



Enhancements in MWM-Array Hidden Corrosion Imaging

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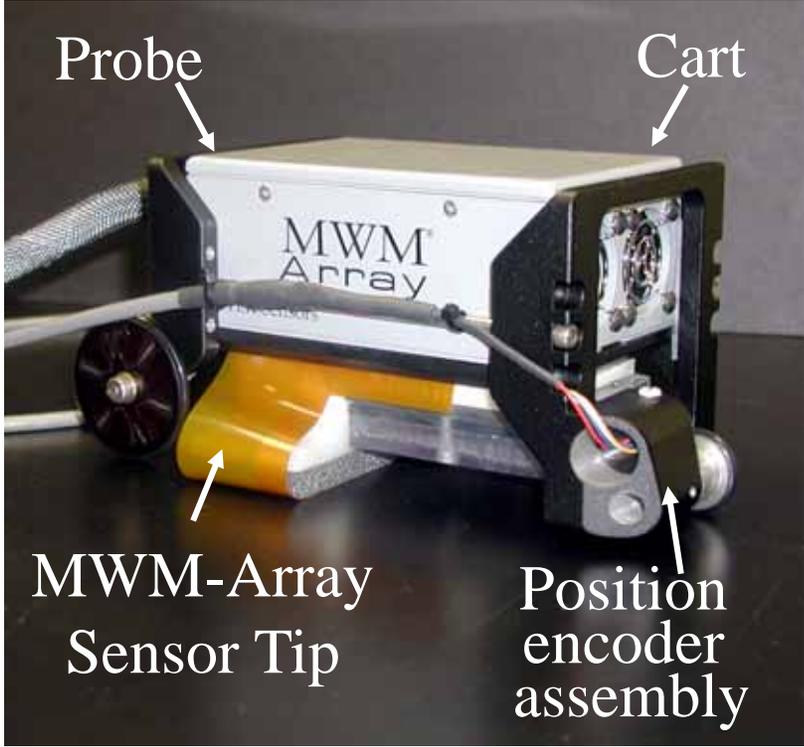
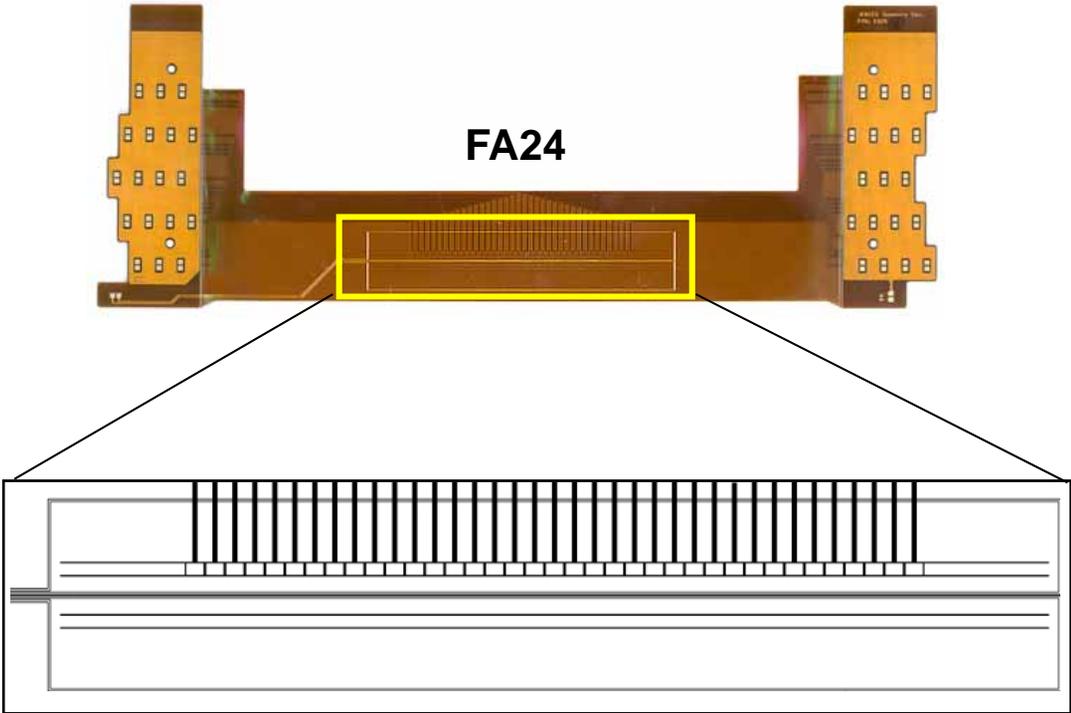
*Work on Hidden Corrosion done under AFRL/MLSA SBIR.

**Work on F-15 done under WR-ALC Funding.

Outline

- MWM-Array Technology
- KC-135 Lap Joint Corrosion
- C-130 Flight Deck Chine Plate
- P-3 Orion Wing Plank
- F-15 Wing Pylon Rib
- Summary of Ongoing NDE, CBM, PHM Programs

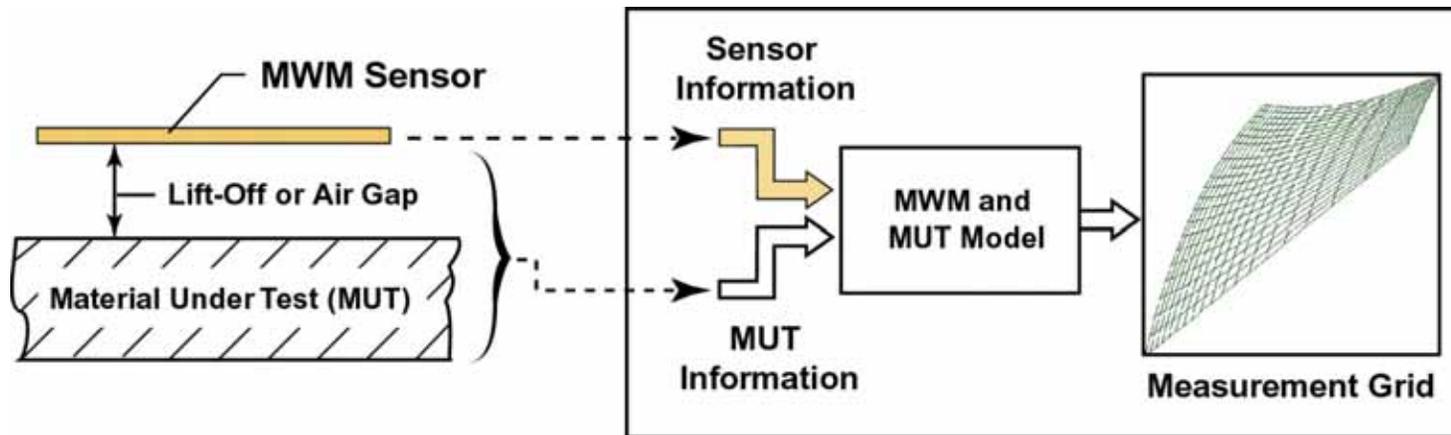
MWM-Array Sensor with Manual Scanning Cart



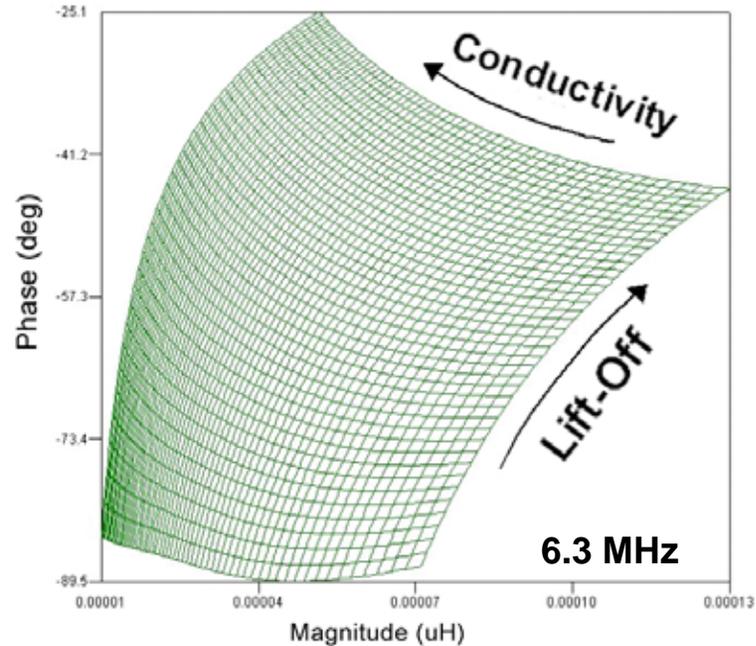
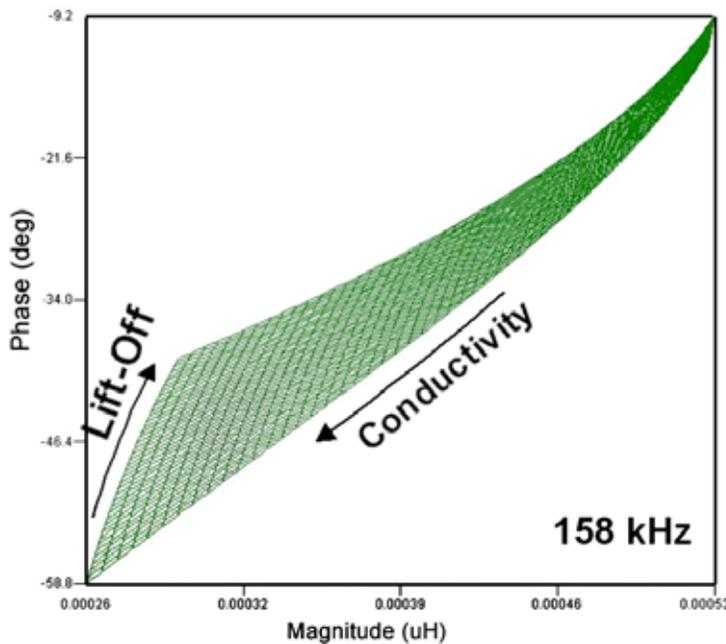
7 Channel MWM-Arrays for Near-Surface Crack Detection



Measurement Grids for **RAPID** Data Analysis/Imaging

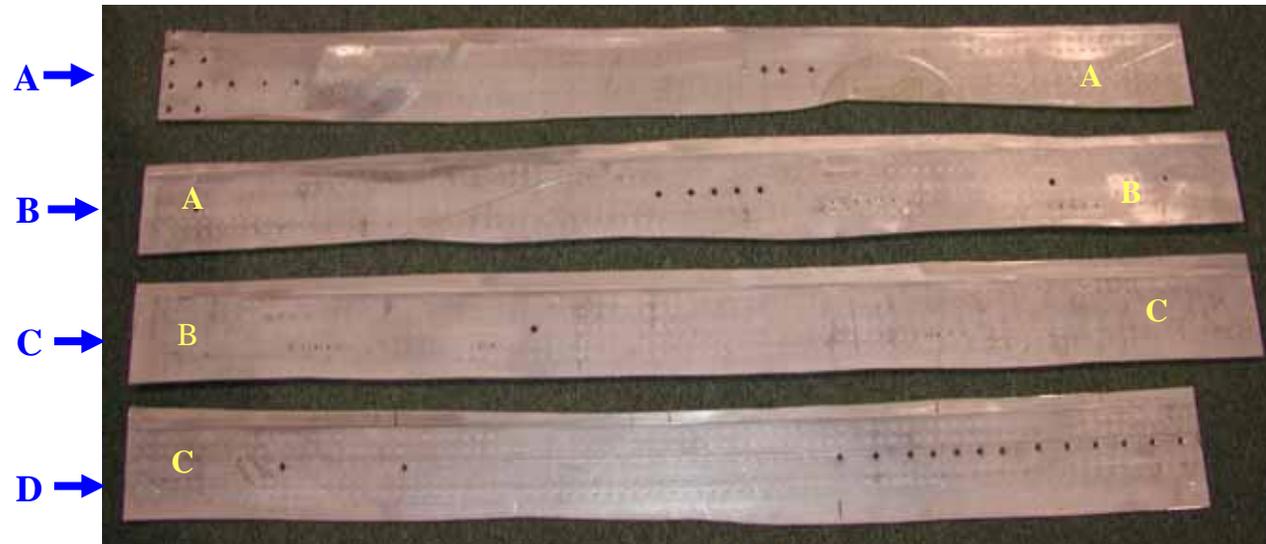


Example Grids for the MWM sensor on Titanium



Actual KC-135 Lap Joints Cut-Out from Aircraft

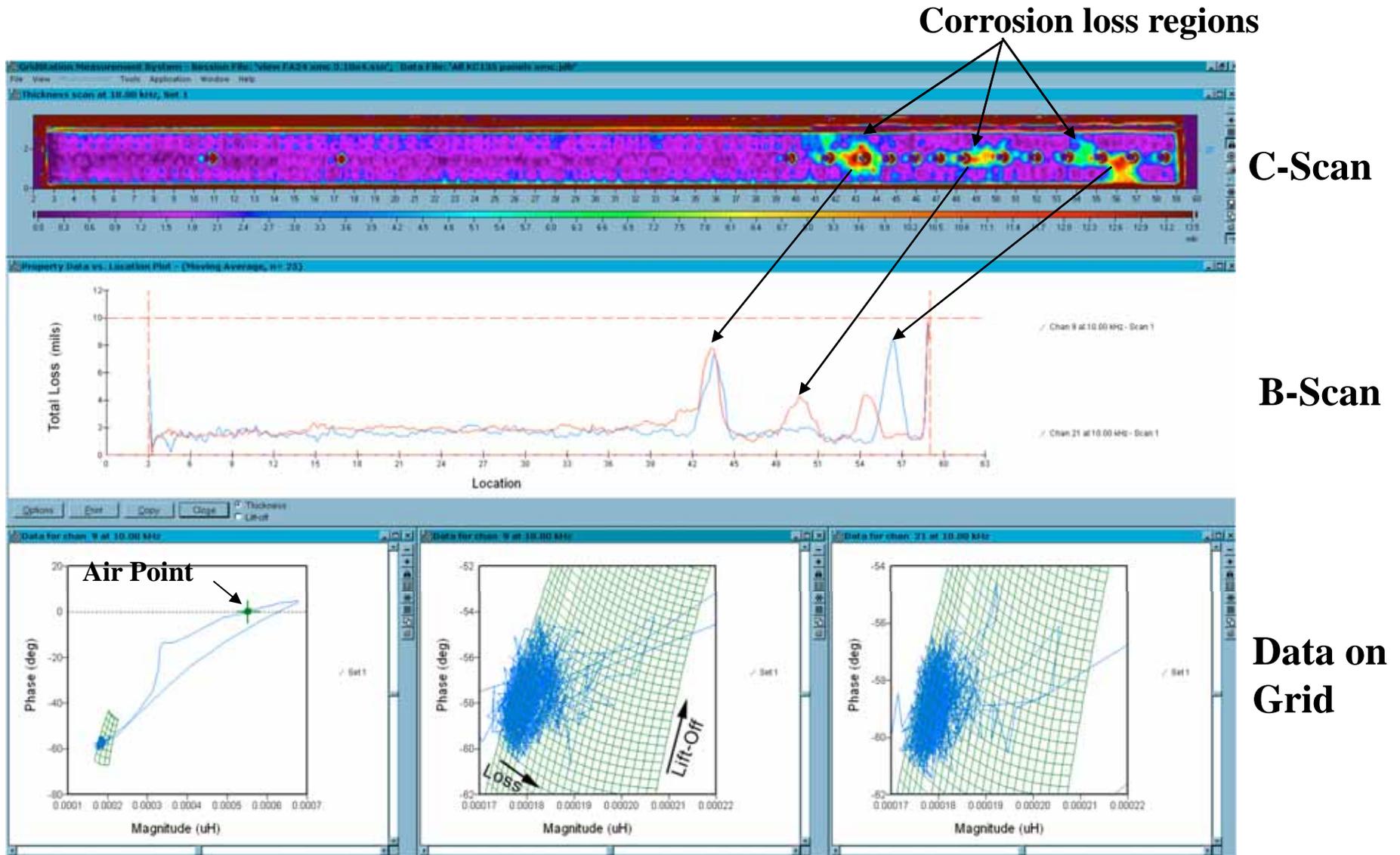
KC135_4
(A,B,C,D)
top view



KC135_4
(A,B,C,D)
bottom view



Example GridStation Software Display



MWM-Array Advantages

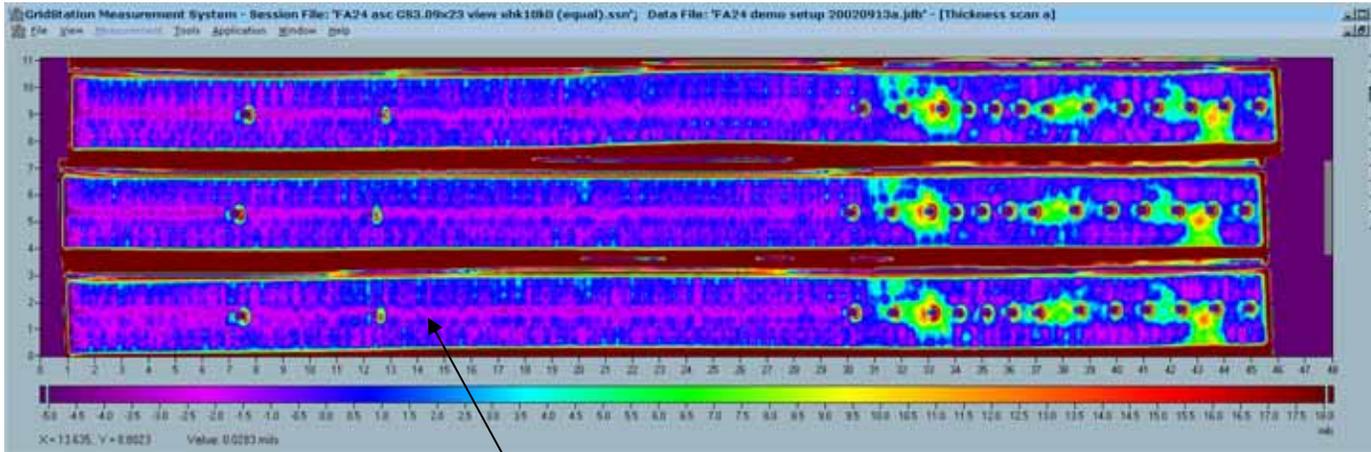
Problem:

- Inspect KC-135 lap joint for hidden corrosion
 - Length > 200”
 - Correct for Gap, Alclad and Skin Conductivity & Lift-Off (paint)

MWM-Array Solution:

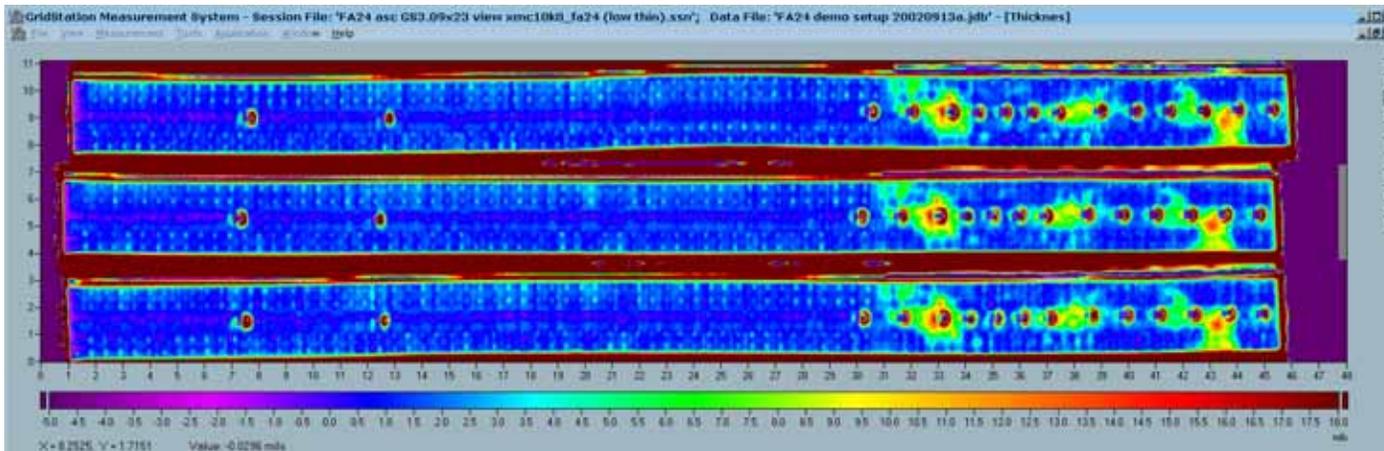
- 2 Unknowns
 - Air Calibration (10 min. setup for 1st lap joint; no setup for 2nd lap joint)
 - < 30 seconds scan time
 - < Few seconds processing time
- 3 Unknowns
 - Air Calibration
 - < 3 minutes scan time
 - ~ 10 minutes processing
- 4 Unknowns
 - Local scanning
 - Gap standards required

2-Unknown Image Assuming Equal Loss



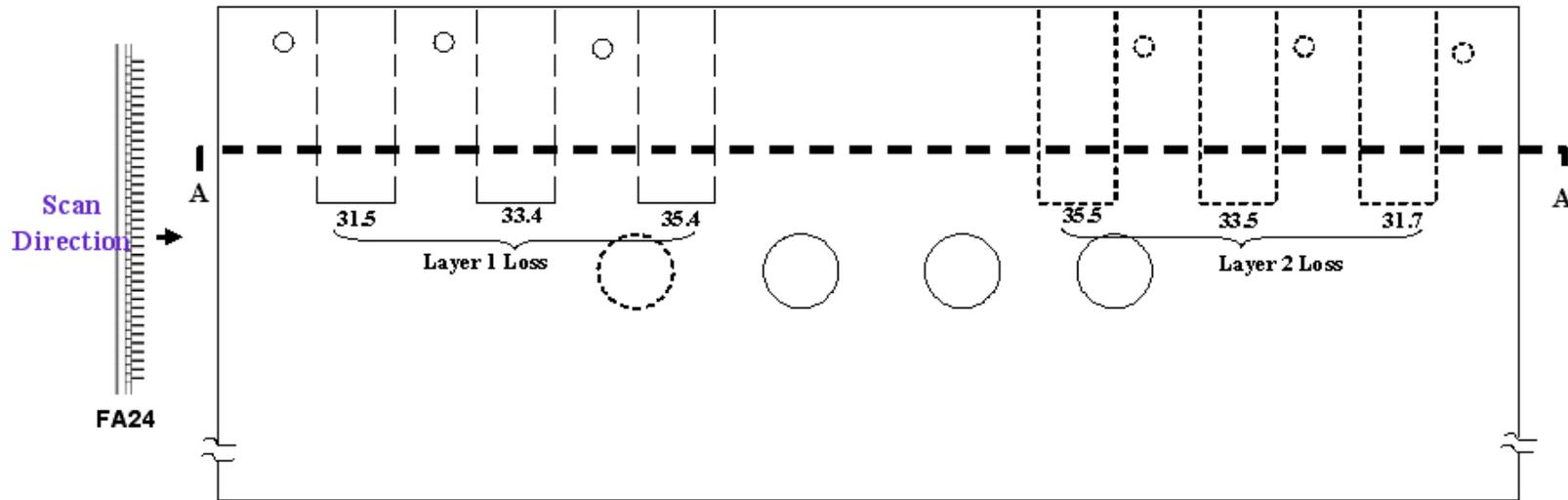
Negative loss shown in pink

Without Alclad in Model

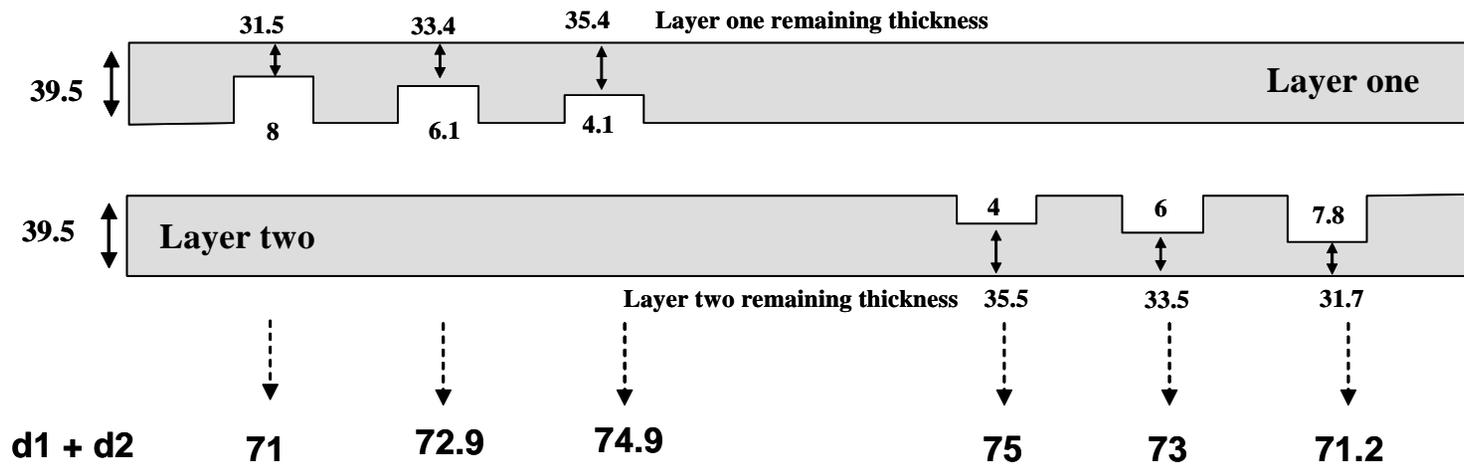


With Alclad in Model

Air Force Material Loss Calibration Standard as Configured for MWM-Array Demonstrations

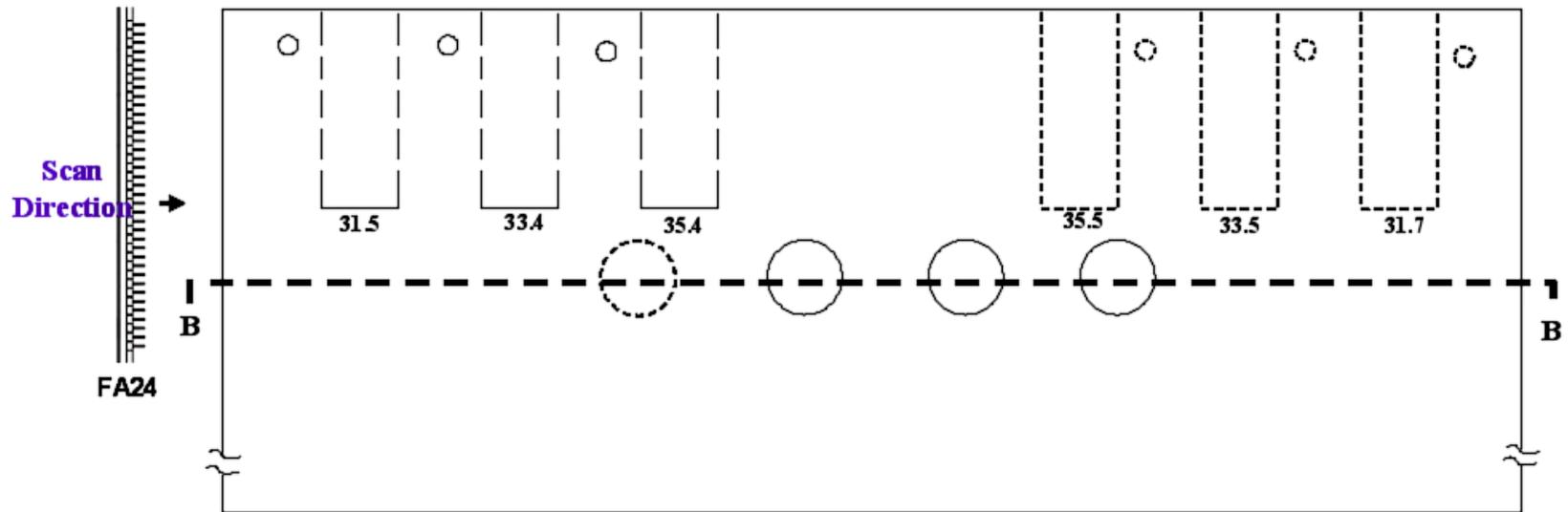


A-A Cross Section

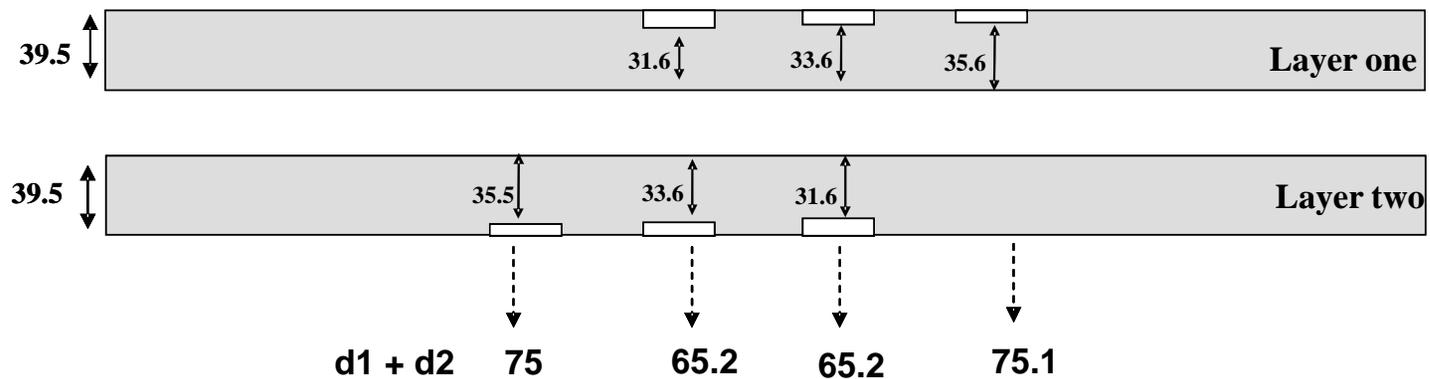


Dimensions in Mils (1 mil = 0.001 in.)

Air Force Material Loss Calibration Standard as Configured for MWM-Array Demonstrations



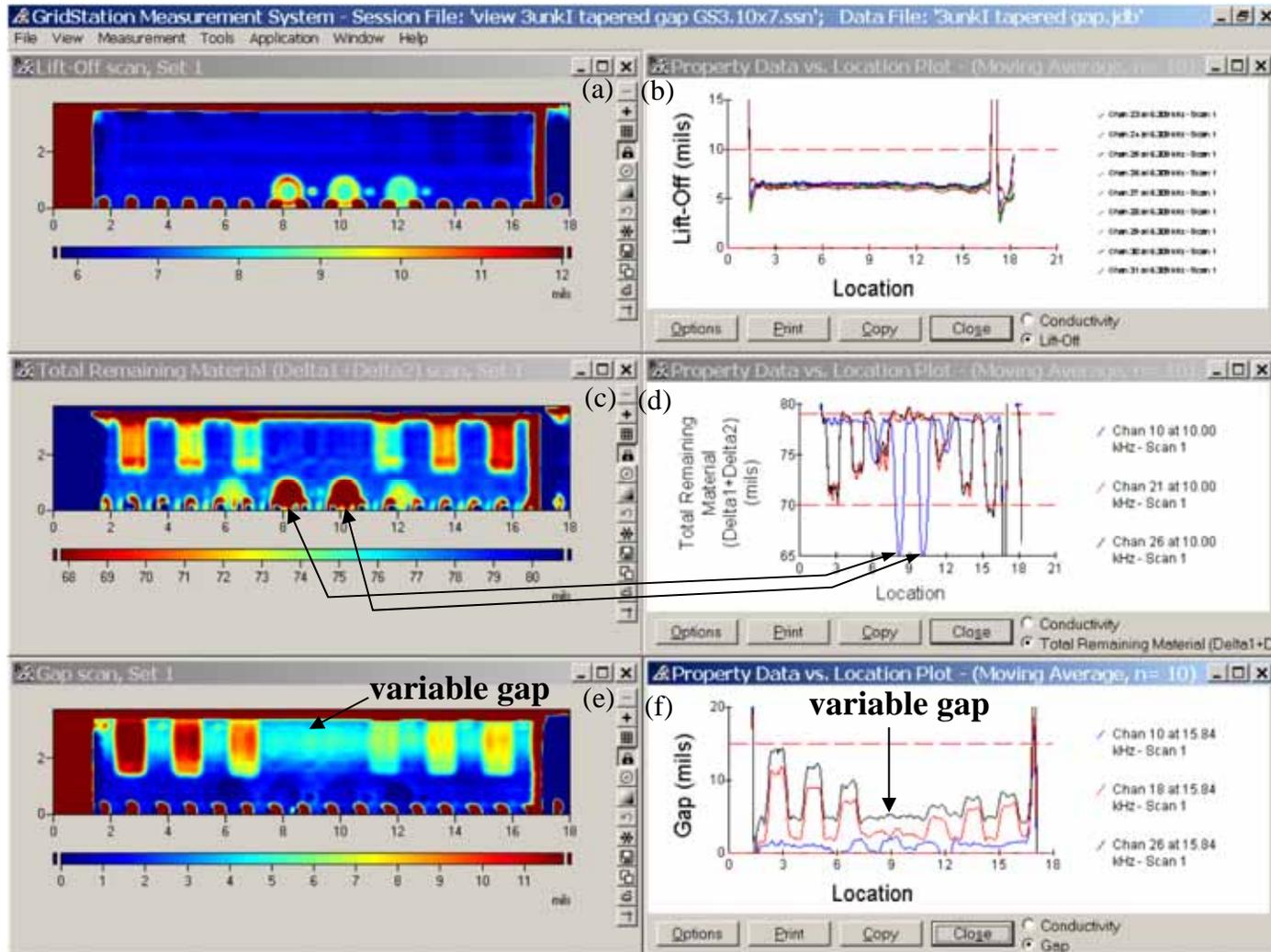
B-B Cross Section



Dimensions in Mils (1 mil = 0.001 in.)

3-Unknown Method Results for MWM-Array Scan of KC-135 Reference Calibration Standard Panels

With 0.005 in. nominal gap across top 1 in. of entire sample length

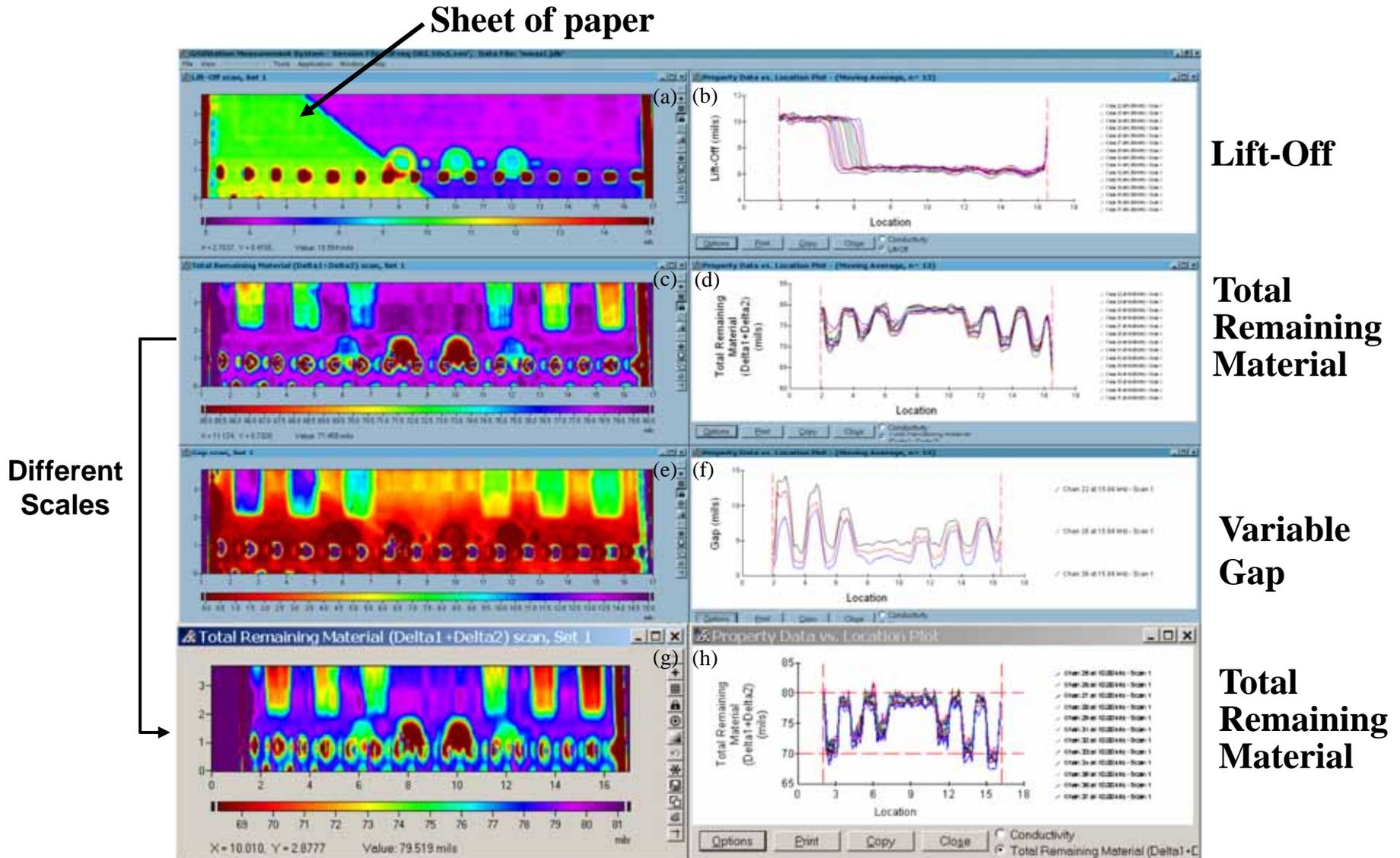


Lift-Off

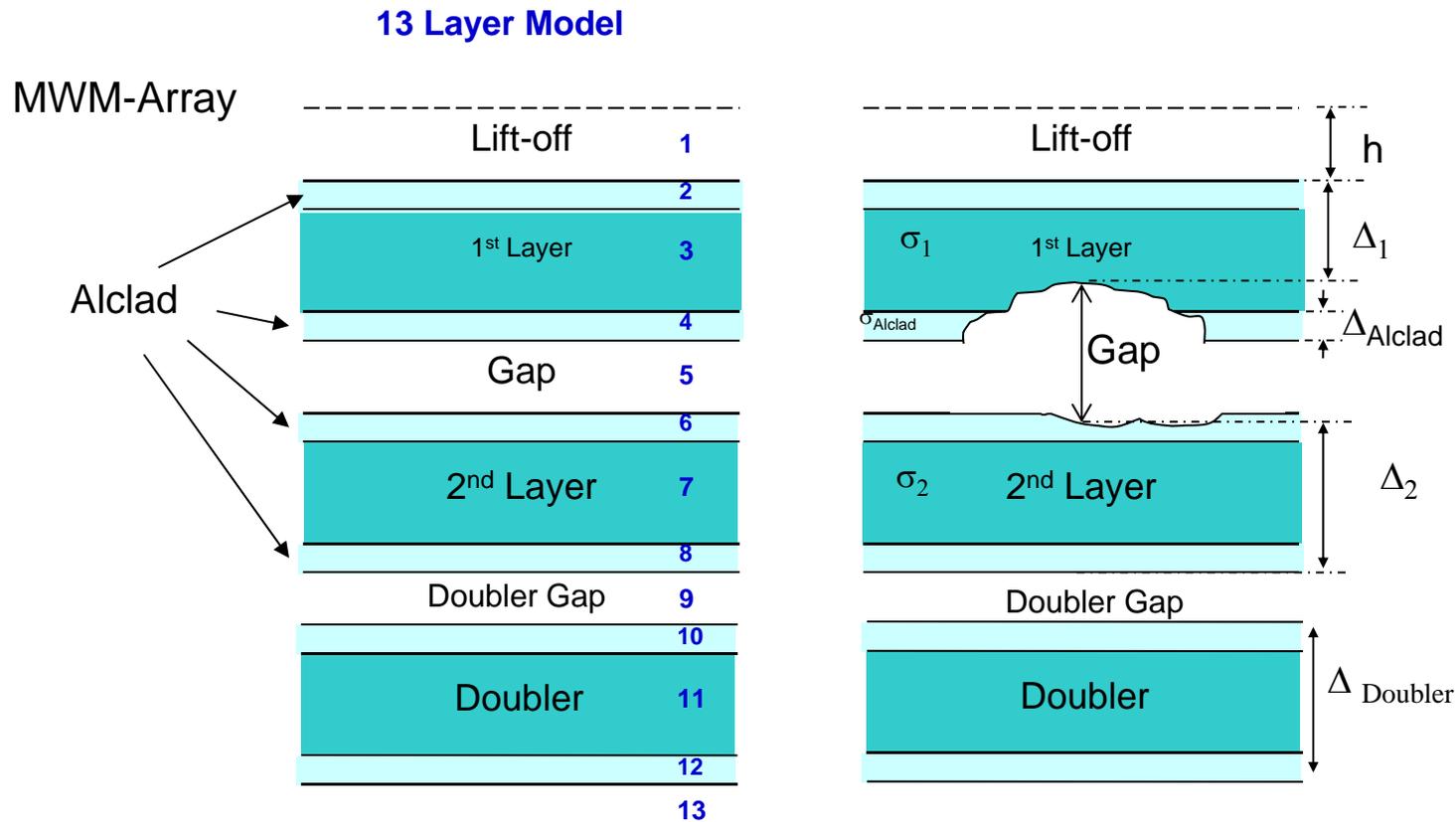
Total Remaining Material

Variable Gap

Variable Lift-Off (e.g. Paint) and Variable Gap



Schematic of 13 Layered Model with Doubler Included for MWM-Array Hypercube Generation



Knowns

$\sigma_1, \sigma_2, \sigma_{Alclad}, \Delta_{Alclad}, \Delta_{Doubler}, \text{Doubler Gap (Approximately only)}$

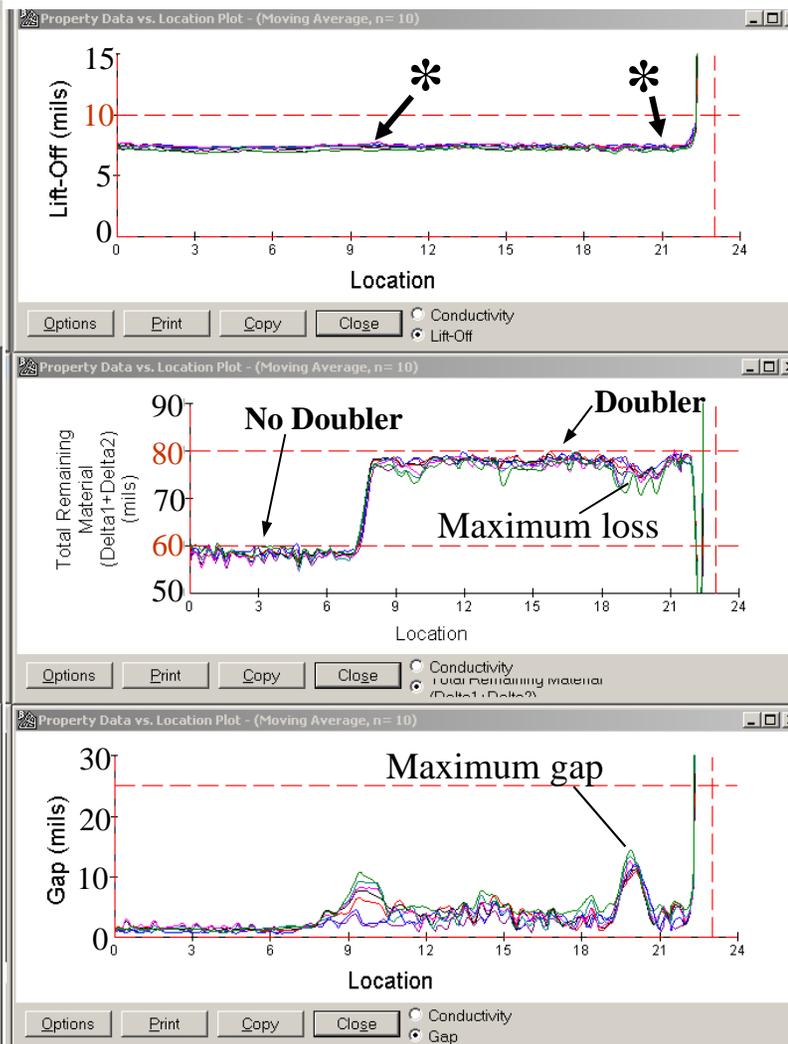
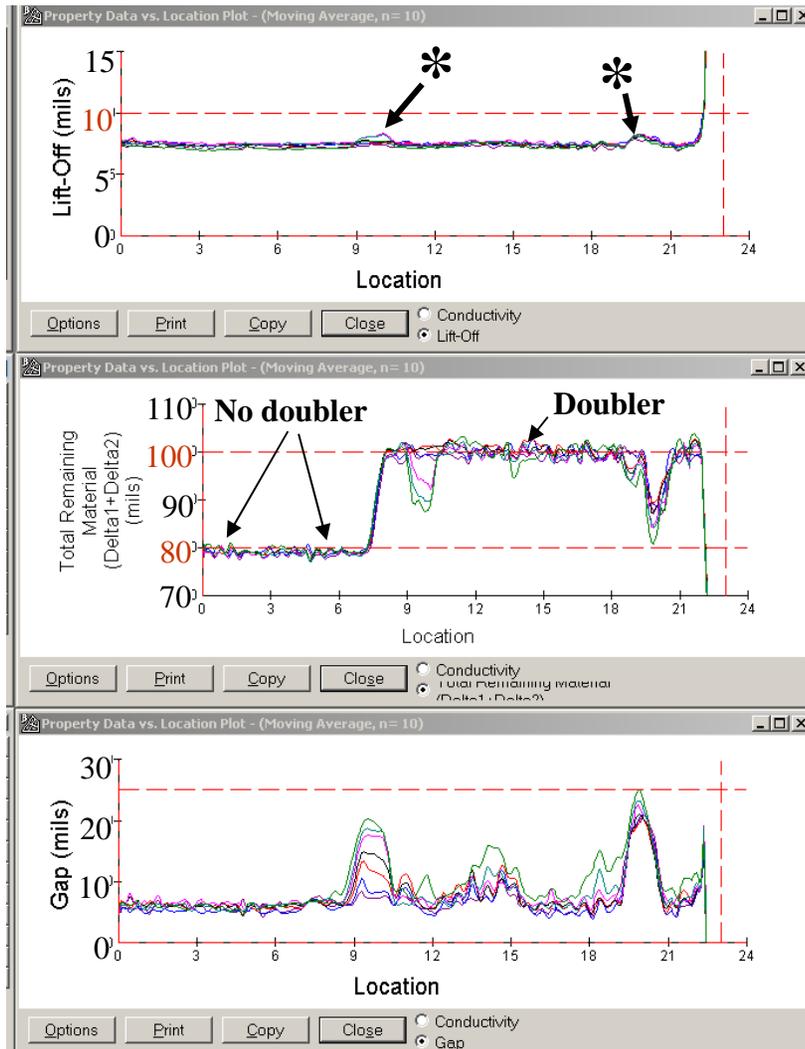
Unknowns

$h, \Delta_1, \Delta_2, \text{Gap}$

3-Unknown Results for Cut-Out Lap Joint

Without Doubler
Included in Model

With Doubler Correction

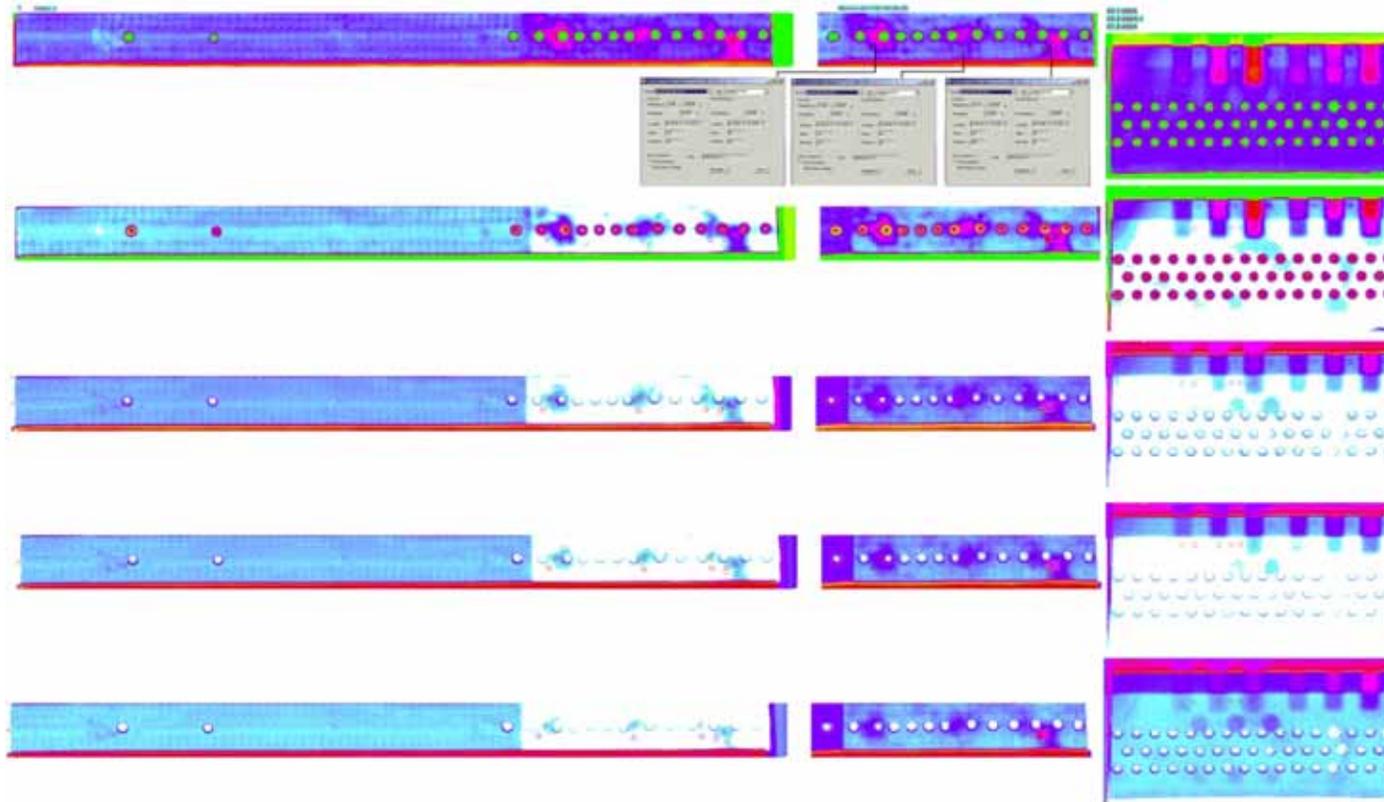


Lift-Off

Total Remaining Material

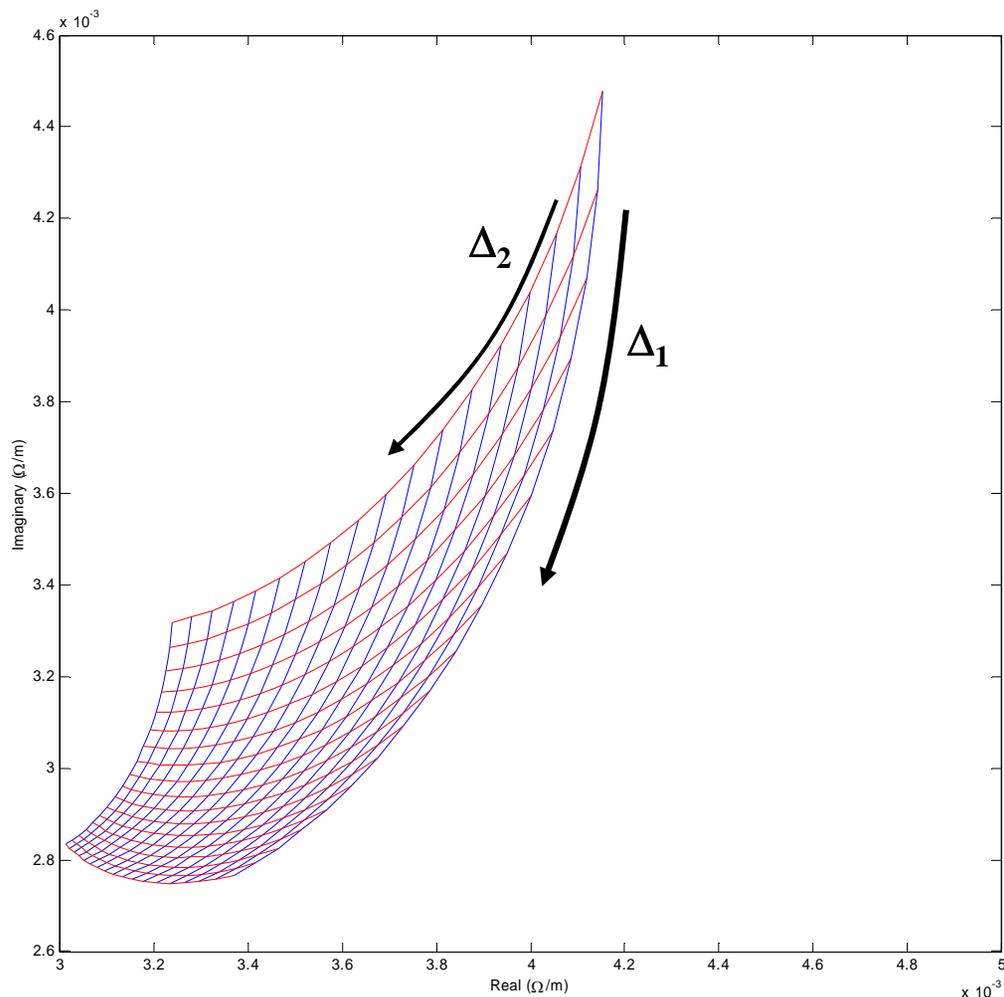
Gap

MAUS Data Displaying Gap Correction Reducing the Estimated Loss Level in the MAUS Data

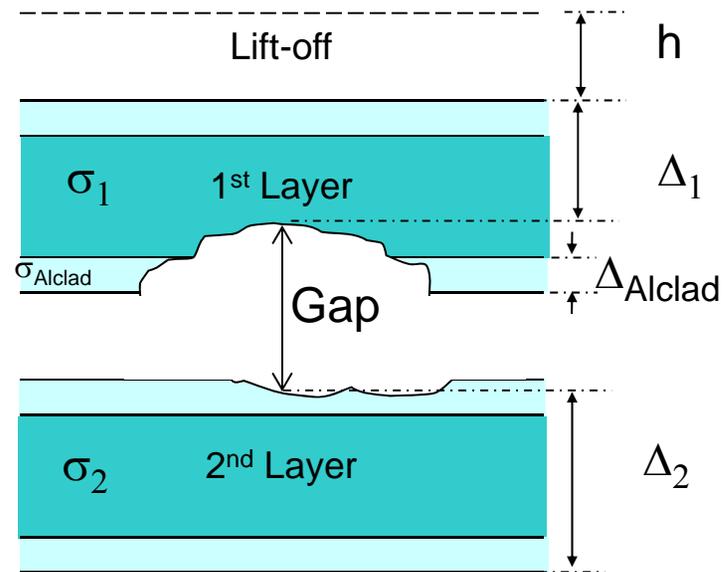


MAUS data for same region as MWM-Array data in previous slide.

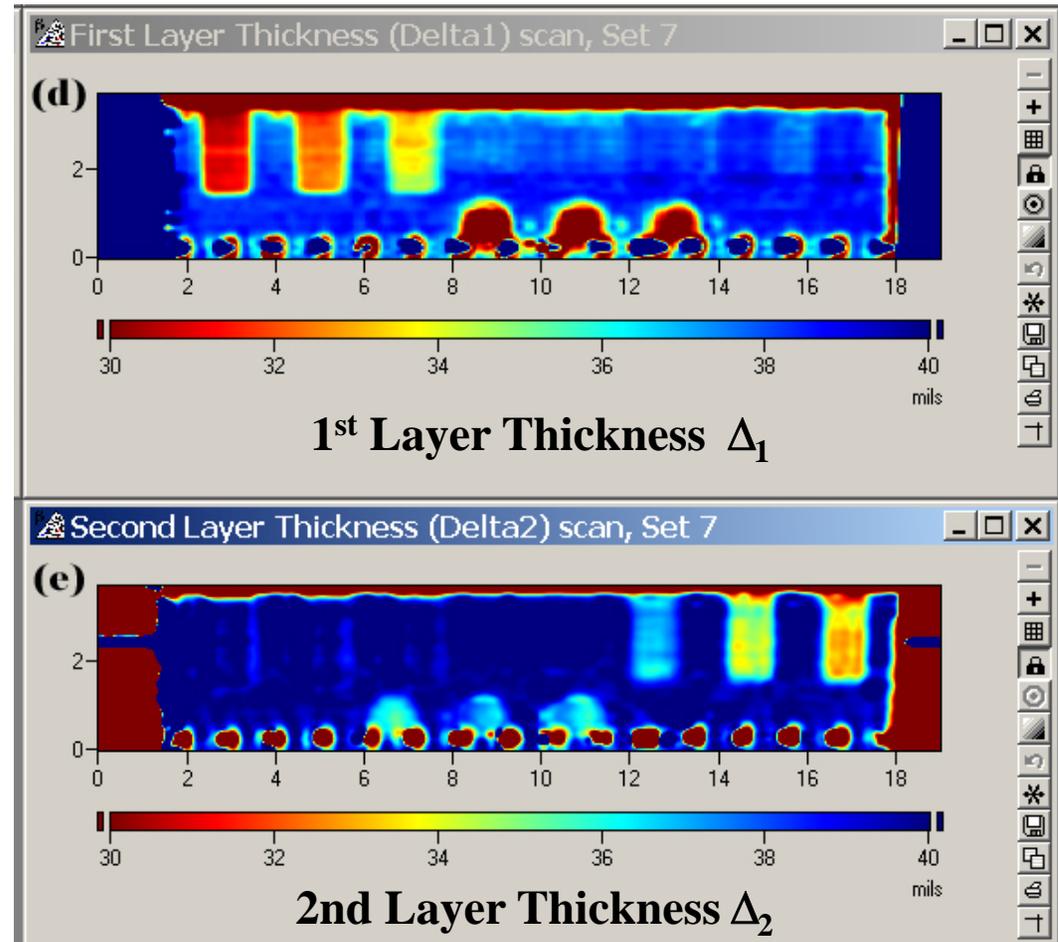
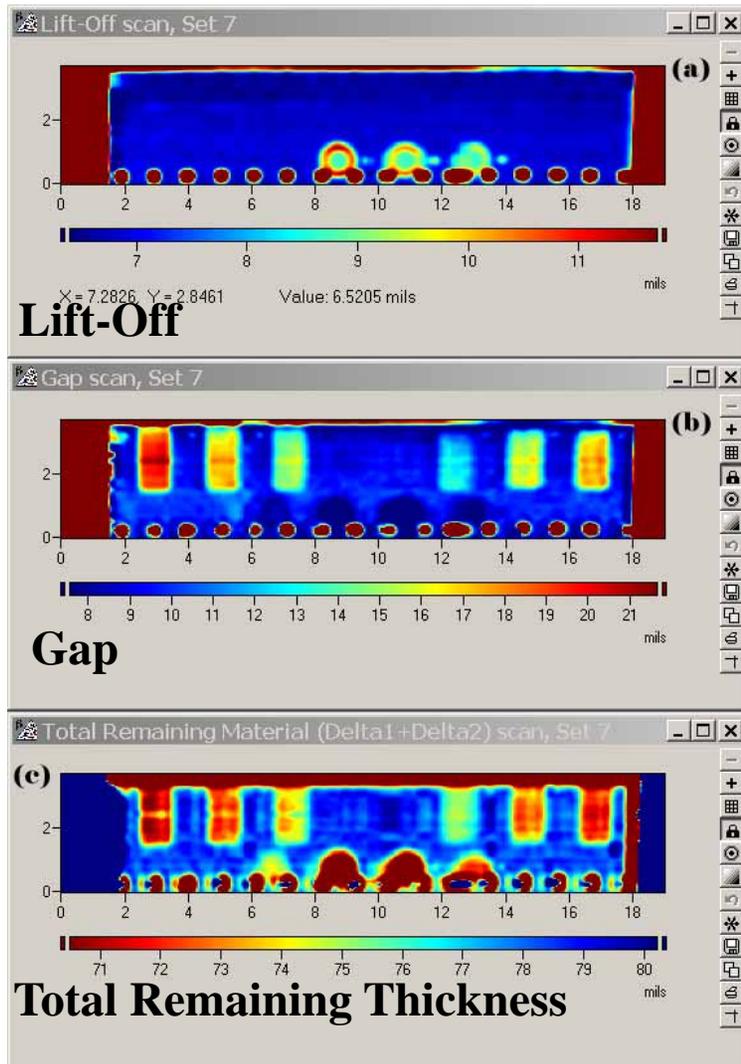
1st Layer Loss vs. 2nd Layer Loss Measurement Grids at 10 kHz for a Gap of 0.011 in.



gap of 11 mils

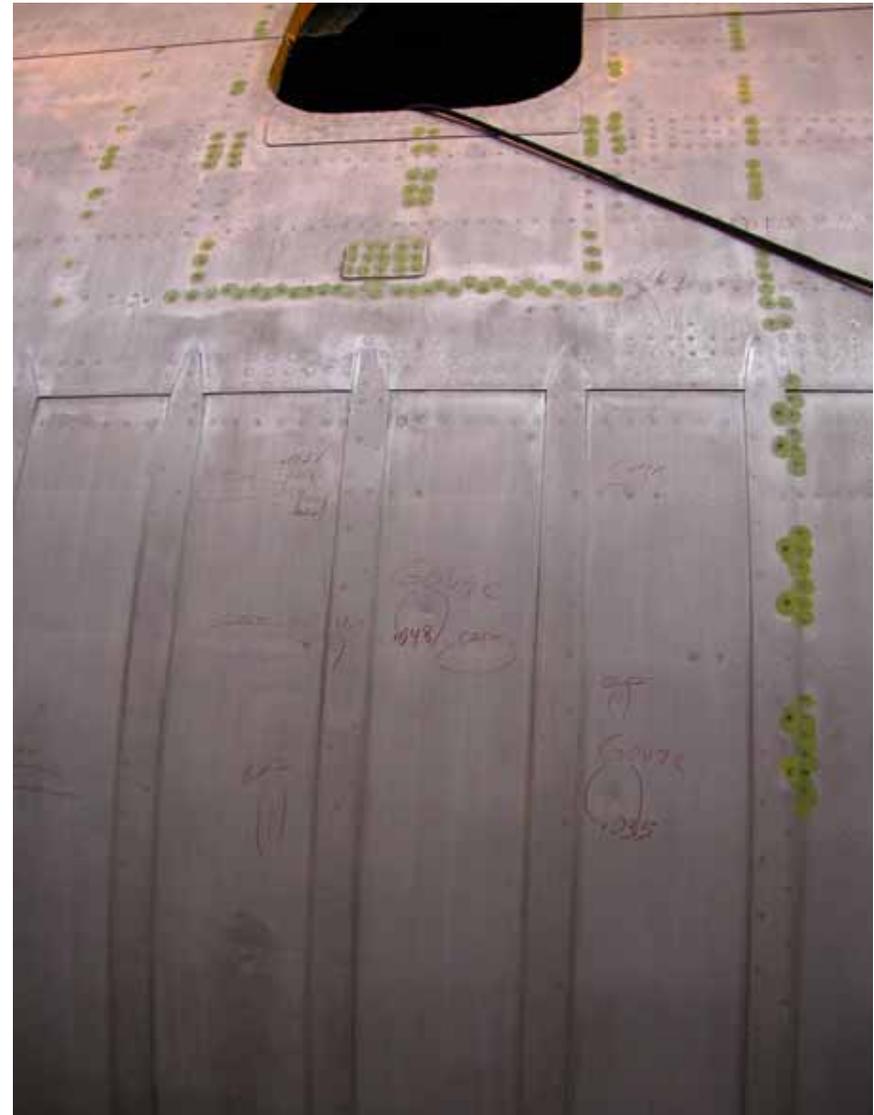
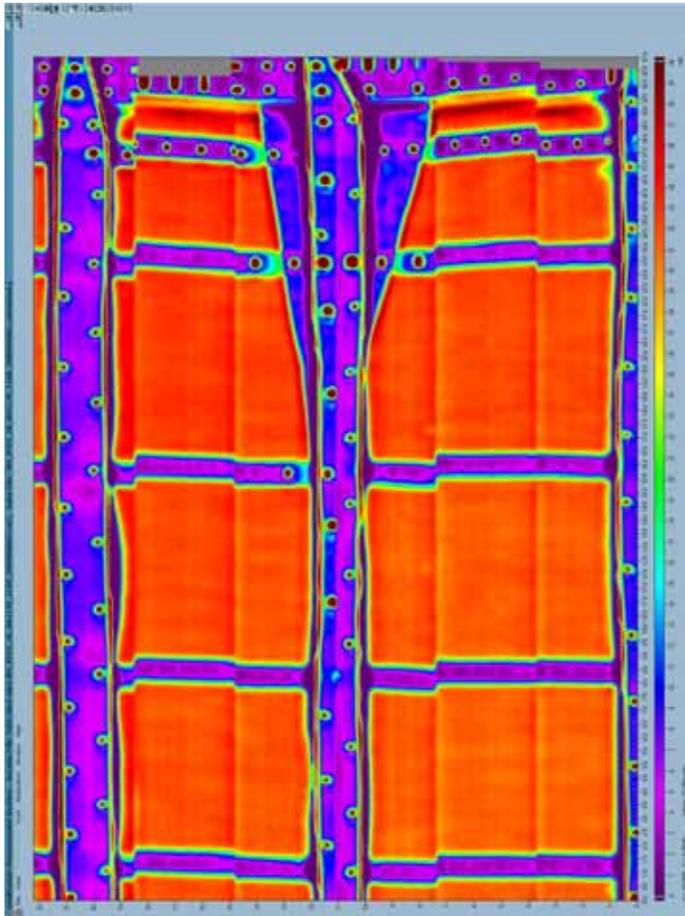


4-Unknown Results h , Δ_1 , Δ_2 , Gap



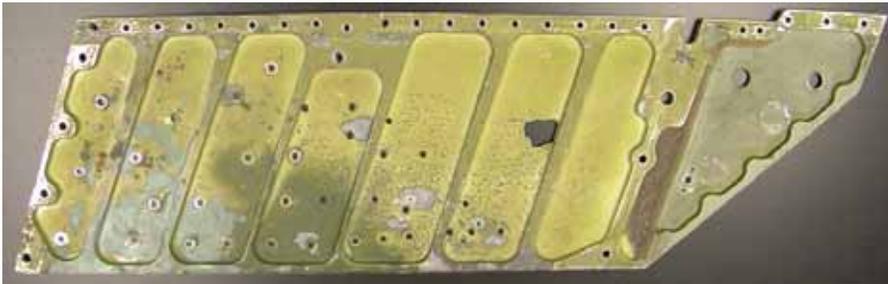
MWM-Array Image of Wide Area

Using Multiple MWM-Array
Scan Passes

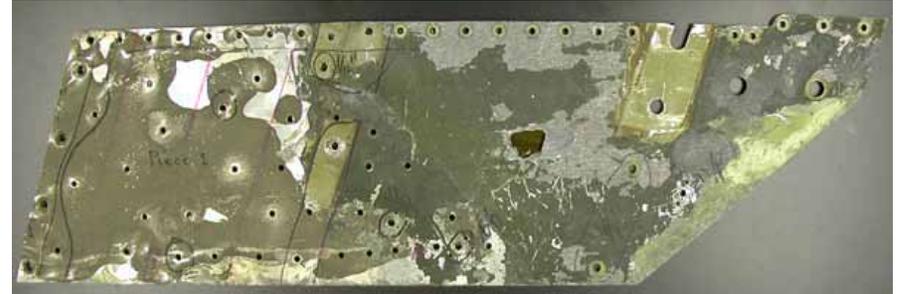


Internal Geometric Feature and Hidden Damage Imaging: C-130 Flight Deck Chine Plate

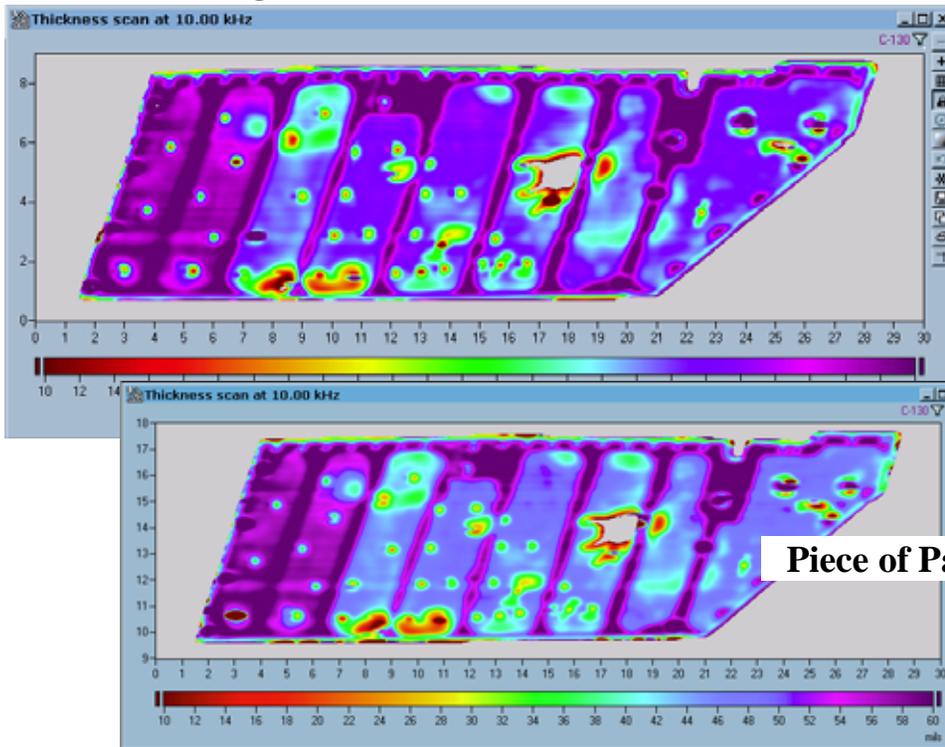
Inaccessible Side



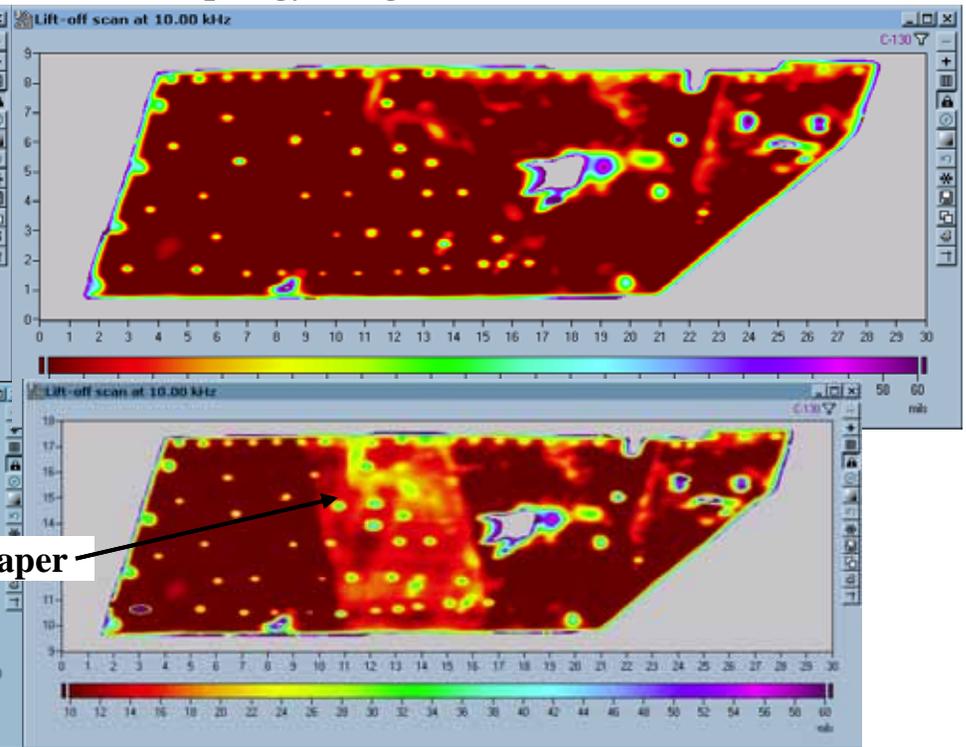
Accessible Side



Thickness Image from Accessible Side



Surface Topology Image

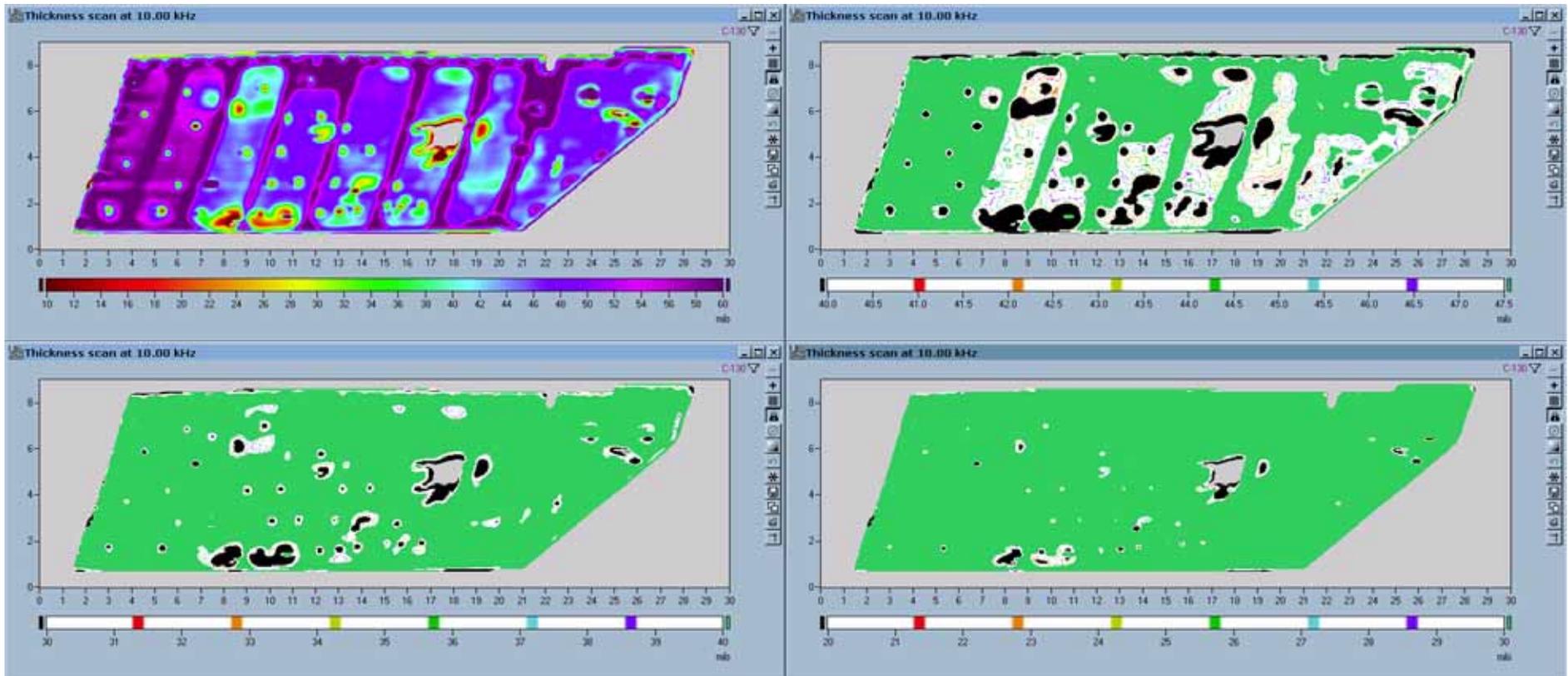


Piece of Paper

Hidden Damage Imaging of C-130 Flight Deck Chine Plate

Thickness Image

Green: < 5% Material Loss
White: 5-20% Material Loss,
Black: >20% Material loss



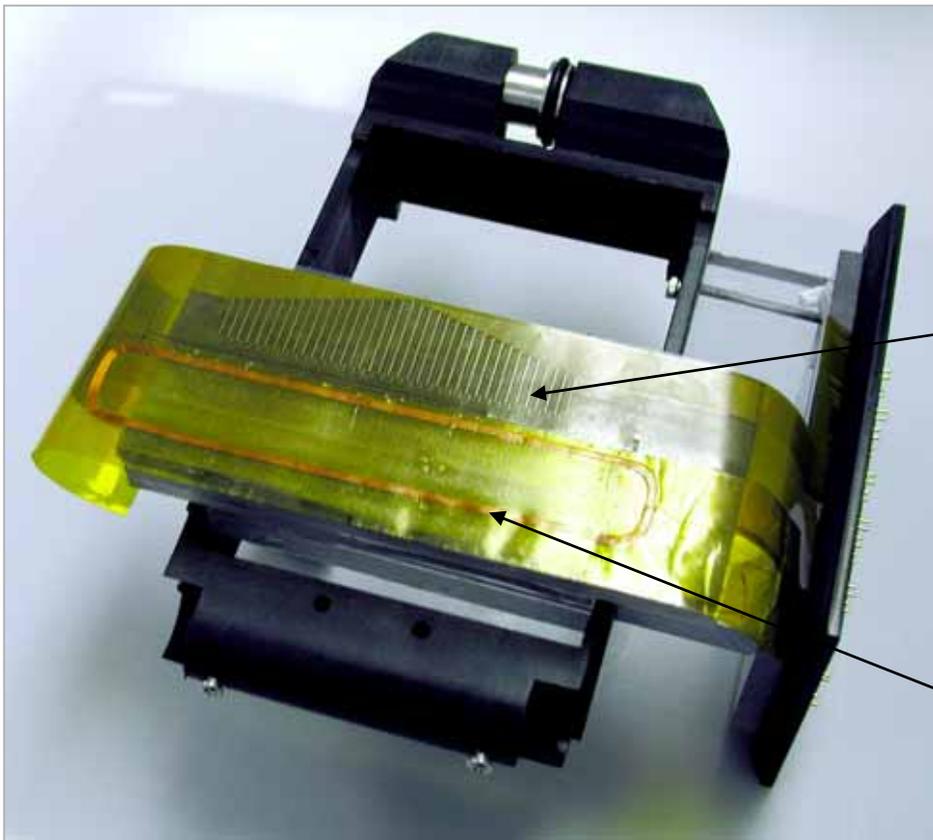
Green: < 20% Material Loss
White: 20-40% Material Loss
Black: >40% Material loss

Green: < 40% Material Loss
White: 40-60% Material Loss
Black: >60% Material loss

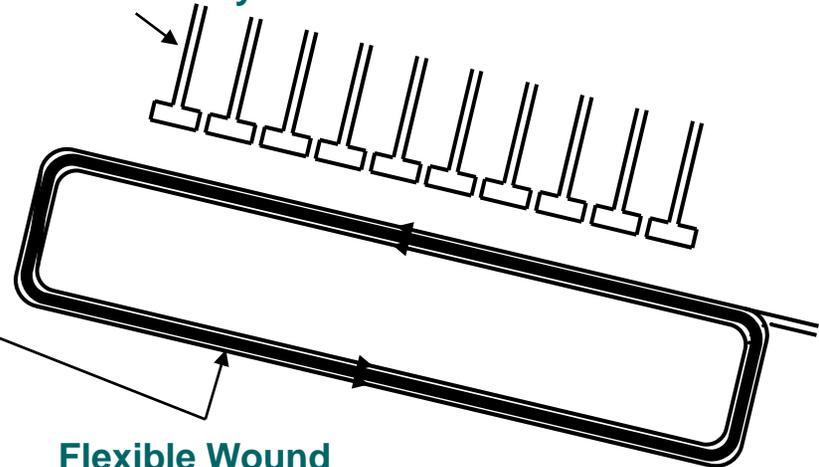
Hybrid Wound/Etched MWM-Array

Patents Pending

- Wound drive winding - permits lower frequency operation
- Etched sense element array - controlled element geometry and registration

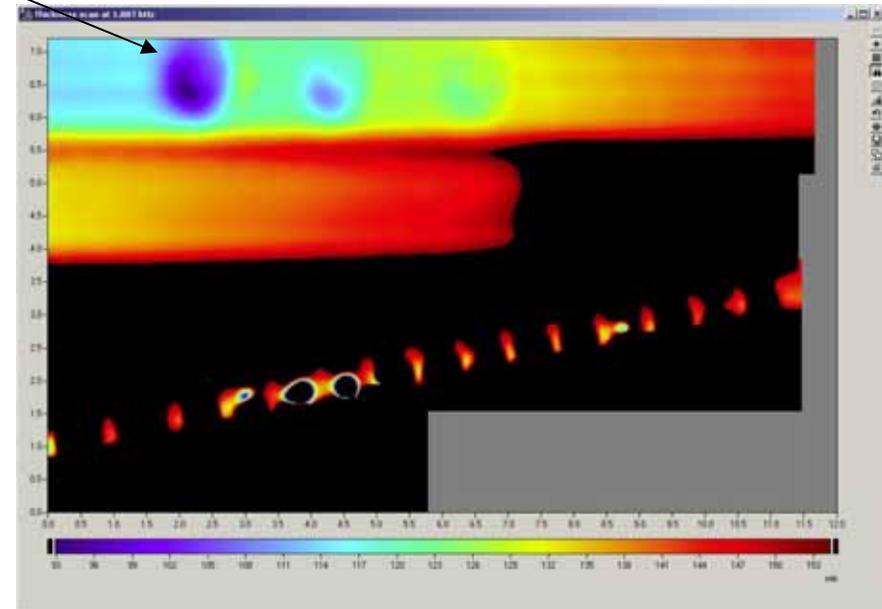
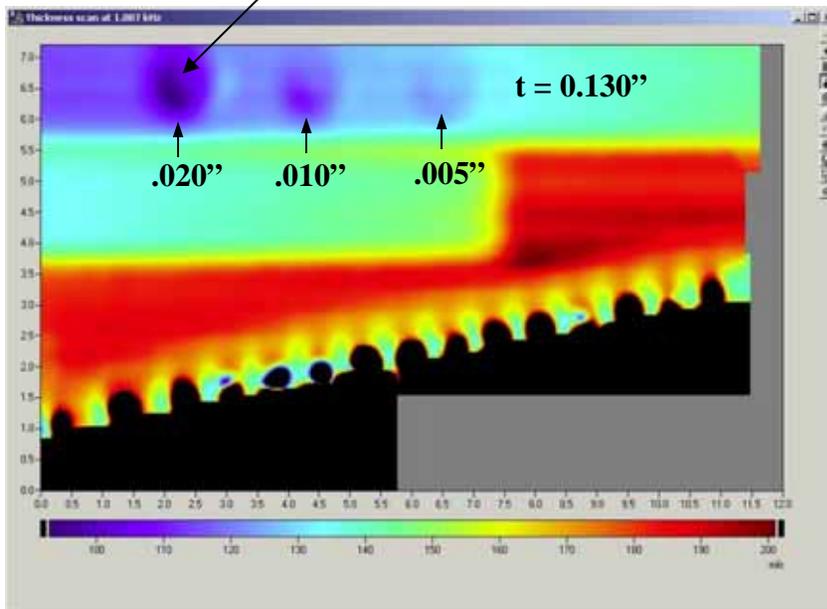
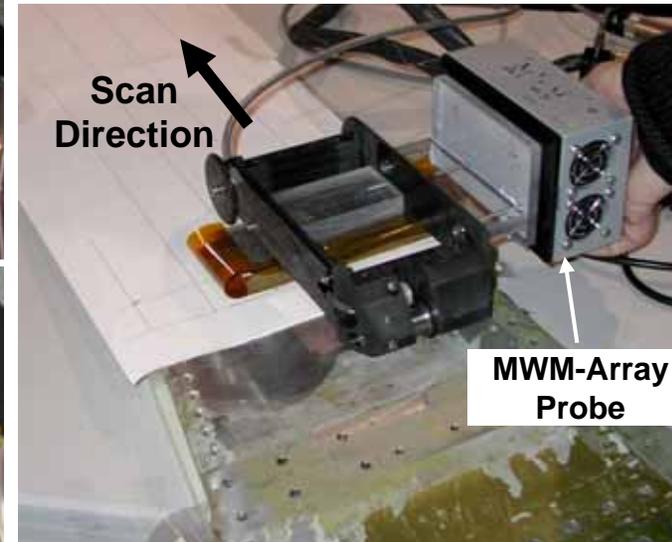
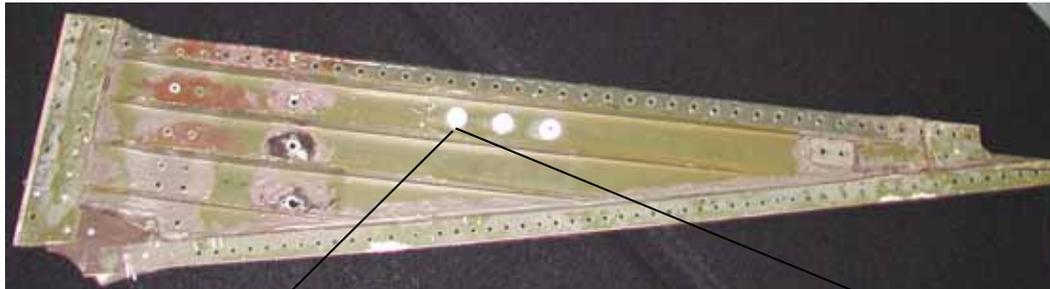


Etched Sensing Element Array

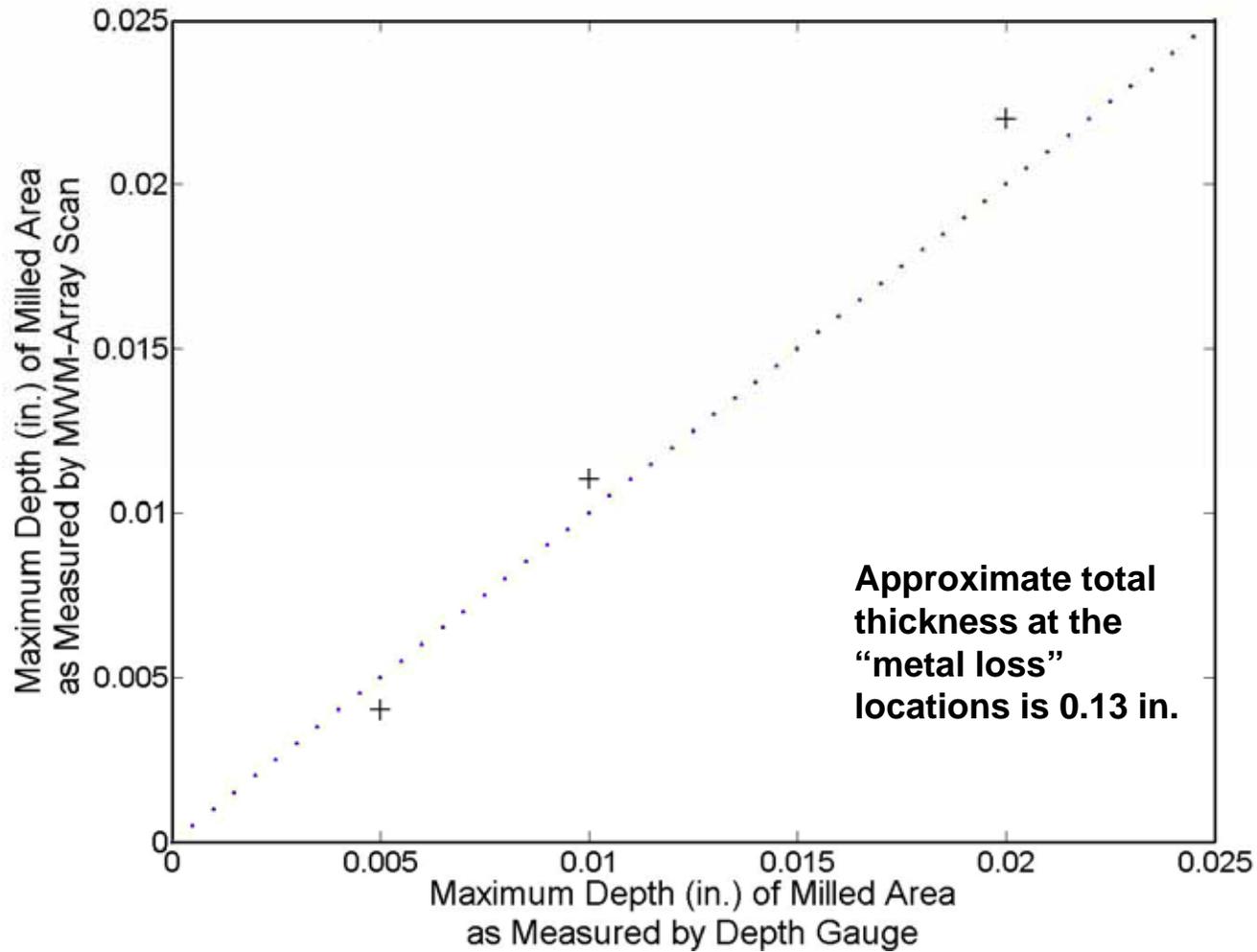


Flexible Wound Drive Winding

MWM-Array Scans of a Wing Plank from Navy P-3 Aircraft

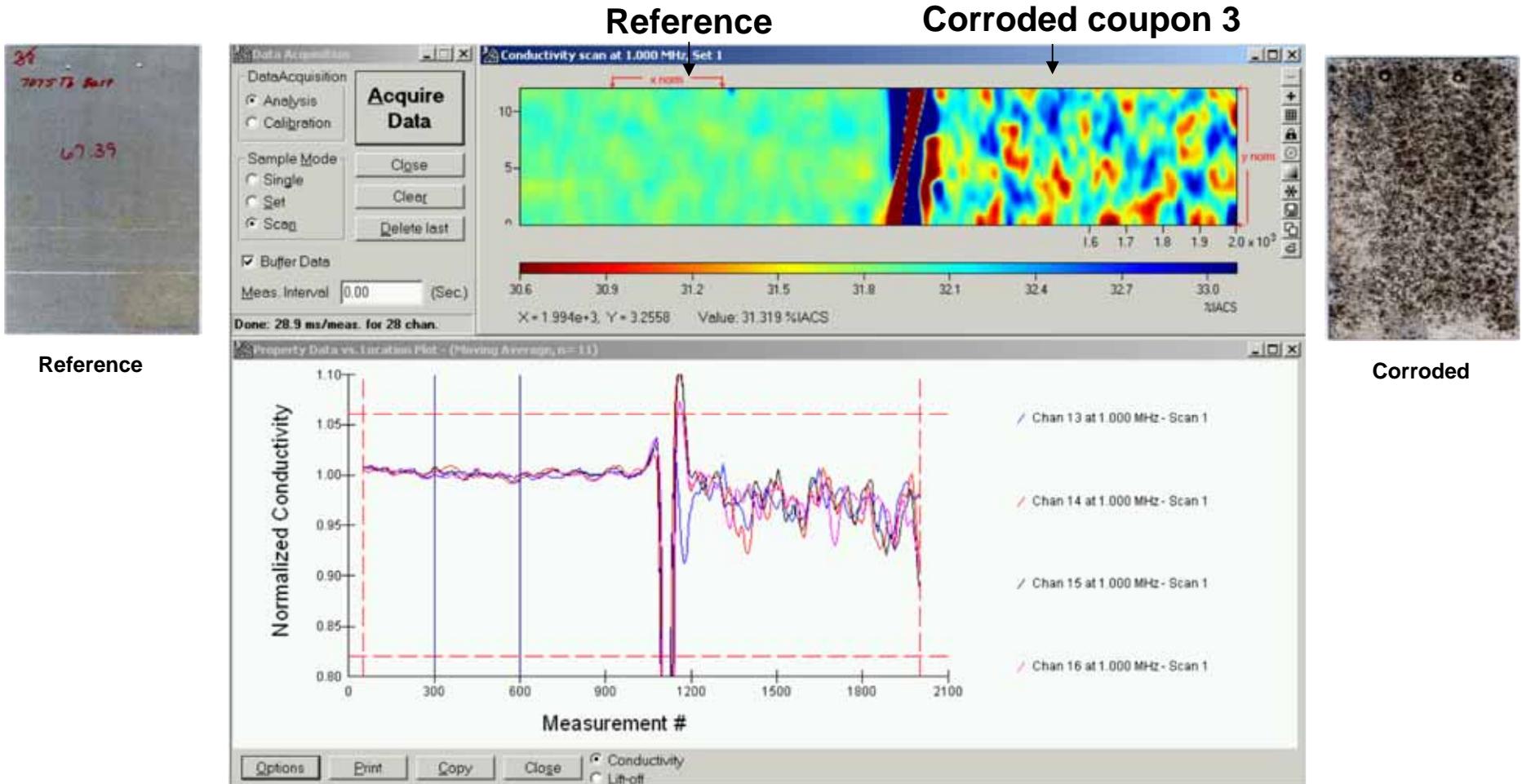


MWM-Array Hidden Metal Loss Estimates for the Three Milled Out Regions vs. the Actual Depth Measured with a Depth Gauge



Corrosion Images without Paint Removal

Images of reference Al 7075-T6 coupon (left) and the more severely corroded Al 7075-T6 coupon (right) obtained at 1 MHz



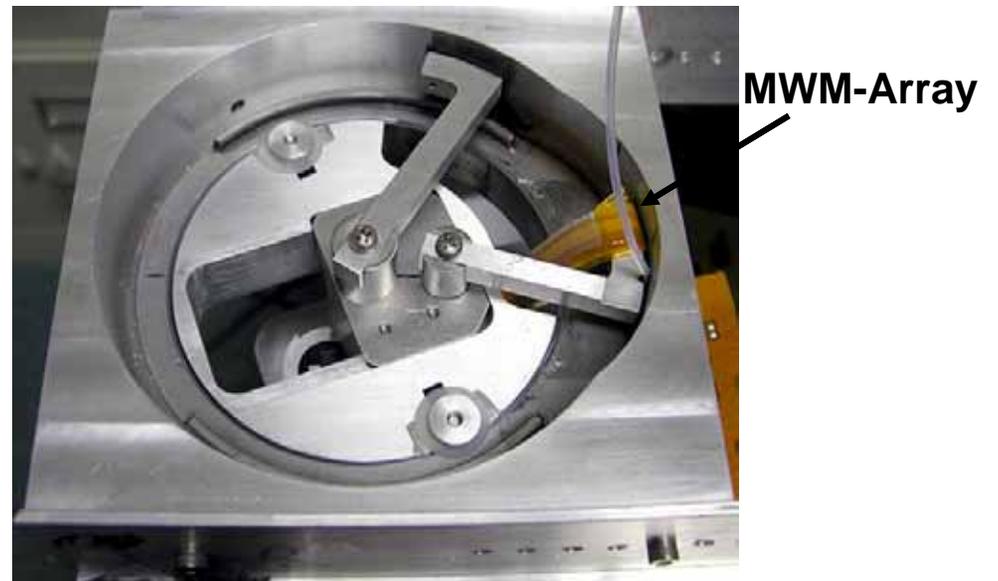
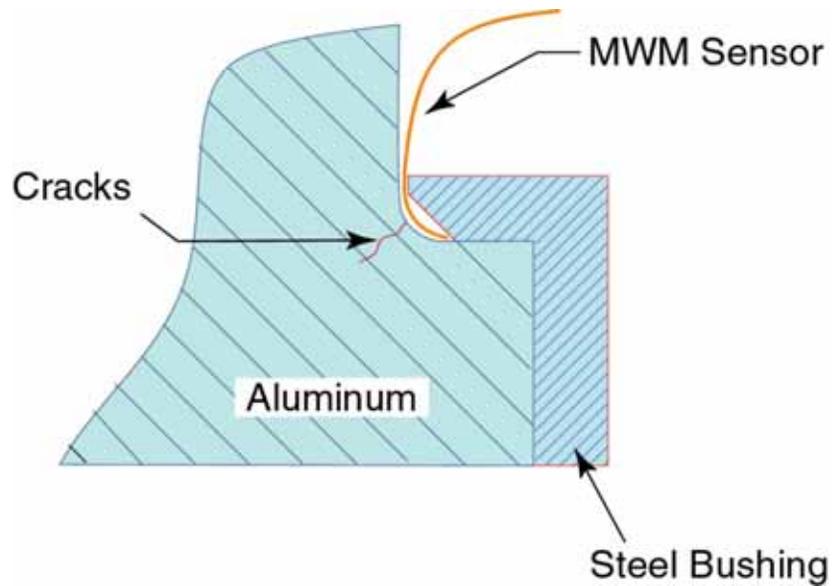
Note: **0.004 in. insulating shim** used to simulate paint layer

Scan width 12 mm, scan length 100 mm

F-15 Wing Pylon Inspection



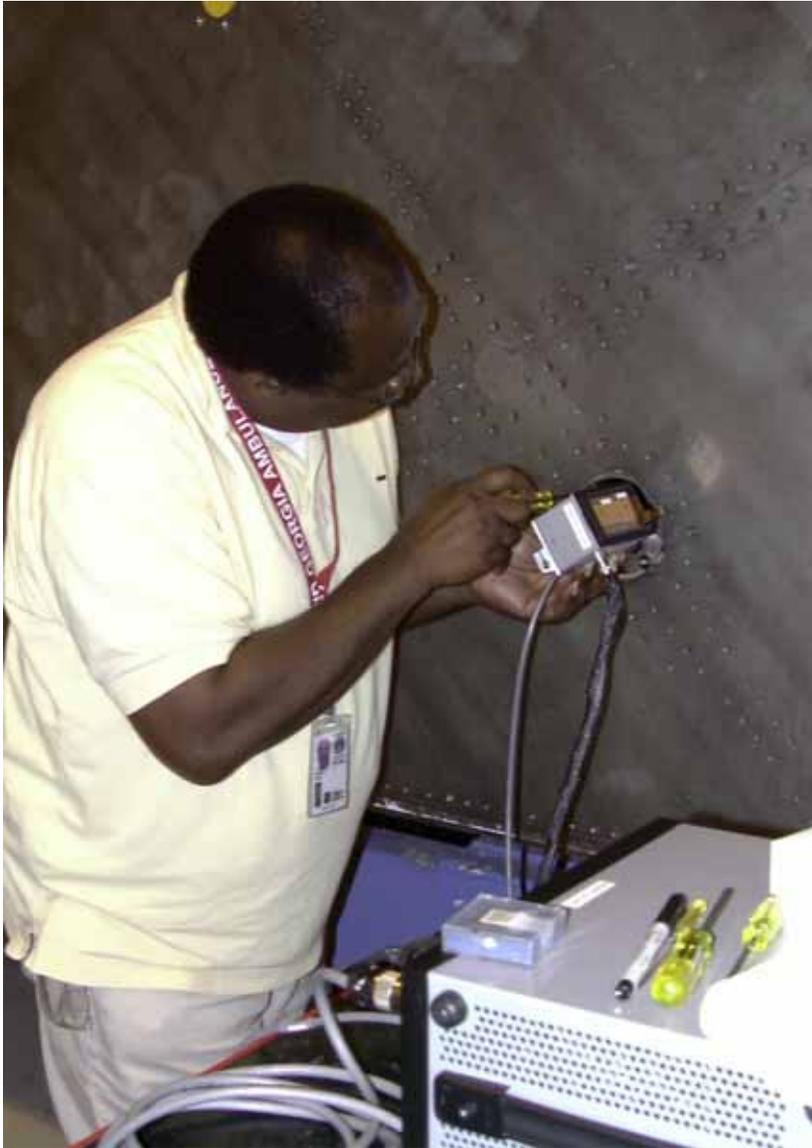
With Bushing in Place



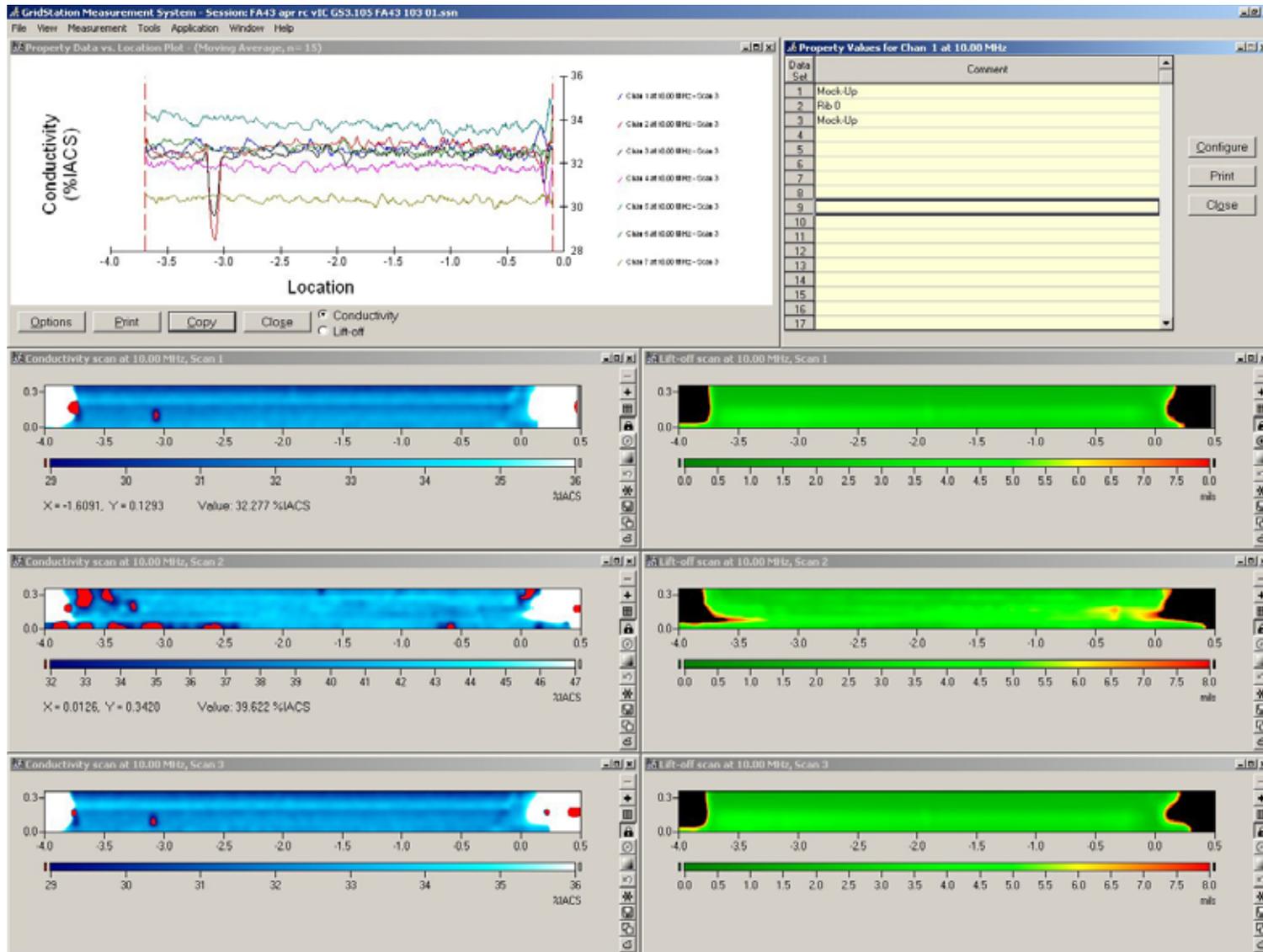
WR-ALC Training (on Mockup) with Bushing Removed



WR-ALC Training with Bushing Removed



MWM-Array Corrosion Pitting/Crack Imaging



Example MWM-Array Ongoing **NDE**, **CBM** and **PHM** Programs

PHM

- **Health-Monitoring for JSF**
(Navy SBIR Phase II)
- **P-3 Orion Fatigue Test**
(Navy/Lockheed Martin)
- **Landing Gear Stress & Fatigue**
(AF Phase II SBIR)
- **Through-Wall Stress and Temperature Measurement**
(NASA Phase II SBIR)
- **Coupon Testing for Multi-Site Cracking**
(Air Force/Lockheed, OEMs)

CBM

- **C-130/P-3 Propeller Cold Work**
(WR-ALC)
- **Coating Degradation**
(DOE Phase II SBIR)
- **Grinding Rework, Repair Quality**
(Air Force, Army)

NDE

- **Engine Disk Slot Inspection (CFM 56)**
(AFRL, NAVAIR)
- **F-15 Wing Pylon Rib**
(WR-ALC)
- **F-16 Wing Attach Fittings**
(Lockheed/Air Force)
- **AV-8B/Harrier Turbine Blade Welds**
(NADEP Cherry Point)
- **Lap Joint Cracks/Corrosion**
(Air Force, FAA, OEMs)
- **Friction Stir Weld Quality Assessment**
(Lockheed/NASA, Eclipse Aviation)
- **Deep/Hidden Damage**
(NASA Phase II SBIR)
- **2- and 3-D Buried Flaw Imaging**
(Air Force SBIR Phase II, FAA)