

July 16th, 2026

Joe Oncken

Control Systems Research Scientist

Nuclear Reactor Controls: Past, Present, and Future

INL/MIS-26-93982

Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy



Idaho National Laboratory

Joe Oncken

Instrumentation and Controls Research Scientist
Idaho National Laboratory (INL)



- **Education**

- Ph.D., Mechanical Engineering — Michigan Technological University
- B.S., Mechanical Engineering — University of North Dakota
- High School — Red River High School, Grand Forks, ND

- **Current Work**

- Develops predictive and advanced control methods for autonomous nuclear reactor operation
 - Both on land and in space!
- Principal Investigator on multiple efforts designing remote operations systems for advanced reactors

Agenda

- INL's Role in the history and future of Nuclear Energy
- What are control systems?
- Current and past state of nuclear reactor controls
- Advanced control for nuclear reactors research



The National Laboratories



The Crown Jewels Of The Nation's Research And Innovation Ecosystem

National Labs address critical scientific challenges:

- Innovations in energy technologies
- Advancements in supercomputing and AI
- Discovering the origins of our universe
- Fortifying national security defenses

17 National Laboratories across the country:

- Employ world-class scientists and engineers
- Collaborate with staff from academia, government, and industry
- Develop and operate unique instruments and facilities

Serve as the epicenter of science and technology research:

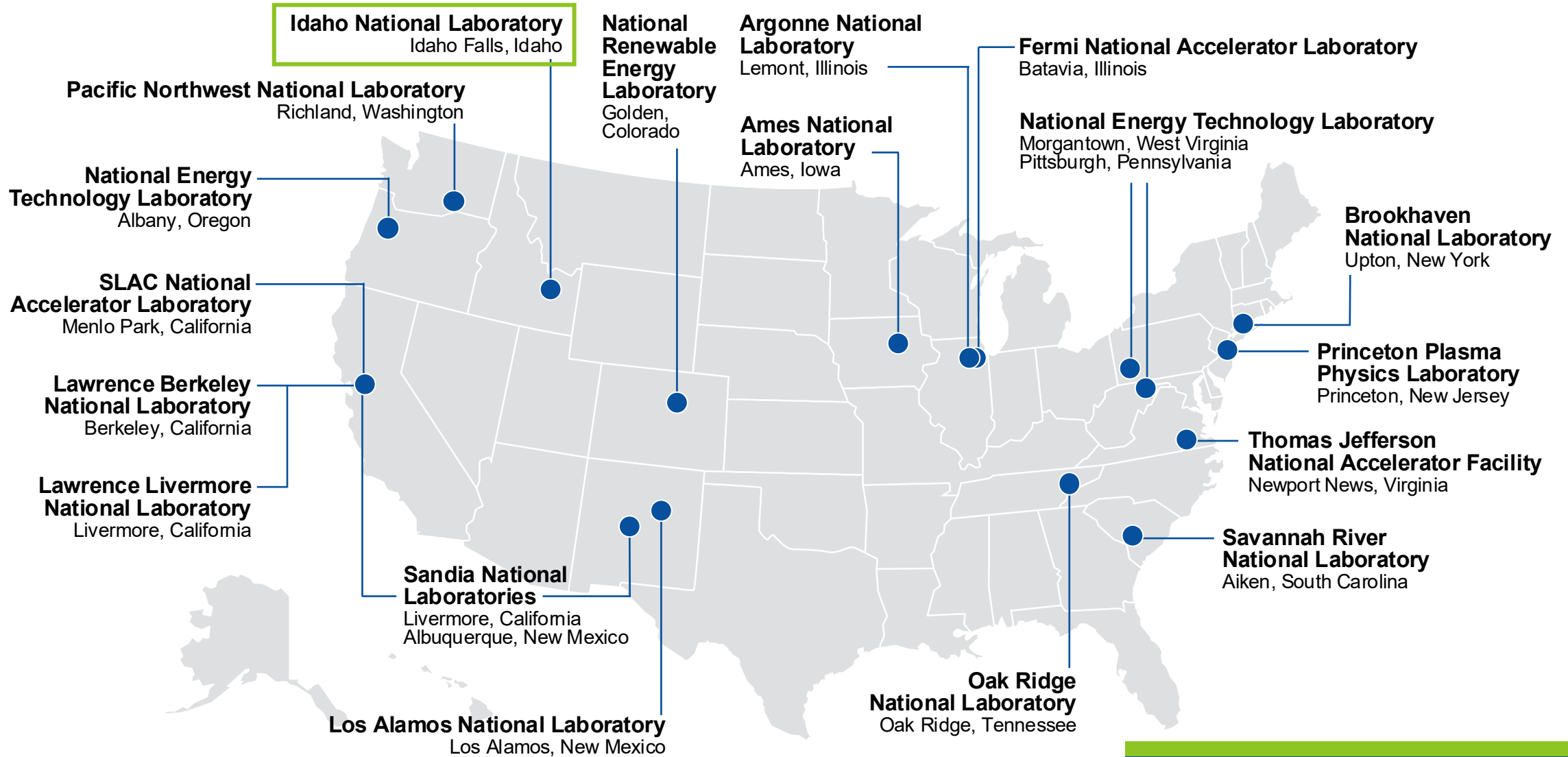
- Address challenges beyond the scope of individual universities or private industry

Our research is for the public:

- OSTI.GOV makes discoverable over 75 years of research results from DOE and its predecessor agencies.



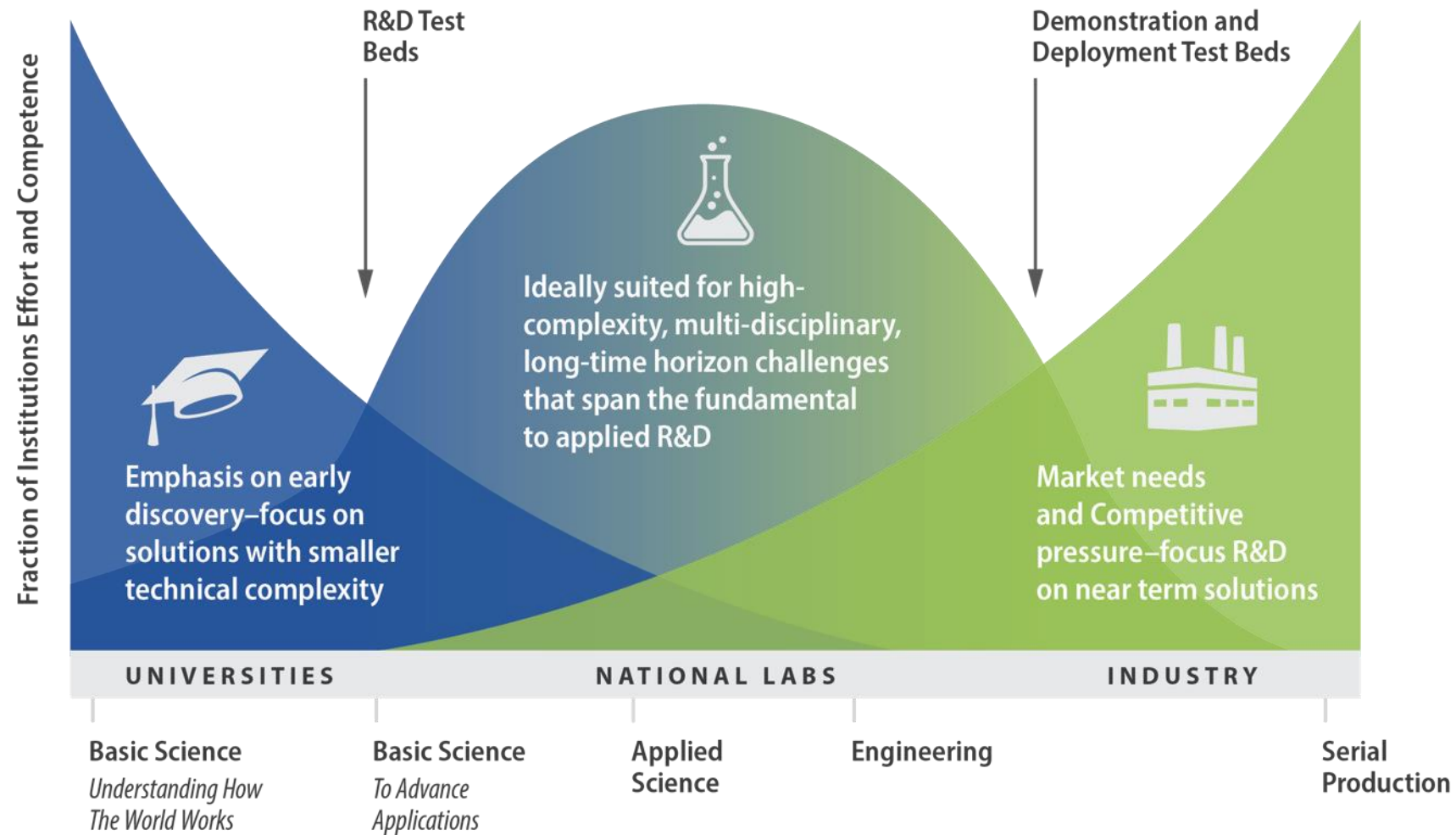
Seventeen DOE National Laboratories



“Spectrum” of DOE Laboratories



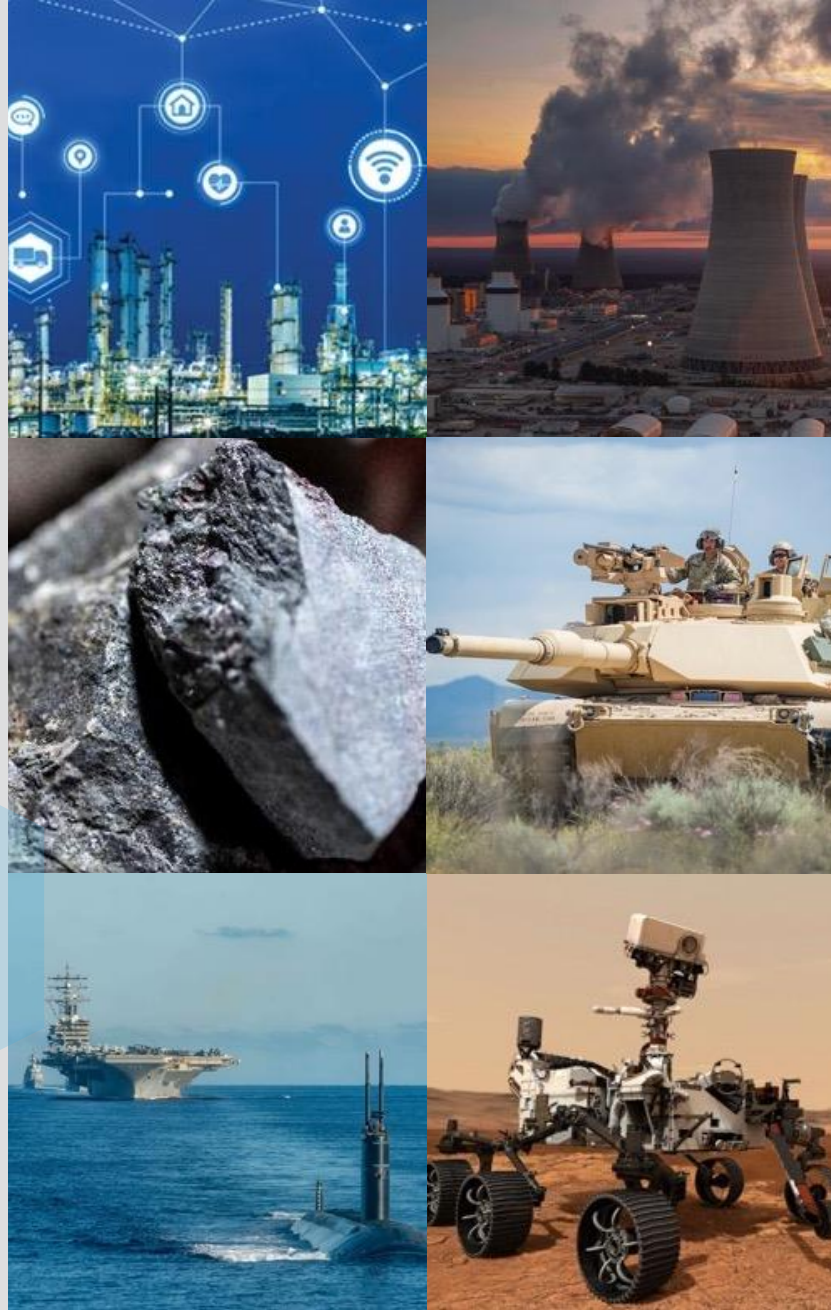
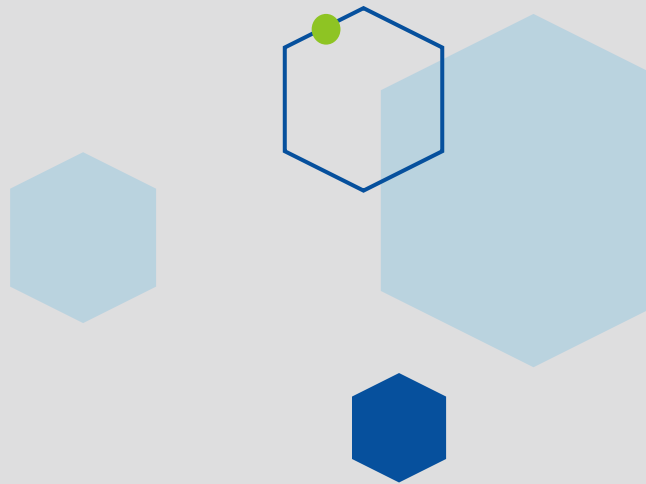
DOE labs support the entire technology lifecycle





Idaho National Laboratory

Enabling energy dominance and security through research, development, and demonstration



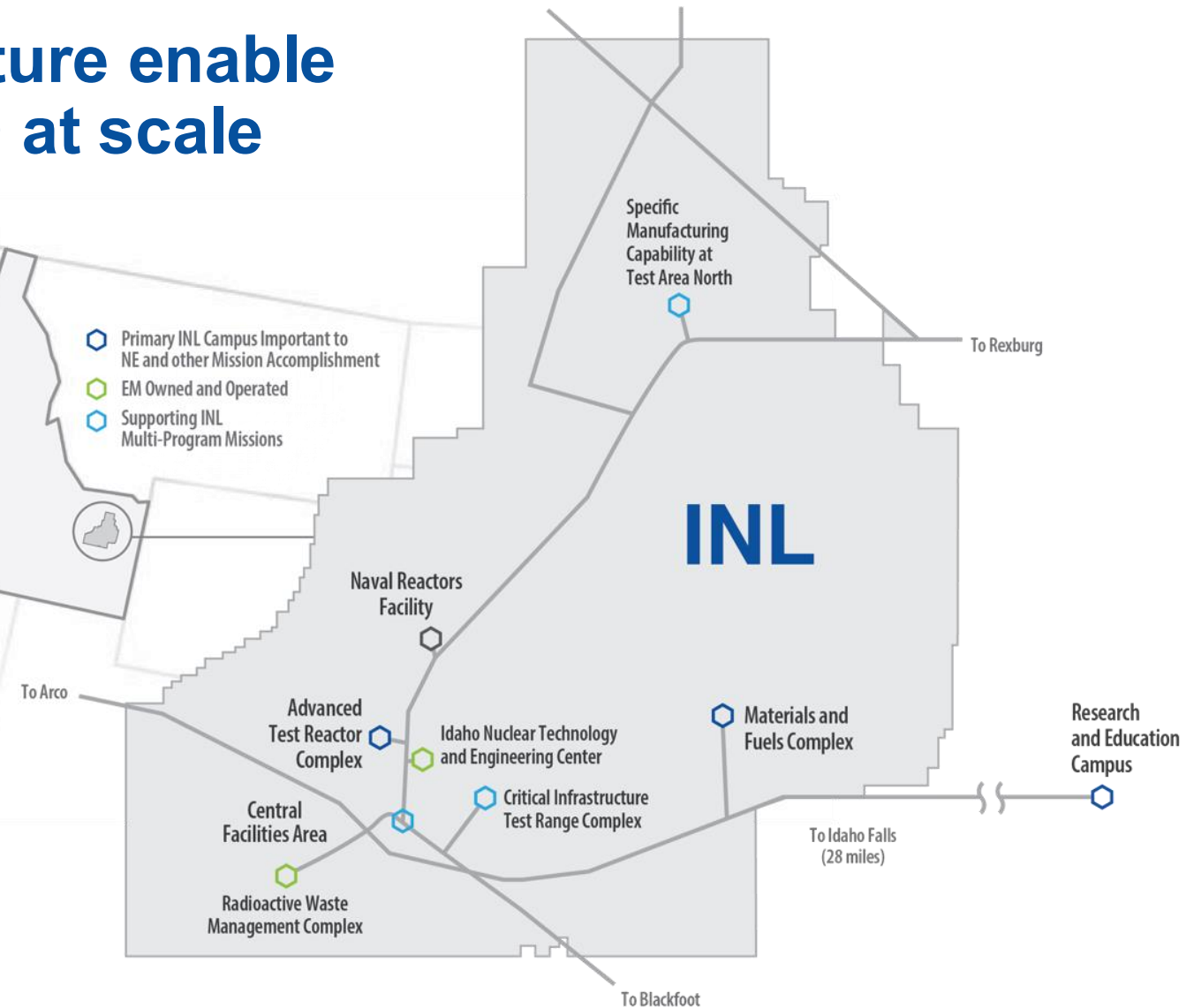
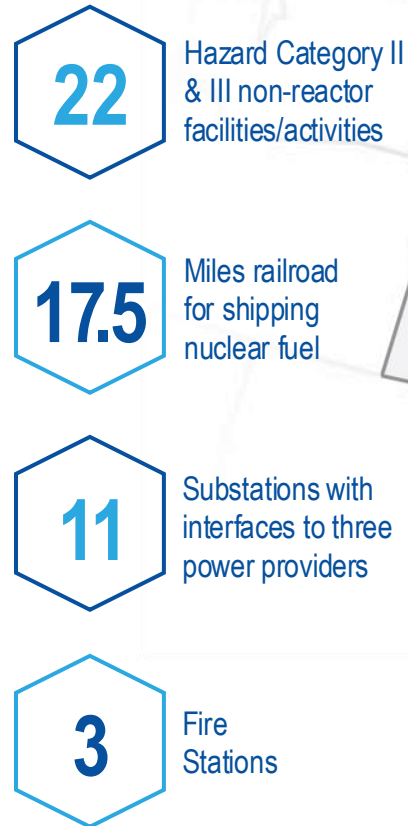
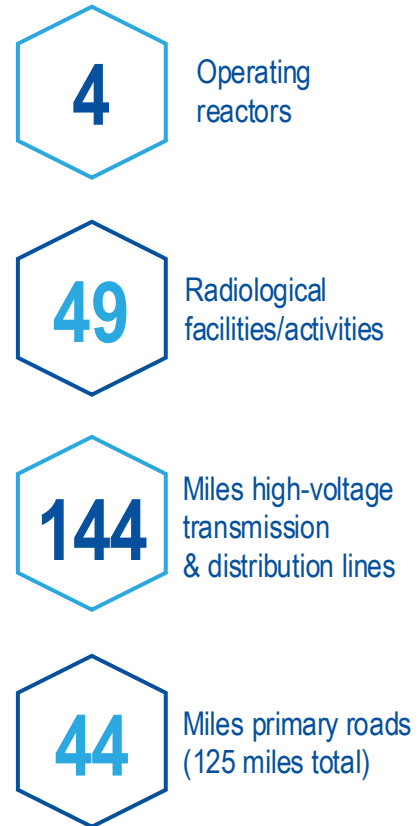
VISION

To change the world's energy future and secure our nation's critical infrastructure.

MISSION

To discover, demonstrate and secure innovative nuclear energy solutions, other clean energy options and critical infrastructure.

Unique site and infrastructure enable energy and security RD&D at scale



Our Heritage: *The National Reactor Testing Station drove nuclear innovation in the U.S. and around the world*

1st

Nuclear power plant

U.S. city to be powered by nuclear energy

Submarine reactor tested; training of nearly 40,000 reactor operators until mid-1990s

Mobile nuclear power plant for the army

Demonstration
of self-sustaining
fuel cycle

Basis for LWR
reactor safety

Aircraft and
aerospace
reactor testing

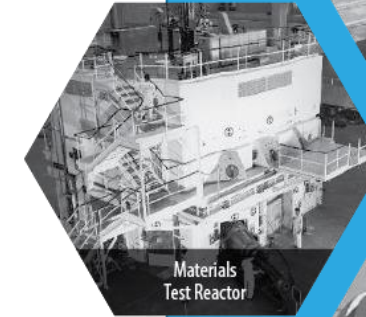
Materials
testing
reactors



Special Power Excursion
Reactor Tests I through IV



Experimental
Breeder Reactor-I



Materials
Test Reactor



Loss of Fluid
Test Facility



Boiling Water Reactor
Experiments I-V

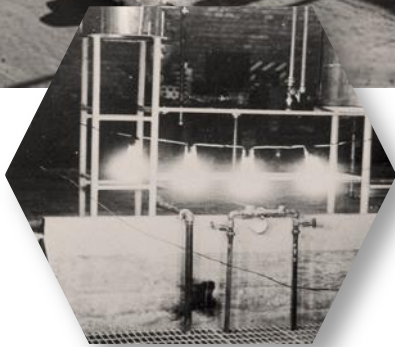


S1W - aka Submarine
Thermal Reactor

National Reactor Testing Station



- Started in 1949 in the Idaho desert
- Goal was to build 10 reactors
- 55! ~~52~~ reactors later
- We are the nation's lab for nuclear energy research



75 Years of Science & Innovation

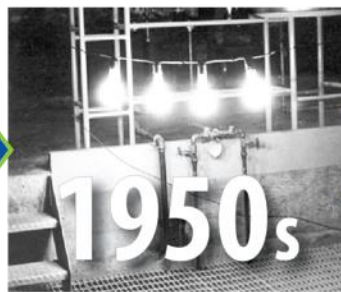


It Started in



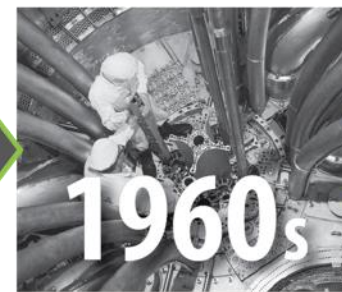
1949

The U.S. Atomic Energy Commission announced it would be building its National Reactor Testing Station in eastern Idaho.



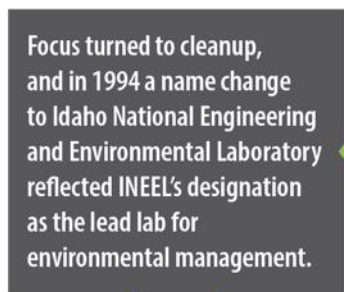
1950s

In 1951, Experimental Breeder Reactor made useable amounts of electricity for the first time in the world.



1960s

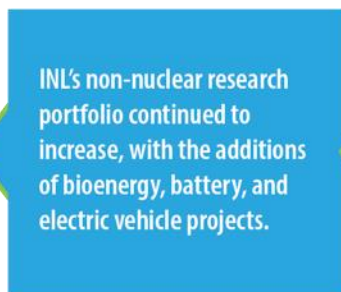
The Advanced Test Reactor came online in 1967. Today it remains the most powerful research reactor in the country.



Focus turned to cleanup, and in 1994 a name change to Idaho National Engineering and Environmental Laboratory reflected INEEL's designation as the lead lab for environmental management.



1990s



INL's non-nuclear research portfolio continued to increase, with the additions of bioenergy, battery, and electric vehicle projects.



1980s



With major commercial reactor concepts demonstrated in Idaho, focus turned to enhancing proven concepts and improving safety standards.



1970s



2000s

DOE Activities were divided into two contracts – one for the Idaho Cleanup Project, and one combining research activities, the origins of today's INL.



2010s

New cutting edge research facilities allow for mission growth and diversification. TREAT restarted in 2017 bringing transient testing capabilities back to the United States.



2020s

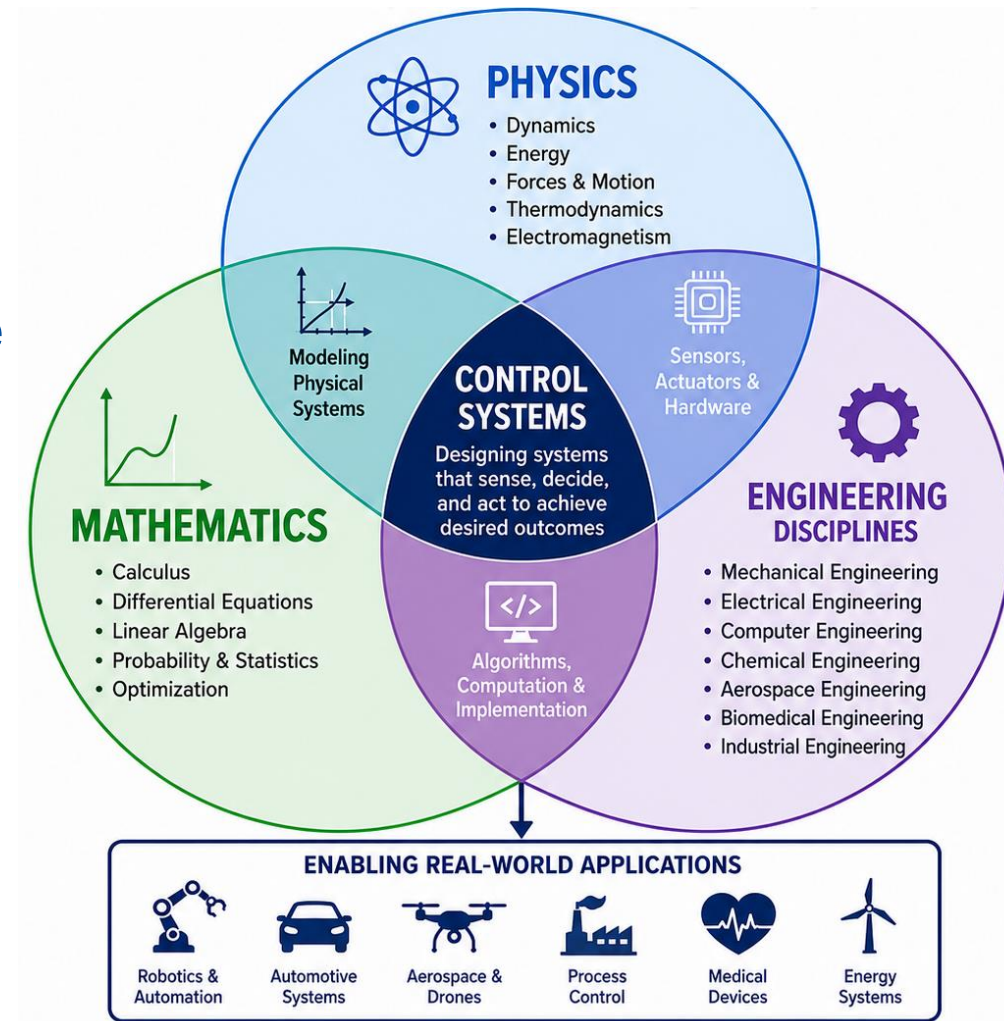
Research advancements over the next decade will include microreactors, testbeds, a new Energy Technology Proving Ground, and increased focus on INL's national security mission.



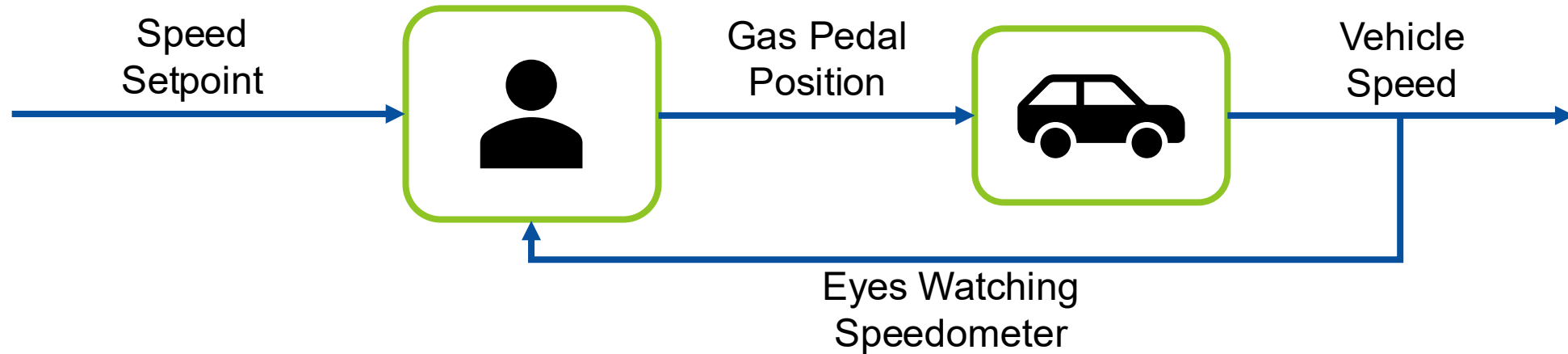
What are Control Systems?

What are Control Systems?

- A **control system** manages, commands, directs, or regulates the behavior of other devices or system.
 - They are the hidden systems that not just make the world turn but turn it in the way we want.
- Controls live at the intersection of all STEM disciplines
 - **Mathematics** is the tool used to model the world
 - **Physics** to understand how the world works
 - **Engineering** to combine math, physics, and learned experience into something useful
 - **Technical and Trade** skills to put everything together
- People can enter the field of control systems from a background in any of these disciplines.

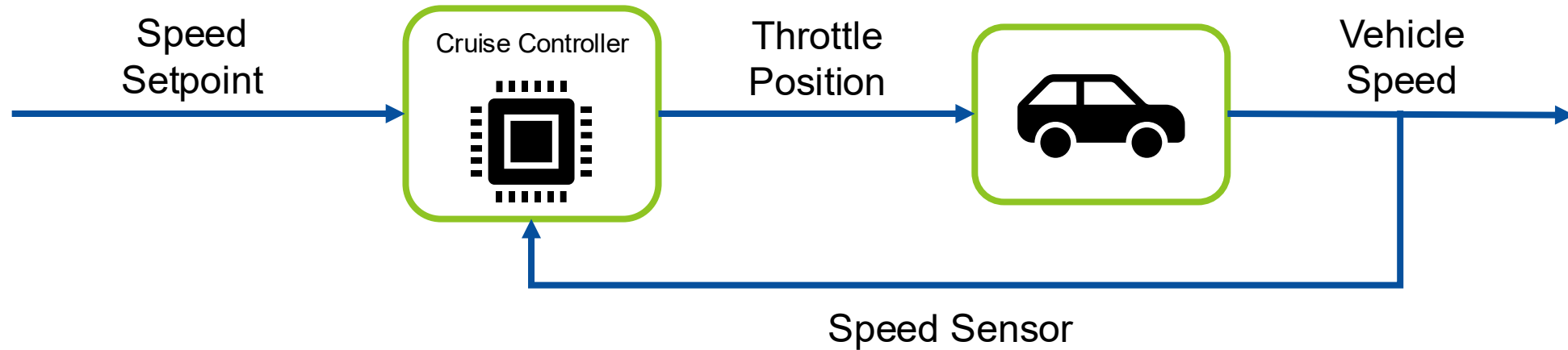


What are control systems?



- A road has a speed limit that should be followed.
- The driver uses their eyes to observe the speedometer and compares against the speed limit.
- The driver manipulates the gas pedal if speeds don't match.
- The vehicle speed changes based on the gas pedal position.
- The driver uses their eyes to observe the speedometer and compares against the speed limit.
- And the process repeats...

What are automatic control systems?

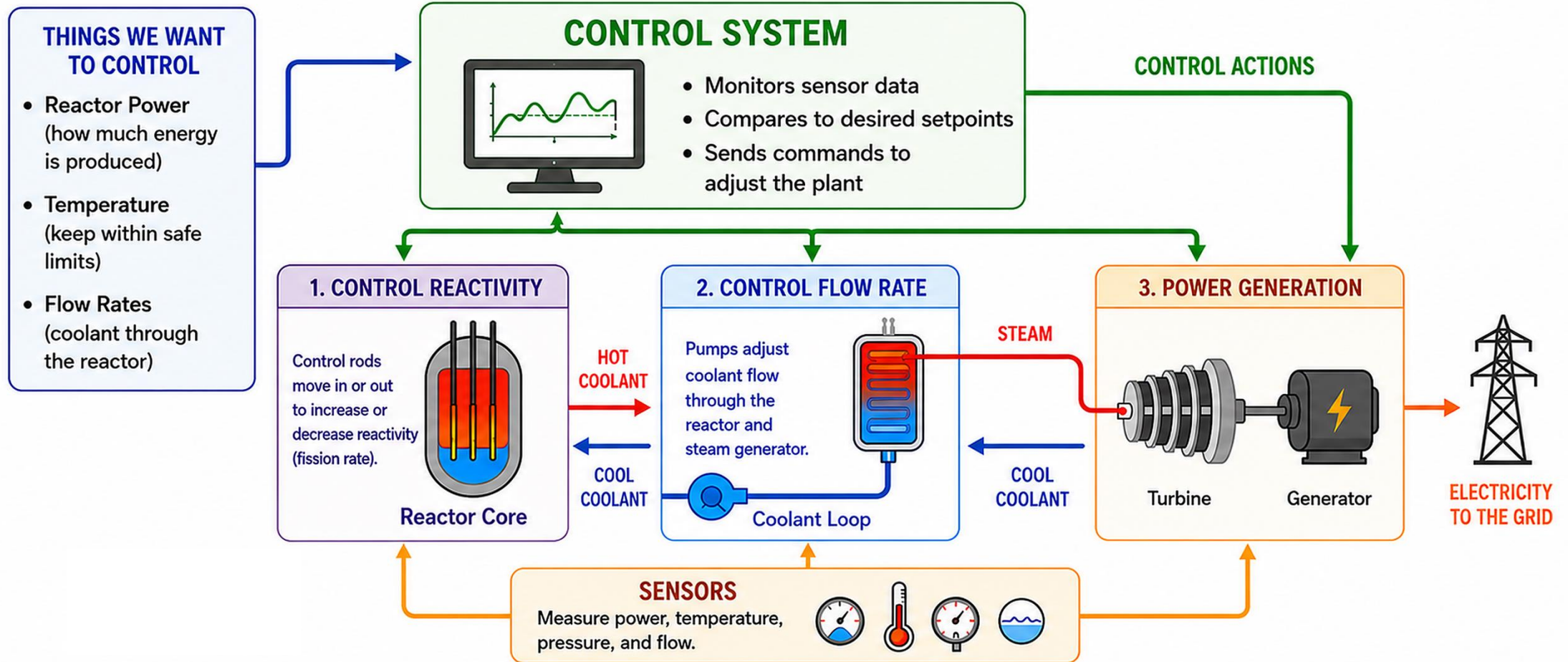


- The driver sets a speed setpoint
- A sensor is used to measure vehicle speed.
- The cruise controller compares the measured speed against the desired speed.
- The control manipulates the throttle if speeds don't match
- The vehicle speed changes based on the throttle position.
- The cruise controller compares the measured speed against the desired speed.
- And the process repeats...



Control of Nuclear Reactors

Control of Nuclear Reactors



The Past, Present, and Future of Nuclear Reactor Control

	Level	Automation Tasks	Human Tasks
Where We Started	(1) Manual Operation	No automation	Operators manually perform all tasks.
Where We Are	(2) Shared Operation	Automatic performance of some tasks	Operators perform some tasks manually.
	(3) Operation by Consent	Automatic performance when directed by operators to do so, under close monitoring and supervision	Operators monitor closely, approve actions, and may intervene to provide supervisory commands that automation follows.
Where We're Going	(4) Operation by Exception	Essentially autonomous operation unless specific situations or circumstances are encountered	Operators must approve of critical decisions and may intervene.
	(5) Autonomous Operation	Fully autonomous operation. System cannot normally be disabled but may be started manually	Operators monitor performance and perform backup if necessary, feasible, and permitted.

Nuclear Regulatory Commission NUREG-0700

How have we controlled nuclear reactors in the past and present?

EBR-1 Control Room



<https://www.ksut.org/history/2021-12-21/idaho-experiment-that-showed-nuclear-power-was-more-than-a-weapon-turns-70-years-old>

Historic

Analog

No Automation

Watts Bar Control Room Simulator



<https://www.knoxnews.com/gcdn/authoring/authoring-images/2025/12/04/PKNS/87610135007-knstva-watts-bar-1.jpg?width=1320&height=880&fit=crop&format=pjpg&auto=webp>

Legacy

Hybrid

Some Automation

AP1000 Control Room Simulator



Testing of the Westinghouse AP1000 control room simulator software in preparation for training of Vogtle 3 and 4 plant operators.

<http://photos.prnewswire.com/pmh/20161017/429447>

Modern

Digital

Lots of Automation

Past

Present

The Future of Nuclear Reactor Controls

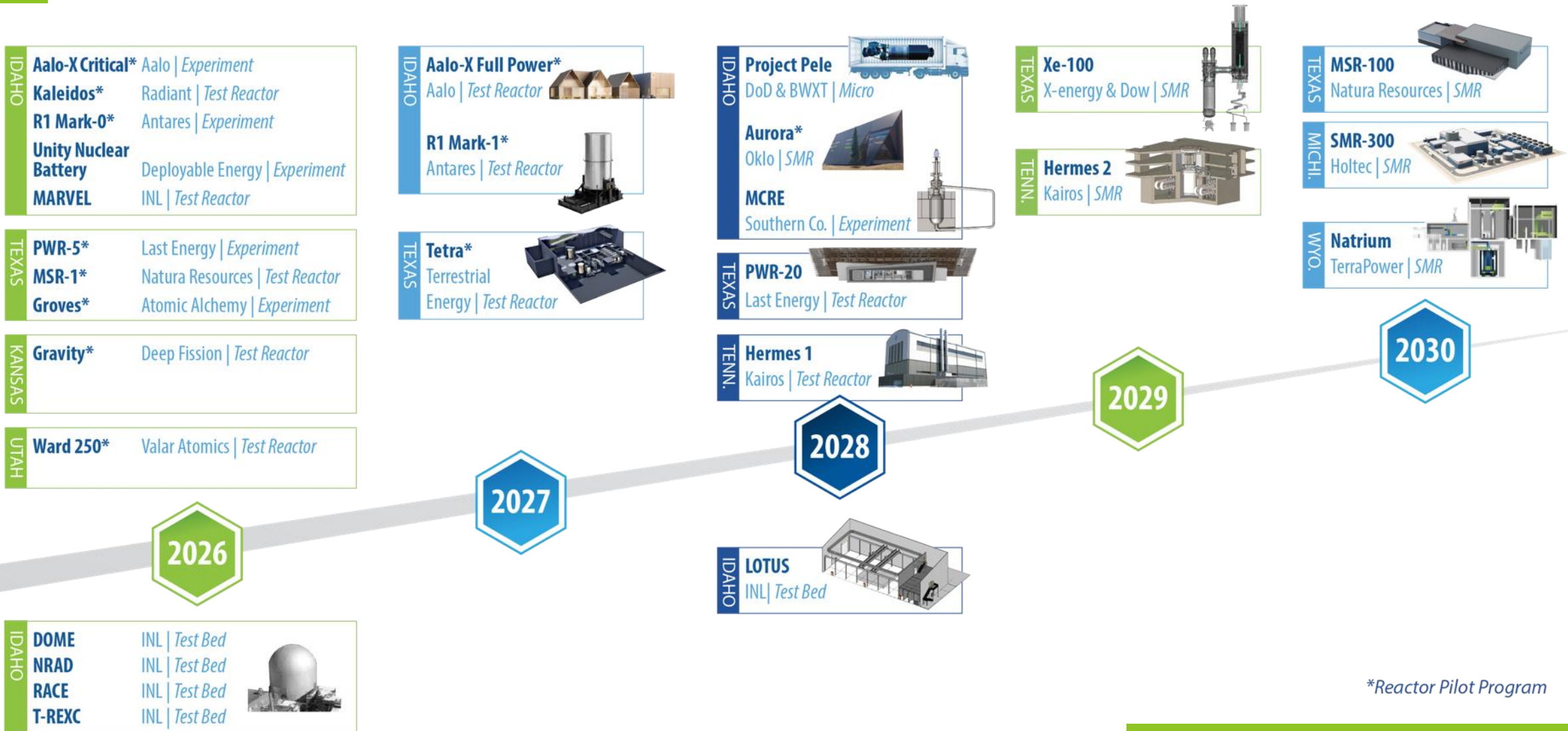
Domain	Current Reactors	Advanced Reactors
Technology	Analog	Digital
Procedures	Paper Procedures	Computerized Procedures
Control	Human	Automation
Operator Training	Years	Months
Operator Role	Monitoring + Control	Monitoring
Monitoring Type	Deductive	Inferential/Predictive
Operator Span	Single Unit	Multiple Units
Control Station	Control Room	Workstation
Operations Location	Local	Remote
Number of Operators	Crew	Individual
Communications	Oral	Digital

IFE HAMMLAB SMR
Control Room Simulator



<https://ife.no/wp-content/uploads/2020/01/hammlab-2048x1367.jpg>

Accelerating advanced reactor demonstration and deployment





Idaho National Laboratory

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.

WWW.INL.GOV