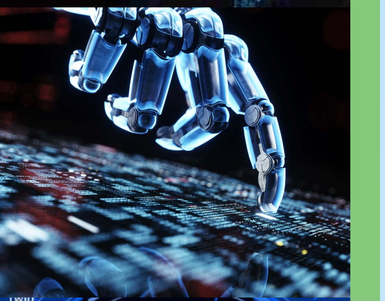
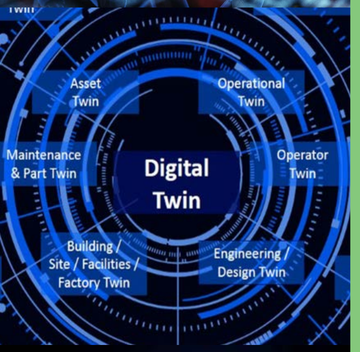
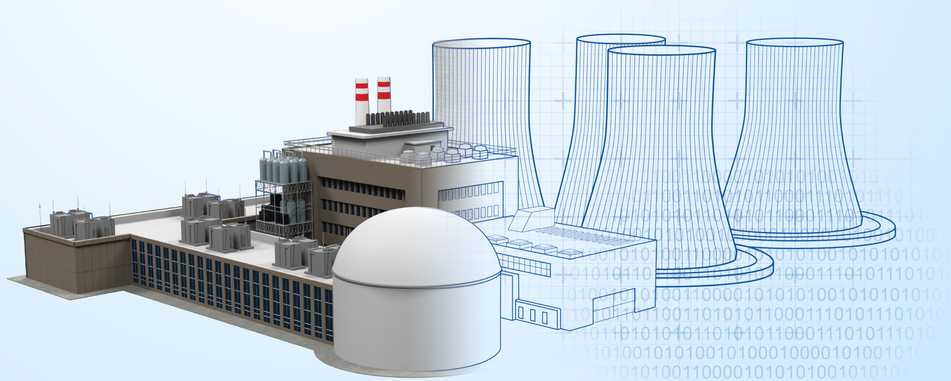




U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NRC Perspectives on Advanced Sensors for Nuclear

Raj Iyengar, Chris Ulmer
Division of Engineering
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission



October 2022

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

We Make **SAFE** Use of Nuclear Technology **POSSIBLE**

One Unifying Vision

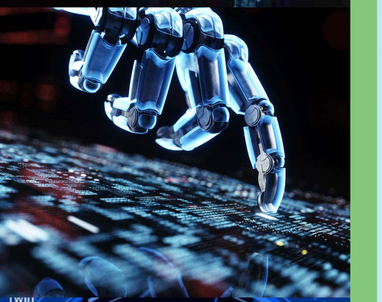
Safety and Security Mission

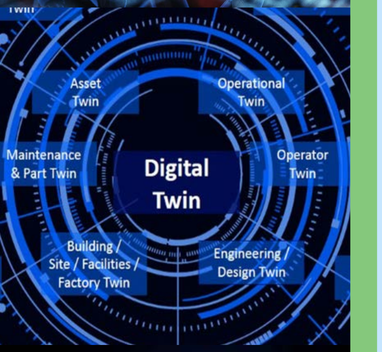
Our People

Principles of Good Regulation

NRC Values

Innovation and Transformation





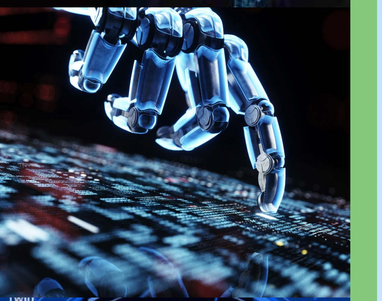
Driver for Change

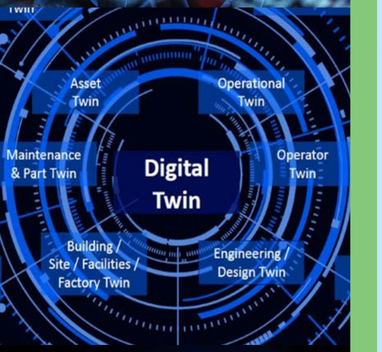
Advanced technologies offer new opportunities

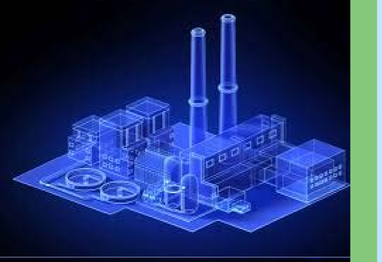
- **Enhance Reliability**
- **Improve Efficiency**
- **Reduce Uncertainties**

Digital Innovations could impact each these areas

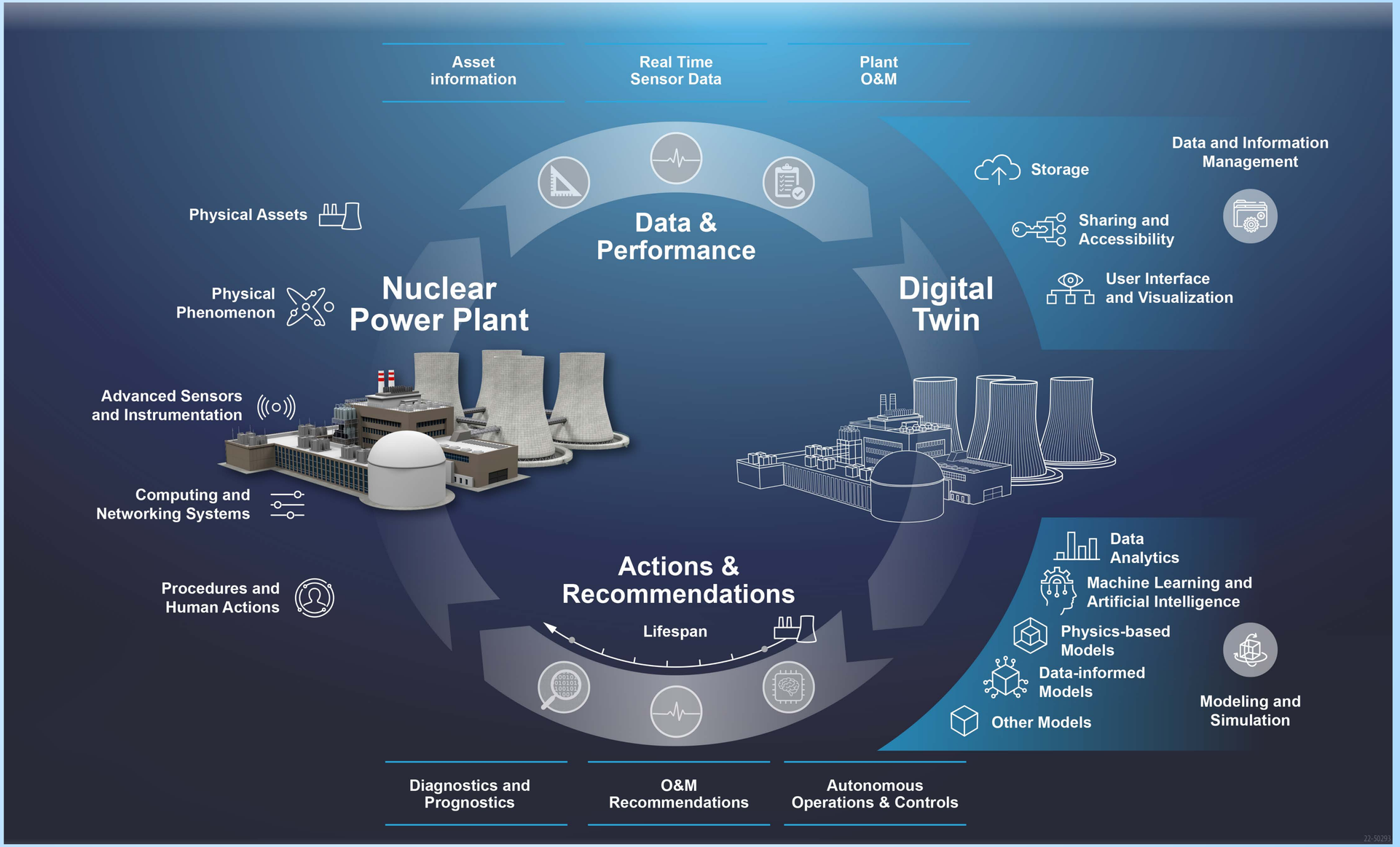
We Are Keeping Pace with Technological Innovations and Reducing Barriers to Enable the Safe and Secure Use of Technological Innovations in Nuclear Facilities

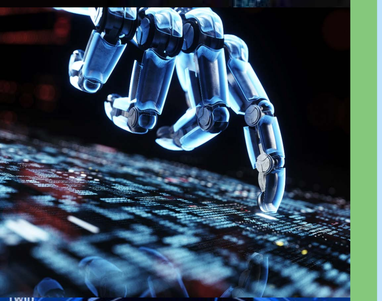


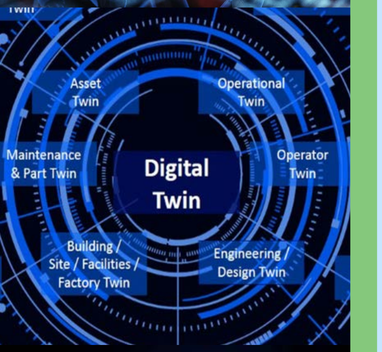


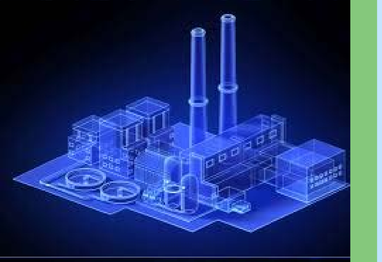


What is a Digital Twin?

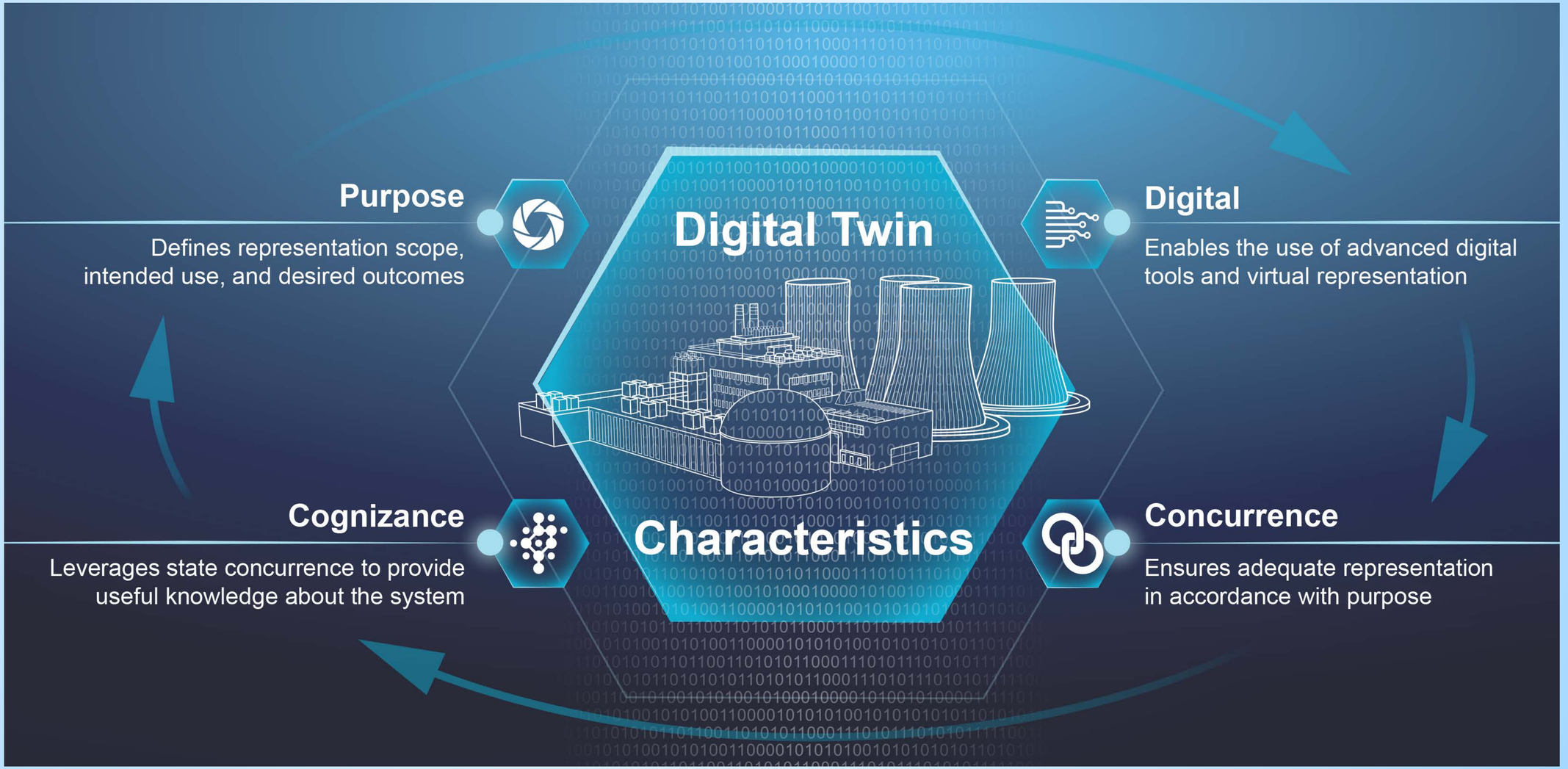


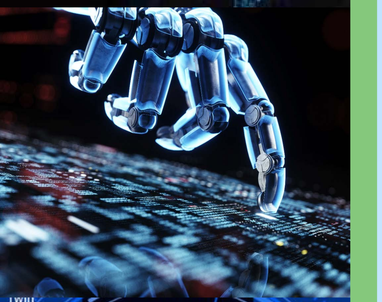


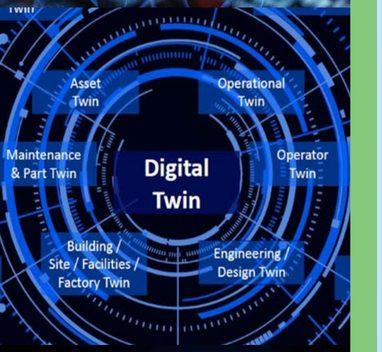


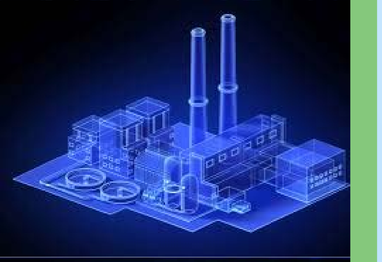


Digital Twin Characteristics



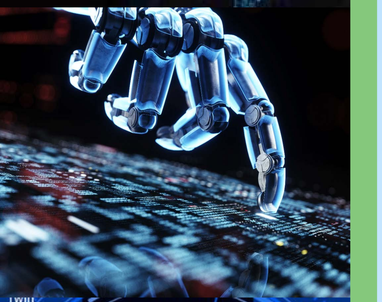


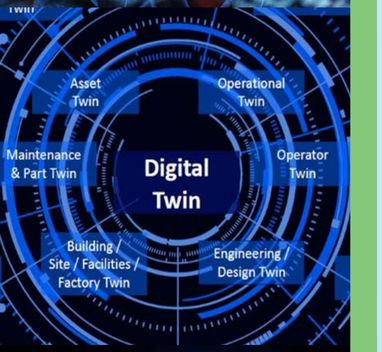


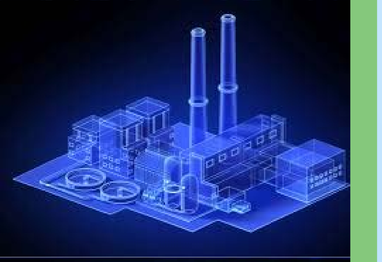


Technical Challenges & Gaps

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







Advanced Reactors

Selected Research Activities

Molten Salt Chemistry

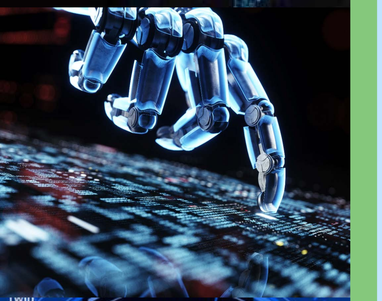
- Molten Salt Compatibility/Corrosion
- Modeling & Simulation
- Molten Salt processing for metallic and molten salt fuels

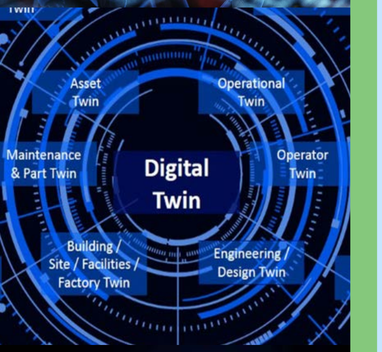
Reliability of Components & Risk Reduction

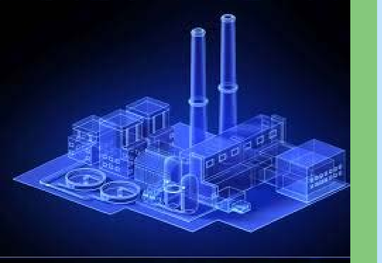
- Component Performance/Integrity
- Performance monitoring
- Surveillance programs
- Advanced sensors
- Off-gas control

Fuel Cycle

- Graphite waste and disposal
- Technical challenges: enrichment, fabrication and transportation of HALEU fuel
- Storage systems for waste streams from MSRs



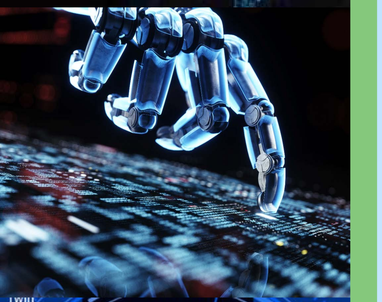


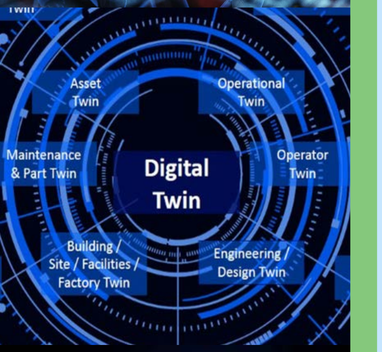


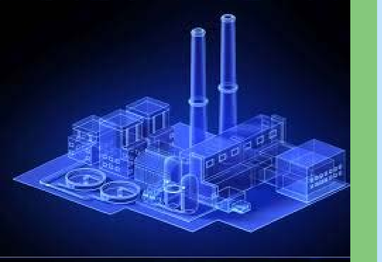
ASI Enabling Technologies

Advances are now enabling longer-lived sensors capable of more precise measurements in regions previously difficult to instrument

- advanced manufacturing
- advanced materials
- advanced batteries
- edge and cloud computing
- radiation-hardened sensors
- embedded sensors
- nanotechnology
- power harvesting
- optical sensors
- multi-modal sensors







ASI Selected Applications

Materials Degradation and Component Performance

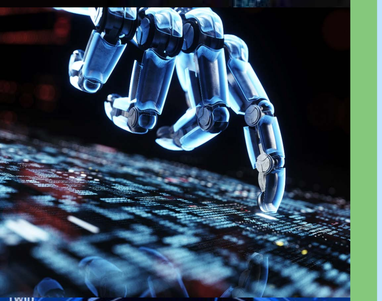
- High-temperature and harsh environments
- Flux and Radiation
- Performance monitoring

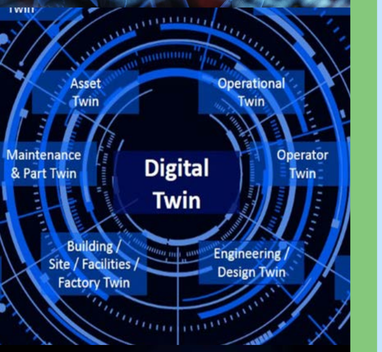
Mechanical/Vibration

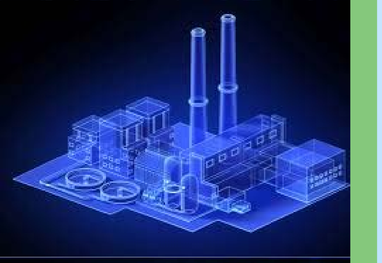
- Motor-pump systems
- Flow induced vibration of mechanical systems

Chemistry

- Corrosion behavior and redox potential in MSRs
- Off-gas control
- Waste streams
- Electro chemical processing







ASI Challenges and Gaps

Design

- Performance and reliability-based design
- Environmental resistance
- Nano-sensors for in-core requirements
- Multimodal sensors

Operating Environment

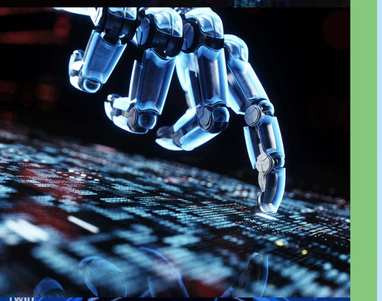
- Qualification process and data
- Performance and reliability

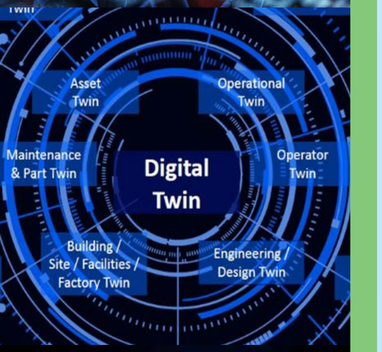
Sensor Communication

- Addressing wireless cybersecurity concerns
- Qualifying heterogeneous, multi-band wireless networks

Power Supply

- Addressing limitations of cabling and battery power
- Developing power harvesting for self-powered sensors





Thank You

These activities were supported by multiple NRC offices including:

- **Nuclear Regulatory Research**
- **Nuclear Reactor Regulation**
- **Nuclear Security and Incident Response**
- **Nuclear Material Safety and Safeguards**

For further information, questions, or comments, please contact:

Raj.Iyengar@nrc.gov