2013 CSAT Workshop
June 18-19, 2013
Worcester, MA

Nondestructive Evaluation of Cold Spray Repairs

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Outline

- Technology Overview
- Success Story Examples
- Coating Thickness Measurement
- Disbond Detection and Imaging
- Cold Spray Coating Thickness and Quality
- Proposed Future Work

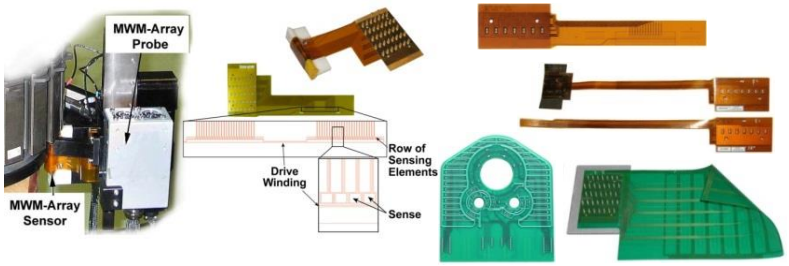
Core JENTEK Technologies

MWM®-Arrays

- Patented scanning and embeddable Eddy Current Sensor product
- **Two decade lead** over all technology in the market

Solving problems that have been unsolved for decades

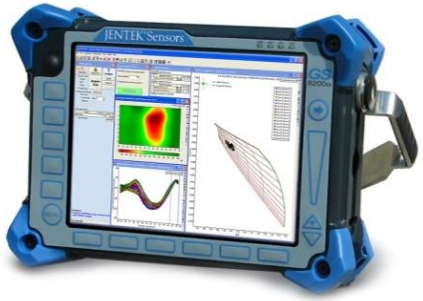
Strong IP position



GridStation® Systems

- Portable and Hand-Held versions

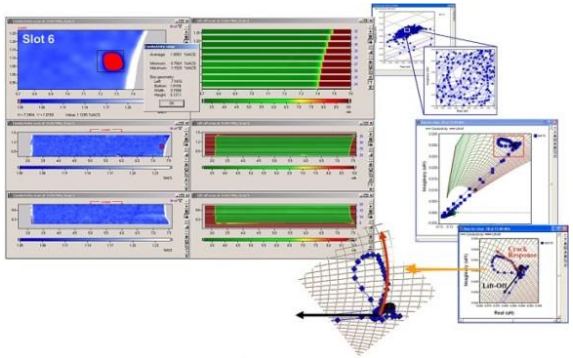
Delivered GS-D8000β

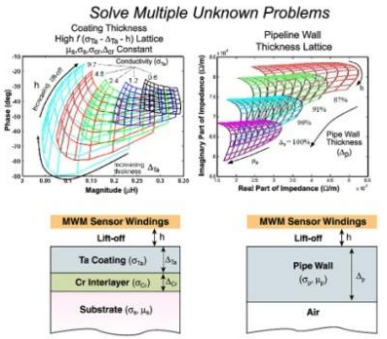


Next Generation GS-8200α

GridStation® Software using Hyperlattices™

- Performs multivariate inverse methods – i.e. fast, autonomous data analysis for decision support in NDT, CBM and SHM



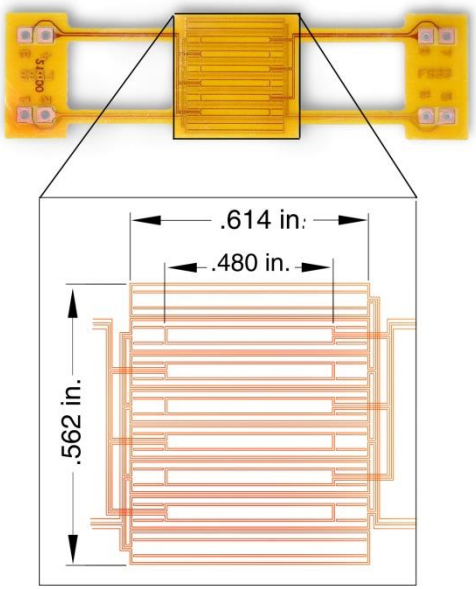


Fuzzy-Hyperlattices

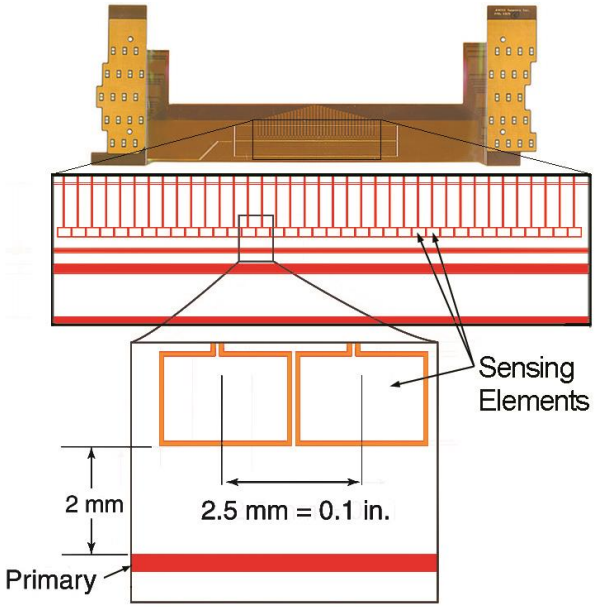
- Remaining Useful Life Prediction (RUL) and rapid uncertainty estimation

MWM® & MWM-Array Eddy Current Sensors

Single-channel
MWM sensor FS33



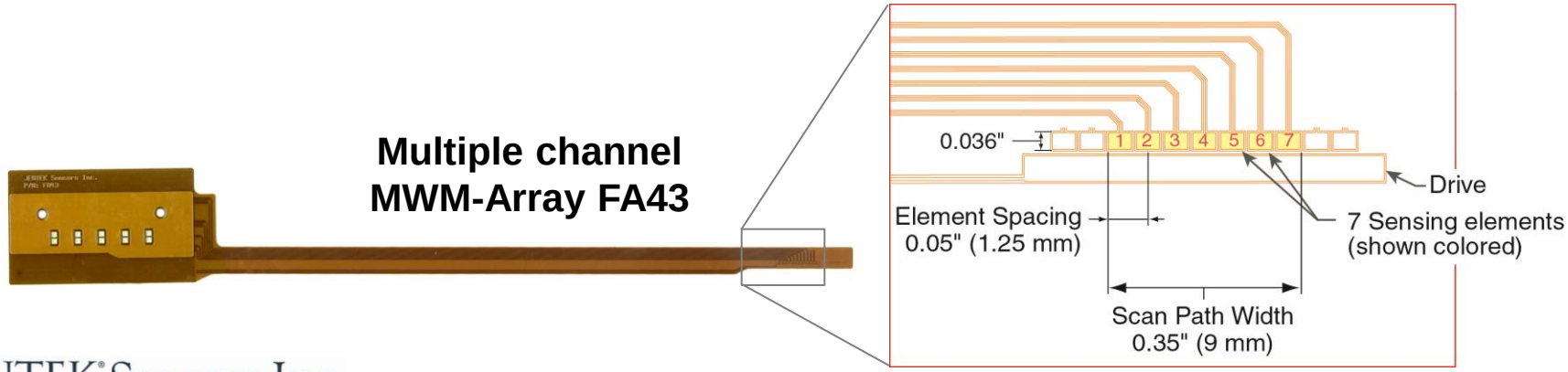
Multiple channel
MWM-Array sensor FA24



Paradigm Shift

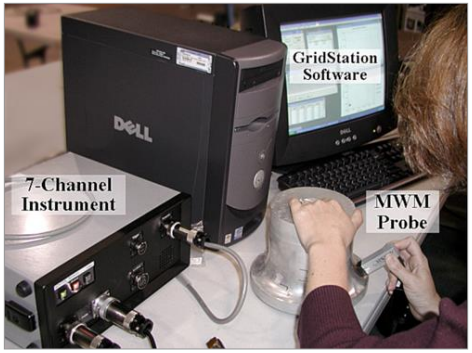
Design Sensors with rapid and accurate modeling as the primary focus

Multiple channel
MWM-Array FA43

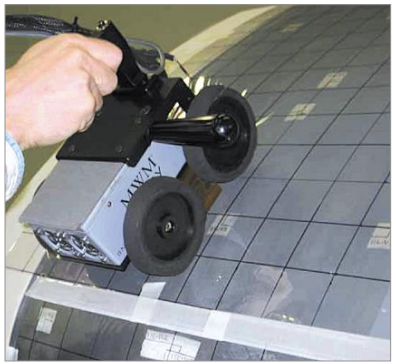


Example JENTEK MWM & MWM-Array Success Stories

Air Force/Navy Propeller Cold Work

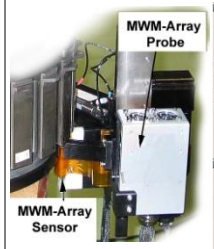


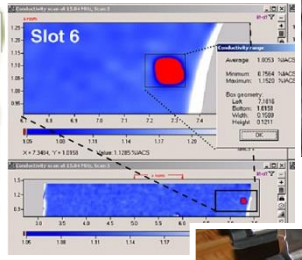
NASA Space Shuttle Leading Edge

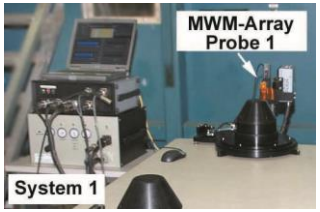


Navy Disk Slot Inspection & Blade Dovetail Inspection

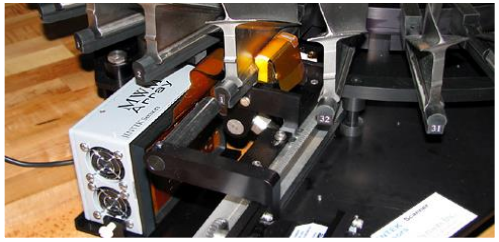
Disk Slot Inspection



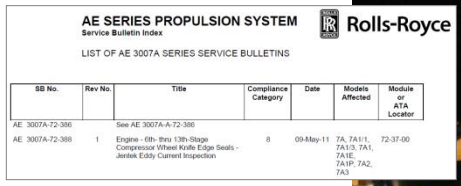




Blade Dovetail Inspection

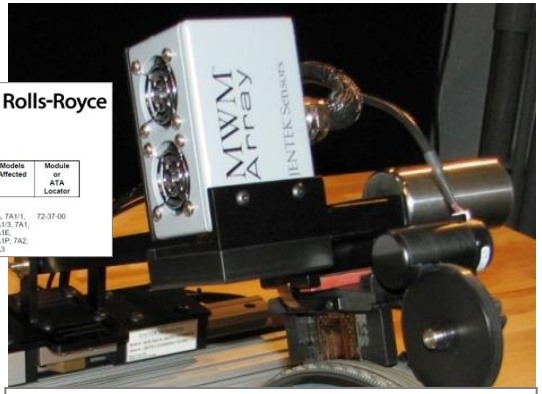


Engine Component Inspection


AE SERIES PROPULSION SYSTEM
Service Bulletin Index
Rolls-Royce
LIST OF AE 3007A SERIES SERVICE BULLETINS

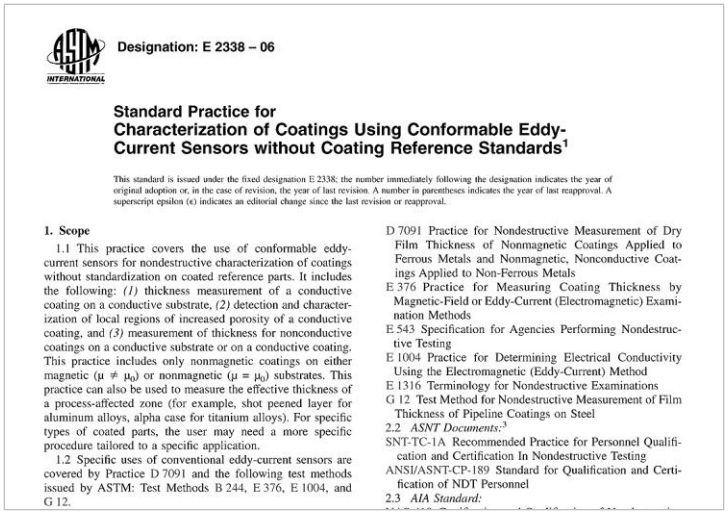
SB No.	Rev No.	Title	Compliance Category	Date	Models Affected	Module or ATA Locator
AE 3007A-72-386		See AE 3007A-A-72-386				
AE 3007A-72-388	1	Engine - 6th- thru 13th-Stage Compressor Wheel Knife Edge Seals - Jentek Eddy Current Inspection	8	09-May-11	7A, 7A1/1, 7A1/3, 7A1, 7A1E, 7A1P, 7A2, 7A3	72-37-00

MWM-Array FA43 Sensor



"Technical aspects of the method are FAA approved."

Coating Thickness Measurements



Designation: E 2338 – 06

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.

1. Scope

1.1 This practice covers the use of conformable eddy-current sensors for nondestructive characterization of coatings without standardization on coated reference parts. It includes the following: *(1)* thickness measurement of a conductive coating on a conductive substrate, *(2)* detection and characterization of local regions of increased porosity of a conductive coating, and *(3)* measurement of thickness for nonconductive coatings on a conductive substrate or on a conductive coating. This practice includes only nonmagnetic coatings on either magnetic ($\mu \neq \mu_0$) or nonmagnetic ($\mu = \mu_0$) substrates. This practice can also be used to measure the effective thickness of a process-affected zone (for example, shot peened layer for aluminum alloys, alpha case for titanium alloys). For specific types of coated parts, the user may need a more specific procedure tailored to a specific application.

1.2 Specific uses of conventional eddy-current sensors are covered by Practice D 7091 and the following test methods issued by ASTM: Test Methods B 244, E 376, E 1004, and G 12.

D 7091 Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals

E 376 Practice for Measuring Coating Thickness by Magnetic-Field or Eddy-Current (Electromagnetic) Examination Methods

E 543 Specification for Agencies Performing Nondestructive Testing

E 1004 Practice for Determining Electrical Conductivity Using the Electromagnetic (Eddy-Current) Method

E 1316 Terminology for Nondestructive Examinations

G 12 Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel

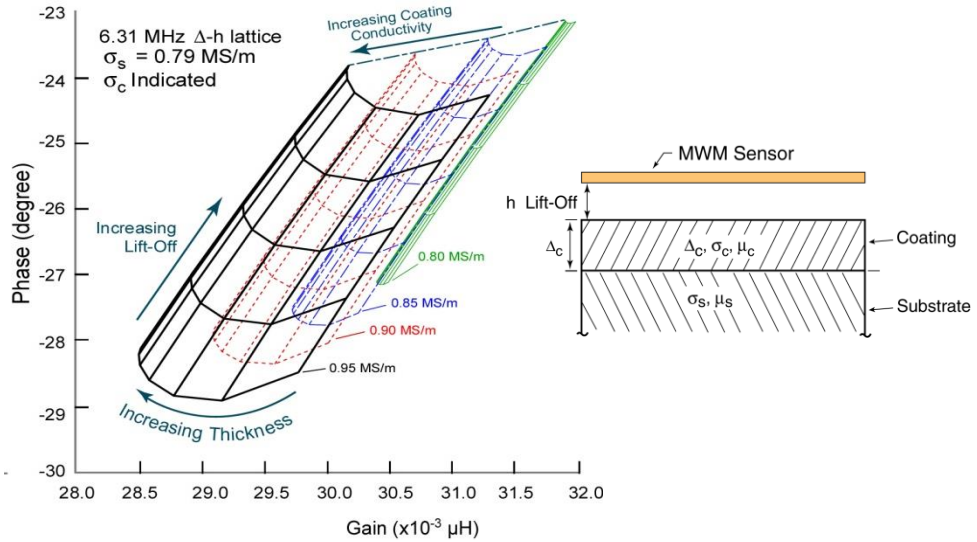
2.2 *ASNT Documents:*[3]

SNT-TC-1A Recommended Practice for Personnel Qualification and Certification In Nondestructive Testing

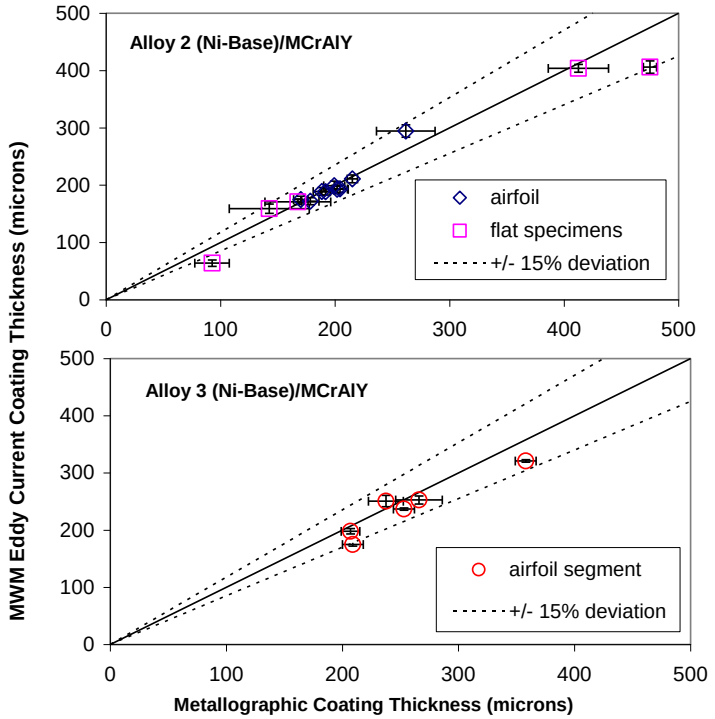
ANSI/ASNT-CP-189 Standard for Qualification and Certification of NDT Personnel

2.3 *AIA Standard:*

JENTEK Grid Lattice
Four-Unknown Coating Problem Example



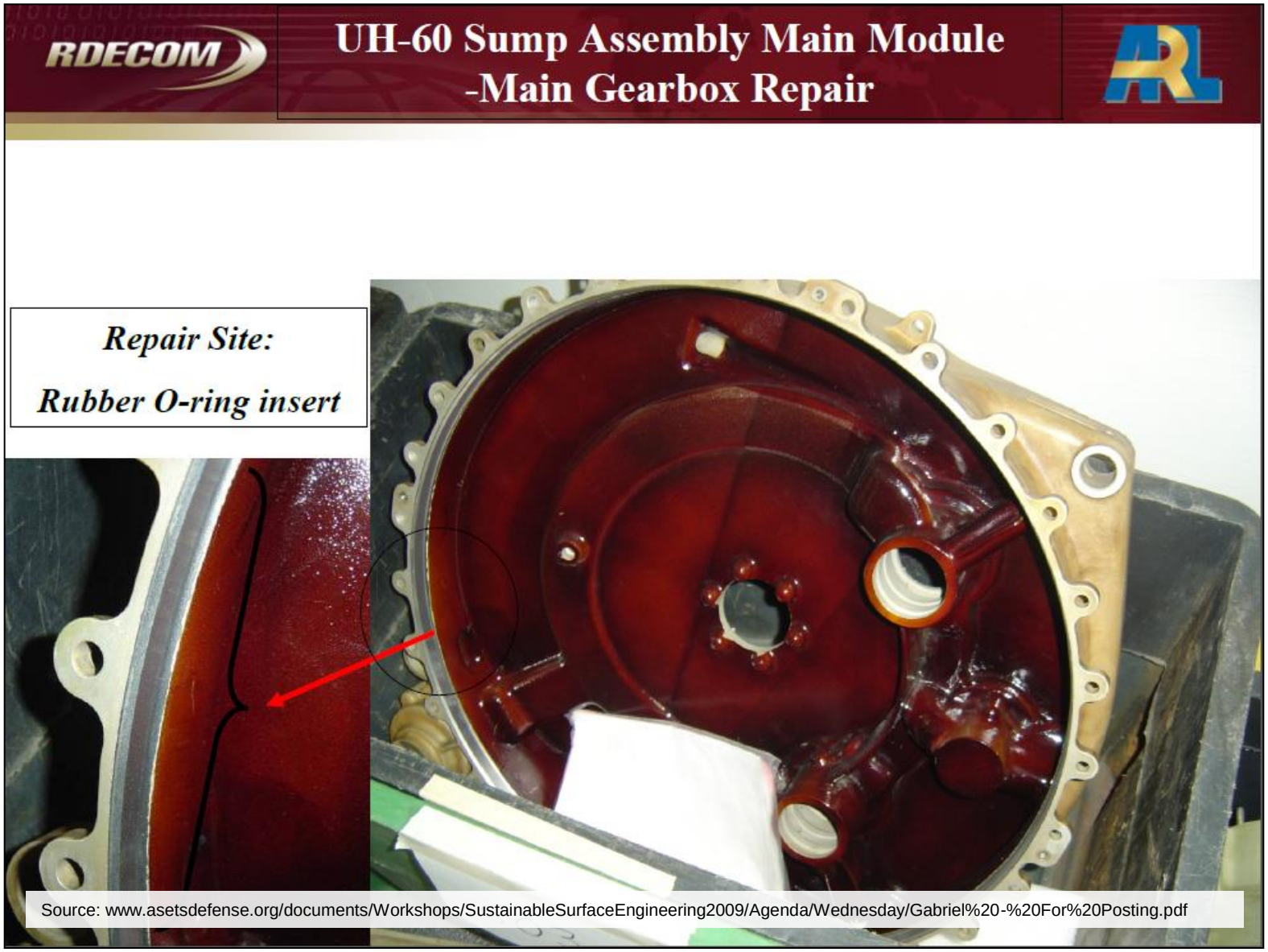
Comparison of MWM with Metallographic MCrAlY Coating Thickness Measurements



Independent Evaluation by Siemens

Published, proceedings of ASME/IGTI Turbo Conference, June 2003, Atlanta, GA

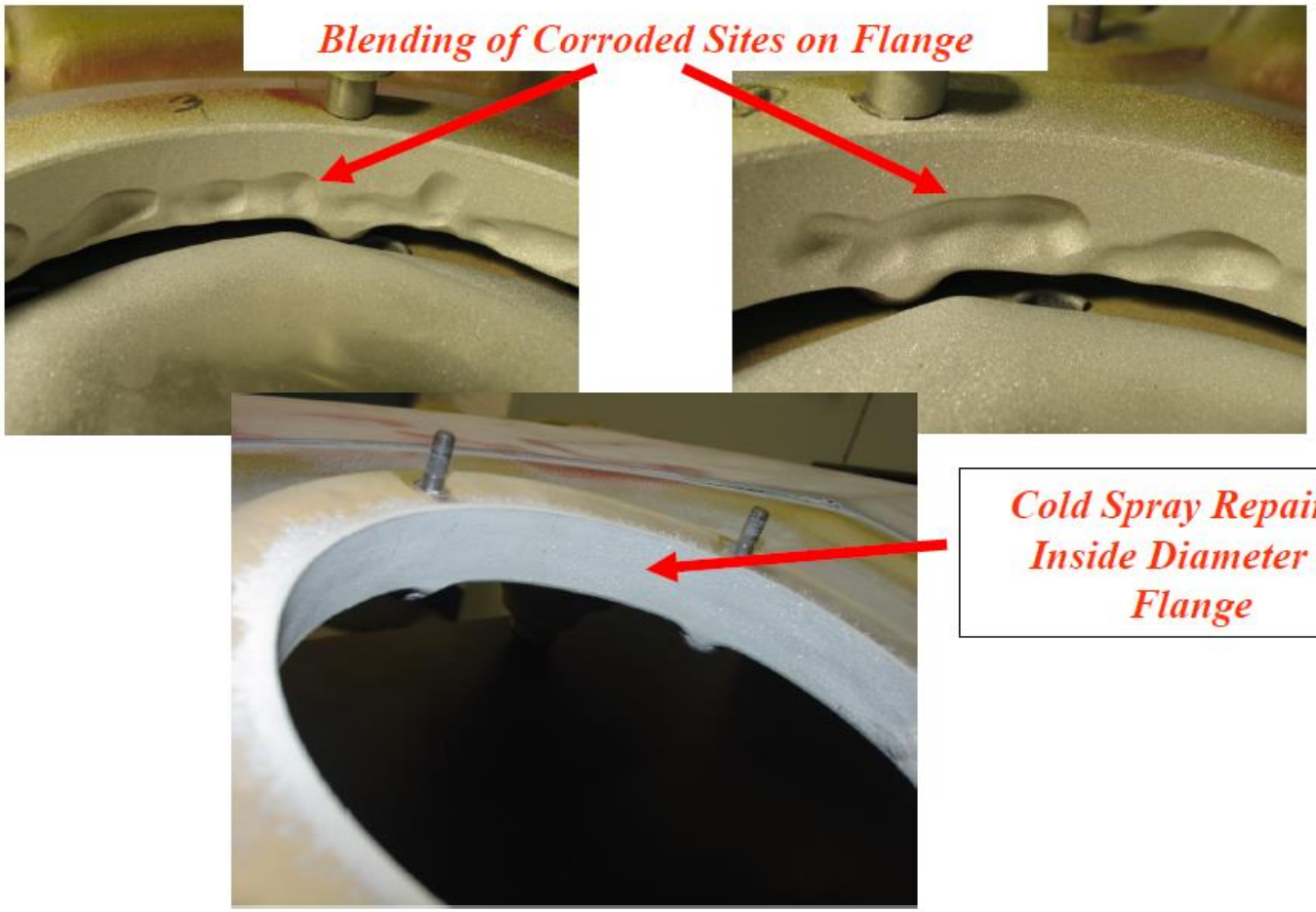
H-60 Sump Repair Sites



Source: www.asetsdefense.org/documents/Workshops/SustainableSurfaceEngineering2009/Agenda/Wednesday/Gabriel%20-%20For%20Posting.pdf

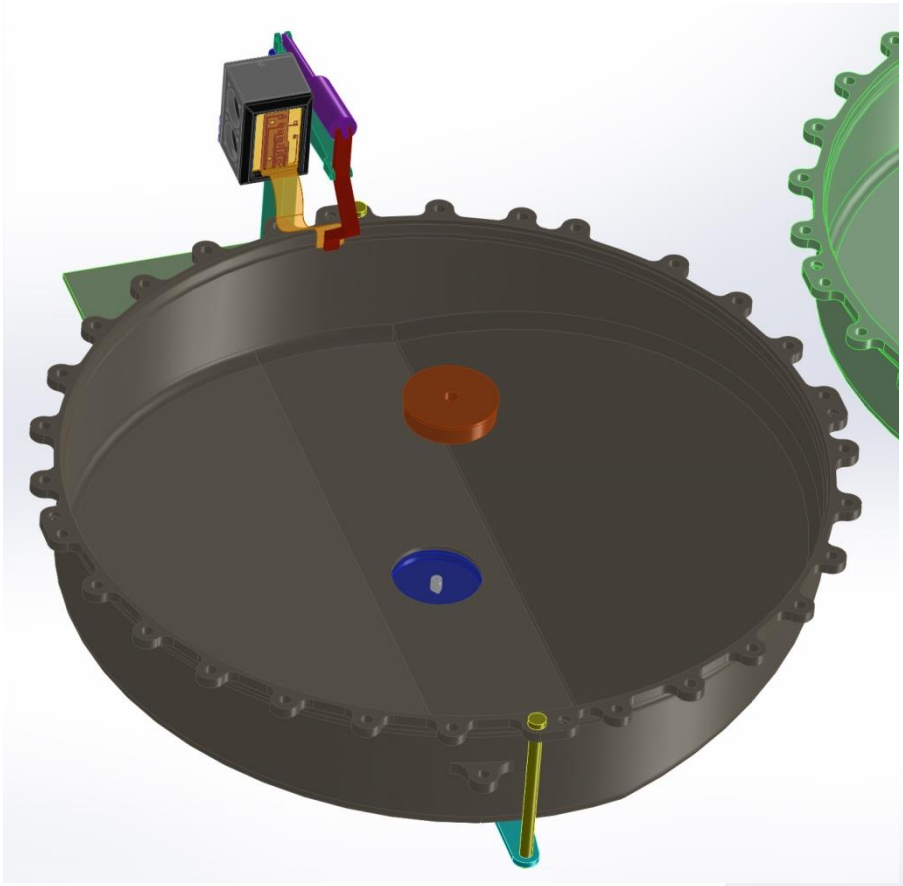
H-60 Sump Repair Sites

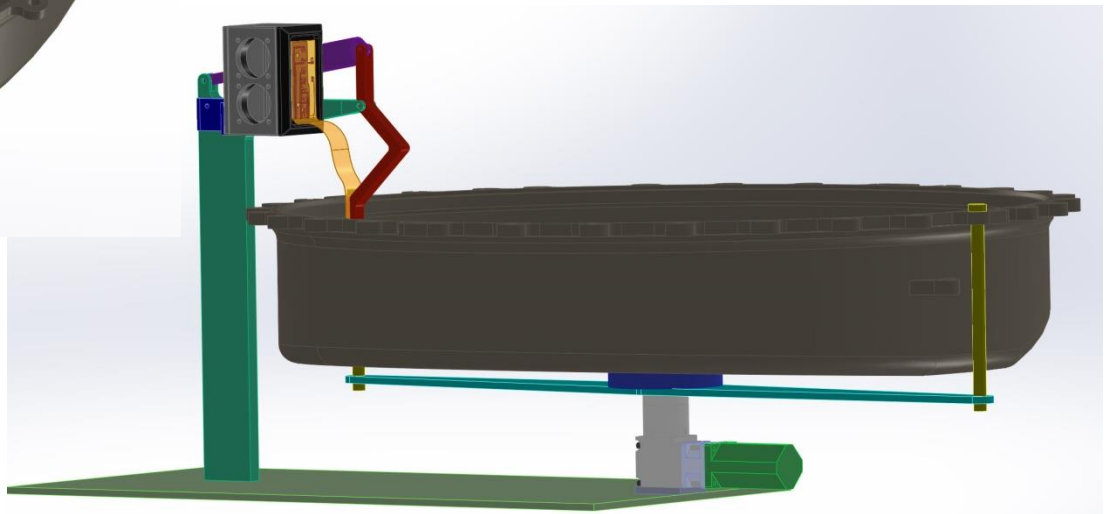
UH-60 Sump Assembly Main Module -Main Gearbox Repair



Source: www.asetsdefense.org/documents/Workshops/SustainableSurfaceEngineering2009/Agenda/Wednesday/Gabriel%20-%20For%20Posting.pdf

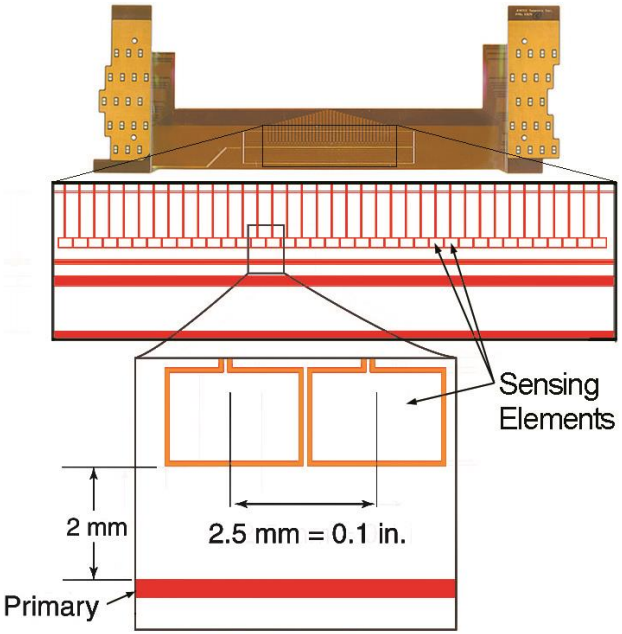
Scanning Concept

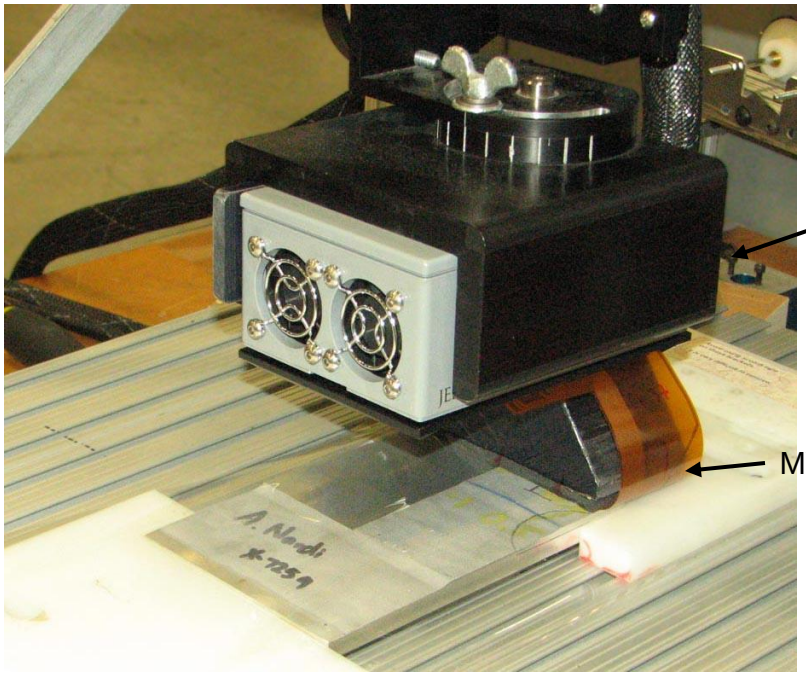




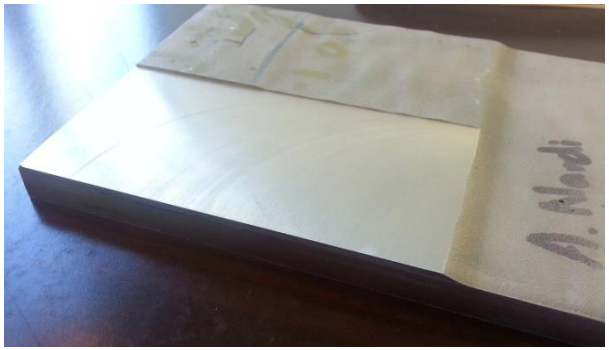
MWM-Array FA24 Scans on Simulated Disbond Sample

MWM-Array FA24



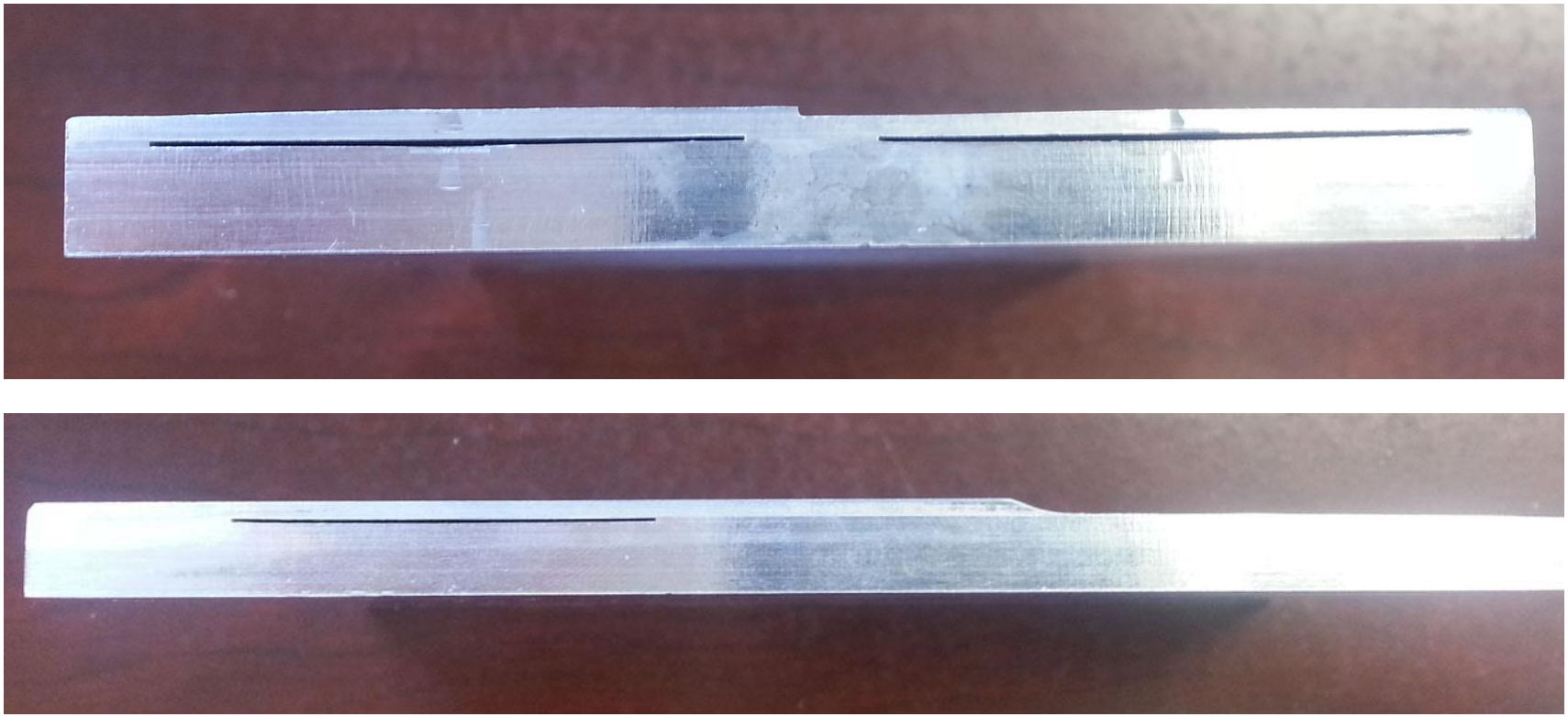


ARL Sample



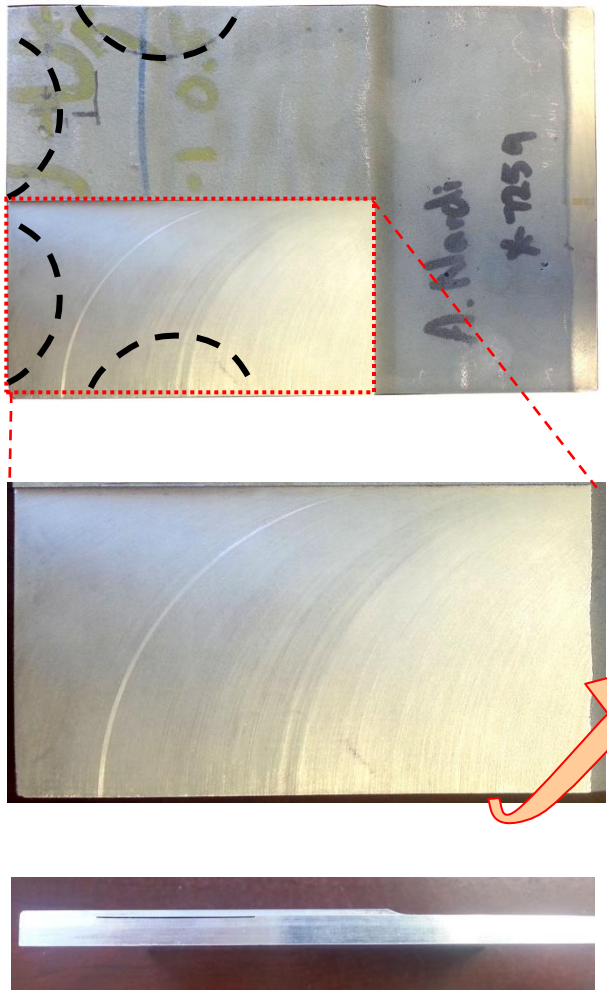
Nominal Dimensions

- Al Cold-Spray Thickness: 70 mils (1.8 mm)
- Delamination Gap: 10 mils (0.25 mm)
- Mg Substrate Thickness: 275 mils (7 mm)

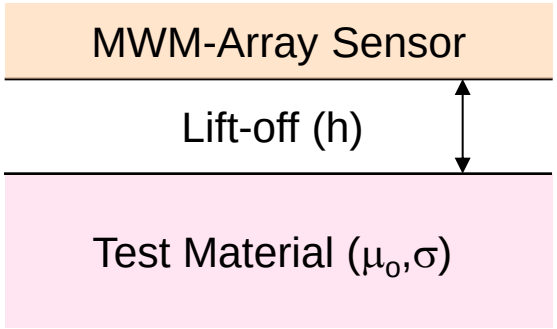


Preliminary “Disbond” Imaging Results

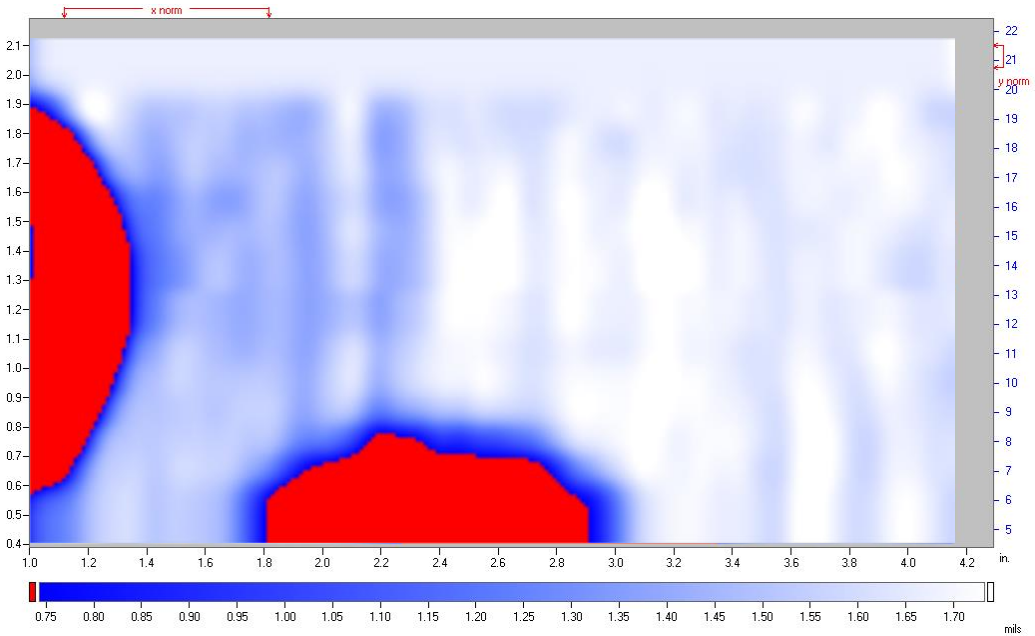
ARL Sample



Model

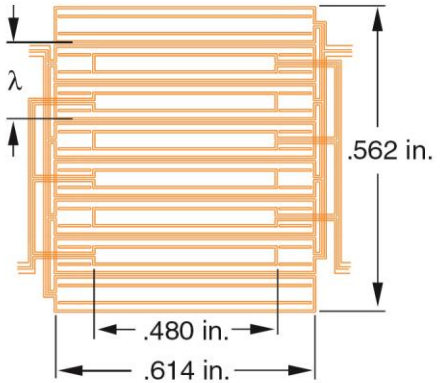


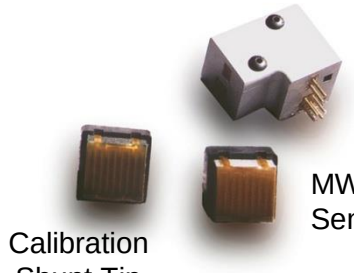
Scan Direction



MWM Coating Thickness Measurement & Q.A.

Single Sensing
Element MWM Sensor FS33



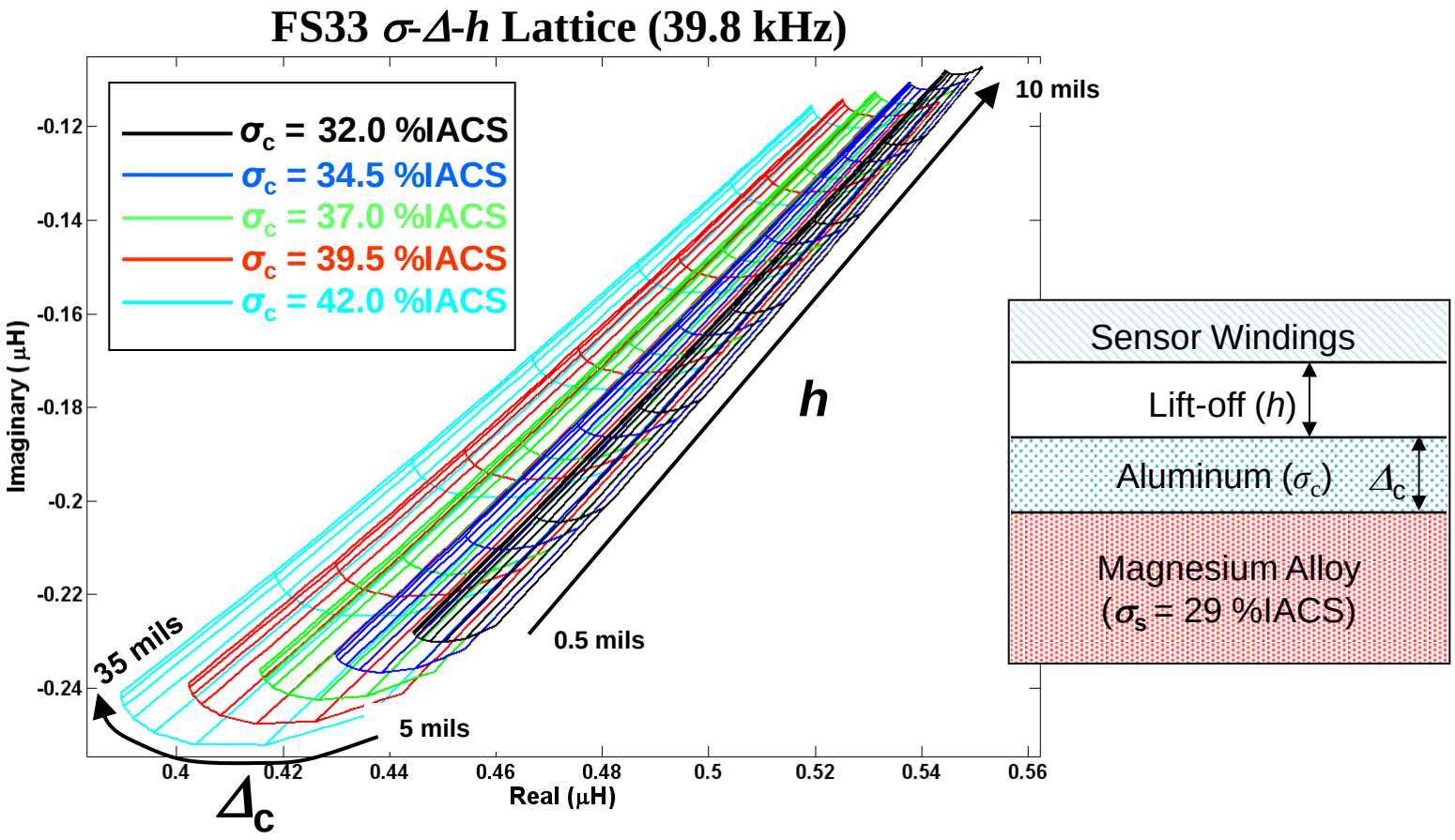


Right Angle
Adapter

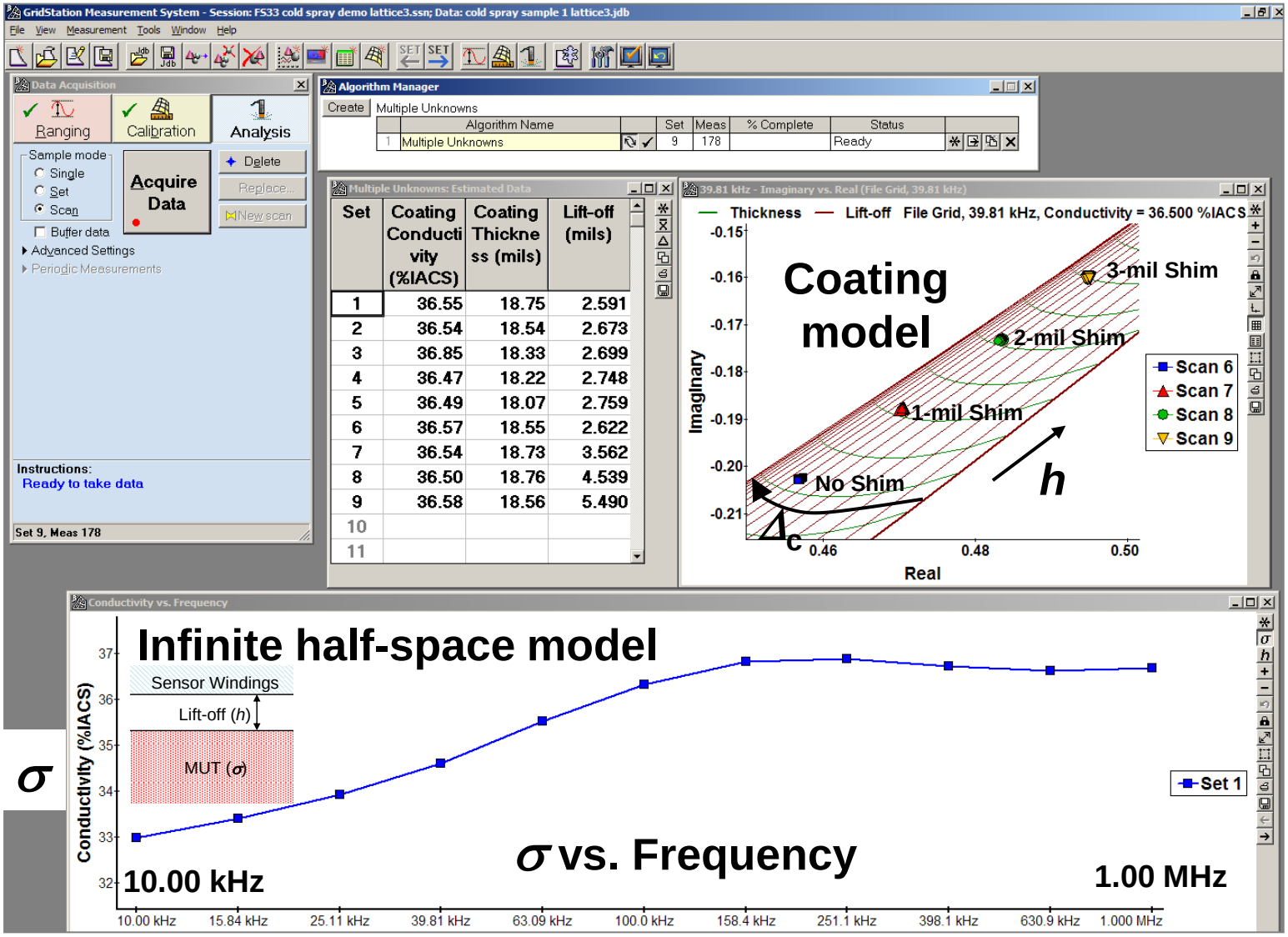
MWM
Sensor Tip

Calibration
Shunt Tip

Measurement Lattice for Coating Characterization

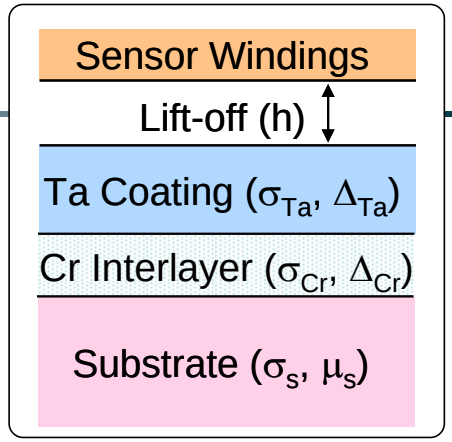


Coating Thickness & Conductivity Measurement Results



Benet Labs Problem Definition

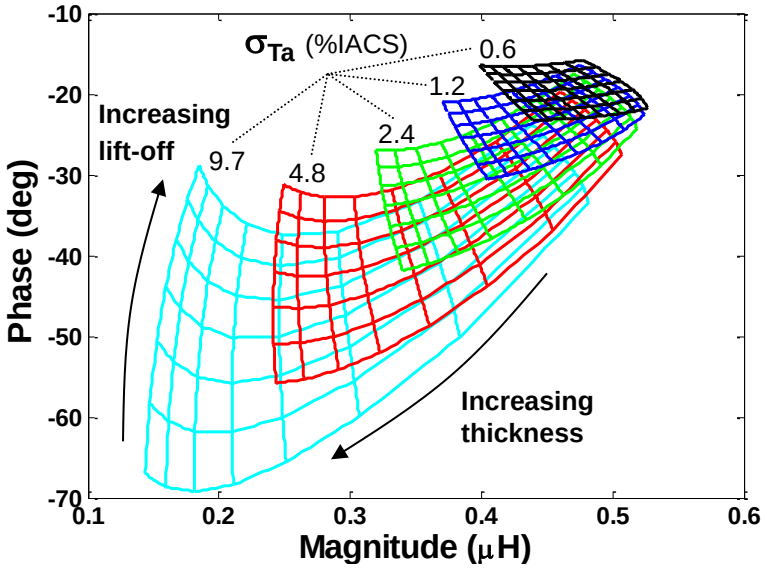
(Gun Barrel Coatings)



- Measure Four Unknowns
- Provide high resolution image of **each unknown**
- Automated & Real-Time

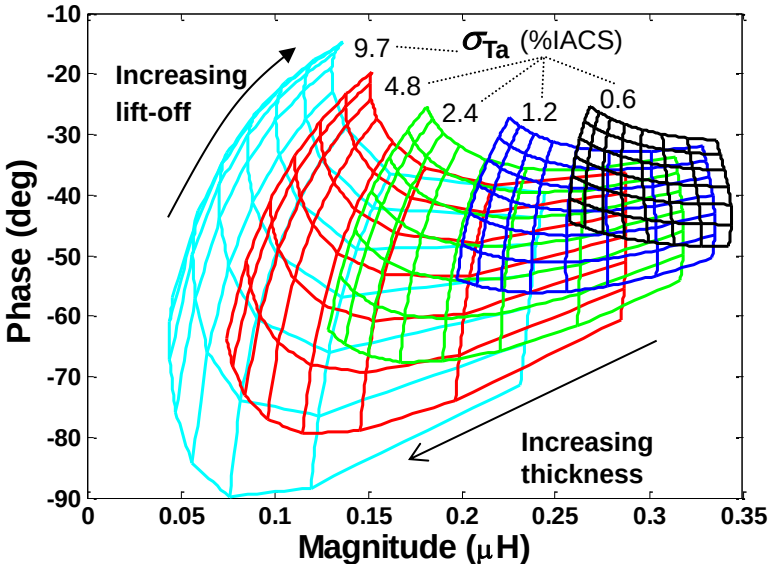
Low f σ_{Ta}- Δ_{Ta}- h Lattice

μ_s, σ_s, σ_{Cr}, δ_{Cr} constant



High f σ_{Ta}- Δ_{Ta}- h Lattice

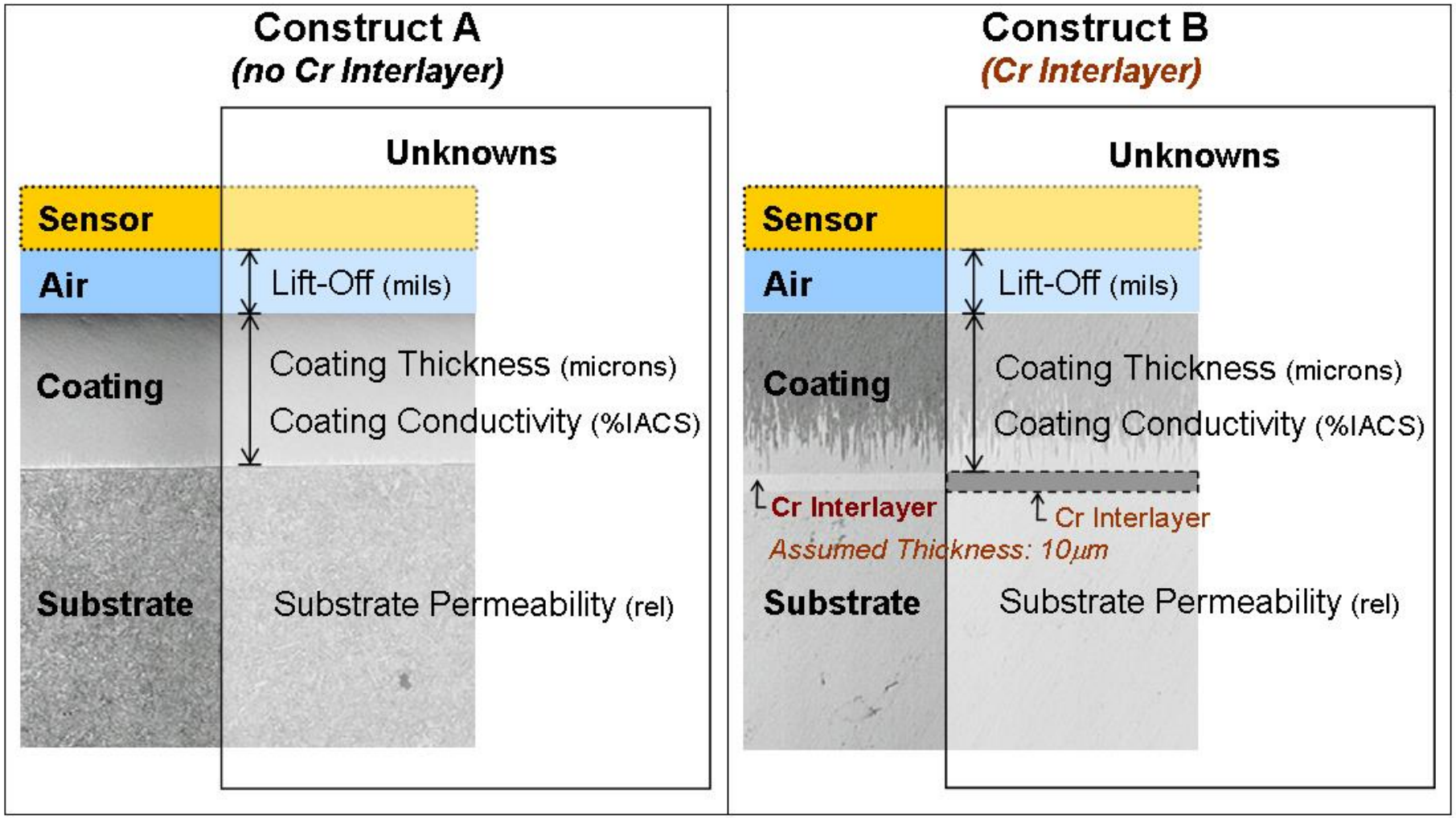
μ_s, σ_s, σ_{Cr}, δ_{Cr} constant



Zilberstein, V., Evans, L., Huguenin, C., Grundy, D., Shay, I., Goldfine, N., Mulligan, C., **"Quality Assessment of Refractory Protective Coatings using Multi-Frequency Eddy Current MWM-Arrays,"** QNDE Conference, August 2005, AIP Conference Proceedings, Vol. 25B, pp 1067-1074, 2006.

Benet Labs Problem Definition

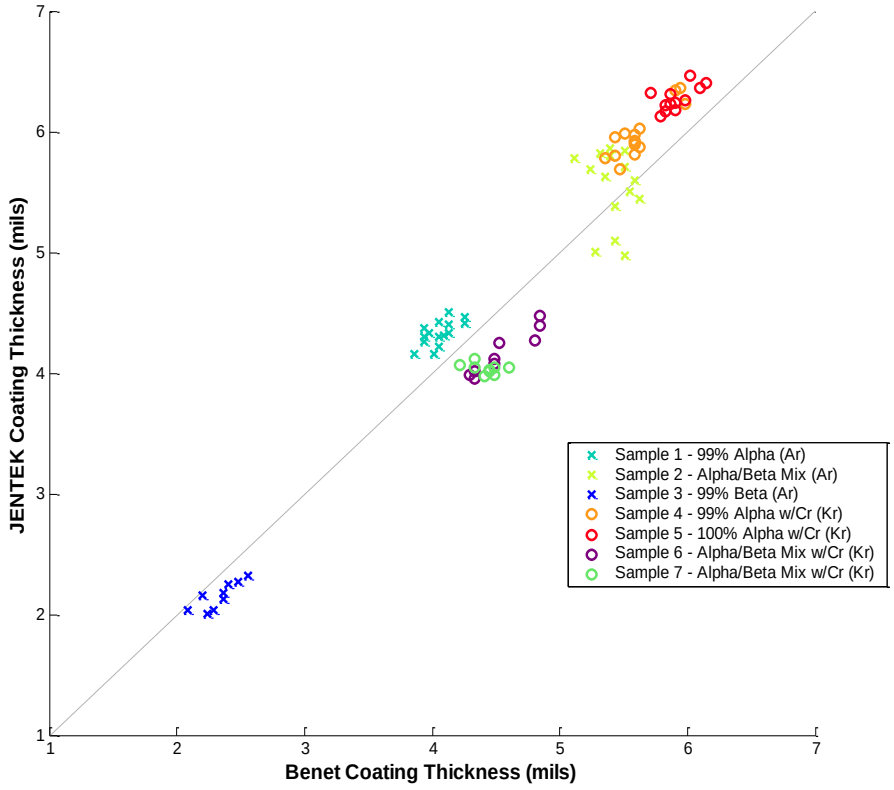
Schematics of 4-Unknown Constructs



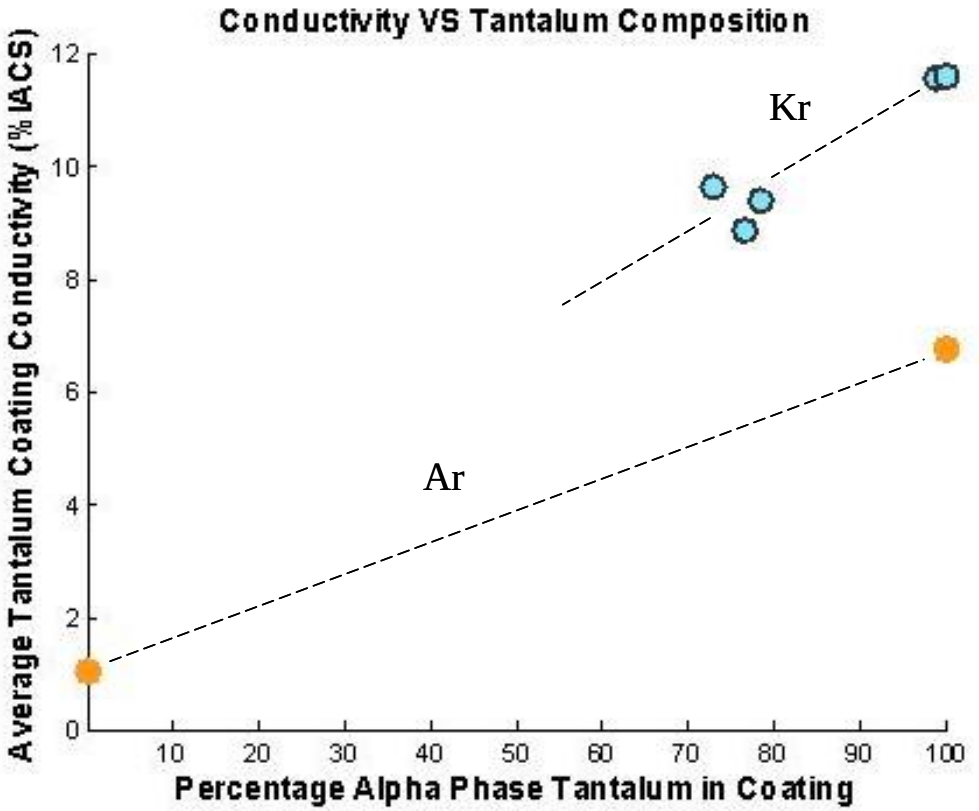
Zilberstein, V., Evans, L., Huguenin, C., Grundy, D., Shay, I., Goldfine, N., Mulligan, C., **"Quality Assessment of Refractory Protective Coatings using Multi-Frequency Eddy Current MWM-Arrays,"** QNDE Conference, August 2005, AIP Conference Proceedings, Vol. 25B, pp 1067-1074, 2006.

Benet Labs Program Results

MWM-Array Measured Tantalum Coating Thickness Values



Conductivity vs. Phase Composition for Tantalum Coatings

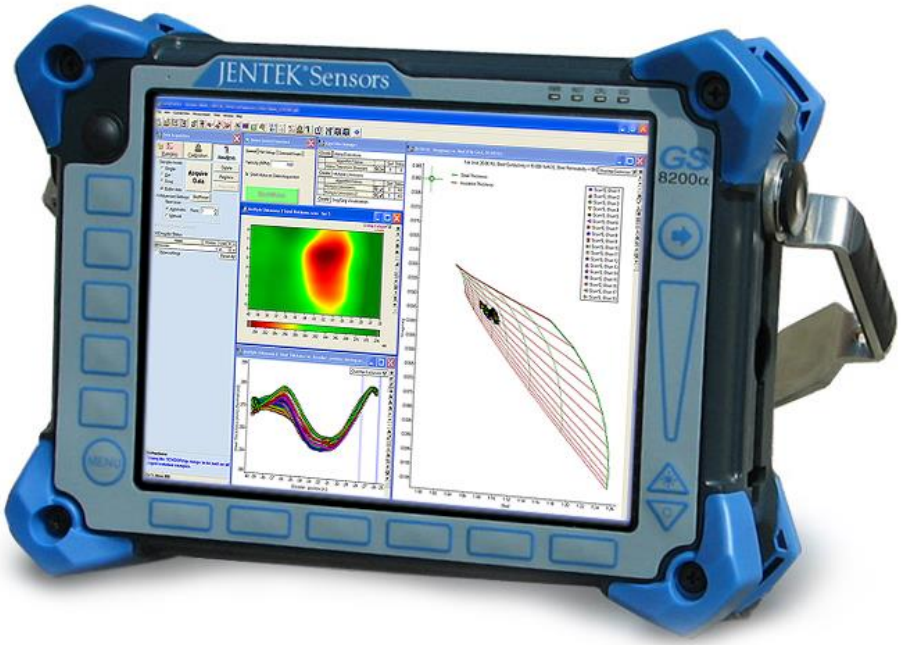


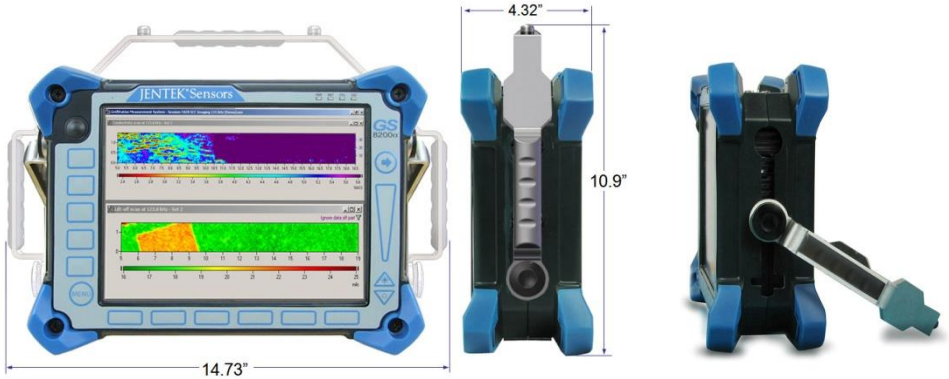
Zilberstein, V., Evans, L., Huguenin, C., Grundy, D., Shay, I., Goldfine, N., Mulligan, C., **"Quality Assessment of Refractory Protective Coatings using Multi-Frequency Eddy Current MWM-Arrays,"** QNDE Conference, August 2005, AIP Conference Proceedings, Vol. 25B, pp 1067-1074, 2006.

GridStation 8200α System

Available for purchase as commercial product in early 2014

- 19 to 118 channel standard configuration
- 100× faster
- 10× Improved signal-to-noise
- 5Hz - 20MHz operating frequency
- Windows® 8 operating system
- Intel Core i7, 3rd gen
- Multi-touch screen
- Weight: 8 lbs.
- Weight with probe electronics unit (PEU): 12 lbs





Questions?

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