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DRAFT FINAL REPORT
DOT Project No.:
Contract Number: 693JK31810001

Improvements to Pipeline Assessment Methods and Models to Reduce Variance

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Executive Summary

During the fourth quarter the project collaborators focused on achieving common platforms to facilitate the quantification of uncertainties and the impact of these uncertainties on assessment.

The FEM platforms used by GTI and MSU have been standardized to make it possible for transfer of 3-D models from the structural analyses focused on damage propagation to the NDE simulation process. The objective is to assess that ability of the NDE methods to resolve increases in the amount of damage present in a pipe segment due to interacting threats. The intent is to open fresh damage surfaces based on the GTI simulation of damage propagation and to feed these revised geometries to MSU for NDE simulation.

The collaboration between ASU and GTI focused on:

- Uncertainty quantification of material properties
- Methods of introducing random corrosion defects into the physical models so that interacting defects can be studied
    - Axial cracks
    - Dents with random orientation, aspect ratio and depth of dent as a ratio of pipe radius
    - Random corrosion

The methods for generating these separate defect types and combining them have been worked through and we are now ready to receive input from the TAP as to which combinations of defect types, boundary conditions and material characteristics we should focus on in the remaining two years of the project.

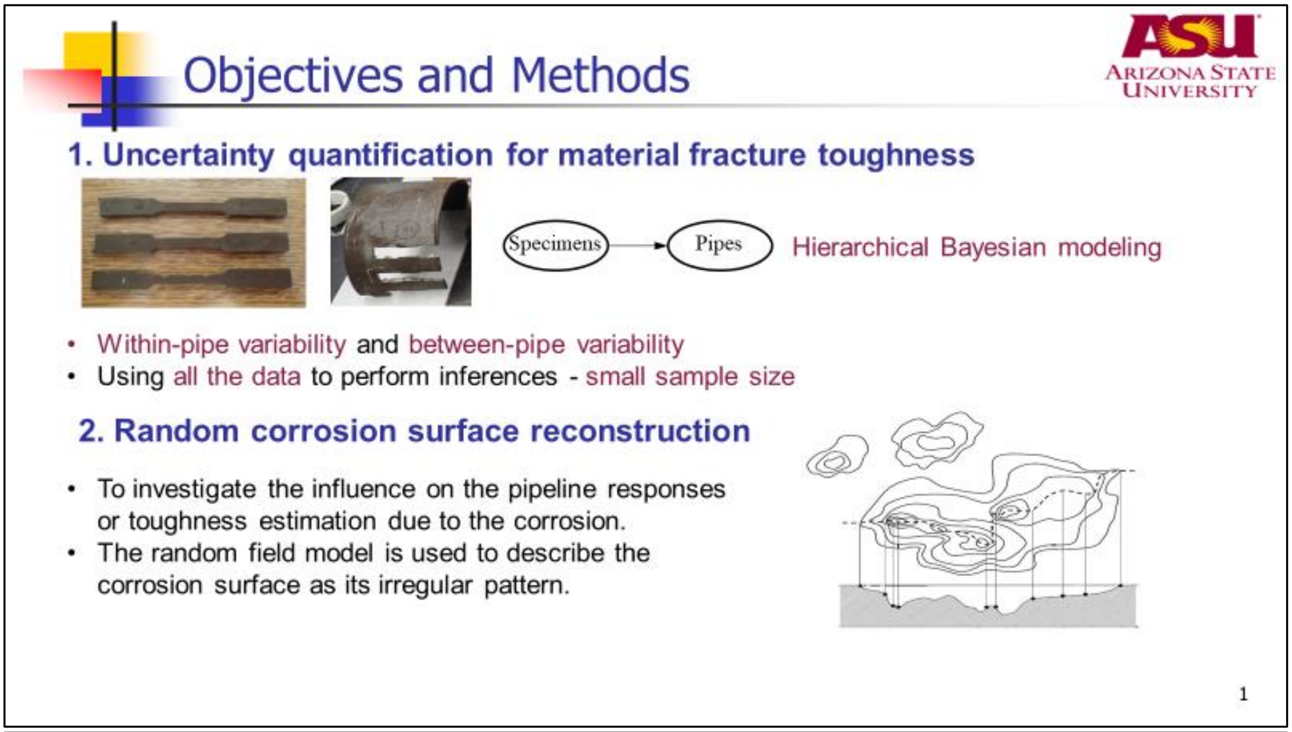
We are now ready to focus on exactly what form of guidance on uncertainty and methods to reduce uncertainty will be most useful to the industry as deliverables from this project.

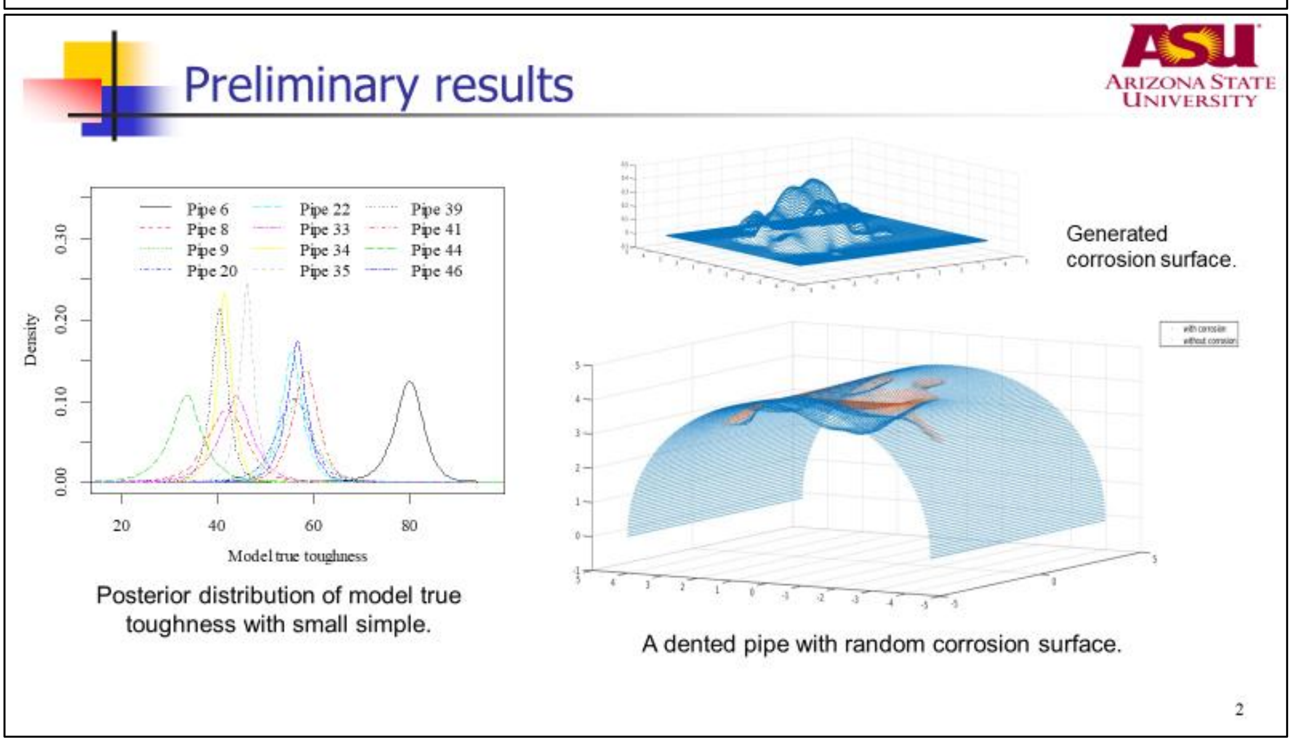
Next Steps

- Convene a web meeting with the Technical Advisory Panel (TAP) to:
    - Review the method development that has been the focus of the project in the early stages
        - Material testing
        - Damage models
        - Uncertainty quantification
        - NDE simulation
        - Full scale validation testing
    - Solicit guidance on what the project focus should be given the analysis methods we have developed
    - Solicit input from the TAP as to what the most useful form of guidance would be for the industry

- Brief summaries of the ASU, GTI and MSU work have been prepared together with the questions the three teams would like the TAP to address. These will be sent out together with a poll for suitable dates for a webinar.

ASU





Help needed

1. Fracture toughness prediction from surface measurements

Need more fracture toughness data and complete surface measurement data (chemical, grain size, hardness, corrosion pit, etc.)

2. Random corrosion surface generation.

Need real pipe corrosion data to identify the statistical information. The corrosion data file should contain the depth or the loss of materials due to corrosion at each x-y coordinate. (depth-x-y)

3. Identification of important/interested interactive threat types

Need to develop individual and joint uncertainty quantification models for each threat and their interaction/correlations

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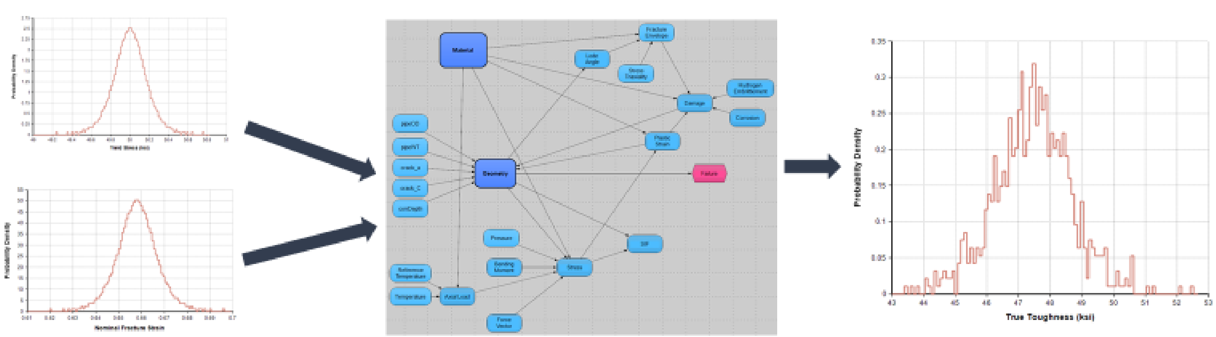
GTI

Objectives and Methods

> Develop, validate, and demonstrate improved assessment methods and models to:
  - Lower the variance of model outputs when assessing the impact of interactive threats
  - Provide enhancements in general knowledge, models, and methods pertaining to the assessment of overlapping defects in natural gas



GTI Overview 1

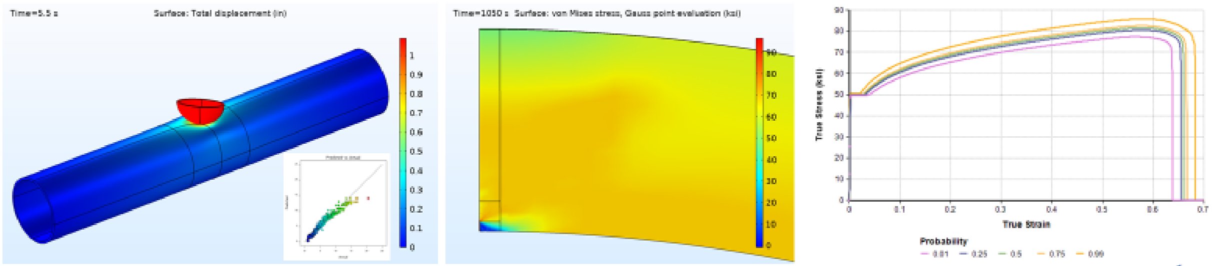
gti

Preliminary Results

> Denting simulation model created, first DoE run completed.
  - Extracted SIFs as a function of denting tool shape, dent depth, yield stress, and pressure.

> DoE of axial crack simulations with full material toughness completed.
  - With full toughness, crack propagation is minimal.

> Causal model for steel damage created.
  - Able to aggregate all uncertainties in material properties to uncertainty in material toughness



Questions for TAP

1. TAP guidance regarding which damage interactions are of interest

   We need to know which interactions are of interest, for example: denting and corrosion, axial cracks and corrosion, circumferential cracks and denting, etc.. Field data will be helpful in both the definitions of pipe deformations and defects and quantifying the uncertainties in those definitions.

2. Static (hydro-test) vs. Dynamic (impact) Toughness

   Our steel damage model can be improved with better definition of fracture strain dependence on stress-triaxiality, Lode-angle, and strain-rate. Data correlating Charpy V-notch toughness to pipe burst tests and/or field failures will be helpful.

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Objectives and Methods

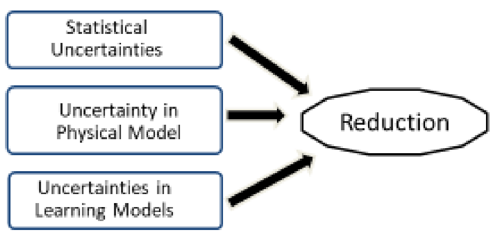
1. Physics modelling of Multi-NDE inspection technique

Multi-NDE sensing model enable us to do faster inspection with deeper signal penetration depth as well as higher sensitivity and linearity.

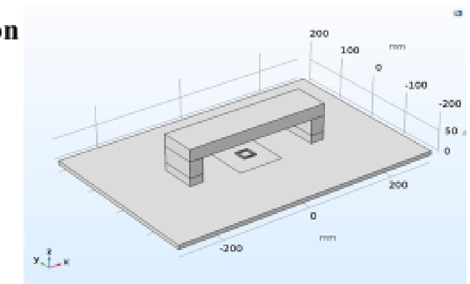
2. Dynamic updated transfer learning

Growth pattern of defect is thoroughly studied in time domain. Comprehensive scanning data source is of great interest but it is time consuming regarding simulation. Classification algorithm can be enhanced via transfer learning, whose data source is much easier to obtain.

3. Uncertainty quantification & Reduction



Sources that contribute to NDE uncertainty



Schematic design of Multi-NDE inspection framework consist of magnetic flux leakage(MFL) and pulsed eddy current(PEC) probe with material under test(MUT) underneath the scanning equipment

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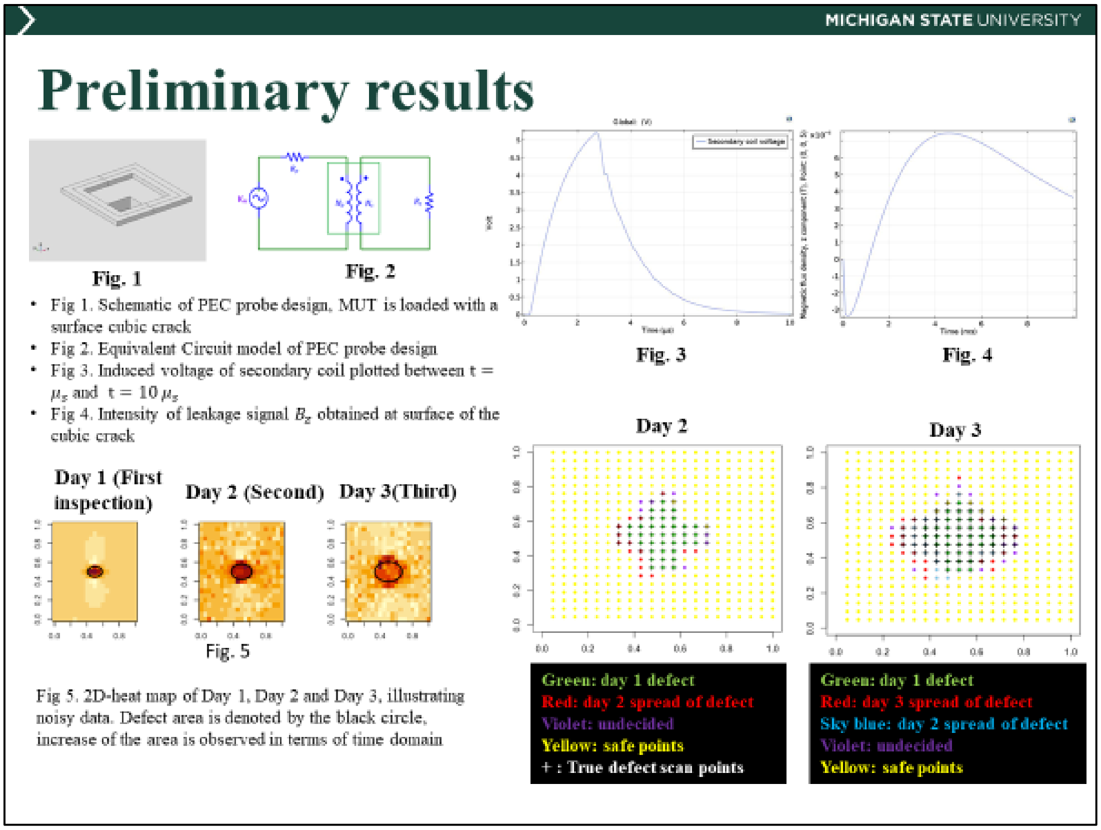
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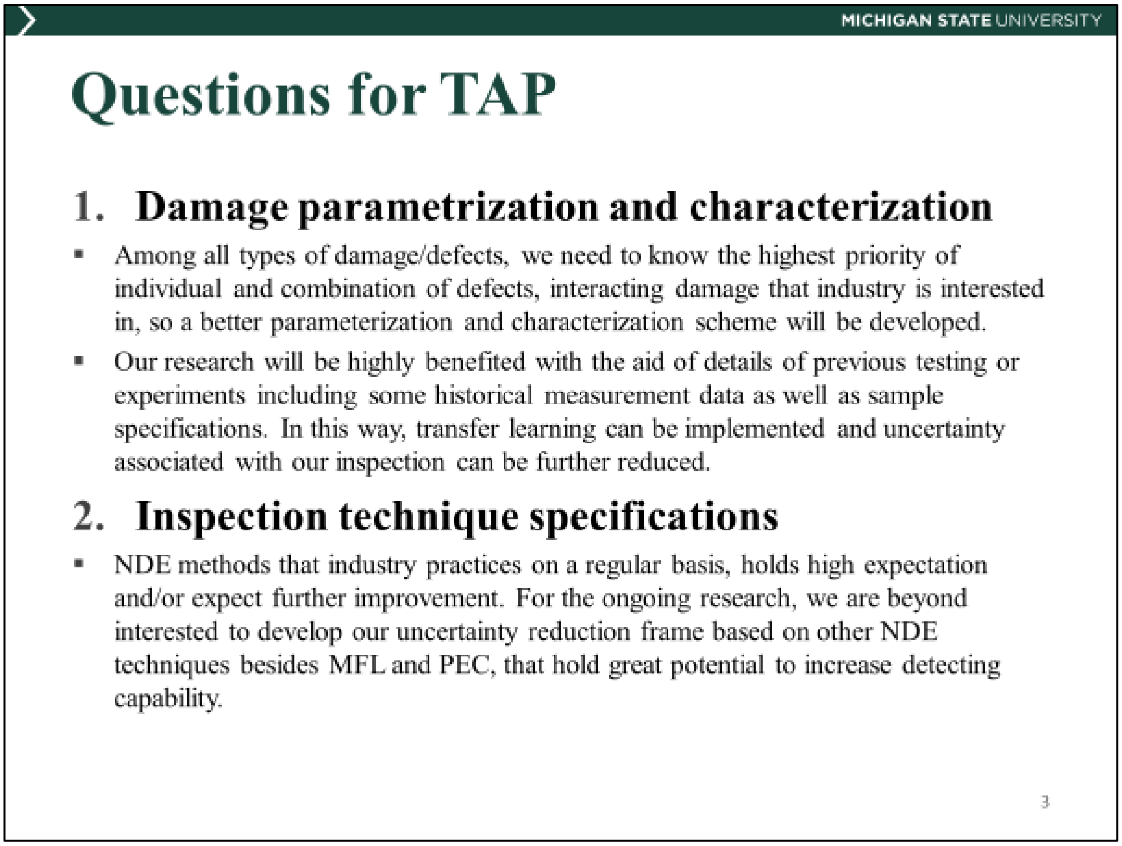
Preliminary results
Fig. 1
Fig. 2
Fig. 3
Fig. 4
• Fig 1. Schematic of PEC probe design, MUT is loaded with a surface cubic crack
• Fig 2. Equivalent Circuit model of PEC probe design
• Fig 3. Induced voltage of secondary coil plotted between t = μ_s and t = 10 μ_s
• Fig 4. Intensity of leakage signal B_z obtained at surface of the cubic crack
Day 2
Day 3
Day 1 (First inspection)
Day 2 (Second)
Day 3(Third)
Fig. 5
Fig 5. 2D-heat map of Day 1, Day 2 and Day 3, illustrating noisy data. Defect area is denoted by the black circle, increase of the area is observed in terms of time domain
Green: day 1 defect
Red: day 2 spread of defect
Violet: undecided
Yellow: safe points
+ : True defect scan points
Green: day 1 defect
Red: day 3 spread of defect
Sky blue: day 2 spread of defect
Violet: undecided
Yellow: safe points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Questions for TAP
1. Damage parametrization and characterization
Among all types of damage/defects, we need to know the highest priority of individual and combination of defects, interacting damage that industry is interested in, so a better parameterization and characterization scheme will be developed.
Our research will be highly benefited with the aid of details of previous testing or experiments including some historical measurement data as well as sample specifications. In this way, transfer learning can be implemented and uncertainty associated with our inspection can be further reduced.
2. Inspection technique specifications
NDE methods that industry practices on a regular basis, holds high expectation and/or expect further improvement. For the ongoing research, we are beyond interested to develop our uncertainty reduction frame based on other NDE techniques besides MFL and PEC, that hold great potential to increase detecting capability.
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