Competitive Academic Agreement Program

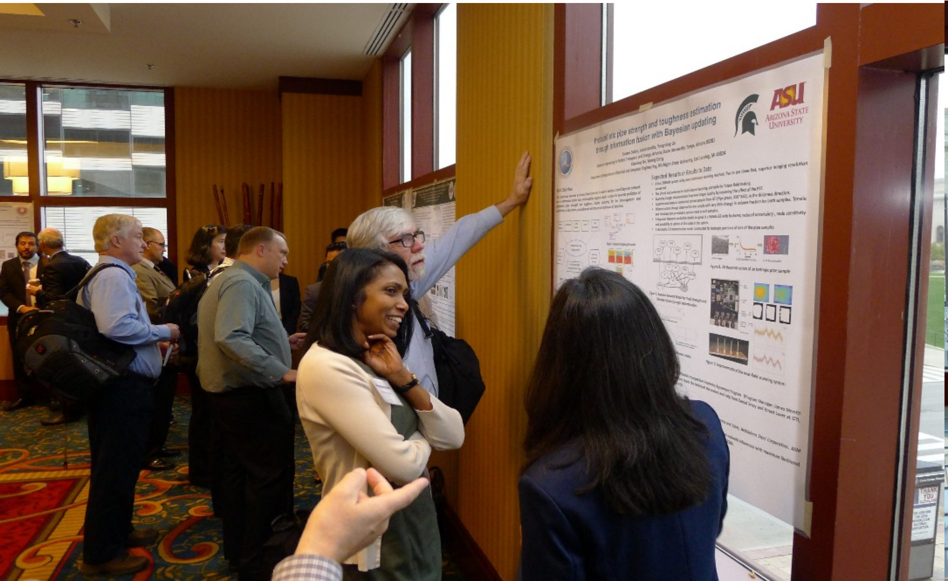
Program Overview and Discussion
February 19-20, 2020

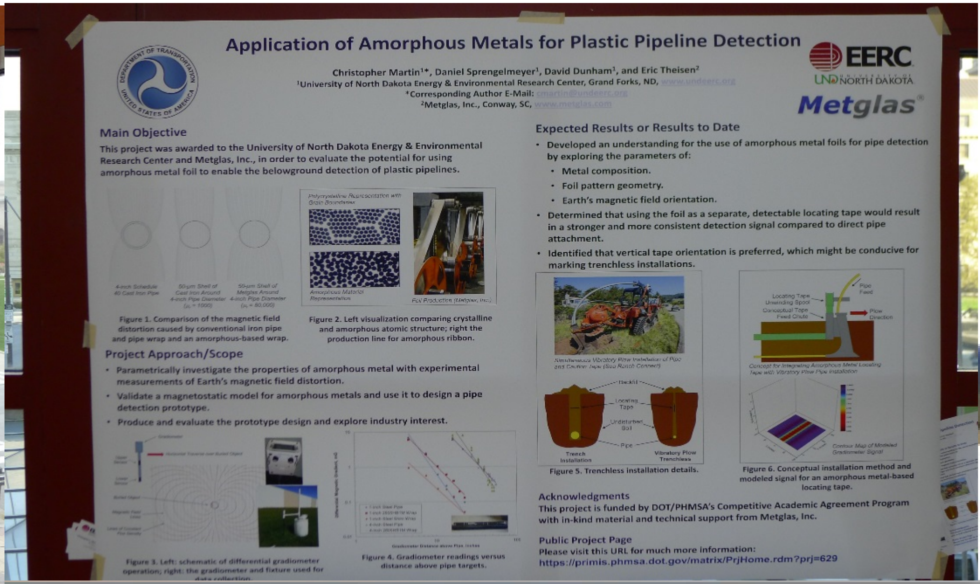
Competitive Academic Agreement Program (CAAP) Objectives

1. Spur innovation, high risk/high reward research
   – Pipeline projects into PHMSA's core research program
2. Involve students with technical/engineering pipeline challenges

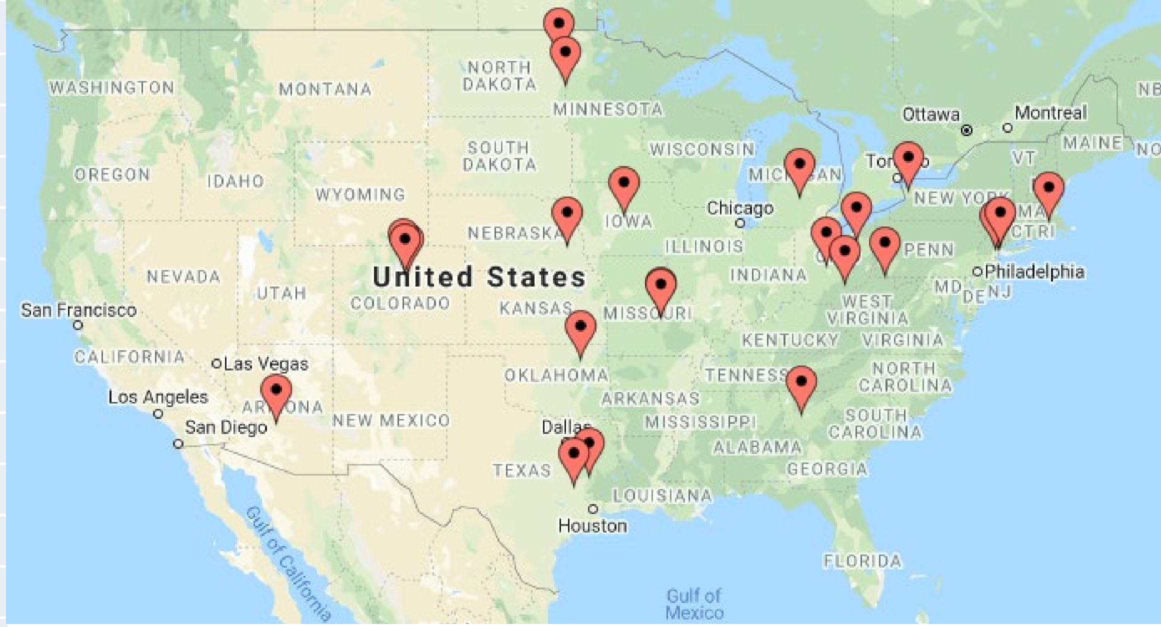
CAAP: Historical Summary

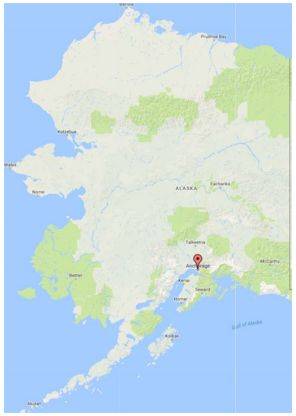
Announcement	Awards	PHMSA	Resource Sharing	HS Students	Undergrad	MS	PhD	Total Students	Internships	Career Employed
CAAP-1-13	8	$814K	$353K	1	23	19	16	59	3	4
CAAP-2-14	7	$719K	$391K		4	14	10	28	1	3
CAAP-3-15	11	$2,976K	$888K		16	21	25	62	8	5
CAAP-4-16	3	$909K	$368K	7	6	9	7	29	3	
CAAP-5-18	13	$3,855K	$1,028K	2	21	8	21	52	2	
CAAP-6-19	8	$1,956K	$608K		3		1	4		
Totals	**50**	**$11.2M**	**$3.6M**	10	73	71	80	**234**	**17**	**12**





University	City, State
Arizona State University	Phoenix, AZ
Brown University	Providence, RI
Colorado School of Mines	Golden, CO
Columbia University	New York, NY
Georgia Tech	Atlanta, GA
Iowa State University	Ames, IA
Michigan State University	East Lansing, MI
North Dakota State University	Bismarck, ND
Ohio State University	Columbus, OH
Ohio University	Athens, OH
Rutgers, The State University	New Brunswick, NJ
Stevens Institute of Technology	Hoboken, NJ
Texas A&M	College Station, TX
University of Akron	Akron, OH
University of Alaska, Anchorage	Anchorage, AK
University of Buffalo	Buffalo, NY
University of Colorado, Boulder	Boulder, CO
University of Colorado, Denver	Denver, CO
University of Missouri, Rolla	Rolla, MO
University of Nebraska, Lincoln	Lincoln, NE
University of North Dakota	Grand Forks, ND
University of Texas, Austin	Austin, TX
University of Tulsa	Tulsa, OK
West Virginia University	Morgantown, WV





CAAP 2013-2019:

24 Universities

50 Projects

$11.2M PHMSA /$3.6M Cost Share

Arizona State University

AI-enabled Interactive Threats Detection using a Multi-camera Stereo Vision System

PI: Yongming Liu
Co-PI: Yang Yu
Students: Rahul Rathnakumar, Chinmay Dixit, Utkarsh Pujar, Kailing Liu, Omar Serag

Arizona State University

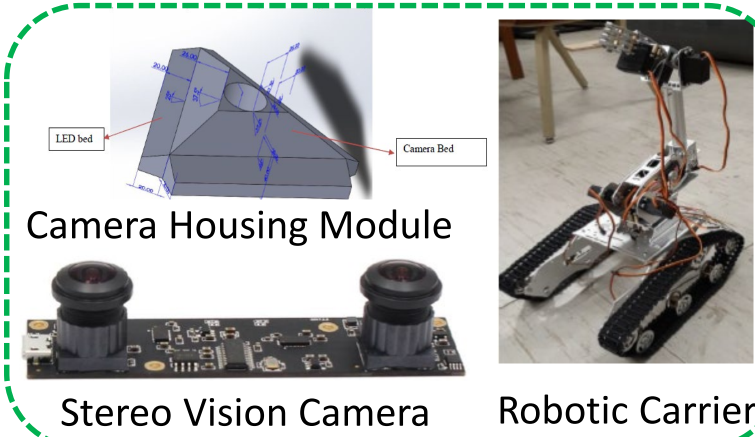
Objective:

Develop a vision-based inspection tool using stereo vision and **AI-enabled** computer vision algorithms for **real-time automated** pipeline interactive threats detection and characterization.

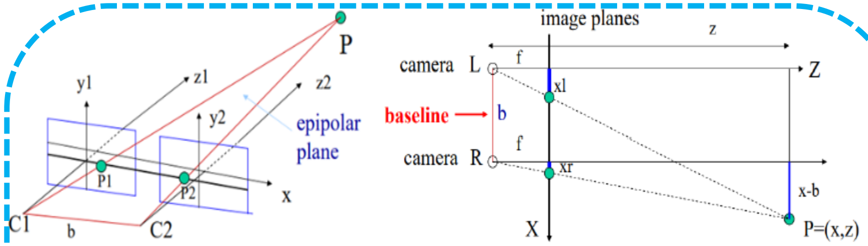
Proposed Tasks:

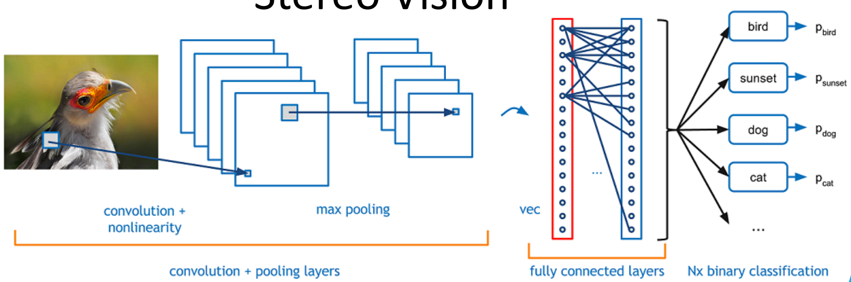
Task 1. Stereo vision system for 3D reconstruction

Task 2. AI-based automatic pattern recognition

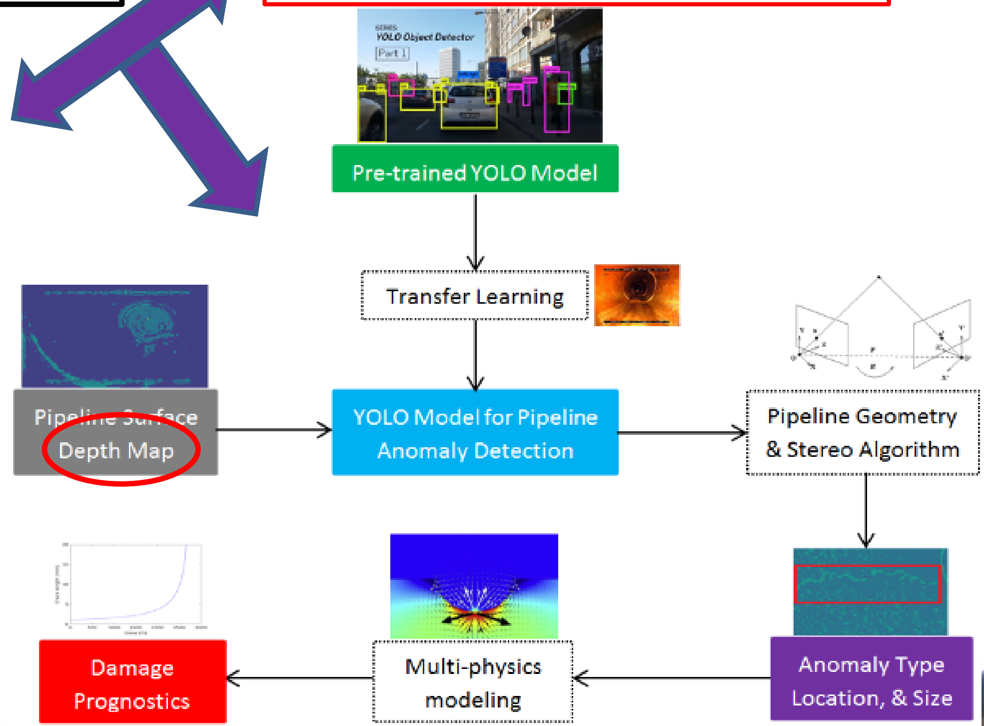


Hardware Design and Prototyping

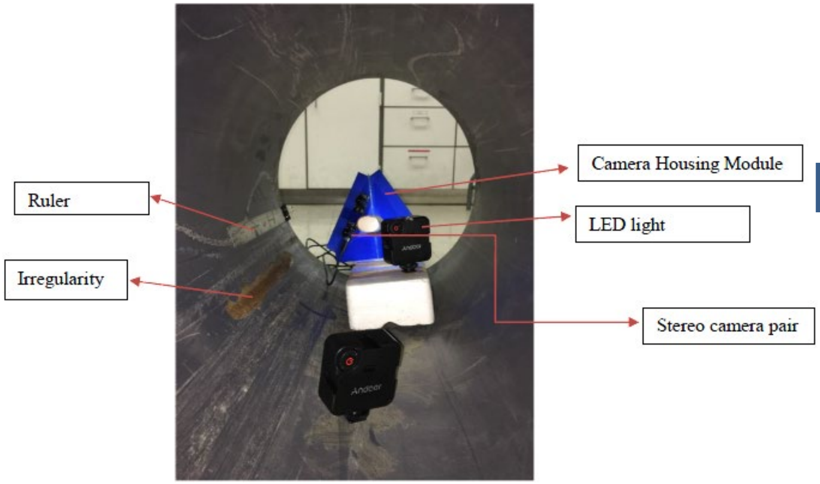




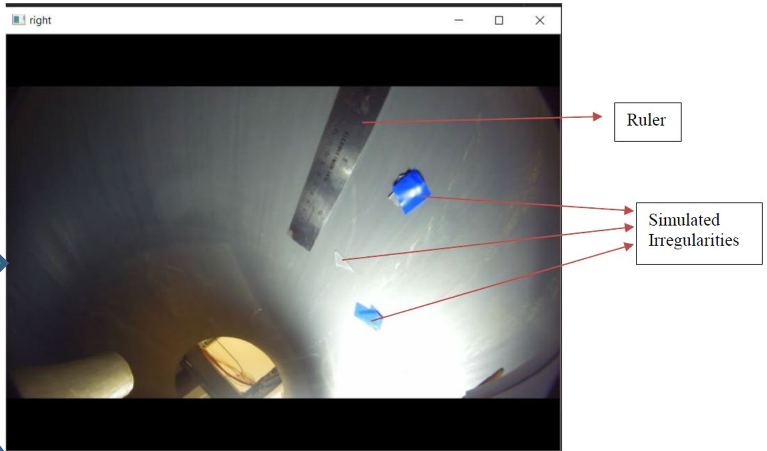
Algorithm Development



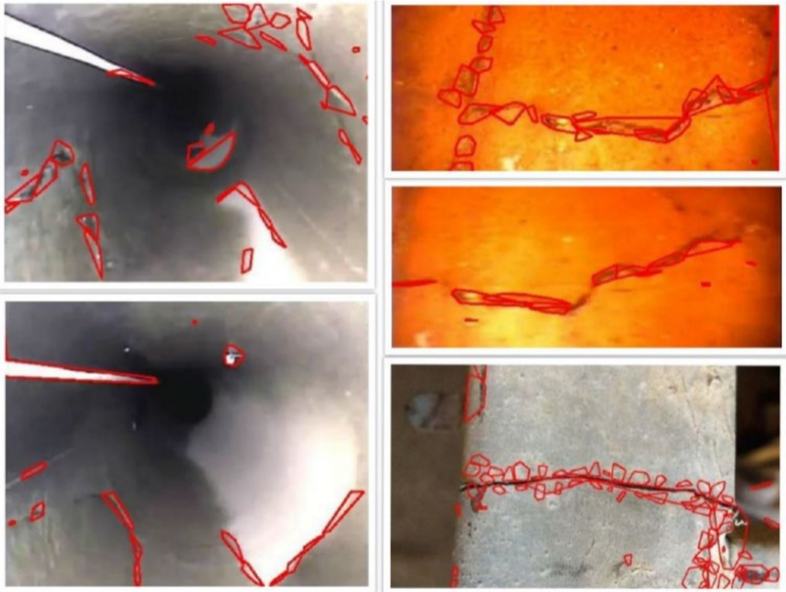
Preliminary Demonstration



Experiment setup



Captured Image



AI-based Automatic Defect Detection

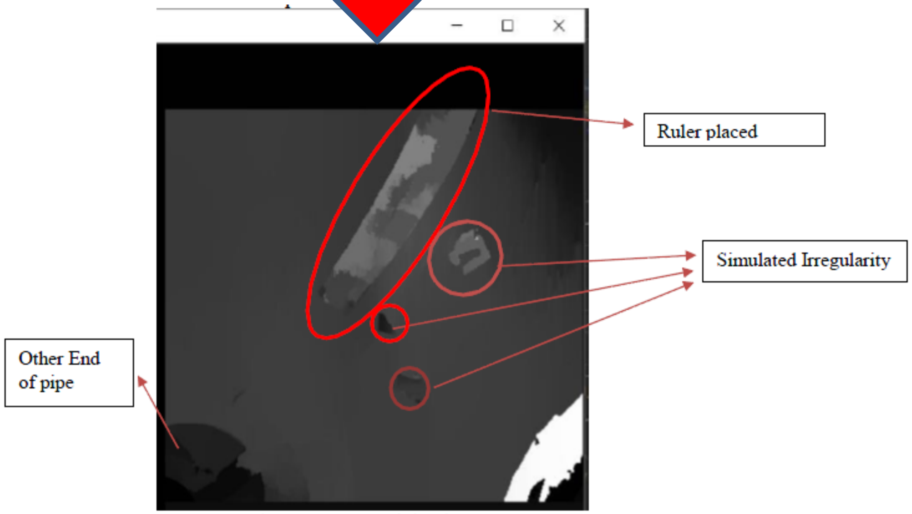


Fig. 14 Generated depth map

Depth Map obtained for defect size quantification

Colorado School of Mines & Michigan State University

Low-variance Deep Graph Learning for Predictive Pipeline Assessment with Interacting Threats

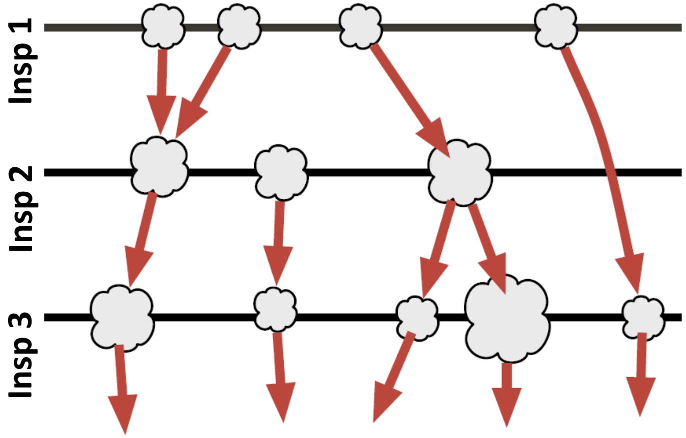
PIs: Hao Zhang[1], Yiming Deng[2]

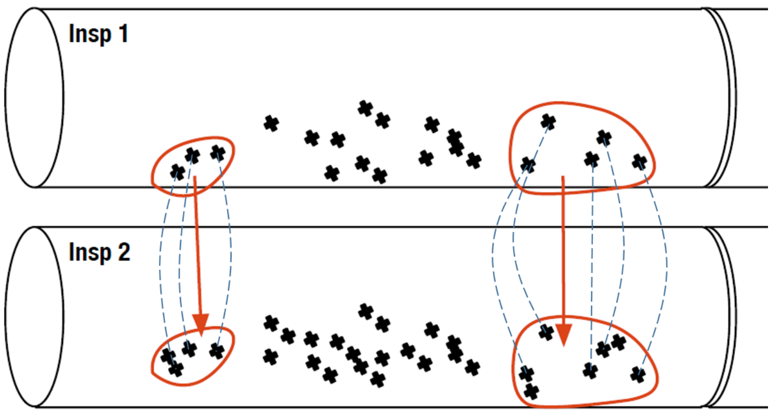
PhD Students: Peng Gao[1], Xuhui Huang[2], Subrata Mukherjee[2]

1. Colorado School of Mines, 2. Michigan State University

Main Objective

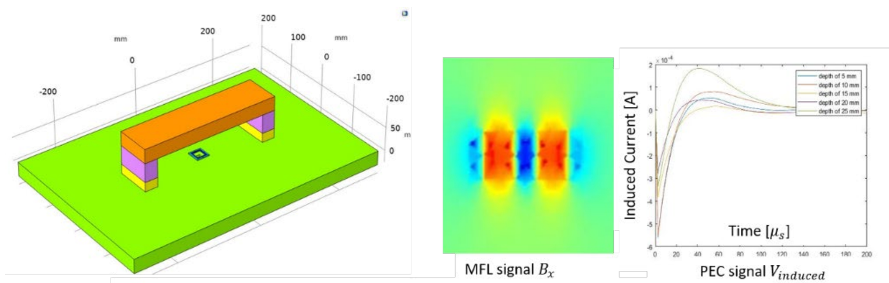
This project develops low-variance interacting threat assessment methods that address the key gap of interacting threat modeling and variance reduction, by proposing new data-driven approaches that integrate deep learning and graph theory.



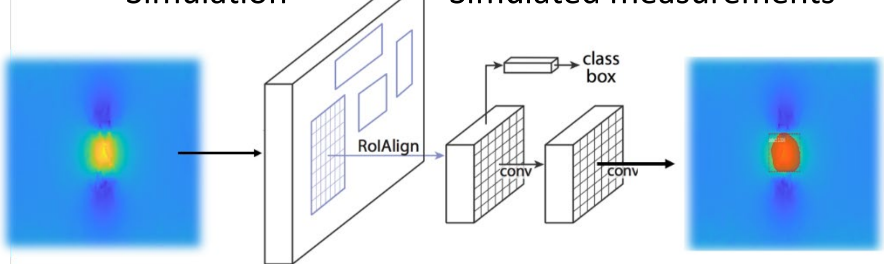


Results to Date

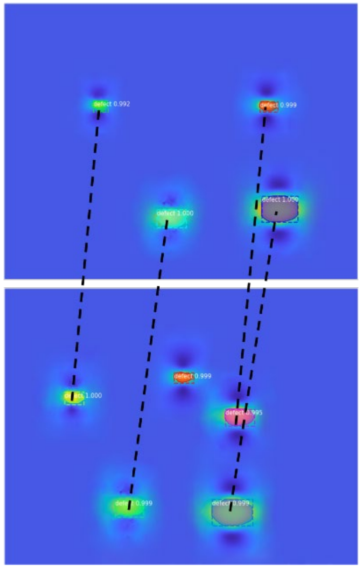
We have developed computational methods for (1) hybrid modeling of interacting threats, (2) individual threat detection and boundary identification, and (3) spatiotemporal interacting threat matching.



Simulation   Simulated measurements



Deep learning for threat diagnosis


Interacting threat matching

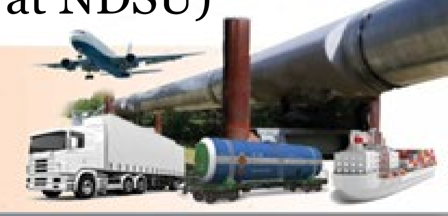
North Dakota State University and Rutgers

Fluorescent Chemical Sensor Array for Detecting and Locating Pipeline Internal Corrosive Environments

North Dakota State University (NDSU)
& Rutgers University New Brunswick (RUNB)

PIs: Dr. Ying Huang, Associate Professor of Civil Engineering, NDSU
Dr. Wenfang Sun, James A. Meier Senior Professor of Chemistry, NDSU
Dr. Hao Wang, Associate Professor of Civil Engineering, RUNB

Graduate Students: Shuomang Shi (Ph. D. student in civil at NDSU)
Hafiz Usman Ahmed (Masters student in civil at NDSU)
Jiapeng Lu, (Ph. D. student in chemistry at NDSU)
Baiyu Jiang, (Ph. D. student in civil at RUNB)
Undergraduate Researchers: Gina Blazanin (senior in civil at NDSU)
Alex Glowacki (junior in civil at NDSU)



Background

- The simultaneous presence of carbon dioxide (CO_2), hydrogen sulfide (H_2S) and free water can cause severe corrosion problems in oil and gas pipelines as shown in Fig.1 (Ref.1).
- Internal corrosion of metal pipelines is a serious threat to the safety and operation efficiency of the pipelines.
- As shown in the Fig.2 (Ref.2), the presence of different corrosive components may induce different corrosion mechanism for corrosion prediction.
- However, currently, it lacks tools to measure the corrosion environment inside pipelines.

Fig.1 Example internal corrosion (Ref.1)

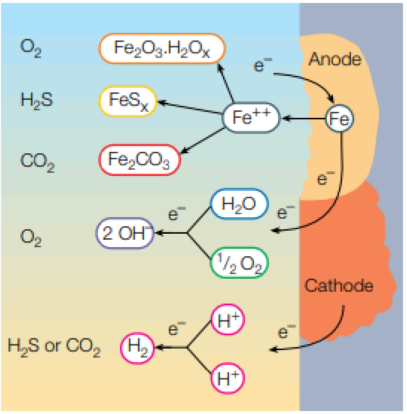


Fig.2 Internal corrosion potential mechanisms (Ref.2)

Project Objective

This project will develop a passive fluorescent or colorimetric chemical sensor array which is applicable in oil/gas environment to detect changes in corrosion environments inside pipelines. The sensor array will display the potential corrosive environments by changes in probe molecule color and/or switch on their fluorescence (as seen in Fig.3), including the concentrations of HCO_3^- /CO_3^{2-}, S^{2-}, Fe^{3+}, and H^+ changes.

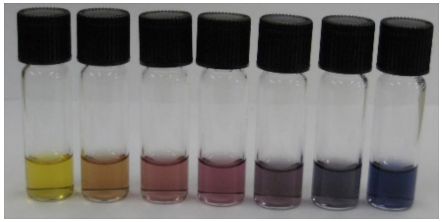


Fig.3 Example molecule color changes (Ref.3)

Ref 1: http://www.phmsa.dot.gov/ pipeline/phmsa-proposes-new-safetyregulations-for-natural-gas-transmissionpipelines
Ref. 2: R. N. Tuttle, "Corrosion in oil and gas production," J of Petrol Technol, 39:756–762, (1987)
Ref. 3: Z. Ji, Y. Li, **W. Sun**, "Acid/base sensitive platinum terpyridyl complex: Switching between metal-to-ligand charge transfer (MLCT), ligand-to-ligand charge transfer (LLCT), and intraligand charge transfer (ILCT) states", J. Organometallic Chem. 694, 4140-4145 (2009).

Preliminary Results

- ✓ The developed PMMA/CA sensor film can detect changes in Fe^{3+} concentration (Figs. 4);
- ✓ The sensor film can survive gas/oil in atmospheric condition, and the color change stayed unchanged after immersing the sensor film in gas/oil in atmospheric condition, which indicates that no cleaning service is needed (Fig. 5);
- ✓ The expected force on the sensor film from the regular oil/gas flow (at 0.5 m/s) was estimated to be around 8 N (Fig. 6) and from passing a cleaning pig (Figs. 7 and 8) was estimated to be around 100 N, indicating that the cleaning service would control the sensor size design;
- ✓ The attached sensor film maintained their color and function during lab simulated cleaning service (Fig. 7), indicating that the sensor film can survive and maintain functional when a cleaning/inspection pig passing.

Fig.4 Sensor films to detect Fe^{3+} concentration changes

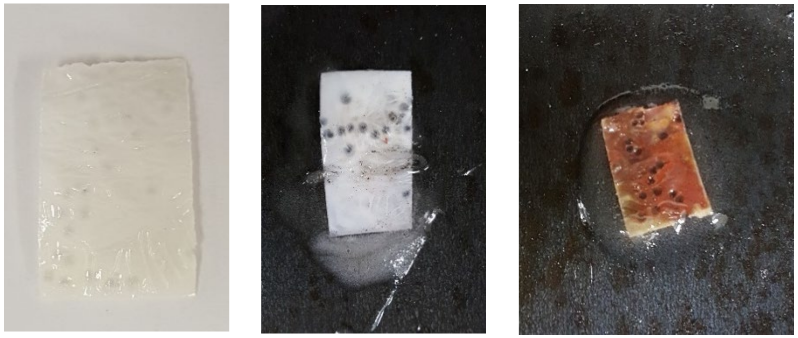


Fig.5 Sensor film to detect Fe^{3+} before attached to steel (left), attached to steel after immersed in gasoline (middle), and after the presence of Fe^{3+} after immersed in gasoline (right)

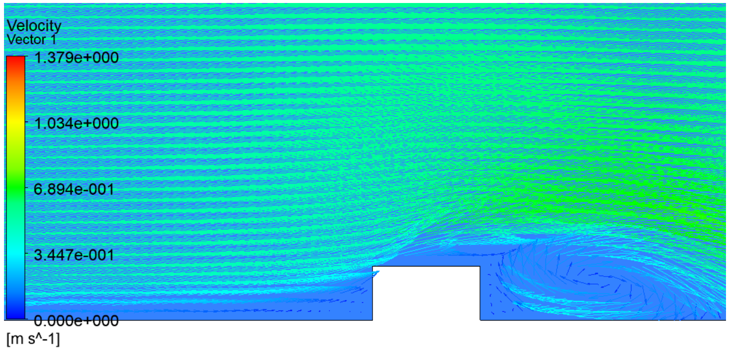


Fig.6 Numerical analysis with Oil/gas flow passing the sensor film

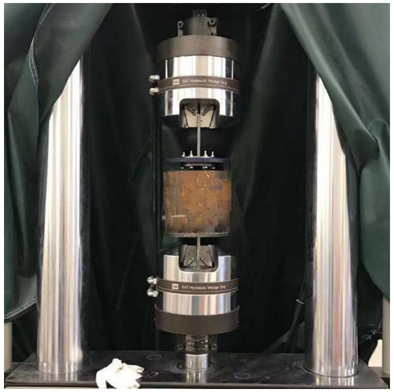


Fig.7 Lab testing for cleaning pig passing

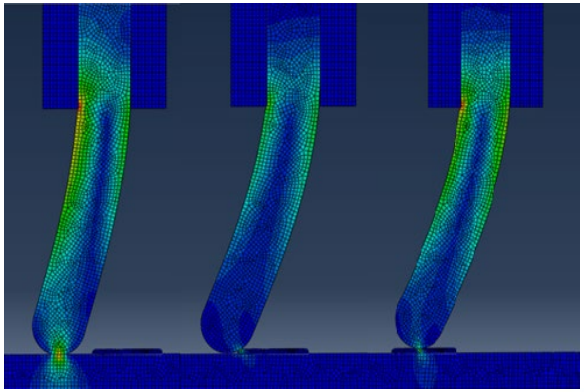


Fig.8 Simulation for cleaning pig passing

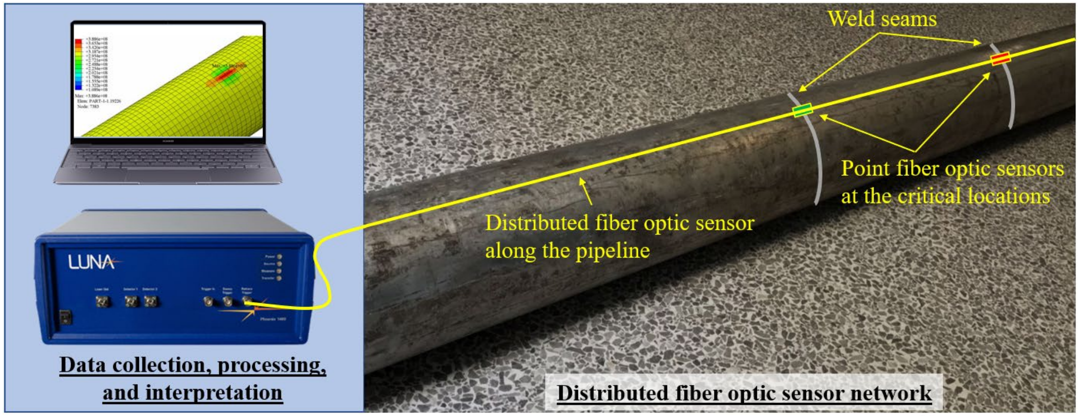
More results to come as project progress (contact the PI at ying.huang@ndsu.edu for updates).

Stevens Institute of Technology & North Dakota State University

Distributed Fiber Optic Sensor Network for Real-time Monitoring of Pipeline Interactive Anomalies

PI: Dr. Yi Bao, Email: yi.bao@stevens.edu
Graduate student: Xiao Tan
Advanced Structures & Process Innovation Research (ASPIRE) Laboratory
Department of Civil, Environmental and Ocean Engineering
Stevens Institute of Technology, Hoboken, New Jersey 07030
Co-PI: Dr. Ying Huang, Graduate student: Luyang Xu
Department of Civil and Environmental Engineering
North Dakota State University, Fargo, North Dakota, 58105

- **Overview**
  - Inadequate evaluation of interactive threats is a frequently cited shortcoming of integrity management programs, which may lead to underestimating the true magnitude of risks to a pipeline. This research aims to develop an innovative distributed fiber optic sensing technology that provides real-time in-situ monitoring data of pipelines subjected to interactive defects for improving pipeline safety.
- **Objectives**
  - Develop distributed fiber optic sensor network for detection, localization, and characterization of interactions anomalies, such as cracking, dent, corrosion, etc.
  - Develop data processing methods for real-time sensor data analysis to improve the pipeline safety and management.
- **Experimental set-up**
  - The distributed sensor network will seamlessly integrate multifunctional distributed and point fiber optic sensors and provide fully distributed measurement along the pipelines.



Conclusions

Here is a summary of findings that we obtained from the research in the first quarter.

- Interactive threats are the coincidence of two or more threats in a pipe segment. The result of interactive threats is more damaging than either of the individual threats.
- The detection, characterization, and quantification of interactive threats represent technical challenges for existing pipeline inspection technologies based on non-destructive evaluation methods and point sensors.
- Distributed fiber optic sensor can provide spatially distributed measurement of multiple variables over a long distance (more than 100 miles). It has good promise for real-time in-situ monitoring of the health condition of pipelines.
- Distributed fiber optic sensor may be integrated with multiple point fiber optic sensors and form a fiber optic sensor network for pipelines subjected to multiple types of threats.
- Further research is needed to prove the performance of distributed fiber optic sensor network.

University of Akron & Michigan State University

Multi-modal NDE Assisted Probabilistic Pipeline Performance Evaluation under Interactive Anomalies

(PHMSA-CAAP 2019, 09.31.2019 − 09.31.2022)

PI: Qindan (Chindan) Huang, Ph.D.
Associate Professor, Civil Engineering, Univ. of Akron (UAkron)

Co-PI: Qixin Zhou, Ph.D.
Assistant Professor, Chemical, Biomolecular, & Corrosion Engineering, UAkron

Co-PI: Yiming Deng, Ph.D.
Associate Professor, Electrical & Computer Engineering, Michigan State Univ. (MSU)

Students

Kiswendsida Jules Kere*, Graduate student, Civil Engineering, UAkron*

Karthik Gopalakrishnan*, Graduate student, Electrical and Computer Engineering, MSU*

Research Goal: develop **probabilistic** pipeline performance evaluation framework based on multi-modal NDE assisted by **physical** and **mechanical** modeling under **interactive** anomalies

Representative anomalies: isolated & colony defects; corrosion defect & crack-like defect

Task 2 (Dr. Deng)

Probabilistic characterization of defect profiles

- NDE system development
- NDE modeling & validation
- NDE data processing

Task 1 (Dr. Zhou)

Generate realistic corrosion & cracking defect profiles

- Laboratory testing
- Electrochemical simulation (COMSOL)

Task 3 (Dr. Huang)

Probabilistic failure pressure prediction models

- Failure pressure database
- Model development (corrosion, crack-type anomalies, interactive anomalies)

Probabilistic time-evolution models for defect profile quantities

Task 4 (Dr. Huang)

Reliability analysis

- Impact of various physical quantities and uncertainty sources on reliability

Threat identification → Reduced capacity → Probability of failure

Current Progress

- A 2-D **axisymmetric** model has been developed to propagate **Ultrasonic Guided Waves** in long complex pipelines.
- The effect of **pitting corrosion** has been numerically modelled using COMSOL, and clear **defect signatures** have been obtained for different **pit depths** & multiple **interactive pits.**
- A total of **525** different burst test results for **isolated defect** are collected from 13 literatures and numerical analysis conducted from this study using ABAQUS.
- **Probabilistic** model formulation is constructed using **existing deterministic prediction models** currently adopted in practice as independent variables.

Benefits and Impact

- An expanded and new **multi-modal NDE** (UT-GWs, EM) framework will be developed enabling the missing **capability** to assess interactive anomalies with integration of lab-, field- and simulation-environment validation.
- A better **evaluation** of interactive anomalies characterization in isolated and colony profiles using NDE, and its impacts on the **integrity** of a pipeline.
- Industry-ready probabilistic prediction models for **failure pressure** of pipelines containing interactive anomalies, providing predictions that are **unbiased** with **reduced variability.**

Michigan State University & Arizona State University

A novel structured light based sensing and probabilistic diagnostic technique for pipe internal corrosion detection and localization

PI:
- Yiming Deng (Michigan State University)

Co-PI:
- *Yongming Liu* (Arizona State university)

Students:
- Mohand Alzuhiri
- Rahul Rathnakumar

Project Manager: Robert Smith, PHMSA

Project Overview

Overview

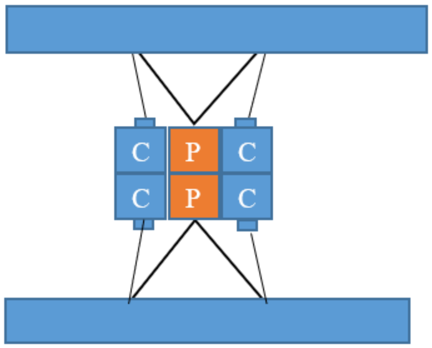
Development of a novel structured-light based imaging solution for internal corrosion detection to simplify the detection process and have high accuracy 3D maps for better evaluation

Objectives

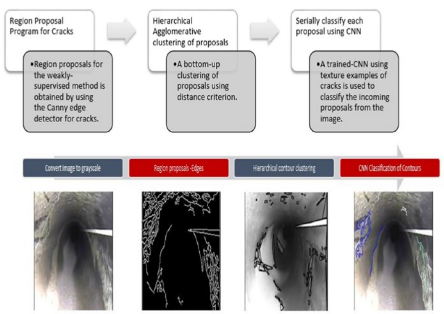
- **Develop a movement enhanced phase measurement sensor to have high fidelity 3D internal surface maps**
- **Build a machine learning based model to enable automatic defect detection and classification.**

Methods

- **Design a stereo assisted moving phase measurement profilometry (MPMP) sensor**
- **Develop a MPMP based surface reconstruction algorithm**
- **Develop a weakly-supervised machine learning model inspired by the fully-supervised R-CNN**

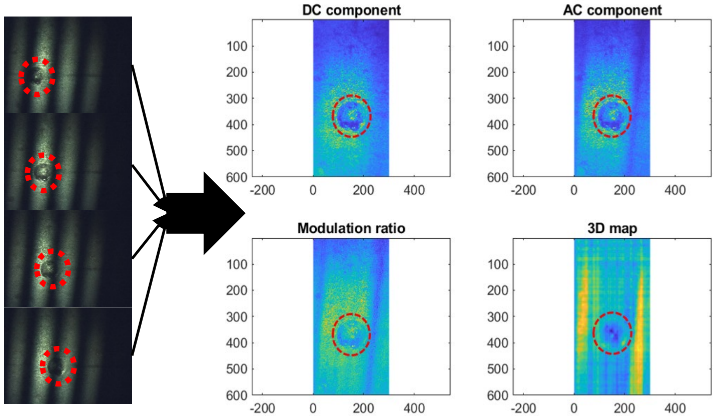


Schematic of the structured light sensor

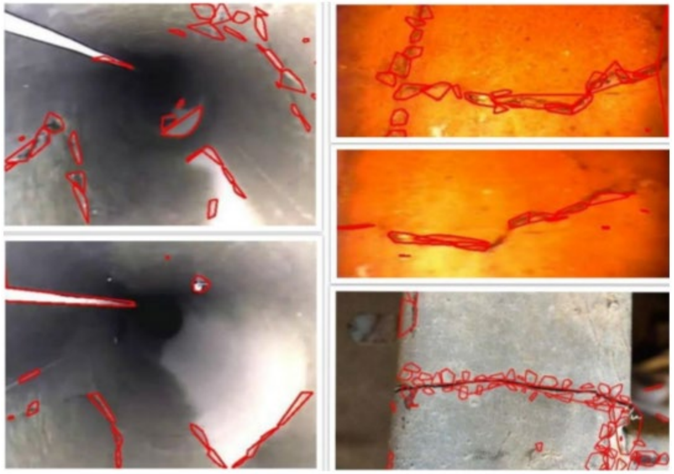


Block diagram of the automatic damage detection algorithm

Results and Discussion



Scanning of a corroded sample : SL scanning and reconstruction results



Demonstrative examples: Automatic detection of cracks

- **Design and fabrication of stereo assisted MPMP sensor with the associated 3D Reconstruction algorithm**
- **Successful testing of the developed platform on artificially created corroded samples**
- **Development of Deep learning algorithm for automatic cracks detection**

University of Akron

Development of an Electrochemical Approach to Detect Microbially Influenced Corrosion in Natural Gas Transmission Pipelines

Chelsea Monty-Bromer (PI), John Senko (Co-PI), Anwar Sadek, Sai Prasanna Chinthala, Joshua Davis, The University of Akron

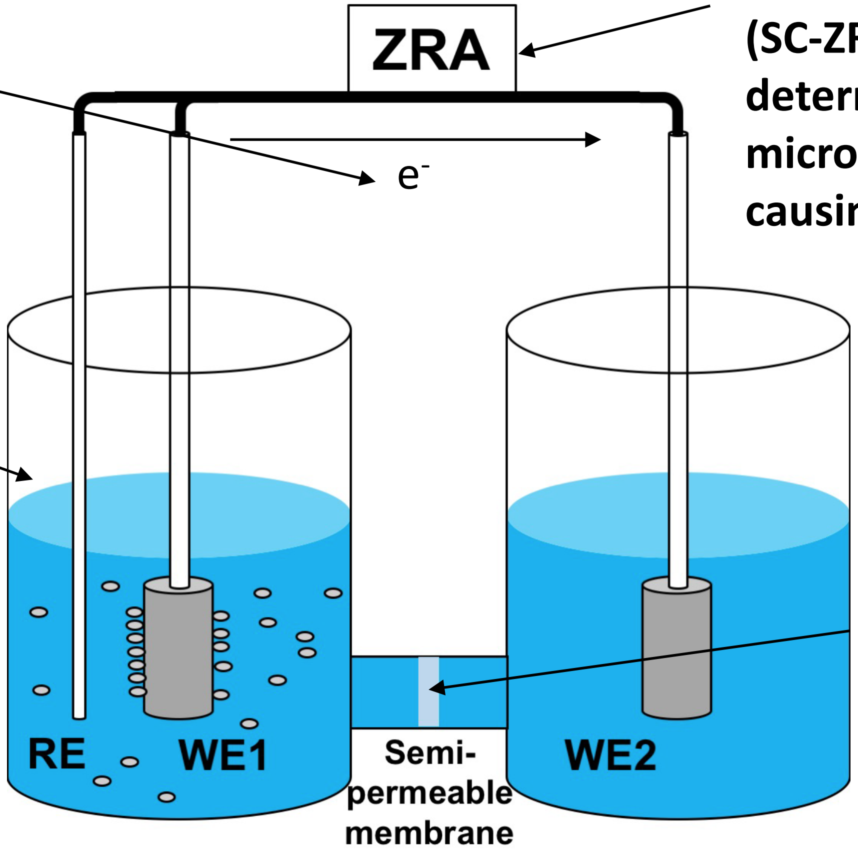
Aim to answer the question: When does microbial growth lead to corrosion?

Monitor flow and direction of electrons to determine corrosion rate

Use of a split-chamber zero resistance ammeter (SC-ZRA) allows us to determine when microbial growth is causing corrosion

Microorganisms added to one side of a split chamber set up

Sterile chamber is connected to inoculated chamber via semi-permeable membrane



Obtain Samples

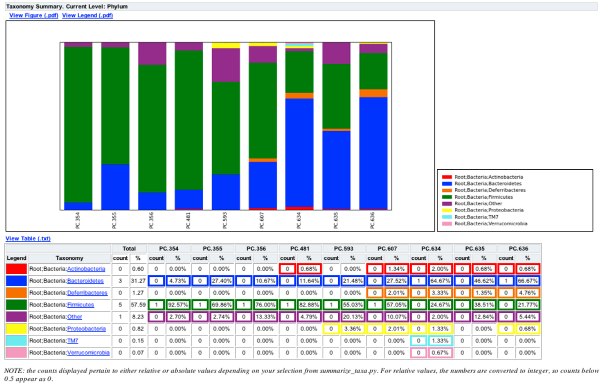
- Working with DNV and Dominion

Characterization

- Enrichment and isolation
- 16S rRNA
- Chemical analysis of water

SC-ZRA measurements

- Using isolated microorganisms alone and in consortia
- Use direct samples and synthetic media



Missouri University of Science and Technology 1&2

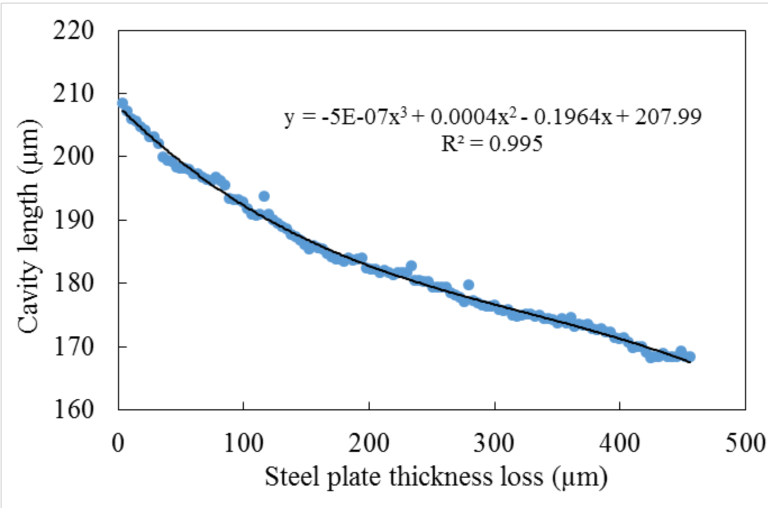
Magnet-assisted Fiber Optic Sensing for Internal and External Corrosion-induced Mass Losses of Metal Pipelines under Operation Conditions

Missouri S&T
Missouri University of Science and Technology

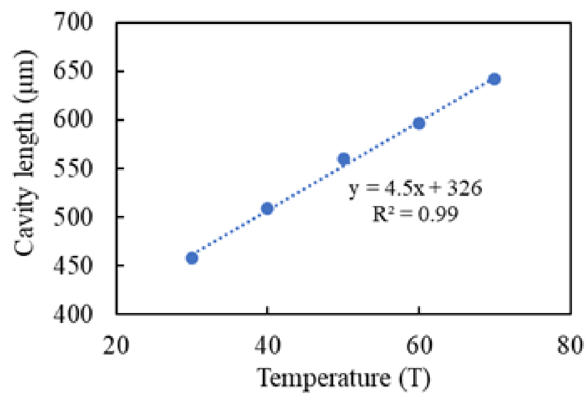
Contract #693JK31850012CAAP
PI: Dr. Genda Chen
Student: Dr. Chuanrui Guo

Results & Conclusions

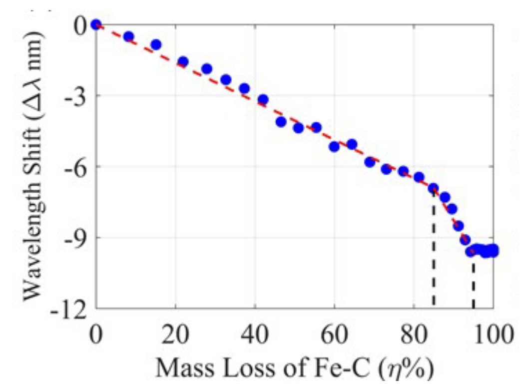
- Results



EFPI cavity length vs. steel plate thickness



EFPI cavity length vs. temperature measured by FBG



Fe-C mass loss vs. resonance wavelength shift of LPFG

- Conclusions
  - The proposed sensors can measure the corrosion induced mass loss of the pipeline accurately in both external and internal setup
  - The combined EFPI/FBG can simultaneously measure the corrosion induced mass loss and temperature

PHMSA/DOT Project

An Unmanned Aerial System of Visible Light, Infrared and Hyperspectral Cameras with Novel Signal Processing and Data Analytics

MISSOURI S&T
Missouri University of Science and Technology

Contract #693JK31950005CAAP
PI: Genda Chen, Ph.D., P.E.
Student: Pengfei Ma

Research Overview

Main objectives:

- Develop and integrate a robust unmanned aerial system (UAS) with multiple sensors for data collection.
- Explore novel signal processing techniques for data analysis concerning pipeline assessment.
- Evaluate field performance of the integrated UAS.

Figure 1. . Integrated UAVs

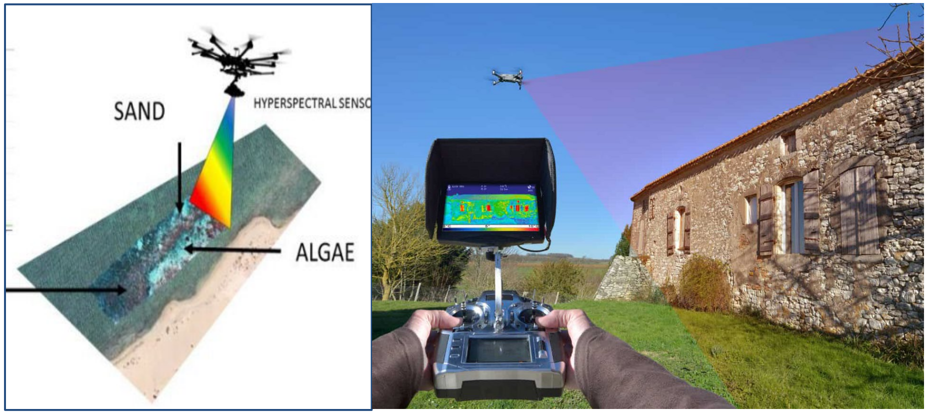


Figure 2. Hyperspectral and thermal imaging

Expected Results

- An integrated UAS equipped with visible light, infrared, and hyperspectral cameras that can reliably collect correlated images for pipeline leakage detection.
- Data processing techniques with data fusion that can enhance the probability of detection in application.
- A performance datasheet of laboratory and field demonstrations of the UAS in pipeline applications.
- Comparative results between hyperspectral and thermal imaging techniques that can verify each other in detecting the location of pipeline leakage. In addition, thermal images can be used to estimate the volume of the leakage area.

University of Texas at Austin

Internal Corrosion Monitoring in Pipelines by using Helical Ultrasonic Waves

Project Team:

Prof. Salvatore Salamone (PI)

Mr. Stylianos Livadiotis (Ph.D. student)

The University of Texas at Austin

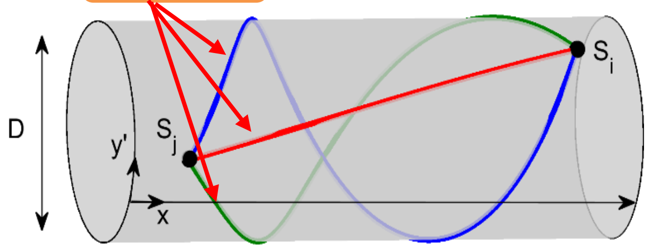
Main objective

- The main objective of this research program is to design, implement and validate a nondestructive evaluation (NDE) technology for detecting, evaluating and monitoring the progression of internal corrosion in pipelines.
- Overall it is proposed to use a novel class of sensing system, helical guided ultrasonic waves (HGUW) and advanced data processing techniques for supporting corrosion diagnosis and decision-making.

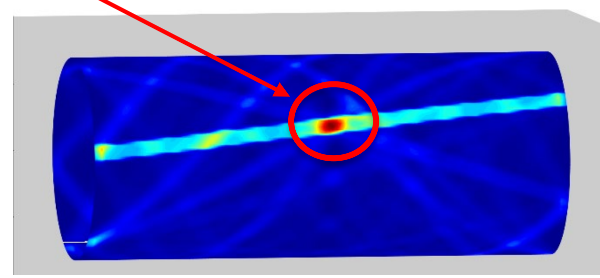
Current work - Results

Completed work: Use of the HGUW to localize various size defects around the circumference of pipes.

HGUW's

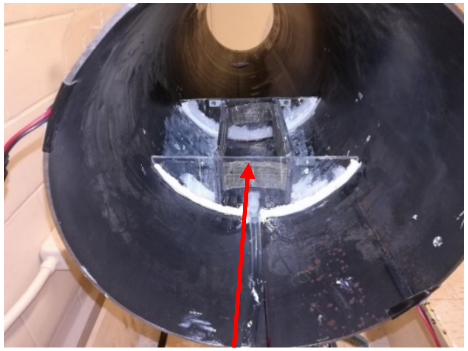


Localized damage



On-going work: Examine how HGUW can be used to assess the stage of corrosion.

- Corrosion induced using impressed current methodology.



Tank inside the pipe

Failure after 20 cycles

University of Nebraska-Lincoln 1&2

UAS assisted pipeline modeling and inspection

PI: Zhigang Shen
Research Assistants: Zhexiong Shang, Chongsheng Cheng

University of Nebraska-Lincoln

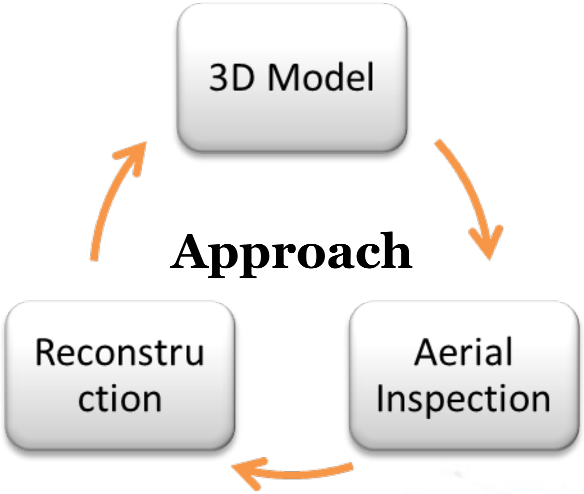
OBJECTIVE

The objective is to achieve autonomous visual inspection and modeling of ground facilities using UAV with

- **high inspection and reconstruction quality**
- **high inflight and post-flight efficiency**
- **collision-free**

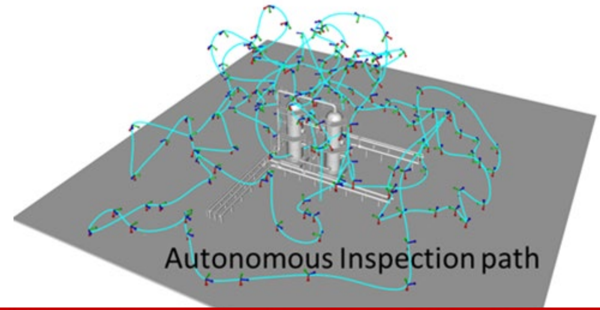
SIMULATION Platform

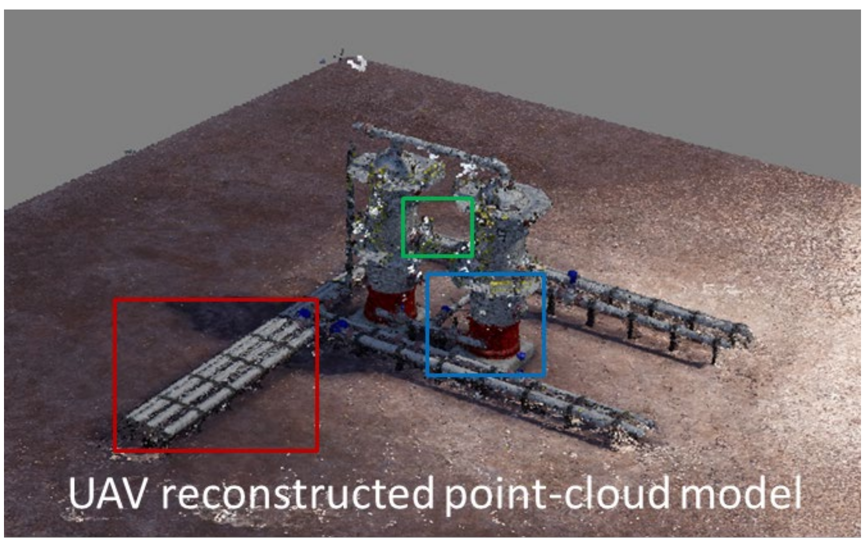
- **Hardware: Dell Precision 7500 Workstation**
- **Software: Ubuntu 18.04, OpenGL**
- **Game Engine: Unreal Engine 4**

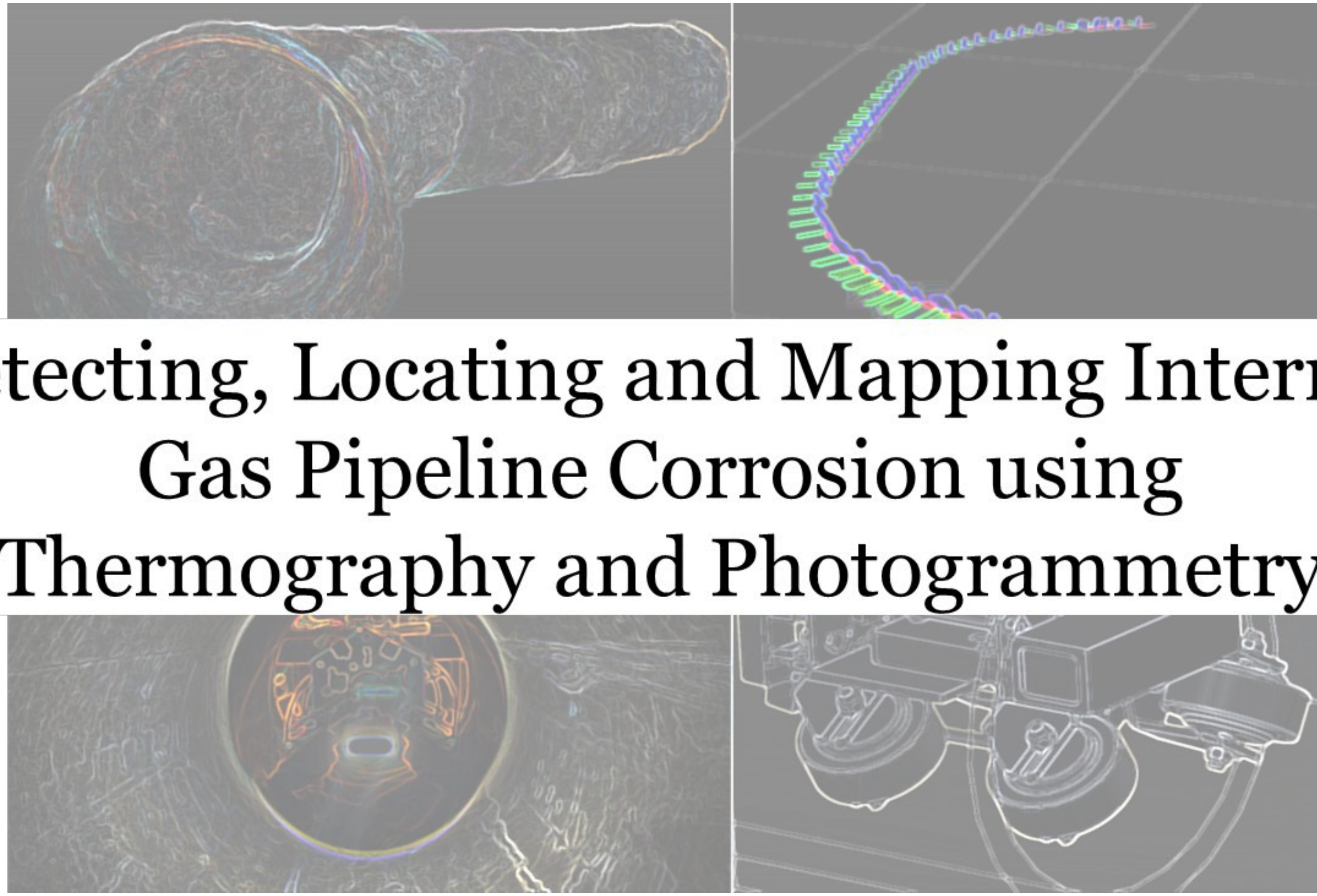


RESULTS


The original inspection scene


Autonomous Inspection path


UAV reconstructed point-cloud model



Detecting, Locating and Mapping Internal Gas Pipeline Corrosion using Thermography and Photogrammetry

PI: Zhigang Shen
Research Assistants: Zhexiong Shang, Chongsheng Cheng, Gabriel Clark
University of Nebraska-Lincoln

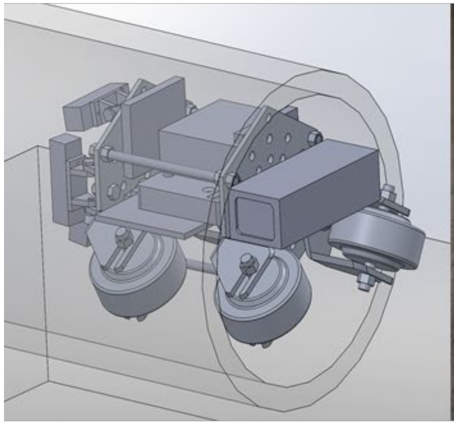
OVERVIEW

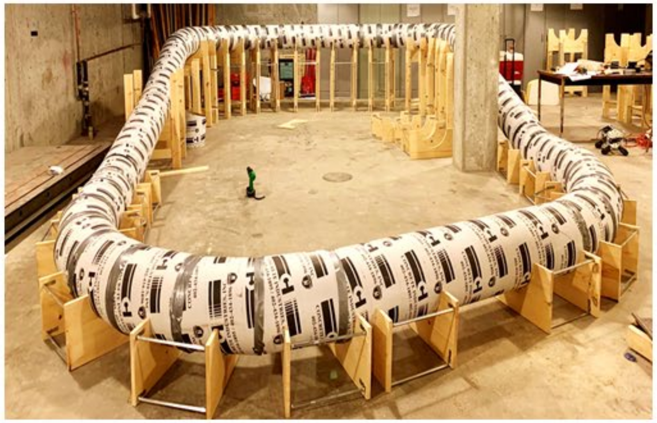
Developing low-cost novel pipeline inspection technology is urgent to ensure the safety, serviceability, sustainability, and affordability of the nation's aging pipeline infrastructure. Recent advancements in computer vision and artificial intelligence opens doors to novel solutions to address the dire infrastructure situation.

OBJECTIVE

The objective is to detect, locate, and map pipeline defects by using low-cost inline inspection rover and multi-spectrum computer vision. The developed technology can be applied to both piggable and un-piggable pipelines.

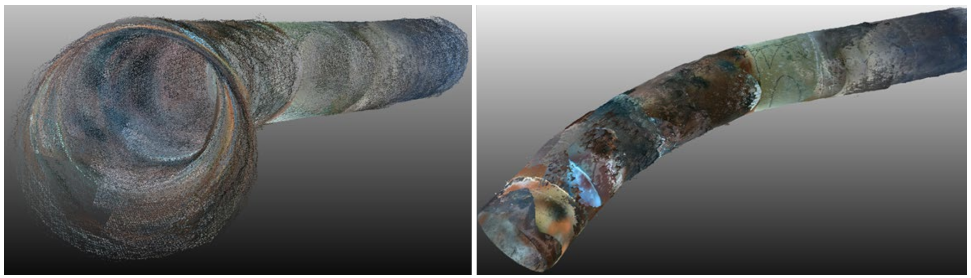
EXPERIMENTS



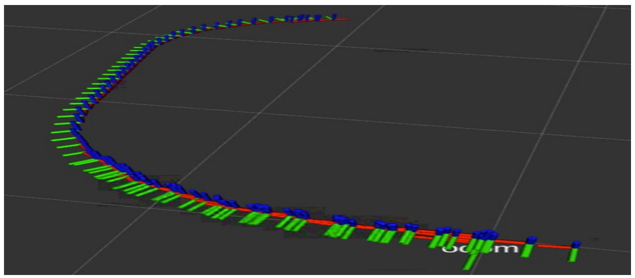


RESULTS

Pipe internal surface model - dense point cloud



Camera pose trajectory estimate

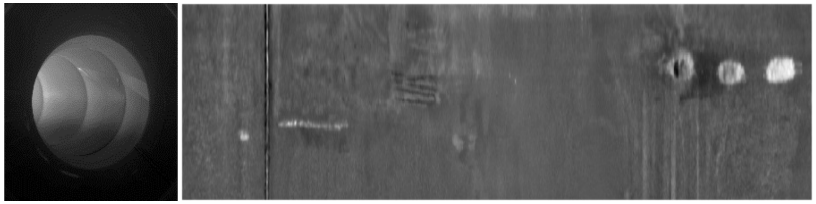


Thermographic detection of internal defects under different conditions

Small pitting

Crack

Wall thinning



Thermal image: with heated air flow

North Dakota State University 1-3

Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion

PI: Dr. Zhibin Lin [a]

CO-PIs: Dr. Dante Battocchi[b]
Dr. Xiaoning Qi[b]

Graduate students:
- Xingyu Wang[a], Ph.D.
- Hong Pan[a], Ph.D. (post doc)
- Mingli Li[a], Ph.D.
- Matthew Pearson[a], M.S.

Undergraduate students:
- Devin Neubeck

[a]Department of Civil and Environmental Engineering, North Dakota State University
[b]Department of Coatings and Polymeric Materials, North Dakota State University

Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion

❖Objective:

Develop and implement new multifunctional composite coatings for new-constructed or existing pipelines to achieve a design with the integration of the anti-corrosion, anti-fouling and superior abrasion into one compact unit (composite coating).

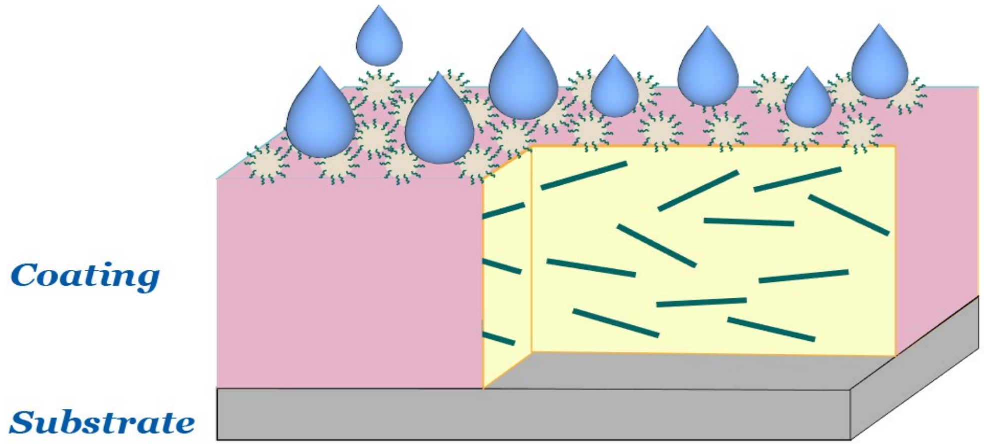


Figure 1. Proposed high-performance multifunctional coating

Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion

The developed coating offered the following advantages:

1) Solvent-free dispersion method with low priced materials
2) Excellent corrosion resistance and mechanical properties
3) Robust superamphiphobic surface

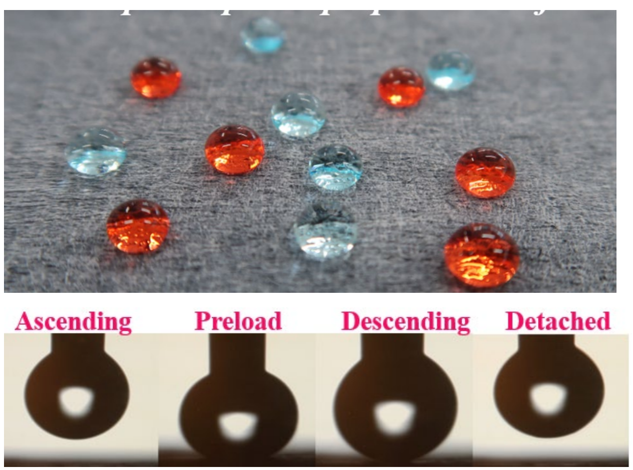


Figure 2, Water droplet ascending and descending of the coating surface

- Two keynotes speeches and two invited talks associated with this research
- PhD student, Xingyu Wang, published three journal papers, two under review, and over 10 conference papers
- Two patent applications
- Recruited over 10 high-school students in the research since 2016

Brain-Inspired Learning Framework to Bridging Information, Uncertainty and Human-Machine Decision-Making for Decoding Variance in Pipeline Computational Models

PI: Dr. Zhibin Lin [a]

Graduate students:

- Zi Zhang[a], Ph.D
- Hong Pan[a], Ph.D. (post doc)
- Matthew Pearson[a], M.S.

Undergraduate students:

- Alex Hubbard

[a]Department of Civil and Environmental Engineering, North Dakota State University
[b]Department of Coatings and Polymeric Materials, North Dakota State University

Brain-Inspired Learning Framework to Bridging Information, Uncertainty and Human-Machine Decision-Making for Decoding Variance in Pipeline Computational Models

❖Objective:

This study is to develop and implement new learning framework to bridge information, uncertainty and human-machine decision making to meet pipeline environments that are becoming increasingly complex and demanding because of the high uncertainty, and heterogeneous data.

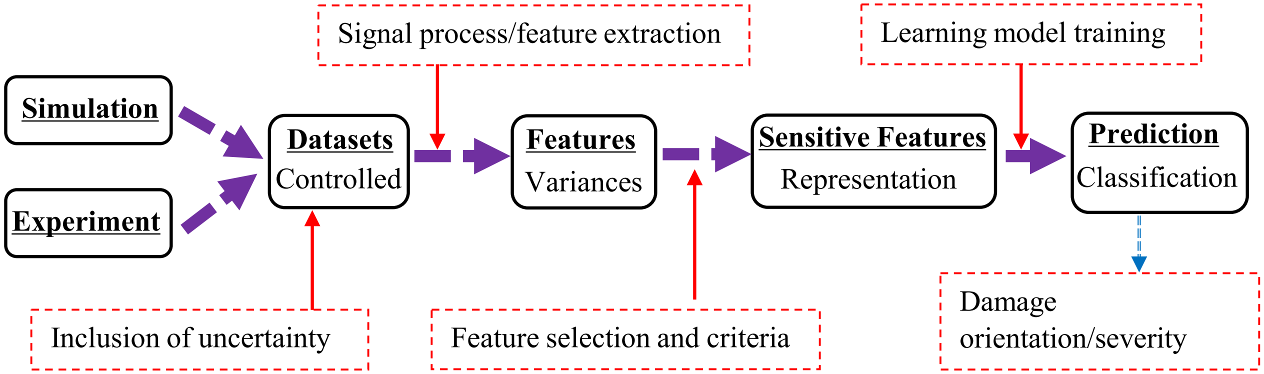


Figure 1. Framework of machine learning-enriched method for damage detection

Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion

The current work mainly focuses on the variance widely ranging from material/structural integrity (e.g., damage types, damage size and morphology) using experimental and numerical studies through different datasets:

- Simulation of different scenarios with damage
- Experimental validation and verification
- Characterization of damage features
- Identification of unique features

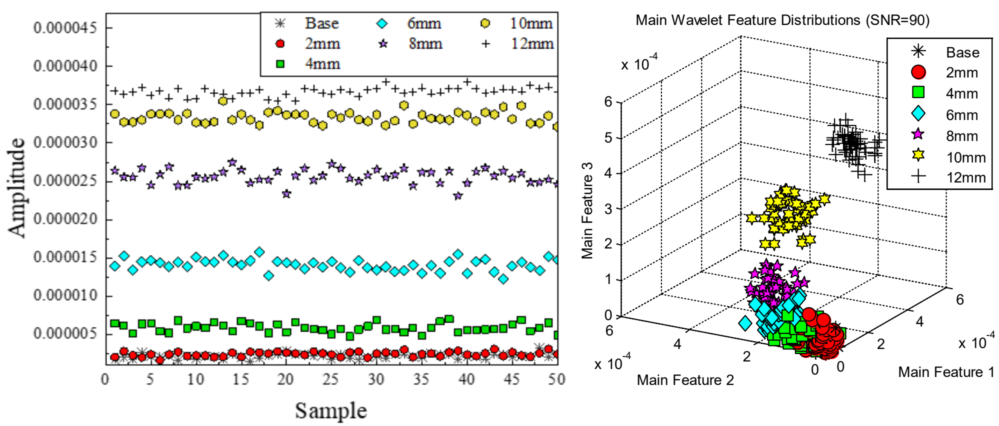


Figure 2, Features for decoding structural integrity

- One invited talk associated with this research
- PhD student, Zi Zhang, published 4 conference papers, and one manuscript under review
- Recruited two high-school students in the research in summer 2019

New Bio-Inspired 3D Printing Functionalized Lattice Composites for Actively Preventing and Mitigating Internal Corrosion

PI: Dr. Zhibin Lin [a]

CO-PIs: Dr. Bashir Khoda[b]

Graduate students:
- Yiming Bu[a], Ph.D.
- Hong Pan[a], Ph.D. (post doc)
- Matthew Pearson[a], M.S.
- Adeeb Ibne Alam [b], Ph.D.

Undergraduate students:
- Johnstone Brandon

[a]Department of Civil and Environmental Engineering, North Dakota State University
[b]Department of Mechaincal Engineering, University of Maine

New Bio-Inspired 3D Printing Functionalized Lattice Composites for Actively Preventing and Mitigating Internal Corrosion

❖Objective:

Develop and implement new 3-D printing functionally graded composites for new-constructed or existing pipelines to prevent and mitigate the early-age internal corrosion.

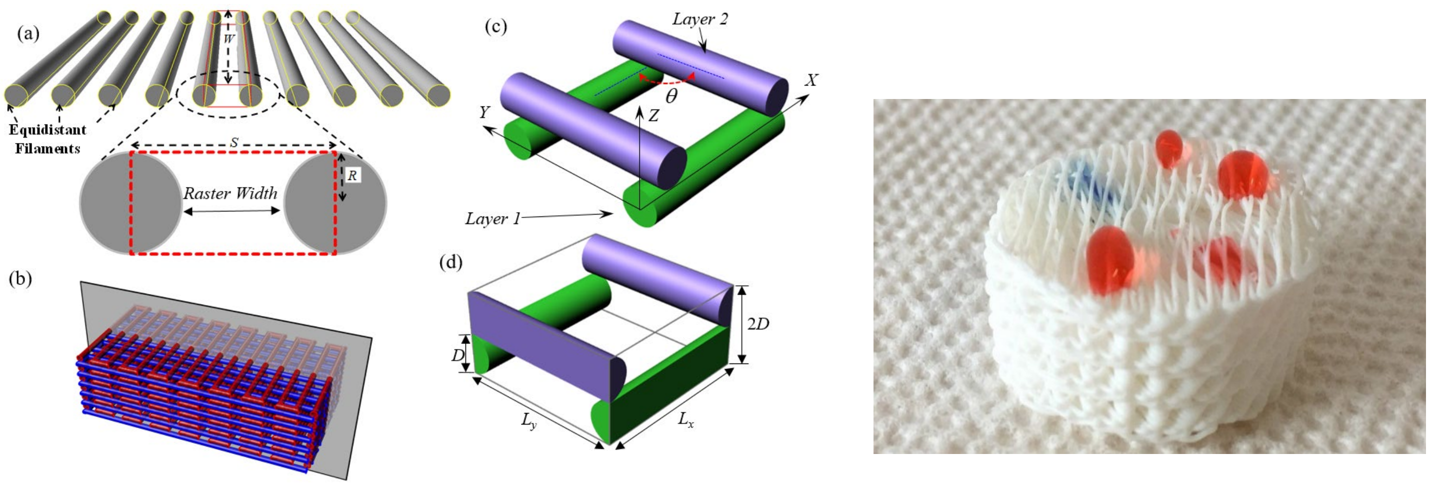


Figure 1. Proposed concept of 3D printing lattice composites

New Bio-Inspired 3D Printing Functionalized Lattice Composites for Actively Preventing and Mitigating Internal Corrosion

The 3D printing lattice composites offered the following advantages:

1) Tailored lattice patterns using 3D printing technology
2) Surfaced treatment for enhanced wettability properties
3) Excellent chemical resistance and mechanical properties

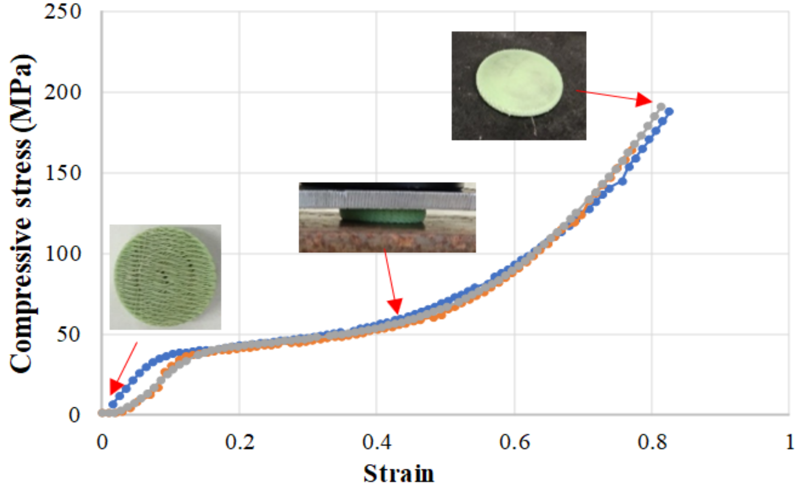


Figure 2, Mechanical behavior of 3D printing lattices

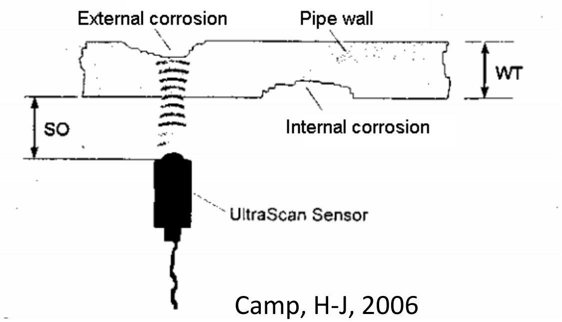
- M.S. student, Matthew Pearson, published 3 conference papers, and one manuscript under review
- One patent application under the way
- Recruited two high-school students in the research in summer 2019

Brown University

Improved NDT Detection and Probabilistic Failure Prediction for Interacting Pipeline Anomalies

Program manager: Dr. Joshua Arnold
Brown University team:
P.I.: Vikas Srivastava
Sijun Niu, Ph.D. student
Alex Le, undergraduate student

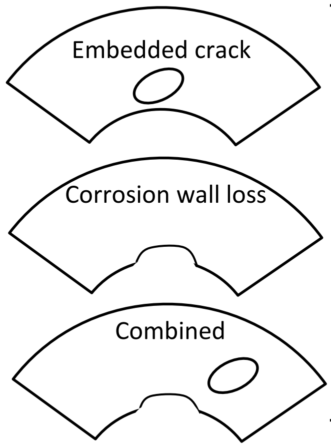
Ginzel, R.K. 2002



Camp, H-J, 2006

Aim: Reduce uncertainty in flaw detection and failure prediction for pipelines

***Uncertainty* in ultrasonic non-destructive testing (NDT) remains problematic**



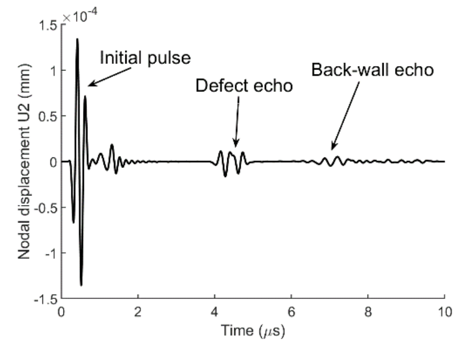
Size?
Type?
Location?
Orientation?

Significant uncertainty

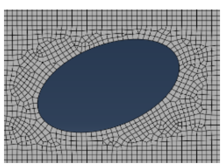
Ultrasound testing (UT):

- ✓ Surface/subsurface crack
- ✓ Cost effective
- ✓ Better image quality
- ✓ Superior in depth

- × Extensive training
- × **Manual interpretation**
- × **Lack of standardization**



Objective 1: Simulation driven, automated machine learning (ML) characterization of flaws
Objective 2: Probabilistic prediction of pipeline failure loads

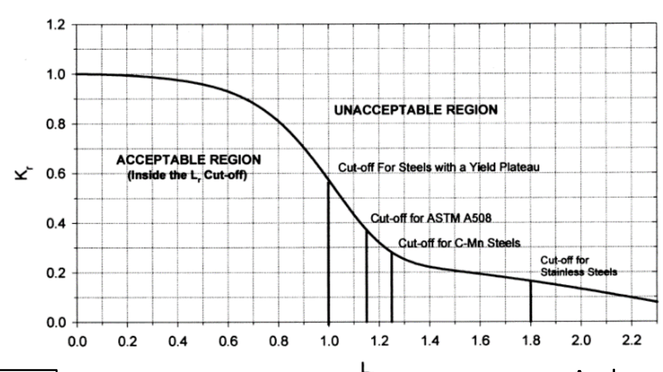


FE Simulations

- Probing error sources in UT
- Significantly reduce **expense and time for large set of data** compared to experiments

Research: Large dataset by simulation → Feature extraction → *Training* → ML algorithm → Algorithm Validation

Application: Field data → Validated ML algorithm → Better prediction



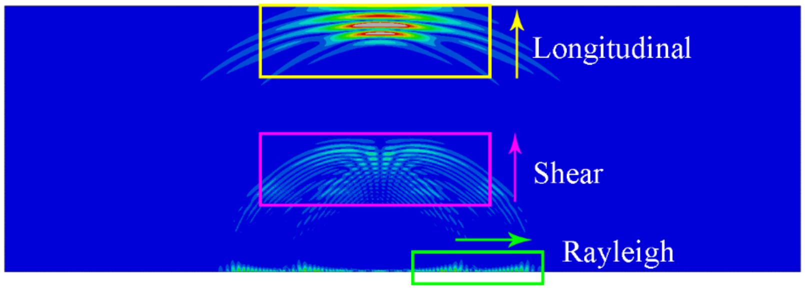
Current failure assessment are ***deterministic and empirical***

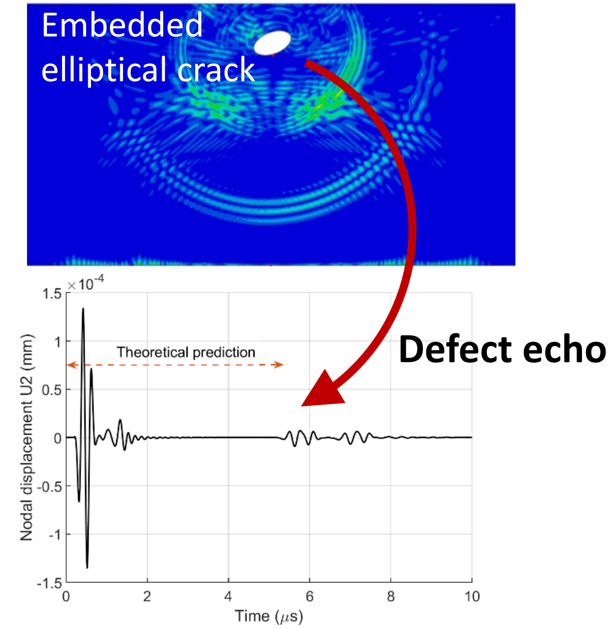
Anderson, T. 2000

Ongoing research

Current result:

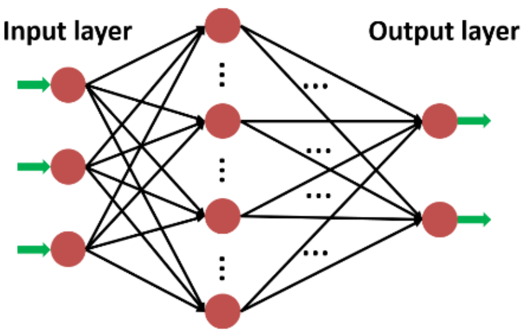
- Established wave propagation simulation method
- Dynamic FE simulations for UT crack detection



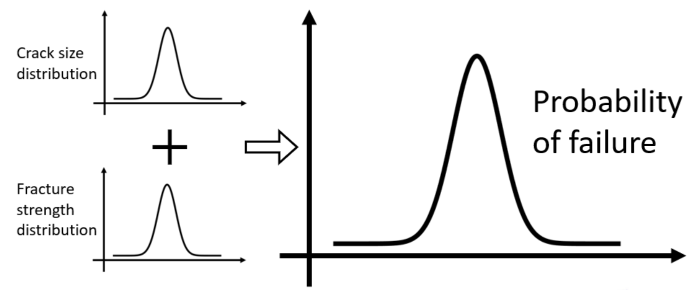


Future work:

- <u>Machine learning</u>
  - Neural network
  - Support Vector Machine
  - Decision Trees
  - Regression Analysis
- <u>Validation experiments</u>



- <u>Probabilistic failure prediction</u>



Texas A&M

Development of a Prediction Model for Pipeline Failure Probability based on Learnings from Past Incidents and Pipeline Specific Data using Artificial Neural Network (ANN)

Guanyang Liu, Pallavi Kumari, Mason Boyd
Noor Quddus and James Holste

Mary Kay O'Connor Process Safety Center
Artie McFerrin Department of Chemical Engineering,
Texas A&M University System, College Station, Texas

Overview and Objectives

- ❑ Pipeline incident reports typically collects causes without providing sufficient detail of root cause of the incident
- ❑ Incidents investigation reports express identified root causes in a variety of ways that produce inconsistent taxonomy

- Learning about root causes behind pipeline failure
  - Employ natural language processing (NLP) to analyze narrative comments of incident reports and incident investigation reports
- Implementation of learning to predict failure
  - Develop artificial neural network (ANN) model to predict failure utilizing learnings extracted by the NLP code and other failure data

Results and Conclusions

- Data gathered from PHMSA (HL, GTG), NEB (Canada), EGIG (Europe) datasets
- Literature review conducted on pipeline incident analysis
- Causal factors used in PHMSA, NEB, and EGIG datasets compared
- Pipeline failure data analyzed to identify the contributing factors to be used in ANN model
- Natural language processing (NLP) model is developed and being tested with different datasets
- Artificial neural network (ANN) model is being developed

Iowa State University

Fundamental Understanding of Pipeline Material Degradation under Interactive Threats of Dents and Corrosion

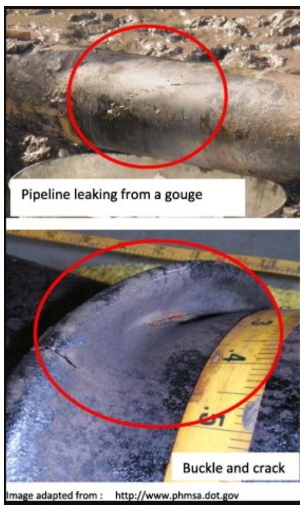
Profs. Ashraf Bastawros, Kurt Hebert
Grad. Students: A. Abdelmawla, K. Kulkarni
Undergrad Students: Jessica Dwyer, Taylor Burton
Iowa State University

Industrial Partners: Mark Piazza, Colonial Pipeline
Paul Panetta, ARA Inc.

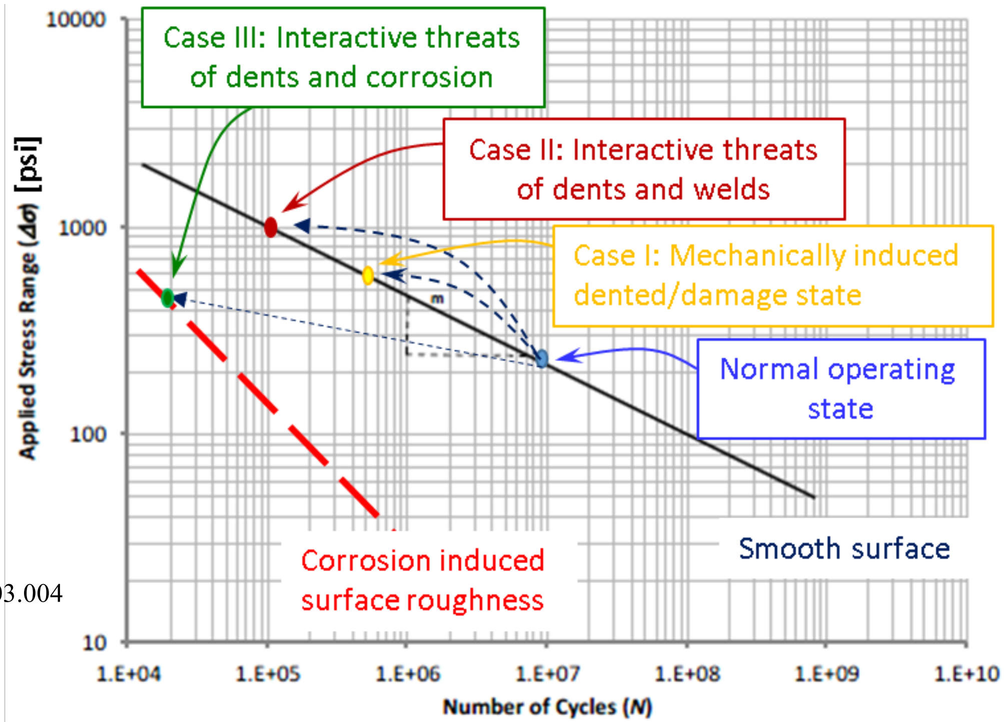
Project No.: 693JK31950003CAAP- 9/2019 - 9/2022

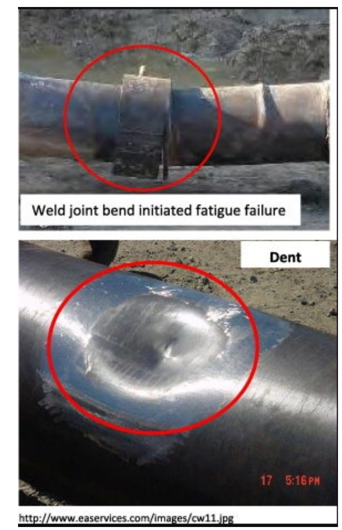
Enhance pipeline safety

Evaluate interactive threats of external mechanical dents and secondary features, through integrated lab-scale experimental and numerical framework to characterize and better predict the remaining safe life and operating pressures, while projecting the needs for mitigation measures.



doi.org/10.1016/j.engfailanal.2015.03.004





Provide pathway “hypothesis” to address degradation and interactive threats

Project Expected Outcome

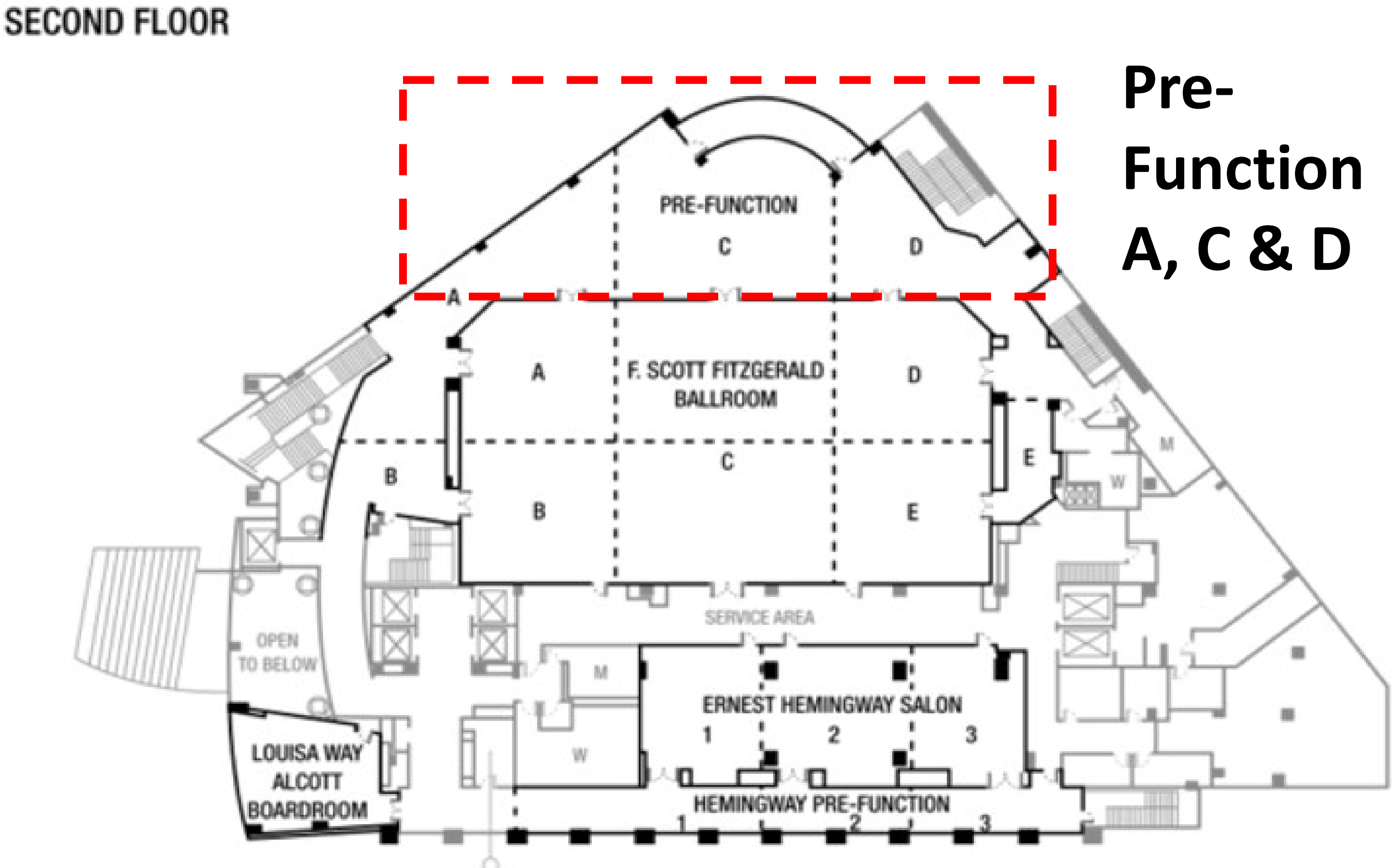
(A) Identify Physics of Interactive Threats:

Provide fundamental understanding of measurable degradation parameters at the local level, that can assist in the variance reduction of threat assessment of the damage at the pipeline structure scale.

(B) Model Based Prediction:

Provide lab-scale experimentally calibrated computational framework with the potential to assist in quantifying the burst pressure under interactive threats.

WHERE TO FIND POSTERS



Pre-Function A, C & D