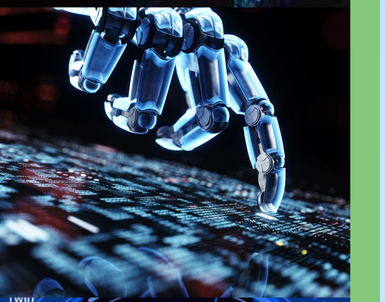
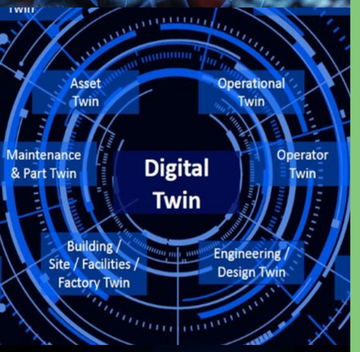
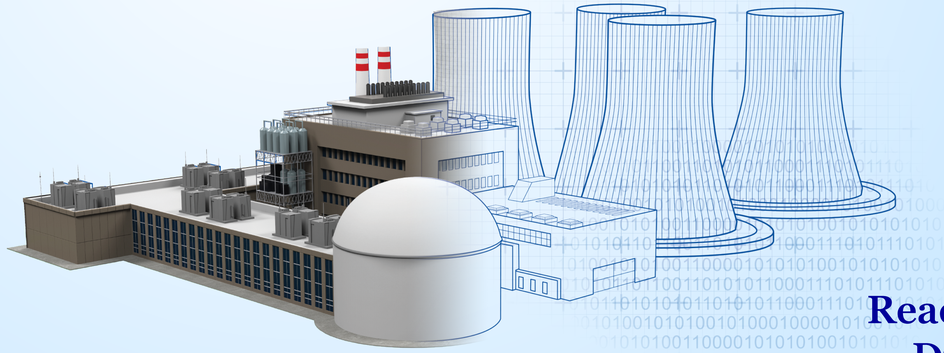




Digital Twins Project

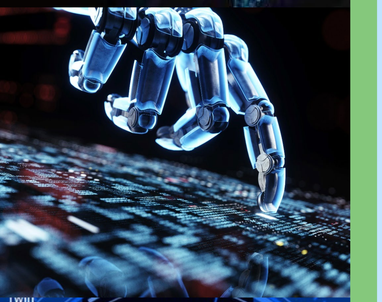
DIVISION OF ENGINEERING

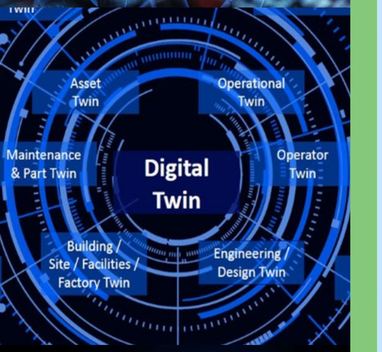
Enabling Technologies for Digital Twins

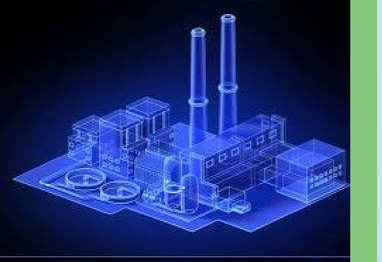


Raj Iyengar
Reactor Engineering Branch
Division of Engineering
Office of Nuclear Regulatory Research

September 2022

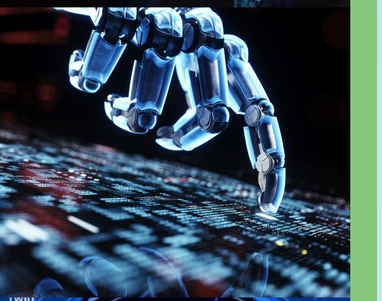


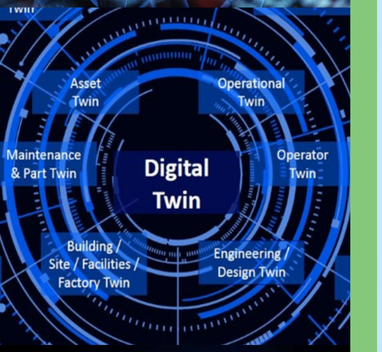




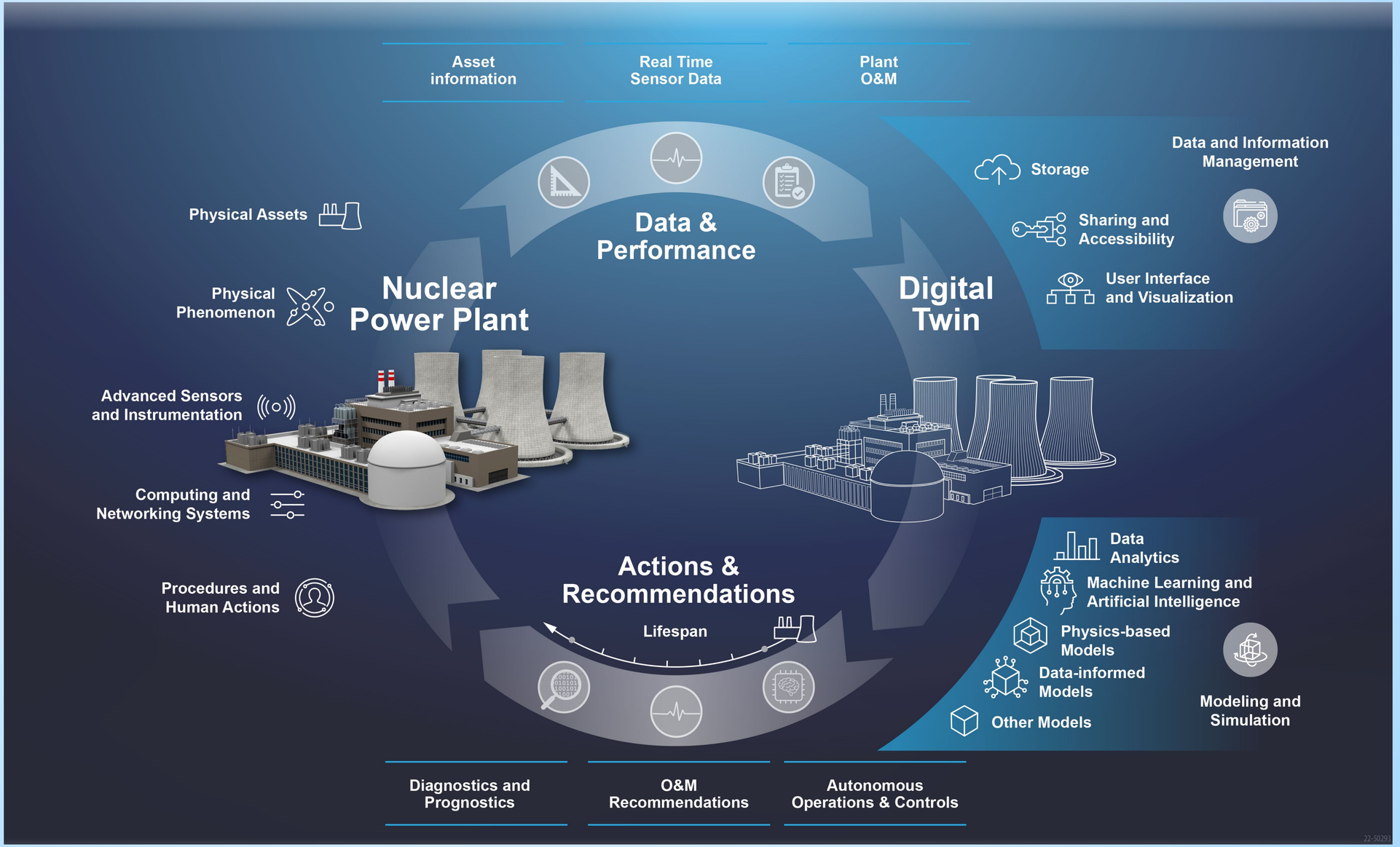
Contributors & Collaborators

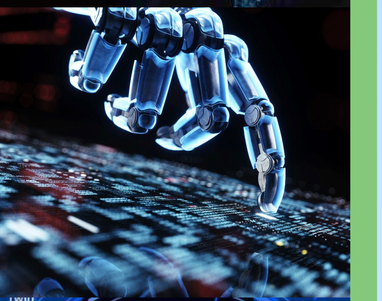
Jeanne Johnston (NRR)	Raj Iyengar (RES)	Angie Buford (NRR)	Jesse Carlson (RES)	Doug Eskins (RES)
Al Tardiff (NSIR)	Ramon Gascot (RES)	Chris Ulmer (RES)	Tom Scarbrough (NRR)	Juris Jauntirans (NSIR)
Daniel Ju (OCHCO)	Candace de Messieres (NRR)	Nachiketh Chandran (RES)	Mathew Dennis (RES)	Lew Clayman (OCIO)
Bruce Lin (RES)	Joshua Kaizer (NRR)	Raul Hernandez (NRR)	Anders Gilbertson (RES)	Dan Widrevitz (NRR)
Glenn Tuttle (NMSS)	Bern Stapleton (NSIR)	Ian Tseng (NRR)	Michael Breach (NRR)	Chris Nellis (RES)

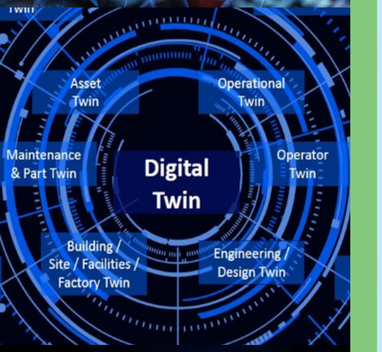


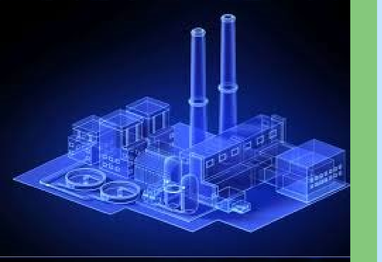


What is a Digital Twin?

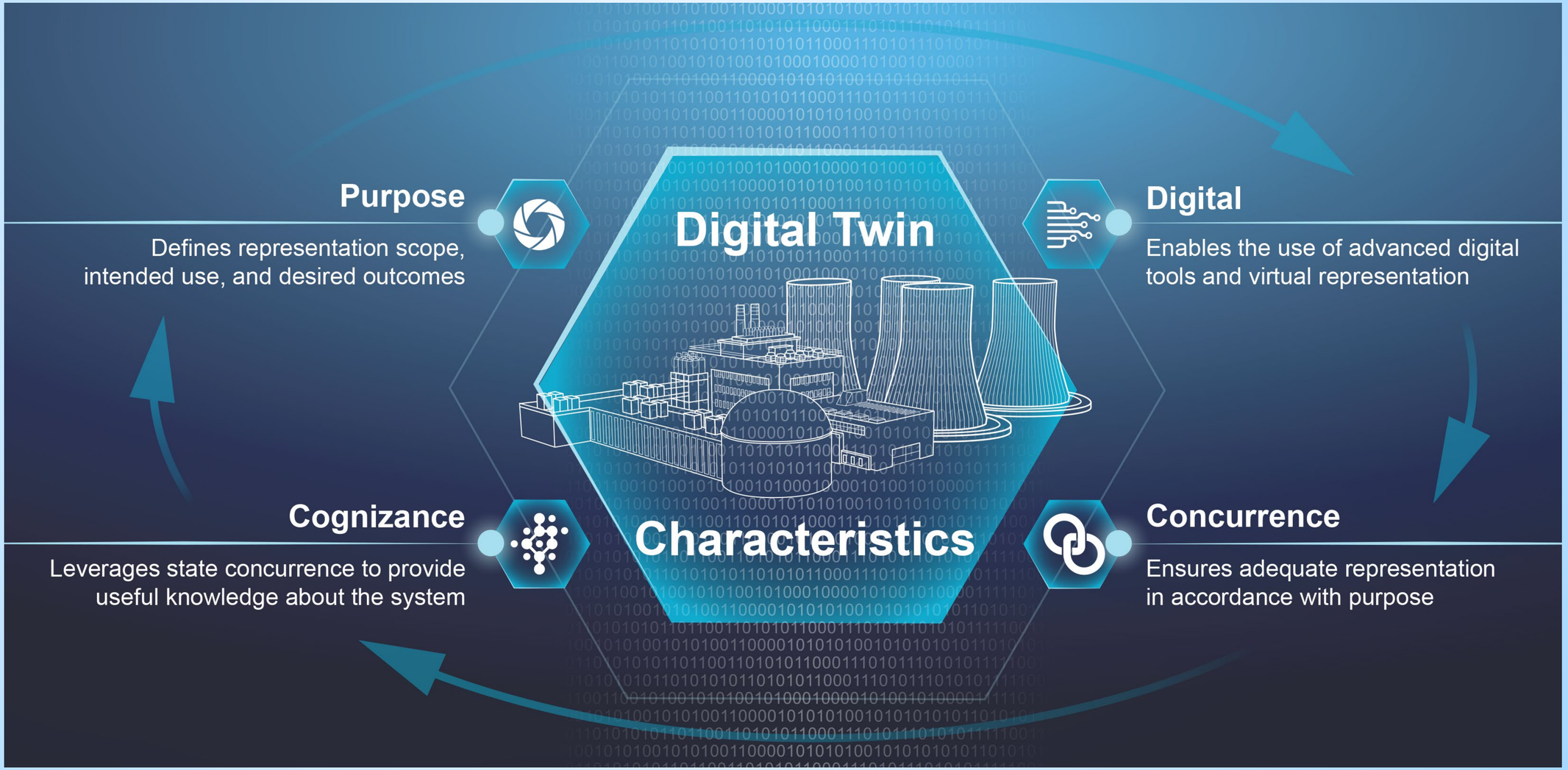


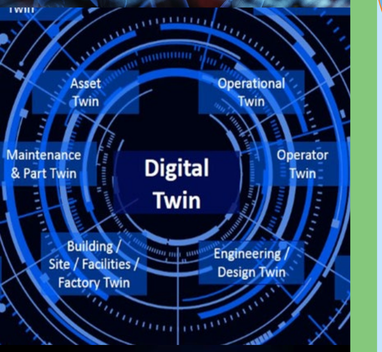






Digital Twin Characteristics





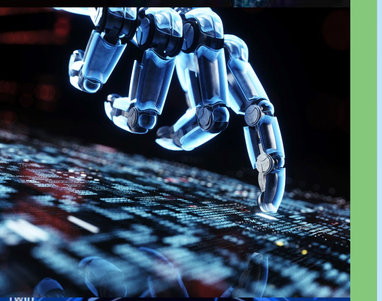
DT Project Overview

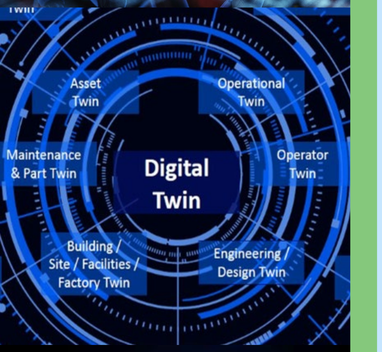
Main Goals

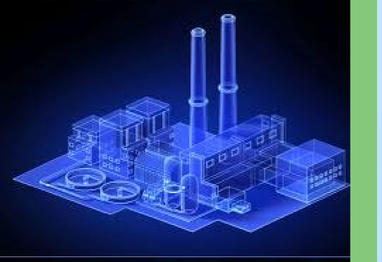
Technical Letter Report*

Research Information Letter

* ML21160A074, ML21361A261, ML22192A046, ML22235A643

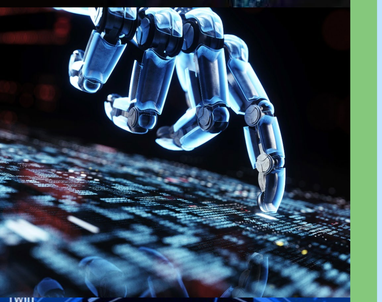


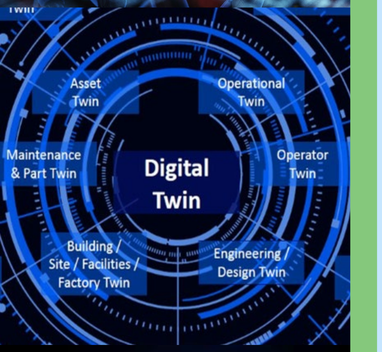


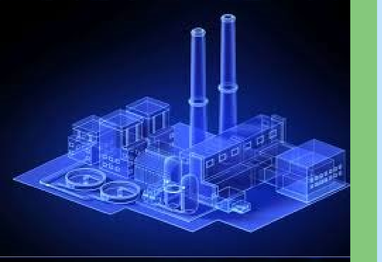


Technical Challenges & Gaps

Enabling Technology	Key Challenge
Advanced Sensors & Instrumentation (ASI)	Building adequate ASI infrastructure
Data and Information Management	Developing user interfaces for data and information
Data Analytics	Implementing scalable, integrable data analytics
Artificial Intelligence (AI)/ Machine Learning (ML)	Establishing AI/ML trustworthiness and explainability
Modeling and Simulation	Constructing real-time, high-fidelity physics-based simulations
	Developing real-time, data-informed models
	Verifying and validating integrated models







Impact

Office of Nuclear Regulatory Research
Future Focused Research

Digital Twins Project 2020-2022
BY THE NUMBERS

Idaho National Laboratory

Workshop 1
Digital Twin Applications for Advanced Nuclear Technologies

Workshop 2
Digital Twin Enabling Technologies for Advanced Reactors and Plant Modernization

Public Meeting
Regulatory considerations and opportunities for digital twin

50+ Presenters

THREE DAYS

one hundred+ Participants

four DAYS

29 Presenters

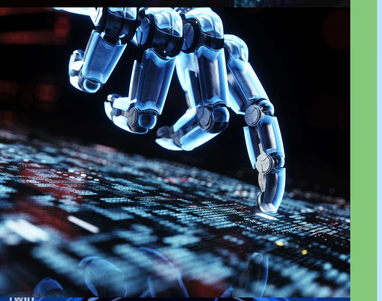
6 PUBLICATIONS INCLUDING

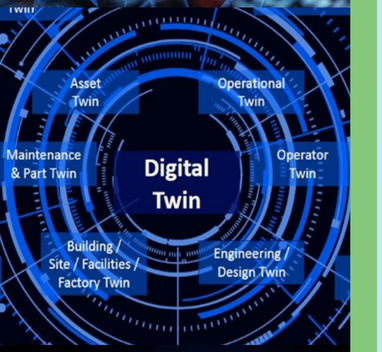
400+ Participants

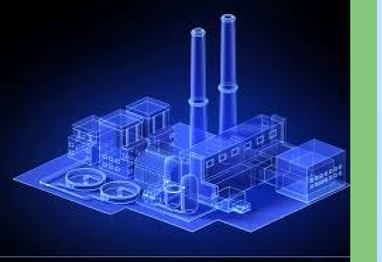
324 Participants

3 technical reports

Industry-Led Activity on Generalized Framework
Presentation at Standards Forum on Sept. 28th



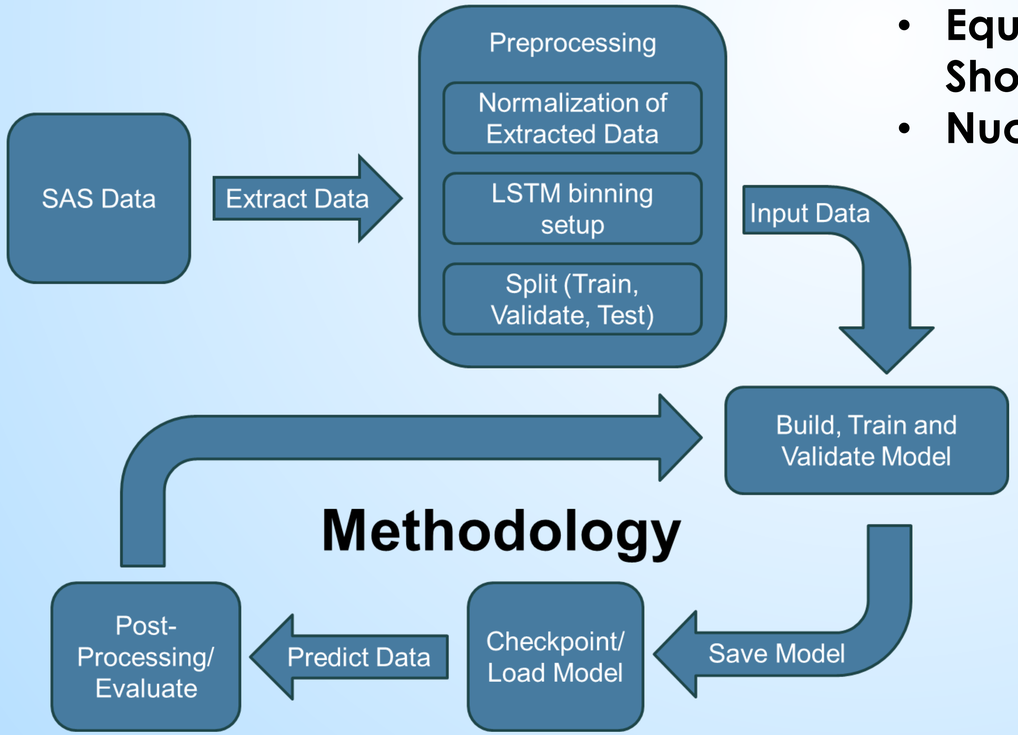


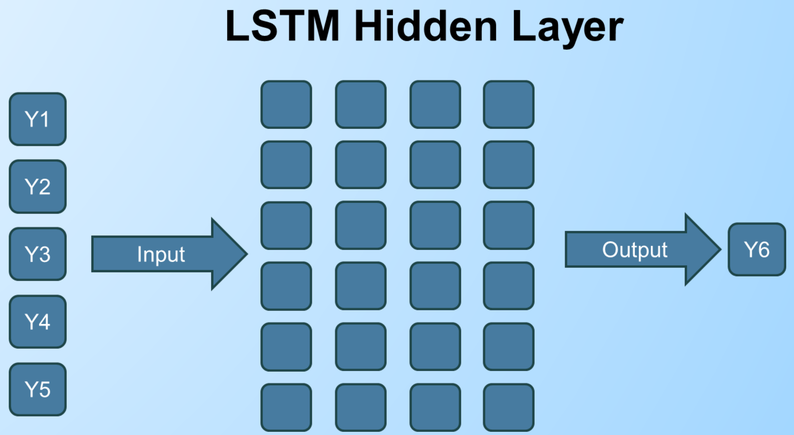


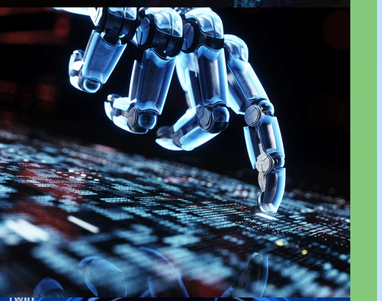
Opportunities for Advanced Modeling

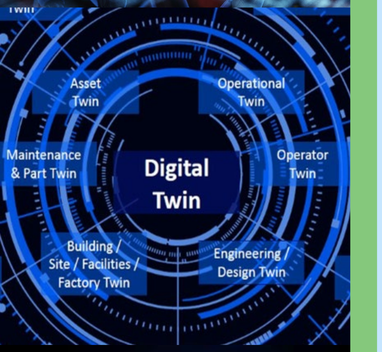
- **Enhanced Data-Informed Modeling using AI/ML or Multiphysics**
  - **Improved Verification and Validation**
  - **Realtime Data for Training AI/ML Models**
  - **Reduce uncertainties**
  - **Improved Explainability of Predictions using AI/ML**

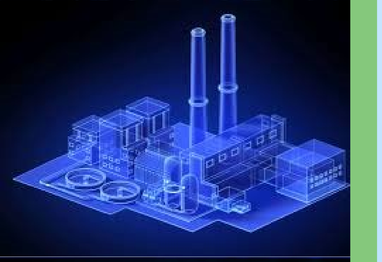
- **Case Studies**
  - **Equipment Performance Monitoring using ML and Long Short-Term Memory (LSTM) Forecasting**
  - **Nuclear Materials Safeguards**



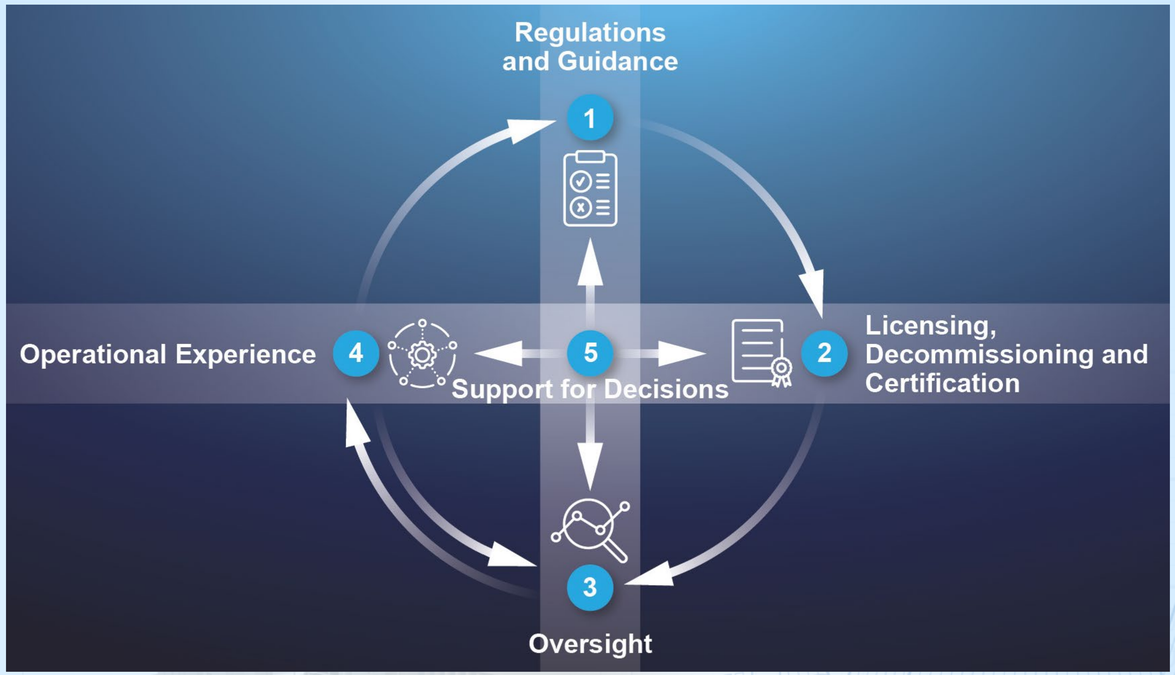






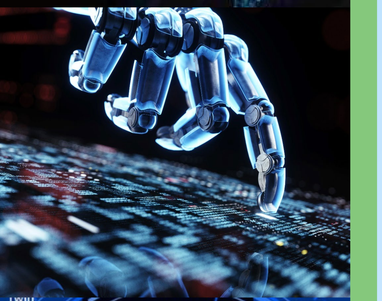


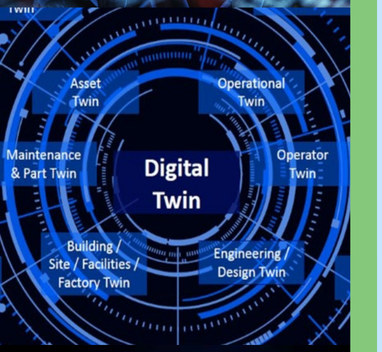
Regulatory Considerations & Opportunities



Examples:

Regulatory Consideration	Opportunity
Information Reporting	Data and report generation
Operator Licensing	Up-to-date and validated simulator model
Component Performance	Real-time condition-based monitoring and preventative maintenance
Event Assessment	Virtual environment event replay
Safety Analysis	Integrated modeling and simulation to support decision making





Thank You

The project was supported by multiple NRC offices including:

- **Nuclear Regulatory Research**
- **Nuclear Reactor Regulation**
- **Nuclear Security and Incident Response**
- **The Chief Information Officer**
- **Nuclear Material Safety and Safeguards**
- **The Chief Human Capital Officer**

For further information, questions, or comments on the NRC Digital Twin Project, please contact:

Raj.Iyengar@nrc.gov