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Automated Engine Disk Inspection for Detecting Cracks in Regions with Fretting Damage

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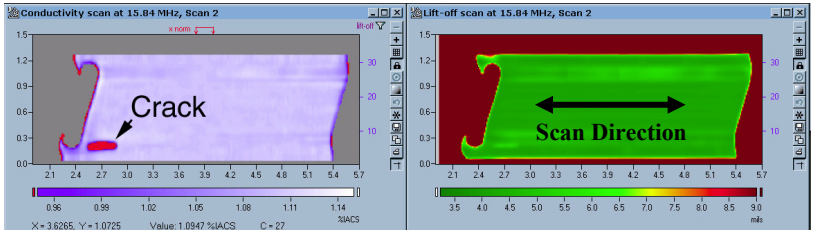
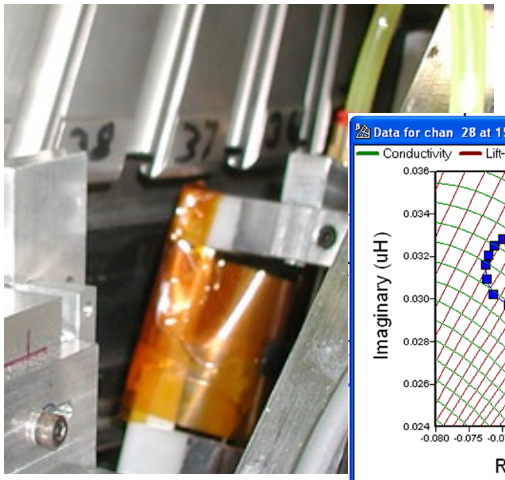
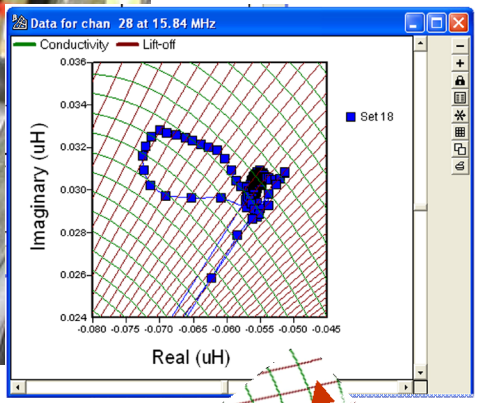
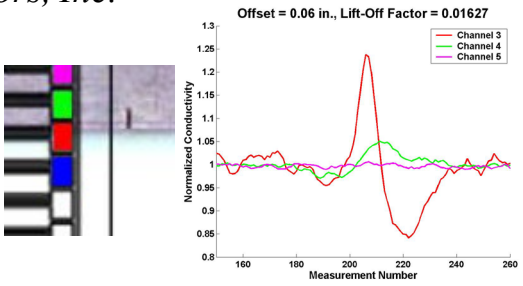
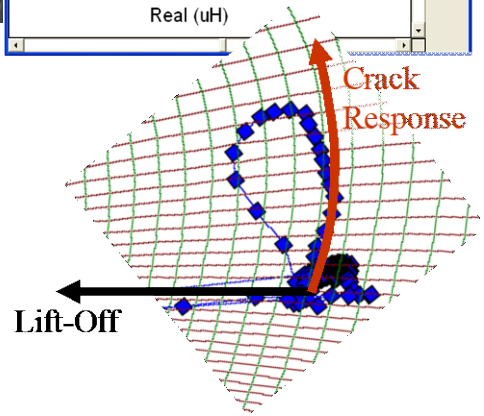
JENTEK Sensors, Inc.











Patents Issued and Pending

Overview

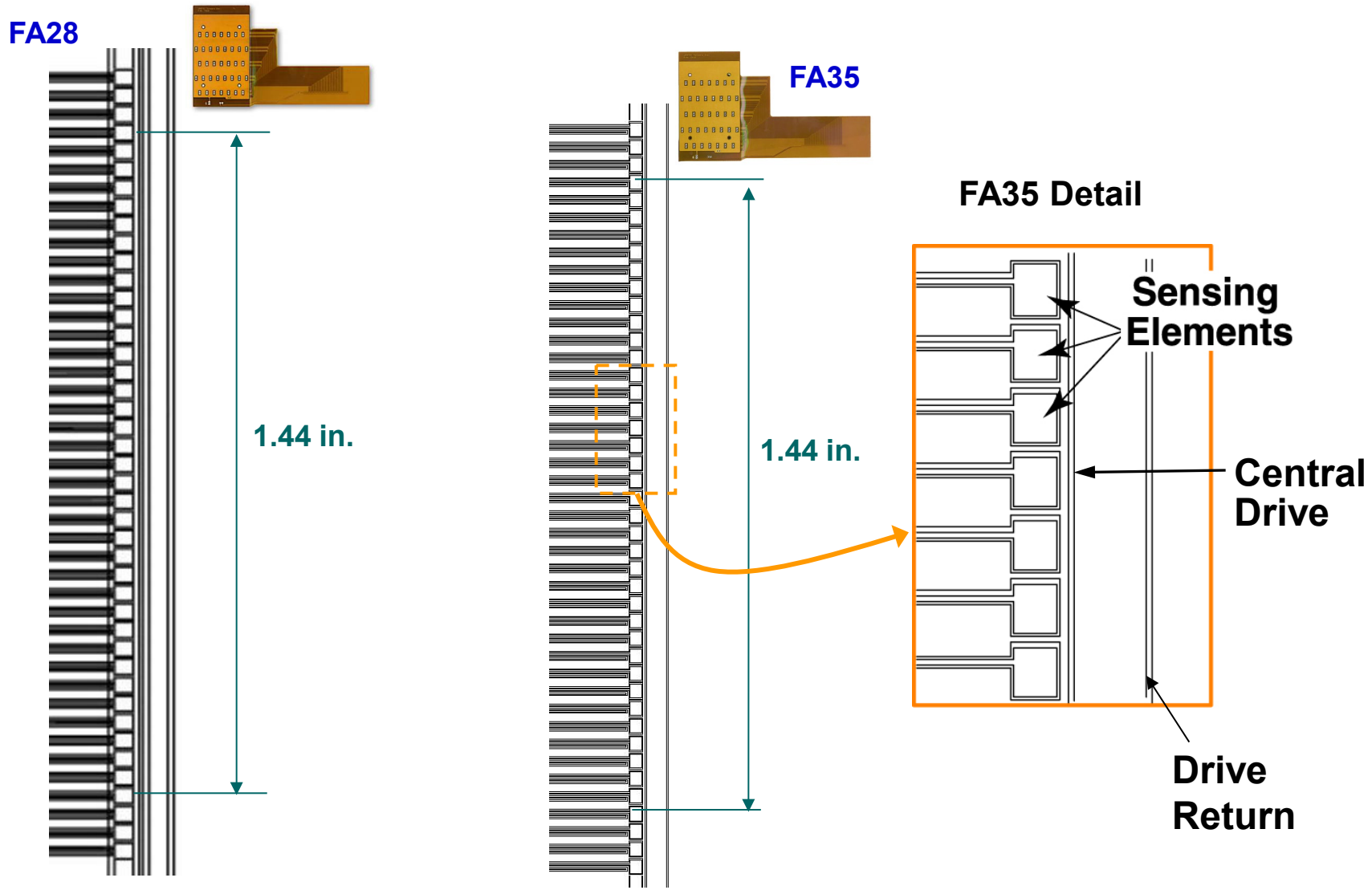
- Engine Disk Slot Inspection
- Bolt Hole Inspection
- Real Crack Specimen Fabrication

Engine Disk Slot Inspection

- **MWM-Array Engine Slot Inspection is NOW in production use at a Depot**
- **Funding History**
  - FAA 1990s
  - DoD 2000 – 2005
- **Performance Validation Studies**
  - FAA funded POD study on ENSIP plates
  - Extensive DoD funded performance studies on actual components with substantial destructive validation and acetate replica based validation

- Principal MWM-Array Implementation Capabilities
  - Detection of cracks in regions with and without fretting damage
  - Automated Inspection
  - Calibration without crack standards (see ASTM standard for air calibration)
  - Continual Validation/Verification using real crack specimens and/or actual field hardware
  - Self Diagnostics using lift-off images and absolute conductivity

MWM-Arrays for Engine Slot Inspection



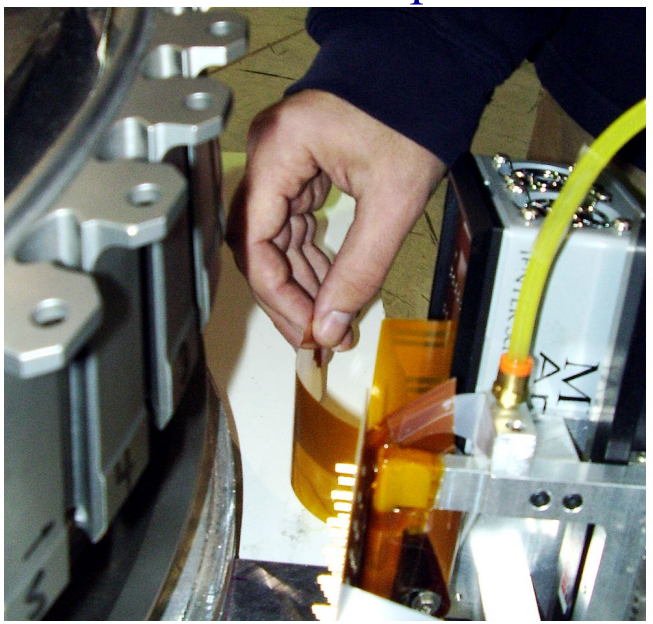
Air Calibration without Crack or EDM Notch Standards

- **Air Calibration performed with removable MWM-Array sensor and shunt tips**
  - Estimate cable properties and correct for channel to channel variations on each of 37 channels automatically
  - Verify calibration performance using:
    - lift-off and conductivity images (absolute properties)
    - Scans on flight run hardware with verified cracks of typical sizes
  - Real crack specimens used in performance studies to
    - select thresholds for crack detection
    - develop correlations between crack size and MWM-Array response
- **One Point air recalibration performed periodically enables rapid recalibration without sensor tip removal**

Air, Shunt Calibration (No Crack Standards)

Sensor in “air”

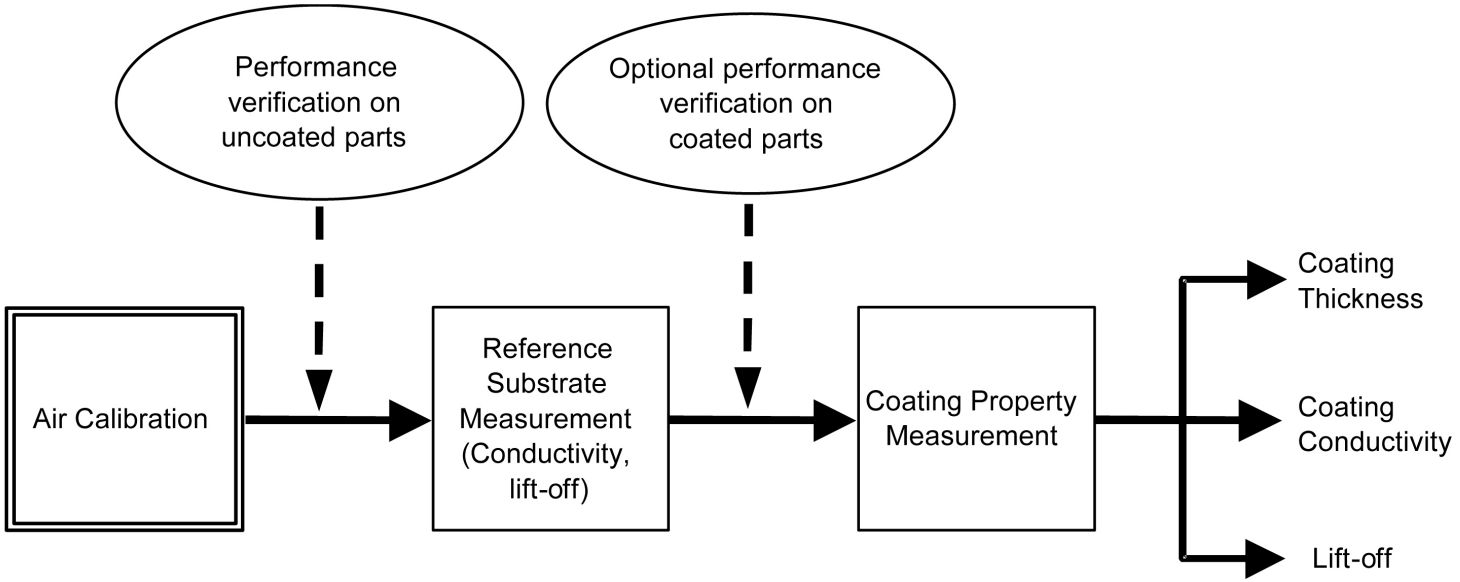
Shunt Tip



Easy to Replace Cartridges:

- Sensor
- Shuttle
- Balloons

ASTM Standard – "Air Calibration"



ASTM INTERNATIONAL

Designation: E 2338 – 04

Standard Practice for Characterization of Coatings Using Conformable Eddy-Current Sensors without Coating Reference Standards[1]

This standard is issued under the fixed designation E 2338; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

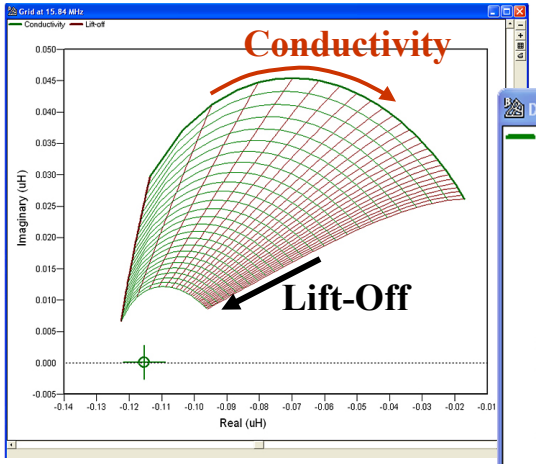
Calibration and Val/Ver for Engine Slots and Bolt Holes

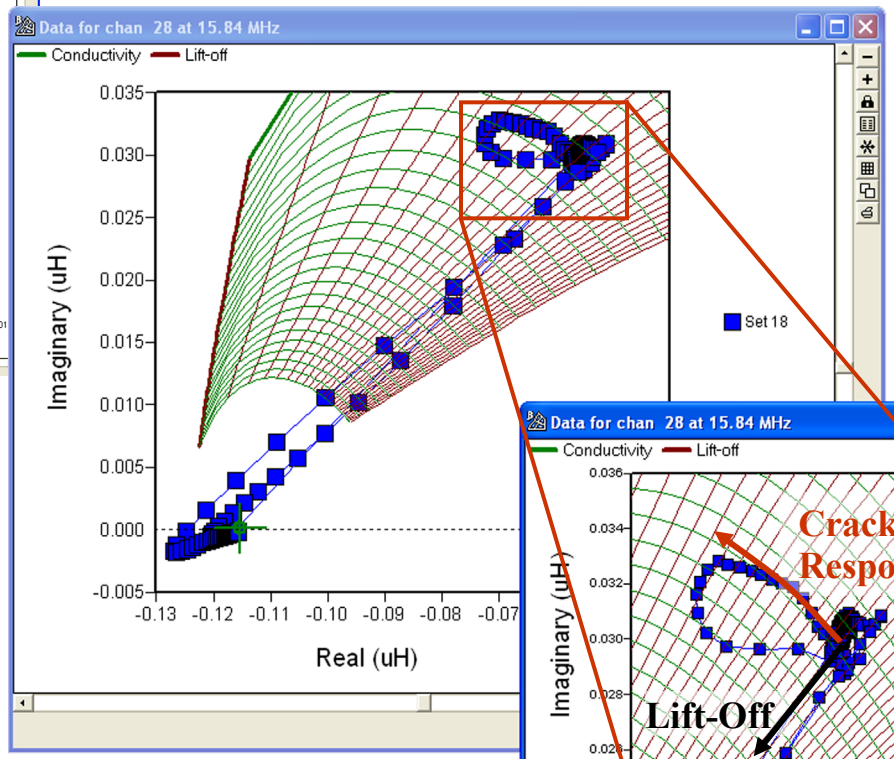
- Calibrate in air
- Verify conductivity and lift-off on engine component
- Verify crack detection performance
- Use statistical process control means to ensure performance

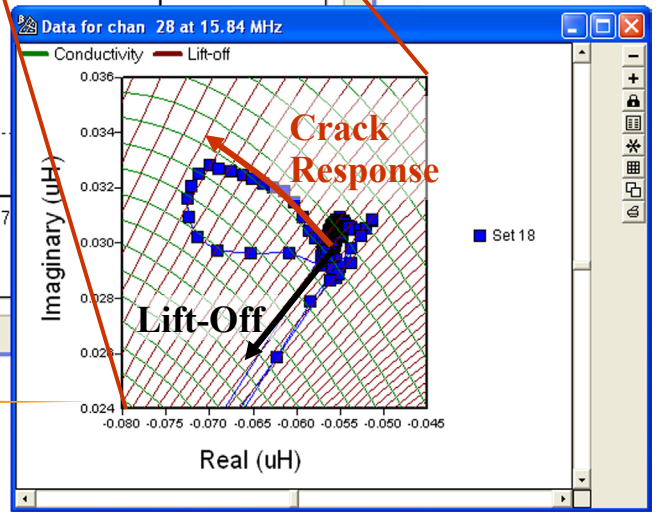
Two-Unknown Inversion Method

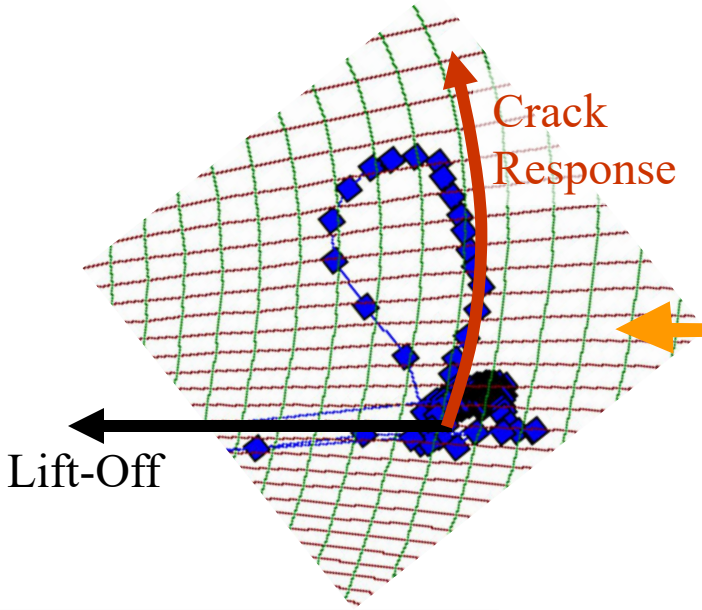
- **Measurement Grids** generated using physics based models of sensor interactions with material under test
- **Rapid table look-up** enables data visualization in real-time during disk scanning
- **100% parallel architecture** instrumentation and reliable **absolute impedance** measurement enable rapid scanning <1 minute per slot
- Absolute measurement of conductivity and lift-off enables **self-diagnostics**

Comparison of Grid Methods with Standard ET Method

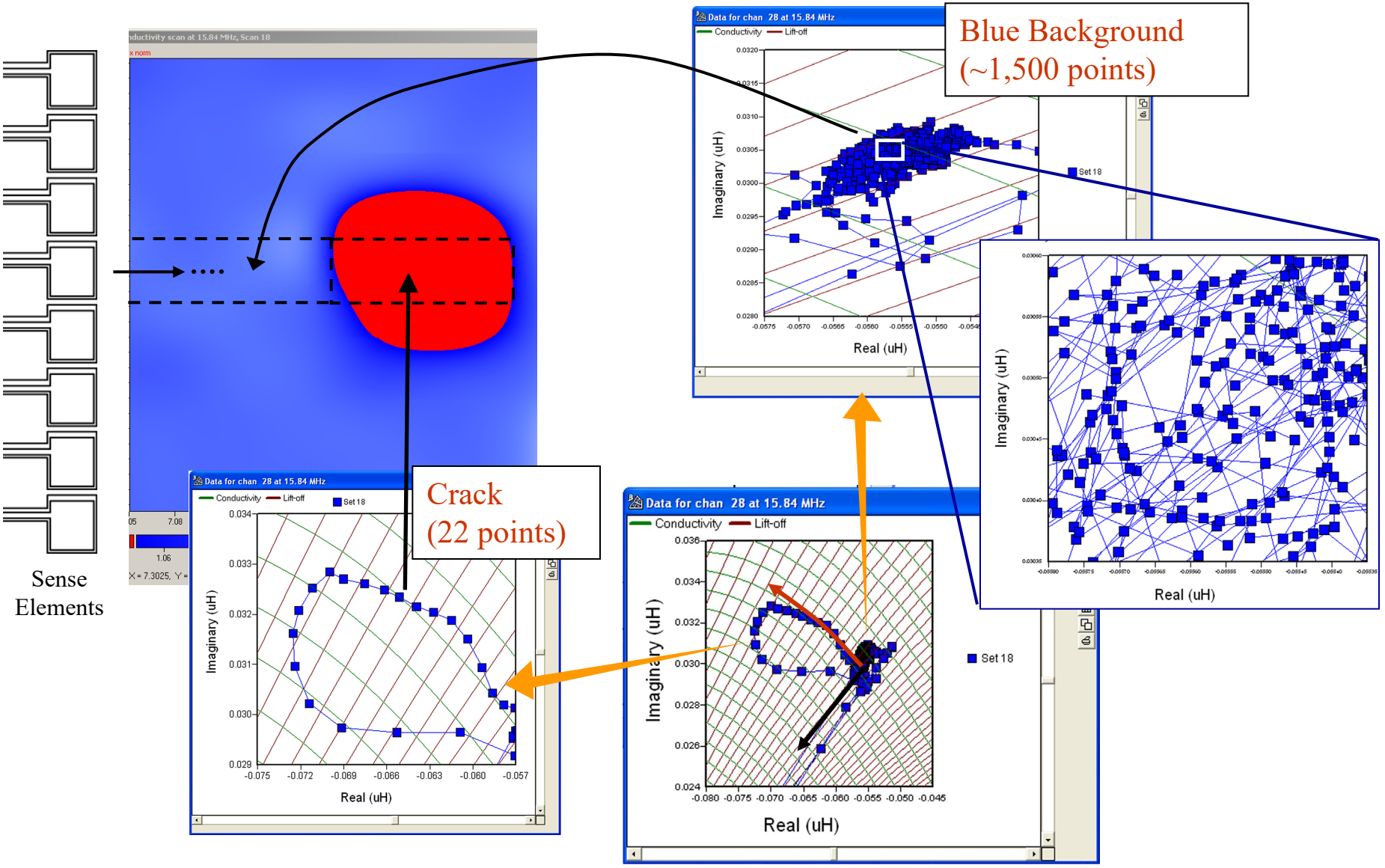








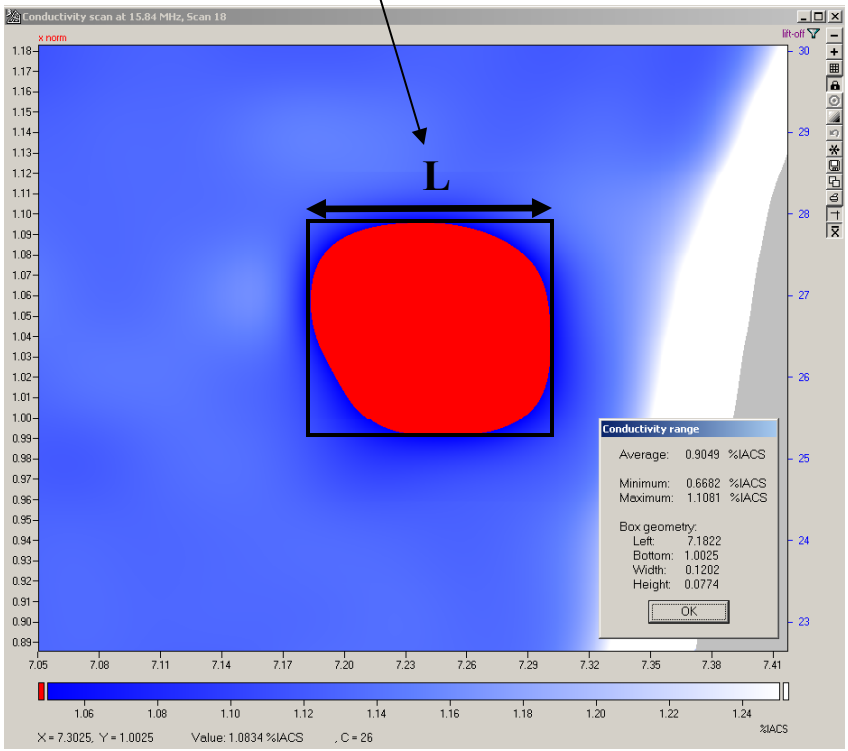
Rapid Data Processing with Grid Methods



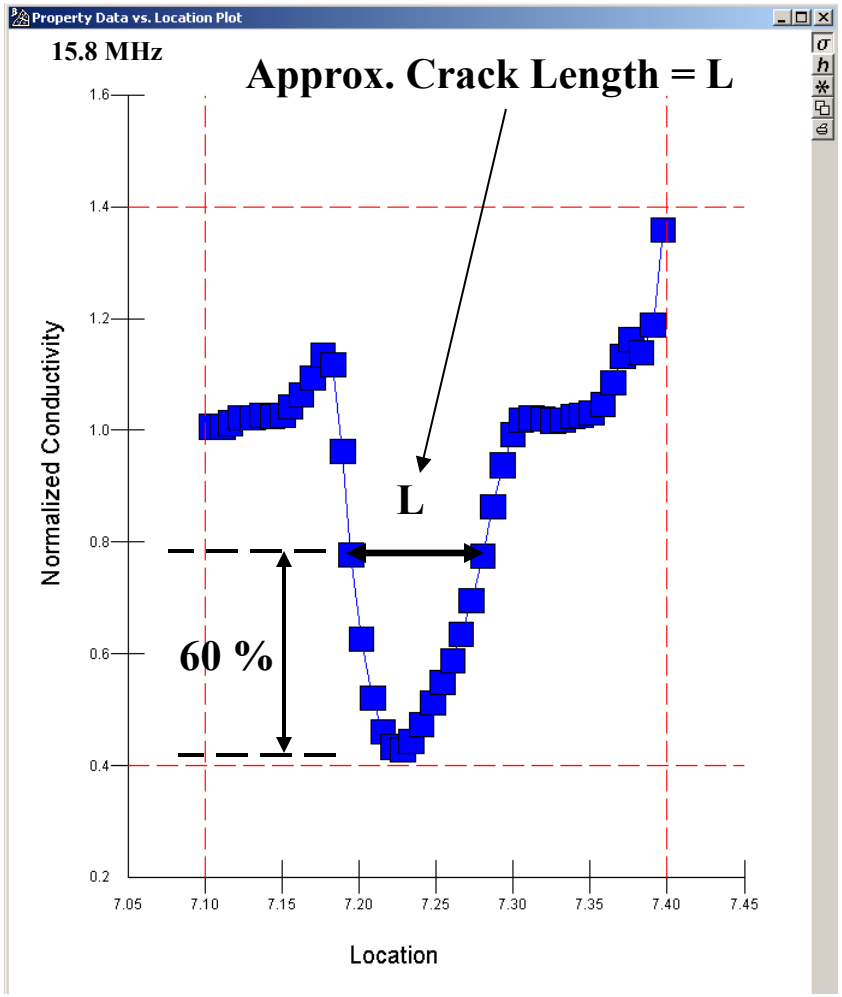
Simple Crack Sizing Methods

C-Scan Method

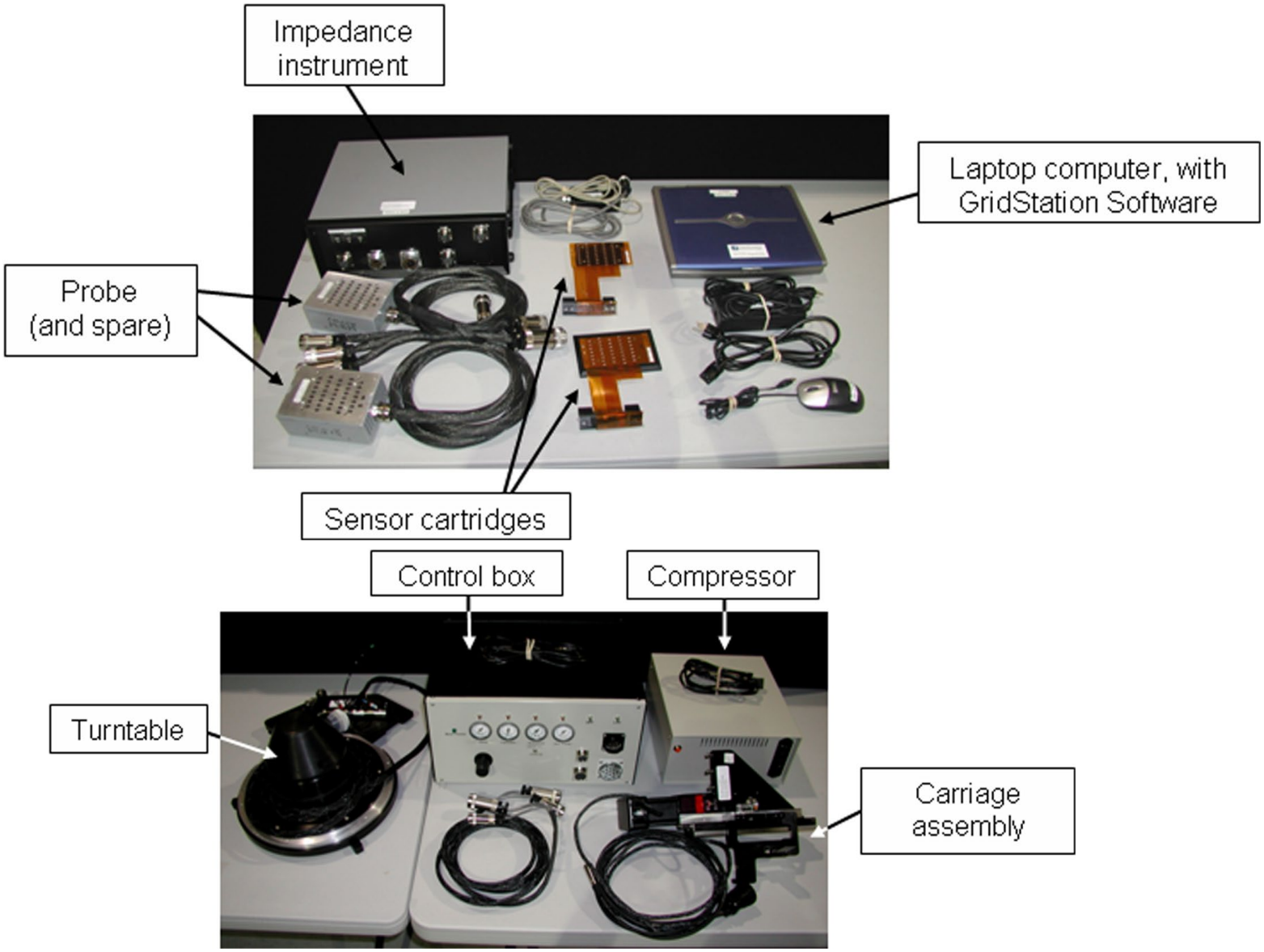
Approx. Crack Length = L × F



B-Scan Method

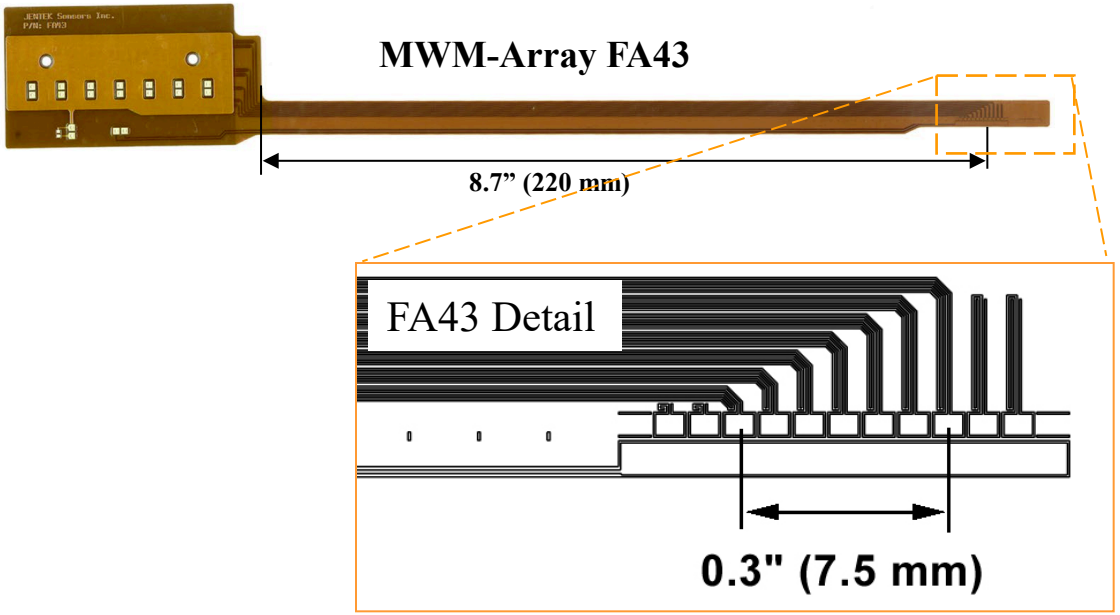


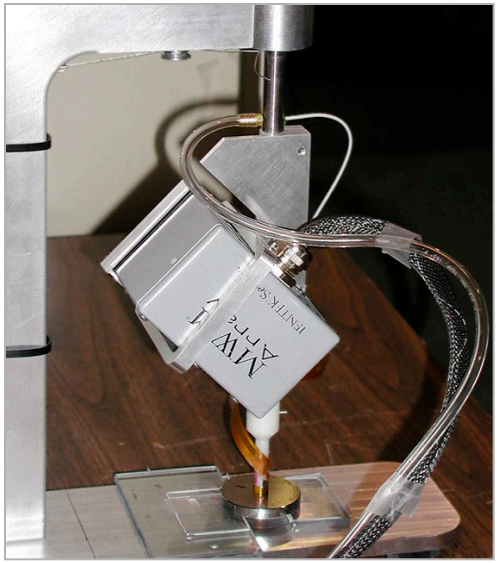
JENTEK Production/Depot GridStation System

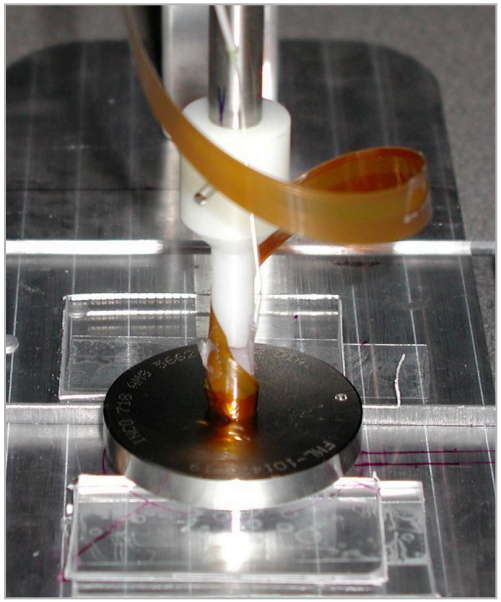


Bolt Hole Inspection

- C-Scan Imaging using MWM-Arrays
- Detection of Cracks at Edges with edge location correction
- Spatial Filtering for Cracks at Edges





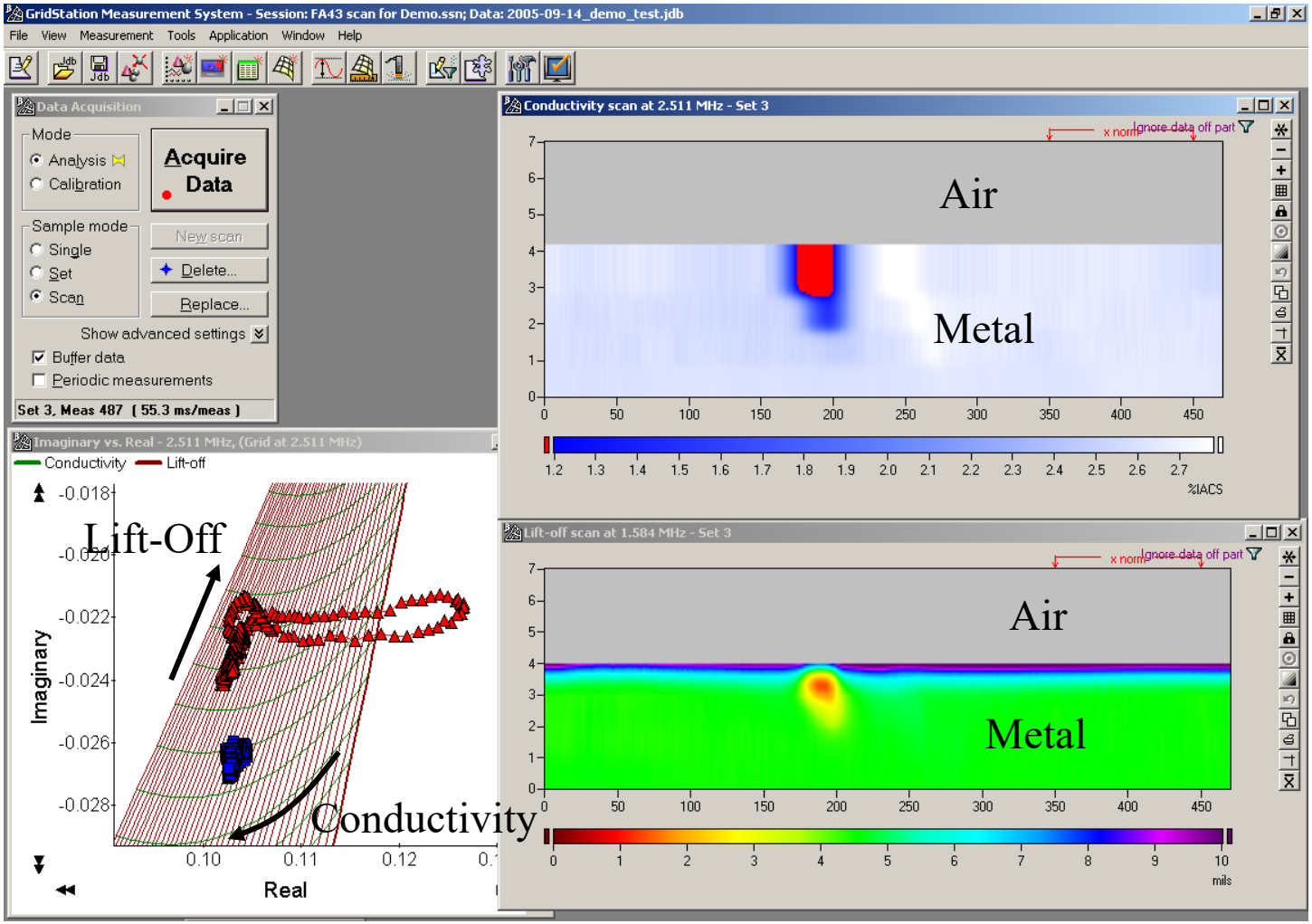


Patents Issued and Pending

Bolt Hole Inspection

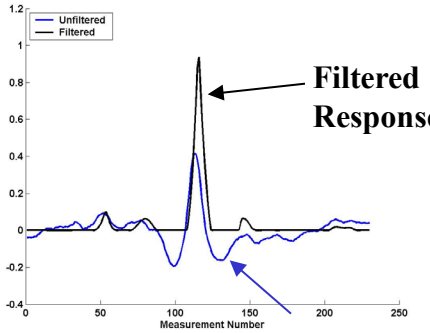
Detection of Cracks at Edges with Edge Location Correction

GridStation Conductivity/Lift-Off Images (Unfiltered)



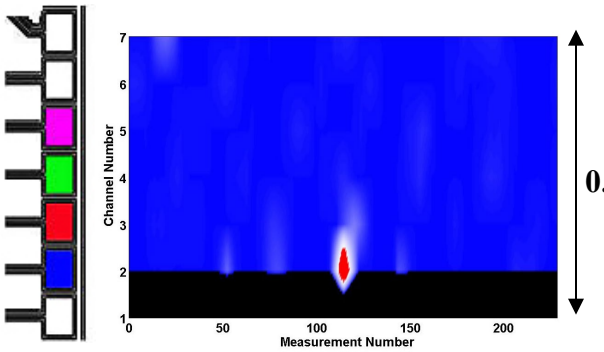
Detection of Cracks at Edges with:

- Edge location correction, and
- Spatial filtering, using signature libraries



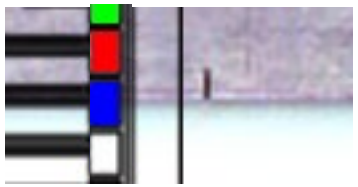
Filtered Response

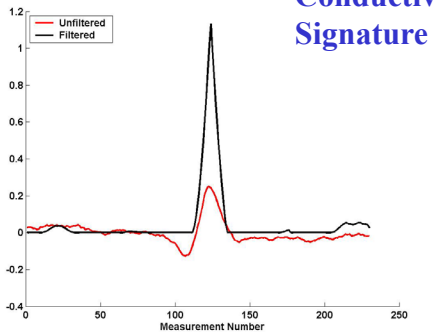
Conductivity Signature

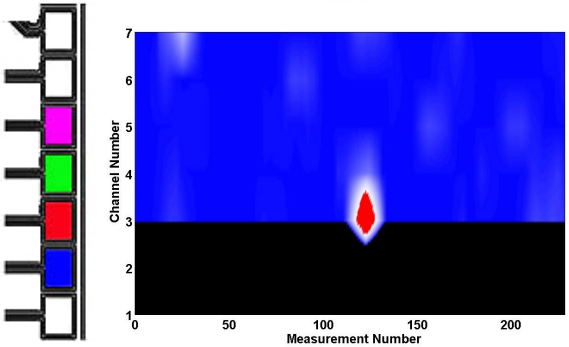


0.30 in.

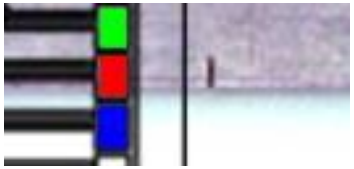
Channel 2, Lift-Off Factor = -0.69

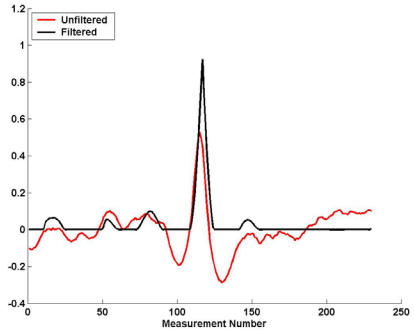


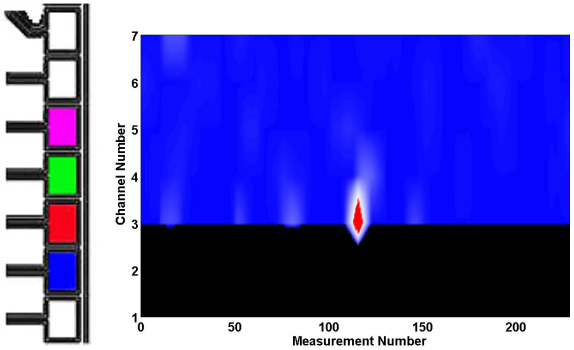




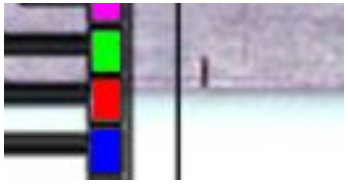
Channel 3, Lift-Off Factor = -0.96



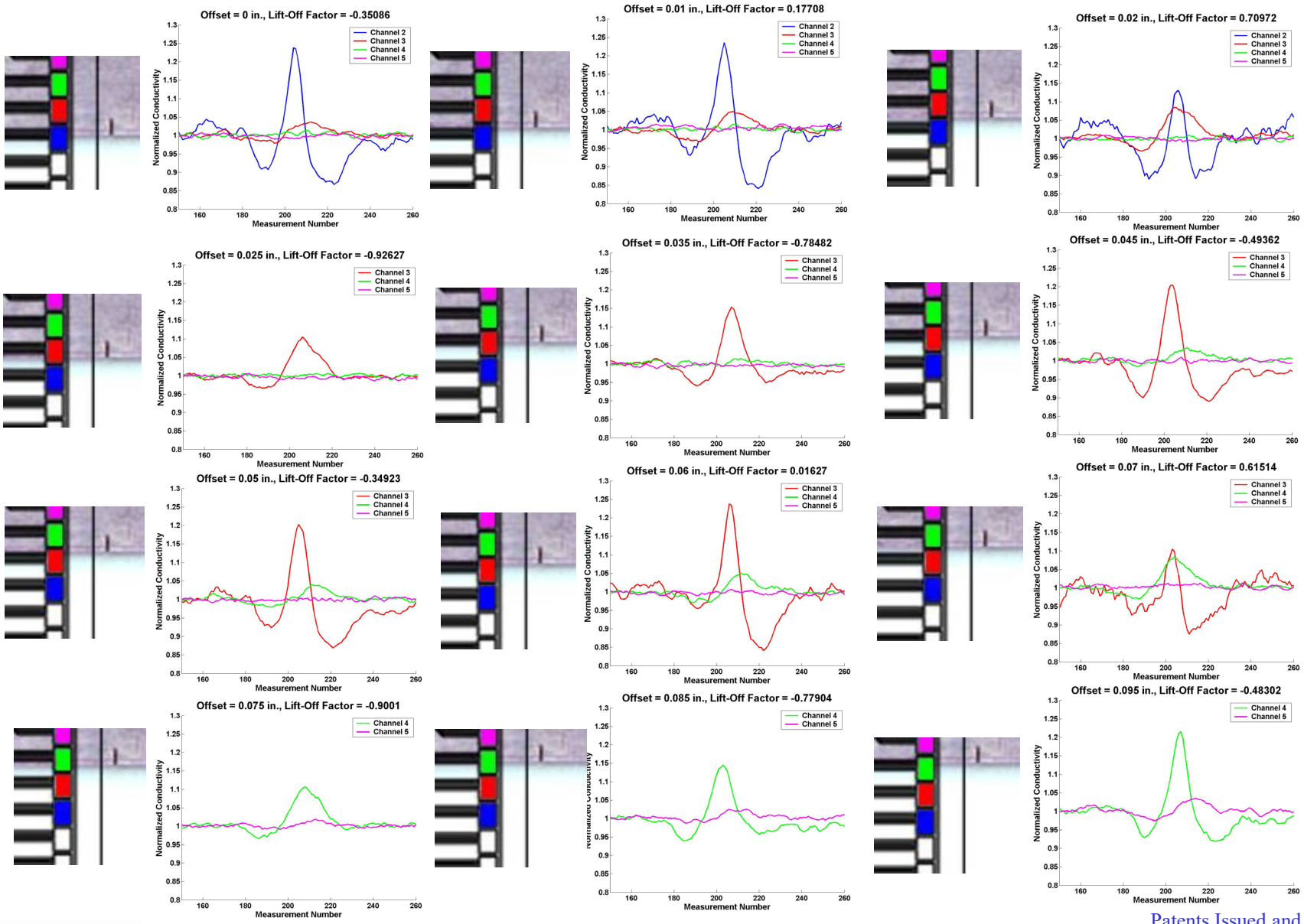




Channel 3, Lift-Off Factor = -0.47



Signature Library



Patents Issued and Pending

Real Crack Specimen Generation

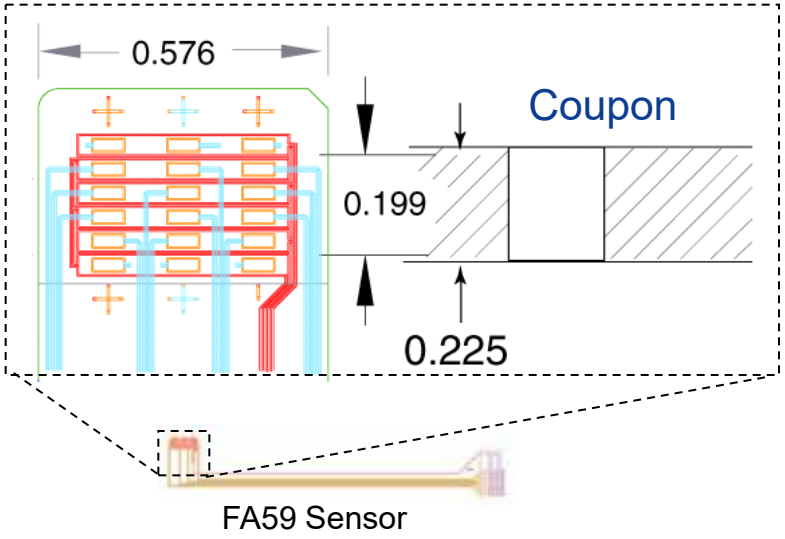
Problem: EDM Notches do not accurately represent cracks – especially in regions with shot peening or fretting damage

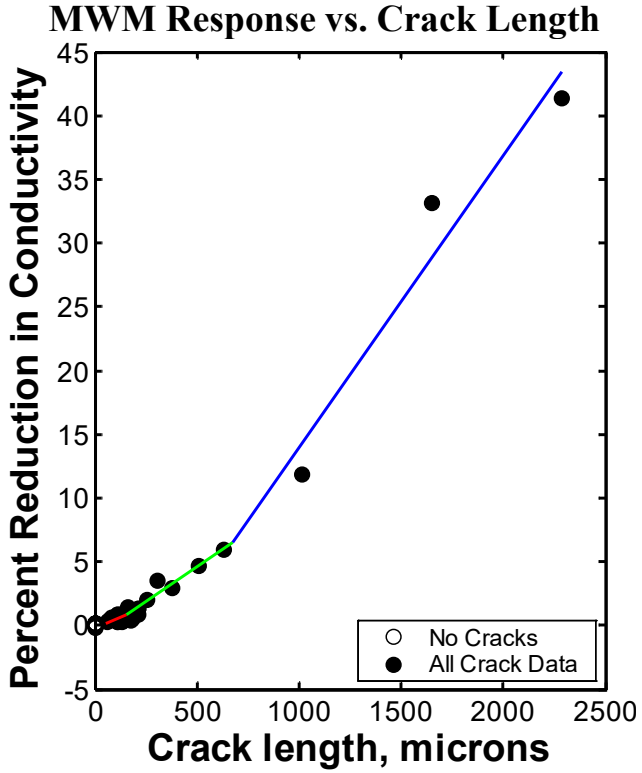
Solutions: (1) use service generated cracks when available

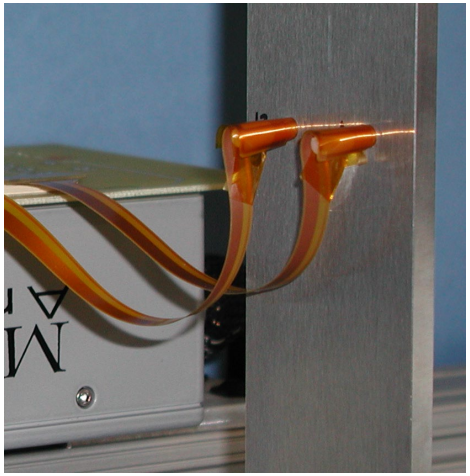
(2) generate real cracks under representative conditions **without starter notches**

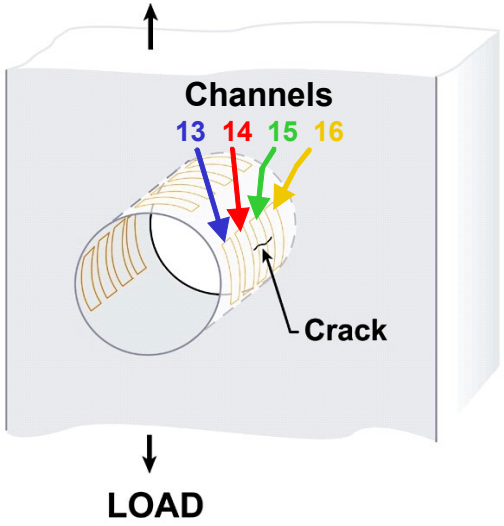
Note use of starter notches to generate fatigue cracks will result in open cracks that are more easily detected

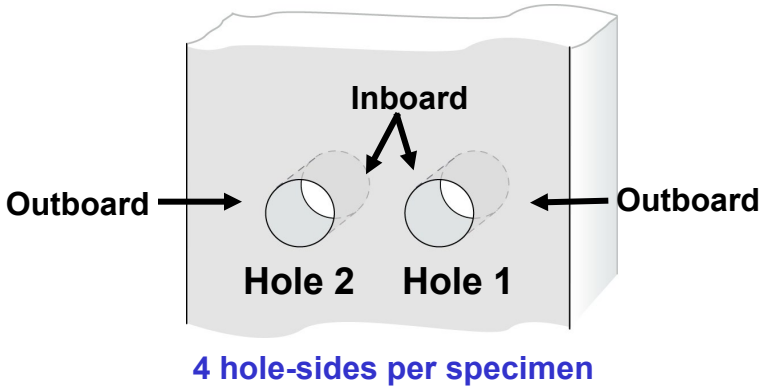
Real Crack Specimen Generation











4 hole-sides per specimen

Hole 2 Outboard

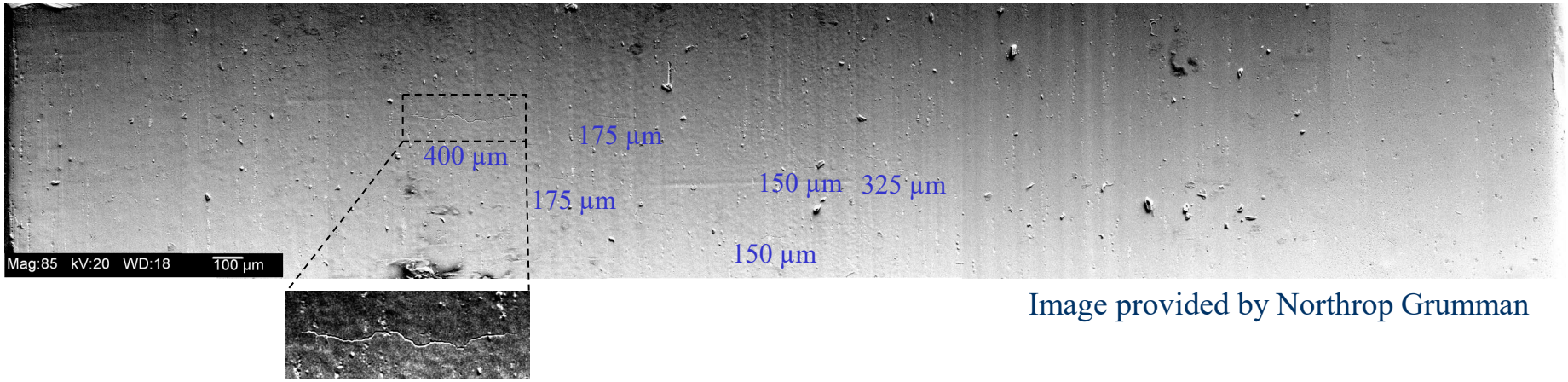
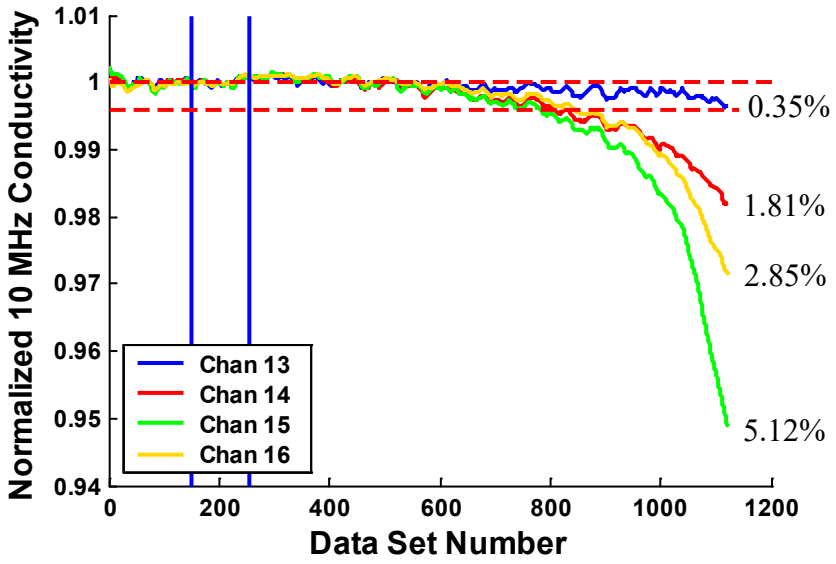
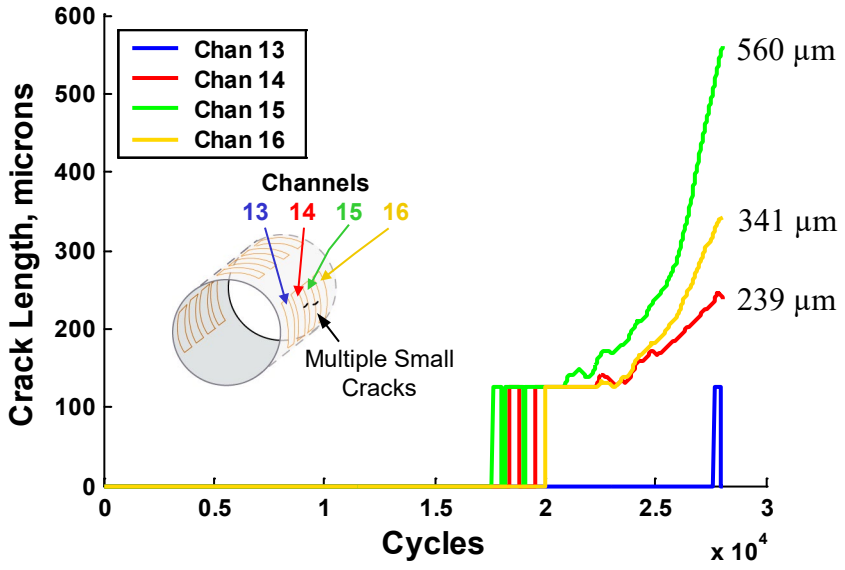


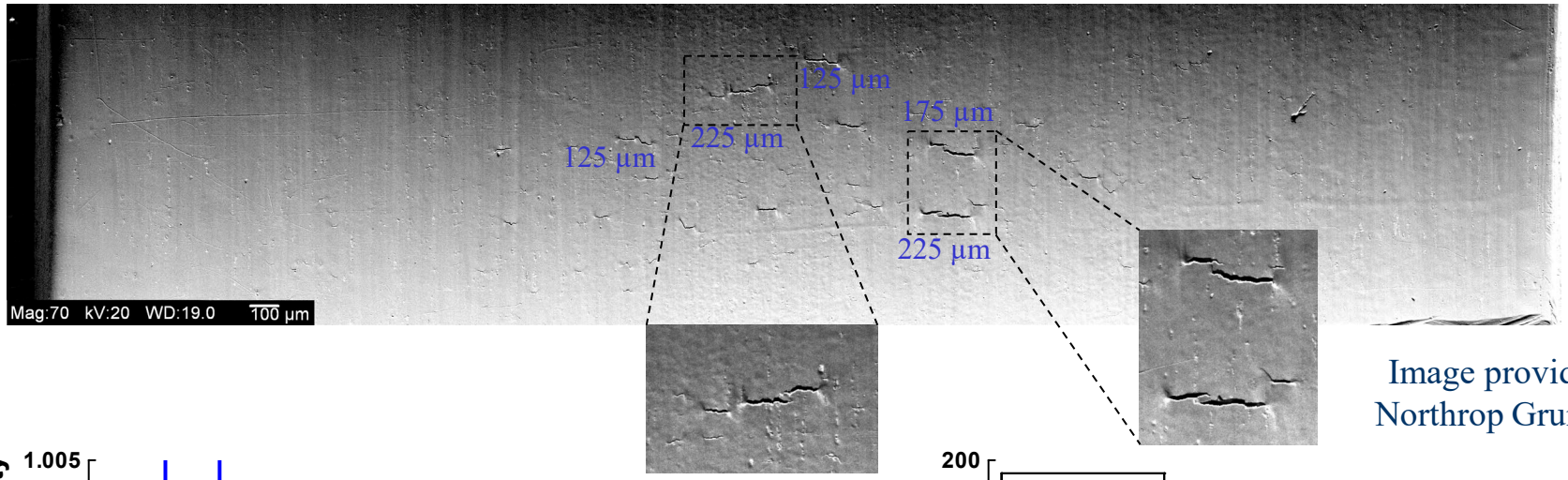
Image provided by Northrop Grumman





125 µm Crack Length, Detection Threshold

Hole 1 Inboard



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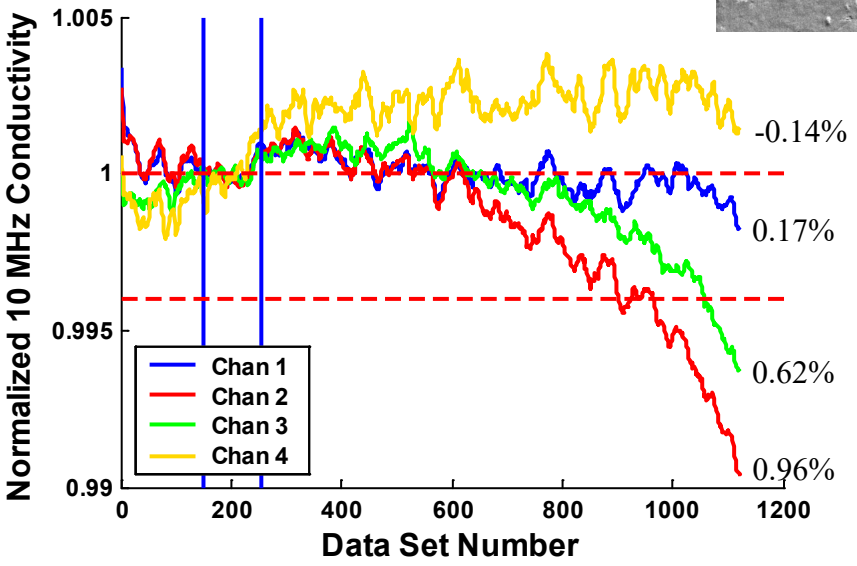

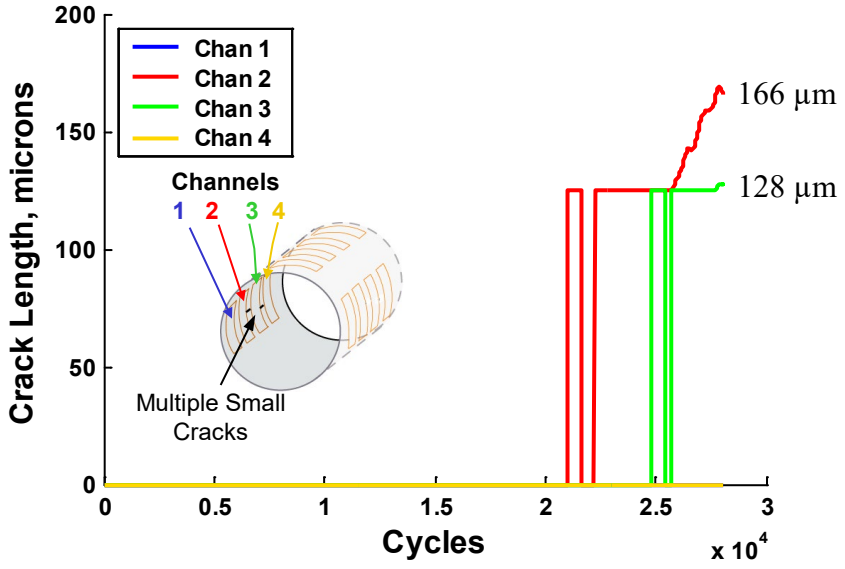

125 µm Crack Length, Detection Threshold

Summary

- MWM-Array Engine Disk Slot Inspection is now in use
- Bolt Hole Inspection is transitioning to use
- Real Crack Specimens have been generated to support testing of both MWM-Array and other NDT methods for POD studies