NRC RESEARCH ACTIVITIES IN DIGITAL TWINS

Raj Iyengar

Reactor Engineering Branch

Division of Engineering

Office of Nuclear Regulatory Research

Nuclear Regulatory Commission

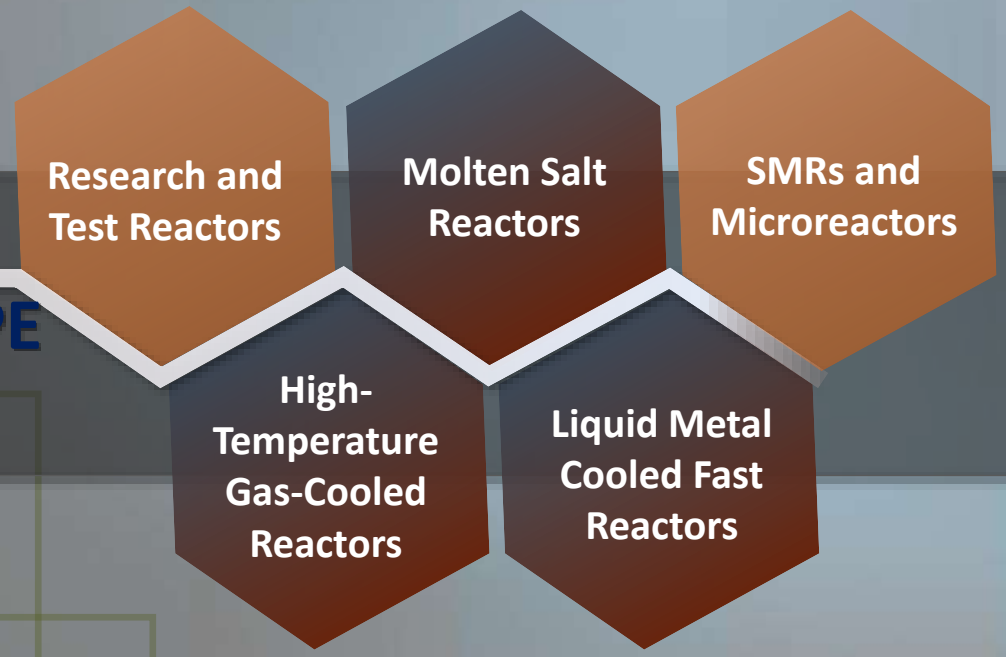
DOE-NE WORKSHOP ON ADVANCED REACTORS AND NEED FOR ADVANCED CONTROL SYSTEMS

ARGONNE, IL

July12-14, 2023

NRC PREPARING FOR ADVANCED REACTORS

EVOLVING LANDSCAPE



20+ Current & potential applications by 2027

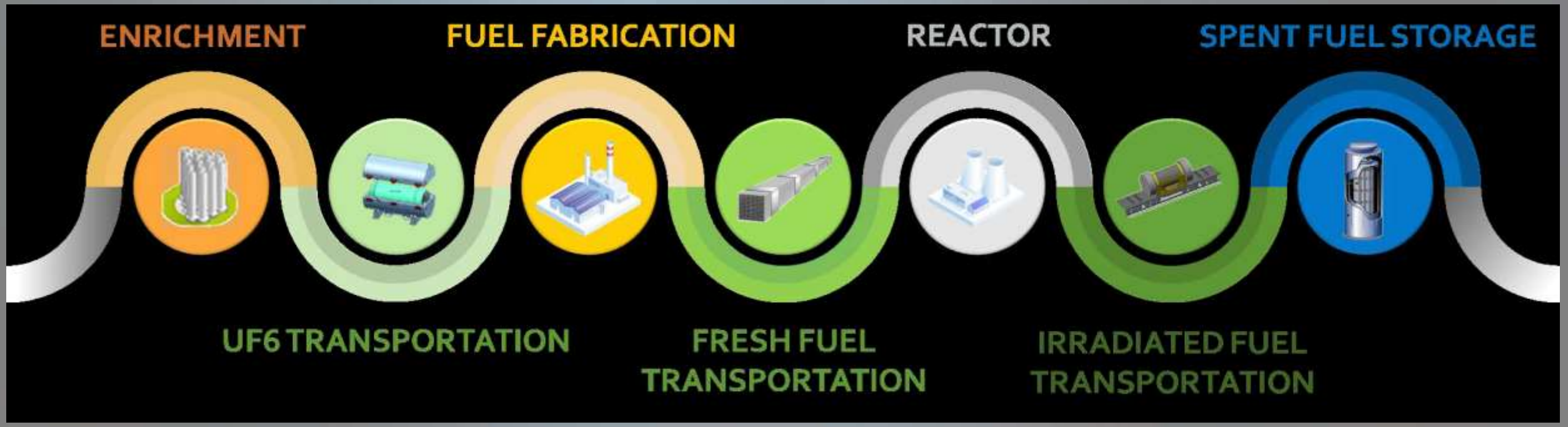
6+ Potential operating licenses by 2027

15+ Entities actively engaged in pre-application activities

79 Topical reports and white paper reviews completed for 7 vendors

42 Topical reports and white papers under evaluation from 8 vendors

NRC ADVANCED FUEL CYCLE LICENSING READINESS



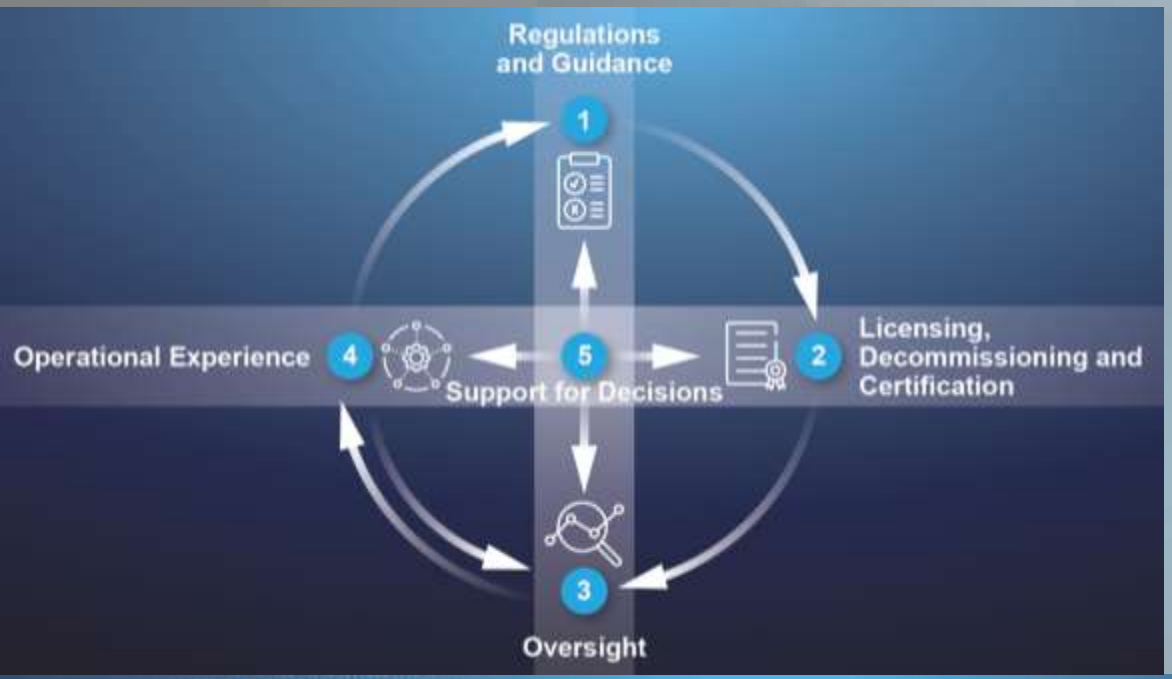
New Fuels

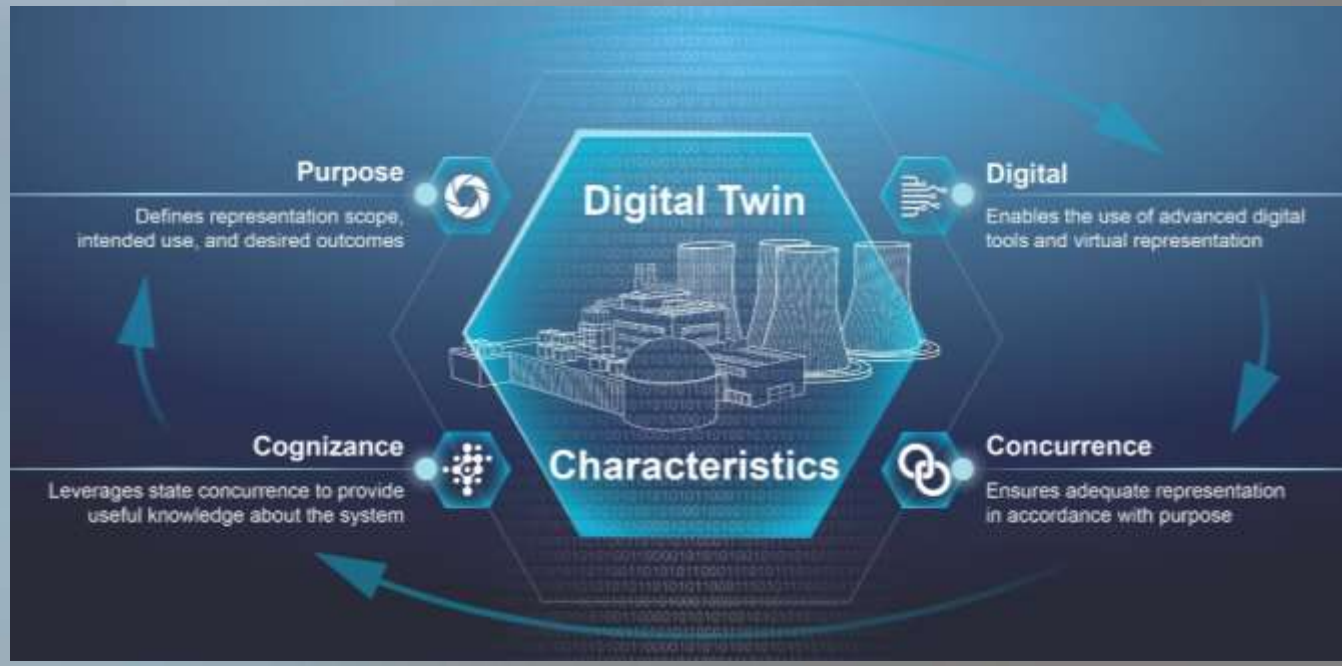
- TRISO
- Metal
- HALEU
- Molten Salt Fuel

Current Licensing Activities

- Research Support
- Generic Technical Assessments
- Accident Tolerant Fuel
- High-Assay Low-Enriched Uranium (HALEU)
- NEIMA Review Schedules
- Hearing Opportunities
- Public Involvement

DIGITAL TWIN CHARACTERISTICS & CAPABILITIES





DIGITAL TWINS: 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
AI/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

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

ADVANCED SENSORS AND INSTRUMENTATION

Challenges inherent to ASI and CT

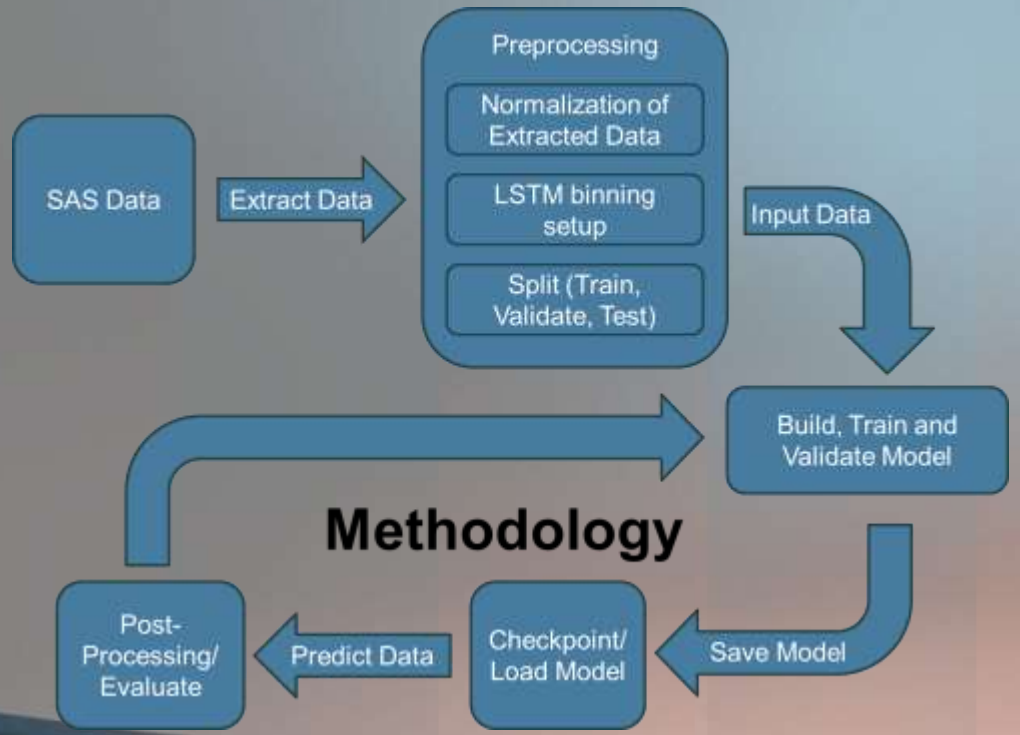
- Meeting the requirements for environmental qualification, performance, reliability, and maintainability
- Ability of communication technology to evolve as scalable, agile, and modular
- Enabling the implementation of multimodal sensors
- Supporting edge computing and smart sensors
- Cyber Security

Integration of ASI and CT with DT

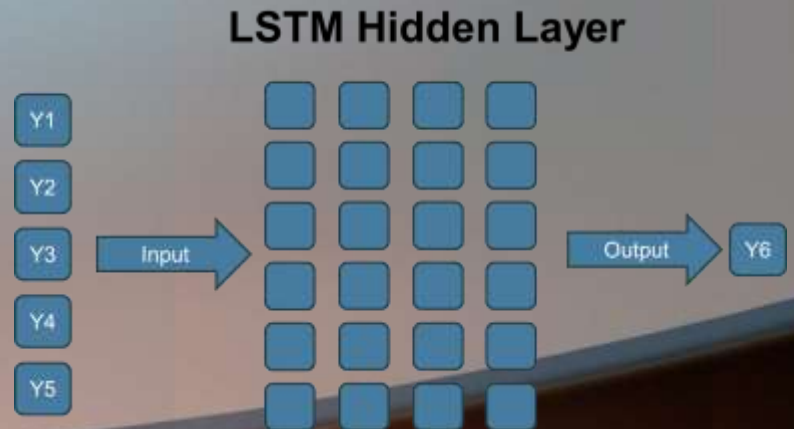
- Supporting real-time integration of advanced sensors and instrumentation and communication technology with a digital twin for state concurrence
- Ensuring adaptability of a digital twin to accommodate different technological advancements in advanced sensors and instrumentation and communication technology
- Developing a digital twin for performance and reliability of advanced sensors

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



DIGITAL TWINS TO INTEGRATED CYBER-PHYSICAL SYSTEMS

EMBEDDED SYSTEMS

MULTI SENSORS FUSION

SENSORS – ACTUATORS INTEGRATION

SMART COMPONENTS

EDGE COMPUTING

LAYERED DATA SPACES

Future Planned Activities

Assessment of Standards – Stakeholder Engagement

Demonstration of Applicability/Predictability

Develop Regulatory Guidance

Communication and Knowledge Management

THANK YOU

https://www.nrc.gov/reactors/power/digital-twins.html