Plant Modernization Pathway

Digital Architecture and Plant Automation

Vivek Agarwal

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I&C Data Architecture

Online Monitoring and Plant Automation

- Replacing the current labor intensive plant monitoring with a centralized online monitoring approach

- Developing a risk-informed predictive maintenance strategy

  - **Data Analytic Capabilities** –
    Developing diagnostics and prognostics
    models using data driven techniques and advancement
    in sensor technologies

  - **Risk assessment capabilities** – Revisiting probabilistic risk assessment to achieve risk-informed revision of current design basis, margin recovery, and the application of new technologies

- Outcomes will…
  - Reduce LWR Fleet operation and maintenance costs
  - Improve efficiencies gained through automation of plant activities
    - Replace or augment current inspection-based aging management plan with online monitoring capabilities

Data Architecture
- Common Data Model
- Online Monitoring
- Advanced Analytics

Fiscal Year 2019 Research Projects

- Technology Enabled Risk-informed Maintenance Strategy (TERMS)
  - Integrate advancements in online asset monitoring and data analytic techniques with advanced risk assessment methodologies to reduce maintenance costs and enhance the reliability of plant assets

- Advanced Remote Monitoring for Operation Readiness (ARMOR)
  - Automate the labor intensive processes of monitoring plant operation

- Advanced Remote Monitoring of Concrete Structures in Nuclear Power Plants
  - Enhance structural health monitoring framework using machine learning and data analytics techniques to augment or replace the current manual inspection based aging management plan

- Advanced Remote Monitoring of Secondary System Piping in Nuclear Power Plants
  - Address the technology gap in the area of piping erosion and corrosion/erosion monitoring by adding new sensor modality to enable condition-based piping repair

Online Monitoring Research

Online monitoring of active assets **(FY 2011 – FY 2015)**

| Assets	Fault Signatures	Diagnostic Model	Prognostic Model
Generator step-up transformer	Yes	Yes	Yes
Emergency diesel generator	Yes	Yes	No
Induction Motors	Yes	Partially	No

Online monitoring research **(FY 2018 onwards)**

- Replacement of prescriptive-based maintenance strategy with a **risk-informed predictive maintenance strategy**
- INL is working on developing a risk-informed predictive maintenance strategy in collaboration with nuclear industry that includes
  - **Online monitoring capabilities**
 - **Advanced data analytics techniques**
  - **Risk assessment methodologies**
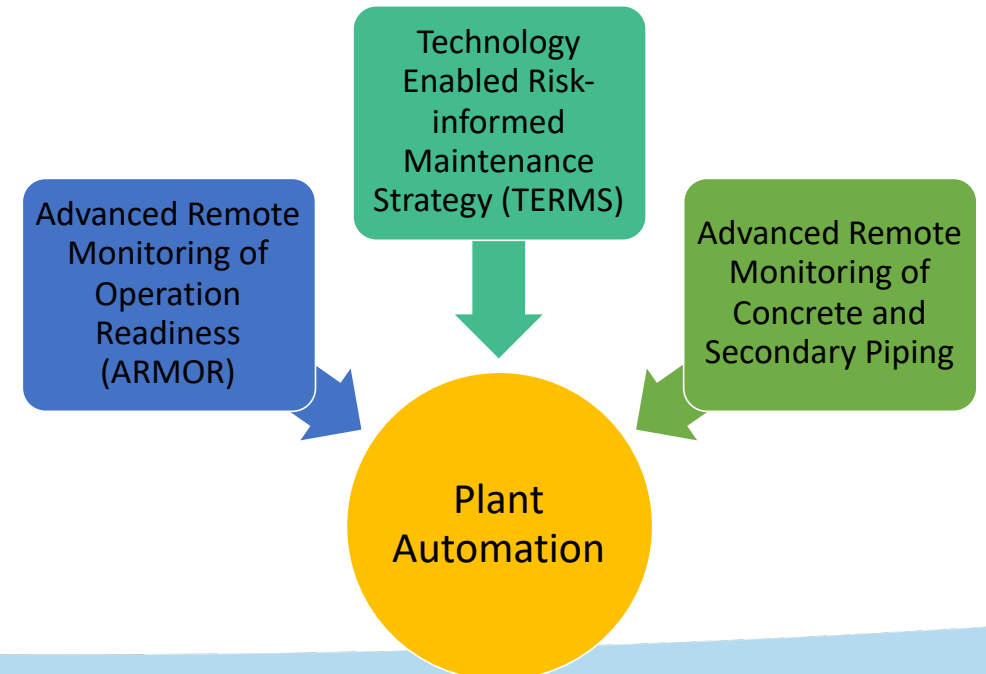
Advanced Remote Monitoring of Operation Readiness (ARMOR)

Technology Enabled Risk-informed Maintenance Strategy (TERMS)

Advanced Remote Monitoring of Concrete and Secondary Piping

Plant Automation

Technology Enabled Risk-informed Maintenance Strategy (TERMS)
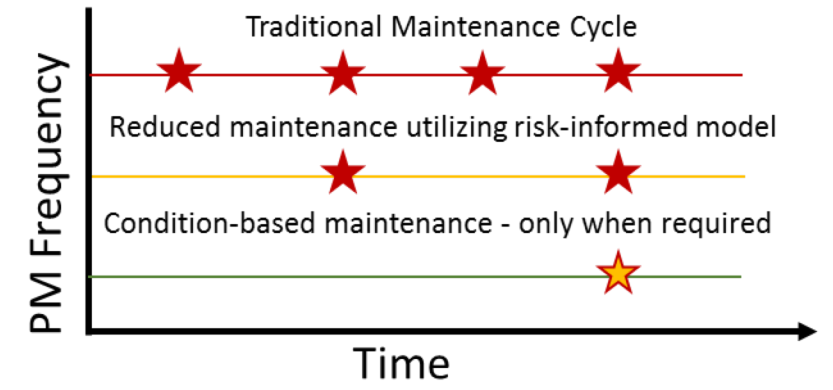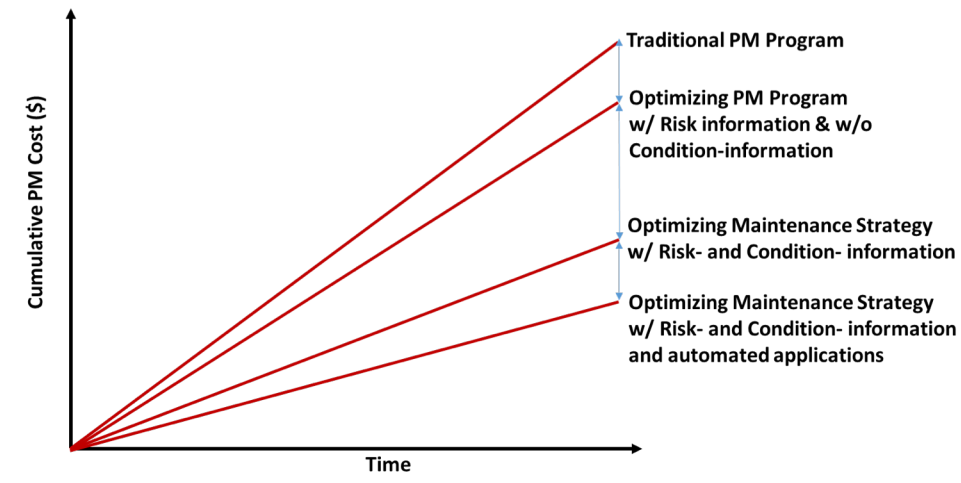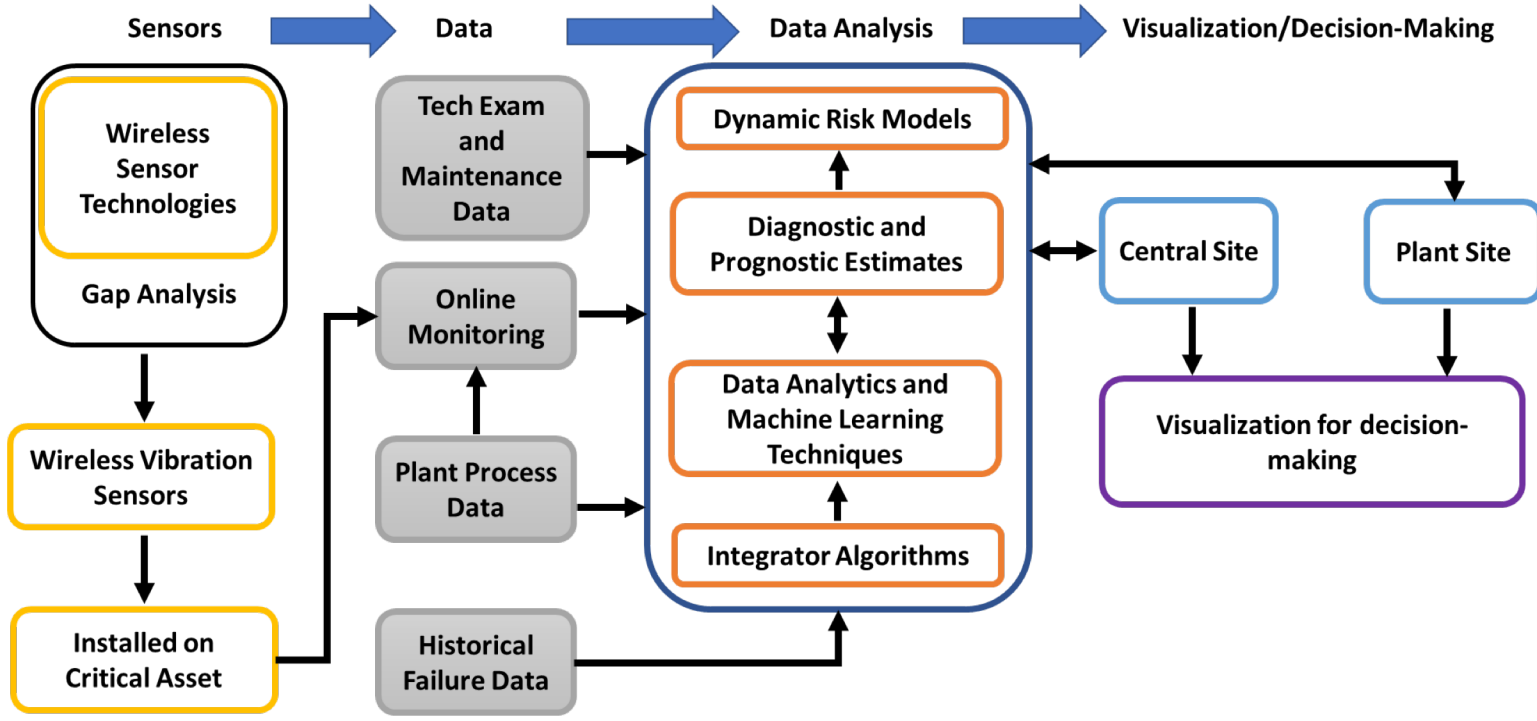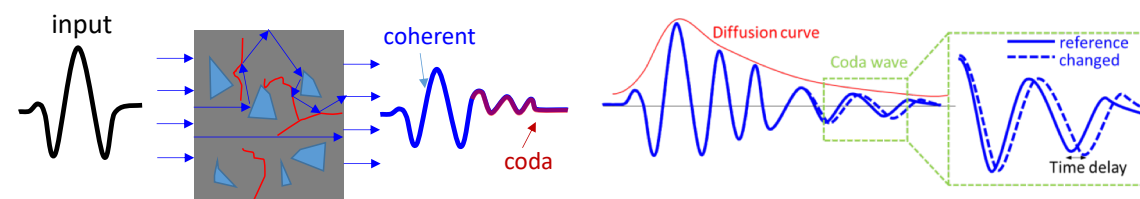
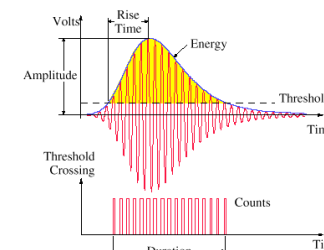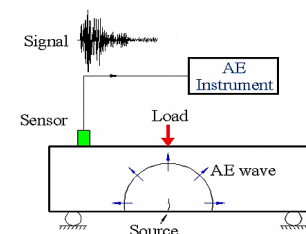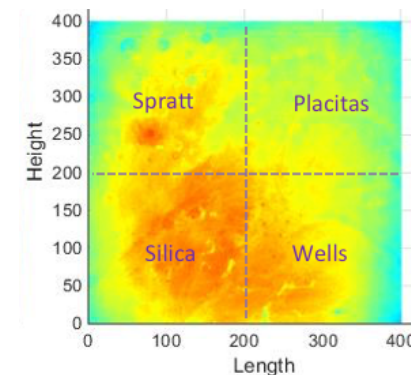# Advanced Remote Monitoring for Operation Readiness (ARMOR)
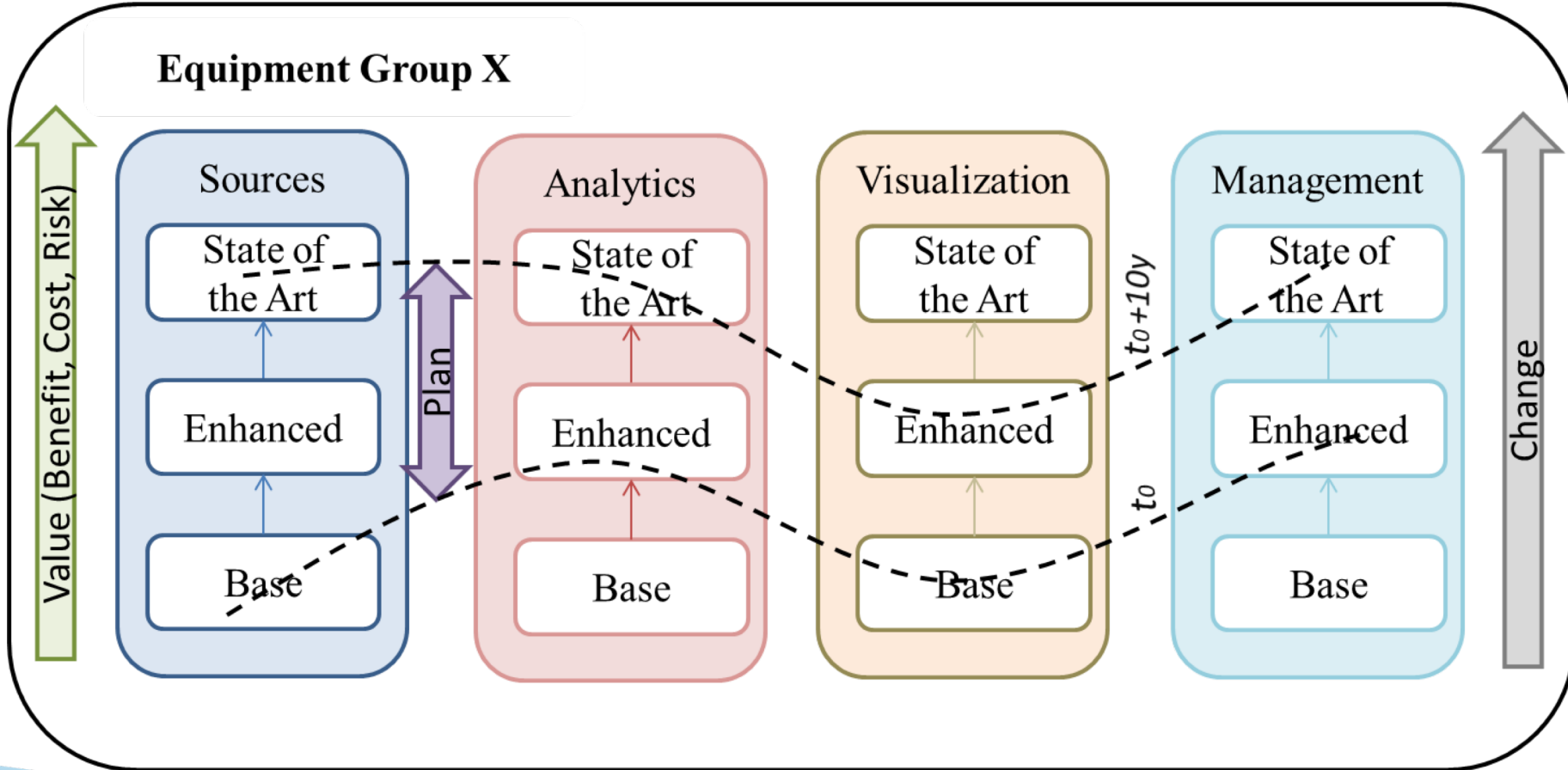
Advanced Remote Monitoring of Concrete Structures in Nuclear Power Plants

- **Multi-institute concrete** structural health monitoring research effort would integrate monitoring techniques to
  - Detect, localize, and estimate Alkali-Silica Reaction degradation mode in concrete structures
  - Develop diagnostic and prognostic models using machine learning techniques
  - Apply Bayesian technique to integrate different sources of uncertainties
- Current SHM in the nuclear industry is strictly an **offline process** and lacks application of **advanced technology solutions**
- The expected benefits are
  - Prevent **premature closure** due to aging-related degradation of structures
  - Technical evidence to support **second license renewal** process
  - Replace or augment current inspection-based aging management plan with online monitoring capabilities
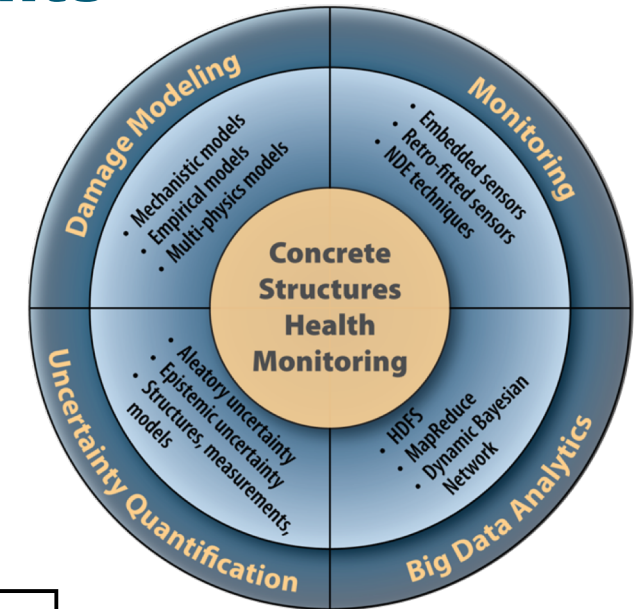
Advanced Remote Monitoring of Concrete Structures in Nuclear Power Plants

- All the techniques are nondestructive

- Noncontact monitoring techniques
  - Infrared thermography
  - **Digital image correlation**

- Contact monitoring techniques
  - Mechanical deformation
  - Active acoustic monitoring
    - Nonlinear impact resonance spectroscopy (NIRAS)
    - **Vibro-acoustic modulation (VAM)**
    - Diffuse ultrasonic wave method
  - Passive acoustic monitoring
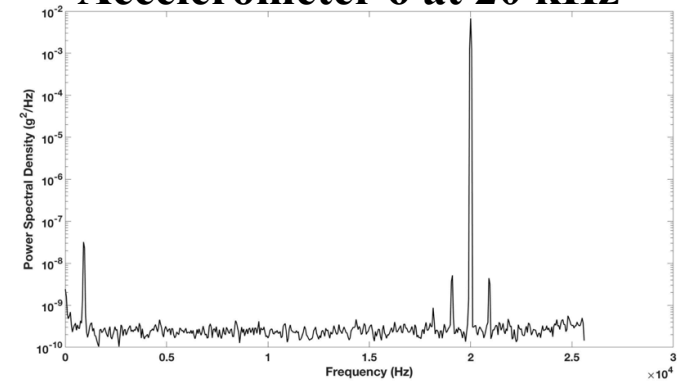   - Acoustic emission
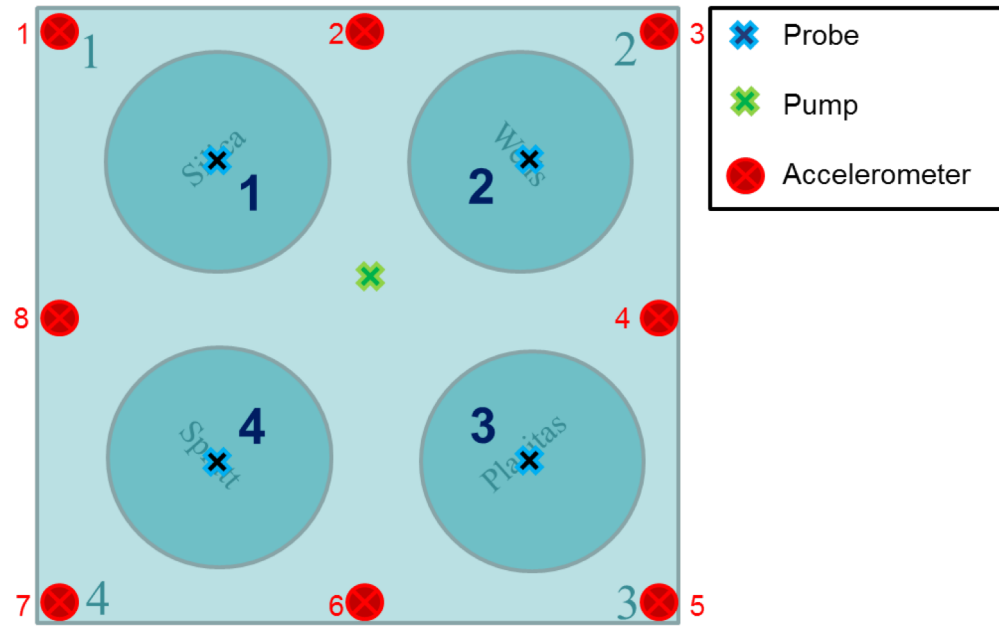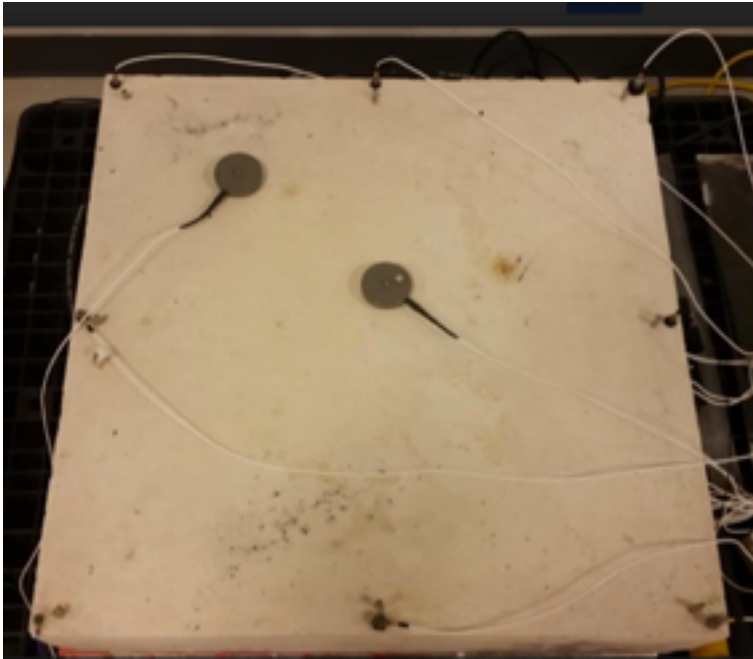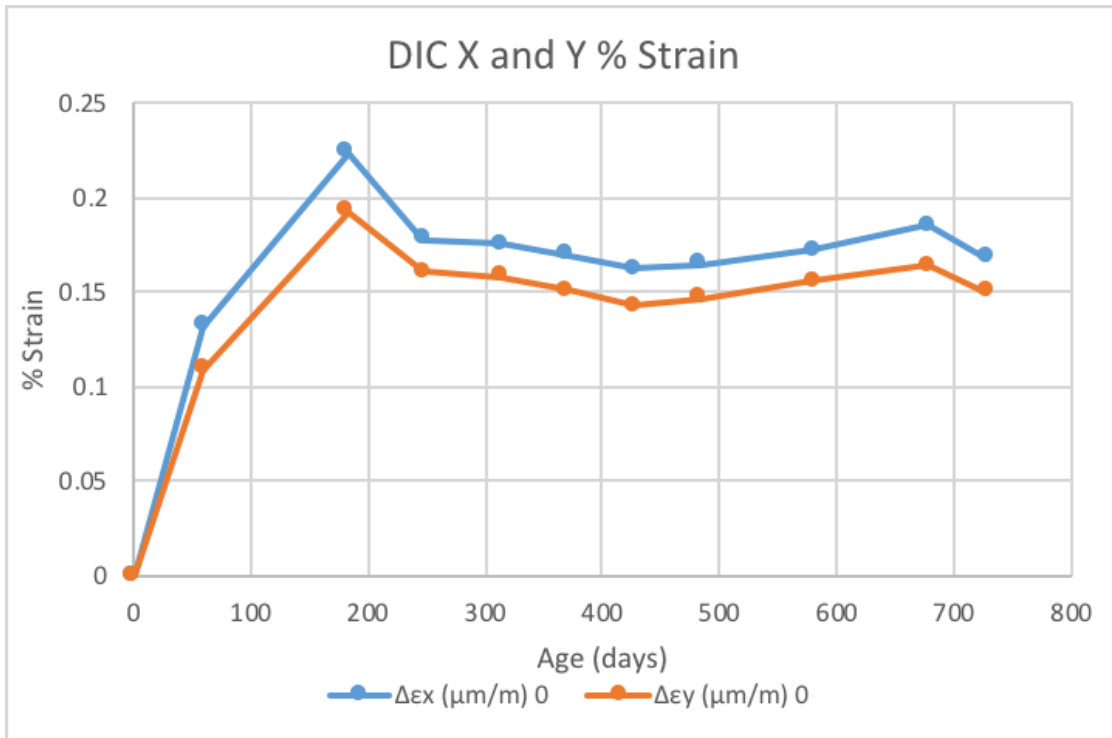
Accelerometer 3 at 20 kHz
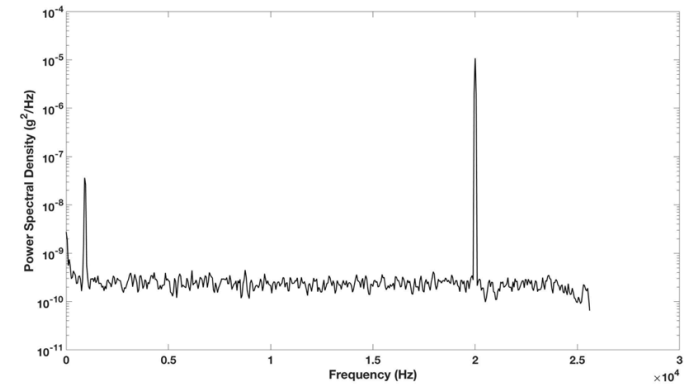
Accelerometer 6 at 20 kHz

Digital Image Correlation and Epsilon X Strain Images

- Digital image correlation is a full-field and non-contact technique
- Implemented at laboratory scale concrete samples and large size reinforced concrete samples


DIC X and Y % Strain

Advanced Remote Monitoring of Secondary Piping in Nuclear Power Plants

- **Goal:** Prototype of integrated piping monitoring system

- Piping is one of the most important and high-maintenance asset

- Majority of scheduled inspections find no piping degradation

- The goal is to identify where and when to inspect thus significantly reducing the number of inspections and maintenance cost

- Technical approach is online monitoring through permanently mounted sensors with significant piping coverage
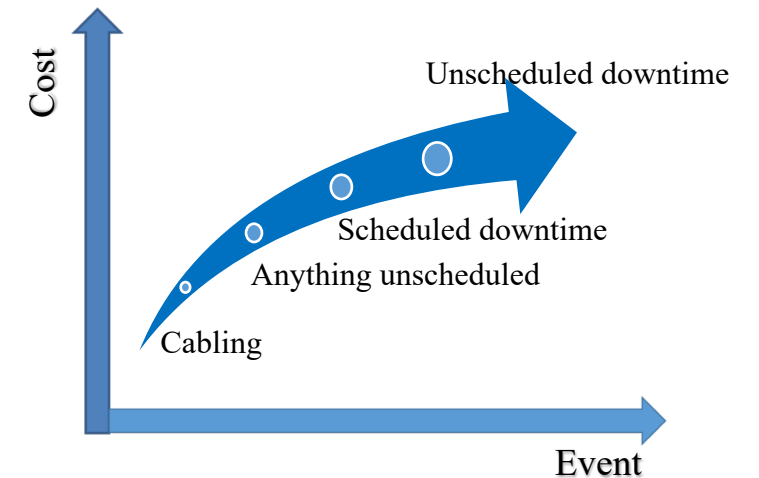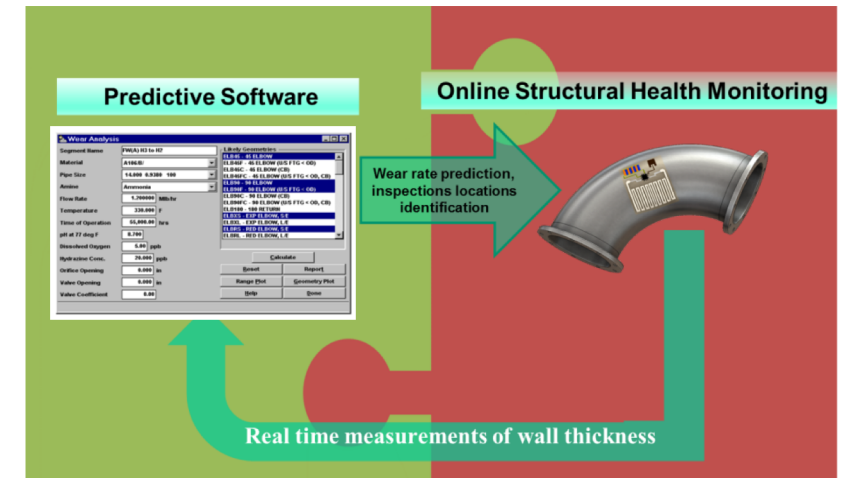
Technical Approach

- The guided waves systems (GWS) will be permanently installed on a secondary piping component

- GWS will be integrated with other sensor modalities, such as fiber optics

- The data will be collected on a continuous or more frequent than NDE activities basis

- If significant discrepancy between current and historical data is detected, detailed NDE inspection can be scheduled

- The data will be used to develop advanced signal processing and pattern recognition techniques to improve sensitivity and range of the guided waves technology
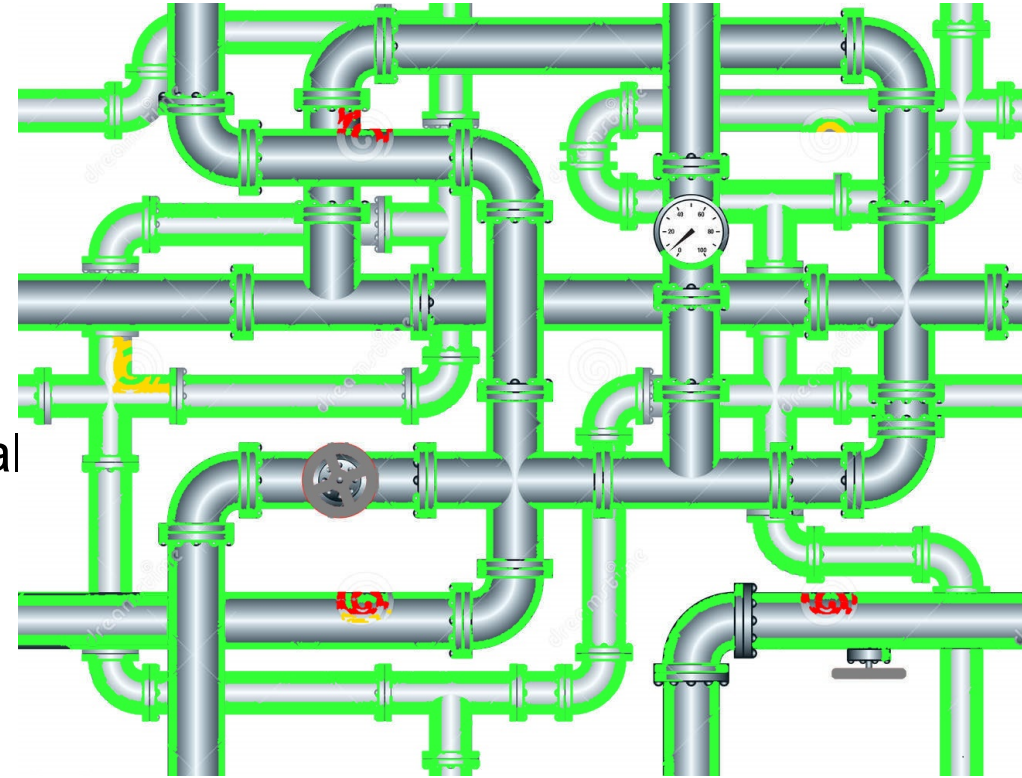
Summary

- Four research and development projects supporting plant automation highlights the significance of
  - Utilizing technology to augment or replace manually performed tasks
  - Advanced data analytics and machine learning techniques to mine the existing and new plant asset data to assess plant asset health enable condition-based decision-making
  - Integrating plant asset health information with advanced risk models to enable risk-informed predictive maintenance decision-making
  - Structural health monitoring research to replace or augment current inspection-based aging management plan with online monitoring capabilities

Thank you for your time

Any Questions?

For additional questions, please contact

Vivek Agarwal (Vivek.Agarwal@inl.gov)

Ahmad Al Rashdan (Ahmad.Alrashdan@inl.gov)