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PIPELINES 2017 CONFERENCE

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Wireless Sensor Networks for Health Monitoring of Welded Joints in Onshore Metallic Pipelines

Dr. Zhibin Lin

Dept. of Civil and Environmental Engineering

North Dakota State University

Hong Pan, Ruisi Ge, Xingyu Wang, Drs. Jinhui Wang and Na Gong

North Dakota State University

PHMSA Pipeline and Hazardous Materials Safety Administration

North Dakota LEGENDARY

NDSU NORTH DAKOTA STATE UNIVERSITY

Reliability and Resiliency through Sustainable Design and Construction

Acknowledgment

- **Collaborators**

  Drs. Dante Battocchi and Xiaoning Qi (NDSU)

  Drs. Fardad Azarmi, Yechun Wang (NDSU)

  Dr. An Chen (ISU) Dr. Genda Chen (MST)

  Drs. Konstantin Sobolev, Habib Tabatabai, Jian Zhao (UWM)

- **My students**

  Dr. Fei Yan (2016), Mohsen Azimi (2017), Qusay Alkaseabeh (2015)

  Mingli Li, Xingyu Wang, Muhammad Naveed, Ganghyun Hyung

- **Sponsors**

  US Department of Transportation-CAAP

  US Department of Transportation

  ND DOC Venture

PHMSA
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Outline

- **Background and Challenges**
- **Proposed Concept in Pipeline Safety and Assessment**
- **Proposed Wireless Sensor Networks**
- **Data Mining for SHM and Damage Detection**
- **Summary**

1. Background

Pipeline spill and pollutions

http://www.occupy.com/article/20000-barrels-spilled-north-dakota-pipeline-rupture?qt-article_tabs=2

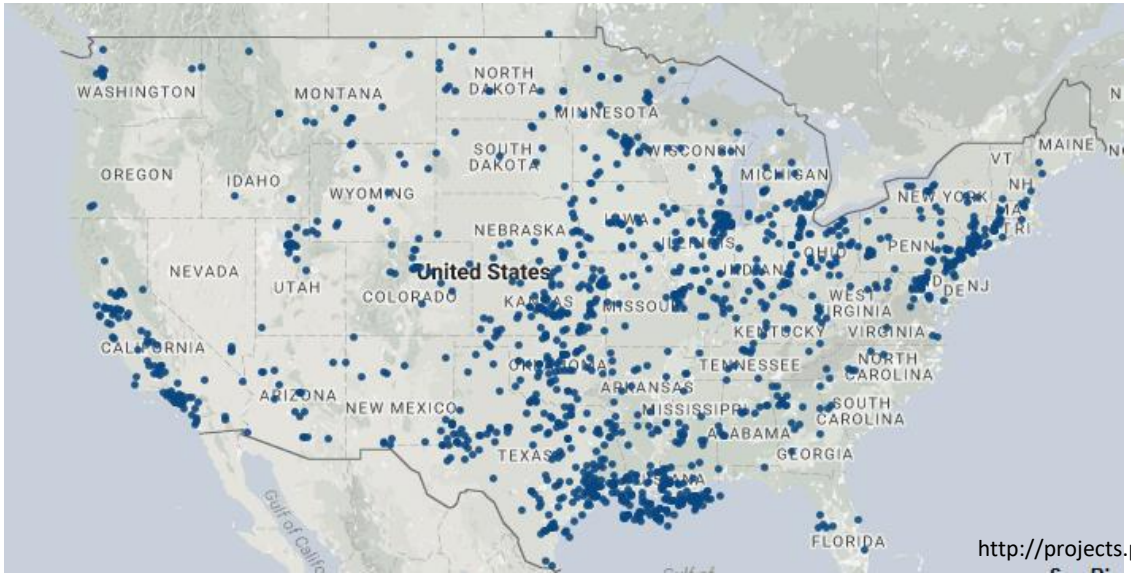
Left: pipeline explosion (West Virginia, 2012) and right: Taiwan, 2014

1. Background

Damage-induced pipeline accidents at North Dakota

Accident	Location	year	Loss
Pipeline spill	Tioga, ND	2014	One gas pipeline exploded and burned
Pipeline spill	Tioga, ND	2013	**865,000 gallons (<u>one of the largest to happen onshore in U.S. history</u>)**, over two years still cannot be fully cleaned up
Pipeline spill	Sargent County, ND	2011	Spilling 400 barrels of crude oil
Pipeline spill	Neche, ND	2010	Releasing 3,784 barrels of crude oil
Pipeline spill	Mantador, ND	2004	Nearby residents were evacuated, and a rail line was shut down
Pipeline spill	Barnes County, ND	2003	Releasing 9,000 barrels of propane
Pipeline ruptured	Bottineau, ND	2001	1.1 million US gallons (4,200 m^3) of gasoline burned
Pipeline spill	Harwood, ND	2001	Spilling 40 barrels of fuel oil

Damage-induced pipeline accidents national wide

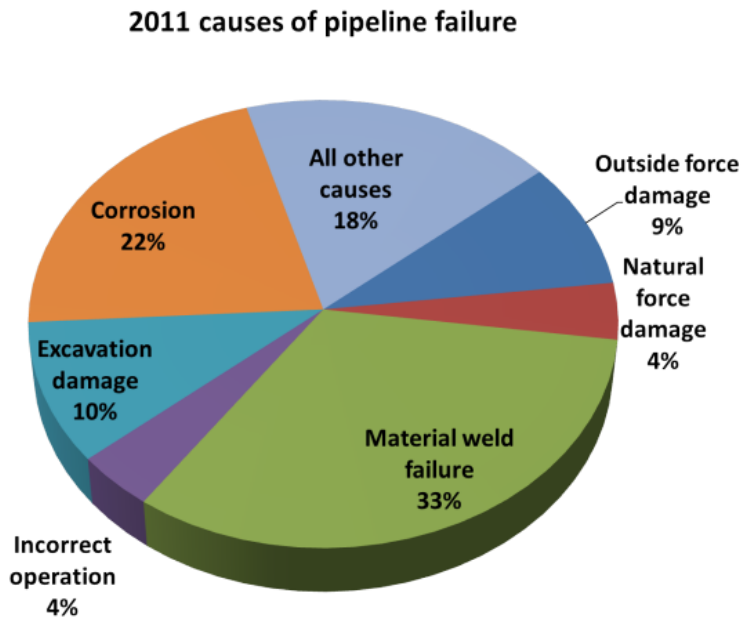


http://projects.propublica.org/pipelines/

1. Background

Damage/corrosion-induced pipeline

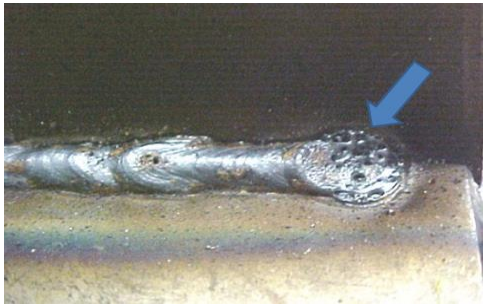
Oil and Natural Gas Pipeline



https://blog.enerdynamics.com/2013/02/03/natural-gas-pipeline-safety-a-crisis-or-a-manageable-issue/

http://napipelines.com/prime-connections/

cracks



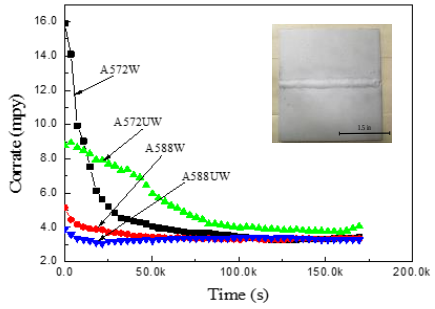
porosity

2. Proposed Concept in Pipeline Safety and Assessment

Framework of High-Performance System

Failure Mechanism

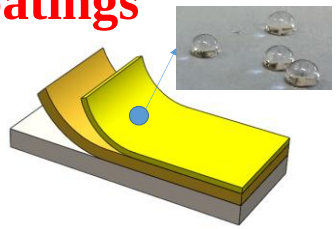
Soil, welds, metallic types



High performance underground structures

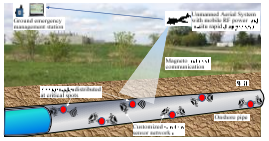
Mitigation and Protection

New coatings



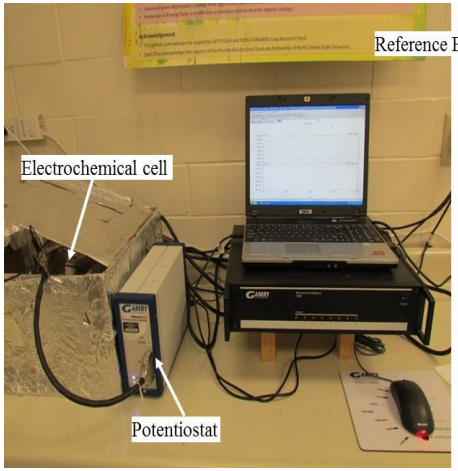
Monitoring and Diagnosis

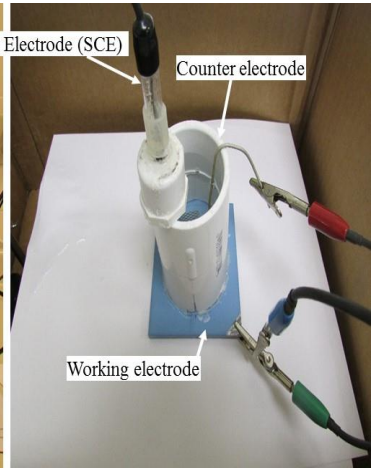
Wireless sensor networks
Rapid damage detection

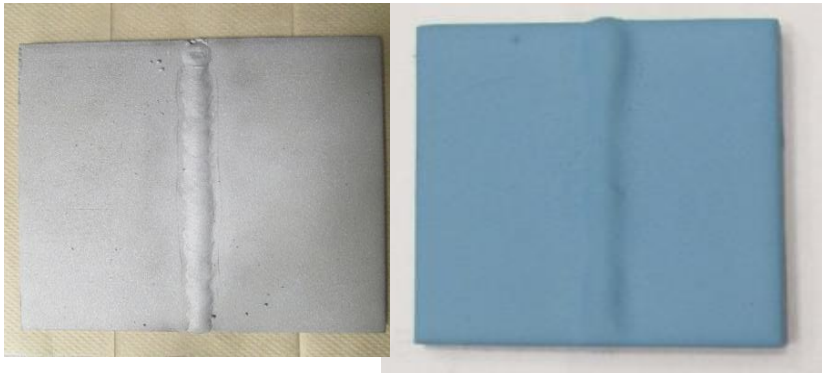


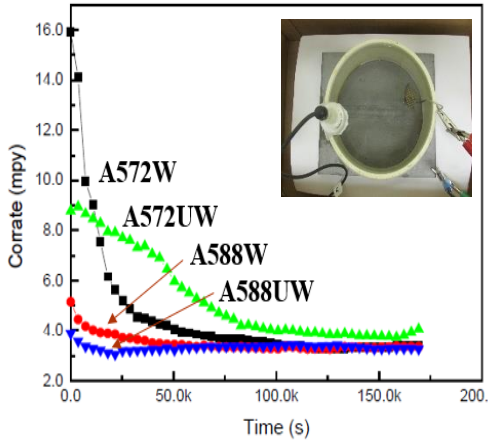
2. Proposed Concept in Pipeline Safety and Assessment

NDDOC funded weldment (on-going)







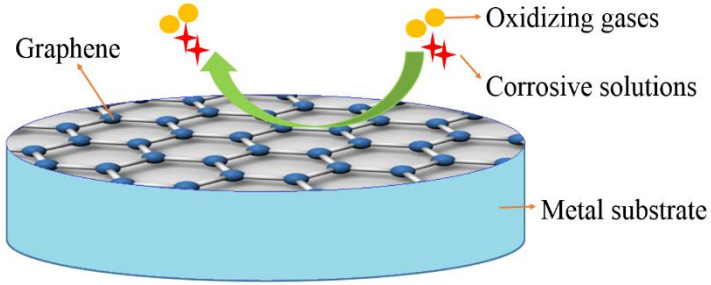


2. Proposed Concept in Pipeline Safety and Assessment

USDOT CAAP funded multifunctional coatings (on-going)

Fig. 1 Internal corrosion: a) localized pits[2], b) fouling[3] and c) wear/erosion[4]

New multifunctional nano-modified coatings



Corrosion resistance

Anti-fouling capacity

Abrasion-resistance capacity

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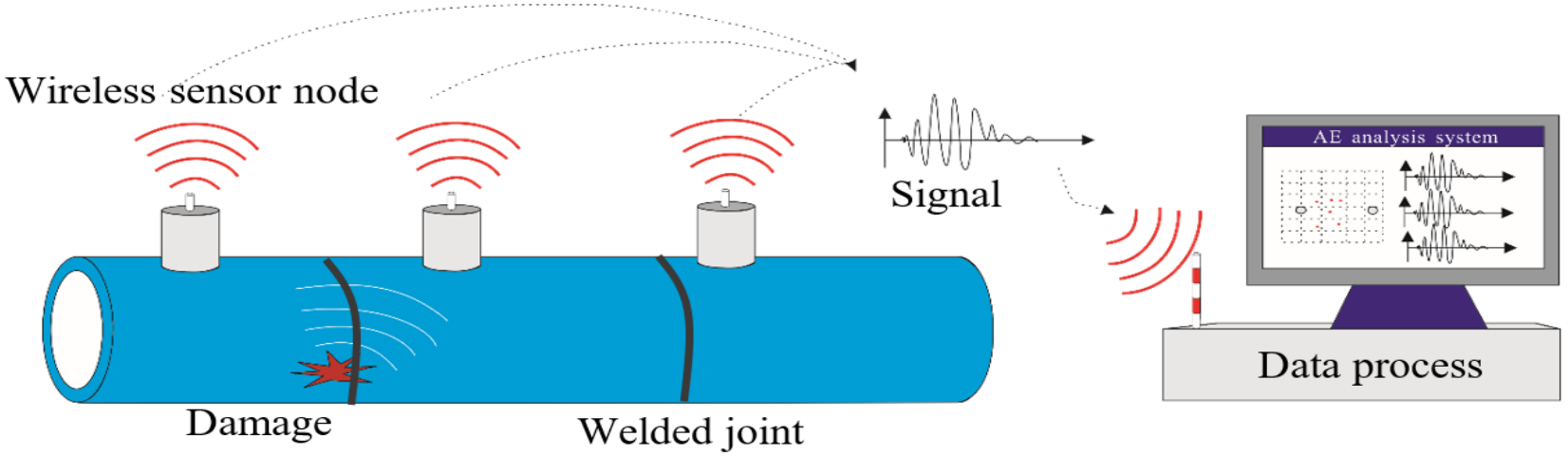
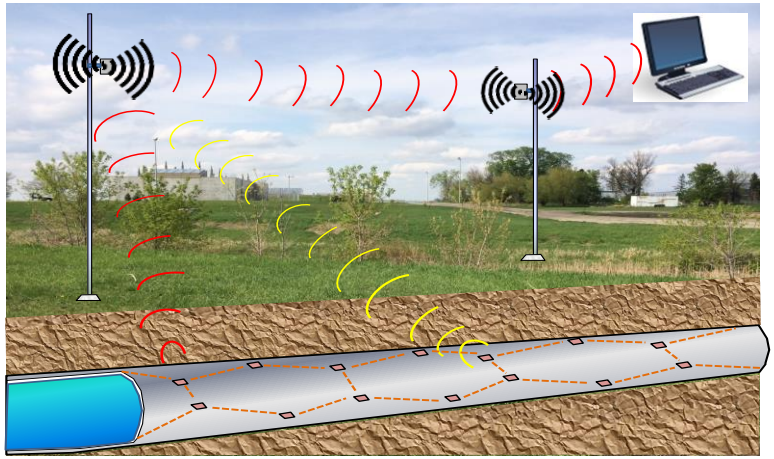
http://www.flickriver.com/photos/59127492@N07/5416927808/ http://www.icorr.org/news/180/index.phtml

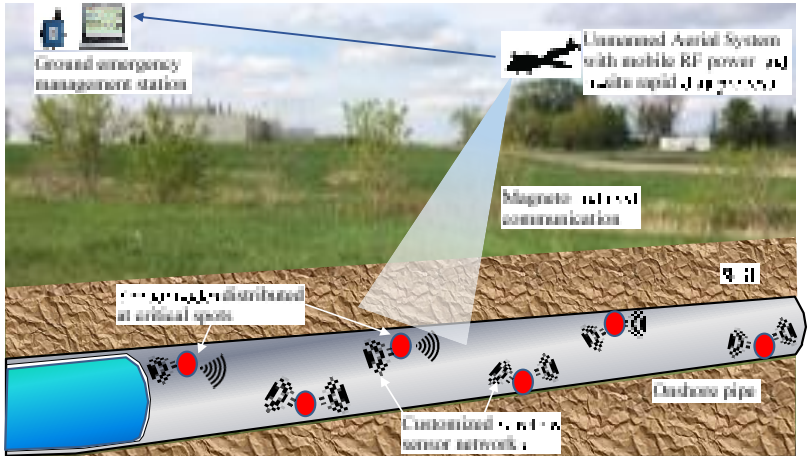
https://sites.google.com/site/metropolitanforensics/root-causes-and-contributing-factors-of-gas-and-liquid-pipeline-failures

2. Proposed Concept in Pipeline Safety and Assessment

Integrated WSN w/ and w/o UAS for Pipeline Monitoring

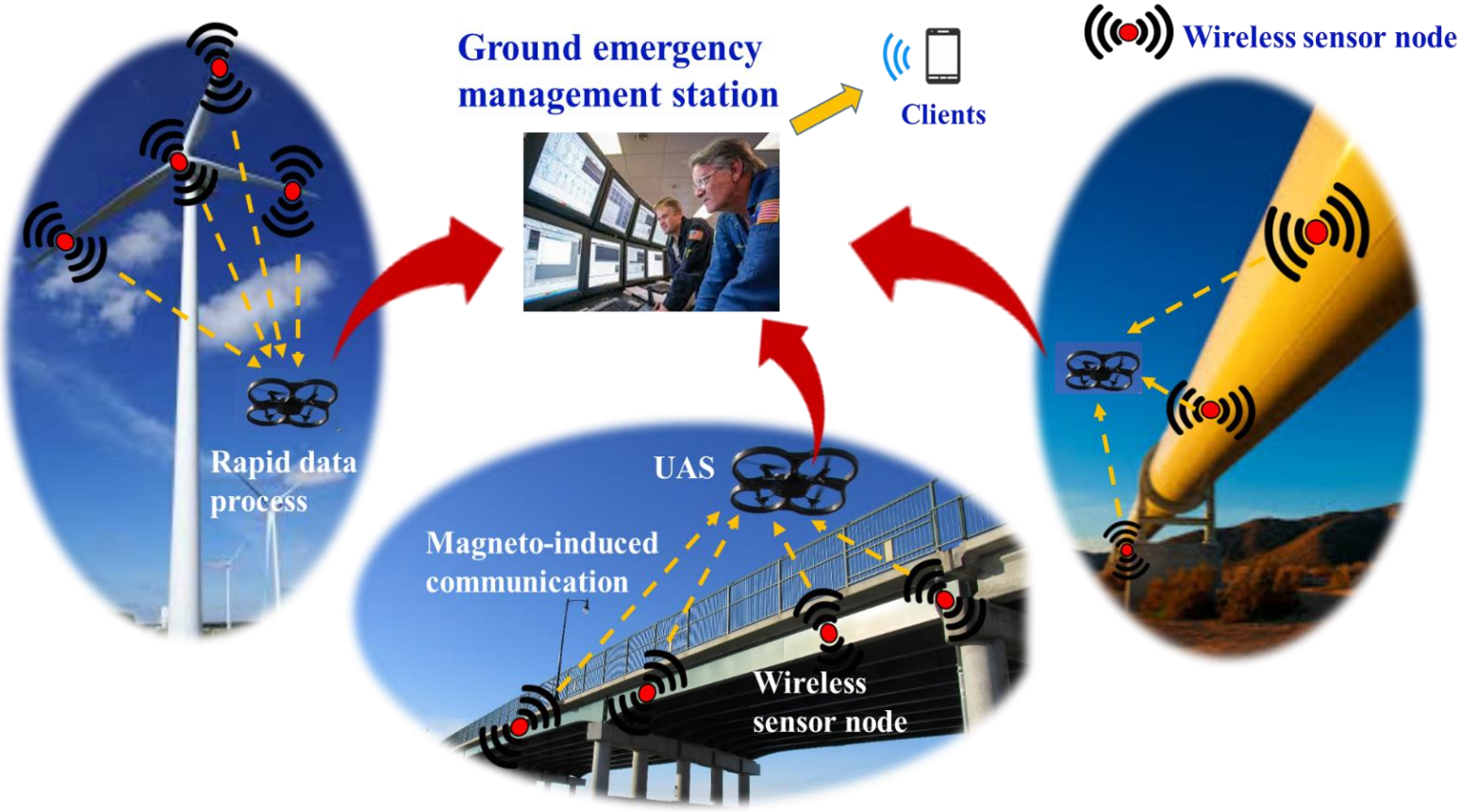






2. Proposed Concept in Pipeline Safety and Assessment

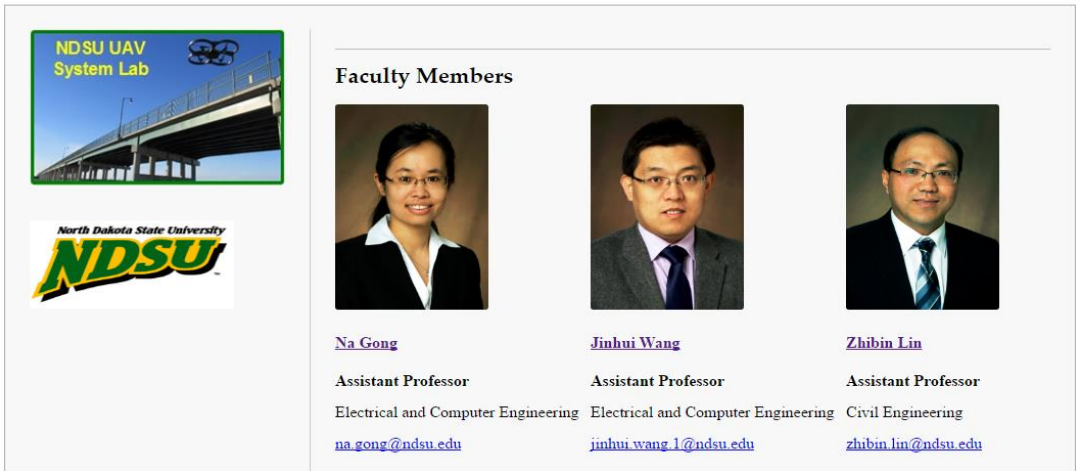
Applications to other critical large-scale/long-span civil infrastructures



2. Proposed Concept in Pipeline Safety and Assessment

Wireless sensor networks integrated with UAV

NDSU UAV System Lab

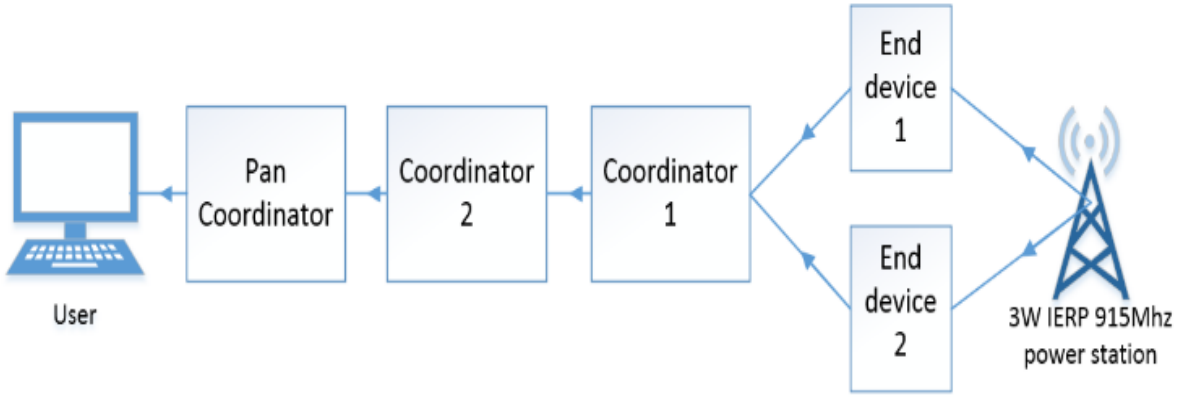


https://www.ndsu.edu/pubweb/~nagong/uav.html

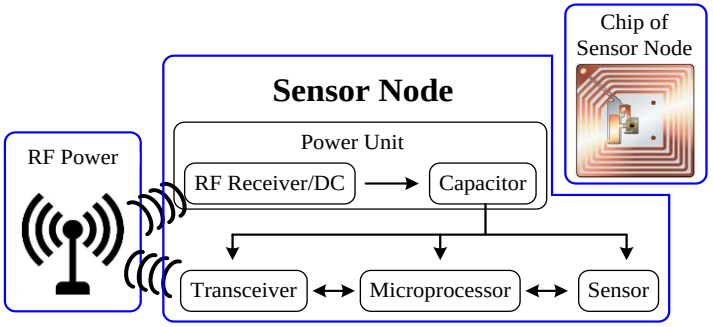
Research, Industry, Outreach

3. Proposed Wireless Sensor Networks

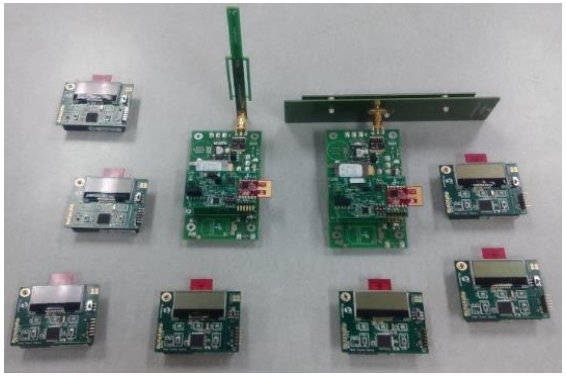
-WSN for Long-Distance/Large Scale Monitoring



RF power battery-less wireless system overview



Architecture of the proposed sensor node

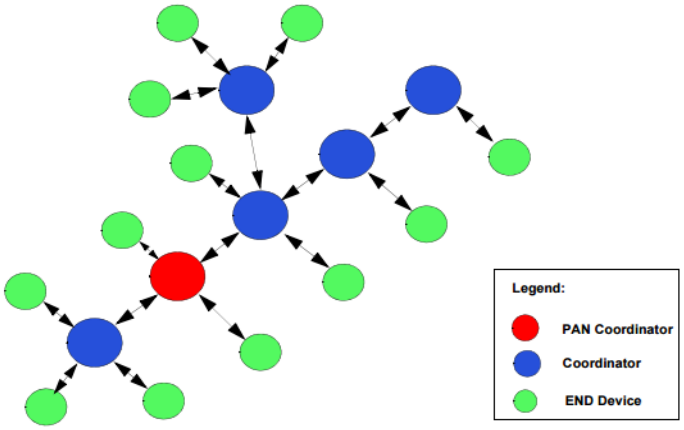


Developed wireless devices for networks

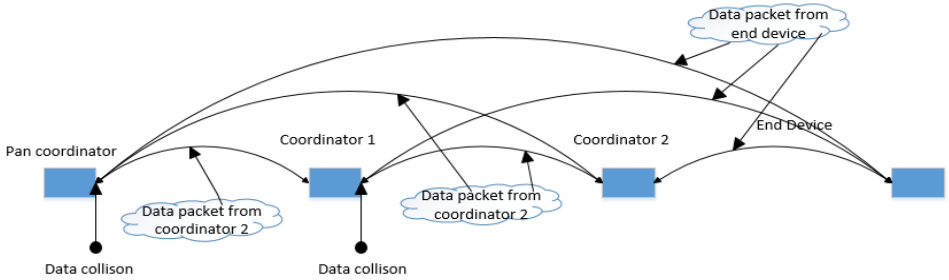
3. Proposed Wireless Sensor Networks

-WSN for Long-Distance/Large Scale Monitoring

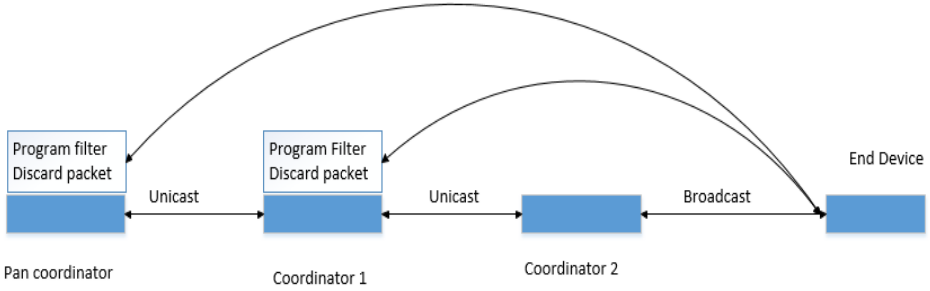
Network topology for MiWi Pro protocol



Data Collision



Possible data collision

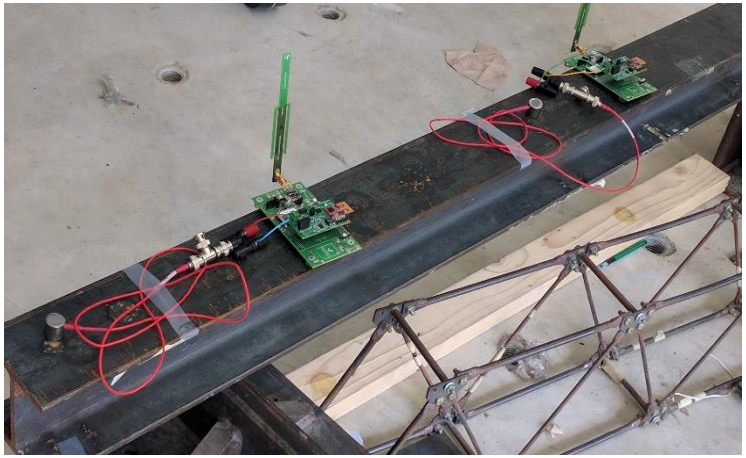


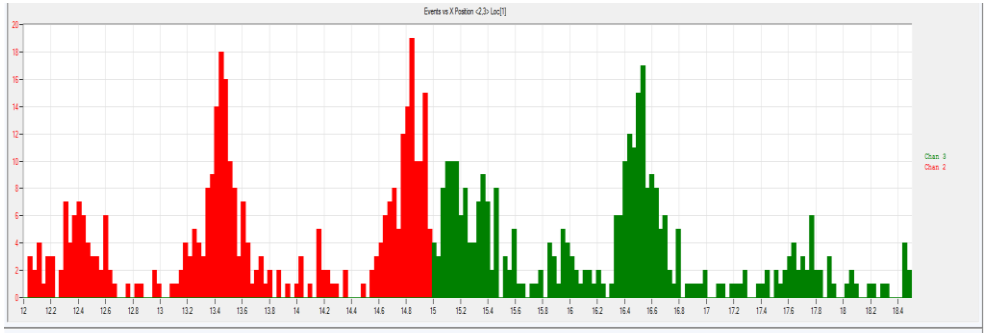
Method for solving data packet collision

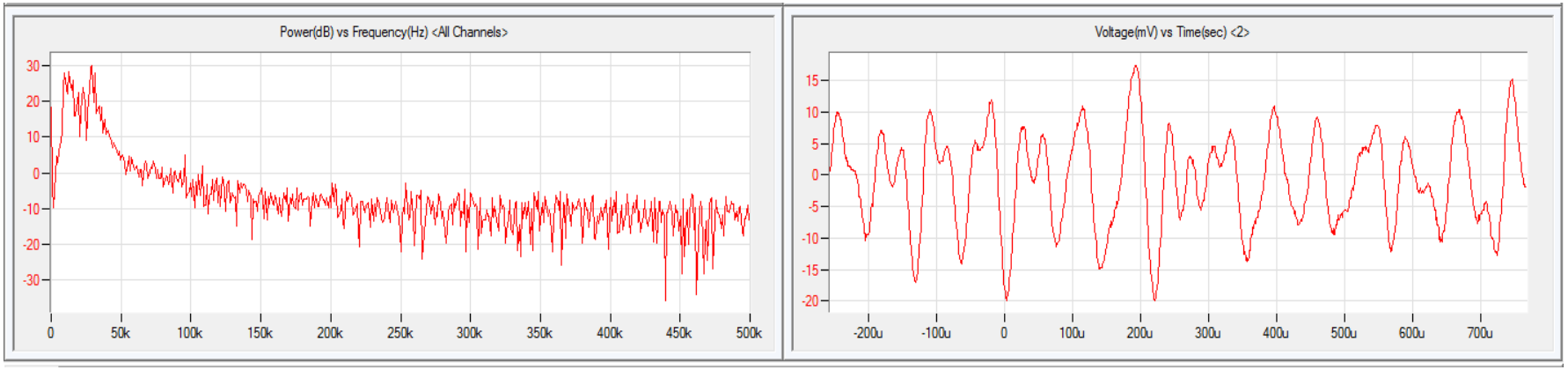
3. Proposed Wireless Sensor Networks

-Specific Lab Demonstration

Damage detection (localization and levels)







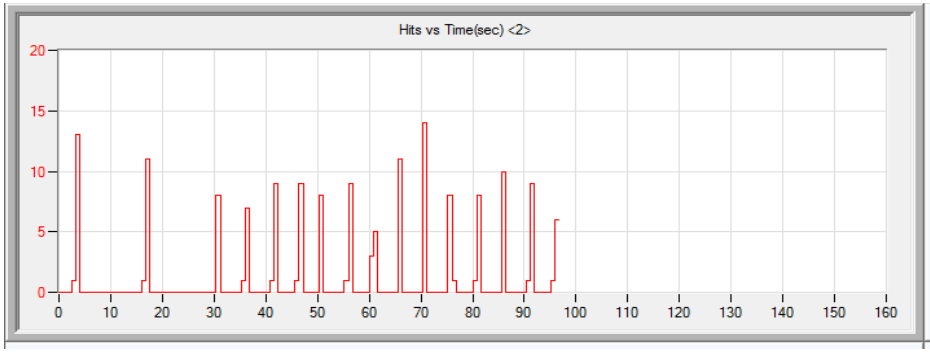
Damage-induced wave spectrum

Damage-induced wave time history

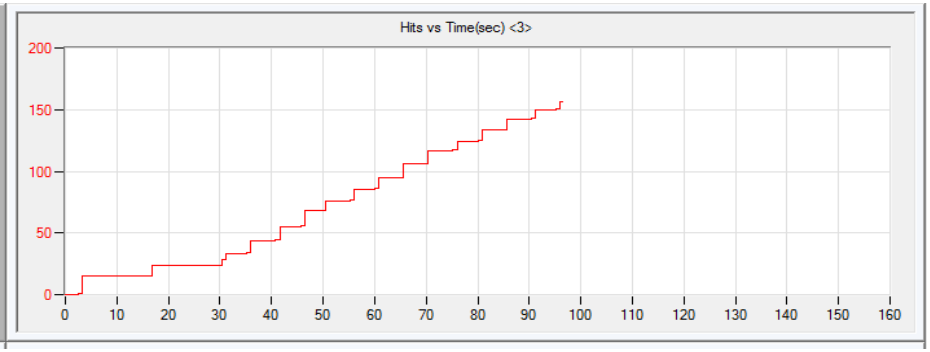
3. Proposed Wireless Sensor Networks

-Specific Lab Demonstration

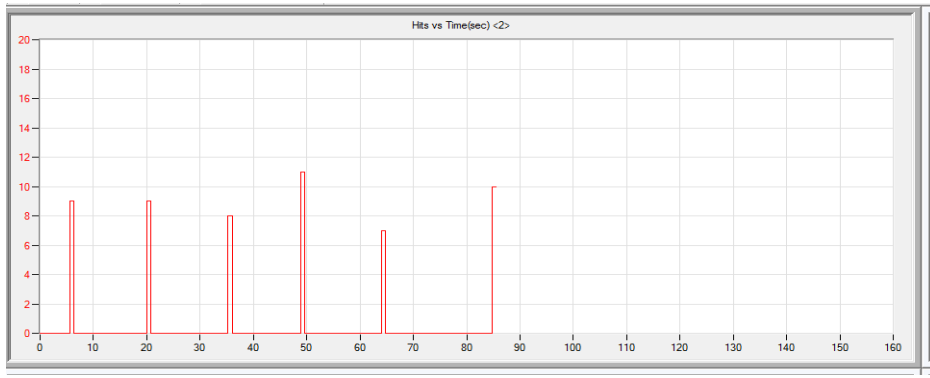
Damage detection (localization and levels)



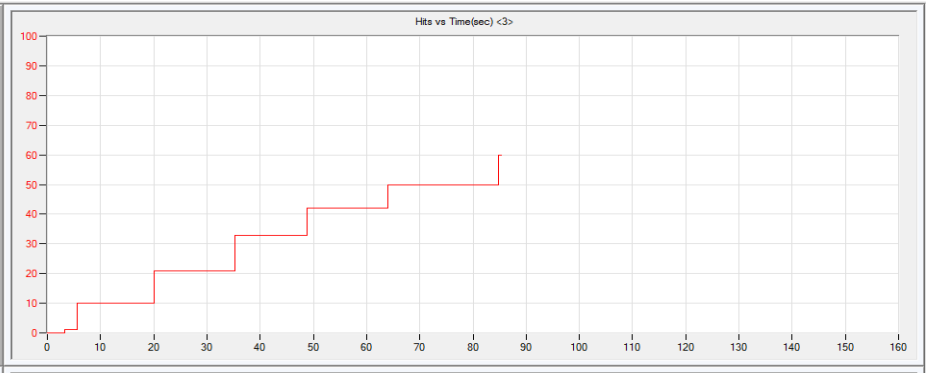
Damage-induced hits (scenario 1)



Hit accumulation (scenario 1)



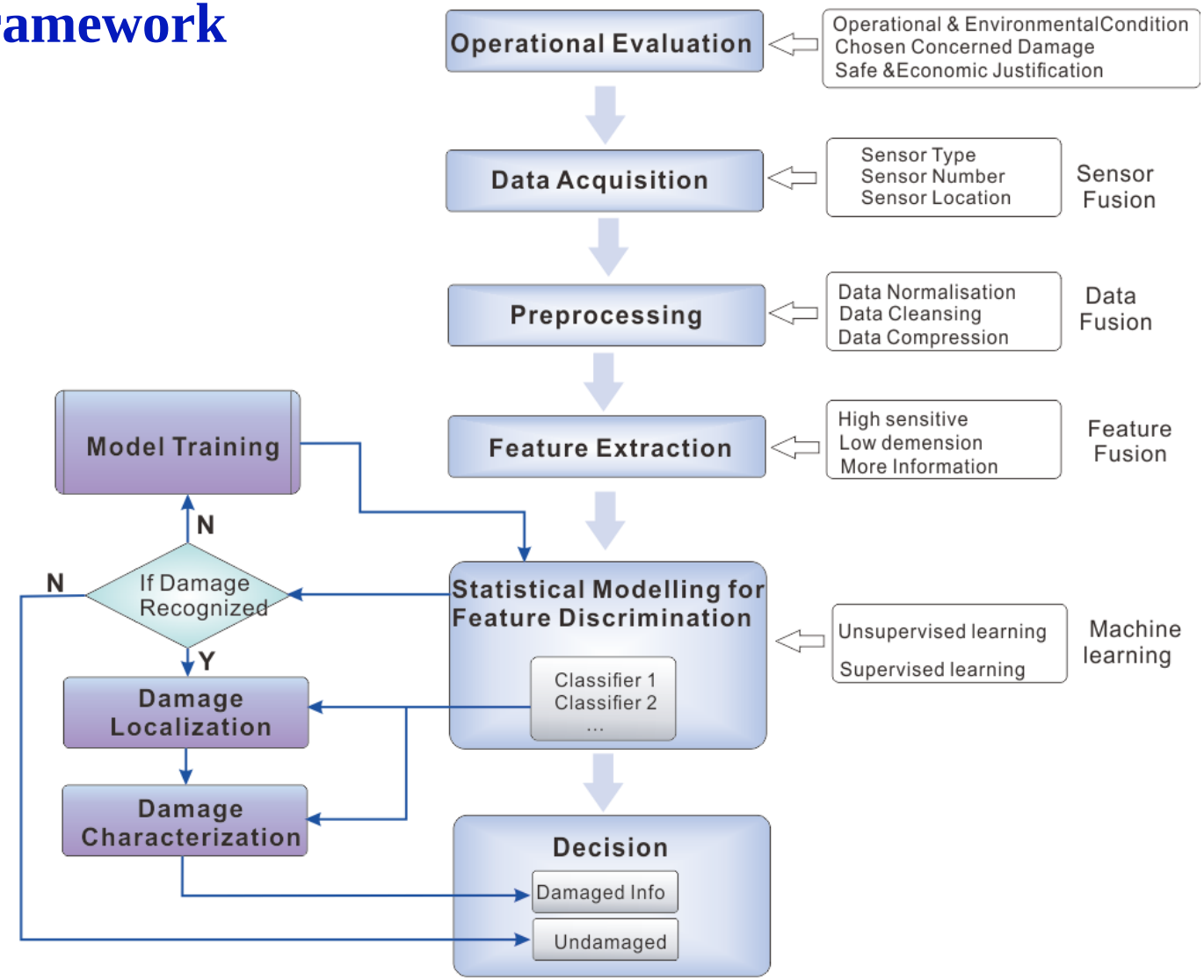
Damage-induced hits (scenario 2)



Hit accumulation (scenario 2)

4. Data Mining for SHM and Damage Detection

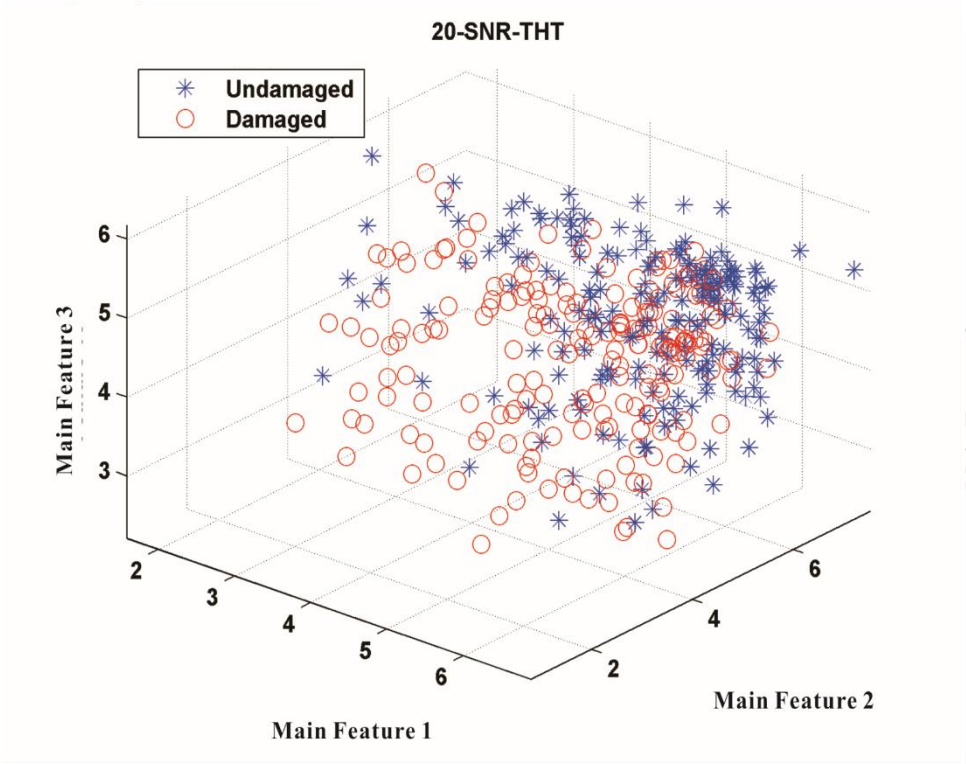
-Framework

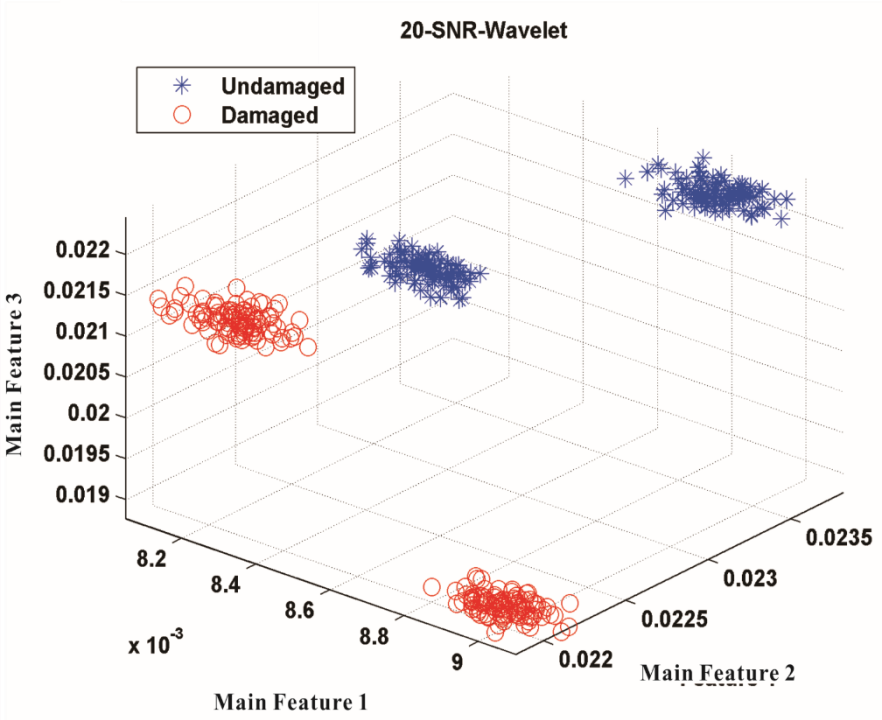


4. Data Mining for SHM and Damage Detection

- Data-driven models: Machine Learning and Optimization

Support Vector Machine

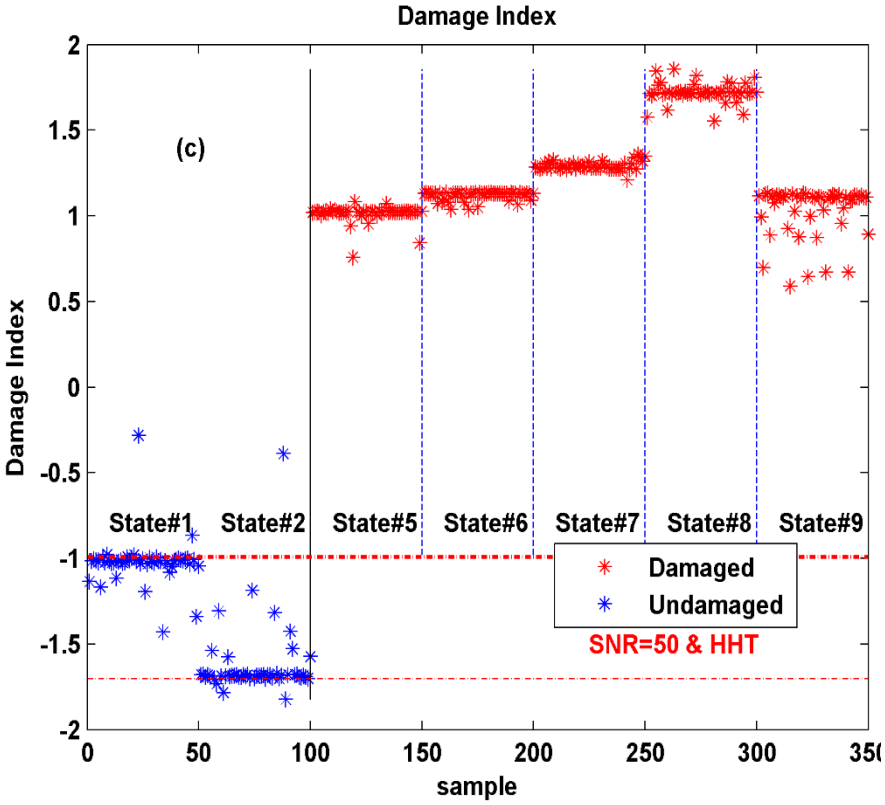




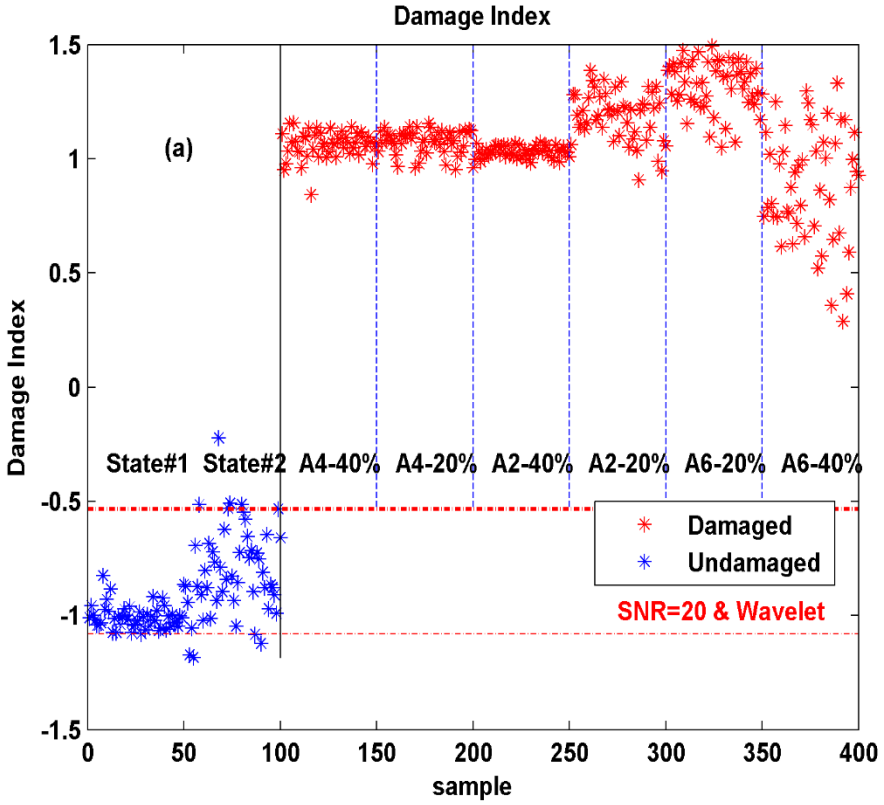
Early-age detection from vast amount of data

3. Data Mining for SHM and Damage Detection

- Data-driven models: Machine Learning and Optimization



Damage Level



Damage Location

5. Summary

-Pipeline condition assessment techniques

Developed technology will have a **high impact** on pipeline assessment techniques:

- wireless sensor networks (or integrated with UAS technology) has recently demonstrated great potential for full-spectrum SHM

- Data-driven models are robust to rapidly identify the key information from complex sensor data

5. Summary

-Pipeline operation safety

Developed technology will have a **high impact** on pipeline operations and management:

- Timely monitoring and managing performance of pipelines, thereby minimizing pipeline oil spill and damages.

- Improve the quality and safety operation, thus prolonging the useful life span of pipelines.

Questions ?

Thank You!

Zhibin.lin@ndsu.edu