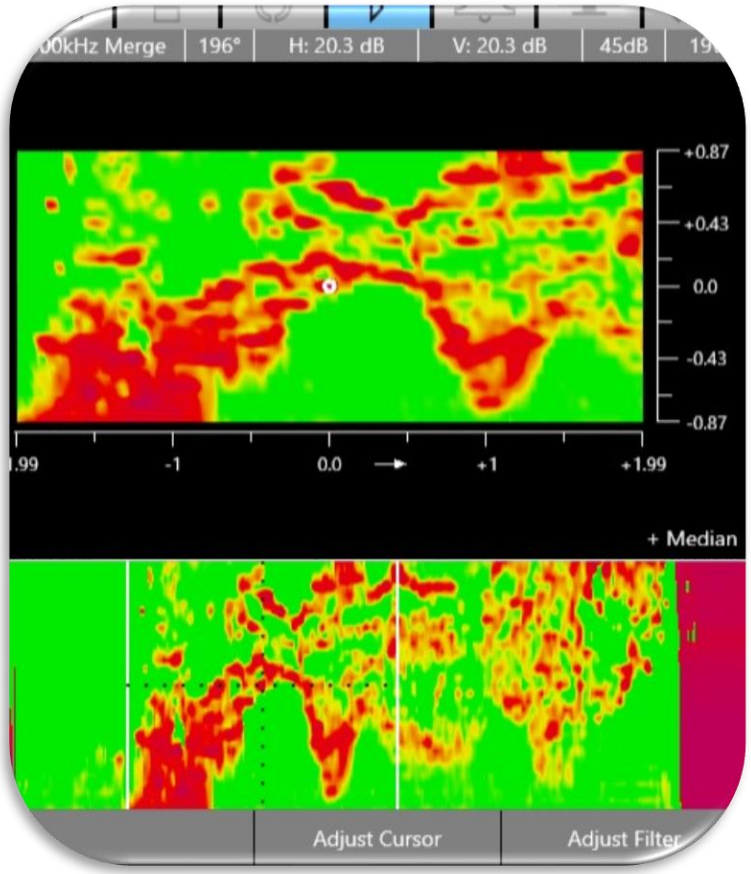
Multimodal Damage



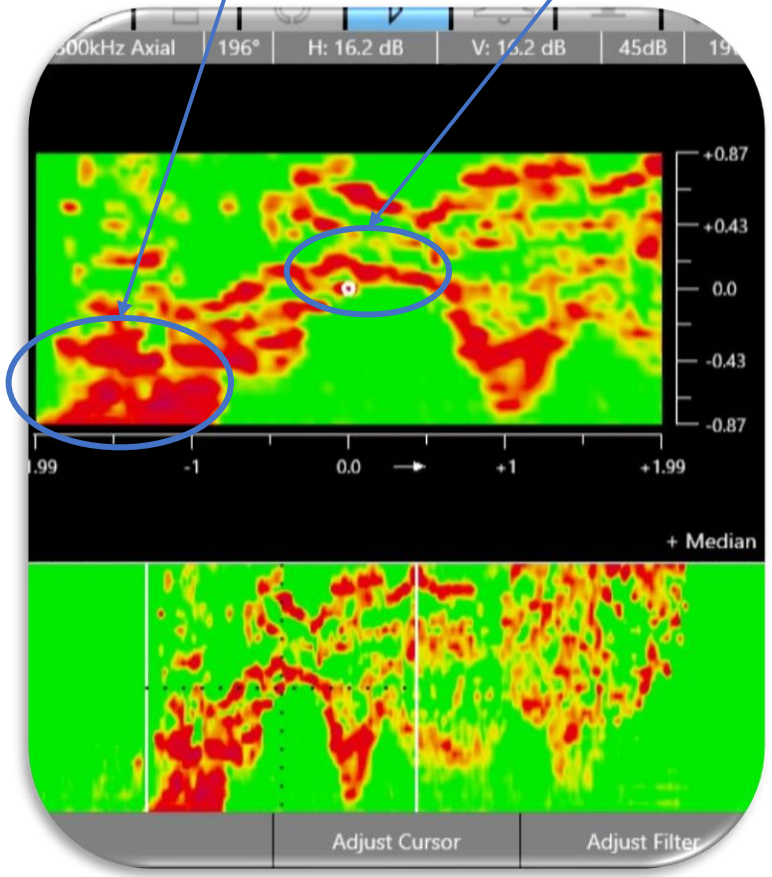
Damage Characterization

Example area of significant corrosion (seen on axial and transverse channels)

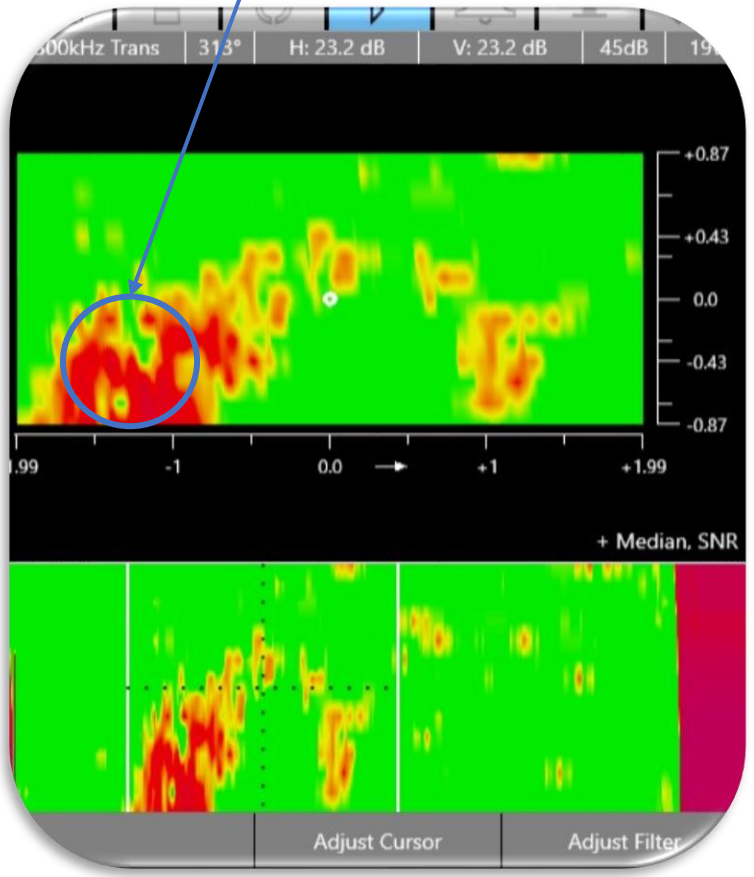
Example area of axial cracking (only seen on axial channel)



Merge channel



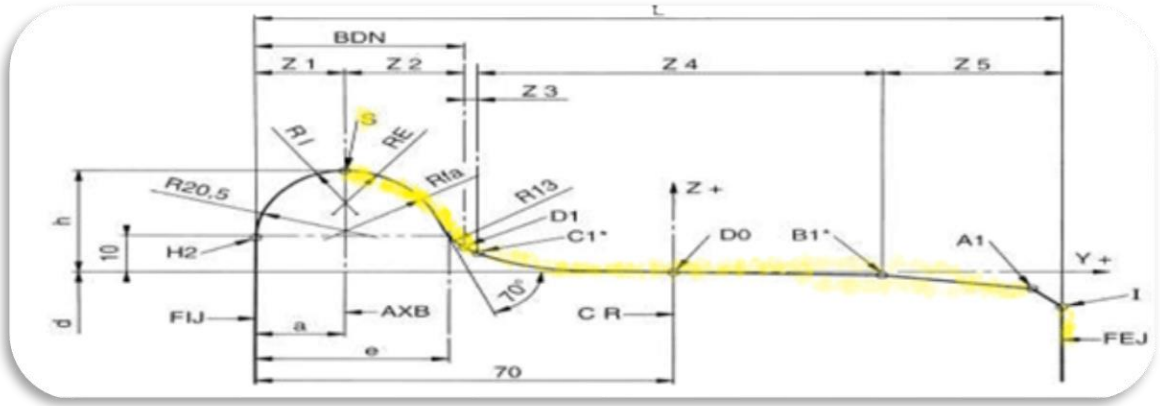
Axial channel



Transverse channel

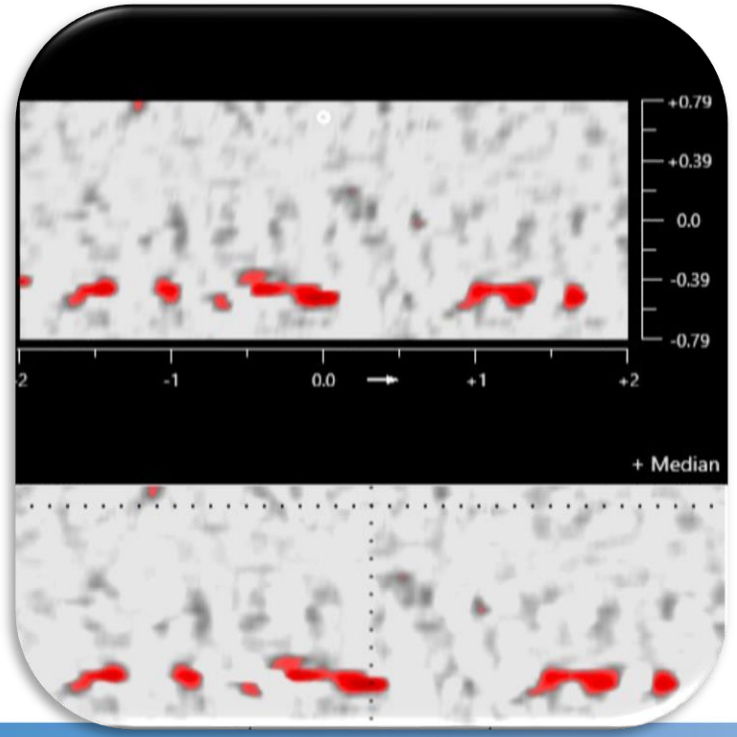
Train Wheels

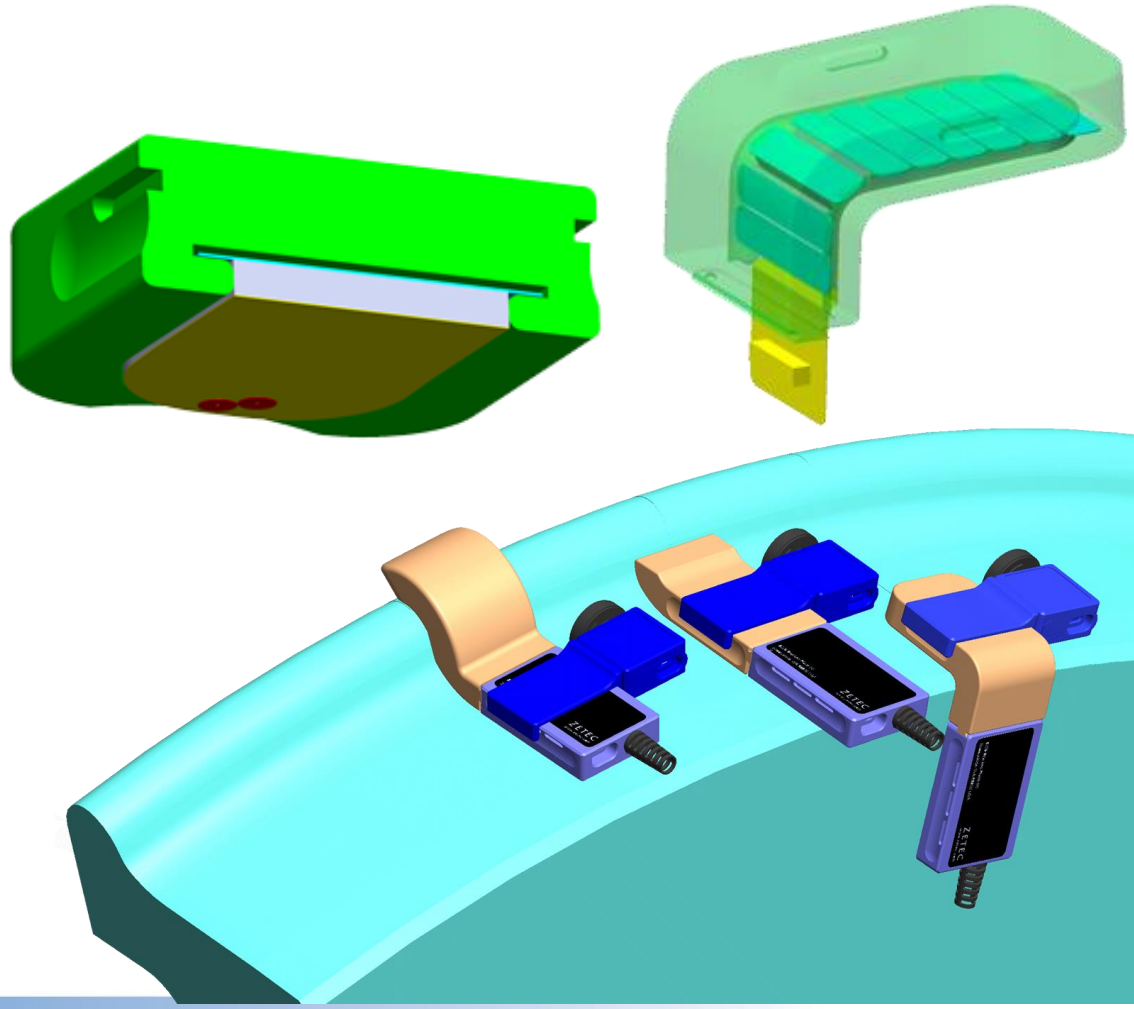
- Replace MT/PT
- Inspect wheel contour in 3 passes or less

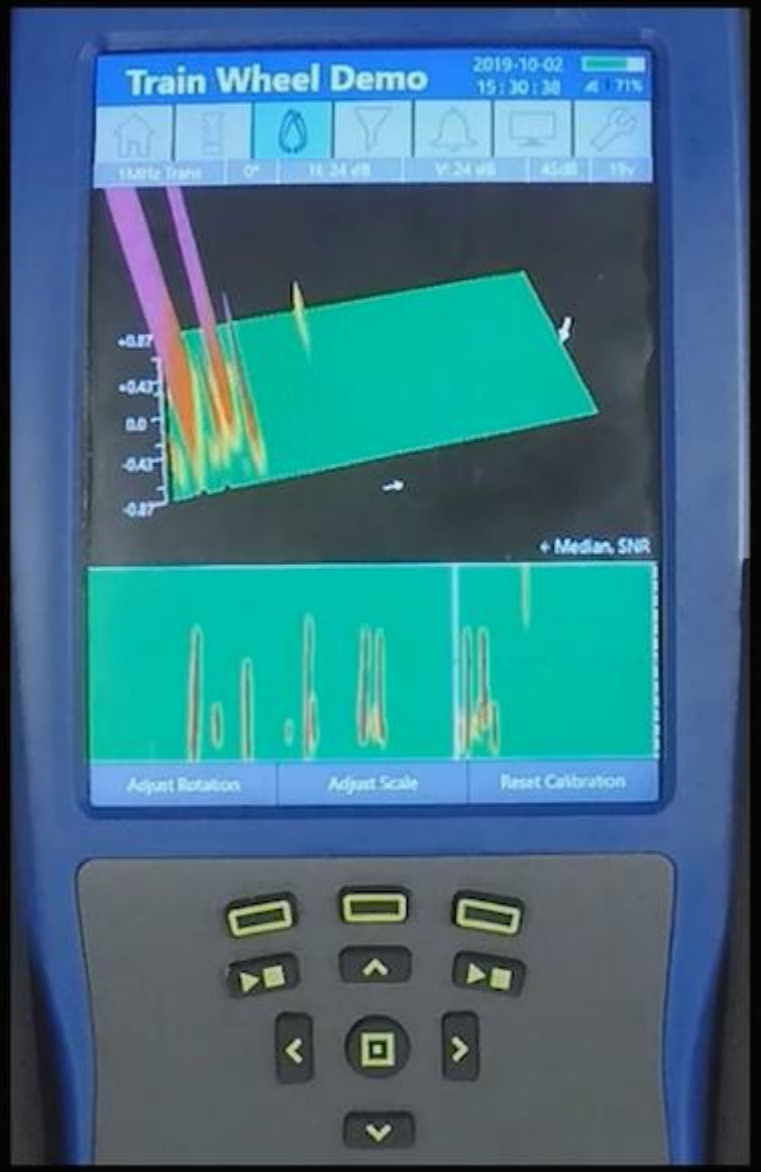


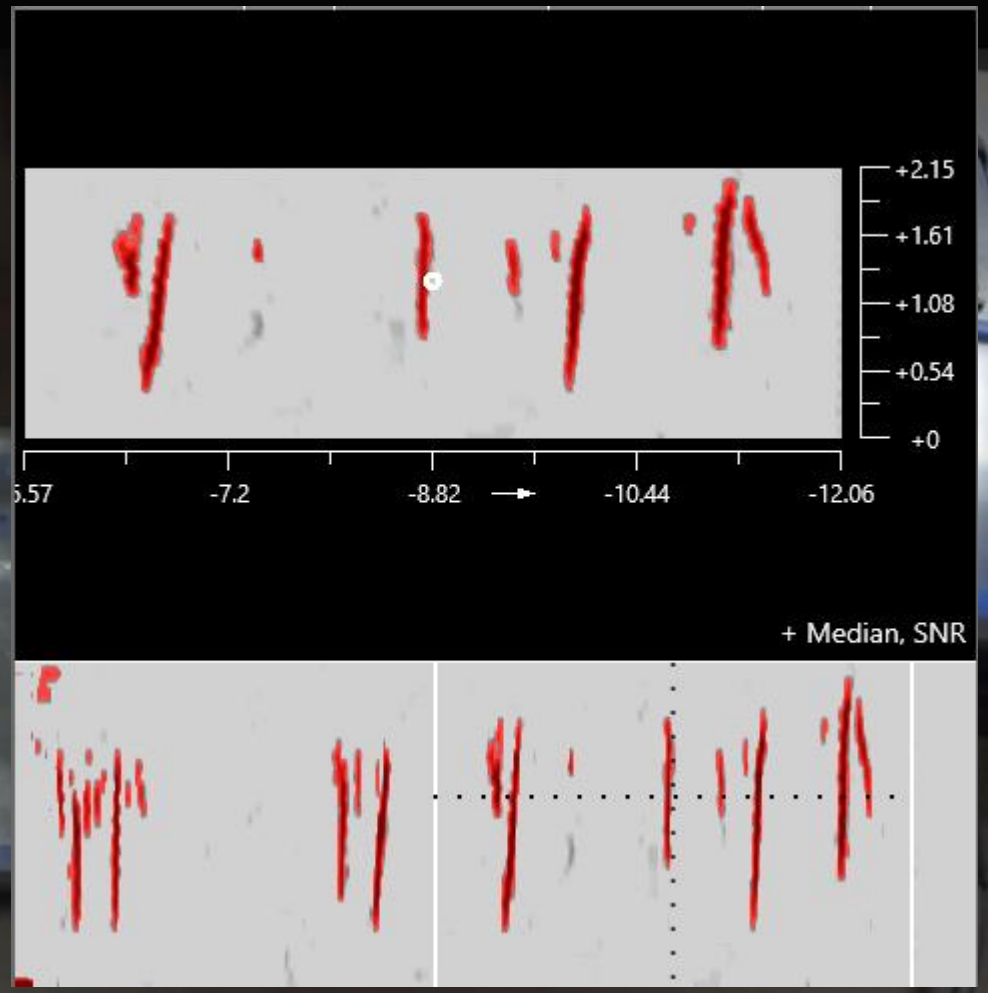
Train Wheels

- Tape probe with custom probe forms
- UHMW wear surface
- Customized color palette



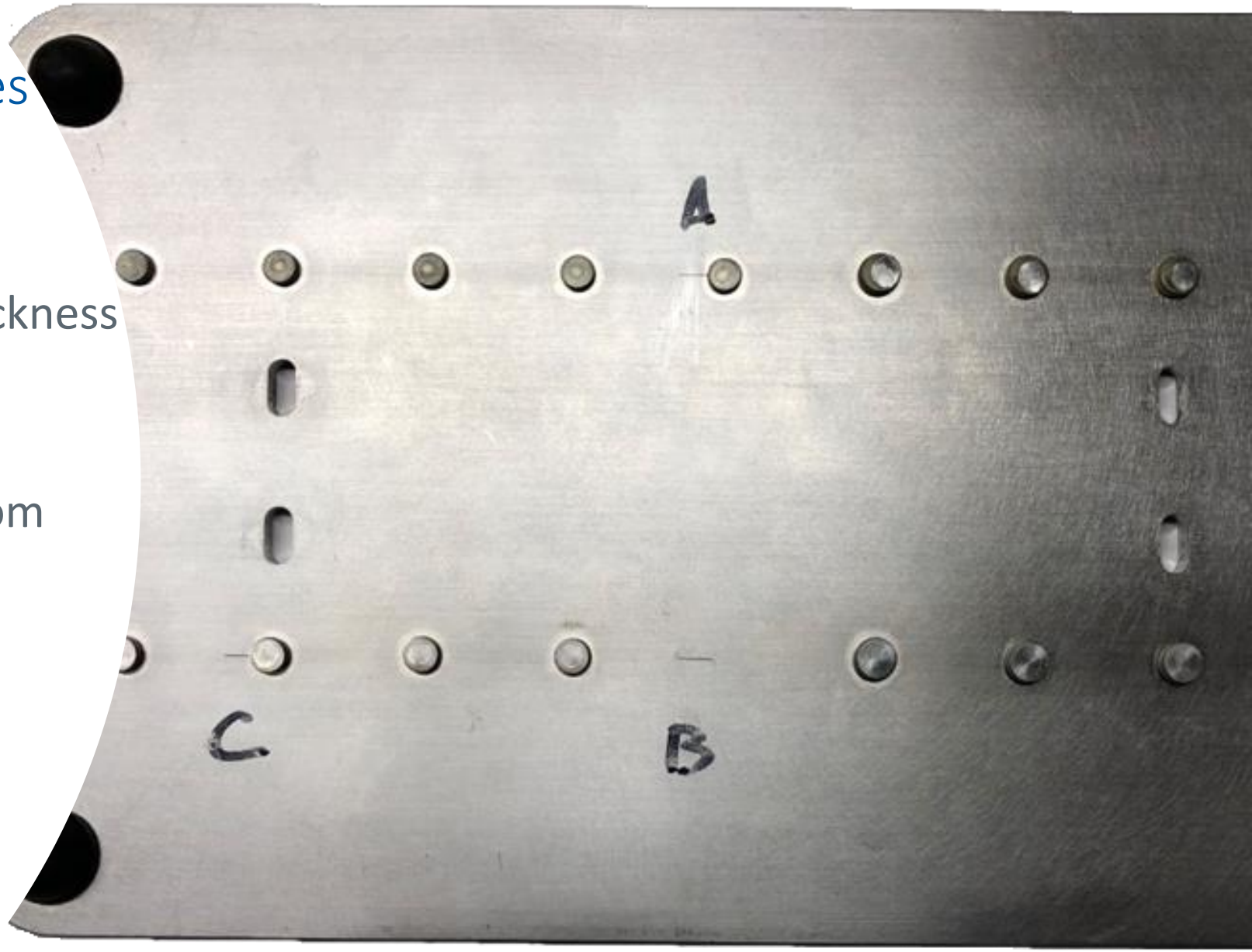



Train Wheel Demo
2019-10-02
15:30:38
+ Median, SNR
Adjust Rotation
Adjust Scale
Reset Calibration


+2.15
+1.61
+1.08
+0.54
+0
-7.2
-8.82
-10.44
-12.06
+ Median, SNR

Aircraft Multi-Layer Structures

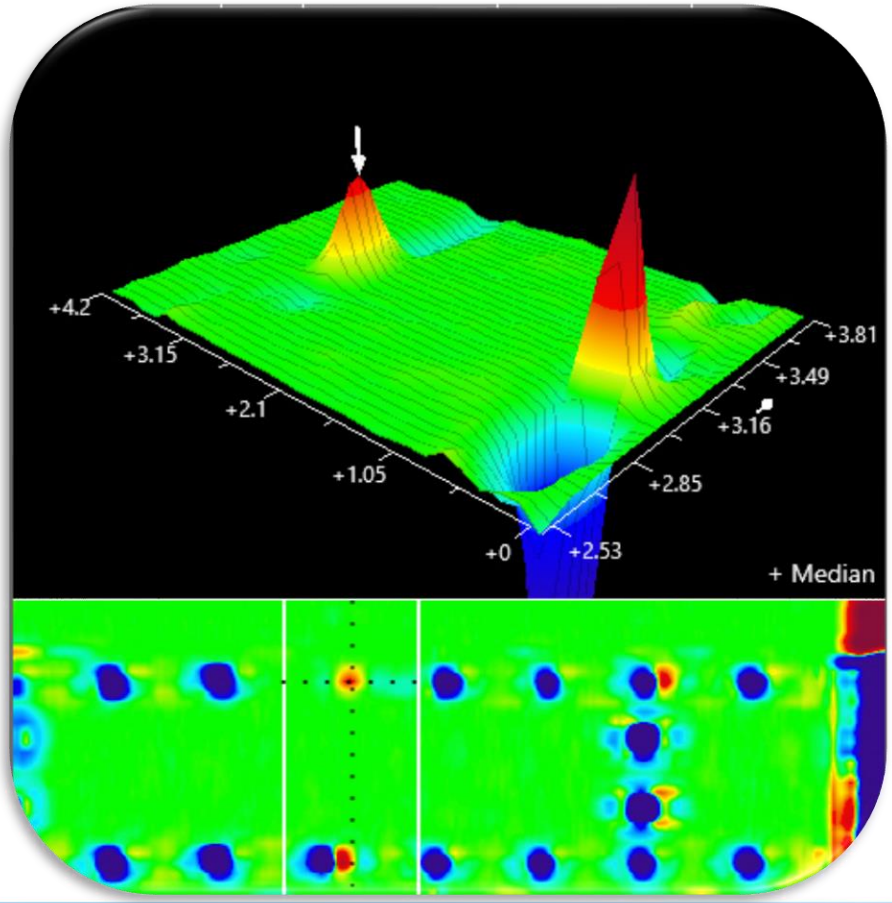
- 1087 reference standard
- 0.19 in. (4.8 mm) combined thickness
- 0.25 in. (6.35 mm) notch length
- Subsurface cracks stemming from rivets



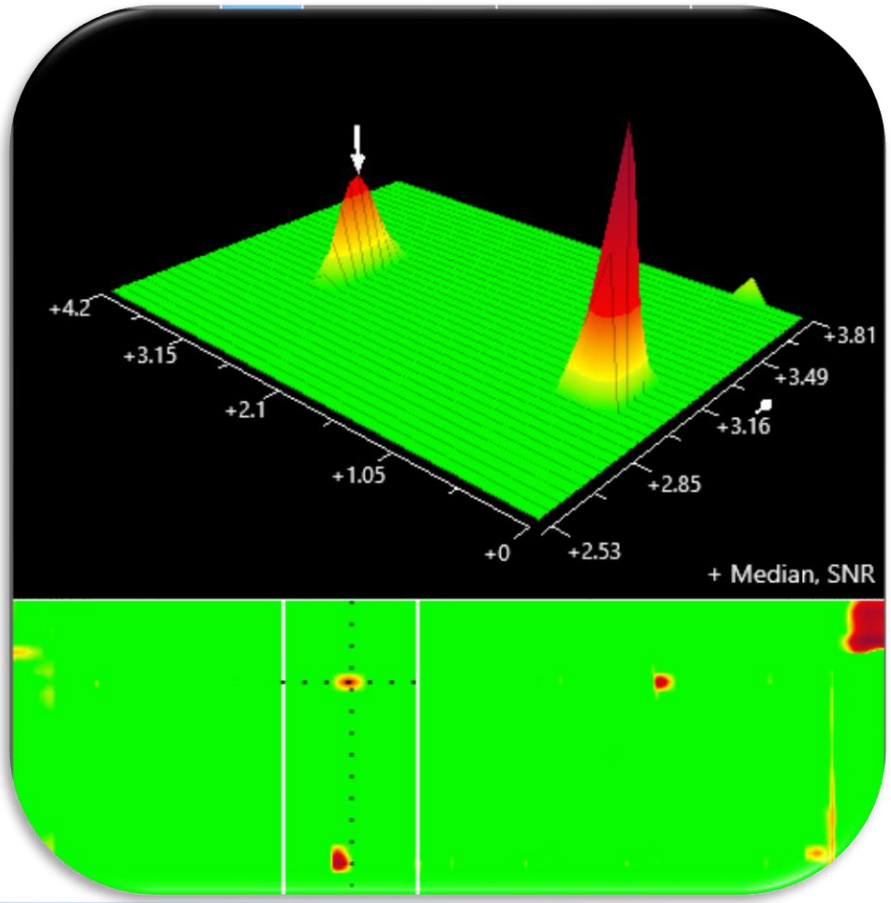

A
B
C
ZETEC NDT1087-8 SN ZE10062

Notches A & B

Rivet signal in view



Rivet signals removed



And Many More….

- Aircraft corrosion
- Helicopter rotors
- Inspecting rows of fasteners in aircraft
- Chem mill cracking on airframes

- Ask yourself if a MT/PT inspection can be augmented by ECA?
  - Augment example: Perform ECA over large surface. Follow up with MT/PT in small areas discovered by ECA.

Technique Comparison

	MT	PT	ECT	ECA
Effective on coating/paint surface	No	Limited	**Yes**	**Yes**
Pre & post cleaning	Yes	Yes	**No**	**No**
Chemical/consumables	Yes	Yes	**No**	**No**
Inspection speed	Low	Low	Medium	**Very High**
Sizing capabilities	No	No	**Yes**	**Yes**
Recording data	No	No	**Yes**	**Yes**
Post inspection data analysis	No	No	**Yes**	**Yes**
Trending capabilities	No	No	Limited	**Yes**
3D Imaging	No	No	No	**Yes**

FAQ

Remember - eddy current is eddy current!

1. What is the minimum flaw size? 
2. What is the frequency range?
3. Can I just use the C-scan?
4. How deep into the material can you detect flaws?
5. What is the sizing accuracy? 

Conclusions

- ECA can be used to bolster MT/PT inspections, especially for mission critical assets
- ASME code now allows for the use of ECA
- ECA has been demonstrated to provide superior results on a variety of materials and applications
- Details such as flaw morphology can be analyzed and saved for historical tracking
- POD is higher as compared to conventional ECT

Thanks!

Many thanks to Toni Bailey for providing samples and MT/PT results!

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Additional Questions?

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Thank you for participating!

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