JANUARY 2020

NUCLEAR SCIENCE AND TECHNOLOGY DIRECTORATE

2020-2025 STRATEGIC PLAN AND IMPLEMENTING FRAMEWORK

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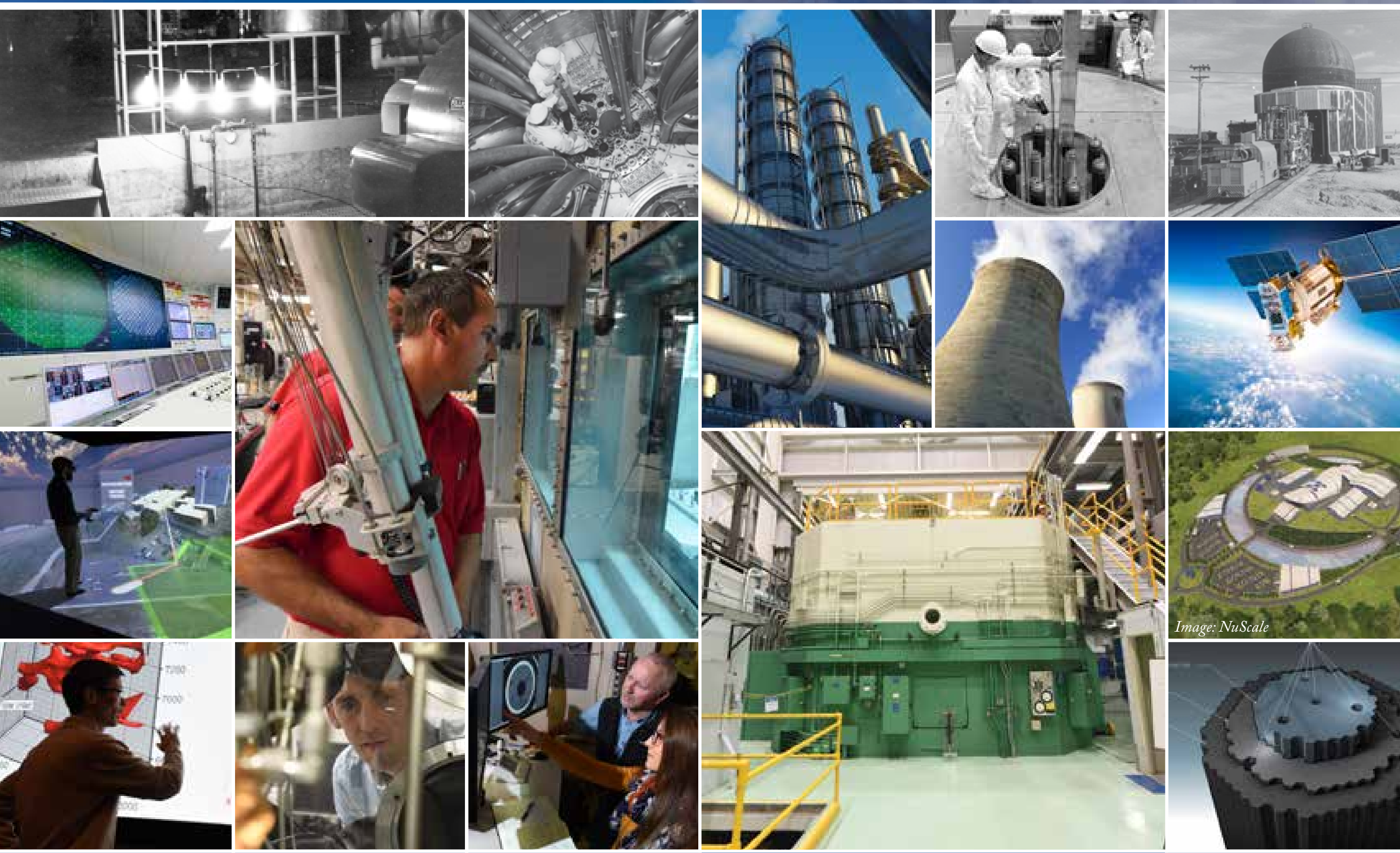
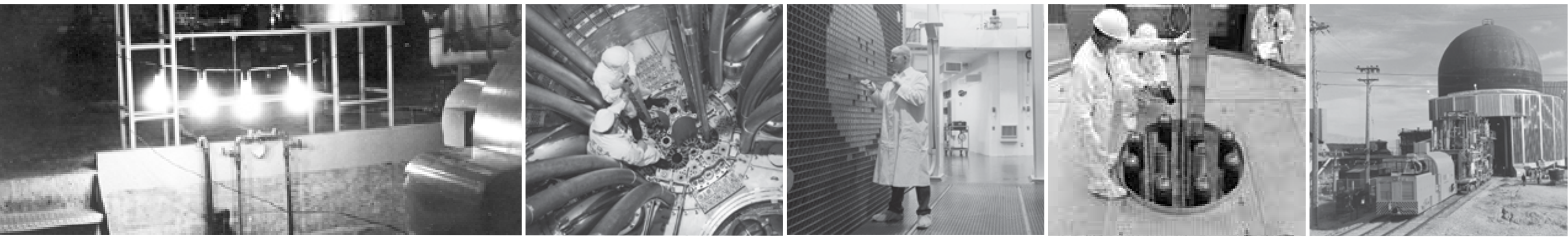
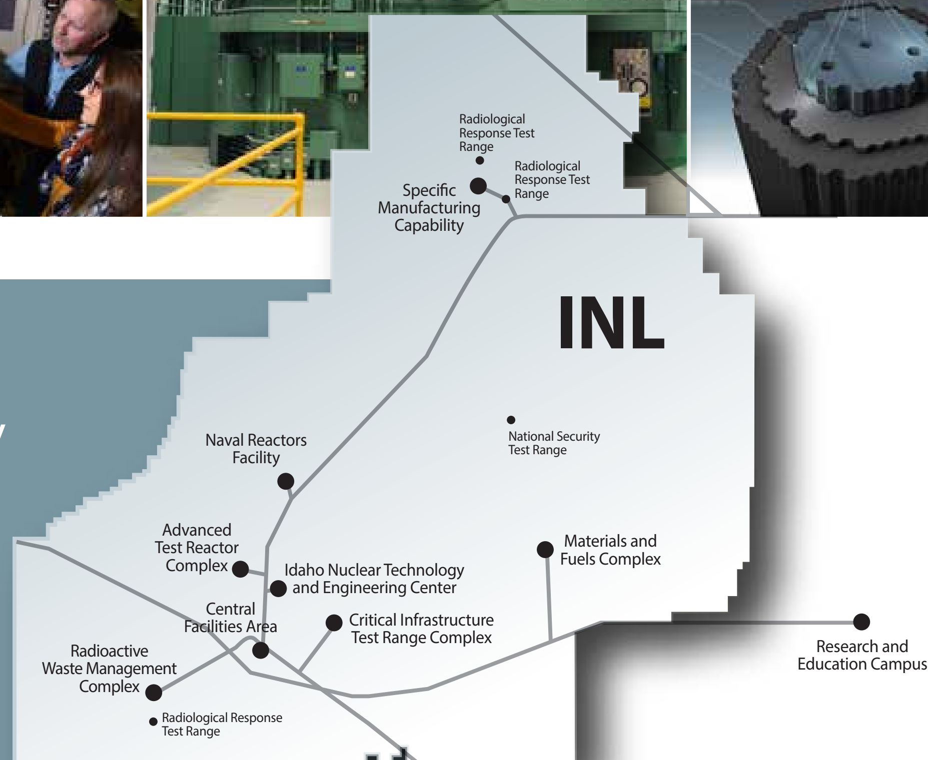


Idaho National Laboratory



INSPIRED BY THE PAST TO CHANGE THE FUTURE



NS&T Vision:
Change the world's energy future by advancing nuclear

NS&T Mission:
Enable nuclear energy expansion through innovation

John Wagner
Associate Lab Director
Nuclear Science & Technology

Dear colleagues,

Nearly 70 years ago, the United States established the National Reactor Testing Station on the sprawling Idaho desert to be a hub of nuclear energy innovation. The promise of nuclear energy was tremendous – it was envisioned to supply energy "too cheap to meter." The research conducted here led to the creation of an entire industry – commercial nuclear power – as well as the strategic infrastructures and partnerships essential to creating the regulatory, legal, operational and international norms for that industry. It was an exciting time.

Today, the commercial nuclear power industry in the United States is undergoing market-driven change with early closure of reactors and stiff competition in the energy market. The headlines are daunting, and the news about the current fleet rarely seems positive.

Outside of the U.S., however, the market environment for nuclear energy is much different. Population-dense countries such as India and China are investing heavily in nuclear energy to support their growing economies. Nuclear energy deployment around the world is growing at its fastest pace in 25 years, creating a multitrillion-dollar global market. At the same time, the world faces unprecedented environmental challenges as it tries to provide clean electricity to a world of 8 billion people. And nuclear energy is an essential part of the global response.

American companies and entrepreneurs are responding by pursuing a new generation of advanced reactors markedly different from today's fleet. They are smaller, modular, and can be used to generate electricity as well as power industrial processes. American innovation once again is poised to drive the global market.

As a national laboratory, our challenge and opportunity today is as profound as it was 70 years ago. But it is different. It must be. We must develop approaches to help existing technologies be more economical while also creating and demonstrating disruptive innovations that lead to expanded markets for nuclear energy in the global economy. In this pursuit, we will work with the Department of Energy to establish the National Reactor Innovation Center (NRIC) at INL, with exciting research and demonstration challenges and home to incredible new national strategic assets including small modular reactors, microreactor systems with groundbreaking operations simplicity, and world-leading science machines such as the versatile test reactor.

INL will lead in creating and defining this next phase of global nuclear energy. We will once again change the world and establish America's place in the growing global energy marketplace. And as we do so, we will deploy our science, our engineering, and our infrastructure to tackle a host of national challenges and build the next-generation laboratory, directorate, and research culture. The promise of our laboratory and our technologies is as great as ever.

I am excited by the opportunities before us and am confident that we will rise to the challenge ahead.

Sincerely,

John Wagner

NS&T: Connecting Science to Deployment

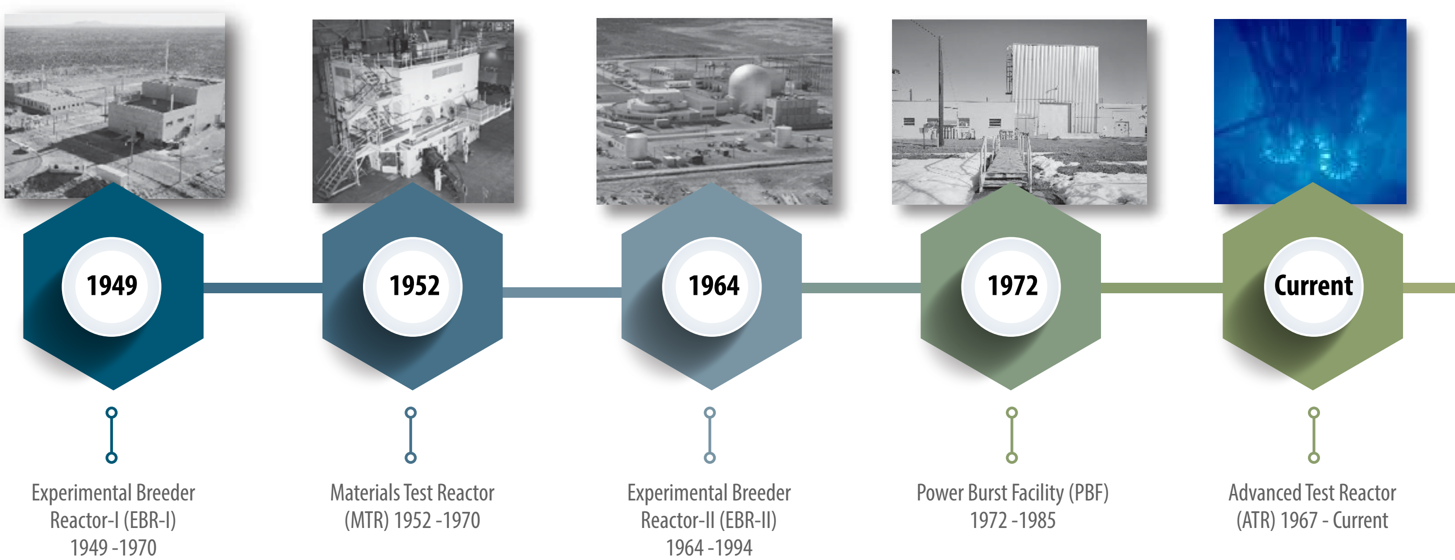
INTRODUCTION

INL (and its predecessors) has a proud history in performing engineering research to support the development and deployment of nuclear energy systems. Over the past 70 years, INL has created an enduring legacy of nuclear energy-related accomplishments and impacts that have shaped the industry of today, including:

- Establishment through extensive testing (e.g., Semiscale, Loss-of-Fluid Test Facility (LOFT), Power Burst Facility (PBF), Special Power Excursion Reactor Test (SPERT)) of the safety bases of light-water reactors ('60s and '70s)
- Development and operation of aqueous fuel processing supporting national security missions ('60s, '70s, and '80s)
- Development of state-of-the-art computational codes (Reactor Excursion and Leak Analysis Program (RELAP5) and Systems Analysis Program for Hands-on Integrated Reliability Evaluation (SAPHIRE)) used to calculate the safety behavior and risk, and establish regulatory bases, of light-water reactor systems around the world ('70s, '80s, and '90s)
- Qualification of sodium-cooled fast reactor technologies to enable commercialization of fast reactor and fuel cycle systems ('80s and '90s)
- Qualification of high temperature gas-cooled reactor technologies to enable commercialization of high temperature gas-cooled reactor systems (2000-today)

This proud history is part of the DNA of INL's people, its facilities and how we approach our research missions today, and will be going forward into the future. We are at our core an engineering research laboratory, one that builds on science fundamentals to demonstrate and evaluate systems performance at scale in order to establish regulatory bases for approval and minimize risk and the cost of nuclear systems deployment. And we have deployed this capability to impact broad national challenges involving security, competitiveness, environmental sustainability, health, and education.

Going forward, we recognize that our challenges and opportunities are substantially changed from those of our past. The economics of domestic nuclear energy are not as favorable, while global competition has eroded U.S. leadership in growing international markets. Where in the past INL deployed engineering research to establish the foundations of an entirely new industry, the industry today is mature yet evolving. What is the role of the lead nuclear research directorate within the nation's nuclear energy laboratory in this context?



This plan provides a vision to lead and realize a paradigm shift in U.S. leadership in nuclear energy for the future. This future will be realized through our efforts in developing and demonstrating new nuclear materials, concepts, and technologies – establishing a new legacy of nuclear energy-related accomplishments and impacts that will shape the next 50 years and beyond while serving a unique role as a national strategic asset broadly.

Individual division strategies and planning bases will provide the next level of granularity necessary for meeting the goals outlined in this plan. The foundations and targets put forth in this plan will be used to guide investment strategies, priorities and approaches; to guide coordination and leverage across directorates; and to gauge progress in meeting impact objectives for both mid- and long-term time frames. The plan will be updated annually.

PURPOSE

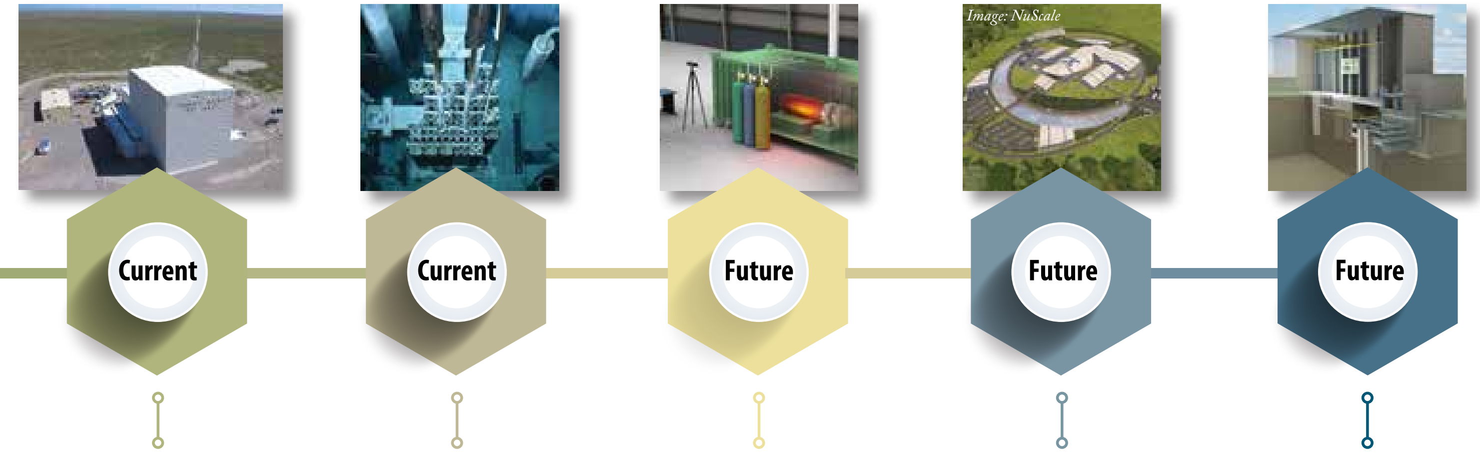
The purpose of this plan is to:

- Provide strategic reference, objective targets for research impact, and an implementation framework for the Nuclear Science and Technology (NS&T) directorate to substantively impact U.S. competitiveness and security.
- Identify key aspects of the organizational philosophy and approach that will provide a foundation to create a high-performance directorate for the future.
- Provide NS&T staff a clear understanding of why their work is important, what the role of the national laboratory is in a changing nuclear science and technology market, and how we will have impact on a national and global level through game-changing innovation and infrastructure stewardship.

The goals put forth in this plan are consistent with the INL Laboratory Plan and Laboratory Agenda, while providing appropriate granularity not included in those plans.

From Vannevar Bush to President Roosevelt, in a July 1945 letter of transmittal of his report, "Science, The Endless Frontier," which helped shape the national basic and applied research programs of today.

"The pioneer spirit is still vigorous within this nation. Science offers a largely unexplored hinterland for the pioneer who has the tools for his task. The rewards of such exploration both for the Nation and the individual are great. Scientific progress is one essential key to our security as a nation, to our better health, to more jobs, to a higher standard of living, and to our cultural progress."



Transient Reactor Test Facility (TREAT) 1959-1994 2017 - Current

Neutron Radiography Reactor (NRAD) 1975 - Current

Microreactor 2023

Small Modular Reactor (SMR) 2026

Versatile Test Reactor (VTR) 2026

PLANNING FOUNDATION

The years covered by this plan present the NS&T directorate an extraordinary opportunity for leadership to advance critical national objectives. As we enter the seventh decade of commercial nuclear energy, the future for the U.S. nuclear industry is exceptionally challenging, with a competitive landscape that is leading to the closure of commercial nuclear generating stations before the end of their capital and regulatory life. At the same time, the global market for applied nuclear technologies, including commercial nuclear energy and niche nuclear energy applications, such as small and portable reactors, is robust and growing with an array of technology providers serving a market expected to be valued at over $2.6 trillion in the coming 20 years. International nuclear and radiological security and nuclear nonproliferation pose dynamic and complex challenges that will continue to shape U.S. energy and export policy. At the same time, the U.S. is entering into a new industrial market reality of broad and aggressive global economic competition shaped by rapidly growing mega economies in which applied nuclear science and technology are incorporated into myriad markets.

In the realm of nuclear science and technology, the U.S. is quickly entering a new day, characterized by a poor economic environment for large-scale domestic nuclear energy; diminished leadership and influence in a mature and growing global market; policy, regulatory, and economic environments that challenge the development and deployment of nuclear technology domestically and internationally; and an uncertain federal energy research budget environment. However, there is also significant recent demonstration of support for nuclear energy from the policy community, as demonstrated by the passage of the Nuclear Energy Innovation Capabilities Act (NEICA) of 2018; interest in niche applications for nuclear energy to power military, remote, space, and emergency response applications; and many new private sector entrants to nuclear energy innovation. And the growing recognition that climate change threatens to fundamentally disrupt societies is creating a broader appreciation of the need for nuclear energy. These challenges and opportunities offer an extraordinary chance to shape the future.

As a national laboratory, the role of INL is to provide technology innovation, creativity, objectivity, and strategic assets that ensure our nation's competitiveness, economic strength, and security in this dynamic global environment; this is a mandate incorporated in the present U.S. national security strategy. Our ability as a nation to innovate, rapidly translate those innovations to deployable products, and lead in creating new technology markets is essential to meeting these goals.

The role of INL is important for U.S. competitiveness, particularly in markets involving nuclear science and technologies, as private sector and academic stakeholders many times do not have the special assets required to advance new nuclear technology. The imperative to maintain and enhance national nuclear science and technology assets that strengthen U.S. competitiveness is compelling. As a directorate, our mission emphases, concentration, and ability to efficiently deliver must be equally compelling and focused to serve the national need in this time of rapid global change.

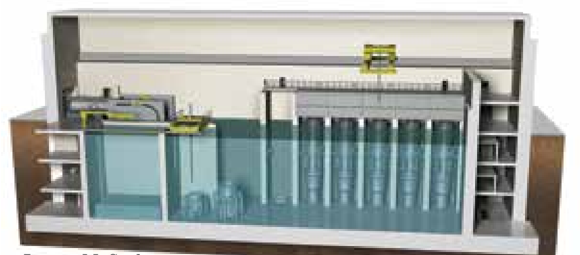


Image: NuScale

Image: Third Way

As the directorate that provides principal leadership of national nuclear science and technology research, development, and demonstration (RD&D) assets, NS&T engages with a sense of urgency in creating a new American future in applied nuclear science and technology suitable for global markets, just as our predecessors created the offerings that dominate today's markets. We also believe it is essential to this outcome that we create an organization that fosters the innovation, creativity, and culture of excellence required to lead the nation's nuclear science and technology enterprise into a future of increased global competition. This plan provides a framework to achieve these aims.

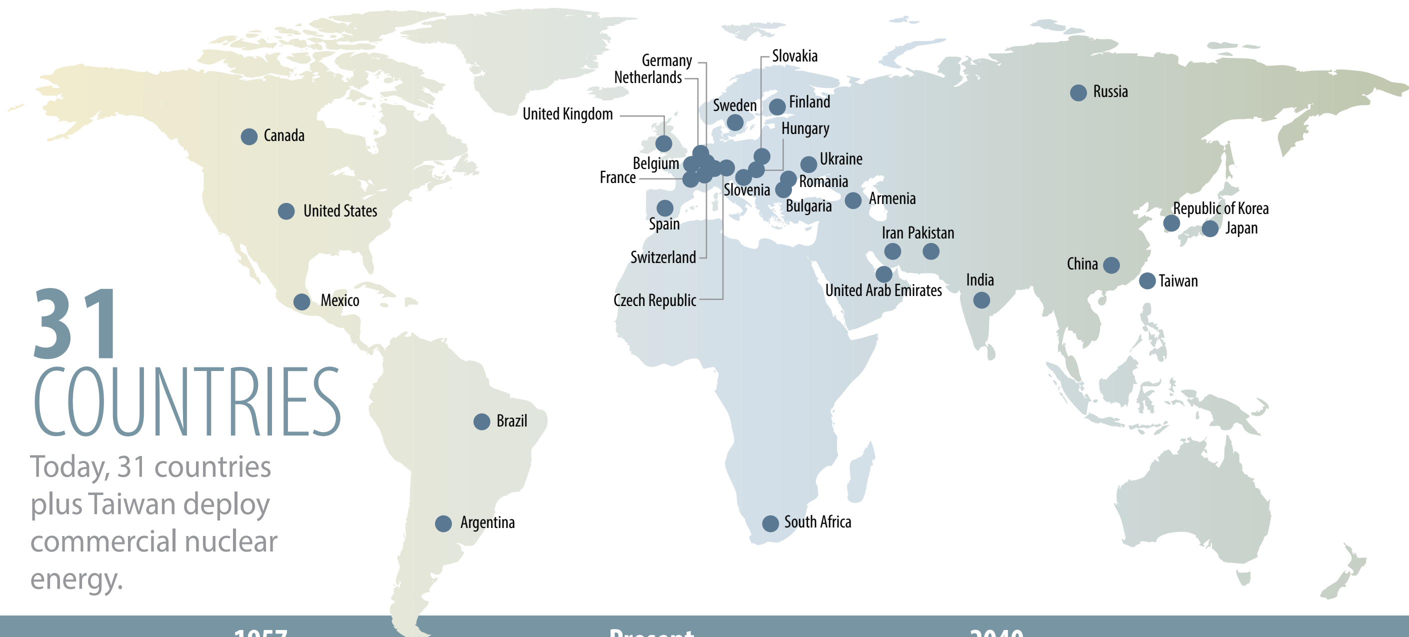
New Path for American Nuclear Technology Competitiveness

- Emerging civilian and military demand for small nuclear power systems, and corresponding support for reactor demonstrations.
- Expanding global nuclear energy and technology markets.
- Technology revolutions in materials and embedded intelligence driving industrial paradigm shifts.
- Climate change shaping the future of the energy economy.

Our Strategic Intent: Enable Nuclear Energy Sustainment and Expanded Deployment and Advance Integrated Fuel Cycle Solutions

Lead and enable the development of technology that shapes the next 50 years of U.S. leadership and competitiveness in global nuclear energy markets by seeking disruptive technology approaches, and steward national strategic assets to enable innovation and ensure global nuclear and radiological security.

BUILDING ON THE PAST—LEADING THE FUTURE



31
COUNTRIES

Today, 31 countries plus Taiwan deploy commercial nuclear energy.

	1957	Present	2040
GLOBAL POPULATION	2.8B	7.6B	9.0B
NUCLEAR TECHNOLOGY	1 Nuclear technology is new, novel technology; First U.S. commercial power plant at Shippingport, PA, comes online	449 449 reactors, 31 countries, 398 GWe, 11% of global generation	↑↑↑ Asymmetric global growth in base-load commercial nuclear energy while markets expand as nuclear powers more industry and nonbaseload operations
ENERGY CONSUMPTION	130 quads global primary energy consumption	575 quads global primary energy consumption	736 quads global primary energy consumption
U.S. GDP PER CAPITA	$3,000	$62,641	$90,000
U.S. ROLE	Global trade accelerates; America dominates emerging commercial nuclear markets	Globally integrated supply chains necessary for competitive position; multiple national market offerings for reactors	Global partnerships powering nuclear supply chain; American dominance in innovation, fuels, operations
GLOBAL MARKET	America leads the creation of international standards and norms for nuclear energy	Rapid growth in emerging markets; global supply chain estimated at $2.6T/20 years	Markets for nuclear energy expand to megacities, industrial, and niche applications as importance of secure, zero-carbon energy is realized

CORE STRATEGIES AND DIFFERENTIATORS

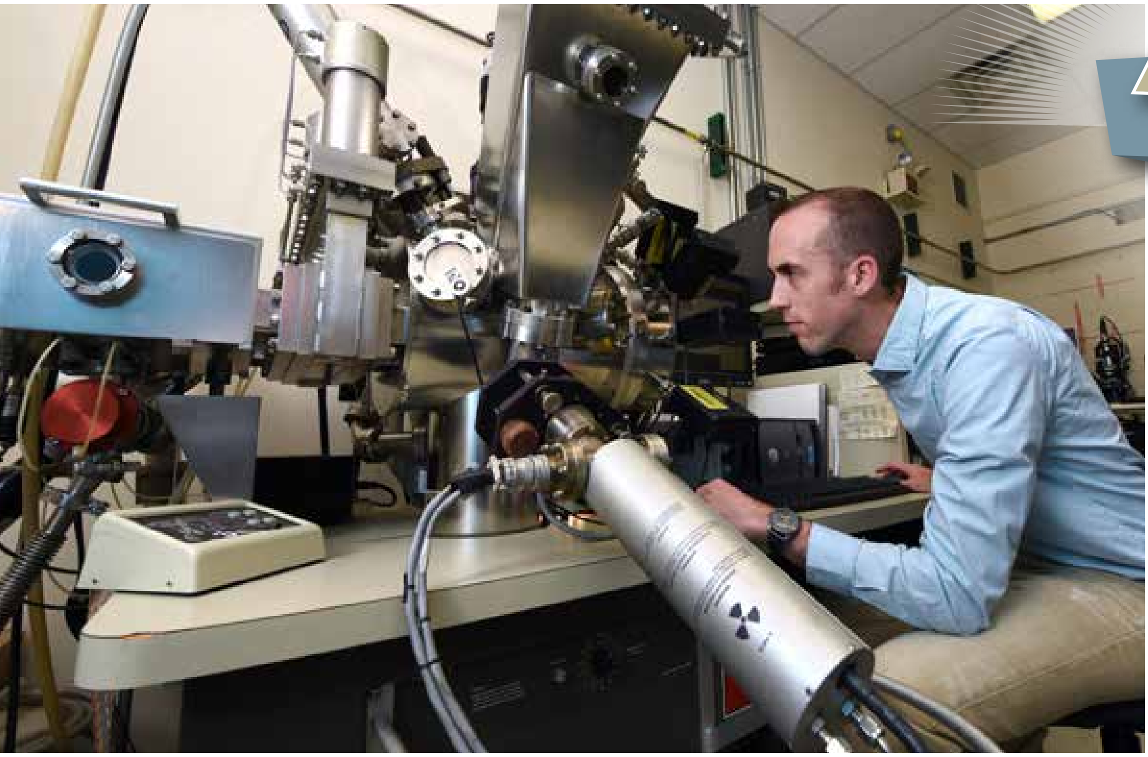
As the steward of the nation's most complete nuclear fuel cycle operations and research assets (fuel cycle being defined holistically) including infrastructure, materials, and talent, INL is exceptionally well differentiated; we are the nuclear energy research laboratory for the United States.

Our laboratory integrates these assets with a seven-decade-long culture and capacity for exceptional engineering research at scale, creating a world-class ability to generate knowledge necessary to advance, innovate, and assess nuclear energy technologies and applications. INL possesses the ability to develop and integrate new fuels and materials, technologies, and approaches into thoughtfully instrumented and controlled experiments and prototypes; develop the science, technology, and infrastructure to support the safe, secure, and economic management of nuclear fuel from manufacturing to disposition; provide the validated computational tools to predict performance; validate performance envelopes through at-scale experimentation; and use the resulting knowledge to guide development to improve the science and technology, reduce or retire risks associated with technology uncertainty, and inform regulators and stakeholders of risks and performance limitations and characteristics. These well-established engineering research abilities place our laboratory in an exceptionally well-defined position to advance U.S. nuclear energy technology competitiveness.

Building on this base of differentiation, the NS&T directorate incorporates six core strategies into its approach to nuclear energy science and technology innovation. By incorporating these core strategies into our research emphases, NS&T is able to address key challenges that limit the full potential for nuclear technologies to enhance U.S. competitiveness and security. These core strategies include:

NS&T Key Differentiator

NS&T is the nation's nuclear energy research leader and a national leader in at-scale engineering research used to establish technology performance bases.



1.

Innovate: Seek disruptive approaches.

To capture the full potential of nuclear science and technology in modern and future markets, NS&T will seek disruptive approaches through the leverage of science and technology advances across a spectrum of fields and integrate these using our leadership-class engineering research abilities and facilities into deployable, game-changing systems.

2.

Accelerate: Accelerate concept to deployment.

NS&T will develop new concepts and implement concepts from other industries that markedly reduce the concept-through-deployment time frame of new technology, particularly advanced materials, fuels manufacturing, and reactor systems, therefore providing U.S. industry validated technology options in a competitive time frame.

3.

Expand: Expand the market for advanced nuclear technologies.

NS&T will advance U.S. competitiveness by maintaining a deep understanding of domestic and global market drivers, dynamics, and requirements to best identify, assess, and target strategic opportunities for impact. It will influence those markets through rigorous customer needs assessment, technology outlook assessment, and industry engagement, identifying and developing the means for nuclear technology to integrate into a broader array of applications and processes, thereby diversifying our research portfolio and expanding global market potential and opportunity for U.S. stakeholders.

4.

Focus: Focus on lowering costs and reducing uncertainty and risk through demonstrations and innovation.

This being the heart of engineering research and key to our industry engagement and impact, NS&T leads in identifying and quantifying technology, systems, and deployment risks, as well as in identifying, reducing, and retiring risk through coupled computational and experimental analyses, and risk-informed, performance-based regulatory framework development, and addressing gaps through innovation that will advance competitiveness.

5.

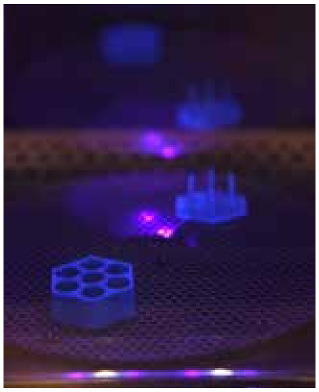
Leverage: Leverage the full assets of our laboratory, and academic and industry partners.

NS&T will live a "one-lab" business model, seamlessly incorporating capabilities throughout the laboratory into compelling, well-differentiated capability offerings to achieve our strategic goals. We will lead in developing new approaches for and fostering productive partnerships with industry and academia that advance mutual benefit to each organization.

6.

Communicate: Effectively communicate our purpose, vision, and impact locally, regionally, and globally.

NS&T will communicate our mission, vision, capabilities, initiatives and successes, and our value proposition, in an effective manner throughout the laboratory, the region, and the national and international energy community. NS&T will utilize modern mechanisms of communication to increase our visibility and expand our sphere of recognition and influence. In addition to our research development, demonstration, and deployment (RDD&D) capabilities and accomplishments, the merits and potential for nuclear energy to address the growing global need for clean energy will be emphasized.



DIRECTORATE GOALS

Path to Impact: A One-Laboratory, One-Strategy Approach

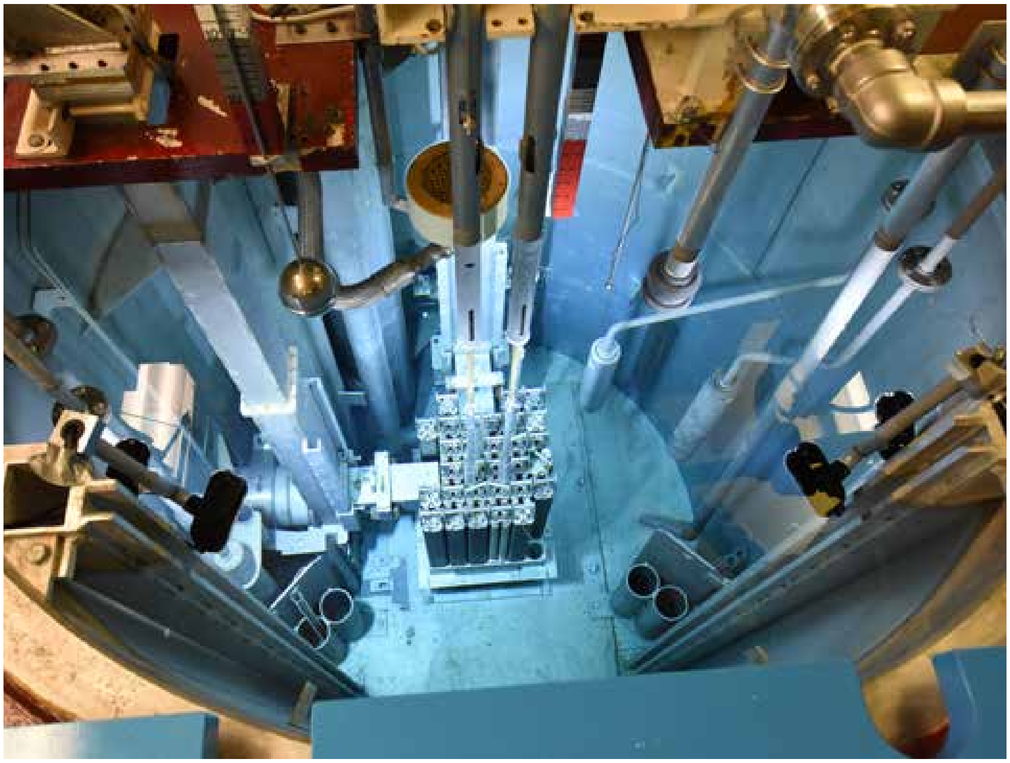
Delivering the NS&T directorate strategic intent to "enable nuclear energy sustainment and expanded deployment and advance integrated fuel cycle solutions" requires deliberative and focused leverage of the broader INL activities, initiatives, and investments. Simply stated, the power of NS&T to translate core capabilities and core strategies into impact is based on synthesizing the totality of relevant assets at INL and those of our partners to focus on our stated goals and strategic intent.

NS&T will take the lead role for INL in synthesizing the capabilities that will comprise NRIC, the programmatic research led by NS&T, laboratory-wide initiatives detailed in the INL Laboratory Plan, and capabilities stewarded across the five research directorates, creating a "One-Lab, One-Strategy" approach to disrupting and transforming the nuclear energy landscape.

INL's world-leading engineering research abilities place it in an exceptionally well-defined position to advance U.S. nuclear energy technology competitiveness.

When synthesized to focus on delivering the five strategic goals and 17 associated key outcomes, including tackling two "grand challenges," the investments, thought leadership, and core competencies linked to the laboratory initiatives and INL directorate strategies are singularly well-aligned to efficiently and effectively achieve the global impact sought.

The NS&T "One-Lab, One-Strategy" approach enables this level of global impact.



GRAND CHALLENGES—CHANGING THE FUTURE

Disruptive advances in science and technology have defined the economic landscape of today's world; we seek to leverage, extend, and build upon these advances to realize our vision of nuclear energy sustainment and expanded applications. Two areas of particular opportunity capture our imagination: development of techniques and approaches to revolutionize discovery and validation of new materials, and the disruptive potential of microreactor systems to change the paradigm for nuclear energy deployment and utilization. Each of these areas provides a "grand challenge" that, if successfully engaged, could dramatically alter the cost, operations performance, and applicability of future nuclear systems. To these ends, we will establish multidisciplinary initiatives to inspire, engage, and advance our research, leading to a new era of U.S. nuclear energy leadership. These initiatives, built of the Grand Challenges, are described below.

1) Fission Battery Initiative. This initiative will lead to greatly simplified operations, dramatically reduced operations costs, and expanded market applications for nuclear energy. The notion of a "fission battery" conveys a vision focused on realizing very simple "plug-and-play" small nuclear systems that can be integrated into a variety of applications requiring affordable, reliable electricity and/or heat. Central to realizing this vision is embedding intelligence into the reactor systems, creating "smart" nuclear systems. Applying rapidly evolving design and simulation capabilities, along with the embedded intelligence approaches, will open new frontiers in design, manufacturing, and operations of microreactors. The resulting "smart energy modules" will allow very affordable, highly efficient nuclear energy modules to be deployed in a variety of energy applications. Our approach will incorporate advances in materials, sensing, diagnostic techniques, advanced controls, real-time risk analyses, and multilayered and multiscale hybrid physics-artificial intelligence (AI) techniques being developed in other industries to achieve unmatched resilience, affordability, operational simplicity, and application relevance; in other words, a "fission battery." These smart, flexible systems will exhibit unparalleled transparency in system-state knowledge, opening a range of possible exciting functionalities including predictive maintenance, autonomous or semiautonomous operations, remote control, adaptive anti-fragile behavior, optimal life-cycle management and a dramatic reduction in operations staff. Techniques that lead to these functionalities will be developed and demonstrated by designing and computationally creating and validating the first-ever "secure and intelligent" microreactor. This approach will drive questioning of the art of the possible enabled by rapid technology advances coming from other industries combined with insight to design an entirely new reactor system architecture. The Fission Battery Initiative will assume a clean regulatory slate, followed by design of what an appropriate regulatory structure would be for such a revolutionary system, and consider implications for export and nonproliferation paradigms.

2) Accelerated Nuclear Materials Discovery and Qualification. Develop a synergistic set of techniques, infrastructure, and tools that markedly accelerate the discovery and validation process for advanced materials. Pursue and combine innovations in combinatorial materials synthesis, multiscale materials modeling, predictive analytics, and statistical analyses to create new and improve existing materials for nuclear systems applications. As part of the National Reactor Innovation Center, develop and deploy a global library of advanced fuels and materials options, performance characteristics, and advanced tools and techniques for nuclear energy applications and component manufacturing.

The library will enhance the competitive position for U.S. industry innovation and speed to market, incorporating experimentally and computationally improved historical data on existing materials; deploy data synthesis and analysis methodologies that reduce time necessary to produce performance data and reduce data uncertainty; and accommodate development of new materials using combinatorial materials and broader analytic science techniques and research processes to substantially speed innovation to qualification time. The data center and library of techniques and tools will provide researchers and industry a game-changing tool in nuclear systems design, manufacturing, and analyses and provide regulators a high-fidelity resource to help speed the licensing processes. This will place INL in a global leadership position for fuels and materials science and engineering.

ONE LAB — ONE STRATEGY

IDAHO NATIONAL LABORATORY COMBINED ASSETS

Capabilities

Advanced computer science, visualization

Applied materials science and engineering

Chemical and molecular science

Chemical engineering

Condensed matter physics and materials science

Cyber and information sciences

Decision science and analysis

Large-scale user facilities/R&D facilities/advanced instrumentation

Mechanical design and engineering

Nuclear and radiochemistry

Nuclear engineering

Power systems and electrical engineering

Systems engineering and integration

Infrastructure

Advanced Test Reactor

Collaborative Computing Center

Cybercore Integration Center

Energy Systems Laboratory

Materials and Fuels Complex

Transient Reactor Test (TREAT) Facility

Versatile Test Reactor (under development)

Initiatives

Nuclear Reactor Sustainment and Expanded Deployment

Integrated Fuel Cycle Solutions

Advanced Materials and Manufacturing for Extreme Environments

Integrated Energy Systems

Secure and Resilient Cyber-Physical Systems

Partnerships

Academia

Industry

Laboratories

International Stakeholders

NS&T DIRECTORATE: Synthesize capabilities, infrastructure, investments, and initiatives to meet goals and grand challenges

GRAND CHALLENGE: Paradigm shift in application of nuclear power systems

GRAND CHALLENGE: Accelerated nuclear materials discovery and qualification

Goal 1:
Strengthen the domestic commercial nuclear energy enterprise

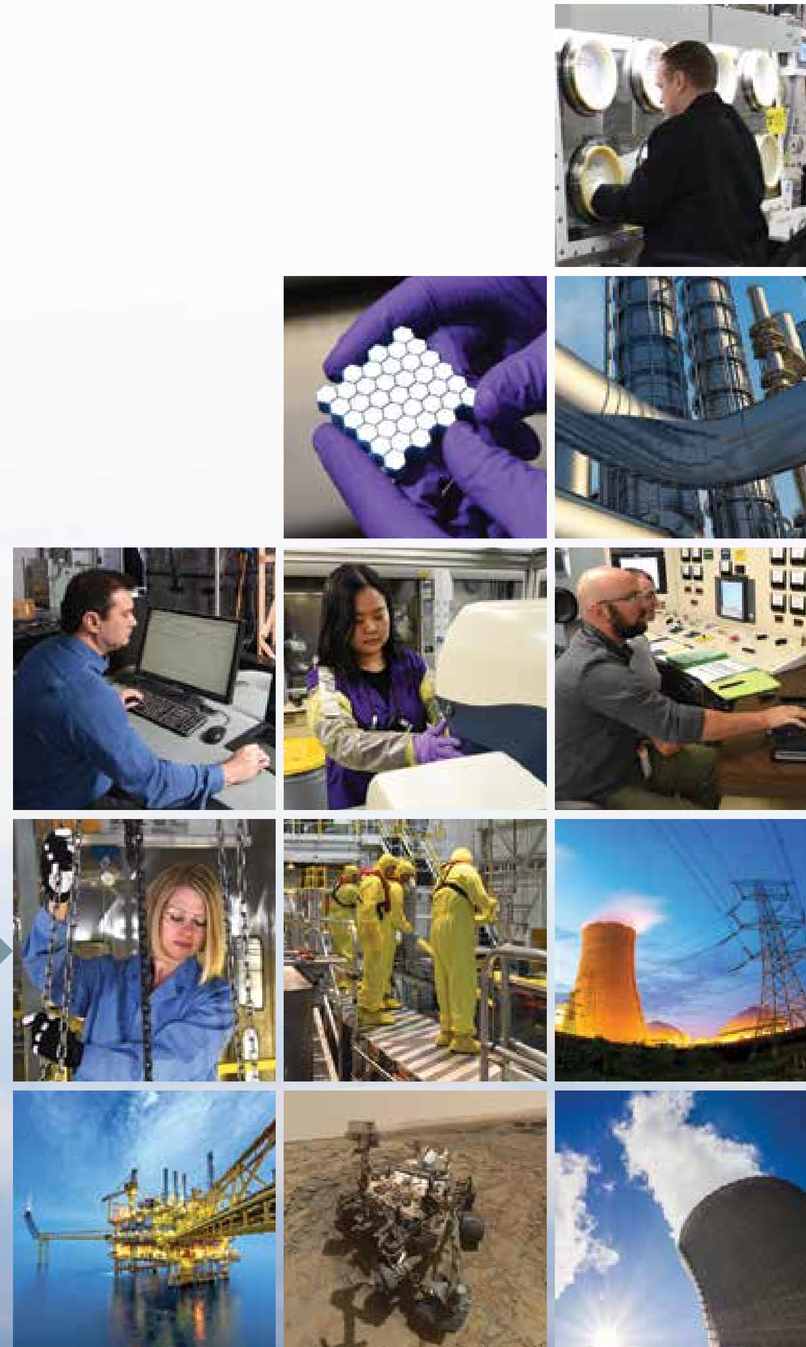
Goal 2:
Enable United States leadership in global nuclear energy markets

Goal 3:
Expand and deploy national nuclear energy strategic assets

Goal 4:
Expand impact across markets

Goal 5:
Create the next-generation research organization

STRATEGIC INTENT:
Enable nuclear sustainment and expanded deployment and advance integrated fuel cycle solutions



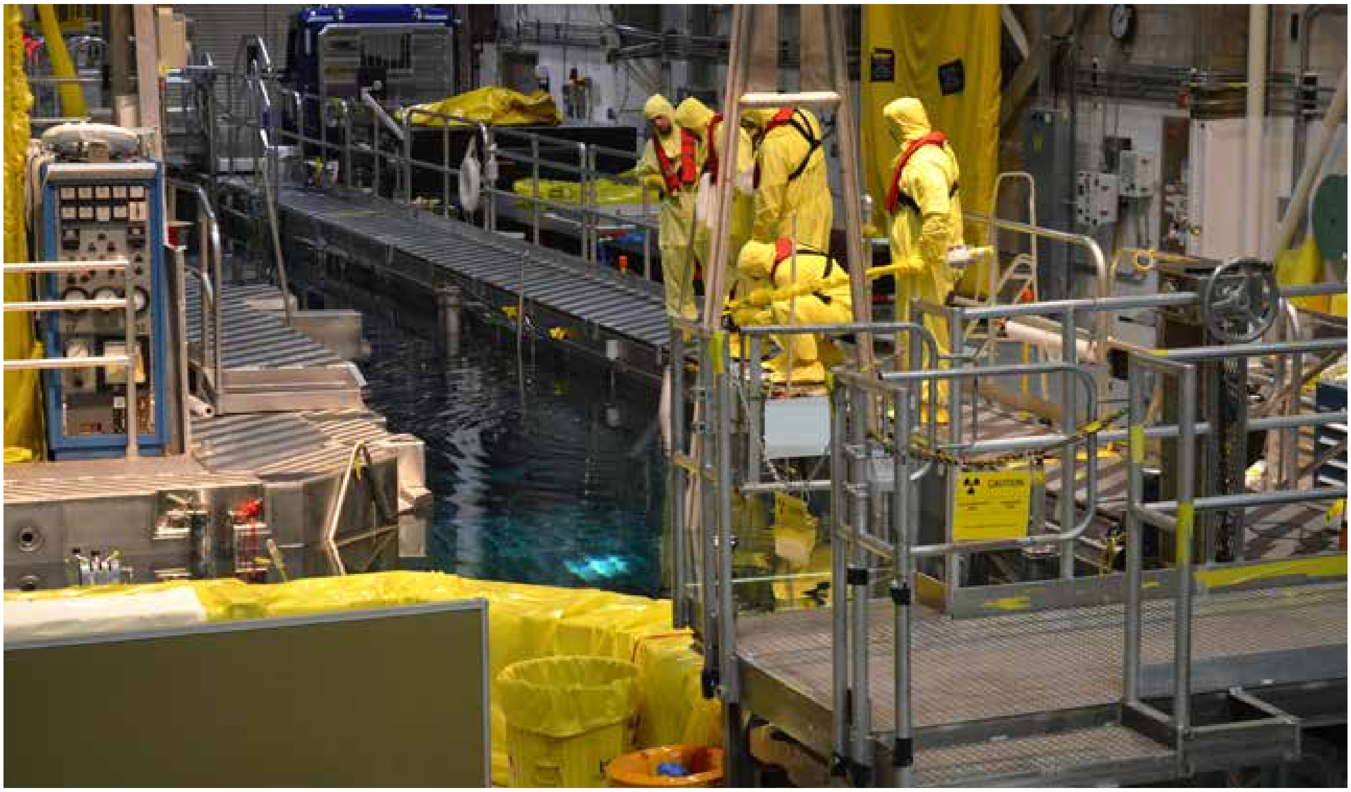
AMERICAN NUCLEAR FUTURE

Goal 1

Strengthen the Domestic Commercial Nuclear Energy Enterprise

Commercial nuclear energy is a key strategic asset for the economic engine of the U.S. Today, nuclear energy provides approximately 20% of the electricity consumed in the nation's industrial, commercial, and residential sectors. Nuclear energy systems serve several key strategic roles in the nation's electric generation portfolio, including helping maintain the stability of electrical grids; providing nearly 60% of the nongreenhouse gas-emitting electricity consumed; serving as a valuable asset in national fuel-source diversity, price stability, and clean energy; and providing resiliency and reliable power during extreme weather events. However, many commercial nuclear power facilities in the U.S. are under significant economic stress. The economic challenges stem from several coincident forces, including energy market structures not well aligned with nuclear power business and operations bases, the very low price and firm availability of natural gas, a historically low growth rate of electricity demand, and declining cost and expanded deployment of renewable energy. These stressors are precipitating early closure of a number of nuclear power plants, principally those in nonregulated markets. This situation is projected to remain for the foreseeable future, requiring reactor owners to redouble efforts to substantially reduce operating costs, as well as evaluate options for improving revenue, to remain economically viable.

As high-performance materials, operational knowledge, sensing, control, and other systems technologies advance within and outside of the nuclear energy field, the opportunity exists to enhance operational efficiency and safety, and thus reduce costs and extend the operating lifetimes of the domestic fleet by embedding these new



technologies or altering operational protocols. Additionally, technology and informed policy innovations may allow for economic, safe, and acceptable options for the disposal of waste and used fuels. The NS&T directorate will develop technologies and approaches and provide key analyses that enable more efficient, sustainable, and longer operation of the domestic nuclear reactor fleet; will assist industry in achieving enhanced safety, operational efficiency, and extended operating lifetimes; and will provide solutions and analyses that offer safe and accepted management of used fuels and waste for the near and long term.

To these ends, NS&T efforts will focus on impacting four key strategic outcomes, detailed below.

Key Outcome 1.1: Improve Economic Performance

Target challenges:

1) Implement Advanced Technologies. Develop and enable deployment of advanced technologies that facilitate transition from current labor-centric business models to technology-centric operations. Lower cost of maintenance and operations through the application of systems intelligence and secure automation. Emphasize the development and validation of advanced systems intelligence techniques combining sensing, computational engineering, operational data, and advanced algorithms to create component, subsystem, and systems control, diagnostics, and prognostics that achieve heightened state-space awareness and predictive maintenance.

2) Risk, reliability, and performance management. Deploy existing risk assessment methodologies and develop and deploy advanced risk and reliability techniques that incorporate advanced computational methodologies, including dynamic probabilistic risk analysis (PRA) and real-time approaches, to inform and train industry, policy, and regulatory stakeholders and establish more cost-effective operations. The emphasis is on Nuclear Regulatory Commission (NRC) interaction, particularly involving risk-informed regulatory strategies, as well as enabling risk, reliability, and performance quantification by developing and utilizing whole-plant analysis tools. Enable regulatory enhancement through the efficient use of risk-informed information for both existing and advanced reactors.

Key Outcome 1.2: Improve Operations Performance and Sustainability

Target challenges:

1) Improve light-water reactor (LWR) fuels and materials. Improve accident tolerance and performance of light-water reactor fuels, emphasizing the development and performance validation of fuels that exhibit improved reaction kinetics with steam, enhanced retention of fission products, more robust cladding under extended and off-normal conditions, and better fuel isotopic utilization. Enhance the body of knowledge related to fuels and materials performance through extended-time and transient testing and advanced computational analyses.

2) Plant Modernization. Enable owner-operators of the existing fleet to deploy existing digital technologies needed to replace aging and obsolescent analog instrumentation and control technologies to transition from a labor-centric to a technology-centric business model for operating the commercial fleet of nuclear power plants. Demonstrate through private-public partnerships how to broadly improve plant operations with newer technologies that significantly reduce operating costs while improving reliability and availability of plant systems and plant components.

3) Aging Management. Develop and deploy risk-based aging management techniques for advanced inspection technologies, and predictions modeling capabilities to drive optimal plant maintenance, risk-based operations management, and lifetime extension. Special emphases include regulatory reform based on acceptance of the risk-based techniques.

Key Outcome 1.3:
Expand Revenue

Target challenges:

1) Enhance revenue model. Provide technical leadership to enable more flexible and economically competitive operations of large reactors within a dynamic power production and load environment, including enabling industrial process integration, grid-scale energy storage techniques, and nonelectric power production applications to expand the market for nuclear generation.

2) Conduct demonstrations. Working with owner-operators and the first movers of the existing fleet, conduct demonstrations of integrated energy systems at operating commercial nuclear power plants to produce nonelectric products for use in new markets. Address the engineering, safety, regulatory, and market-based issues needed to support demonstrations of hydrogen electrolysis and continue the scale-up from electrical systems to thermal systems to advance production and efficiency to meet the long-term production goals of this technology for the commercial nuclear fleet.

3) Identify revenue options. Develop and deploy systems analysis tools and techniques to quantify and assess the economic and operational performance, safety bases, and environmental impacts associated with nuclear energy deployment options and technologies, particularly to allow new deployments and properly value the existing fleet.

Key Outcome 1.4:
Ensure Effective, Efficient, and Deployable Waste Management Options

Target challenges:

1) Interim storage solutions. Develop, validate, and deploy computational and measurement methodologies to assess, monitor, and ensure the safety of nuclear fuel transportation and storage systems; provide management strategy options

for interim storage; and develop management and technology options to ensure the safe, secure, and economic management of the existing and future inventory of civilian and defense used nuclear fuel and high-level radioactive waste, including accident tolerant and high-burnup fuels.

2) Long-term storage options. Provide technical and programmatic leadership to enable fact-based policy decisions and strategy options for long-term used fuel repositories.

FY 2020-2021 KEY PERFORMANCE INDICATORS

- Complete and bring operational the integrated energy systems testing laboratory.
- Enable commercial deployment of accident tolerant fuels, including necessary irradiation campaigns.
- Develop the conceptual design for a digital safety related Reactor Protection System (RPS) with a commercial nuclear utility and NRC to support a decision on a license amendment request for an analog RPS system replacement.
- Develop the end-state approach and strategy for plantwide modernization at operating commercial nuclear plants that enable broad transformation of the plant operating business model.
- Engage nuclear plant owner-operators to demonstrate and develop the scale-up of integrated energy systems and thermally integrated systems for production of nonelectrical products from the operating fleet.

Goal 2

Enable United States Leadership in Global Nuclear Energy Markets

As the U.S. enters the seventh decade of commercial nuclear energy, we are faced with a dramatically changed competitive and market climate from that of the past. Today, U.S. industries and innovators are among a growing number of competitors engaged in a global market projected to be valued at $2.6 trillion over the coming two decades. As the commercial nuclear energy industry has matured, the diminished competitive position of U.S.-sourced nuclear energy systems across the global supply chain has not been unexpected; as markets mature and supply chains globalize, national dominance often gives way to niche specialization and focus on niche markets. Just as the national laboratories played a substantial role in developing the early technological foundations of what is today a mature market, the national laboratories will need to play an equally important role in developing the foundations of the next phase of U.S. engagements in these markets.

The NS&T directorate will help create the advanced reactor future and necessary fuel cycle options to lead this next phase of nuclear energy markets. The directorate will provide thought leadership, disruptive technologies, and approaches that leverage broad technological innovation from outside the nuclear markets to develop and validate the technologies and approaches that will create new markets for nuclear science and technology-based systems. These markets will extend beyond advanced systems for baseload electricity to make practical a number of applications with systems that exhibit unmatched resilience and safety and are economical to build and operate. These efforts will provide a robust pipeline of advanced nuclear energy technologies.

Image: NuScale

Developing these technologies and approaches with the global marketplace in mind will provide a realistic path to much more economical domestic deployments and enhance U.S. competitive positions in industrial technologies.

NS&T will accomplish this through demonstrating (designing, building, and operating) advanced nuclear energy systems; developing of leadership-class advanced computational design and analysis tool sets for fuels, materials, systems, and components; excelling at integrating technological advances from other fields into whole-system designs; developing economical manufacturing approaches that enable breakthrough systems performance; and developing and operating experimental facilities necessary to validate the computational methods and test and validate component, subsystem, and whole-systems performance in order to retire risk of deployment.

Key Outcome 2.1:
Demonstration and Testing of Advanced Reactors

Target challenge:

1) Enable prototypes and demonstration programs. In partnership with private-sector developers, establish aggressive demonstration and testing programs that couple with research and innovation programs to assess technology performance, establish regulatory bases, and identify research and development gaps. Near-term emphases include a microreactor demonstration by 2023, demonstration of multiple advanced reactor technologies via very small reactor systems, and hosting a private-sector small modular reactor (SMR) demonstration by 2026.

Key Outcome 2.2:
Disruptive Innovation in Nuclear Reactor Design and Fuel Cycle Technologies

Target challenges:

1) Advanced concepts. Develop and validate advanced reactor concepts that substantially improve resilient operations through inherent safety and embedded intelligence; exhibit high-performance fuel economy, elevated outlet temperatures, and improved overall thermodynamic efficiency; and allow for economical manufacture and construction, particularly through modular construction. Develop and benchmark core neutronic, heat transfer, and whole-plant characteristics of these systems by developing and validating applied modeling and simulation tool sets, and develop analysis and validation methods for reactors and systems.

2) Reactors for expanded markets. Develop and validate advanced reactor systems concepts that allow for atypical, nonbaseload operations, including remote site placement, mobile use, economical industrial integration, and nonterrestrial application. Develop and benchmark core neutronic, heat transfer, and whole-plant characteristics for these systems by developing and validating applied modeling and simulation tool sets. Emphasize very-small reactor development and demonstration. These efforts will be combined with key outcomes associated with heat and reactor management (below), and disruptive potential will be pursued.

3) Advanced fuel cycles. Develop and validate fuel cycle management options and enabling technologies that accommodate advanced reactor technologies, fuels options, and anticipated deployment and resource availability scenarios, with an emphasis on advancing actinide management and enabling cost-effective disposal options. Support nonproliferation strategies for treaty verification for advanced nuclear fuel cycle facilities and nuclear forensics with a focus on detecting misuse of nuclear materials and technologies.

4) Computational and validation tools. Develop world-leading tools necessary to effectively design, analyze, manufacture, and qualify advanced reactor, fuel cycle, and whole-plant designs. Design computational methods that allow faster than real-time simulation to enable revolutionary diagnostics and control strategies. Emphases are on development of multiscale computing tools for static and dynamic analyses, visualization tools, and systems and component validation and qualification experimental facilities (including reactor prototype and critical facilities, energy conversion and transport test rigs, materials irradiation capabilities, thermal systems validation capabilities), and enabling measurement, design, and analytical abilities.

Key Outcome 2.3:
Disruptive Innovation in Nuclear Fuels and Materials

Target challenges:

1) Accelerated innovation and validation approaches. Develop disruptive approaches for rapid innovation and qualification techniques to markedly accelerate the development of fuels and materials options that enable advanced reactor applications, emphasizing combinatorial materials science and accelerated testing and validation with substantial leverage on computational tool sets.

2) Advanced design and fabrication. Develop advanced fabrication techniques that enable higher-performance materials and fuels fabrication, including spatially varied compositions, sensing intelligence, integration/joining of dissimilar materials, and computationally enabled experiments for validation. Emphasize multiscale simulation-driven advanced manufacturing techniques.

3) Fuels and materials performance. Develop tools and techniques necessary to design and qualify fuels and materials performance, including liquid, particle, metallic, and ceramic fuels, with an emphasis on development of computational design methods, combinatorial analyses techniques, computational performance modeling tools, and test capabilities to validate models and materials performance under varied conditions, with special emphasis on utilization of Advanced Test Reactor (ATR), Materials and Fuels Complex (MFC), and Transient Reactor Test (TREAT) Facility, through advanced modeling and simulation. Develop and expand data analysis tool sets that reduce uncertainty in computational design.

Key Outcome 2.4:
Disruptive Innovation in Energy Conversion, Transport, and Systems Monitoring and Control

Target challenges:

1) Embedded intelligence for state prediction and transparency. Develop and validate systems intelligence strategies that provide disruptive, game-changing state-space awareness enabling economical, resilient operations through massively embedded sensing, integration of sensing data with faster than real-time computational analyses, computational and measured data analysis and synthesis using advanced algorithms, and incorporation of dynamic risk and reliability assessment techniques.

2) Advanced control strategies. Develop, assess, and validate methods for remote and autonomous systems operations and control, with particular emphasis on very small reactor designs, and autonomous and unattended operations. Develop hybrid physics-AI based strategies and approaches to enable adaptive control.

3) Energy conversion and thermal management. Develop and validate more economical, efficient, and resilient reactor heat transfer methodologies, with emphases on advanced heat exchangers, nonwater heat transfer media, and novel thermal management approaches.

4) Systems integration and operational flexibility. Develop and validate technologies and approaches, including computational and test and validation capabilities that enable reactor operation in a dynamic load environment, including load-following and control strategies, grid-scale energy storage, and black-start approaches while allowing for optimal economic performance.

5) Technologies and approaches to enable broader application of nuclear energy. Develop technologies that enable nuclear-grade heat utilization and integration of reactors into industrial processes. Techniques may include those to raise the temperature of reactor heat or reduce the activation temperatures of key chemical/industrial process and may include electrochemical, chemical looping, and catalytic approaches.

Key Outcome 2.5:
International Recognition and Leadership in Areas of Core Competency

Leveraging the marketing and management paradigms associated with the National Reactor Innovation Center and the INL Glenn T. Seaborg Institute, raise INL impact, engagement, and recognition in the global community by focusing on the following target challenges.

Target challenges:

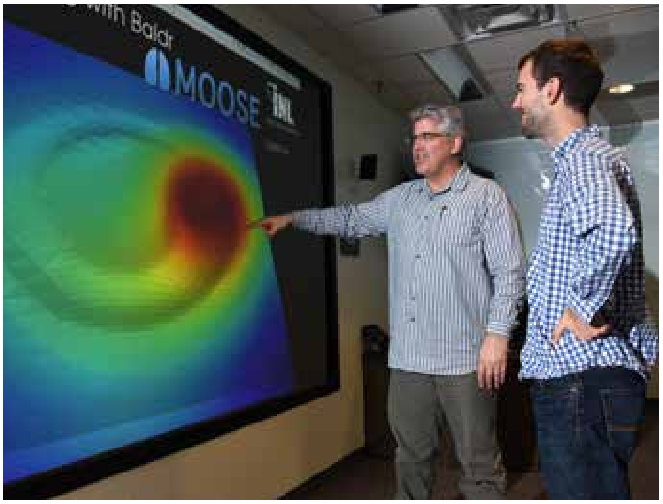
1) Nuclear fuels and materials performance. Building on strategic program drivers and INL irradiation, post-irradiation examination, and modeling and simulation capabilities, establish INL as an international center of excellence in nuclear materials and fuels performance, emphasizing recognized scientific leadership and advancement of international training and development programs.

2) Multiscale, multidomain modeling and simulation. Develop NS&T as a recognized world leader in advanced applied modeling and simulation methods and techniques covering thermal hydraulics, materials and fuels behavior, neutronics, systems dynamics, intelligent monitoring and control, heat and mass balance, and electrical systems dynamics with a strong emphasis on multiscale modeling and simulation. Embed these methods as key components of risk and reliability methods, embedded intelligence applications, and accelerated materials and fuels innovation and develop the Collaborative Computing Center (C3) into a world-class facility to integrate advanced computational engineering, risk and reliability, embedded intelligence, and fuel and materials performance with experimental validation.

3) Risk and reliability research. Building on strategic nuclear energy program drivers and expanding with advanced techniques and applications, develop INL into an international center of excellence and a destination for risk and reliability research, education, and training, including nuclear and non-nuclear emphases.

4) Separations science. Strengthen and expand INL separations science and technology core competencies, with an emphasis on aqueous separations, electrochemical molten salt separations, and radiation chemistry to establish INL as an international leader in separations science.

5) Embedded intelligence for energy. Leveraging advanced modeling and simulation capabilities and the Fission Battery Initiative, develop INL into a leadership-class laboratory for embedded intelligence for energy systems optimization, resilience, and efficiency, including development and incorporation of advanced data analytic frameworks, multiscale modeling and simulation, and advanced sensing, and the combination of these techniques.



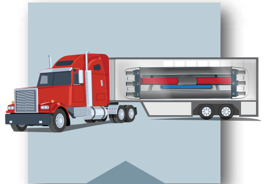
MOOSE

ADVANCED REACTOR FUTURE AT IDAHO NATIONAL LABORATORY

2023

Microreactor (<10MW) demonstration by early 2023

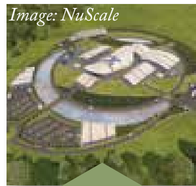
- Resolve key advanced reactor issues
- Open new markets for nuclear energy
- Provide a 'win' to build positive momentum



2025

Microreactors deployed

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



2026

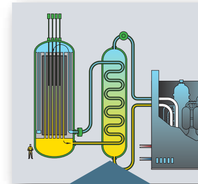
Small Modular Reactors (SMRs) operating by 2026

- Enable deployment through siting and technical support
- Joint Use Modular Plant for federal RDD&D

2026

Versatile Test Reactor (VTR) operating by 2026

- Establish fast-spectrum testing and fuel development capability
- Supported by microreactor demonstration
- Support non-LWR advanced reactor demonstration



2030

Non-LWR advanced demonstration reactor by 2030

- Demonstrate non-LWR technology replacement of U.S. baseload clean power capacity

FY 2020-2021 KEY PERFORMANCE INDICATORS

- Establish the framework and begin execution of the Nuclear Materials Discovery and Qualification Initiative, including direct funding capture, indirect investment strategy, and establishing first-year emphases and projects.
- Establish the framework, partnerships, and research emphases for and begin to execute the Fission Battery Initiative.
- Establish national repository to capture and disseminate new and historical reactor and fuels data and knowledge.
- Complete first phase of High-Assay Low-Enriched Uranium (HALEU) extraction, execute opportunity for industry to obtain HALEU for testing and demonstration of microreactors.
- Engage broadly and partner with select industrial firms to design a mobile microreactor for military use.
- Assist Department of Energy (DOE) and Department of Defense (DOD) in designing and establishing the National Defense Authorization Act (NDAA)-directed microreactor pilot project.
- Plan and develop bases for at least one "global nuclear innovation leadership forum," a workshop-based event focused on one of the INL signature core competencies.
- Complete first non-nuclear microreactor test bed thermal test of a test article with integrated heat pipe(s) and structural core.

Goal 3

Expand and Deploy National Nuclear Energy Strategic Assets

Deployment of new nuclear technologies and techniques generally requires extensive testing and validation at various scales, including at full scale. Validation of performance envelope; establishing the bases for regulatory approaches, assessment, and validation of operational characteristics and materials performance; and other experimentally based or experimentally validated parameters rely on access to specialty assets such as nuclear materials, facilities, and expertise. Enabling innovative design verification may also require special materials not readily available. INL and NS&T serve a key role in providing these capabilities.

NRIC, encompassing key INL capabilities and infrastructures including MFC, ATR, TREAT, Energy Systems Laboratory (ESL), C3, and nonproliferation research assets, will provide the business model and organizing principle to steward and deploy INL's national nuclear energy strategic assets. As we move to establish U.S. competitive advantage in future nuclear technology markets and to respond to national security needs involving nuclear fuel cycle issues, NRIC and Gateway for Accelerated Innovation in Nuclear (GAIN) will collaborate in synthesizing these assets into deployable solutions and impactful programs while efficiently engaging a variety of public and private sector stakeholders. Under this umbrella, NS&T will leverage these assets to establish NRIC as a global destination for nuclear energy innovation, demonstration, and data sharing. In a sense, we will be "going back to the future" to develop the next-generation national reactor testing station, including infrastructures, expertise, and modern business and engagement models.

Three major outcomes that substantially enhance the national strategic infrastructures include:

- Deliver world-class nuclear fuels, materials, and systems testing assets, including construction of the versatile fast test reactor for materials and fuels science.
- Establish the National Reactor Innovation Center.
- Enable industry and academic innovation through access to capability and partnership development.

Key Outcome 3.1:
Deliver World-Class R&D Assets

1) Reestablish fast neutron-spectrum testing capabilities. Develop and construct the versatile test reactor (VTR) and supporting fuel fabrication, irradiation testing, and post-irradiation examination capabilities to support advanced fuels and materials testing.

2) Expand and deploy fuels and materials testing assets. Enhance existing assets to be more broadly applied and develop necessary new assets, with emphasis on effective utilization of TREAT, development of the Sample Preparation Laboratory for irradiated materials research, expanding post-irradiation examination needs, addressing post-Halden irradiation needs, and preservation and enhancement of thermal-spectrum irradiation capabilities served by ATR.

3) Improve efficiency and reduce costs associated with irradiation experiments. Develop and implement approaches to improve the efficiencies in performing irradiation experiments in ATR and TREAT, taking advantage of conservative and bounding analyses at an early stage of experiment design in order to minimize the number of iterations required prior to final acceptance. The goal is to reduce the time and costs needed to execute experiments.

4) Integration of experimental and modeling and simulation capabilities to improve RD&D efficiency and outcomes. Develop and apply modern code sets to enhance utilization, performance, and effectiveness of experimental facilities, with an emphasis on irradiation experiments in ATR and TREAT, and ultimately enable the ability to develop and demonstrate more predictive modeling and simulation capabilities. Develop testing and validation capabilities for highly digitized advanced reactors to enable and accelerate adoption of "smart" systems technologies.

5) Expand and deliver supporting computational resources. Enhance existing high-performance computing, visualization, and supporting capabilities, with a special emphasis on expanding scientific computing capacity, providing easy access to INL hardware and software resources, and providing access to large-scale data sets and associated processing analytics capabilities.

Key Outcome 3.2:
Establish and Grow the National Reactor Innovation Center

Target challenges:

1) Develop NRIC business and engagement model. Develop efficient, functional, and effective business models to enable full and efficient use of INL strategic capabilities and infrastructures with public and private sector partners, manage intellectual property, reduce time and costs of contracting, improve access to legacy data, enable secure access, and reduce overall costs of facilities stewardship. Establish a reactor demonstration evaluation committee and criteria and develop and provide technical resources to potential investors to assist in their understanding and decision-making.

2) Assess capabilities and needs. Document existing facilities and capabilities and their characteristics relative to the NRIC mission. Conduct a gap analysis of available facilities and features to inform investment needs and associated planning.

3) Expand and deploy world-leading digital design and development assets. Develop physical and digital infrastructures to integrate digital design, manufacturing, and operations including a systematic incorporation of modeling and simulation to speed and increase quality of experimental activities as a key element of technology innovation and validation and as collaboration medium for laboratory and private- and public-sector stakeholders. Provide high-fidelity modeling, simulation, and measurement capabilities enabling operation of key NRIC assets, including ATR, TREAT, and MFC research capabilities.

4) Address materials and infrastructure needs. Develop and provide physical assets as defined by new fuels and reactor needs, particularly HALEU. Develop and deploy fuel-feedstock materials and processes and fuel fabrication assets.

5) Provide fuel processing and storage assets. Develop and manage nuclear fuel separations, waste storage management, and other fuels and materials science assets to enable materials disposition as well as provide new materials for advanced systems development.

6) Provide systems demonstration assets. Develop systems demonstration and testing assets, including heat management, grid integration, reactor, and reactor-system dynamics test bed and site characterization.

Key Outcome 3.3:
Enable Industry and Academic Innovation Through Access to Capability and Partnership Development

Target challenges:

1) Strategic partnerships. NS&T will identify, develop, and strengthen strategic partnerships in industry and academia that enhance the partner's and INL's ability to innovate by leveraging Nuclear Science User Facilities (NSUF) and GAIN, building on the international outreach and collaboration model, and leveraging business models associated with NRIC. NS&T also will strengthen strategically important national lab partnerships in synergy with industry and academic efforts.

2) Strengthen and Extend GAIN

Expand and improve access to financial support opportunities and national laboratory capabilities (facilities, expertise, experience, and tools) to accelerate commercialization of innovations. Modernize contracting processes to significantly reduce the time required to establish agreements and better support private sector needs. Work with industry to identify gaps, gather needs, and develop viable paths forward to remove barriers for industry and inform DOE research programs; support continued development of a regulatory framework for advanced reactor technologies and provide advanced nuclear industry entities access to legacy information to support their R&D and technology commercialization efforts; and ensure the advanced nuclear technology industry (all stakeholders) is informed about opportunities and capabilities available throughout the DOE complex.

Image: Idaho National Laboratory

FY 2020-2021 KEY PERFORMANCE INDICATORS

- Establish leadership and framework for NRIC; begin deployment of new business model.
- Deliver, through industry and academic collaboration, documentation necessary to obtain Critical Decision 1 (CD-1) for VTR.
- Through GAIN, modernize contracting processes and current limitations related to terms and conditions to enable more effective laboratory-industry partnerships.
- Prepare HALEU for microreactor demonstrations.
- Establish non-nuclear microreactor test bed at ESL.
- Deliver C3; integrate C3 strategy with NRIC framework; establish the Nuclear Computational Resource Center.
- Complete design of TREAT water and sodium loops, and continue to expand and deliver TREAT to advance accident tolerant fuel development.
- Complete design of I-Loops for prototypic testing of pressurized water reactor (PWR) and boiling water reactor (BWR) fuels in ATR.
- Demonstrate accelerated, semi-integral fuel testing in ATR.
- Deliver additional 5 petaflops of high-performance computing (HPC) capacity.
- Demonstrate loss-of-coolant accident (LOCA) testing capability in TREAT and initiate the first tests on accident tolerant fuel (ATF) concepts in support of industry licensing activities.

Goal 4

Expand Impact Across Markets

The NS&T directorate stewards key national assets and capabilities that, when combined, provide core competencies of national importance. Many of the capabilities and competencies, including materials science, digital sciences, advanced multiscale, multidomain modeling and simulation, risk and reliability research, and systems design and analyses, are powerful enablers of non-nuclear systems research, operations, and design, and for nuclear defense and nuclear nonproliferation applications. The latter market is particularly well aligned with INL core competencies and, working closely with other INL directorates, will be an emphasis for NS&T impact. NS&T will identify where, other than our core nuclear energy applications missions, directorate strengths could serve to advance U.S. interests in these broad markets.

Expanding the market for key directorate competencies and capabilities helps strengthen and stabilize the financial and intellectual base of the organization, provides leverage to add expanded capabilities, may provide excellent recognition for the institution, and helps develop broader, higher-impact partnerships. Therefore, the focused, strategic expansion of the NS&T customer base is a key element of the directorate's national responsibility.

The NS&T directorate, using a formal business development framework, will coordinate with INL marketing leads to identify target markets, integrate with broader laboratory capabilities, and deploy key competencies across varied markets.

To these ends, the focus of diversification is twofold: Apply NS&T capabilities for national nuclear security and nonproliferation applications, and apply NS&T capabilities across a variety of broader defense and nondefense markets.

Key Outcome 4.1:
Enhance National Nuclear Security and Nonproliferation Interests

Target challenges:

1) Nuclear and radiological detection and forensics. Leverage nuclear fuel cycle competencies and capabilities, particularly trace detection, separations science, and nuclear systems and process modeling and simulations to become a national go-to laboratory for nuclear fuel cycle and reactor design, radiological forensics, and proliferation detection.

2) Specialty analyses. Leverage nuclear fuel cycle capabilities and competencies to provide expert analyses of fuel cycle and reactor capabilities, informing emergency responders, the intelligence community, and other stakeholders in regard to technology attributes and issues.

3) Nonproliferation stewardship and analyses. Leverage systems analysis, modeling, and simulation to assess and quantify proliferation aspects of present and next generation nuclear systems.

4) Materials disposition. Develop techniques and approaches to minimize the quantity and risk of fissile materials globally.

5) Advanced systems design and testing. Develop nuclear energy and related systems for national security deployment and specialty applications.

Priority customers include National Nuclear Security Administration (NNSA), Defense Threat Reduction Agency (DTRA), Armed Services, DoD Energy and Infrastructure, and the intelligence community.

Key Outcome 4.2:
Deploy Capabilities Across Broad Markets

Target challenges:

1) Advanced modeling, simulation, and design: Provide neutronic, thermal hydraulics, and whole-systems modeling tools and analyses, and irradiation effects testing and analyses to advance the ability of the U.S. military to develop next-generation nuclear technologies, and ensure the safety, security, and operability (including cyber) of present nuclear technology platforms. Special emphases are on computational and materials testing needs of naval nuclear propulsion and radiation effects testing using key INL infrastructures, and deploy modeling and simulation in a variety of appropriate markets.

2) Sensing, diagnostics, automation, and controls: Develop and deploy diagnostic and control methodologies to enhance operability and safety in energy and other platforms. Special emphasis is on developing sensors for harsh environments, developing multiscale modeling enabled predictive maintenance, diagnostics and control strategies for energy applications, and model-based diagnostics systems for advanced manufacturing.

3) Risk, reliability, and regulatory research: Provide risk and reliability analyses for energy generation sectors, with an emphasis on broadening and deepening assistance to the Nuclear Regulatory Commission. Niche applications in transportation, infrastructure, and energy transmission will also be explored.

4) Materials innovation and performance: Develop and validate performance of advanced materials, with special emphases on harsh environment applications in energy generation and energy transmission.

Priority customers include Nuclear Regulatory Commission, National Aeronautics and Space Administration (NASA), and federal and private sector entities involved in transportation, energy generation, aerospace, and specialty manufacturing.

FY 2020-2021 KEY PERFORMANCE INDICATORS

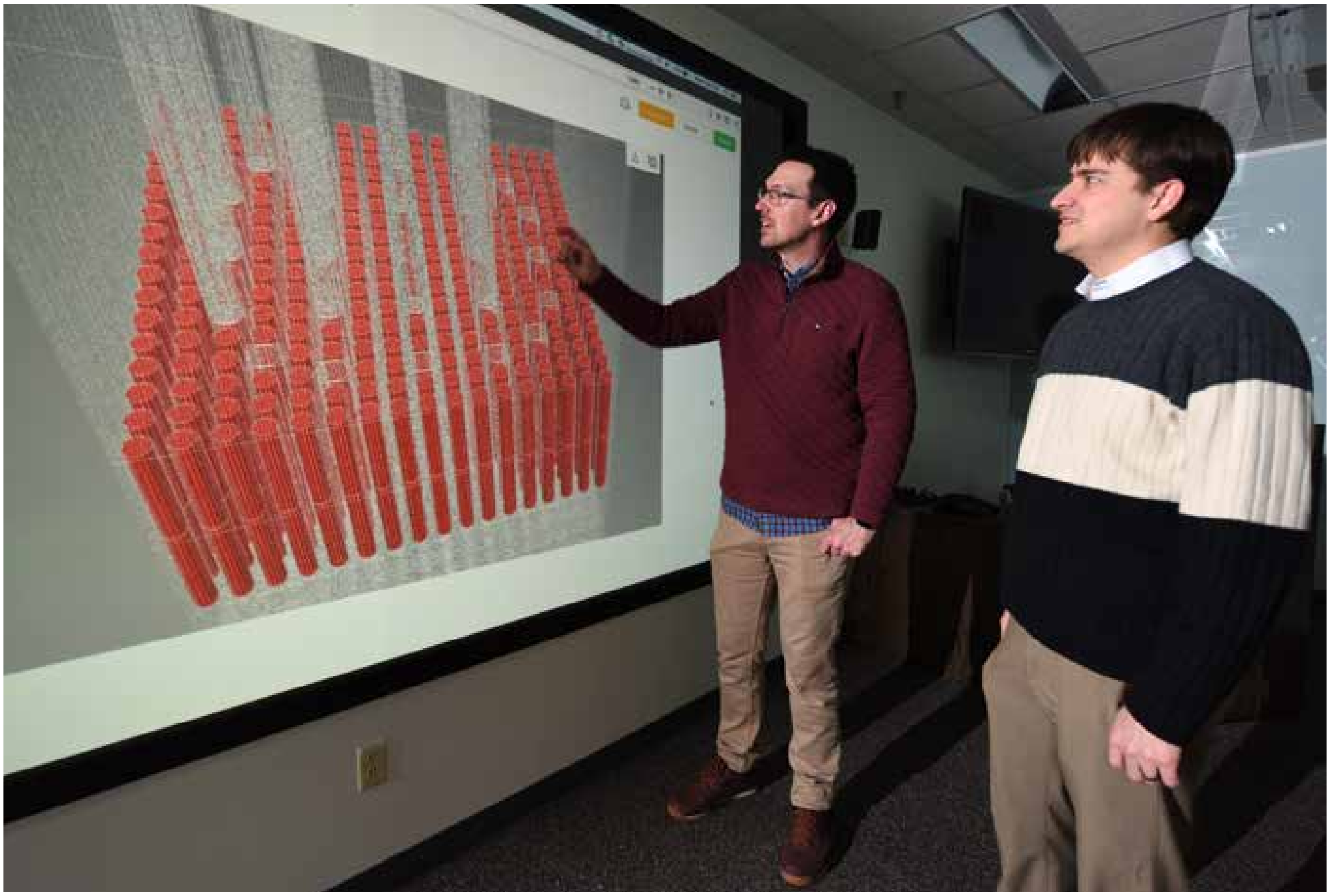
- Deploy INL multiscale modeling and simulation assets to key national security challenges, including naval propulsion and manufacturing, resulting in long-term strategic partnerships and jointly funded collaboration.
- Expand regulatory research business base with NRC and non-NE customers.
- Develop and execute a framework for intralaboratory collaboration to expand nuclear nonproliferation program's impact, and deliver programmatic solutions related to separations science for NNSA.
- Develop business in accordance with risk-based monitoring, control, and predictive maintenance for military, energy transport, and aerospace sectors.
- Using a multidirectorate collaboration, capture advanced manufacturing program, with NS&T elements focused on multiscale modeling and simulation and materials performance.

Goal 5

Create the Next-Generation Research Organization

Changes in U.S. and global nuclear markets and in national policy are influencing changes in the program priorities and opportunities of INL and NS&T. Combining these changes with the accelerating shift in the generational demographic across the directorate, NS&T will have the challenge and opportunity to create the organizational foundation of the next two decades. The way the directorate approaches talent growth and development – the research and operations cultures created and fostered, and the priorities and emphases that are enabled and rewarded – will form the foundation of this directorate's future for many years to come.

It is the intent of NS&T to develop an exceptionally high-performance organizational culture – one that emphasizes innovation and impact through science-based engineering research; builds a research culture appropriate for a national laboratory of the future; focuses on meaningful research outcomes; and fosters professional growth, excellence, and diversity of thought while valuing the inextricable link between research operations safety and research quality as the foundation paramount to our success in enhancing U.S. interests.



Key Outcome 5.1:
Culture of Impact Through Innovation and Research Excellence

Target challenges:

1) **Recognition.** Encourage, invest in, and incentivize professional and research recognition for all professions through national and international awards, professional outreach, broad-impact publications, and other recognition paths.

2) **Impact.** Seek, invest in, incentivize, and recognize research, business, and operations activities that make measurable and notable positive impact worthy of national laboratory effort. Focus on and communicate the mission of this national laboratory in all that we do.

3) **Thought leadership**. Encourage, incentivize, and invest in pushing the envelope in applied technology research, reaching for game-changing approaches, and thinking beyond traditional bounds; develop signature events (e.g., seminars, named intern programs, sabbaticals, international events) that spark creativity and innovative thinking, build meaningful research partnerships, and demonstrate laboratory leadership in nuclear science and technology.

4) **Business of research to advance research.** Provide research and support professionals with training, tools, and processes that dramatically improve success in and reduce costs of research capture and impact recognition. This includes the capture management approach to identifying and prioritizing opportunities, investing in development, divestiture management, engaging customers, and effectively communicating.

5) **Work environment and culture.** From each other, expect and encourage an atmosphere of innovation, intellectual honesty, professional debate, personal respect, mutual support, and openness. Expect that individuals are responsible for their own safety, and also the safety of others.

6) **Research excellence.** Establish standards and enable researchers in meeting the highest standards for quality, engagement, open debate, honesty, and integrity, and encourage all to hold each other accountable in meeting the standards of research excellence.

Principles of Our Strong Research Culture

1. All employees are engaged in the success of the science and technology mission.
2. An environment of creativity, inquisitiveness, and constant questioning is fostered.
3. The highest level of scientific integrity is expected.
4. Staff aspire to generate scientific products at the forefront of their field.
5. Scientific successes are celebrated and actively promoted.
6. Scientific failure is valued as a mode of learning.
7. Professional development and mentoring are encouraged and valued.
8. Diversity of backgrounds, an inclusive environment, and teamwork lead to innovation.
9. Independent input and review are sought and valued to improve research quality and impact.
10. Our research tools and facilities are recognized globally as unique and state of the art in our fields of study.

Key Outcome 5.2:
Excellence in Talent Development and Professional Growth

Target challenge:

1) Innovative professional development and recruiting. Commit to and invest in strategic professional growth and development, including integrating opportunities for advanced learning, new job responsibilities and assignments, joint appointments, temporary assignments, and mentoring.

2) Merit-based reward. Develop leadership-class extrinsic (financial) and intrinsic (professional pride) reward mechanisms based on merit with a transparent and clearly articulated process.

3) Professional progression. Shared ownership between management and staff of professional progression and development planning. Within accepted policies, develop innovative ways to progress in and across job categories to enhance recognition and performance. Implement an active professional development planning process for research and operations leadership positions that allows candidates to gain leadership experience necessary to progress.

4) Effective execution of performance planning. Build added clarity and rigor into the execution of performance planning and assessment processes, including commitment to clearly defined roles and responsibilities, regular dialogue between management and staff, and assistance with professional development to fill gaps and capitalize on strengths.

Key Outcomes 5.3:
Business and Operational Excellence and Efficiency

Target challenge:

1) Performance-based management. Develop and implement transparent and rigorous program and investment prioritization processes. Develop meaningful metrics and timely dashboards, incorporating data to enable look ahead, look behind, and goal monitoring in a timely manner in order to assess business and research progress and compare outcomes with prior expectations.

2) Efficiency through technology and innovation. Continually search for ways to incorporate advanced technologies to ease researcher and manager burden, enhance research quality, improve overall work management processes, and improve situational awareness. Develop and deploy innovative approaches to improve operational efficiencies and reduce overhead burden while maintaining or enhancing safety.

3) Safety enabling quality. Develop a culture that equates safe work to quality work, engendering organizational trust.

FY 2020-2021 KEY PERFORMANCE INDICATORS

- Implement focused business development and strategy framework and processes, addressing investment targeting, investment performance management, divestiture, and situational awareness.
- Implement focused talent development initiative, including developing and implementing a rigorous framework to identify talent growth needs and opportunities; leverage indirect investment and direct program opportunities, research culture maturation, and internal promotion.
- Substantially mature strategic university framework, showing strategic growth in interns, research collaborations, and strategically focused bilateral engagements.
- Implement talent recognition strategies to identify potential recognition paths (awards), candidates for recognition, and staff gaps and needs to capture desired recognition.
- Substantially enhance NS&T recognition through a deliberate and targeted strategic communications approach.
- Deploy key elements of work-process efficiency initiative, and procedures streamlining and improvement.
- Establish and execute a directorate seminar series that features internationally recognized thought leaders.

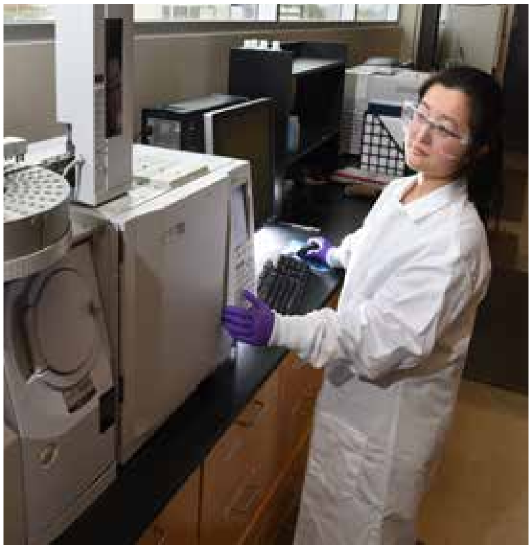
IMPLEMENTING FRAMEWORK

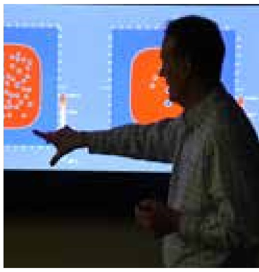
NS&T will implement a "one-directorate" management approach, leveraging programs and investments across directorate organizational boundaries to most efficiently and effectively meet the impact targets conveyed in this plan. This "one-directorate approach" will incorporate several features, including:

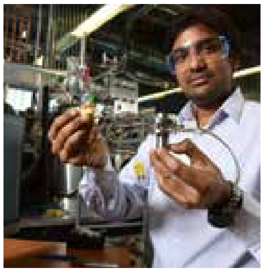
Management: The directorate leadership team will be responsible for setting strategy, prioritizing and assigning resources and investment, and monitoring progress in meeting directorate goals using a business development and strategy (BDS) organization function. The BDS function and approach will synthesize and integrate planning, investment, and directorate business performance analysis as an aid to execution through the division lines of authority and provide a means to ensure progress toward meeting goals.

Planning: Research and business targets will be developed yearly and updated quarterly, with this plan as a guide. To achieve the greatest return (financial, intellectual, talent, and impact), a substantial emphasis will be placed on implementing an integrated planning process that builds on leverage between organizational units within the directorate, and between the directorates. Elements of this directorate plan will be prioritized and assigned leads responsible for execution and delivery, and coordination with the directorate leadership team. Division and initiative strategy and execution plans will identify how elements of the directorate plan will be delivered. Delivery planning and progress tracking will be coordinated through the BDS function and will inform investment planning. Planning and prioritization will include assessment of potential for relevance and impact of a given activity in meeting the directorate goals, knowledge of current and potential customer and stakeholder needs, directorate strengths, and near- and long-term impact potential.

Investment approach: Objective-based investment, targeting strategic outcomes and goals outlined in this plan, will be coordinated at the directorate level through the BDS function and implemented through the divisions, Laboratory Directed Research and Development (LDRD) program leadership, and program development leadership. This approach includes evaluating the investment avenues, direct and indirect, that can be leveraged to achieve a given objective or goal; level of investment required; timing of the investment; potential strategic benefits and impact; progress toward goals, where appropriate; and other criteria. Direct program activities, talent activities, and indirect investment mechanisms (professional development, program development, strategic hiring, LDRD, and other) are considered an integrated package to leverage together to efficiently enable success in meeting the established goals. The BDS approach will also consider ideas for advanced concepts or "blue-sky" ideas and approaches, and weigh evolving opportunities, markets, and needs not identified in this plan.

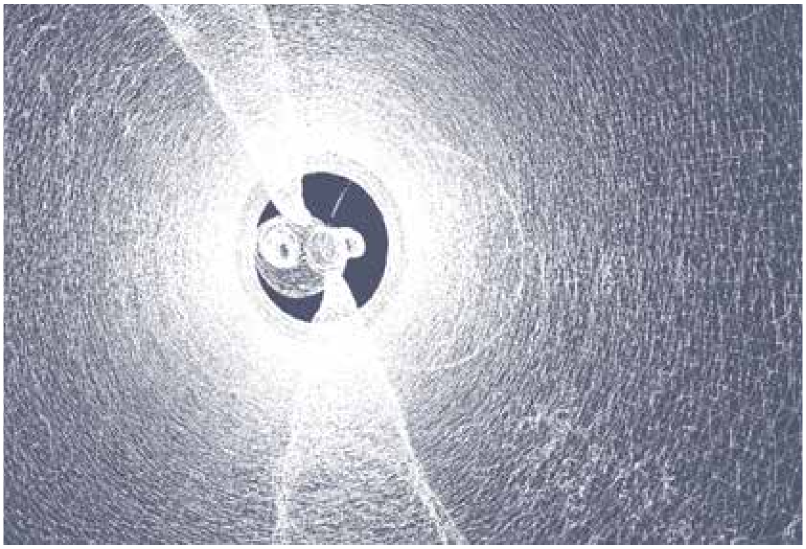


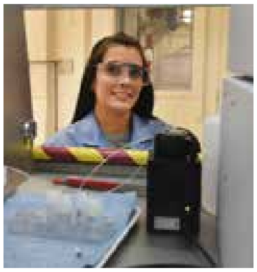




CONCLUSION

The NS&T directorate is facing a generational change, in both market and talent. The opportunity for impact in this environment is exceptional, but the management and contextual challenges are substantial. Using this plan as a framework for action and a guide for building the high-performance work environment of the future, NS&T will define the place of a national laboratory in applied nuclear energy research, become a global destination for top talent, and deliver on the promise to markedly enhance U.S. competitiveness and security through nuclear science and technology innovation.





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