Overview of USAF NDE R&D Activities

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Integrity ★ Service ★ Excellence

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AFRL/RXCA

Materials State Awareness and Supportability

VISION

Reliable, Quantitative, Nondestructive Materials and Damage Characterization, Regardless of Scale

MISSION

Lead, discover, develop and deliver material and damage characterization technologies to assure maximum reliability and availability of current and future Air Force Systems

Sustainment

Aging Fleet

Key to Safety

Enabling CBM + Prognosis

Advanced Materials

Future Systems

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What we are trying to avoid

Mr. Chuck Babish, 2008 presentation

- **NDI is critical to ASIP execution and relied on for safety**
- **NDI workforce is stressed/departing**

Mr. Ted Fecke, 2011

- **NDE/I is critical for any RFC activity**

NDE / NDI

- **Critical element of ASIP and PSIP -- safety inspections!**
- **Used as a Risk Management tool (to lower/achieve acceptable risk)**
- **Attributes of RX's NDE/I Activities to meet USAF needs**
  1. Maintain NDI infrastructure for field locations (TOs, training, etc)
  2. Engineering developments for short-term needs / rapid response
  3. **NDE/I research**
     - **Capability, Reliability, and Efficiency gains**
     - **Enabler for CBM+ and HVM**
       … must know the condition of the aircraft
     - **Discover methods to evaluate advanced materials**
       … initial and changing states

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What are we doing?

Better NDI/E

- **Enhance capability … to detect damage**
- **Improve reliability … of detecting damage**
- **Increase efficiency … in inspection processes**

Highlights

- **Improved Eddy Current Tools**
- **Damage Detection of Multi-Layered Structure**
- **Remote / Limited Access Inspections**
- **Damage Characterization for Turbine Engine Components**
- **NDE of Composite Materials**
- **Digitally Enhanced NDI – *Future Program***

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Improved Eddy Current Tools

Motivation

- Increasing NDI workload as aircraft age
- Routine inspections can be slow and variable
- Increased information desired by decision makers

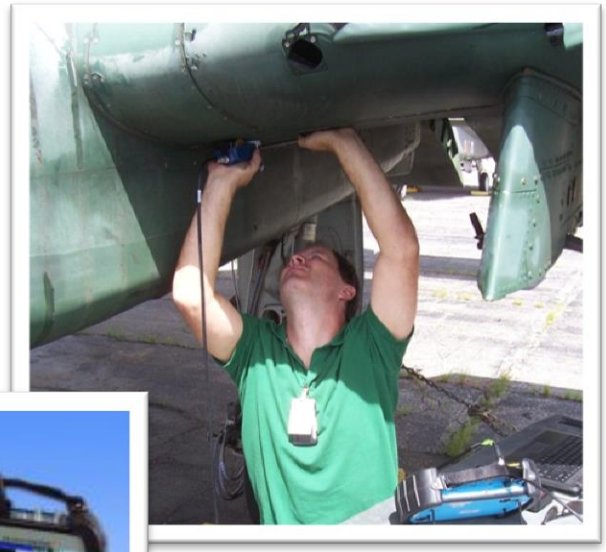
Goal: **More efficient and capable inspection**

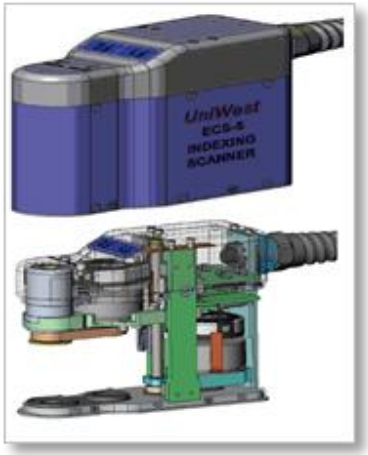
Approach **– New tools for their toolkit**

- Conformal EC probe kits
- Flush head scanning system
- Advanced bolt hole scanner
- Prototypes - trials by the end user
- Validate capability / POD studies

Payoff

- **Reduced MX burden**
- **Easier inspection processes**
- **More complete data/information**





Better capability in tools that are easy to use, reduce variability, & provide better data

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Damage Detection in Multi-Layered Structures

Motivation

- Growing requirement to inspect internal surfaces of multi-layered structures
- Significant MX burden to gain access
- Low frequency EC from outer surface often inadequate

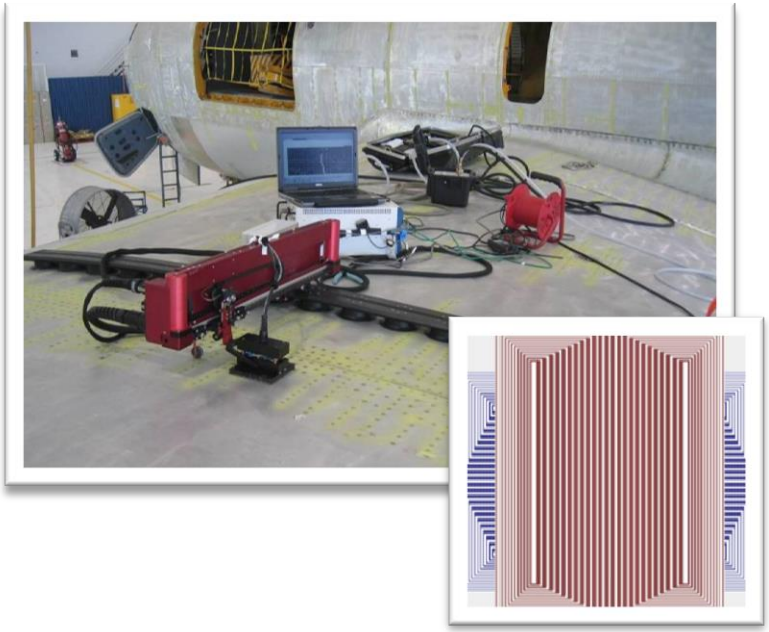
Goal: **More efficient and capable inspection**

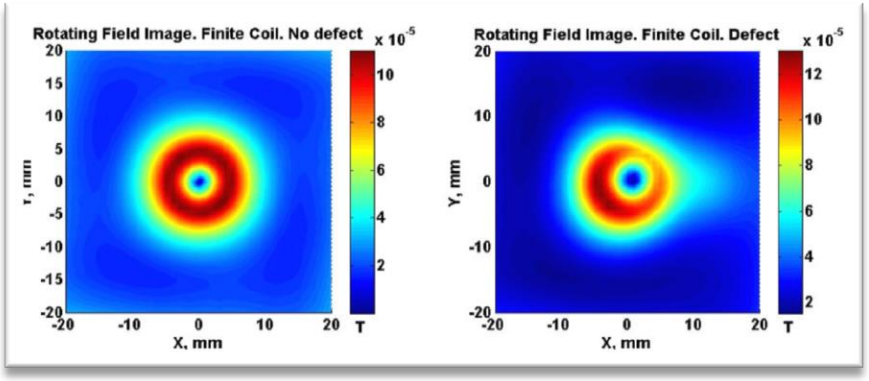
Approach **– MR Sensing**

- Model-driven sensor design
- Model-driven signal processing
- Verify model driven approach
- Prototype demonstration
- Integrate into mobile automated system (MAUS)
- Validate capability (POD study)

Payoff

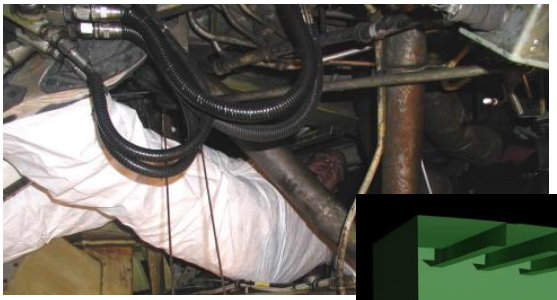
- **Reduced MX burden**
- **Easier inspection processes**

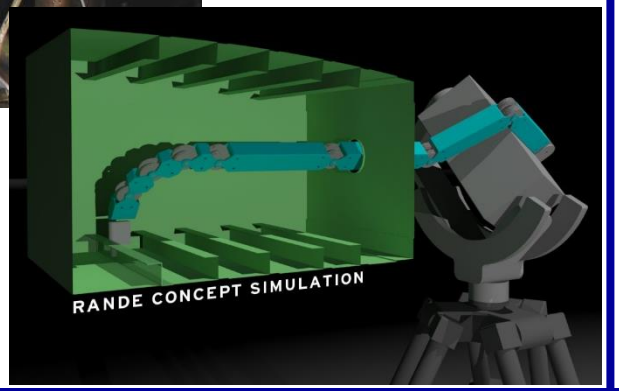




Provide better capability integrated into familiar equipment

Remote Access Non-Destructive Evaluation (RANDE) Program





Challenge

- **ASIP-required inspections in limited-access areas often necessitates structural disassembly or inspectors working in confined spaces**
  - **Time/cost/structural integrity penalties**

Objective

- **Reliable tools for confined space inspection**

Schedule

Calendar year	13	14	15	16
Kick-off meeting & ALC visits	▲			
Master Requirements Document		▲		
Alpha prototype			▲	
Beta prototype				▲
Final report				▲

Approach

- **Develop a robotic inspection capability**
  - **Situational awareness**
  - **Integration of the NDE probes**
  - **Positioning of the EC probes**

Status

- **Master Requirements Document (Jan 2014)**
- **Design Review (Jun 2014)**
- **Alpha Prototype (Jan 2015)**

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Damage Characterization for Turbine Engines

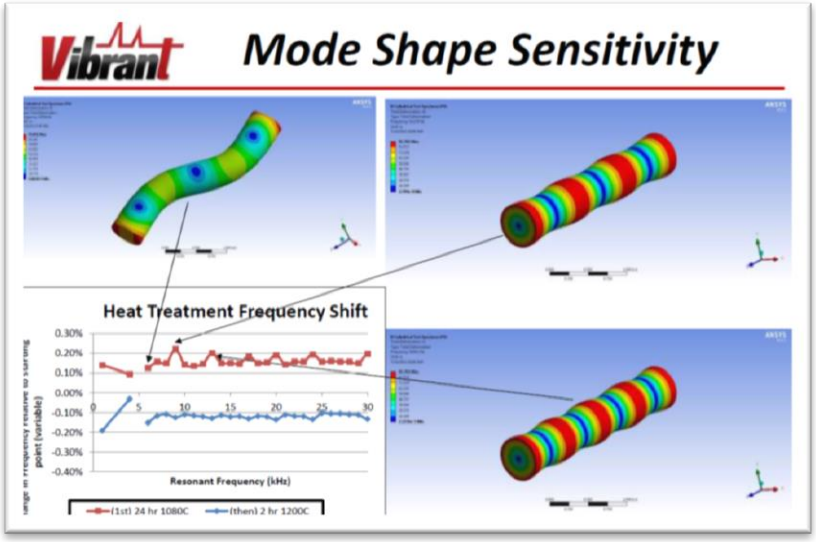
Motivation

- Eddy current: very good capability, but can be very slow
- FPI: Time consuming and generates hazardous waste

Goal: **Quick and accurate inspection of components**

Approach **– Whole-field inspection**

- Sonic IR
  - Develop and validate system for blades
  - Basic understanding of heating mechanisms
  - Explore application to larger parts (disks)
- Process Compensated Resonance Testing (PCRT)
- Model-driven design and data interpretation
- Validate inspection capabilities / POD



Payoff

- **Reduce MX burden**
- **Eliminate hazardous waste stream**
- **Extension of component lives**

Reduce MX burden & improve disposition decisions

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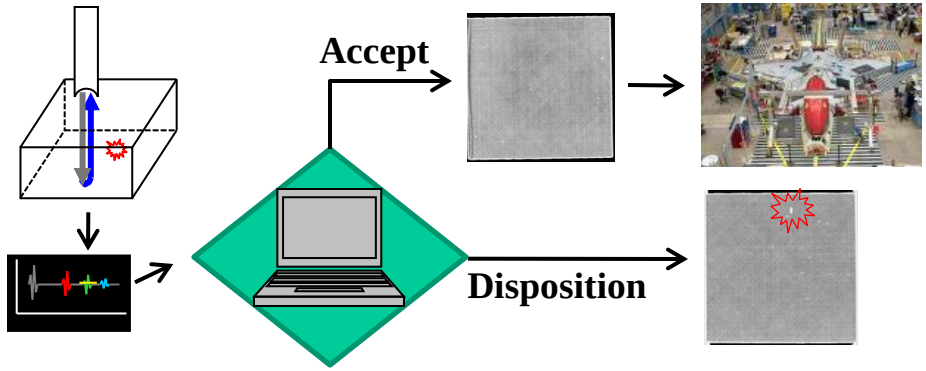
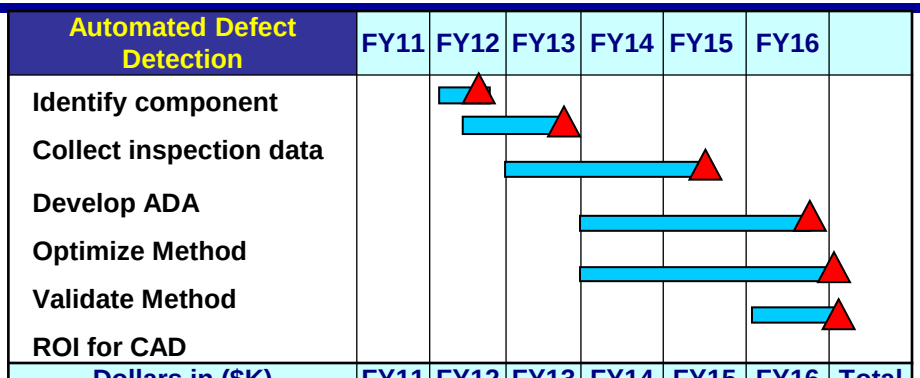
Automated Data Analysis (ADA)
Ultrasonic Inspection / Composite Materials



John Welter, DSN 785-9798, john.welter@wpafb.af.mil



Dollars in ($K)	FY11	FY12	FY13	FY14	FY15	FY16	Total
OSD MS&T MT	2M	0	0.75M	0	0		2.75M
AF ManTech					0.15M	0.35M	0.5M
Total	2M	0	0.75M	0	0.15M	0.35M	3.25M

DoD Problem

- **100% ultrasonic inspection required for composite component acceptance**
- **Manual analysis of ultrasonic inspection data is a bottleneck for full-rate production**

Approach

- Team with OEMs, key suppliers, SPOs, other services
- Identify critical, high payoff component/inspection
- **Develop & demonstrate universal methodology with tailorable component/inspection specific attributes**
- **Establish coordinated implementation plans**

Benefits

- **Decrease Inspection Time**
  - Remove production bottleneck
  - Accelerated acceptance of production components
- **Minimize Human Inspector Interaction**
  - Decrease manual analysis burden
- **Increased inspection repeatability/reliability**

Eliminates production rate constraints due to inspection requirements for part acceptance

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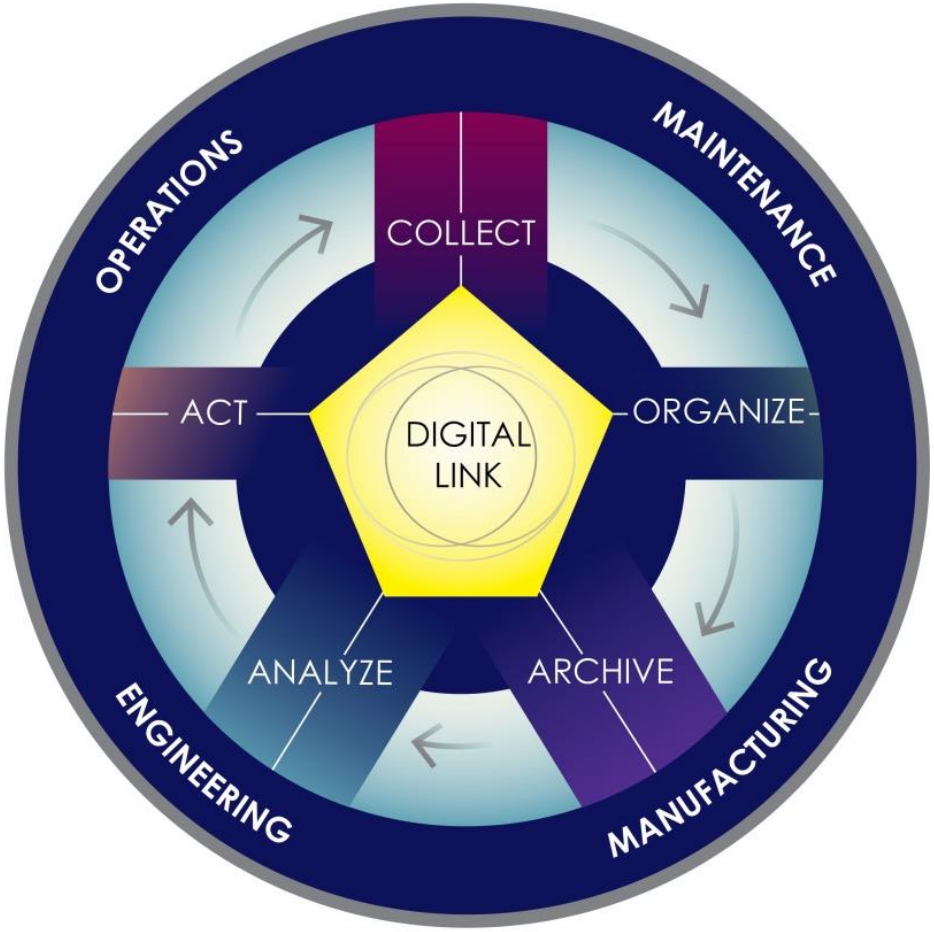
Digitally Enhanced NDI



Act: Physical act of performing NDI

Collect: Documenting results from these actions – collecting data

Organize: Structuring data in manner that can be most useful

Archive: Storing data in such that it can be quickly accessed, now and later

Analyze: Interpreting data in order to derive the best course of action

Act: Corrective actions and/or changes based on the analysis

Strong tie to AFRL's Digital Twin & Digital Thread Initiatives

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NDE / NDI

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Material State Awareness (MSA)

Reliable, Nondestructive, Quantitative Materials / Damage Characterization, Regardless of Scale

- Complete characterization!
  - Macro scale (i.e. cracks and corrosion)
    - Detect … Locate … Size
  - Micro scale (e.g. microstructure)
- Metals, PMCs, CMCs
- Statistical metrics / uncertainty quantification

MSA is our vision for the future of NDE

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In-House Research Challenges

Integrated Computational and Experimental Research

- Modeling and simulation vital
- Variability / confounding factors
- Validation

macroscopic service damage characterization

smaller & incipient damage

initial & evolving (micro)structure characterization

processing - microstructure evolution

residual stress

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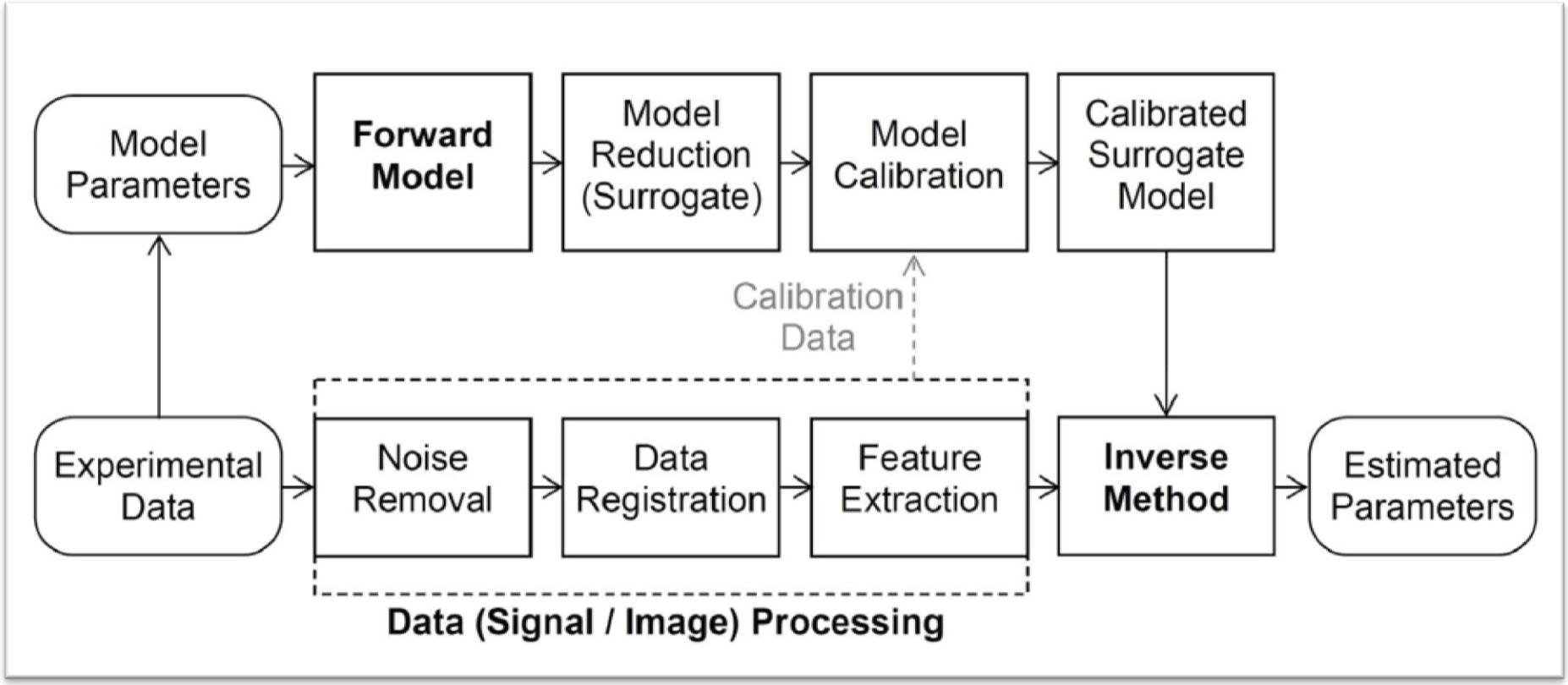
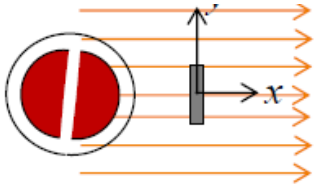
Crack Sizing

- **Modeling is crucial – both forward and inverse models**

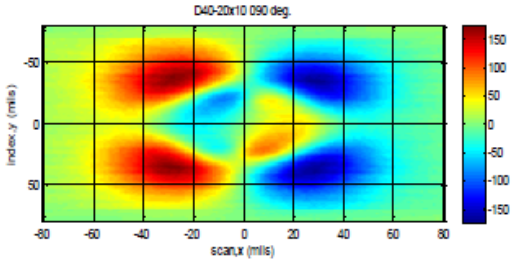


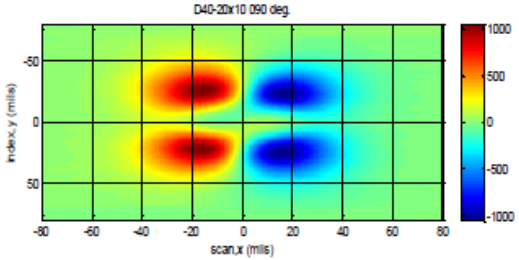
Example
Forward Model - Effect of Probe Orientation

Parameters: 20x10x1.2 mil notch, D40 Probe,
Tangential (90°) Orientation: 5°

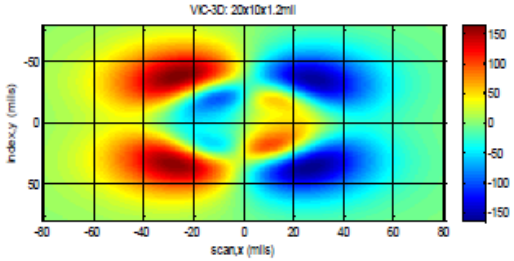


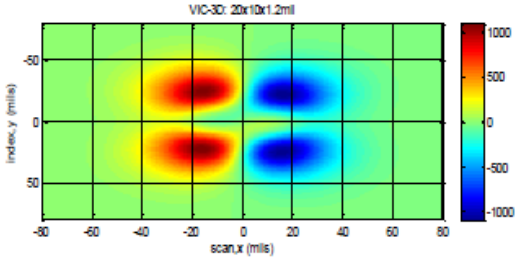
Experimental:





Model:





Must understand and compensate for the variability

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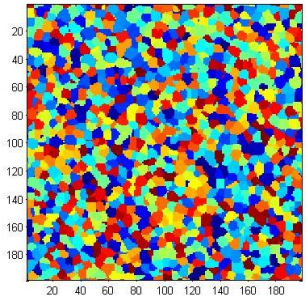
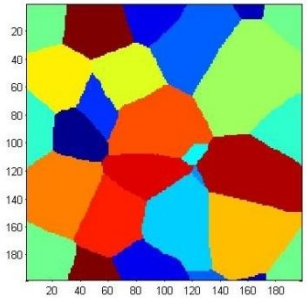
Microstructure Characterization

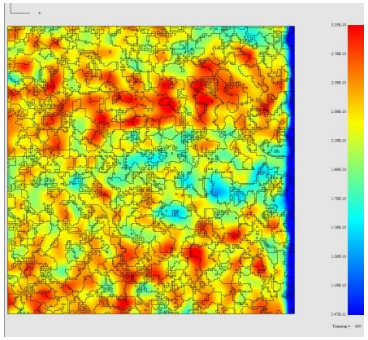
- **Ultrasonic characterization of grain size in Ni and Ti alloys**



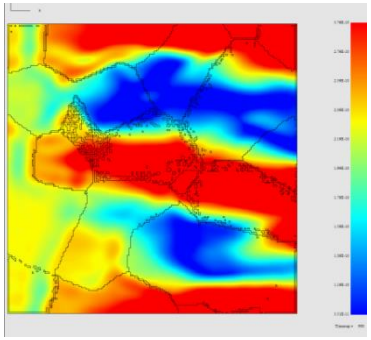
Mean grain size
~ 7 μm
Image 0.2 x 0.2 mm



Mean grain size
~ 60 μm
Image 0.2 x 0.2 mm



Peak
amplitude
image,
d ~ λ/4



Peak
amplitude
image,
d ~ 2λ

Predictive energy flux deviation for ultrasonic characterization

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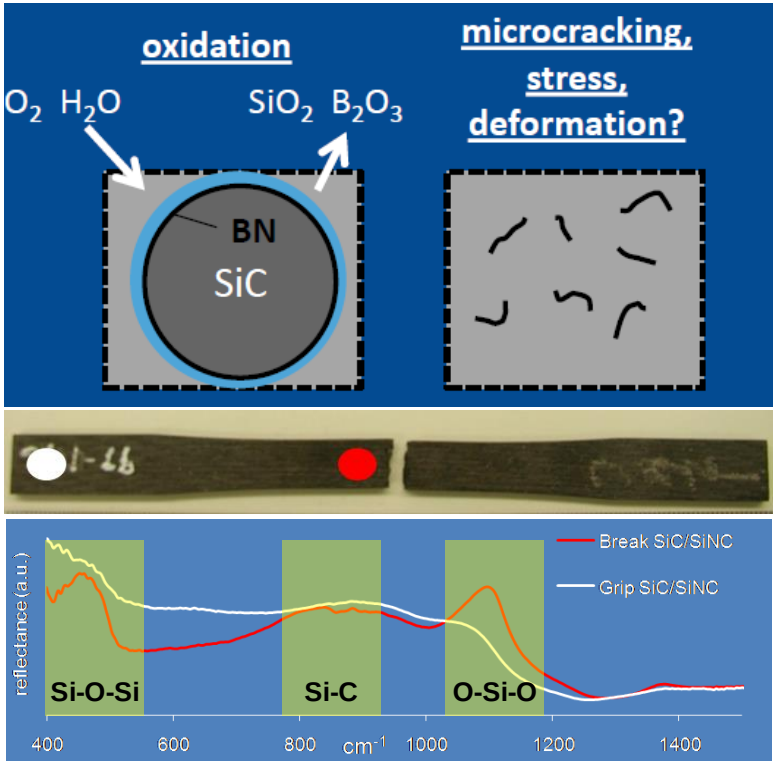
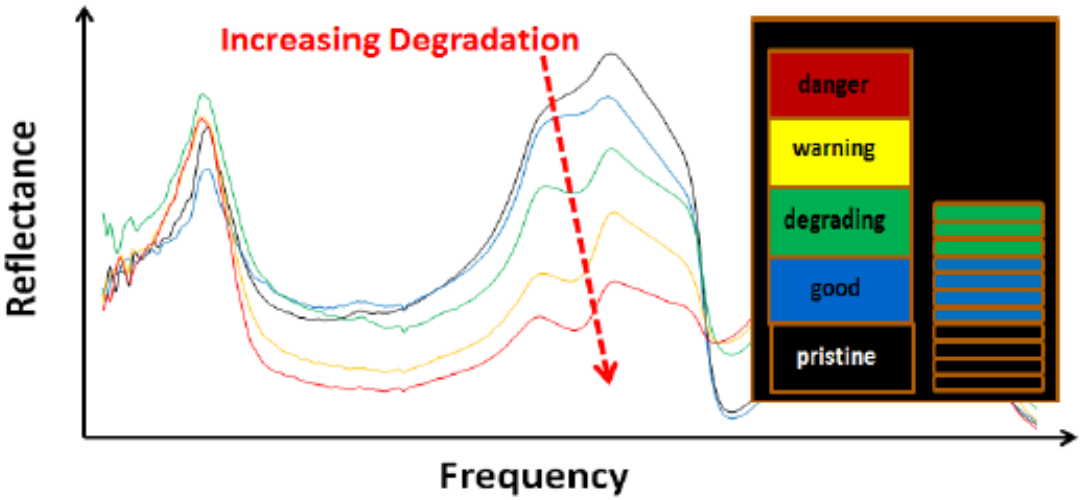
CMC Degradation

- **Spectroscopy to detect subtle chemical changes with temperature exposure**





Need to correlate with degradation of mechanical properties

Summary

- **Nose-cone to rudder, cradle to grave, NDE touches entire aircraft**
  - Sustains current capability
  - Enables future capability
- **Model-centric strategy to realize future capability**
  - Assess condition, not just detect
  - All dimensional scales
- **Broad-based impact to improve availability of high performance, capable, and safe USAF systems**
- **New approaches for materials characterization**
  - Materials development/tailored properties validation
  - Processing enhancements via property measurement and feedback

Capability, Reliability, and Efficiency

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QNDE Presentations – Next Week in Boise

Desirements and Requirements for NDE for Characterization: an AFRL Perspective, Lindgren (RXCA)

Computational NDE as an Integrated Component of ICMSE, Blackshire (RXCA)

Optimization of Coil Design for Near Uniform Interrogating Field Generation, Su (MSU)

Image Processing Algorithms for Automated Analysis of GMR Data from Inspection of Multilayer Structures, Safdarnejad (MSU)

Resonance Ultrasound Spectroscopy Forward Modeling and Inverse Characterization of Nickel-based Superalloys, Biedermann (Vibrant)

Progress on Automated Data Analysis algorithms for Ultrasonic Inspection of Composites, Aldrin (Comp Tools)

Realistic Split D Differential Probe Model Validation, Mooers (RXCA)

Modeling the Effects of Core/Coil Size and Defect Length on Eddy Current Response, Mooers (RXCA)

Role of Interface Conditions in Low Frequency Electromagnetic Testing of Multilayer Structures, A Cherry (RXCA)

Separation and Analysis of Incident and Scattered Waves in Angle-Beam Wavefield Data Alexander, Dawson (GaTech)

Damage Localization Using Ultrasonic Methods in Multi-Layered Metallic Structures, Hopkins (BERCLI)

Case Study on NDE Characterization Metrics for Optimization, Validation and Quality Control, Aldrin (Comp Tools)

Forward Propagation of Parametric Uncertainties Through Models of NDE Inspection Scenarios, M Cherry (RXCA)

Assessing Inversion Performance and Uncertainty in Eddy Current Crack Characterization Applications, Aldrin (Comp Tools)

Demonstration of Model-Based Inversion of Electromagnetic Signals for Crack Characterization, Aldrin (Comp Tools)

Stochastic Inverse Problems: Models and Metrics, Sabbagh (Victor Technologies)

Evaluation of Thermal Properties from Non-Contact Acousto-Thermal Signature (NCATS) Analysis, Criner (RXCA - UDRI)

A Synthetic Aperture Routine to Approximate Rayleigh Wave Surface Imaging Scans Over Anisotropic Media, M Cherry (RXCA)