INL/MIS-22-68110-Revision-0

Sustaining the Existing Nuclear Fleet

July 2022

Bruce P Hallbert

Changing the World's Energy Future

INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance, LLC

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Sustaining the Existing Nuclear Fleet

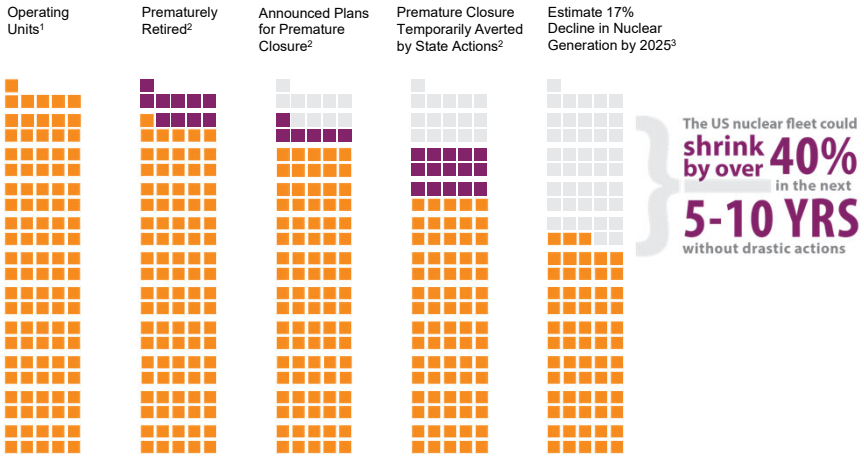
Light Water Reactor Sustainability

Idaho National Laboratory

The Challenge

"These early retirements are noteworthy, since the cost to construct the reactors is sunk. Even in a market where building a new plant would be unprofitable, the continued operation of a well-maintained and operated plant might be expected to be profitable. A decision to close means the wholesale price of electricity does not even cover a plant's ongoing operating and maintenance costs, including any capital investments needed to keep the facility in safe working order."

MIT, The Future of Nuclear Power in a Carbon Constrained World

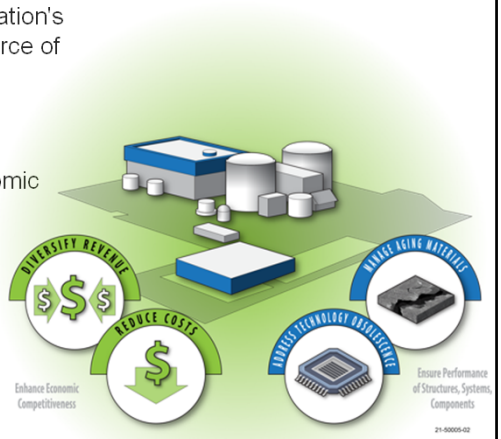


MIT – Massachusetts Institute of Technology
NEI – Nuclear Energy Institute
EIA – Energy Information Agency
US – United States

IDAHO NATIONAL LABORATORY

Light Water Reactor Sustainability Program

- **Goal**
  - Enhance the safe, efficient, and economical performance of our nation's nuclear fleet and extend the operating lifetimes of this reliable source of electricity
- **Objectives**
  - Enable long term operation of the existing nuclear power plants
  - Deploy innovative approaches to improve economics and economic competitiveness of LWRs in the near term and in future energy markets.
  - Sustain safety, improve reliability, enhance economics
- **Focus Areas**
  - Plant Modernization Research and Development
  - Flexible Plant Operation and Generation
  - Risk-Informed Systems Analysis
  - Materials Research
  - Physical Security



Stakeholder Engagement

Develop critical research areas and agreements for demonstrations

+

Develop approach for projects

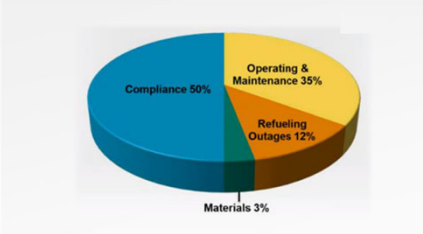
+

Coordinate project development and deploy results across industry

MOUs with NRC and EPRI

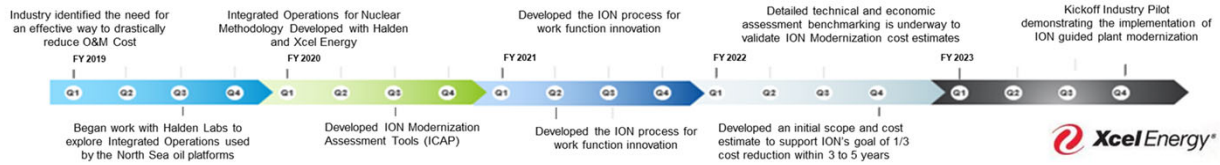
Integrated Operations for Nuclear (ION)

- ION methods support plant modernization, resulting in an economically competitive plant
- ION identifies strategic innovation to enable operating and maintenance (O&M) cost reduction by one-third
  - Evaluating the innovation necessary to deliver a technology-centric and highly automated business model
  - Benchmarking with industry, ION informed modernization's ability to achieve target cost reductions within 3–5 years
- Next phase includes full-scale pilot, demonstrating the effectiveness of ION guided plant modernization



Xcel Energy estimates up to 50% of its O&M cost to work associated with compliance activities.

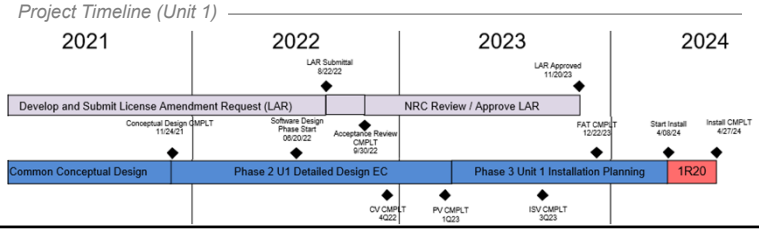
ION – Project Timeline



Modernize the Fleet

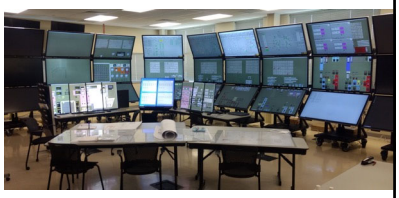
- First echelon safety instrumentation and control (I&C) systems on two units
- Conceptual Design Phase complete
- Detailed Design Phase in progress
- Multiple pre-submittal meetings with Nuclear Regulatory Commission (NRC)
- Human Factors efforts well underway
  - Operating Experience Review (Q3–Q4 of 2021)
  - Function Analysis and Allocation Workshop (March 2022)
  - Task Analysis Workshop (May 2022)

Project Timeline (Unit 1)



Constellation.

Limerick Generating Station



INL Human Systems Simulation Laboratory Task Analysis Workshop

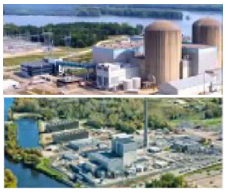
Nuclear-H_2 Demonstration Projects

Late 2022

Constellation: Nine-Mile Point NPP (~1 MWe LTE)

2023–2024

Energy Harbor: Davis-Besse NPP (~1–2 MWe LTE)



~2024

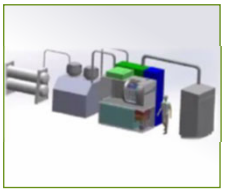
Xcel Energy: Prairie Island *(top)* or Monticello *(bottom)* NPP ~150 kWe steam

Thermal & Electrical Integration (HTSE/SOEC)

~2024

APS/Pinnacle West Hydrogen: Palo Verde Generating Station (~15–20 MWe LTE)

H_2 Production for Combustion and Synthetic Fuels



FuelCell Energy: Demonstration at INL (250 kW)

Nuclear energy and SOEC

HTSE – High-temperature steam electrolysis

SOEC – Solid oxide electrolysis

Light Water Reactor Coupling to Hydrogen Plant

- Pressurized water reactor (PWR) and boiling water reactor (BWR) plant simulators coupled to hydrogen plant
  - Full-scope simulator
  - Sargent & Lundy providing preliminary design of electrical coupling and thermal energy extraction and delivery
  - Westinghouse is guiding the integration of control systems
- Developing and testing operator control concepts and human factors at the Human Systems Simulation Laboratory
- System connected to high-temperature electrolysis (HTE) or LTE modules and digital real-time grid emulator

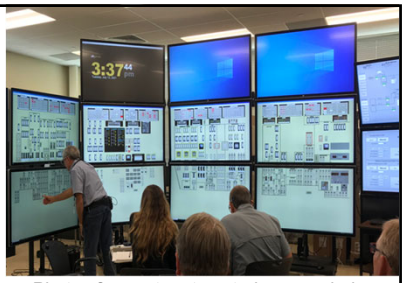
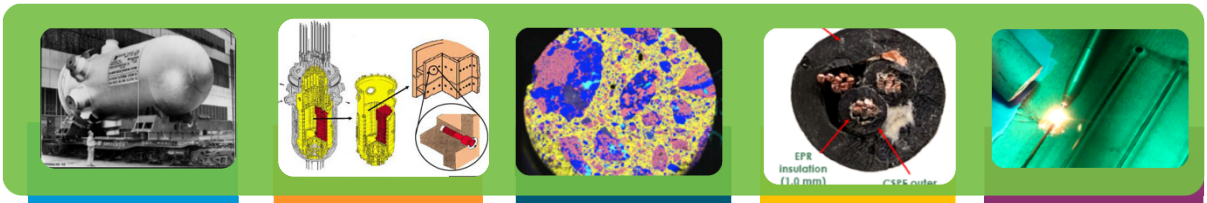


Photo of operator at control screen during study with full-scope simulator.

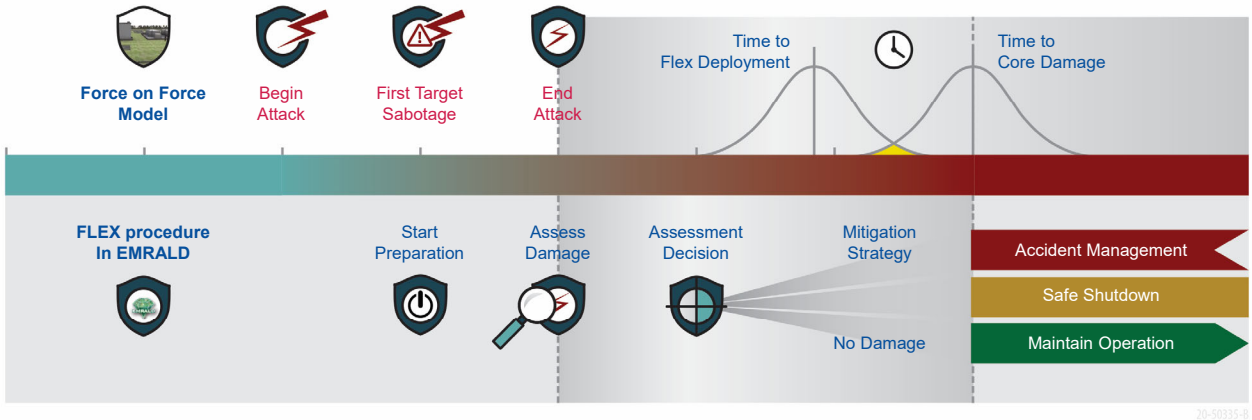
Bloom 100 kW electrolysis system used in controls/hardware demonstration.

Materials Research



Reactor Pressure Vessel	Internals, Pressure Boundaries and Piping	Concrete Degradation	Cable Aging Degradation	Mitigation Methods

Risk-Inform Physical Security to Reduce Costs



EMRALD – Event Modeling Risk Assessment using Linked Diagrams

Summary

- MOU with NRC facilitate direct collaboration and exchange in areas of vital common interest
  - Materials, Modernization, Risk-Informed Research, Diversification of Products, Physical Security
- Need for clean and reliable energy from nuclear power underscore the need to address existential challenges facing the existing fleet
  - NS&T activities address highest priority issues to address continued viability and role of nuclear energy
- Projects follow timelines to impact economic competitiveness and long-term operation
  - Address critical needs in aging and obsolescence
  - Demonstrate the means to substantially reduce the costs of ownership
  - Lead transformation from a labor-centric to technology-centric business model

Battelle Energy Alliance manages INL for the U.S. Department of Energy's Office of Nuclear Energy. INL is the nation's center for nuclear energy research and development, and also performs research in each of DOE's strategic goal areas: energy, national security, science and the environment.