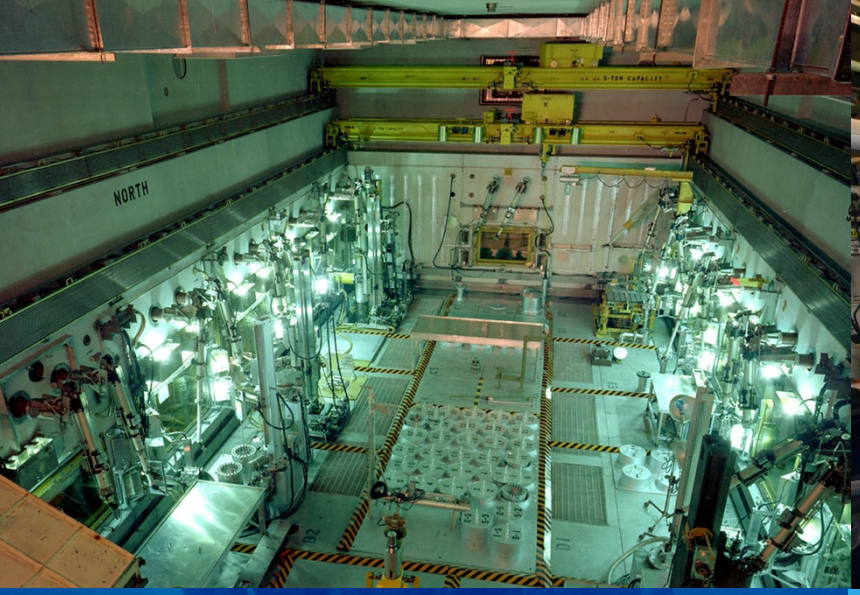
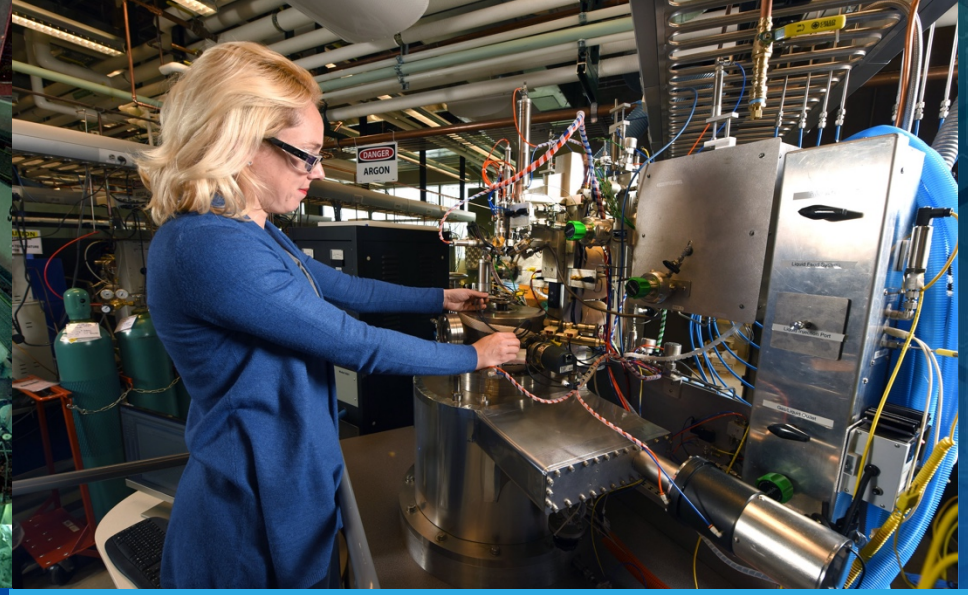




John C. Wagner, PhD
Director, Idaho National Laboratory

Technology Collaborations with Utilities and Private Companies

National Academies of Science, Engineering and Medicine

Virtual Meeting - December 17, 2020

Idaho National Laboratory

INL is uniquely capable of addressing challenges to the nation's energy and security future

INL Values

Excellence, Inclusivity, Integrity, Ownership, Teamwork, and Safety

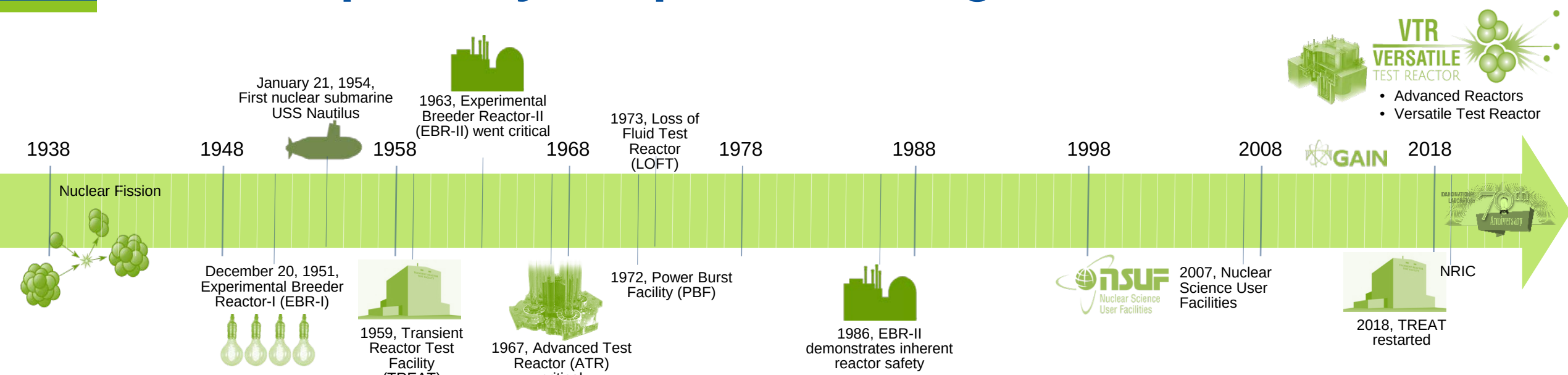
INL Vision

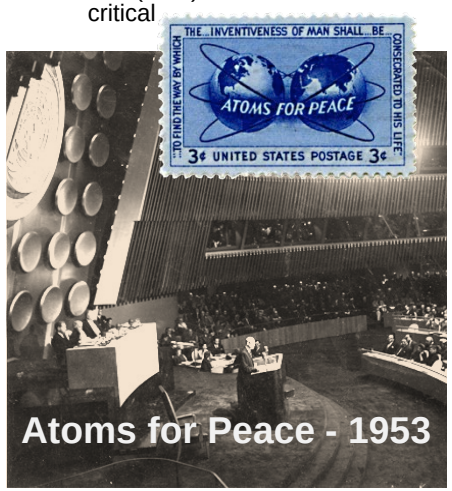
INL will change the world's energy future and secure our critical infrastructure.

INL Mission

Discover, demonstrate and secure innovative nuclear energy solutions, clean energy options and critical infrastructure.

INL – Inspired by the past to change the future





INL addresses energy and security challenges at scale

298 DOE owned buildings & trailers

27 Contractor leased buildings & trailers

25 Nuclear Facilities
Haz Cat I Adv. Test Reactor
Haz Cat II
Haz Cat III

44 Radiological Facilities

4 Operating Reactors

5,224 Staff & Subcontractors
FY20 Business Volume, $1.49B

3.2B $ RPV

3.3M SQ FT Gross

3 Fire Stations

1 Landfill

1 Museum

40 Miles primary roads / 125 total

17.5 Miles railroad for shipping nuclear fuel

7 Substations with interfaces to 2 power providers

112 Miles high-voltage transmission lines

National Reactor Innovation Center (NRIC) will provide capabilities to accelerate technology readiness from proof-of-concept through proof-of-operation

NEICA

Nuclear Energy Innovation Capabilities Act

Signed into law September 2018, NEICA calls for the creation of a ***National Reactor Innovation Center*** *to support demonstration of cost-shared private reactors.*

NRIC

National Reactor Innovation Center

NRIC is a place where government and private companies can test and demonstrate new reactor designs, as well as materials, fuels, and other nuclear energy technologies.

NRIC and GAIN are complementary and coordinated efforts to support the nuclear energy industry

GAIN

- **Established in 2015 as a resource for accelerated development of nuclear innovations with lab partners**
  - Comprehensive resource to entire nuclear innovation ecosystem at all development stages
  - Provides streamlined access to testing, MASL, experimental facilities, lab expertise, and legacy data
  - Regulatory expertise *(e.g. NRC advanced reactor licensing strategy support)*
  - Financial support

National Reactor Innovation Center (NRIC)

Dr. Ashley Finan
Director, NRIC

Nicholas Smith
Deputy Director, NRIC

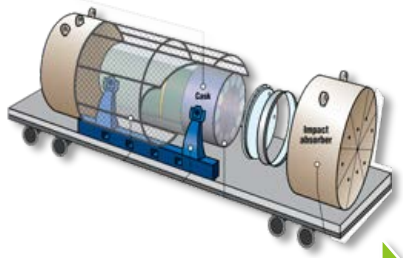
inspire
empower
deliver
NRIC

- The National Reactor Innovation Center (NRIC) was authorized by the Nuclear Energy Innovation Capabilities Act, which was signed into law on September 28, 2018.
- **NRIC shall enable the testing and demonstration of reactor concepts to be proposed and funded, in whole or in part, by the private sector.**
- Address the barriers that prevent industry from undertaking demonstration reactor projects.
- Accelerate the deployment of advanced reactor technology.

Vision for Advanced Reactor Demonstrations and Deployment – The opportunities ahead of us

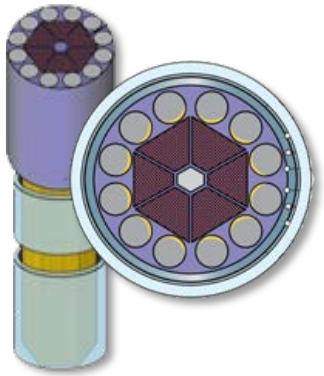
Demonstrate First Microreactors in Early 2020s

- Resolve key advanced reactor issues
- Open new markets for nuclear energy
- Provide a “win” to build positive momentum
- Civilian and federal apps.



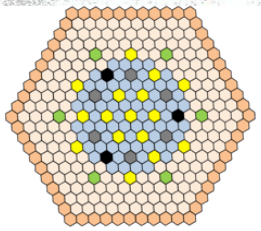
Microreactors Deployed

- Support deployment for remote site power and process heat customers
- RD&D to enable broader deployment



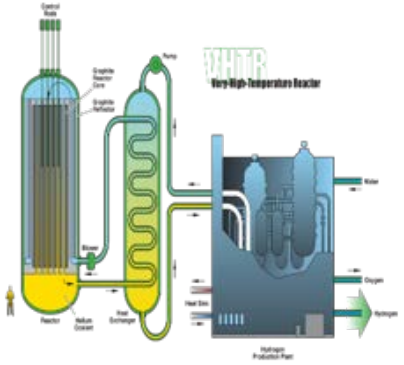
Versatile Test Reactor (VTR) Operating

- Establish fast-spectrum testing and fuel development capability
- Support non-LWR advanced reactor demonstrations



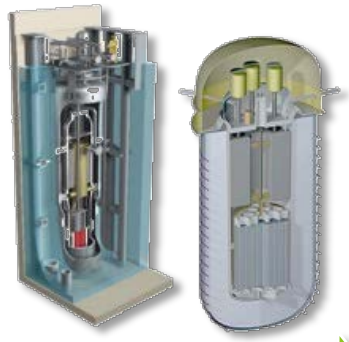
Advanced Reactor Demonstrations

- DOE-NE Advanced Reactor Demonstration Program
- Demonstrate two advanced reactors



SMR Operating

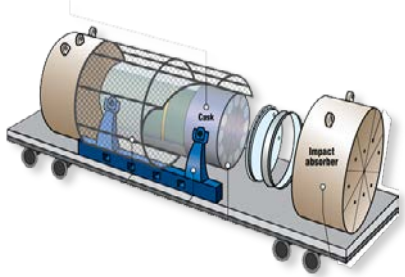
- Enable deployment through siting and technical support
- 2029 - First NuScale module (UAMPS) to commence commercial operation



2025 2028 2029

Enabling Microreactors (vSMR)

- Factory built, transportable, 2-20 MW, inherently safe, reliable power
- Working through a successful demonstration can resolve uncertainties in the advanced reactor licensing and deployment processes at a reduced cost
- Successful deployment in key markets (space, defense, remote off-grid) can open up broader commercial markets
- Applications beyond electricity
- Potential advantages for integration with intermittent sources

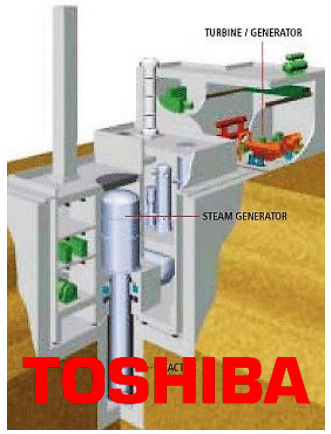


OKLO

HolosGen™

BATTERY
Local Modular Energy

STARCORE NUCLEAR



USNC
ULTRA•SAFE•NUCLEAR

GE

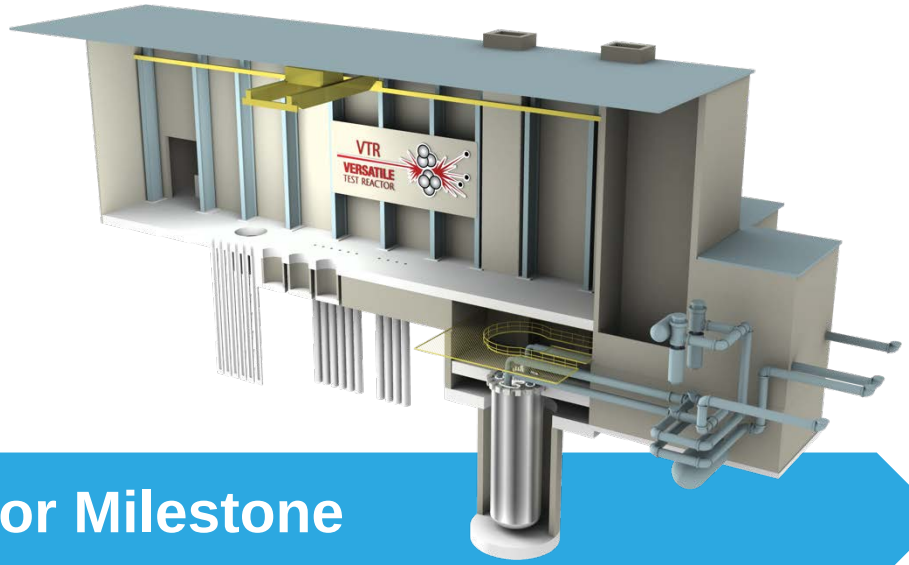
HITACHI

GENERAL ATOMICS

Key features and use-cases:

- **Defense applications:**
  Uninterrupted mobile power; potentially no cyber vulnerabilities; heat and power to support various operational needs
- **Commercial applications**
  Support for remote communities, mining sites, etc. Features similar to Defense applications, but with emphasis on economics

Versatile Test Reactor (VTR) Partnerships and Major Milestones to Date



1st Major Milestone

Critical Decision 0 achieved in 2019, focused on needs of:

- Commercial developers of advanced nuclear energy technologies
- National security interests
- Scientific community

2nd Major Milestone

Critical Decision 1 achieved in September 2020, focused on:

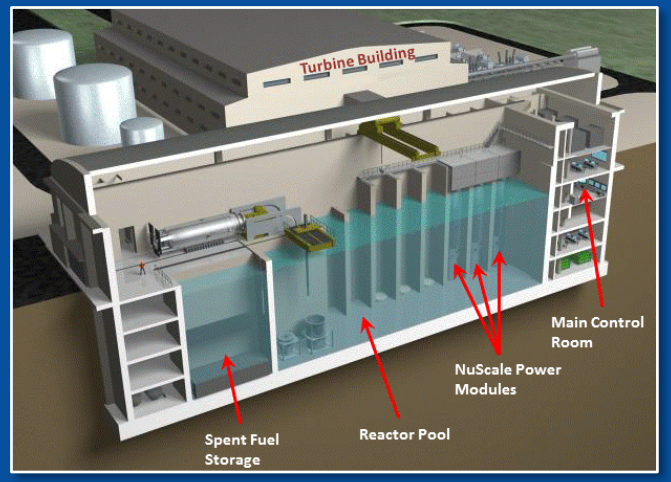
- Analysis of alternatives
- Conceptual design and conceptual safety design
- Cost and schedule ranges

The Blanket Master Contract for the Engineering Design and Construction phase of the project is being negotiated with Bechtel National, Inc. (TerraPower and GE-Hitachi partners)

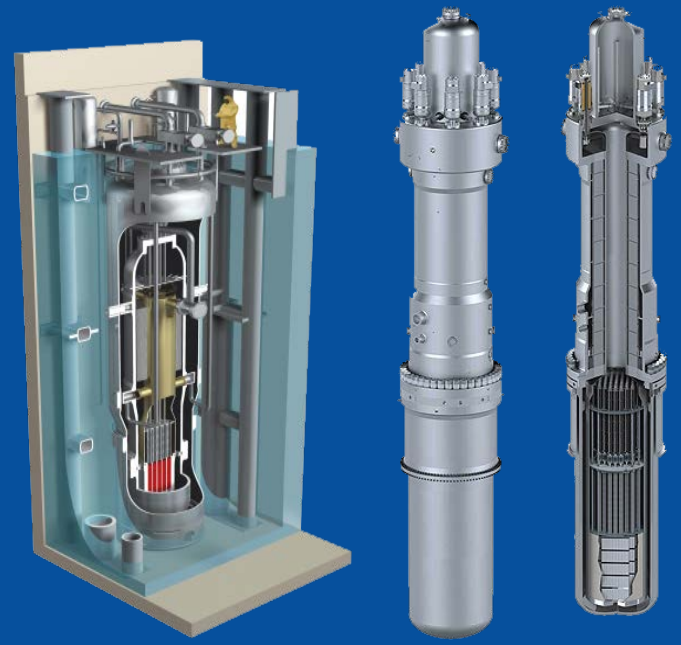
Small Modular Reactors (SMR)

- INL supports site characterization, RD&D, and regulatory support for the first SMR anywhere in the world.
- DOE granted a site use permit to Utah Associated Municipal Power Systems (UAMPS) Carbon Free Power Project (CFPP) in February 2016 that enables UAMPS to study, license and locate a NuScale-designed SMR at INL.
- Joint Use Module Plant (JUMP) concept is being developed to commercially demonstrate Hybrid Energy Systems (HES) and Secure Reliable Microgrid (SRM) applications.

Other advanced reactor companies also interested in siting in Idaho



3-D view of Six NuScale Modules



Sustaining the existing LWR fleet:

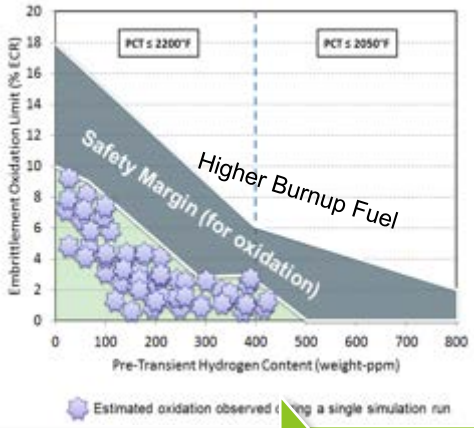
Vision for a Thriving Existing Fleet

Energy systems and market analyses

- Define attributes of zero-emission baseload energy for market recognition
- Establish vital relationships to other market and grid attributes – resilience, reliability, etc.

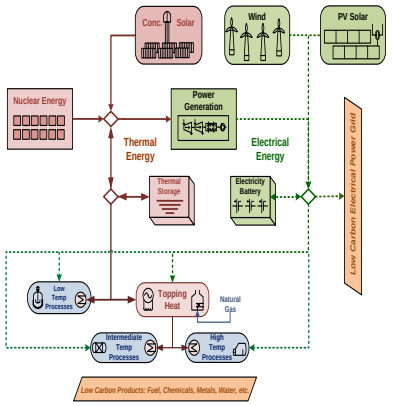
Risk-informed tools and analyses to recover plant margins and reduce cost

- Employ advanced PRA tools and best estimate codes to reduce unnecessary conservatisms that drive costs
- Key to NEI and industry initiatives



Integrated energy system testing

- Revenue and energy supply that addresses grid futures for U.S. fleet
- CRADAs and industry engagement initiated to demonstrate technology

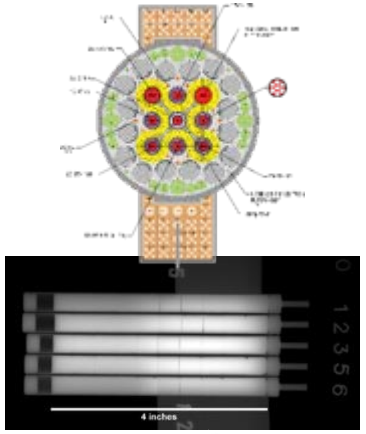


LWR modernization and life extension

- Work with plant operators to implement digital I&C upgrades to modernize plant control rooms
- Provide scientific basis of long-term material performance of SSCs to support license extension
- Develop sensors and more efficient methods and systems for plant health monitoring

Advanced Accident-Tolerant Fuel concepts

- Establish technical basis for licensing and deployment of accident-tolerant fuel concepts



2020 2021 2022

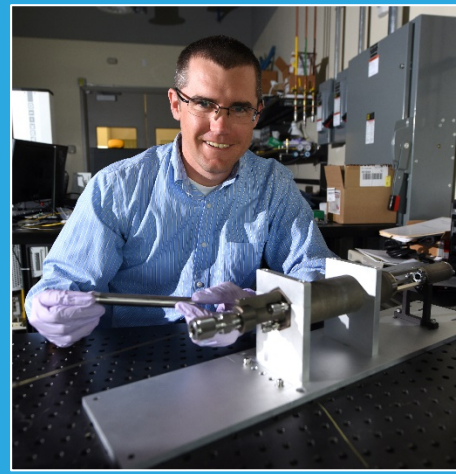
Private-public partnership will use nuclear energy for clean hydrogen production

- **First U.S. pairing of high-temperature steam electrolysis with commercial heat.**
- **More than $10 million in federal funding** will help a Minnesota nuclear power plant make hydrogen in a way that could transform the nuclear energy industry.
- **Minneapolis-based Xcel Energy will work with Idaho National Laboratory** to demonstrate a system that uses a nuclear plant's steam and electricity to split water. The resulting hydrogen will initially be used at the power plant, but it could eventually be sold to other industries.

R&D Capabilities:
Advanced Manufacturing

INL has individual teams focused on:

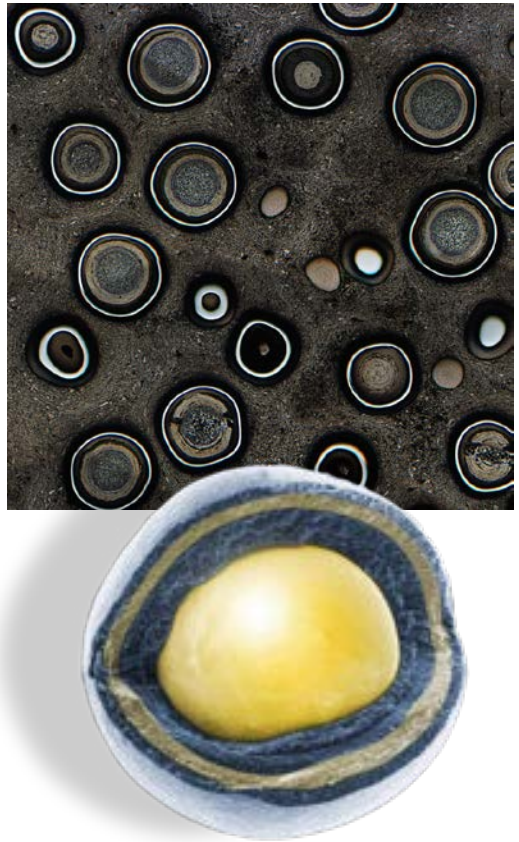
- Critical materials
- Net-zero waste in manufacturing
- Modeling and simulation
- High-temperature materials



R&D Capabilities: Fuel Work

TRISO Fuel: A Paradigm Shift for Nuclear Power

- The Advanced Gas Reactor (AGR) Fuel Development Program was initiated in 2002
- Silicon carbide keeps fission products sealed inside, meaning that a containment vessel failure is no longer necessarily catastrophic.
- Pellets as the first line of containment is a paradigm shift for nuclear regulations/safety



HALEU Feedstock and Fuel Production

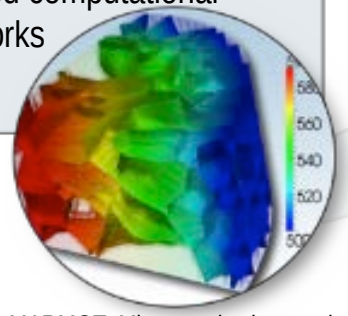
- Initiate recovery of material from irradiated naval fuels and EBR-II spent fuel, and reestablish domestic enrichment.
- Initiate operations to support advanced reactor start-up cores

R&D Capabilities: Advanced Computing

- The Multiphysics Object Oriented Simulation Environment (MOOSE) framework is an industry-leading multiscale, multi-physics modeling platform.
- MOOSE enables simulation tools to be developed in a fraction of the time previously required and makes modeling and simulation more accessible to a broad array of scientists.
- MOOSE-based applications provide support for nuclear energy, materials, structural dynamics, multiphase flow, waste management, and geophysics.

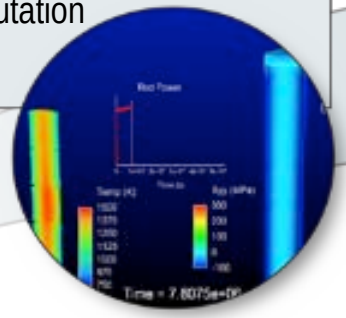
NEAMS
NUCLEAR ENERGY ADVANCED MODELING & SIMULATION PROGRAM

Risk assessment
Risk-informed safety margin characterization and advanced computational frameworks



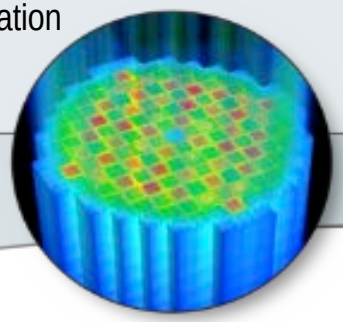
MARMOT: Microscopic changes in nuclear fuel during irradiation

Systems analysis
Advanced safety and systems analysis and predictive modeling for advanced transmutation fuels

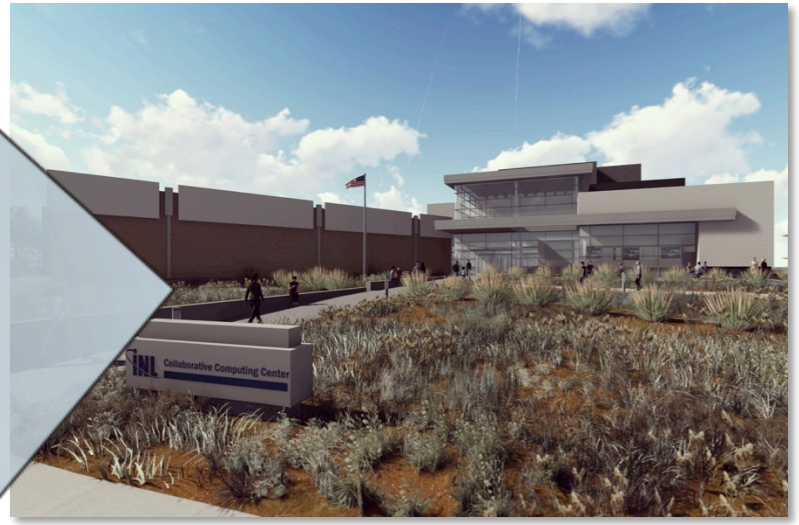


BISON: Nuclear fuel pellet surface simulation

Multi-scale modeling
Multi-scale nuclear fuel performance modeling and simulation



MOOSE: Advanced reactor full-core multiphysics modeling



C3 building will provide updates, supercomputing capacity, and collaborative office space for modeling and simulation experts.

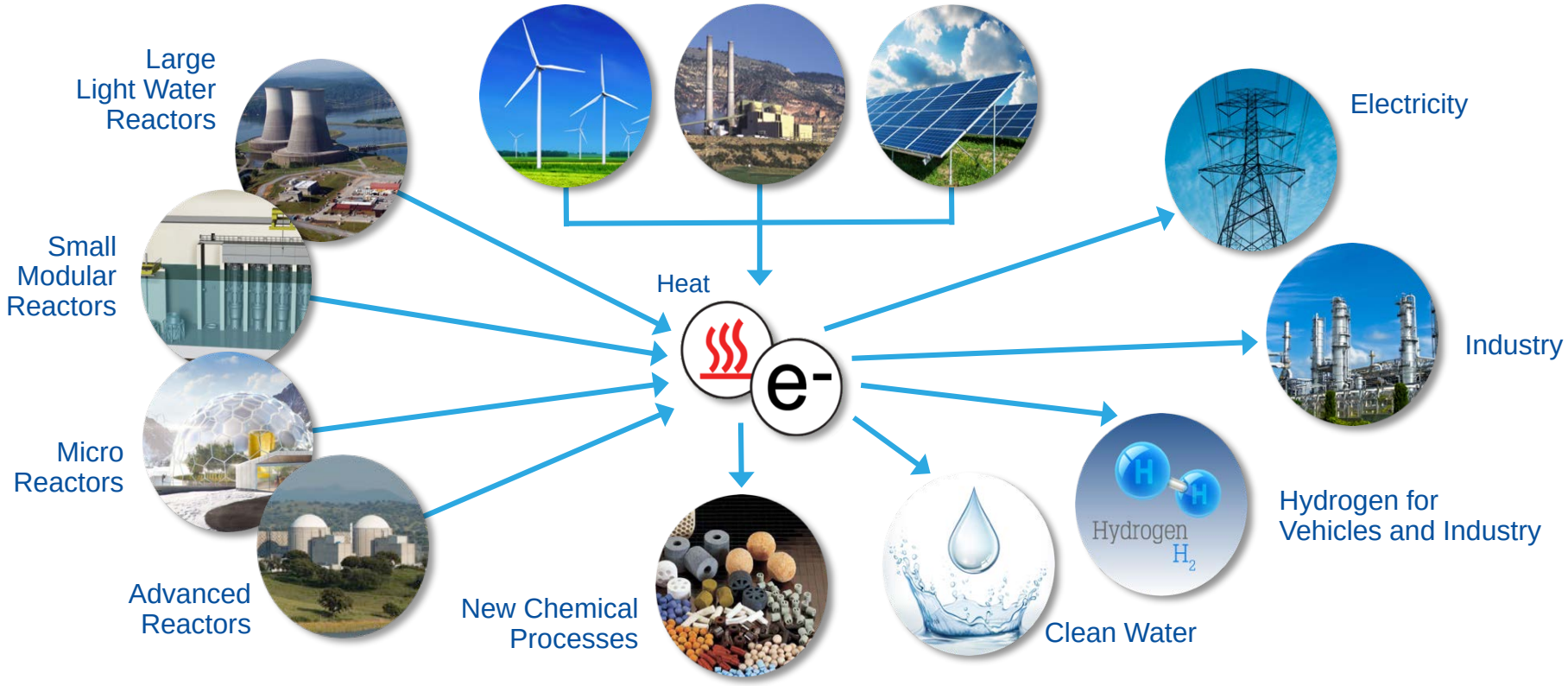
R&D Capabilities: Integrated Energy Systems

Today

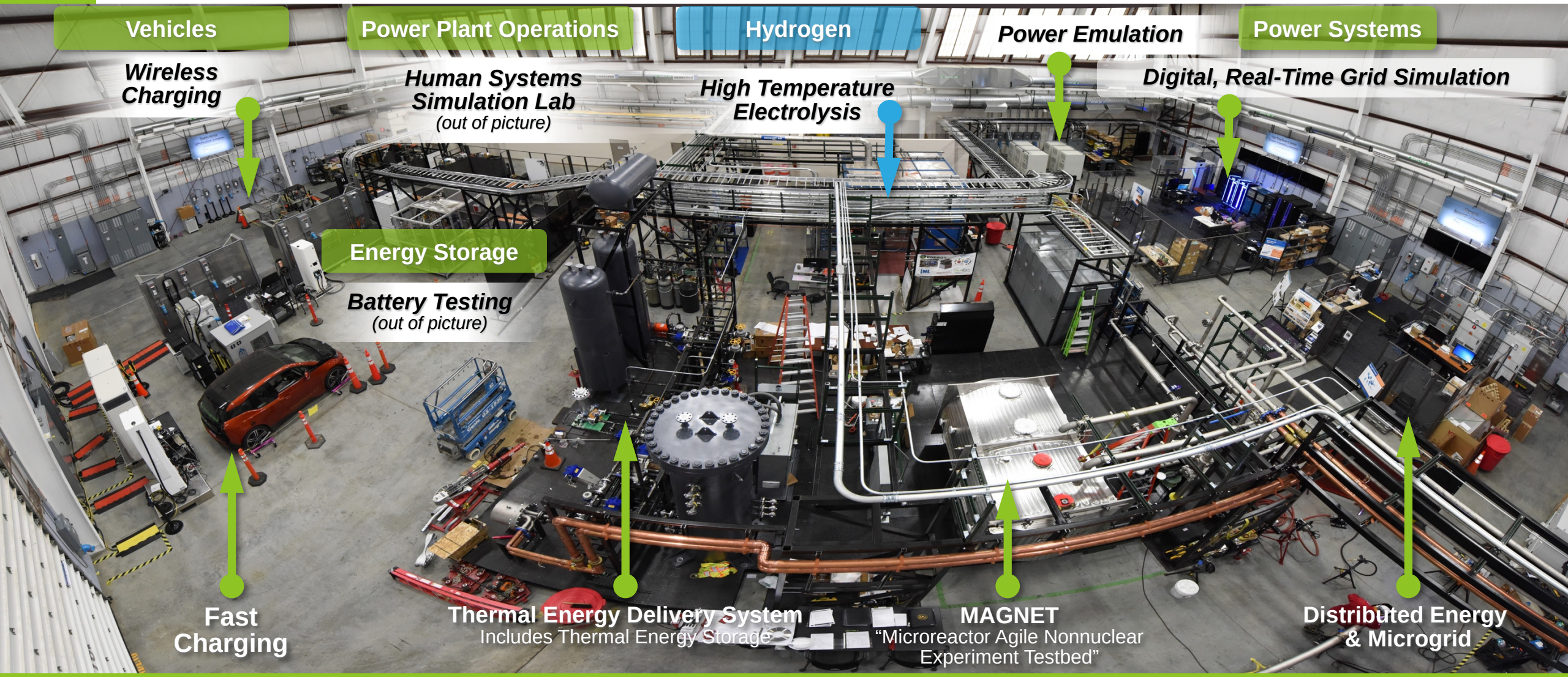
Electricity-only focus

Potential Future Energy System

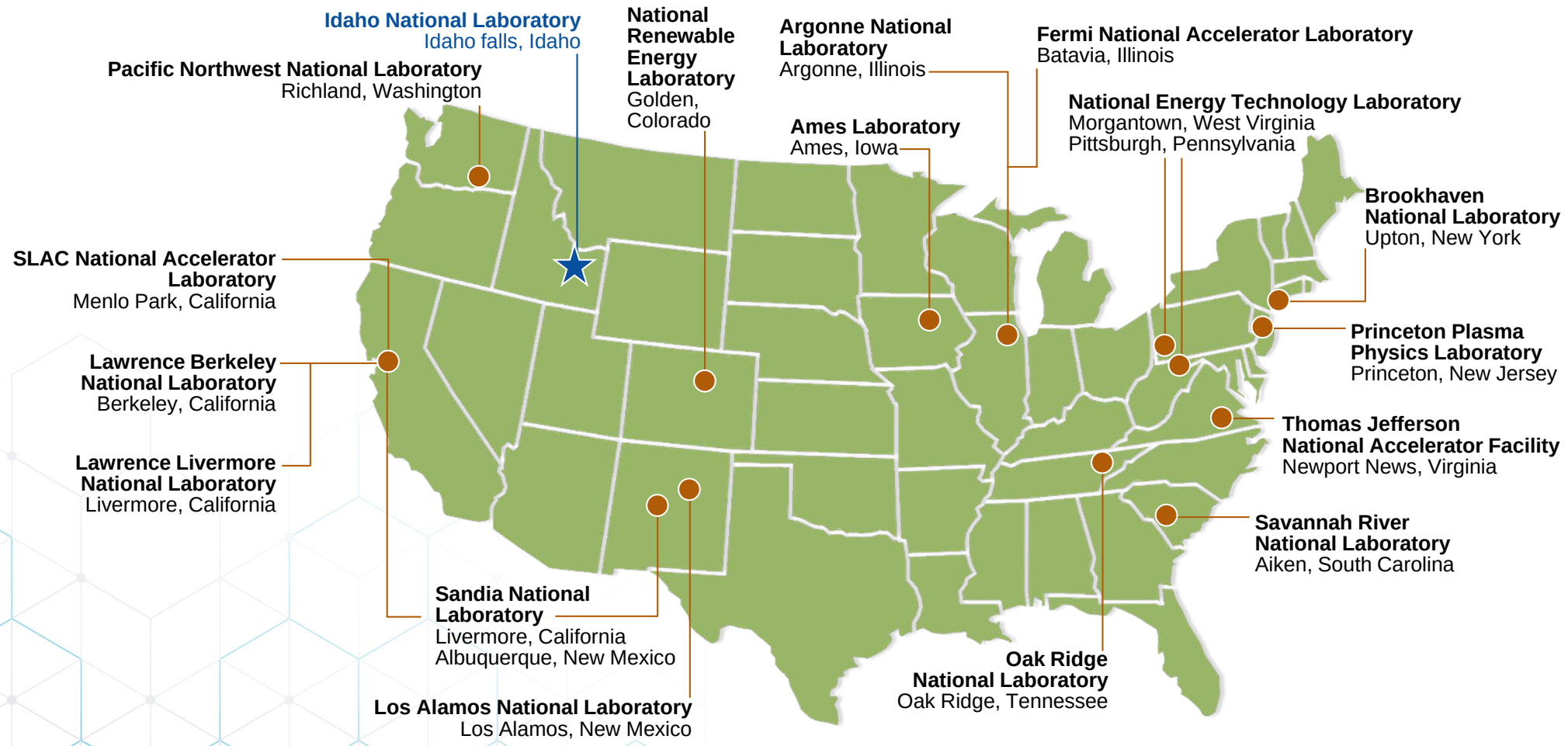
Integrated grid system leverages contributions from nuclear fission beyond electricity



INL Energy Systems Laboratory IES Capability



Partnership with Other Labs



Idaho National Laboratory