U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Clean. Reliable. Nuclear.

Deployable Risk-Informed Predictive Maintenance Strategy for Commercial Nuclear Power Plants

Advanced Sensors and Instrumentation Annual Webinar

November 6, 2019

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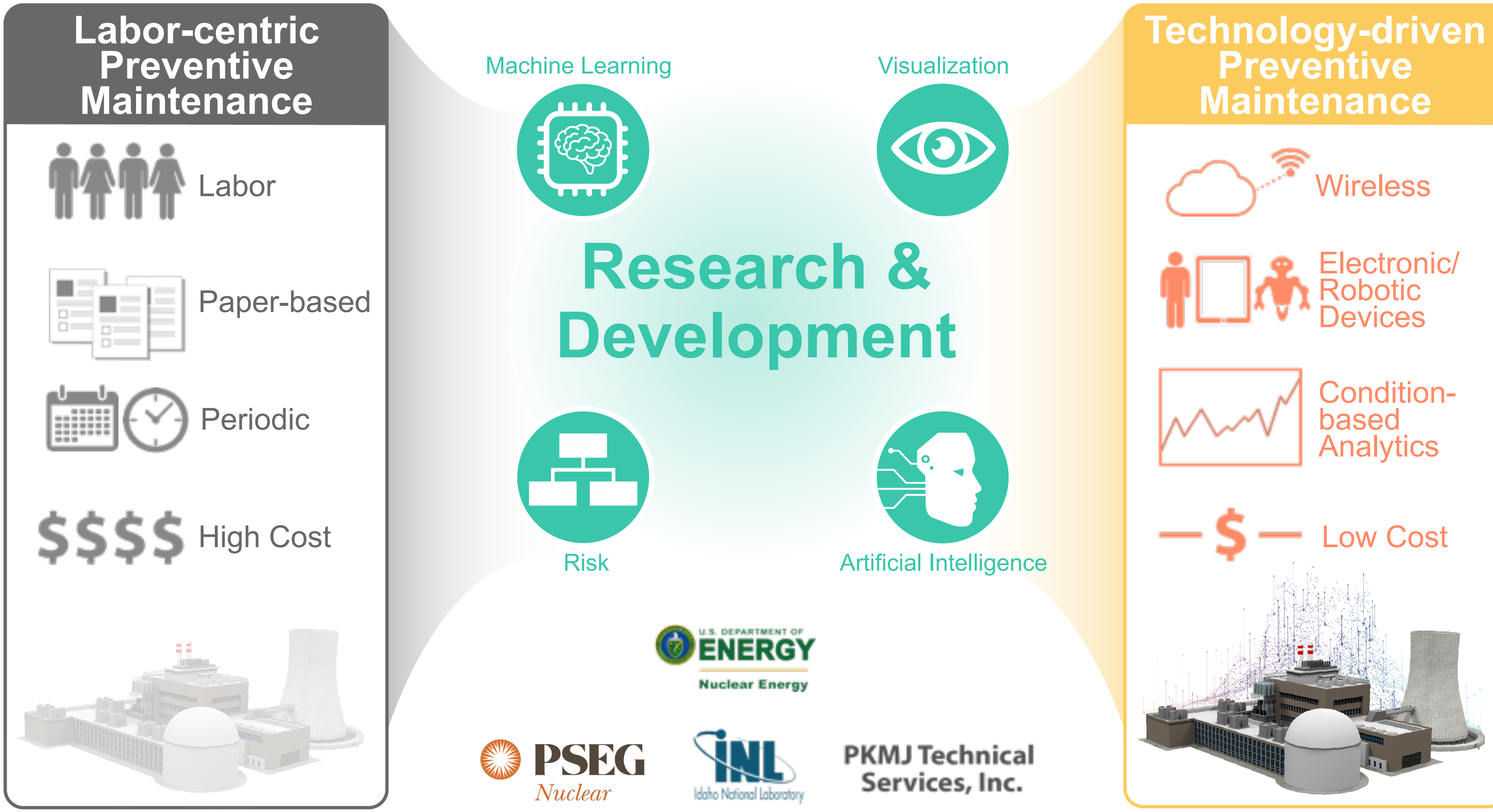
Idaho National Laboratory

Project Overview—Goals and Objectives



Project Overview—Team

- Vivek Agarwal, PhD
- Koushik A. Manjunatha
- James A. Smith, PhD
- Vaibhav Yadav, PhD

Idaho National Laboratory INL

- Francis Lukaczyk
- Michael Archer
- Nicholas Goss
- Mathew Mackay

PKMJ Technical Services, Inc.

- Palas Harry

PSEG Nuclear

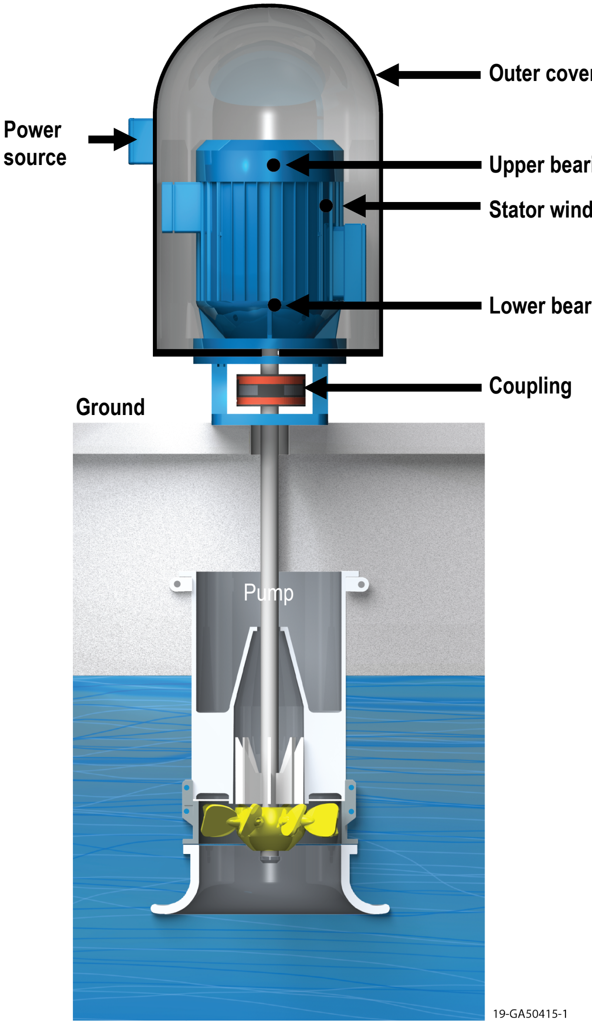
- Period of Performance: 08/1/2018 to 7/31/2020

Accomplishments

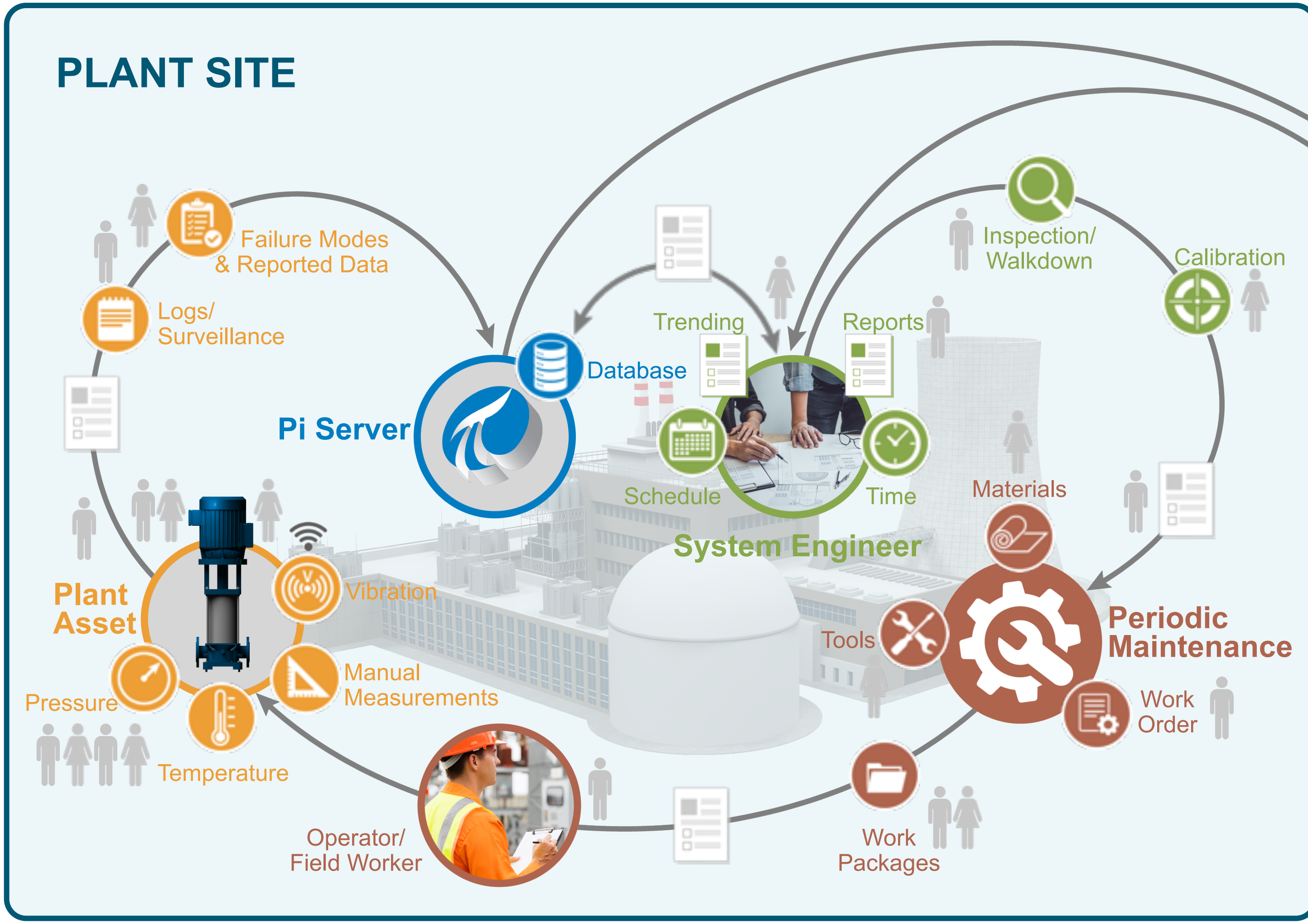
- Evaluated the current preventive maintenance strategy associated with a target plant asset
  - Vertical motor-driven pumps
- Developed a research and development framework to enable the transition to risk-informed predictive maintenance strategy
- Performed data completeness evaluation of historical data on target plant assets
- Enhance online monitoring on target plant asset
  - Installed sixty wireless vibration sensors
- Describe a framework to scale-up the predictive maintenance
  - Across different plant assets at the site level
  - Across different plant sites for the same plant asset across the fleets
- In collaboration with plant owners, developed a deployable risk-informed predictive maintenance strategy to
  - Eliminate labor-intensive time-based preventive maintenance strategy

Accomplishments – Vertical Motor-Driven Pump

- Access plant process computer data on the vertical motor-driven pump
  - Motor stator winding temperature
  - Motor inboard bearing temperature
  - Motor outboard bearing temperature
  - Motor current data
  - Motor status data
  - Inlet Pressure
- Periodic vibration data
- Access to historical maintenance logs and notification logs



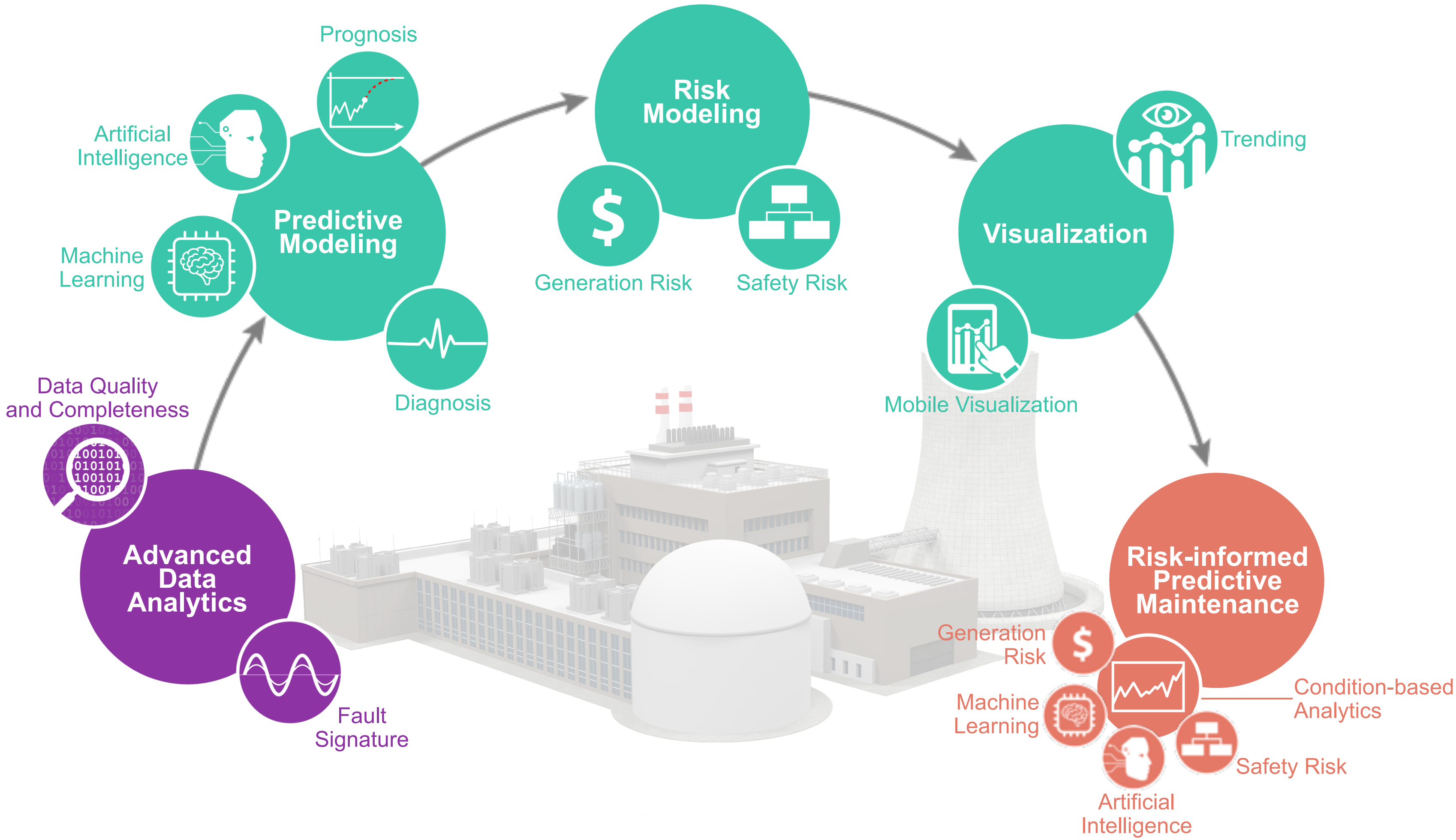
Accomplishments – Current Preventive Maintenance Strategy



Labor-centric Preventive Maintenance

- Labor
- Paper-based
- Periodic
- $$$$ High Cost

Accomplishments – Research and Development Framework

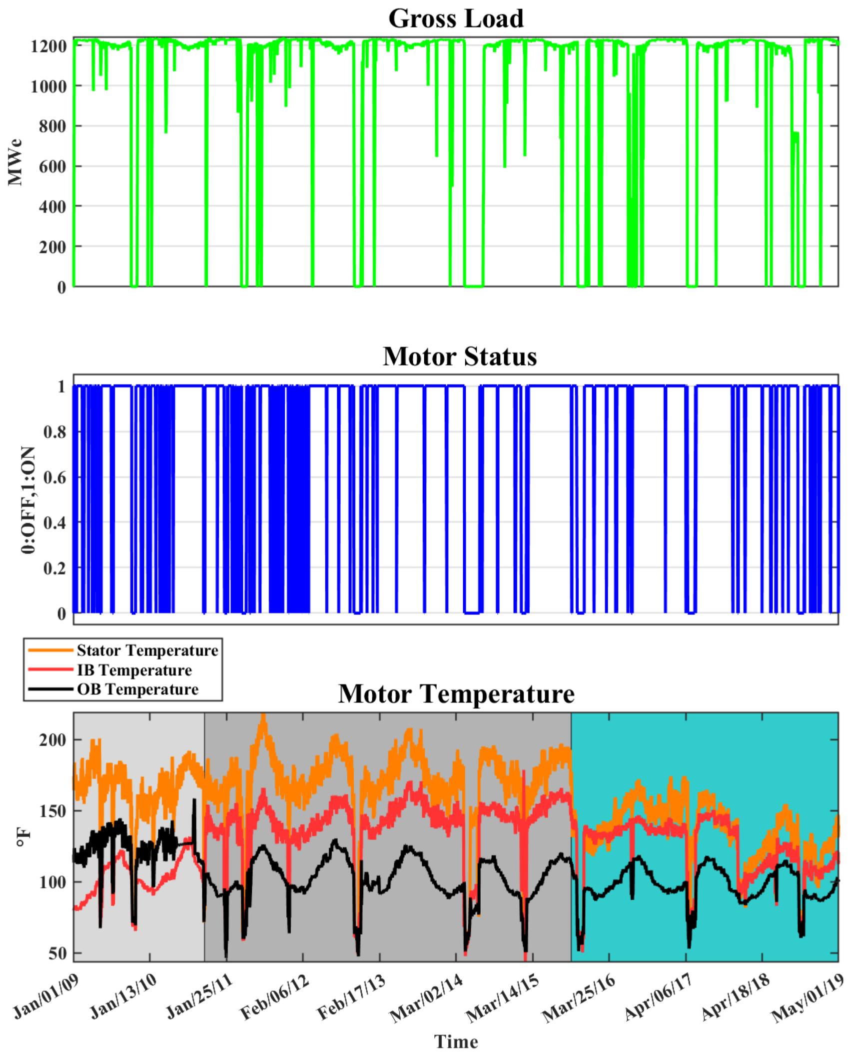


Accomplishments – Data Completeness and Recommendation

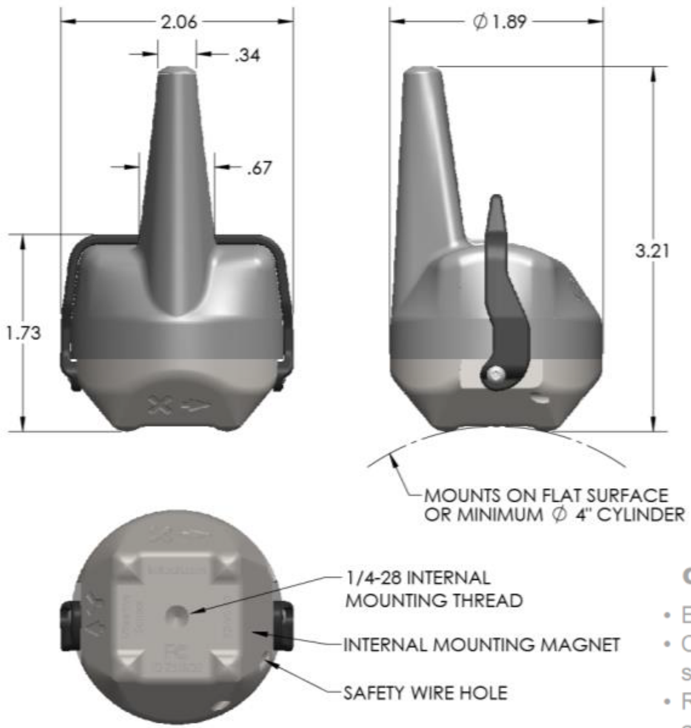
- Data quality assessment
  - Data cleaning
  - Missing values

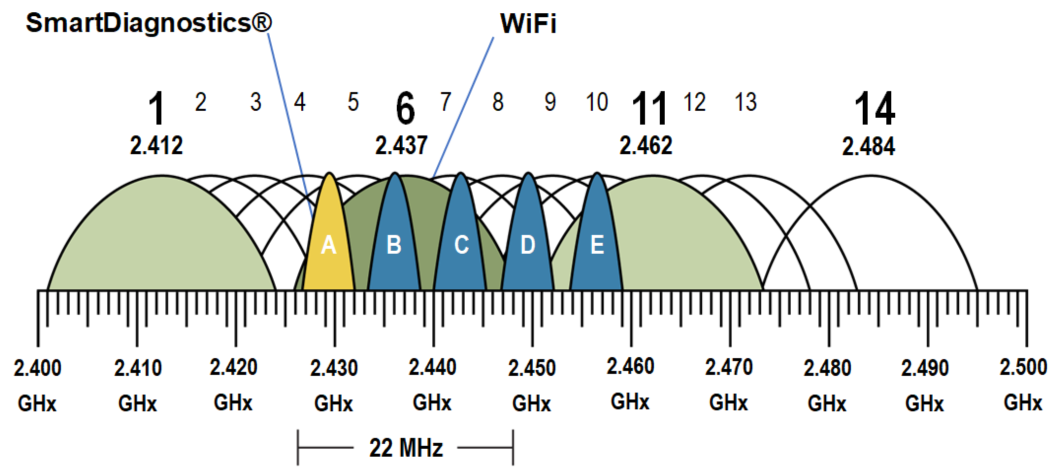
- Performed data analysis on run hours of vertical motor-driven pump over several years

- Identified and marked shifts in the data due to different activities and its impact on gross load



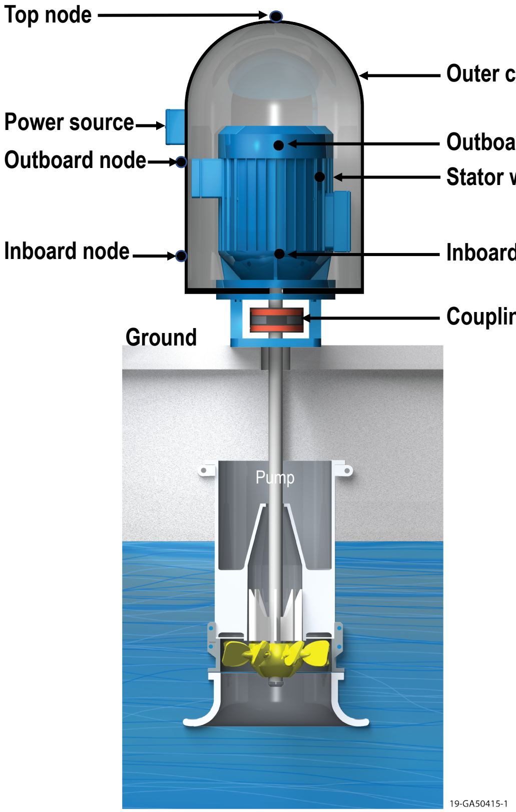
Accomplishments – Wireless Vibration Sensors

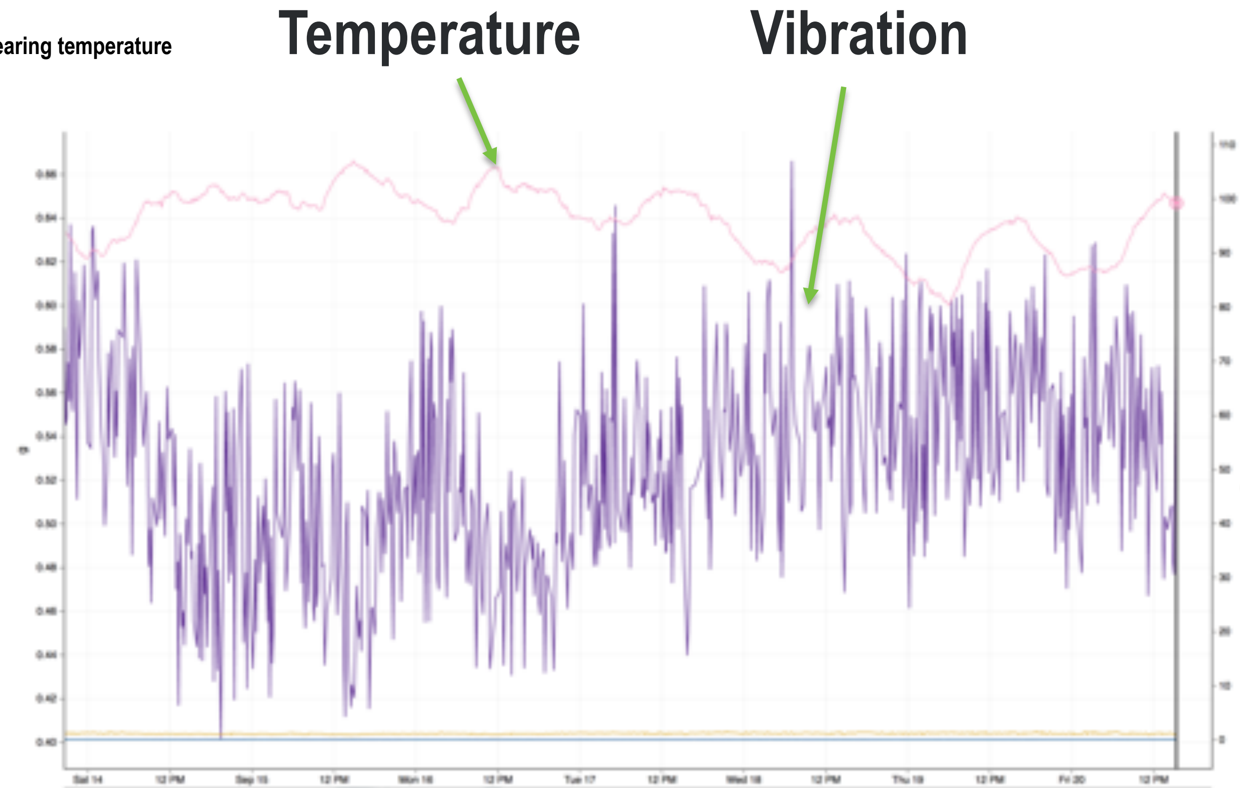




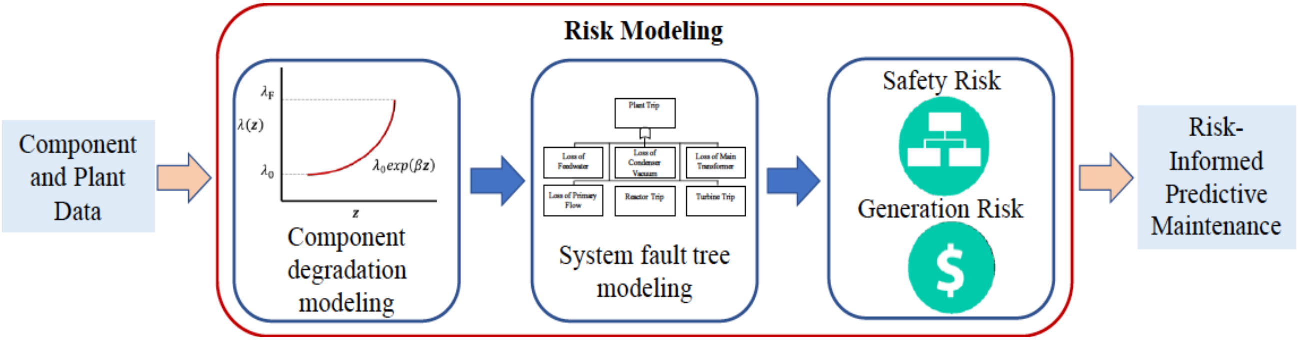
SMARTdiagnostics® Channel	A	B	C	D	E
Center Frequency (MHz)	2429	2436	2443	2450	2457

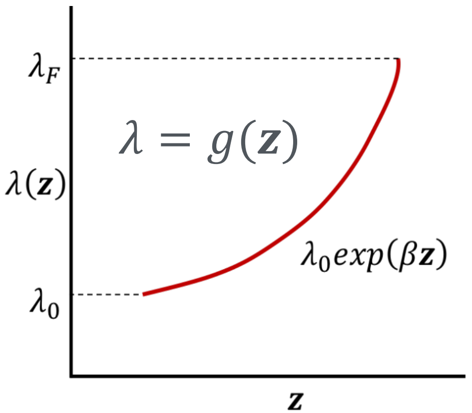
Accomplishments – Vertical Motor-Driven Pump with Wireless Vibration Sensors





Accomplishments – Risk Modeling Framework





$\mathbf{z} = (z_1, \ldots, z_n)$ is the vector of n performance parameters measured for the component and $g()$ is a function capturing component failure due to degradation

- Loss of Power $LoP = \sum_{i=1}^{T} \lambda_T P_{T,i} R_{T,i} + \sum_{j=1}^{D} \lambda_D P_{D,j} R_{D,j}$

λ_T: Trip frequency; λ_D: Derate frequency

$R_{D,j}$ is the restoration time in hours for the an j-th derate event

$R_{T,i}$ is the restoration time in hours for the an i-th trip event

$P_{D,j}$ is the reduced power level due to derate caused by j –th SSC failure or unavailability

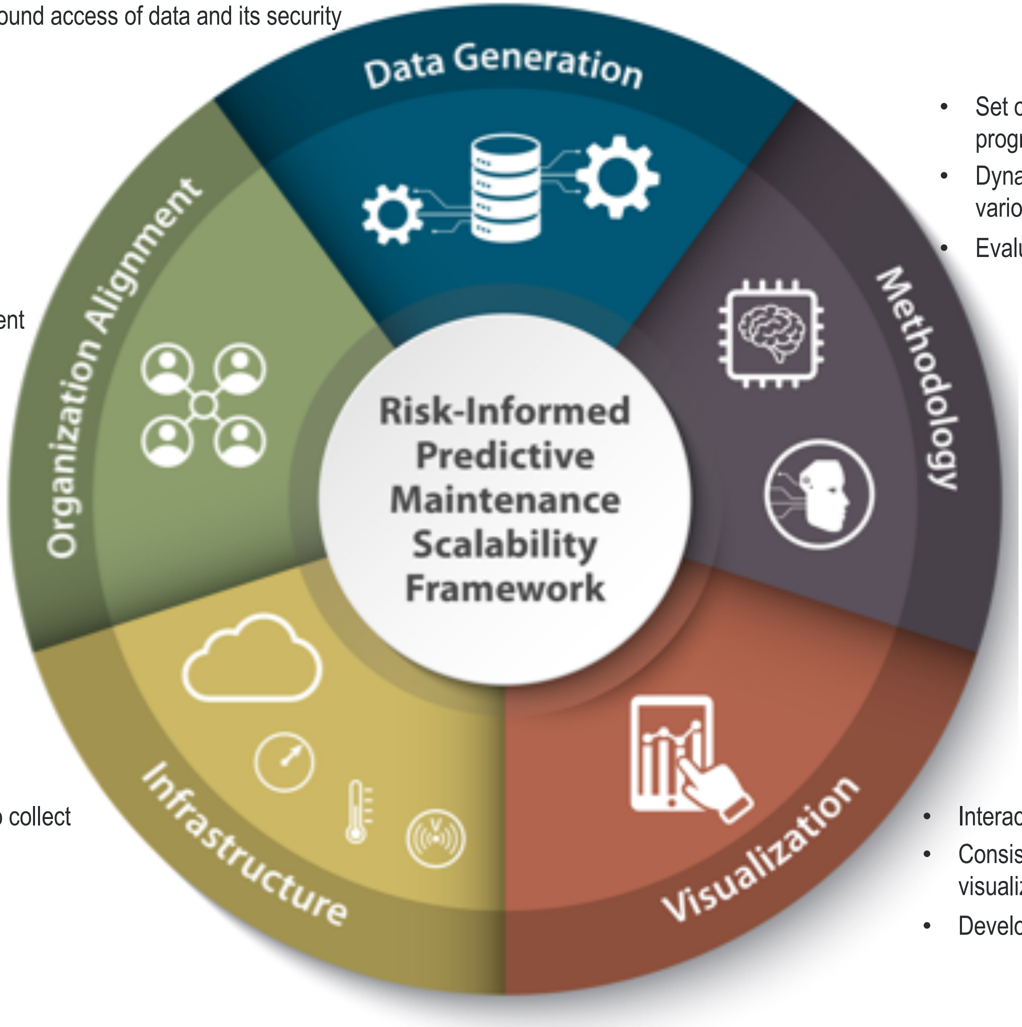
$P_{T,i}$ is the power level due to trip caused by ith SSC failure or unavailability

Accomplishments – Scale-up of Risk-informed Predictive Maintenance Strategy

- Collect, process, prepare, and structure the data
- Data governance for managing the data
- Policy around access of data and its security

- Set of algorithms to perform diagnosis and prognosis
- Dynamic in nature (ability to incorporate data at various scales
- Evaluated against different performance metrics

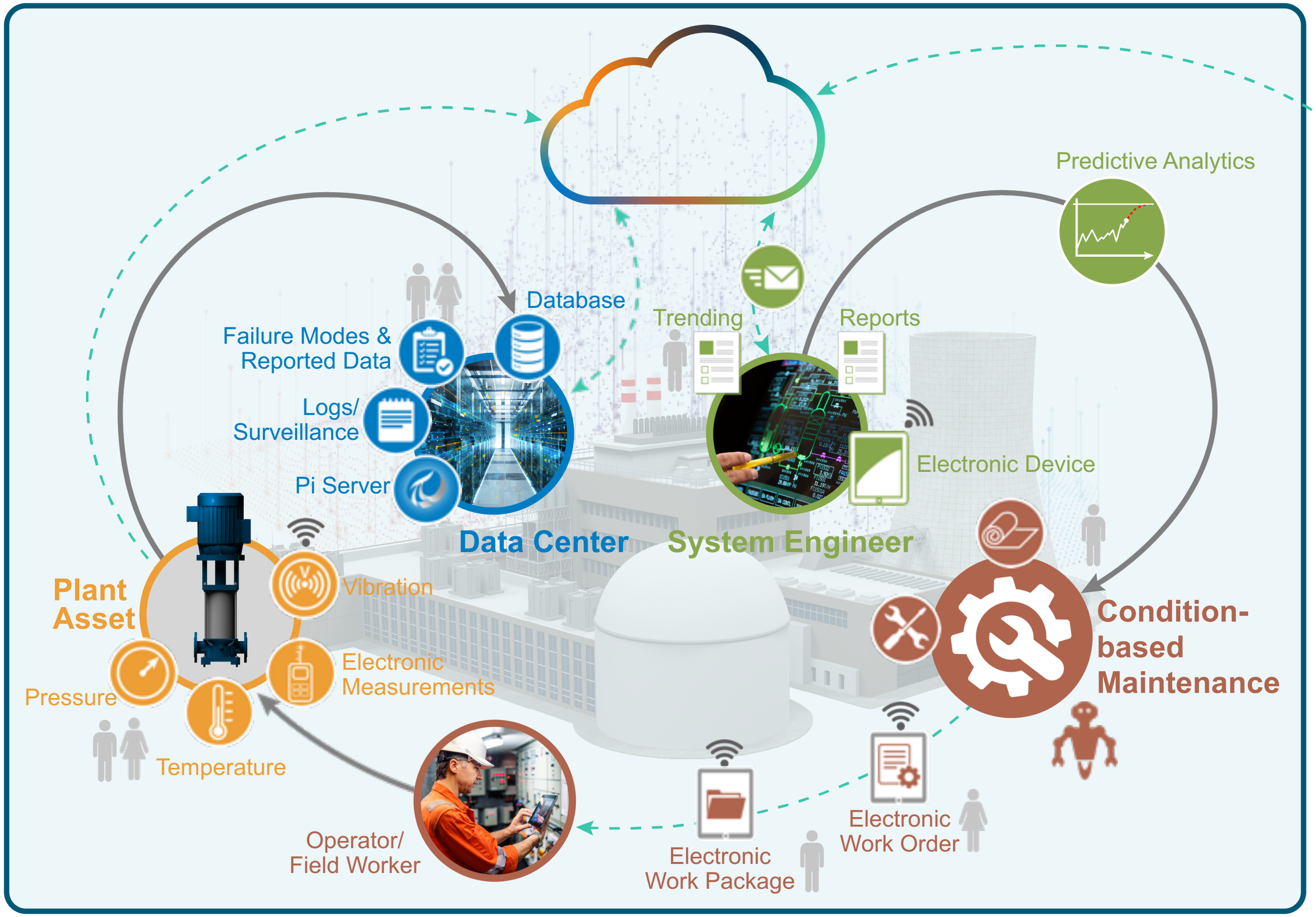
- Organization commitment is necessary
- Early and clear communication of the intent
- Open to feedback and culture change

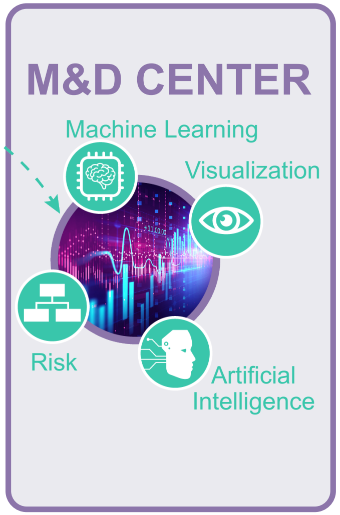


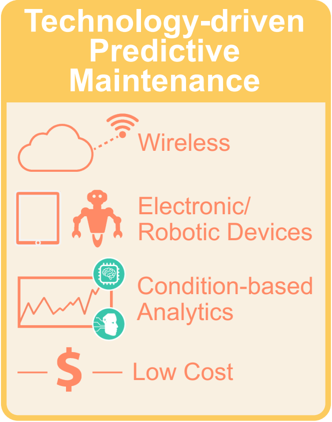
- Sensors, communication, and platform to collect different types of data
- Agile, safe, and secure and open
- Upgradable

- Interactive visualization
- Consistent performance across different visualization platforms
- Development of style-guides or standards

Accomplishments – Risk-informed PdM







Technology Impact (1)

- ***Advances the state of the art for nuclear application***
  - Advances online monitoring at a nuclear plant site for different plant assets
  - Provides machine learning approaches to integrate and analyze heterogeneous structured and unstructured data (i.e., analytics-at-scale)
  - Visualization of information to make informed decision-making
- ***Supports the DOE-NE research mission***
  - Enhance reliability and economic operation of domestic existing fleet
  - Research outcomes can be utilized to develop maintenance strategy for next generation of advanced reactors
  - Develop talent pipeline (interns, post doctoral researchers) to support future nuclear work force

Technology Impact (2)

- *Impacts the nuclear industry*
  - Enable industry to transition from preventive maintenance strategy to risk-informed predictive maintenance strategy
  - Reduce operation and maintenance costs

- *Will be commercialized*
  - This research will be commercialized under the existing award under industry Funding Opportunity Announcement

Conclusions

- Performed extensive data analysis of historical data from a plant site on vertical motor-drive pumps
- Correlated shifts in the data with maintenance records
- Summarizes the installation of sixty wireless vibration sensors on vertical motor-driven pumps
- Presents a risk-informed modeling framework
- A framework to scale-up the risk-informed predictive maintenanace strategy is presented.
- Vivek.Agarwal@inl.gov *any additional questions that may not be answered during the webinar.*

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