INSPECTION SIMULATION TOOLS: DESIGN, OPTIMIZATION AND ASSESSMENT FOR AIRWORTHINESS ASSURANCE

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CENTER FOR NONDESTRUCTIVE EVALUATION

- ***Impact*:** To establish and maintain the safety and reliability of critical engineering systems at minimum cost
  - Use of noninvasive testing methods to detect defects and damage, characterize material state, and/or monitor process parameters
- ***CNDE Approach:*** Develop and implement industrially relevant NDE solutions thru foundational theoretical and experimental research that impact government and industry
- ***Relevant Industrial Sectors:***
  - Aerospace (Commercial and Military Aviation) and Defense Systems (Ground vehicles and personnel protection)
  - Energy (Nuclear, Wind, Fossil)
  - Infrastructure and Transportation (Bridges, roadways, dams, levees)
  - Petro-Chemical (offshore, processing, transport piping)
- ***CNDE capabilities*:** Physics-based models, inspection development, systems development, reliability analysis, e.g. probability of detection (POD) studies, NDE education.

CENTER FOR AVIATION SYSTEMS RELIABILITY

- *Comprehensive program that deals with life cycle inspection needs for aviation systems from design to production to operation/inservice use*
  - *Inspection Methods and Tools to Ensure Materials Integrity*
  - *NDI for Crack, Corrosion and Disbond Detection*
  - *NDI for Composites and Composite Repairs*
  - *Education and Training specific to FAA personnel responsible for inspection oversight*
- *Established strong network with airlines, MRO organizations, and standards bodies*
- *Expanding activities in composites fundamentals and inspection applications*

FAA William J. Hughes Technical Center (1990 –present)
Dave Galella, Paul Swindell , Technical Monitors

ENGINE TITANIUM CONSORTIUM

- *To provide reliable and cost-effective tools for detecting cracks, inclusions, and imperfections in critical rotating materials and hardware*
- *ISU-led consortia with GE Aviation, Pratt & Whitney, Rolls Royce and Honeywell*
- *ISU provides fundamental understanding in support of engineering applications expertise at the OEMs*
- *Resulted in numerous changes to inspection practice thru out the life-cycle of jet engines*

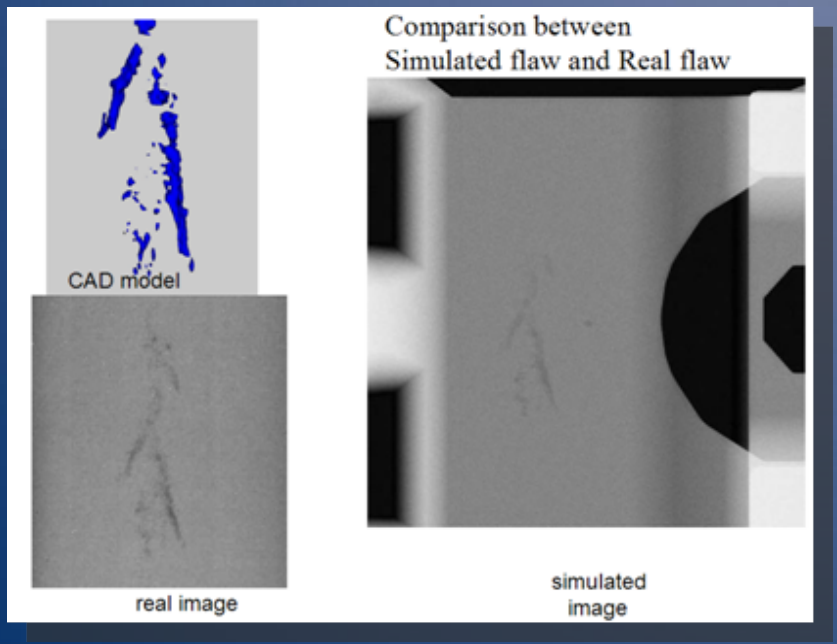
FAA William J. Hughes Technical Center (1992 – present)
Cu Nguyen, Technical Monitor

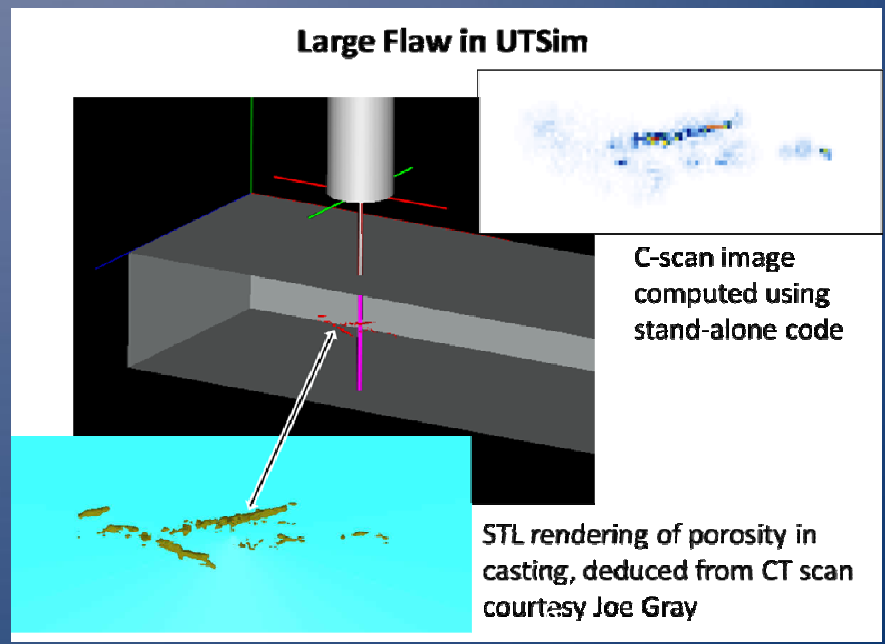
IMPORTANCE OF INSPECTION TO FAA

- *Inspection is an integral element in the continued airworthiness of today and tomorrow's fleets*
- *Numerous references in the FARs as part of certification and safe operation*
- *Airworthiness Directives (1996 - 2000)*
  - *Corrosion - 301*
  - *Cracking - 651*
  - *Composites - 7*
  - *Lugs - 54*
  - *Wiring - 187*
  - *Landing gear - 276*
  - *Visual - 946*
  - *Eddy Current - 251*
  - *Penetrant - 188*
  - *Ultrasonics - 100*
  - *Magnetic Particle - 55*
  - *Radiography - 51*

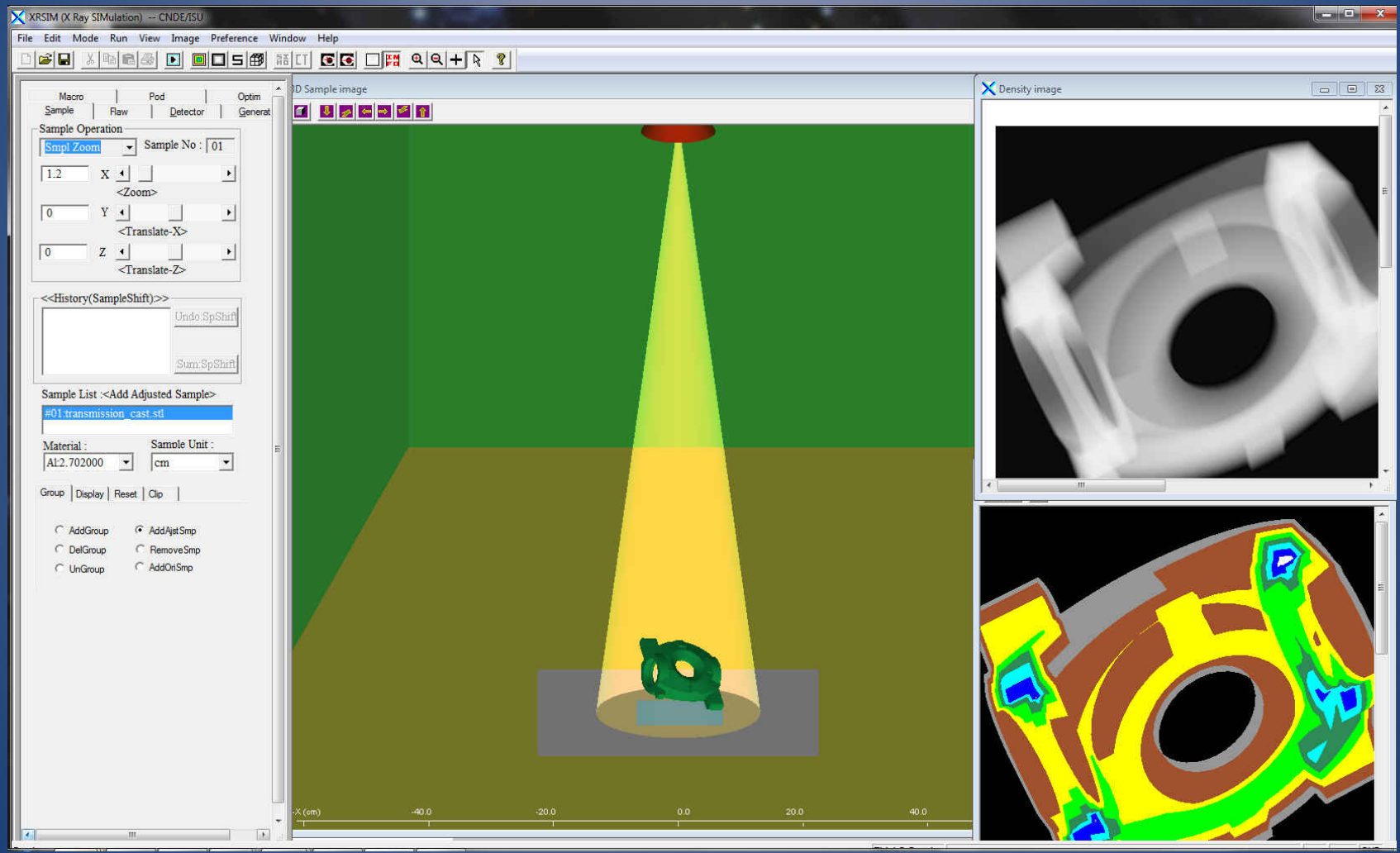
APPLICATIONS BASED ON PHYSICS

- *NDE traditionally viewed as quality assurance tool to ensure fitness for service*
  - *Drive to push for detection of small flaws (as stresses increase)*
  - *Enable life extension (retirement for cause)*
- *Model-based approaches*
  - *Simulations for inspection optimization, data interpretation, training*
  - *Materials Characterization studies were understanding of physics enables interpretation of results*
  - *Guidance in the design and interpretation of probability of detection, including formal MAPOD studies*





X-RAY RADIOGRAPHY - XRSIM



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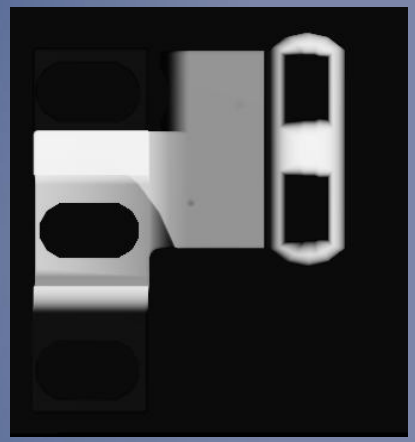
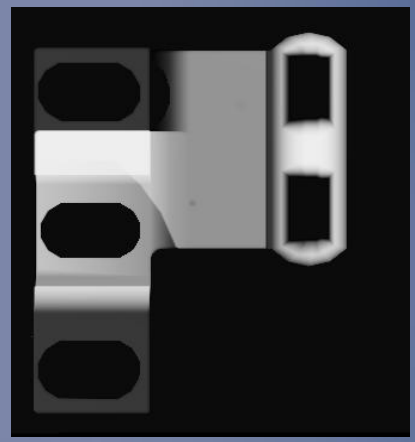
Effect of Generator Kilovoltage

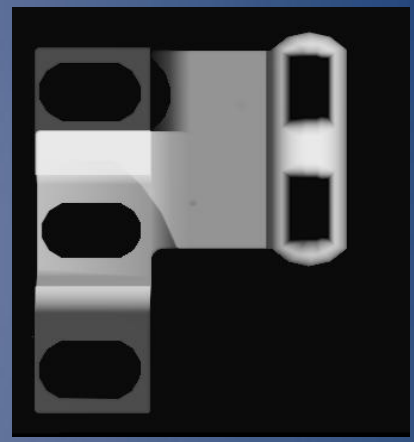
30keV
553000 mAsec



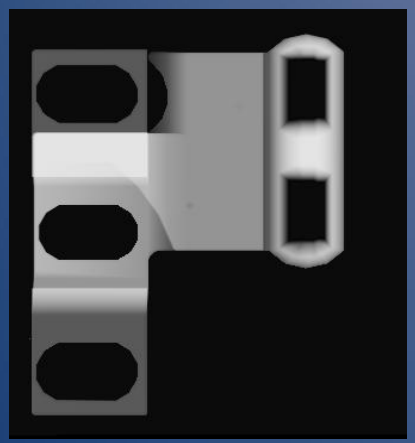
40keV
2345 mAsec



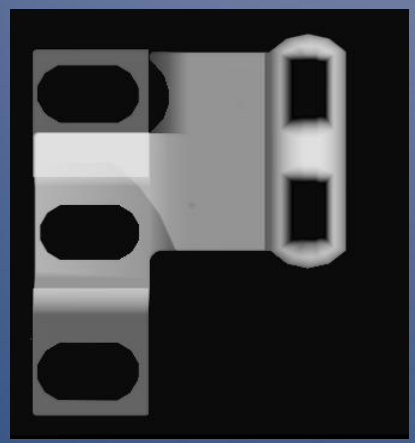
50keV
225 mAsec



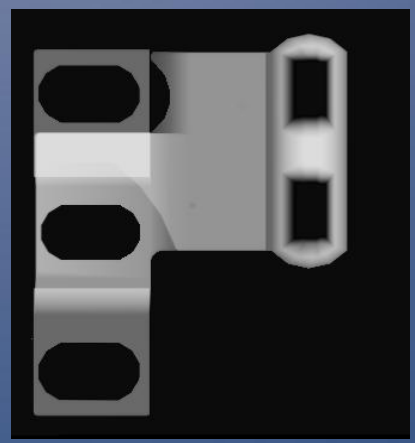
60keV
62 mAsec



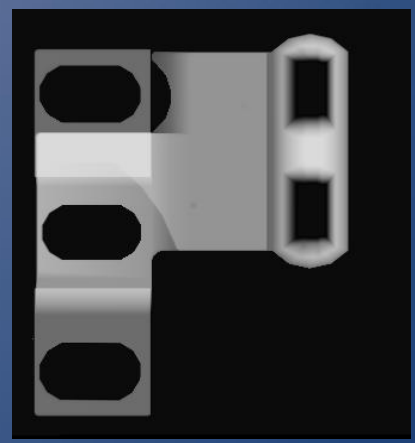
70keV
25 mAsec



90keV
9 mAsec



120keV
4 mAsec

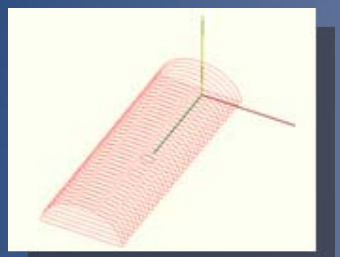
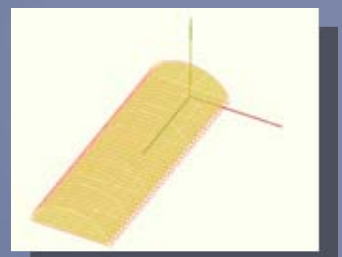
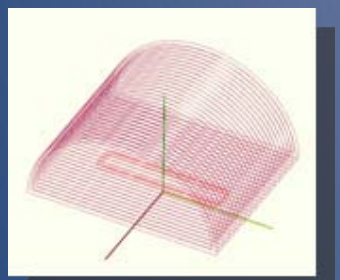
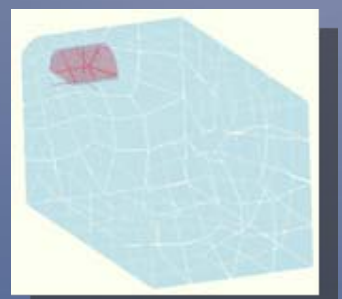
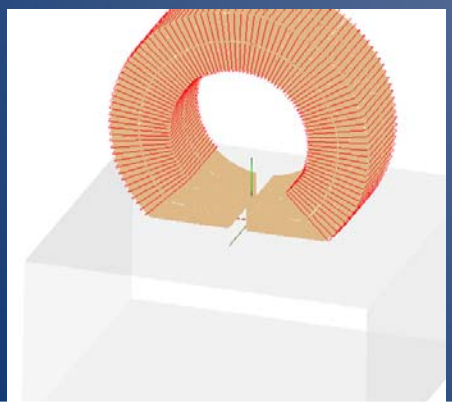
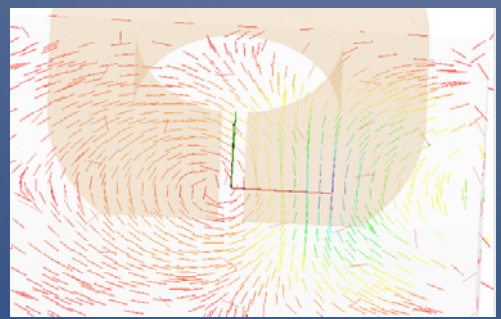


150keV
1 mAsec

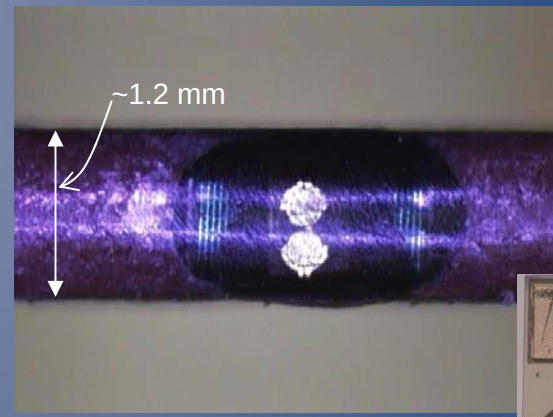
CENTER FOR NDE

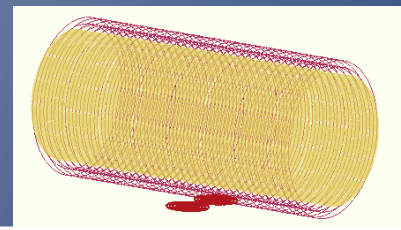
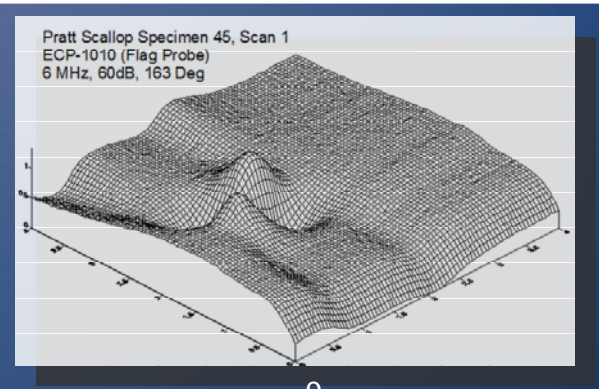
EDGE INSPECTION PROBE DESIGN ITERATION

Design iterations performed at a sponsor site

Implementation(*)



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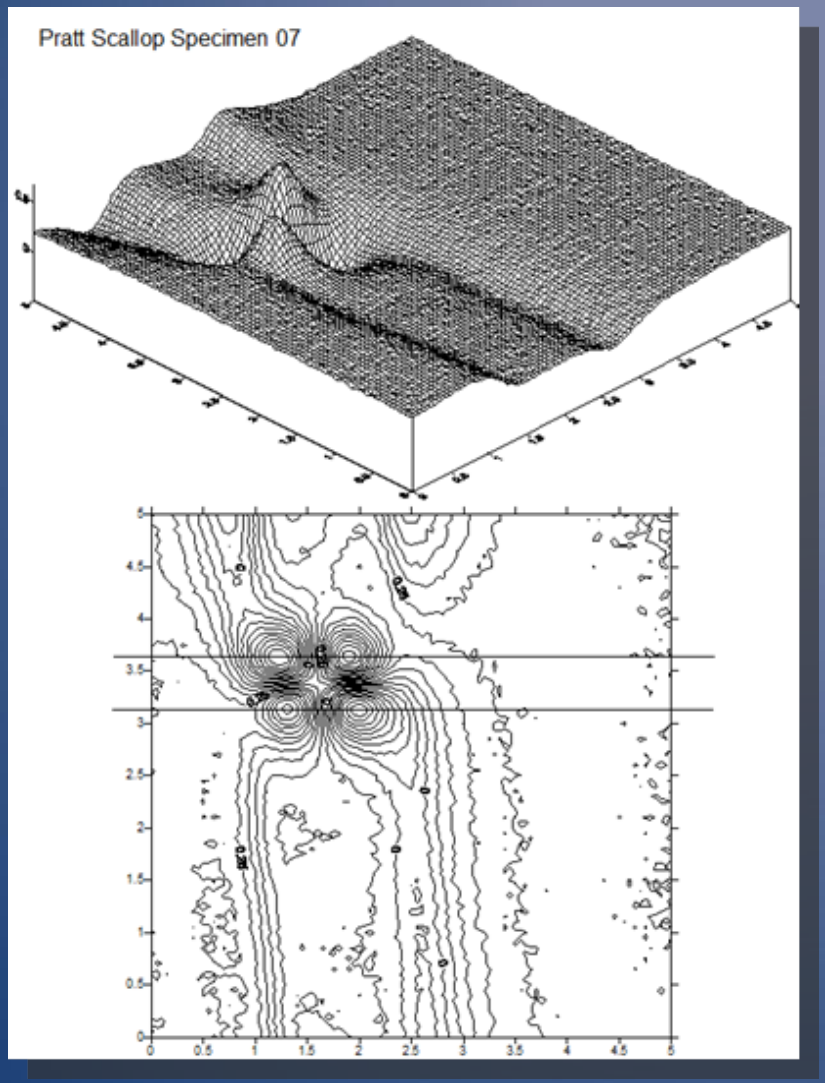
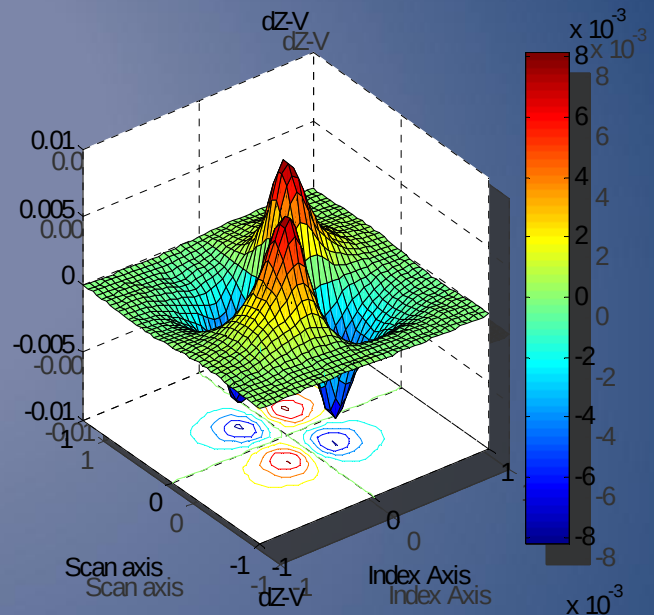
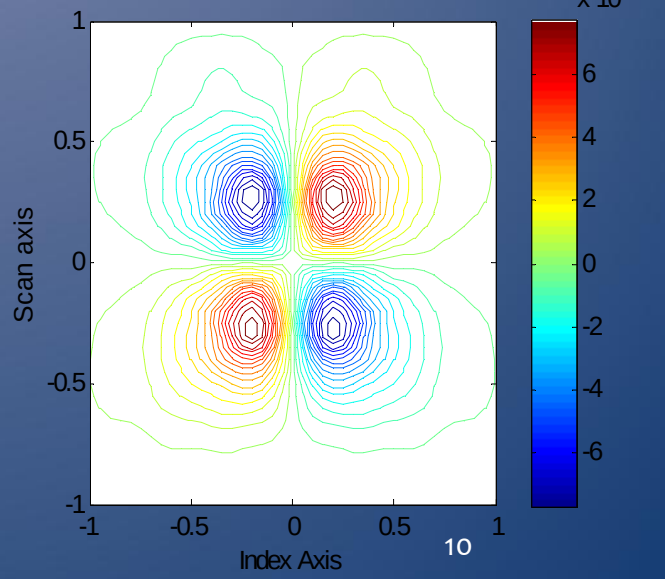
(*)Manufacturability taken into account

EXPT. VS. CALC. SPECIMEN 07







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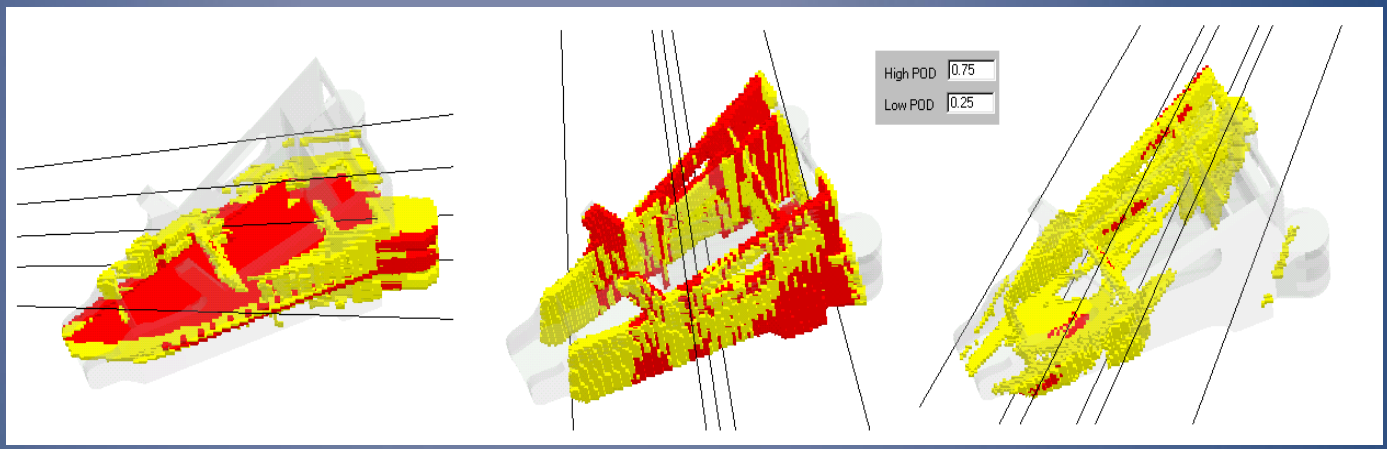
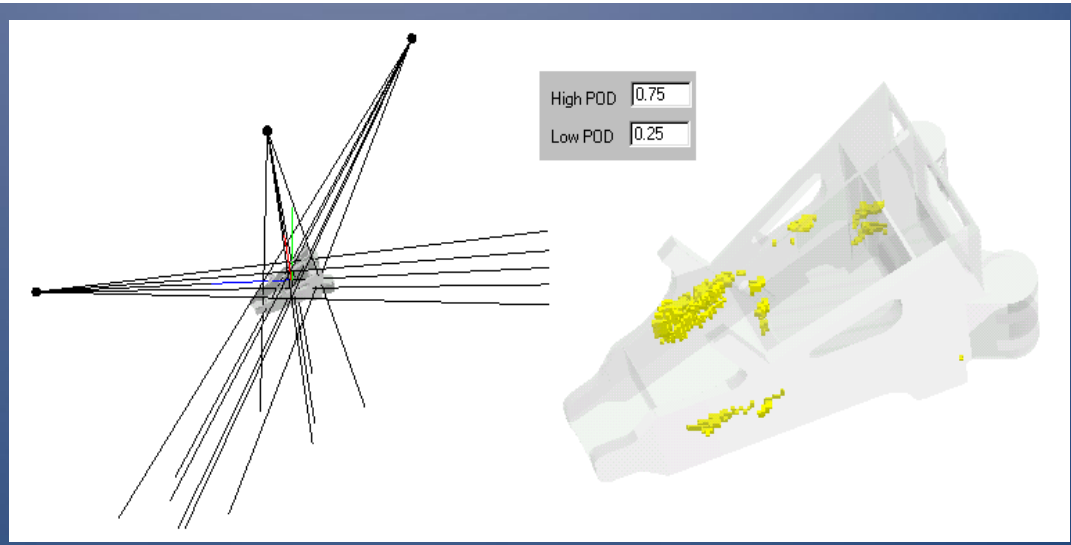
ASSESSMENT OF INSPECTION COVERAGE

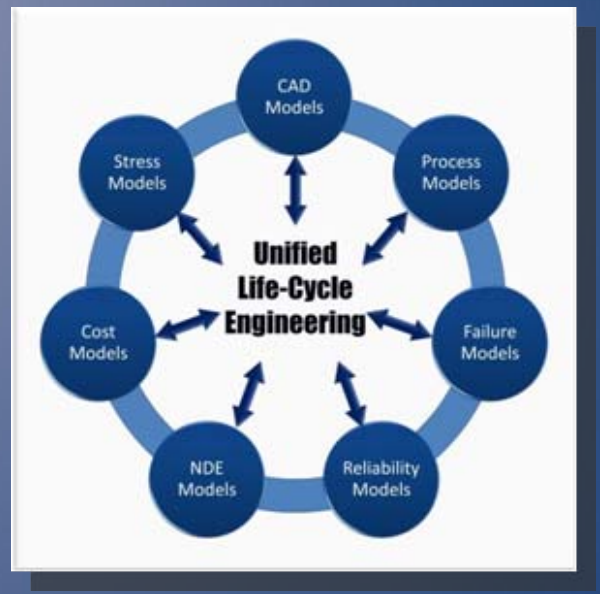




J. Gray, J. Xu

PROGRAM FOR INTEGRATED DESIGN, NDE, AND THE MANUFACTURING SCIENCES

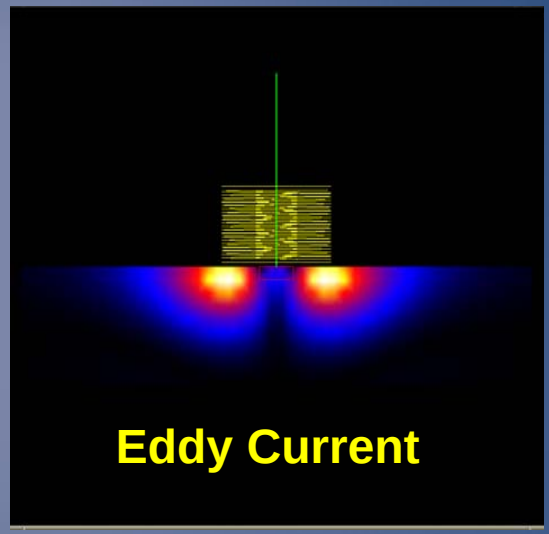
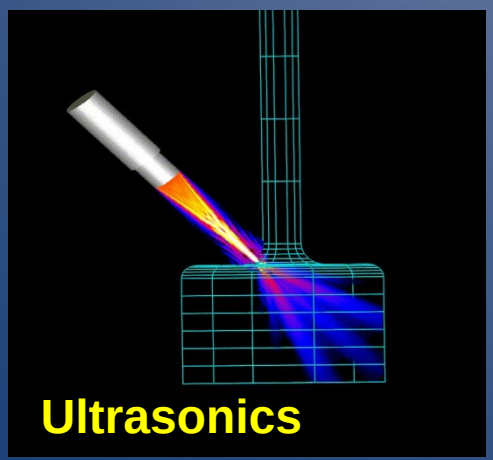
- *Developed simulation models of NDE inspections and demonstrated the power of integrating those models into a concurrent engineering approach.*
- *Allowed NDE for the first time to be included as a full member of a comprehensive concurrent engineering environment called "Unified Life Cycle Engineering"*
- *Provides framework for future integration with design and life management strategies*



NIST (1988 – 1998)
Lyle Schwartz, Technical Monitor

HUMAN RESOURCES

- *Like most technical fields in the US, NDE faces a demographic barrier*
  - *Growing number of NDE engineers and technicians are reaching retirement age without replenishing interest*
- *Increased focus needed on STEM education and recruitment/retention in NDE*

SUMMARY

- *Extensive theoretical and experimental capabilities available to support research and education needs of industry and government*
- *Numerous applications to metal airplanes as well as other aviation applications (engines, rotorcraft, etc.)*
- *Provides tools for optimizing sensors (probe design) and inspection scan plan, including model-assisted probability of detection studies*